# Acknowledgements

I would like to extend my sincere gratitude to all those who assisted with INMARTECH ’98.

Annette DeSilva, John Frietag, Barrie Walden and Sandy Shor collaborated to formulate the session topics and list of invited speakers. They set the groundwork for the Symposium.

Members of the UNOLS Office (Annette DeSilva and Mary D’Andrea,_) and the SIO/STS Business Office (Brenda Ayers, Joanne Digre, and Romy Asch) gave above and beyond the call of duty in corresponding with participants, speakers and industry representatives; making arrangements for catering the meals and social events; scheduling the meeting rooms; enlisting drivers for the shuttles; and all the other unnamed details which made the Symposium a success.

Members of the STS Technical Staff worked behind the scenes during the Symposium, addressing the many and varied small mix-ups before they had a chance to develop into noticeable catastrophes.

The SIO Director’s Office contributed funds to offset a portion of the expense of the Aquarium Reception.

Thank you all,

Woody Sutherland
Symposium Chairman

# INMARTECH '98
# Scripps Institution of Oceanography, La Jolla, CA
# October 20-22
# Program Agenda

## *Welcome to INMARTECH '98!*

**To help make your stay in La Jolla a pleasant one, the following logistical information is provided:**

⇒ **Shuttle Buses -** Shuttle buses will run daily between the Radisson and Empress Hotels and Scripps Institution of Oceanography (SIO) campus. The first morning shuttles will leave the hotels at approximately 07:30 am, with additional trips every 15 to 20 minutes. The shuttles will pick-up passengers outside the hotel lobby doors. The first trip back to the hotels will begin immediately following the end of each day's sessions.

⇒ **INMARTECH '98 Check-In –** Participants can check in for INMARTECH '98 at Sumner Auditorium on SIO Campus starting at 07:45 a.m. on Tuesday, 20 October.

⇒ **Ticketed Events -** The activities in the program agenda denoted by asterisks "*" are ticketed events. Payment for these events must be made prior to the meeting. You will receive your tickets for the pre-paid meals and events at check-in.

⇒ **Meeting Locations -** The concurrent technical sessions will be held at Sumner Auditorium and Hubbs Hall. The program agenda indicates the session site. Signs will be posted to direct foot traffic between the two rooms and a SIO campus map will be distributed during check-in.

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## Tuesday 20, October, 1998

**07:30** ***Start of shuttle service between INMARTECH hotels and SIO campus.***

**07:45** **Check-In at Sumner Auditorium**

**08:30** **WELCOMING SESSION - Sumner Auditorium**

- ***INMARTECH '98 Opening Remarks and Welcome to Scripps Institution of Oceanography*** - Mr. Woody Sutherland, Manager, SIO Shipboard Technical Support
- ***Overview of Ship Operations and Shipboard Technical Support – SIO & UNOLS*** **-** Dr. Robert Knox, Associate Director, SIO and University-National Oceanographic Laboratory System (UNOLS) Chair
- ***SIO International Activities*** - Dr. Lisa Shaffer, SIO
- ***Technician and Instrumentation Support for Seagoing Science by the U.S. National Science Foundation*** - Dr. Alexander Shor, Program Director, NSF Instrumentation and Technical Services Program

**09:45 Coffee Break**

**10:00 Technical Workshop (Sumner Auditorium)**

**UNDERWAY SAMPLING SYSTEMS -** Mr. Anthony F. Amos (University of Texas), Chair

- ***An Interactive Shipboard Scientific Log for Research Vessels* -** Mr. Anthony F. Amos, University of Texas Marine Science Institute
- ***IMET - Improved METeorology - Instrumentation* -** Mr. David Hosom, Woods Hole Oceanographic Institution
- ***Underway Data Collection System on Board RV PELAGIA; Considerations and Design of a New System*** - Mr. J. Derksen, Netherlands Institute For Sea Research

**12:00 Lunch (SIO Pier) ***

**13:00 Technical Workshops (Concurrent Sessions)**

**GEOPHYSICAL TECHNOLOGIES (Sumner Auditorium) -** Mr. Paul Henkart (Scripps Institution of Oceanography), Chair

- ***Seismic Sources in the UNOLS Fleet* -** Dr. John Diebold, Lamont-Doherty Earth Observatory of Columbia University
- ***Sound Receivers* -** Dr. Graham Kent, Scripps Institution of Oceanography
- ***Chirp Sonar Design for In-Hull Applications* -** Dr. Lester LeBlanc and Dr. Steven Schock, Florida Atlantic Institution
- ***Multibeam Technology* -** Dr. Dale Chayes, Lamont-Doherty Earth Observatory

**ROV AND TOWED VEHICLES (Hubbs Hall) -** Mr. Marc Willis (Oregon State University), Chair

- ***A Typical Cruise with the ROV Jason*** - Mr. Robert Elder, Woods Hole Oceanographic Institution
- ***Recent MPL Deep Tow Group Seagoing Work*** - Dr. Fred Spiess, Scripps Institution of Oceanography
- ***Tiburon: MBARI's ROV for Science Research* -** Dr. William J. Kirkwood, Monterey Bay Aquarium Research Institute
- ***A Comparison of Single Body and Two Body Shallow Towed Vehicles***, Mr. Mark Rognastad, University of Hawaii
- ***SeaSoar Metamorphosis* -** Dr. Lindsay Pender, CSIRO Marine Research

**17:00 Shuttle Buses return to Hotels**

**18:00 Reception and Poster Session at Birch Aquarium * -** Parking ($3 per vehicle) is available at the Birch Aquarium

## Wednesday, October 21, 1998

**07:30** ***Start of shuttle service between INMARTECH hotels and SIO campus.***

**08:30** **Technical Workshops (Concurrent Sessions)**

**BOTTOM SAMPLING TECHNIQUES and DECK OPERATIONS AND ONBOARD SAFETY (Sumner Auditorium) –** Woody Sutherland (SIO), Chair

- ***A Large Diameter Piston Corer for Use on UNOLS Research Vessels* -** Dr. Peter Kalk, Oregon State University
- ***MultiCoring*** - Mr. Richard Muller, Moss Landing Marine Laboratory
- ***Dredging and Rock Coring*** - Mr. Ronald Comer, Scripps Institution of Oceanography
- ***Oceanographic Research Vessel Deck Safety*** **-** Capt. Daniel S. Schwartz and Mr. George White, University of Washington, School of Oceanography
- ***Small Research Vessel Deck Operations*** - Mr. Steve Hartz, University of Alaska

**ACOUSTIC DOPPLER CURRENT PROFILERS (Hubbs Hall) -** Dr. Eric Firing (University of Hawaii), Chair

- ***Fundamental Components of Shipboard and Lowered ADCP Systems*** - Dr. Eric Firing, University of Hawaii
- ***Routine Shipboard ADCP Operation: Benefits, Problems, Methods*** - Dr. Eric Firing, University of Hawaii
- ***Lowered Acoustic Doppler Current Profiler: From an Experimental Instrument to a Standard Hydrographic Tool*** **-** Dr. Martin Visbeck, Lamont-Doherty Earth Observatory Columbia University, NY
- ***Acquisition of Vessel-Mounted Narrowband and Broadband ADCP Data using a Sun Logging System on ORV FRANKLIN, FRV SOUTHERN SURVEYOR and RSV AURORA AUSTRALIS*** - Dr. Helen Beggs, CSIRO Marine Research

**12:00** **Bus from SIO Campus to SIO Marine Facility (MarFac)**

**12:30** **Bar-B-Que at MarFac ***

- **Tour of SIO Marine Facility (R/V MELVILLE, FLIP, etc.)**
- **Underway Sampling System Demonstrations (on R/V MELVILLE) -** SIO Oceanographic Data Facility and Shipboard Computer Group personnel
- **Multibeam Processing Demonstration (on R/V MELVILLE) -** Mr. Stuart Smith, Scripps Institution of Oceanography

**1700** **Bus back to Hotels,** ***Evening is Open***

## Thursday, October 22nd

**07:30** ***Start of shuttle service between INMARTECH hotels and SIO campus***

**08:30** **Technical Workshops**

**SHIPBOARD NETWORKING AND SEANET (Hubbs Hall) - Mr. Barrie Walden (Woods Hole Oceanographic Institution), Chair**

- ***Data Collection and Distribution*** - Mr. Barrie Walden, Woods Hole Oceanographic Institution
- ***SeaNet - Extending the Internet to Oceanographic Research Platforms*** - Mr. Andrew Maffei and Mr. Steve Lerner, Woods Hole Oceanographic Institution
- ***National Oceanographic and Atmospheric Administration (NOAA) Networks*** - Mr. Dennis Shields, NOAA
- ***E-mail on the Woods Hole Oceanographic Ships*** **-** Mr. James Akens, Woods Hole Oceanographic Institution
- ***Direct Connection Network Sensor Interfaces*** **-** Mr. Richard Findley, University of Miami

**12:00** **Lunch (SIO Campus) ***

**13:00** **Technical Workshop (Sumner Auditorium):**

**CTD PACKAGES -** Mr. Woody Sutherland (Scripps Institution of Oceanography), Chair

- ***WOCE Operations*** **-** Mr. Frank Delahoyde, Scripps Institution of Oceanography
- ***Seabird Operations*** **-** Ms. Kristen Sanborn, Scripps Institution of Oceanography
- ***Data Quality*** - Dr. James Swift, Scripps Institution of Oceanography
- ***Marine Instrument Calibration "You Know it Makes Sense"*** **-** Mr. Paul Ridout, Ocean Scientific International Ltd.
- ***Insitu Pressure Calibration*** **-** Mr. Sven Ober, NETHERLANDS INSTITUTE FOR SEA RESEARCH

**14:30** **INMARTECH '98 - WRAP-UP SESSION**

**Adjourn** **Shuttle Buses return to Hotels**

**17:30** **Mexican Dinner at SIO Campus ***

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# INMARTECH ’98
# WELCOMING SESSION

## Chaired By
## Woody Sutherland

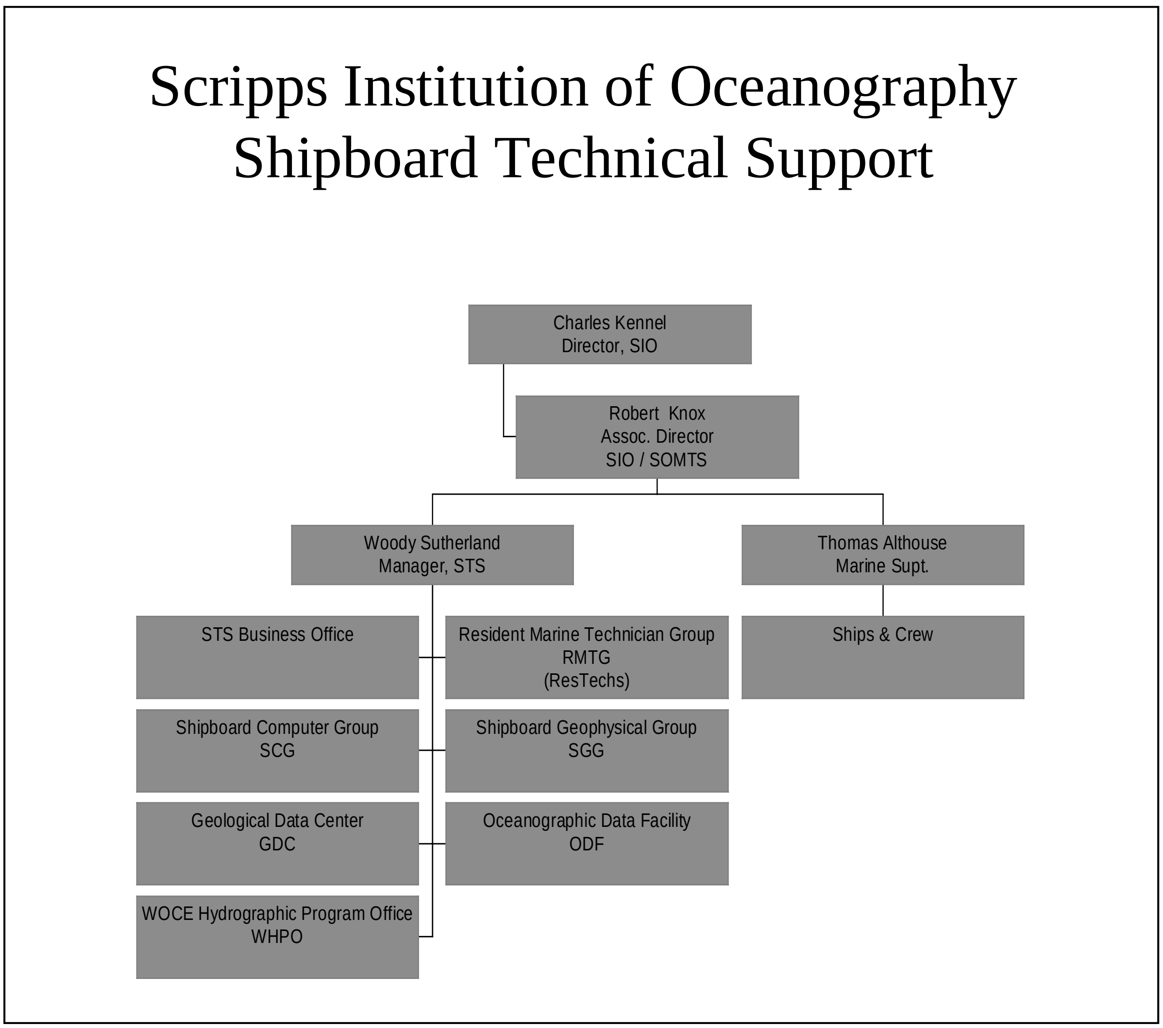
# Opening Remarks

Woody Sutherland
Scripps Institution of Oceanography

Good morning. This is the opening session of INMARTECH '98. So if you're not here for the International Marine Technician Symposium, you're in the wrong place. INMARTECH '98 is hosted by the Scripps Institution of Oceanography and by the RV Tech Committee of the UNOLS Office.

This truly is an international symposium. We have 12 countries represented here. We have people coming from Australia, Belgium, Canada, Denmark, France, Japan, Mexico, the Netherlands, South Africa, Spain, United Kingdom and the United States. Roughly one third of the participants at INMARTECH '98 are from outside the U.S. .

I am Woody Sutherland. I'm the manager of Shipboard Technical Support here at Scripps Institution of Oceanography. For those not familiar, I just want to give you a quick overview of our group. Shipboard Technical Support is under the direction of Robert Knox, the associate director of SIO. You will be hearing from him shortly. He is my immediate supervisor, a fortunate circumstance for me.



We have seven different operating groups within STS. The Resident Marine Technical Group (RMTG or ResTechs) manages each of the cruises on the four SIO vessels. They take care of cruise planning with the scientists, the logistics of getting equipment to the ship, back from the ship, getting it loaded, and getting it secured. They take care of all the deck operations, getting the packages on and off safely.

The Shipboard Computer Group (SCG) manages all the computers on board the ships. They also have a shore-side facility to do software development and testing. We have two extensive computer facilities on the larger research vessels, the Roger Revelle and Melville. We'll be touring the Melville tomorrow, and we'll have members of the Shipboard Computer Group onboard to show you around the facilities.

The Shipboard Geophysical Group (SGG) handles all the seismic operations for STS. They are not tied as closely to the SIO ships as the first two groups I mentioned, and spend a great deal of time on other US and foreign research vessels.

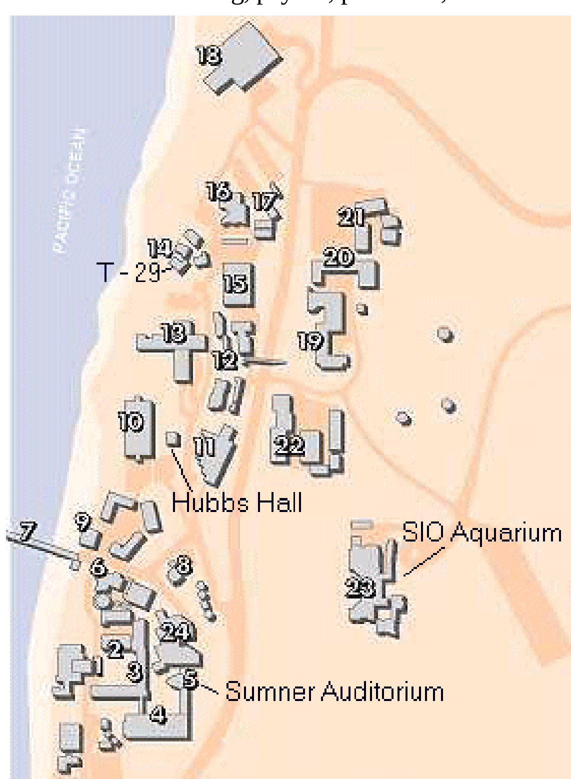
The Geological Data Center (GDC) handles all the data that's collected on SIO vessels. The data come back here, are run through preliminary data quality analyses, and then a copy is placed in our archives. The data is then available for distribution to the PI of the cruise, and to national data archives.

The Oceanographic Data Facility (ODF) is involved with CTD data acquisition and processing. The group also performs analyses of the seawater samples collected with the rosette package -- dissolved oxygen, precision salinity, and nutrients.

And then the newest member STS is the WOCE Hydrographic Program Office (WHPO), which is the U.S. office for the international World Ocean Circulation Experiment Program.

I might also mention that in the Oceanographic Data Facility, we have two subunits. One is the Calibration Lab, to give us that warm and fuzzy feeling that all the numbers we collect from our instruments are actually valid. The other is the STS Electronics Group. They are responsible for keeping the red lights glowing on the ever increasing number of electronic boxes in all of the STS groups.

And finally a Business Office to keep everything going -- handle the accounting, payroll, personnel, travel arrangements, and so forth.




Now, members of STS, the members that are here -- about two thirds of our group are out at sea right now -- the members that are still here have cheerfully volunteered to help out with all the details of the INMARTECH Symposium. They will be the shuttle drivers, collecting tickets, et cetera, et cetera. So feel free to interact with them as you're coming and going.

SIO is a graduate department of the University of California, San Diego, which is right up the hill. This is evident from the official letterhead on much of the correspondence that you have received thus far

Next I want to go through some details, quickly if I can, for the symposium itself. This is where we are right now (indicating) -- a map of the SIO campus. We're in Sumner Auditorium here. You were dropped off right here and came up the steps. During the symposium, at times we'll have concurrent sessions. The other session is in the Hubbs Hall Conference Room. We have yellow signs along the walkway that will direct you from one room to the other. So as you go out the door here, head down the steps. Just look for the yellow signs to lead you over to Hubbs Hall.

Today’s luncheon will be served on the pier. Just head toward the water. You’ll be able to see it. Just follow the coast, the cliff-line down to the pier. Tonight’s reception is at the aquarium, which is just up the hill. You’ll be able to see that as you wander around the campus. And then Thursday’s buffet is at T-29, on the cliffs on the northern end of the campus.

During lunch today, we won’t have exclusive use of the pier. So I ask that you take consideration for anybody that’s doing research out there. There’s also some painting, construction and repair going on, so be attentive of that.

For all of the meals, you have tickets. We’ll be collecting those tickets, because not everyone is signed up for meals, and we need to make sure that everyone that has paid, has plenty of food to eat. So bring those tickets with you to all the meal functions.

At the aquarium tonight, we have two exhibit halls. As you first come into the aquarium, in the entrance area will be the academic exhibits -- mostly posters. They should be self-explanatory, but we’ve asked the authors to stay close by so you can ask them questions concerning the content of the posters. We’ll also have an industry exhibit from manufacturers of equipment that will be discussed in the symposium.

As you turn in your ticket to the aquarium tonight, you can exchange that for a drawing ticket. At the aquarium, we’re going to draw for gift certificates to the aquarium bookstore. It’s a combination bookstore and gift shop. It’ll be open for the first hour of the reception tonight. So you’re free to wander through there and pick up souvenirs to take back with you. If you feel lucky, you might want to wait until the after drawing before visiting the bookstore. We’ll have the drawing about 6:30, to give the winners time to shop.

We’ll also have another drawing at the buffet on Thursday night. Again, when you turn in your ticket, you’ll be given a ticket. We have more souvenirs from SIO to distribute at that time.

You should have received a registration packet when you came in this morning or yesterday. That has all the material for the week. It should have all the tickets, a map of the SIO campus, a map showing both hotels in case you want to see how the other half lives, or if you make some new friends and want to go visit them.

If you need receipts for any of the expenses, then you can see the people that are working the registration tables. They’ll be able to give you receipts to take back to your home institution.

For people that did not elect to have lunches here, we have two snack bars on the SIO campus. We have one that’s right here next to the director’s office. If you just walk down toward the water, go along the coast, you’ll see it. If you’re in Hubbs Hall, there’s another snack bar in this courtyard of Nierenberg Hall. So what you need to do is go up the hill a little ways, go across La Jolla Shores Drive, the main road, to the large office/lab building on the other side and look for the courtyard.

If you have free time in which to visit UCSD, the main campus, there’s a shuttle that runs every 20 minutes between the SIO campus and the UCSD campus. Shuttle stops are located throughout SIO and all throughout UCSD. Just find a sign that says, "Campus Shuttle," and it’ll give you the schedule for that stop. You can go up and wander around. It has a university bookstore, snack bars, et cetera, et cetera, up there -- a very pretty campus with large eucalyptus trees all around.

I hope everyone got the notice that parking is very difficult here at SIO, especially with the construction going on. There are not enough parking spaces to serve everyone that has an annual pass. So when visitors start taking parking spaces, it makes the employees and the faculty here even a little more upset than they usually are.

We’re told that there will be a few spaces available in the south parking lot, which is the lot that’s right out here down by the beach. If it’s necessary for you to drive in, you will have to purchase daily parking passes, which are six dollars per day. You can get those at the registration table, as well.

At the aquarium, there's a large parking facility. So if you elect to drive in tonight, that's fine. There's a $3.00 parking fee there. We will be running the shuttles back and forth, though. And then at T-29 -- I'm looking for confirmation -- but for special events at T-29, we're often allowed to have notices go to the parking police that it's okay to have a few cars here that don't have permits on them, and I think we have those arrangements. So if you want to drive in for the Thursday evening Mexican buffet, it should be okay to park right along there in the university parking spaces.

The shuttle drop-off and pickup for today, tomorrow and Thursday will be right down where you were let off this morning. So if you're at Hubbs Hall at the end of the day, you'll need to walk down to this location to get the shuttle back to the hotels. Today's schedule, at the end of the meetings, the shuttles will take you back to your hotels, immediately starting bringing people back to the aquarium, and we'll just keep going back and forth until we get everyone from here to the hotels, and from the hotels to the aquarium. And then at the end of the evening at the aquarium, the shuttles will take you from the aquarium back to your hotels.

Also, one other building that I want to point out. If you go down to the end of the steps and across the little driveway, you'll find the Marine Research Support Shop, a very well-used shop here at Scripps. We do a lot of in-house machining, construction, developing. We also contract out to a number of other research institutions, as well as industry. The shop foreman has graciously offered to give any tours of the shop, answer any questions. So if you have any questions about machining and the construction of oceanographic instrumentation, feel free to drop in there sometime during this week.

Session formats. We have, essentially, half-day sessions that are on specific topics. The first portion of each session will be formal presentations by invited speakers; we'll take a short coffee break; and then we'll have a question-and-answer discussion period following that.

We are taping all of the sessions. We will transcribe both the presentations and the discussions, edit the transcription, and produce a formal publication that'll be mailed out to all the attendees, and also available to others that could not attend. So during the question-and-answer discussion period, I would ask that you speak clearly and loudly. At least for the first few times, stand up and identify yourself and the institution you come from so that we can have a record of that. Also, the speakers will need to wear the wireless microphones. The session chair will try to remind you of these procedures.

We have had an agenda change. You should have picked that up this morning. We've consolidated a session so that, tomorrow morning, we'll have bottom sampling techniques, deck operations and on board safety all together. And we've eliminated the deck operations separate session, which was scheduled for Thursday morning. So please note that. There's also a late-arriving abstract that you can include in your program agenda, as well, on the multicoring presentation.

Tomorrow, we'll have formal sessions in the morning. Then we'll be transiting down to SIO's marine facilities in Point Loma, about 25 miles away. We're going to try to get everyone down there in one trip. We have a large charter bus that's coming, plus our three shuttles. So we ask that, as we finish up the sessions, that you go directly down to the pickup area, and we'll load everyone up. When we get there, the barbecue should be ready. The research vessel Melville will be in. The FLIP will be available for tour. We'll also tour the marine facilities.

Please try to eat in shifts. So instead of everyone going and eating lunch at one time, and then everyone taking tours, let's try to have half the people eat lunch, the other half take tours, and then we can flip-flop.

On Melville itself, we will have a formal presentation of processing multibeam data, using the Sea Beam data that we collect on SIO ships. There will be a couple of sessions of that. We'll take as many people as we can at one time, and then we'll turn the rest away. They can tour the ship or go eat. Once that session is finished, then we'll start another session if there's enough interest .

The other part of the Melville tour will be an informal question-and-answer session for the shipboard computer facility, and also an informal continuation of the underway data collection discussion. We'll go through the sensor setups that we have on board ship.

As people tire of the marine facilities, we'll start shuttles back from there. So if we have a group that's ready to head back up to La Jolla, we'll take a shuttle back. When another group's ready, we'll bring another shuttle back. If we have a large group, then we'll put them in the bus and bring them back.

On Thursday, we have a Mexican buffet. We've decided to start it a little bit earlier so that we can enjoy the view of the sunset from the cliffs of La Jolla. It will start at 5:30. We figure that, as we finish up the formal presentation Thursday afternoon and the wrap-up discussion session, whoever is staying for the buffet can just mosey on up the hill, and we'll start with Mexican hors d'oeuvres, and beer and margaritas, and then finish up with the buffet and watch the sunset.

Okay. Something that's just come up, and I don't see my colleague at this time. The data manager of the WOCE Program Office is very active in the Leukemia Society and raising funds. He has a child that's stricken with leukemia that he sponsors. He was able to get two tickets donated to Wednesday night's game of the World Series. He is raffling those off to the SIO community exclusively. Right now, he has about 70 raffle tickets sold. He's also opened that up, at my request, to the INMARTECH community. So for a $20 donation, tax deductible, you can buy two tickets to the World Series – or rather the chance --
(Laughter.)
the chance for two tickets to the World Series. I was hoping he would be here this morning to go into a further explanation. But, I'm sure he will be here at coffee break. So if you're interested in the raffle tickets for the World Series, then you can see him during the coffee break.

I was also asked to announce that the location for INMARTECH 2000 has already been decided. It will be held in Holland. So you can start making your travel plans to go to Holland in 2000.

PARTICIPANT: The weather will not be as good as here.
(Laughter.)

MR. SUTHERLAND: Okay. That's all the details I have concerning the symposium. Are there any questions before we go on?

PARTICIPANT: One question. On the old schedule, on Thursday at 8:30, you had a session, "Deck Operations and On Board Safety."

MR. SUTHERLAND: Yes.

PARTICIPANT: There is a piece about fiber optic cables. I was looking over the new itinerary for Wednesday and Thursday, and that particular piece seems to be missing. Has that been dropped?

MR. SUTHERLAND: Yes. That's been dropped. We've had a lot of schedule changes over the last couple of weeks where people had volunteered to give presentations at INMARTECH, and then for one reason or another couldn't make it. The fiber optic presenter was one of those, and so we had to drop that.

# Overview Of SIO & UNOLS Ship Operations And Shipboard Technical Support

Robert Knox
Scripps Institution of Oceanography

**[Editor’s Note: Following is a transcription of Bob’s oral presentation, as edited by himself.]**

It’s a pleasure to welcome all of you here today to Scripps on behalf of both Scripps and UNOLS, the two organizations that have had the most to do with putting this event together. As associate director of Scripps and chair of UNOLS, I’d like to take credit for all of what’s been done, but I can’t. The real work has been done by, on the one hand Woody and many of his people in STS, and on the other hand by the UNOLS Office and Annette DeSilva and Mary D’Andrea, who are lurking somewhere here. It's to them that you owe thanks -- not to me -- for any of the arrangements and preparations that have gone off well as the week develops. So bear that in mind, and talk to them when you get a chance.

I want to talk to you briefly about Scripps Institution of Oceanography and about our fleet. I won't take very much of your time because I know we're anxious to get into the technical sessions. Let me begin by putting up a viewgraph of Scripps.

It's an institution with some history behind it. It began in 1903 as the Marine Biological Association of San Diego down in Coronado Island, down near the main harbor. It moved to the present location in 1907 -- a considerable endowment and support from the Scripps family, hence the name. The Scripps family is big in newspaper publishing and other activities in the United States. It became a part of the University of California in 1912. In 1925, it changed its name to the Scripps Institution of Oceanography, where it's remained ever since. And in 1960 or thereabouts, it became the nucleus around which the entire main campus of the University of California at San Diego grew and expanded. In fact, the very first operations of the university campus were down here at Scripps before buildings were built up on top of the hill back in the early to mid sixties. I'll show you briefly just two slides of this part of the world, sort of then-and- now pictures, if you will. That's the then-picture. If you were a good real estate speculator, you would've bought land then and not now. The now-picture is -- the next one, please -- a more or less modern aerial view of the campus and surroundings. You can see a similar shot over there on the far wall -- some indication of how much this area's grown up in that span of time.

Continuing on with a few brief facts about UCSD, about Scripps overall. We have a staff of some 1200 or 1300 people, something like 160 of those are Ph.D. level scientists, principal-investigator types. Depending on when you count, there may be 300 or so different research projects going on across all the fields of marine, atmospheric and earth sciences. Support for the institution is primarily from research grants from the federal government -- about 75 percent -- primarily from agencies you all -- at least all of you Americans - know: NSF, ONR, and to a lesser extent from some of the other federal agencies, leaving about a quarter of the institution's budget that comes from other sources -- state monies, private monies, and so forth. Total expenditures are on the order of $100 million, and there are some 190 or so graduate students at any one time. Scripps is primarily a graduate education component to the university, although it is very slowly feeling its way into a certain amount of undergraduate teaching as we speak.

I should mention, I think, that just in the last week, a very useful fact sheet about the institution overall has appeared. In fact, the boxes full of the printing run are stacked in the corridor outside my office. But if anybody's interested, we can probably lay hands on this. Talk to Woody or me later. It's a relatively convenient fact sheet for the institution overall.

Let me zero in to our fleet of research vessels, one of the larger ones in the United States, briefly described in this viewgraph. There are four of them. The support base, operating base for them is down on Point Loma, as Woody mentioned, and you'll be seeing that base and one of the ships in the course of the week. It involves

something on the order of a hundred people, counting both the crews on the ships and the people in the shore support facility. Approximately $12 million of annual operating expenditure if all the ships are all running full-time, which amounts to on the order of a fifth or a quarter of the entire UNOLS fleet.
Of course, they vary greatly in size and capability. You can see some rough annual operating numbers for the four ships there (indicating), assuming, again, about a full year's worth of operations.

A great deal of this information is available, both in printed form -- these ship leaflets, which, again, I don't have a full stash of, but we can get more of them -- and/or on the web site, which can walk you through virtually any of this Scripps or marine facilities operation.

Let me turn again to the slides just to give you a few brief pictures of some of the ships. This is far from a comprehensive overview, but it'll give you a little sense of what some of them look like for those of you who don't know that already.

This is an aerial view of the whole facility down there on Point Loma with all four ships in port, which is a relatively rare event. On the far left is *New Horizon*. In the foreground on the seaward side appears the newest vessel, *Roger Revelle*. The other large vessel that's alongside the pier is *Melville*, which you will see. And the little one tucked in the crack in the middle there is *Robert Gordon Sproul*, our local vessel that does primarily short trips in and out of San Diego, although she has been as far away as the coast of Mexico and the Pacific Northwest from time to time.

Next slide. That's the launch of *Roger Revelle* back in the spring of 1995 -- a fairly spectacular event. I hadn't seen the side launch before. It gets your attention.

Next picture. And *Roger Revelle* returning to San Diego for the first time in the summer of 1996.

Next. These go back in time a way. This was in the late 1980s and early 1990s, a major refit and reconfiguration of both *Melville*, which you'll see tomorrow, and the sister ship, *Knorr*, at Woods Hole. They were massively reconfigured. The whole propulsion system was changed from the cycloidal propellers that you see there fore and aft to more conventional Z-drive propulsion. They were stretched 34 feet, and so forth.

Next slide. There's the ship cut in half up on dry land getting ready to insert a new midsection.

Next. And, finally, the reconfigured ship that you'll see back in the water and serving well since then, 1992.

And, finally, I think the last slide just sketches for you the pieces of the ocean that Scripps ships have ventured to over time. That's essentially an historic composite of all the major expeditions of Scripps vessels over the course of the years -- obviously, heavily loaded in favor of the Pacific, but we have wandered into some of the other pieces of turf from time to time.

I think that's it for the slides. Woody's already told you a little bit about the other major component of the Scripps seagoing operations, the Shipboard Technical Support enterprise that he heads and the various groups and so forth that are involved in that. I won't say much more about it. It scales at just roughly half or so the size of the ship operations in terms of both number of people involved, and number of dollars per year, and so forth.

Let me move now to UNOLS and just sketch for you a little bit about what UNOLS is all about and what it's trying to do at this year in time. I should mention, first of all, that there's a UNOLS web site, if you haven't visited it already. Essentially everything I'm going to tell you could probably be learned from the web site if you don't take it away from here.

It's an organization of academic oceanographic institutions. It's not a federal organization. It's not a granting agency. It's not a whole lot of things. It is an organization of institutions. Each institution is a member, a single member. And it's supposed to coordinate and review utilization of facilities, access to facilities, and the current match or mismatch of those facilities to the needs of academic oceanographic programs. It is, at bottom, a creature of the scientific community intended to maximize the effectiveness of the research vessel

fleet in the United States. And as many of you know, it collaborates and enters into discussions with similar operations around the world, although it's an American organization at bottom.
There are some 57 member institutions at the moment, but 20 of which actually operate vessels. The other 37 are institutions that are interested and involved in UNOLS activities, but don't themselves have research vessels to operate. There are 28 UNOLS ships. It amounts to something on the order of $50 million a year of operations. Bear in mind that operations money goes to the institutions that operate the ships. It doesn't go to UNOLS. UNOLS money is essentially the money it takes to run the office. UNOLS doesn't bring in money and hand it out because the system is predicated on the idea that the way to operate these ships is to continue to keep the operations in the hands of individual institutions, but nonetheless overseen and guided by both agency policy and by UNOLS policy to try to maximize the effectiveness of this collectivity of ships.

So it's a funny combination of individual free enterprise per institution on one hand, and some sort of community ethic and cooperation on the other hand. There's an obvious tension between those two modes of working, but somehow it seems to have done rather well for the American scientific community since 1971, when UNOLS began.

Briefly, the structure of UNOLS consists of a council, which is kind of like the board of directors, if you will, and a number of established committees -- you see them listed there -- dealing with various aspects of important UNOLS business. Perhaps one of the more significant ones on an annual basis is the first of those, the Ship Scheduling Committee, which, in conjunction with agencies, attempts to stitch together UNOLS ship schedules that get the right ship to the right place at the right time to handle the funded scientific projects, and neither too much ship nor too little ship to get them done. So people from the East Coast may use Scripps vessels in the Pacific, and people from the West Coast may use East Coast vessels in the Atlantic, and so forth, mixing and matching to try to make those schedules as effective as possible and not waste any more time than necessary simply transiting back and forth from A to B.

This will give you a sense of where UNOLS institutions and ships are. These are the operating institutions of UNOLS. It's probably not worth digging into the details of it, except that, obviously, they are scattered around the United States. Some are single-ship operations, some are multiple-ship operations, and there are ships of various sizes in the UNOLS fleet, as indicated by the different codes there.

The next viewgraph will show you something about who has which ships, where, how big they are, and who owns them. This first is the relatively smaller end of the scale, "the local ships" they're called in UNOLS parlance. You can see that they're scattered around the country. You can also see that only one of them is owned by a federal agency, the last one on the list, owned by NSF. The rest are all owned by institutions -- ranging up in size to 120 feet, used primarily for very local activities and very short trips, for obvious reasons.

This is almost a set of dots on the page to indicate where they go. It's no surprise to see that, with rare exceptions, they stay rather close to where they're home-ported -- in and out and in and out in the local region. These are composites for three years and the sum of all three. And you can't see much separation in the tracks because the dots are too big.

Moving up one notch in size are our intermediate sized vessels. Now you start to see the greater impact of federal ownership. There are six NSF-owned ships in here and one Navy ship; the remainder being owned by institutions. The size range is bigger, of course. They get around the world more, as indicated in this slide. Obviously, they still cluster somewhere their home ports, but they fan out over more of the ocean over time. The same three years are displayed here.

Then the next and final step up in size is the global/expeditionary ships, all of which are owned by the federal government in one way or another, most of them by the Navy.

The ship tracks for the same set of ships, the global/expeditionary ones, carry them all around the world, more or less, depending, again, of course, on the needs of the funded scientific programs.

You do see a good deal of work in relatively difficult parts of the world on this chart. In fact, I happen to know there's another cruise track that goes around Cape Horn the hard way that isn't shown on this plot. So these bigger ships in the fleet are attempting projects that simply wouldn't be tenable for smaller ships. And conversely, it doesn't make sense to use one of the big ones for something that a small one could do. The final slide for UNOLS gives you a snapshot in 1996 of metrics of UNOLS activity -- total number of operating days in the UNOLS fleet, total number of cruises, total number of participating scientists and technicians on board, scientific parties, and so forth -- 153 institutions represented. You'll recall that there are only 50-some-odd UNOLS institutions. So what this means is that the system has fanned out and included scientists from a much broader scientific community than simply the UNOLS institutions. In many cases, it's other American institutions that are not members of UNOLS. And in many cases, it's foreign participants and collaborators. That was the 1996 number, in the mid $40 million of total annual costs.

That's a thumbnail sketch of Scripps, of Scripps fleet, of UNOLS. I'll be happy to answer questions about any or all of the above as the week goes on. But mostly what I want to do is to welcome you to this gathering on behalf of both Scripps and UNOLS. It's the second such meeting, I believe. There's already plans for the third. And I hope very much that the series keeps on going.

Thank you very much.

# SIO International Relations

Lisa Shaffer
Scripps Institution of Oceanography

W. SUTHERLAND: Please excuse me if I read, but I don’t want to leave out any of the details of the next introduction. Our next speaker is Dr. Lisa Shaffer. She’s the director of international relations for Scripps. She joined SIO in July of this year from NASA, where she was the director of external relations for NASA’s Earth Science Program, Mission to Planet Earth. Her career includes ten years at NASA, four years at NOAA in the international office for NES/DIS, the satellite and data component of NOAA, as well as working in the private sector for Bendix, SAIC and others. She has a Ph.D. in public policy, and her talk will cover how Scripps fits into the international arena and will describe the range of international activities here at Scripps. The title of her talk, "The World of Scripps, the World in Scripps, the World and Scripps."

DR. SHAFFER: I appreciate the opportunity to be here. It gave me a chance to learn something more about my job. This is my first official Scripps presentation. So I’m glad to be here.

Scripps Institution of Oceanography

***The World of Scripps***
***The World in Scripps***
***The World and Scripps***

Presentation to
International Marine Technicians Symposium
Inmartech 98

Dr. Lisa R. Shaffer
Director, International Relations
October 20, 1998
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What I wanted to talk about, as Woody said, the international dimension of Scripps activities. It’s probably obvious, but we live in an international society, and we work in an international setting. All of you do, and everyone at Scripps does. And that covers the things that we study and teach about -- the Earth, the oceans and the climate.

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***We live in an international society and work in an international setting***

Science

Education

Technology

The things we study and teach about:
the Earth, the oceans, and the climate

There’s a lot going on in society that is international, and particularly in science. The research enterprise that all of your activity supports is global in nature. We’re in the information age, as opposed to the industrial age and the ages that have preceded us. And information doesn’t really respect national boundaries, but is more global. Attention focuses nowadays more on intellectual property than physical property. We all are aware of global networking, and we’re able to quantify and analyze processes on a global scale.

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***The broad trends in science reinforce the importance of the international perspective***

- Globalization of the research enterprise
  - Major worldwide research programs in all areas
- Start of the Information Age
  - Intellectual property issues rather than physical property
  - Global networking
  - Ability to quantify and analyze global scale processes
- Environmental Stewardship replacing Military Security
  - Environmental security is vital to national interests
  - Global warming is most enveloping of all
  - Int’l cooperation is essential to achieve environmental security

Another change that has happened in the world is the increased attention on environmental management as part of our foreign policy, as opposed to military security. It’s now recognized increasingly that environmental security is an important part of every country’s national interest. Global warming is an example of the broadest kind of environmental concern that transcends any other kind of concern. It involves the sustainability of the planet. In order to deal with some of these issues, we have to work internationally.

Environmental stewardship has really become the heart of our international policy agenda in the United States and elsewhere. Oceans are, of course, an important part of global sustainability and environmental stewardship and affect almost every dimension of life.

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***Environmental stewardship at the heart of the international policy agenda***

- Consensus for a sustainable world
- Oceans play a key role in sustainable development
- Key barriers to sustainability:
  - Food
  - Energy
  - Climate
  - Water

So our work requires us to do a lot of international things. One aspect of our international work is the collection of data on a global scale. We use data from a lot of different sources, and these data are provided by many different countries. Countries are involved in deploying and developing systems, and collecting and analyzing the data, and in managing the distribution of the products that come from those collection systems.

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***Our work requires data collection on a global scale, which requires international cooperation***

Many types of data
-- Space-based and in situ observations
Contributions by many countries
-- Development and deployment of systems
-- Collection and analysis of data
-- Management and distribution of data and products

We also, once we've collected the data, have to analyze it, and that requires, again, international activity in terms of accessing computing facilities and access to intellectual capability and technology. I've given some examples of international programs that Scripps is involved in. I won't go through all the acronyms, because if you don't know them, it probably doesn't matter anyway.

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***Our work requires analysis involving masses of data and large computing capacity. This calls for intellectual and technological cooperation on an international basis***

Examples:
- International research programs
  - WOCE, TOGA, IGBP, WCRP
  - International Research Institute for Climate Prediction (IRI)
- Climate models in Europe, Japan, Brazil, US
- Regional initiatives around the world
  - Interamerican Institute (IAI)
  - EuroGOOS
  - Frontier Initiative in Japan

But some of the global scientific programs -- the International Research Institute, which Scripps is a partner in with Columbia University, where we make the seasonal to inter-annual climate predictions -- the El Niño predictions. There are climate modeling activities and centers around the world. I've listed a few. And there are regional programs, such as the Inter-American Institute, the European Global Ocean Observing System Regional Project, and the Frontier Initiative in Japan to study global climate change and do climate modeling. Scripps is involved one way or another in all of those activities that I just mentioned.

Well, the scientists make discoveries and do their research, and then we need governments and people to take action in response to what we've learned. So for example, with El Niño, the scientists have developed ways to make these seasonal to inter-annual predictions. But then it's the responsibility of governments and of populations to do something with that information; to plan better, to prepare, to bolster their rooftops and their coastlines.
In the case of longer-term climate change, our scientists have documented the increase of $CO_2$ and in global temperatures, and now governments are involved in negotiating reductions of greenhouse gas emissions to try to stop the problem. And an ozone depletion -- scientists discovered the ozone hold, and then governments had to take action to agree on limiting COCs -- eliminating COCs to stop the further deterioration. So that's sort of the big picture view.

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***Our science contributes to social change, which requires action by governments and populations around the world***

Examples:

**El Nino**: experimental forecasts allow for preparedness of coastal communities, food security planning

**Global warming**: research documented changes, scientists studying possible causes. Governments negotiating greenhouse gas emissions reductions

**Ozone depletion**: Science discovered the problem, Governments negotiated and implemented Montreal Protocol. Science needed to monitor impact of Treaty.

Here at Scripps, how do we fit into that broader picture? I tried to update a list that had been here of all the projects Scripps has done or is doing internationally. So far, we're up to almost 350 specific cooperative projects with 61 different countries. Some of these are individual scientists collaborating. Some of them are much broader international programs. In addition, we have formal memoranda of understanding with 33 different organizations and 20 different countries where there's a formal institutional link between Scripps and a partner agency.

A little closer to this group, the global use of the research fleet that Dr. Knox just described, we tallied up on the last five years the Scripps ships -- I have to learn how to say that, "Scripps ships" -- have made 50 calls in 24 foreign ports in 11 different countries. So you can see that this institution is extremely international.

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***Global use of research fleet***

Research cruises around the world with international destinations and participants: Since 1993, Scripps ships have made 50 calls in 24 foreign ports in 11 countries

- American Samoa – Pago Pago
- Australia – Hobart, Melbourne, Port Hedland, Brisbane, Fremantle
- Canada - Patricia Bay
- Chile – Punta Arenas, Valparaiso, Iquique, Easter Island
- Fiji – Suva
- Mexico – Acapulco, Manzanillo, Mazatlan
- New Zealand – Dunedin, Wellington, Lyttelton, Chatham I.
- Peru – Talara, Callao
- Polynesia – Papeete
- South Africa – Capetown
- Tonga - Nuku'Alofa

Beyond the ships, there's other infrastructure that we share and that Scripps is involved in with other countries involving both satellites and in situ collection systems. You have to forgive me for putting "satellite" first, since I came from NASA. I just listed a few of the satellites and instruments that Scripps scientists are involved in, and below that, some of the in situ networks.

We have a lot of ground-based instrumentation that Scripps manages for seismic studies. You're familiar, I'm sure, with the ocean-type in situ observations. We also work on atmospheric modeling around the world.

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***Shared use of infrastructure***

Acquiring data from internationally-provided satellites and in situ networks

- Topex/Poseidon – US/French Satellite
- NSCAT – US instrument on Japanese satellite
- ERS – European radar satellite
- Radarsat – Canadian/US project
- Meteosat – European weather satellite
- GMS – Japanese weather satellite
- OCTS – Japanese instrument on Japanese satellite

- IDA- 34 seismic stations in 20 countries
- US- Australian XBT transects to study heat balance in Pacific
- Analysis of air samples from Canadian environmental stations
- Many more

Again, as was mentioned, Scripps is also an educational institution, part of the University of California, San Diego. About a quarter of the faculty here are from outside the United States, and an equal percentage of the student body is non-U.S.

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***Education at Scripps is international***

- More than one-quarter of the faculty are non-U.S.
  - 26 out of 83 total faculty from 12 countries
- Approximately one-quarter of the graduate students are from outside the U.S.
  - 45 students from 22 countries

So we do research, we teach. That's all done on a global basis. We're also involved in strategic planning on an international scale. These are some examples of international science committees and advisory groups that Scripps experts are participants in. It's not exclusive -- it's not a complete list, but just an example. So we help shape the research agenda for global programs.

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***Strategic Planning***

- International projects science committees, advisory groups (examples)
  - Biological Oceanography Standing Science Committee of the North Pacific Marine Science Organization (PICES)
  - International Panel on Climate Change (IPCC)
  - World Ocean Circulation Experiment (WOCE) Scientific Steering Committee
- Integrated Global Observing Strategy

And we're involved in something that's very near and dear to the heart of the director of Scripps, Dr. Kennel. And I worked with him on this when he was at NASA -- the Integrated Global Observing Strategy. This is a term we use to describe an effort to involve all of the space agencies of the world and, hopefully, all of the agencies around the world that collect in situ data, to look at what the needs are of the entire international community to make long-term measurements for climate change, for ozone monitoring, for weather forecasting, and to identify what observations need to be made on a long-term basis, who's going to make them, to share the burden as equitably as we can among the countries of the world, to look at trade-offs between an in situ or a space-based capability to make a particular observation, to look at calibration, continuity of the data sets, and to build a permanent global archive of what we see in the U.S. system and to be able to understand how the planet is changing.

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***Integrated Global Observing Strategy***

- Integrated
  - Use of existing space-based and ground-based measurements
  - Linking measurement technology with scientific analysis
- Global
  - International participation
  - Environmental problems transcend national borders

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***Integrated Global Observing Strategy***

- Describe and quantify interconnections among the Earth systems
- Provide services deliverable to society for both the short and long term
- Build a permanent, global archive of what is changing, where, and by how much
- Enable us to understand our planet significantly better than we now do

Scripps Institution of Oceanography

***Integrated Global Observing Strategy***

- Observing
  - Data must be complete, continuous, and comparable
  - Observations must be long-term
- Strategy
  - Build on existing and planned capabilities
  - Gain commitment for long-term participation

So in summary, as was probably obvious by the fact that Scripps now has a director of international relations, Scripps is an international institution. Its mandate, its resources, its programs and its relationships, and it's impact, we hope, are all global in nature. That's a necessary part of success in today's society and in facing the challenges ahead of us. So we're pleased to say that we have had an impact, and we hope to continue to have an impact in the longer-term goal of improving the sustainability of the planet.

Thank you very much.

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***Summary & Conclusions***

Scripps is inherently an international institution in its mandate, its resources, its programs, its relationships, and its impact.

Global perspectives are required by today's society and challenges.

Scripps is well-positioned to make major contributions to the goal of achieving long-term sustainability through today's research, teaching, investments, and outreach.

# Technician And Instrumentation Support of Seagoing Science By The U.S. National Science Foundation

Alexander Shor
National Science Foundation

**[Editor's Note: The following is a transcription of Sandy's oral presentation.]**

W. SUTHERLAND: The next person to welcome you to INMARTECH and to the U.S. is Dr. Alexander Shor, known to most of us as Sandy. He's the program director for the Instrumentation and Technical Services Program of the Division of Ocean Sciences at NSF. He will talk on technician and instrumentation support for seagoing science by the U.S. National Science Foundation.

DR. SHOR: I allowed Annette DeSilva from the UNOLS office foolishly to twist my arm at the last minute to speak. It was not my intention to actually speak, and I will keep it very brief. But I will give you a little bit of background, and I'd particularly like to welcome you on behalf of the National Science Foundation (NSF) and our sister agencies, the Office of Naval Research (ONR), National Oceanographic and Atmospheric Administration (NOAA), and other agencies that are involved in UNOLS, to San Diego as part of the inter-nationalization of our technical support, and outreach, and in that forum.
Woody already gave you the title of my position at NSF, which pretty clearly describes what I do. I provide about -- well, probably the bulk of the support for scientific instrumentation that is what we call "shared use" on the research vessels. We have a program of a couple million dollars a year to acquire new CTDs and a whole array -- I'll use them as simply an example -- to maintain a capability across the UNOLS fleet so that it is relatively transparent, although not completely transparent to a scientist moving from within the same class of vessel or trying to do research in different areas and not requiring that they operate out of their home institution.

I also support the marine technicians, the basic marine technical support on the ship of one or two technicians per ship. In addition, we are expanding that to provide some more specialized support now that we think we've got an opening towards a little bit more money, to provide that shared use capability across the fleet.
My own background -- I have spent time in different ways at four of the major oceanographic institutions in the U.S. I grew up here in La Jolla. My father was a researcher, and later the associate director. In fact, had Bob's job here prior to Bob (Robert Knox). So I grew up here, but I left here 29 years ago. I just come back to visit my parents and for an occasional meeting now. I've also been at Woods Hole Oceanographic, where I got my doctorate, and Lamont-Doherty for about seven years, and most recently, the University of Hawaii prior to coming to NSF. So I've put in over a thousand days -- I stopped counting at a thousand -- on research ships of one type or another. And it was a decade ago that I lost track. So it's been a while. I've pretty much stopped going to sea now, although my wife still does.

I've also spent a little bit of time on foreign vessels, but not enough to have a real flavor of the diversity of methodologies, but enough to at least have the flavor. I've been out on Canadian -- particularly in the early and mid-80s -- did quite a bit of work with the Canadians off the East Coast -- and United Kingdom, Norway, and most recently, Korea -- spent a little bit of time on some of those vessels. But I do not have a wide background on other countries' research vessels.
More specifically about NSF, and very briefly, that's our organizational chart. And that is the way we think. (Laughter.) We are bureaucrats.

The Division of Ocean Sciences is one of three divisions in the directorate for geosciences at the National Science Foundation. The geosciences directorate is one of the larger directorates at NSF. Our division director in ocean sciences is Mike Purdy, formerly of Woods Hole Oceanographic Institution for many years. He's been with us for about two years.

Don Heinrichs, who is my boss, heads the Centers and Facilities Section. We support the infrastructure on the ships, the ship time -- the NSF portion of that, and the shipboard technical support. And you see the four

groups. I actually filled two of those boxes temporarily, but my main one is the ocean- -- misspelled -- Oceanography, Instrumentation and Technical Services. I'm also temporarily handling oceanographic facilities, which means winches and the UNOLS Office support, because the program director who handled that retired about two weeks ago, and we are madly trying to replace him.
Dolly Dieter, who many of you know, runs the Ship Operations Program. She was here last week for the ISOM meeting, along with Don Heinrichs. The Ocean Drilling Program is also run out of our section, and that's a separate program about comparable in size to Ship Operations, run by Bruce Malfait.

The Oceanographic Research Section is the drives everything we do in the facilities section. The decisions that are made in the four primary discipline areas, plus the inter-disciplinary and engineering development work, which we do substantially less of than what we call the basic sciences, fall in the Ocean Science Research Section, and have about double the budget of the facilities, and are growing more rapidly. We basically match capability and needs to funding decisions and basic research, and let the research drive the facilities requirements.

This is why an organization like UNOLS is absolutely imperative. Somehow you have to link the requirements with the funded science so that -- the science needs, which are made not entirely in a facilities vacuum, certainly, but largely independently of decisions about where ships are going. We do not lay out ship tracks in advance and fill the science along the way. All of the funding decisions from NSF about what science will get funded are made without requiring that there be a vessel, obviously, available a year from now to do that. That's what makes this job of the Ship Scheduling Committee so particularly difficult, because there are, of course, 28 ships within the UNOLS structure, plus some other international agreements -- interagency and international agreements -- to somehow mesh.

I'll show just some very brief statistics. I only have four viewgraphs, and that was probably the only one of real significance, just to show you who we are. But overall, this is what the UNOLS fleet -- the number of days -- of time that are involved. You see this up in the -- Bob had shown you, I think, 1996 as an example, about 4300 days of total time. This is how it breaks out by class. The red one is the largest, and the blue one is the smallest -- that's right -- of our research vessels in the UNOLS fleet.

To get a sense of NSF's role in this, we fund about half of the days used at the moment, although that's down from a few years ago, when it was up to 80 percent. And you can see a somewhat higher percentage of the larger ships. But, basically, somewhere in the 50 to 80 percent range for the last decade of UNOLS funds have come out of NSF. And we're very pleased to see that percentage getting somewhat smaller, although we're not as pleased to see the decline in some of our own utilization, and some of the things that we hope to do with additional funds that we anticipate being signed today or tomorrow -- although we have learned by rumor it was signed Friday; it was not -- is to put more of that into the research program to get more ship time at sea.

Finally, hopefully very few of you are actually interested in this. This is the actual dollars that go into the UNOLS fleet from NSF, as well as what goes into research, and what goes into the Ocean Drilling Program. You'll see that the facilities dollars, the dollars spent on actually sending ships to sea, has been relatively flat for about five or six years. Actually, one could make a case it hasn't risen much in the 90s at all. And that is true, we have been using over the last few years a bit less and less ship time each year from NSF as some of the large global programs have wound down and the research funds have not really kept pace with the cost of sending science to sea. We are expecting somewhat of a step up in the 99/2000 time frame, but we're not expecting it to be rapid growth. We've been very pleased to see other agencies, particularly the U.S. Navy and different forums, using more of the UNOLS ship time over the last couple of years, and seeing some diversification of agencies of support and of the types of research that are going on in the fleet.

That's basically all I wanted to say is to welcome you and give you a sense of who we are and what we're doing, and on behalf of all of the agencies, to welcome you. If there are any questions at all, I'd be happy to handle them now.

# UNDERWAY SAMPLING SYSTEMS

Chaired By
Anthony Amos

# Welcome To Underway Sampling Systems

A. F. Amos
University of Texas Marine Science Institute

MR. AMOS: Good morning, everybody. I hope you can hear me well. I have this machine on. My name is Tony Amos, and I'm with the University of Texas Marine Science Institute, which is located in Port Aransas, Texas.

I'd like to just give you a little bit of background on myself. I got into this business in 1963. My qualifications at that time were in the electronics field, having worked the eight years prior to that for a rather eccentric English inventor who invented a new color television system that hung on the wall; a flat-screen color television. We were not successful at doing it. However, with that background, I was interviewed at Lamont Geological Observatory [for a marine technician opening], and the interviewer took a look at me and said, "Well, you have a beard." He said, "You look like an oceanographer. Where would you like to go, to the Indian Ocean or the Antarctic?" And I chose the Antarctic, and I've been going there ever since.

We have a couple of announcements about this session. Mr. Jan Derksen from Holland had an unfortunate incident that he got parted from his slides, and they're somewhere between Amsterdam and La Jolla, as far as I can tell. So he will not be able to give his talk now. It has been rescheduled for the shipboard networking session, which is on Thursday morning. However, I will ask him to perhaps come up and just give a five-minute or so review of what he's going to talk about and maybe sit on the panel afterwards to answer questions.

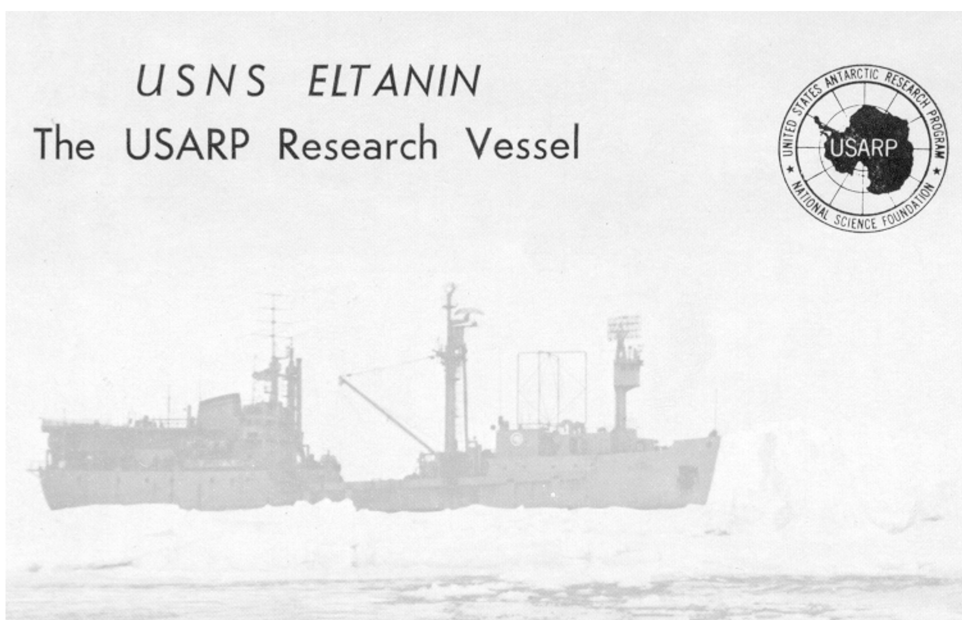
So we're down to two talks, my talk and that of Dr. Dave Hosom.

# A Brief History Of Work On A Research Vessel From The Experience Of A Marine Technician

Anthony F. Amos
The University of Texas
Marine Science Institute

*The following was an introductory presentation to the session on Underway Sampling Systems and used a video made by the session chairman. The video had narration by the author and there were also explanatory remarks made by Amos while the video was being presented. Some editing has been done to the transcript to clarify colloquialisms, to remove repetitive phrases, and to fill in gaps in the transcription. Explanatory information is enclosed in square brackets. The narration on the video was made for general audiences and not for the present audience who are familiar with many of these techniques. The footage in the video was taken aboard the US Antarctic Research Vessel, USNS Eltanin from 1966 to 1969.*

I’m going to take this opportunity to show you a video before I start. This is an 18-minute video. And I do apologize. It is poor quality. But it was done in the early 60s on a research vessel [the original 16mm film was shot using a Bolex camera with no sound and transcribed by making a video of the screen while projecting the film].




The reason for showing it to you is to give some sort of slightly historical context to this meeting. And if my French colleagues will forgive me, it will illustrate the old saying, "plus ca change, plus la meme chose", as you will see.

I have kind of straddled two worlds in this business now. I am a Research Associate at the University of Texas and am a PI on several research proposals, but I remain a technician at heart. And whenever I go to sea, there’s nothing I like more than -- well, I won’t say I like more than repairing things that break down, but I do enjoy setting the equipment up and trying to keep up with the considerable amount of progress that’s happened in this business. So I think I’ll hopefully be able to make this machine [the VCR] work by turning it on. And there it goes. It takes a little while to warm up.

(Pause.)

You will hear me on the film and the me here talking about [what’s going on in the video]--

(Video started.)

MR. AMOS (ON VIDEO): Now we're [the Eltanin] off the Balleny Islands --

MR. AMOS: Can you hear the me on the film? Okay.

MR. AMOS (ON VIDEO): -- some of the most rugged and inaccessible of all the Antarctic islands. They're quite extensive.

There you see somebody putting on the earlier Niskin bottles on the line with the Balleny Islands in the background. The messenger [a weight attached to each bottle that slides down the wire to trigger the next one to collect a water sample] on -- that messenger will get triggered by another messenger. There you can see some incredible real estate that make up the Balleny Islands -- that spire -- that pinnacle behind. [is noteworthy]

Now we're off Cape Hallet.

MR. AMOS: This is the research vessel Eltanin, which was the U.S. Antarctic research vessel from 1962 – 1975.

MR. AMOS (ON VIDEO): -- the electronic devices [an STD], or one of the very first of the electronic devices to measure temperature-[salinity-depth]--

MR. AMOS: That's Stan Jacobs in the background, for those of you who might know him.

MR. AMOS (ON VIDEO): -- Stanley Jacobs in the background and Alvaro Ulloa in the foreground with the red shirt. And they're attaching Niskin bottles, [to] one of the earlier forms of the rosette. This was, in fact, a device developed at Lamont Geological Observatory by Sam Gerard and myself. I had a certain amount to do with it. He called it a "SAMS," a "Surface Activated Multiple Sampler." I called it an "AMOS," an "Automatic Multiple Ocean Sampler."

(Laughter.)

MR. AMOS: It was mostly Sam's work.

MR. AMOS (ON VIDEO): -- [it functioned like the] commercially available rosette samplers, except this one you could trigger any bottle at any time. You did not have to go around in rotation.

MR. AMOS: Each bottle had an individual solenoid similar to the Carousel now in use. That's Stan Jacobs (indicating).

MR. AMOS (ON VIDEO): -- you may see [the Hero Platform]. You have to be a hero to stand on it. You see we've only got four bottles on the -- four or five. Now they're coming up having been tripped. See all the [thermometer frames have rotated less than 180 degrees]. They were all probably turned enough to register the temperature.

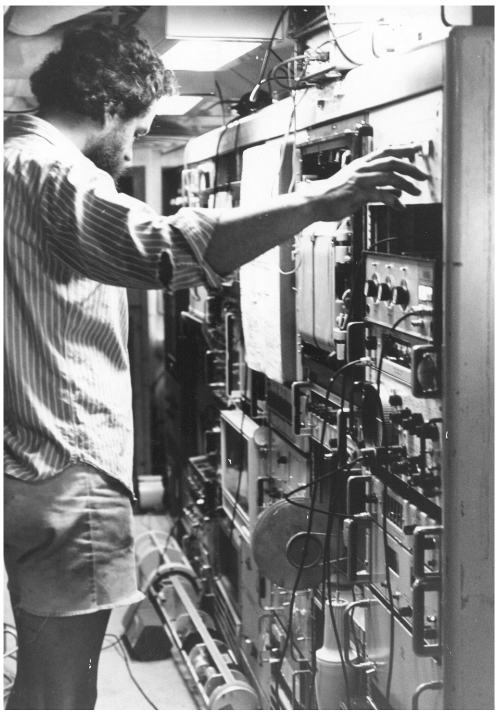
This is a time lapse [of a STD station output on a chart recorder]--

MR. AMOS: Does anybody remember strip chart recorders?

MR. AMOS (ON VIDEO): The surface of the ocean is at the bottom, and so you have to try and stand on your head and look at things. The red traces temperature, the blue

MR. AMOS: Which you won't be able to see. [Film quality did not show the blue well]

MR. AMOS (ON VIDEO): -- traces salinity. And what I'm doing there [in order to get the time lapse] is holding the shutter and clicking it like -- click, click, click, click, click -- for a period of about half an hour in order to obtain this picture.
MR. AMOS: That was an earlier version of me.



MR. AMOS (ON VIDEO): [Here] you can see the "modern" data acquisition system. That was a Hewlett-Packard data acquisition system. And here we see it had a mechanical scanner, and a counter that scanned through three channels, temperature, salinity and depth. It was made by the Dymec division of Hewlett-Packard. And if we look at "*dy*" -- the "*dy*" logo -- that was just "*hp*" turned upside down. That's the salinity number [a frequency value displayed on a Nixie tube readout] -- well, I even recognize, believe it or not, some of those numbers as being typical in so many of these stations. This was a big innovation, by the way, and the data was punched out on punch paper tape.

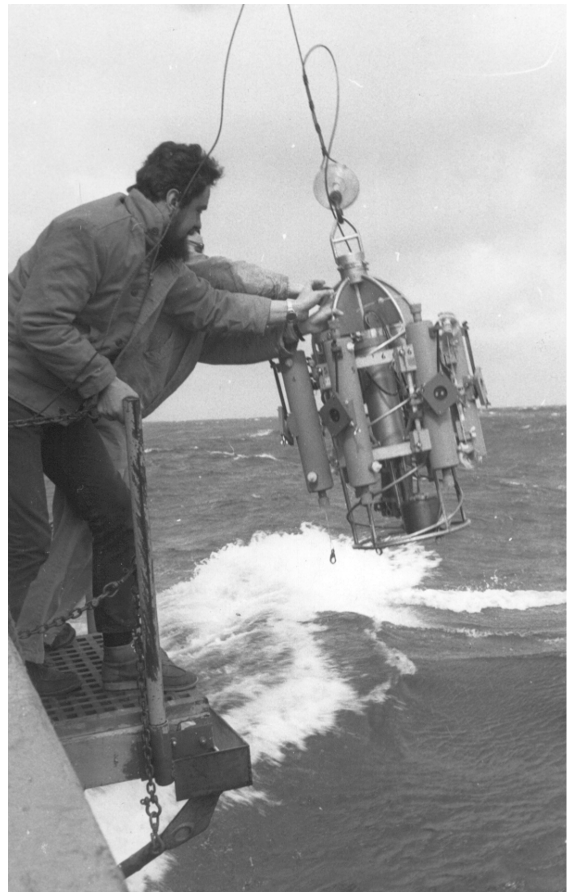
This is a Frenchman. Now, what was his name? He pretends to drop the messenger. He knew he was being filmed. Anyway, you can see, by the way, some of the wire angles that we had to contend with. At times, we actually had to use a kind of a hook to pull the wire in close enough. This man was a bit of a ham [on the video he makes an exaggerated gesture for the camera].

This is a butterfly sampler [a Niskin bag sampler for collecting sterile samples for microbiology].

MR. AMOS: That was a Russian whaling fleet, by the way [a brief shot of whaling ships].

MR. AMOS (ON VIDEO): There's [myself and] Stan Jacobs standing on the hero platform. Note that Stan is roped in -- and rightfully so -- he has his safety harness on.

This is a little later. This is probably Cruise 32, maybe 1967, and this is a later and larger version of the STD, and you see how much he had to lean in order to keep it [the STD] from bashing the side of the ship. And then, of course, there's always this critical period when you tell the winch man to come down on the wire and hope that you've got the balance correct. And there's the same automatic multiple ocean sampler, forerunner of the Niskin rosette sampler.



You're going to see one of the operations that was done extensively on the Eltanin: coring. This is the trigger arm of a piston core. The piston core has already been taken. The trigger arm has released. What you're going to see is the recovery of a deep ocean core, probably a two-piper. And here comes the core "bomb". Inside that housing is probably about 2,000 pounds of lead, then comes the pipe. Each pipe is 22 feet long. They had to first secure that [the pipe] with a chain, and then put a line around it. That [line] is pulled from another area on the Eltanin. This will pull the pipe itself up so the core will ultimately become horizontal, and then it can be laid in the outriggers. And there it comes. There's a little slip. (That often happened). But finally they've got it up, and there they're going to lay it in the outriggers.

And here's perhaps one of the finer jobs to do on an oceanographic research vessel in the sloppy Antarctic Ocean - to remove all the little screws from the collar separating two sections of a piston core pipe. Now the ship is underway to the next station. [Hopefully] they haven't dropped too many screws over the side, then they lowered it down onto the deck. The cores on the Eltanin were done using core liners, although in some cases [core liners were not used]. But the Eltanin did use plastic core liners -- [shot of a scientist] looking at the other section.

And there is the good ship Eltanin plowing through the waves. That's the entrance to the hydrographic lab there where that man just went in. The winch house is just above there. And then those sections of core are sawn into handle-able (sic) subsections.

And here again is yours truly. I'm on PDR watch. Everybody on the ship, every scientist or technician, had to sit for PDR watch four hours a day. [The watchstander had to] mark the [time and depth of the] bottom on the precision depth recorder every half an hour and check the records of all the other things that are going on at the same time. Here [on the video] I'm listening for -- to see how many seconds of delay there is to make sure that we're [the PDR is] on the right scale. This is an old style 19-inch recorder Raytheon.

And now, looking at it [the PDR] still, we're coming up on the slope. The slope is greatly exaggerated, of course, because the exaggeration of depth over distance traveled is considerably enhanced here.

Now, here are some still photographs taken of -- bottom photographs -- one of the jobs we did at every station was to lower a camera on the end of a wire that had a strobe that was triggered only when the trigger weight hit the bottom. So you got a series of 50 or perhaps 100 photographs. You can see the Lebensspuren [literally "life tracks", traces of animal activity left in the sediment]—

MR. AMOS (ON VIDEO): The marks of a starfish there. And then you can see an area of quite considerable current by the ripple marks.

Now, this is interesting. Only a brief shot, but here is the gravimeter. The room itself is moving around [with the roll of the ship], yet the gravity machine is staying still. The gravimeter is on a stable platform. This is an old-style seismic recorder. Lamont Geological Observatory did the first seismic work aboard the Eltanin, probably the first seismic work in the Antarctic. And you're looking again at the bottom of the ocean, only upside down. The seismic signals penetrate [the sediment]. So you not only see how deep the ocean is, but you see the strata and the horizons and the layers of sediment beneath the surface of the bottom.

This is the magnetometer recorder. And there's a man; I can't recall his name, marking the "Maggie," as it was called. And there's a punched paper tape recorder. I don't see it working at the moment. We relied a lot, of course, on the strip charts in those times. Those strip charts had to be annotated carefully.

Now, I do remember this man's name, Des [Desmond], but I can't remember his second name. He's running salinities on one of the first of the [laboratory] salinometers using conductivity ratio, and an inductively coupled transformer. Here he is drawing the sample up into the cell, and you can see the cell being filled there, which would measure the conductivity. The meter must be centered by adjusting the switches. He was nervous because I was taking the picture. Anyway, you balance the needle in the center, and then you read out the dials and you find a ratio, the conductivity of that unknown sample.

Oh, dear! [Shot of Amos trying to climb down a slippery rock on Macquarie Island]. I think I handed my camera to Alvaro [Ulloa], I am demonstrating the Amos style of what I call sea-boot mountaineering.

(Laughter)

MR. AMOS (ON VIDEO): -- [I use the method to] this very day. As you can see. It was a very elegant [maneuver]—

MR. AMOS: We sailors are not particularly good mountaineers.

MR. AMOS (ON VIDEO): What you're watching now [sequence showing Stan Jacobs taking a BT] the –

MR. AMOS: [Does] anybody remember this? Anybody still do this perhaps?

MR. AMOS (ON VIDEO): [This was one of the standard tools of]-- oceanography, namely the Bathythermograph, or BT. This was before the days of the XBTs. Every hour on the hour on the Eltanin, somebody on watch -- and we used to take, I believe, a six-hour watch -- would go out and drop this Bathythermograph, which had a temperature sensor in it and had a Bourdon tube for [measuring] pressure -- free fall 3,000 feet or so of wire, and then the skill was to bring it back up again one-handed with the winch, as Stan Jacobs is doing there -- without running it into the sheave and breaking the cable. The data was recorded on a glass slide. It scratched a mark on a glass slide.

MR. AMOS: Okay. That was "Then", and I'll just show you a few minutes of "Now" -- well, relatively "Now". This is the Nathaniel B. Palmer, the present -- one of the present U.S. Antarctic research vessels.

MALE SPEAKER (ON VIDEO): [indicating an array of screens monitoring various locations on the ship] That's the starboard side, and that's the stern, and that's the bow.

MR. AMOS (ON VIDEO): Down there, as you can see the A-frame and there's the bow. There's the navigation data. There's an icon of the ship. That's the latitude and longitude -- 53.17131 South, 70.90341 more-or-less. The screen shown here [displays] the ship's latitude and weather conditions, sea surface temperature, winds, relative humidity, et cetera. Local time, 15/08/1992.

MR. AMOS: Even this is six years ago.

MR. AMOS (ON VIDEO): And now I'm going to go outside and show you the real thing.

MR. AMOS: This was a winter Cruise, by the way.

MR. AMOS (ON VIDEO): -- 0435 a.m. on July the 15th, 1992. [The video showed the underway-environmental monitoring system deck display on board the N.B. Palmer. The data stream from various sensors is input to a PC and a monitor displays the data and ship's position while a plotter keeps a hard-copy record of data graphically displayed and the day's cruise track.]

MR. AMOS: This is the screen for the system -- an earlier version for the system that I'm going to talk about, the underway system. So I think I'll probably stop that right here.

(Video stopped.)

MR. AMOS: Okay. That should be it. Okay. Well, that's probably enough of that.

# An Interactive Shipboard Scientific Log For Research Vessels

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Nearly thirty years ago, I was co-chairman of the National Academy of Sciences Panel on Continuously Sampled Oceanographic Data (NAS/NRC, 1973). In order to find out what the international oceanographic community was doing in terms of continuously sampled data, the panel sent out 150 questionnaires and received 66 replies, of which 19 were from countries outside the USA.

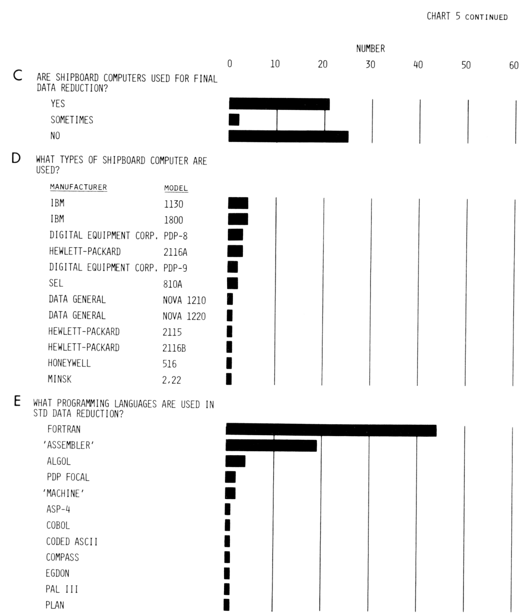



Figure 1 shows a table from the report detailing the use of shipboard computers. Among those responding, 22 said they used computers on board ships at that time (1972). This was ten years after the first Figure 1. Shipboard computer use on oceanographic research vessels in 1972 (from NAS/NRC, 1973)reported use of a computer on a university research vessel (Bowin *et al* 1966). By 1972, mainframe computers were in the majority, although PDP microcomputers were also being used. The first computer (an IBM 1130) that went on board Lamont's R/V ROBERT D. CONRAD in the mid-1960's was accompanied by an IBM engineer to make sure that it functioned properly. Compare this to the cruise of the RVIB NATHANIEL B. PALMER in 1992 shown in the video, where there were 23 PCs in the main laboratory alone. Things have certainly changed.

When I first went to sea in 1963, I was surprised to discover that not much attention was paid to the environmental information (weather and sea conditions) recorded during a cruise. The systematic gathering of such underway data was considered to be secondary to acquiring ship's course, speed, position, and bottom depth for the geophysical work. There was a general feeling among researchers that the surface atmospheric and sea conditions were too variable to be of scientific interest during a cruise. The task of gathering these data was often carried out by the ship's bridge watchstanders and entered in the ship's log. Sea surface temperature was usually measured using a thermometer and bucket, and much discussion ensued on the accuracy of such measurements. Aboard ELTANIN, our first sea surface temperature probe was a thermistor mounted in an old BT bomb hanging over the side on a boom. It was a major innovation to collect continuous sea surface temperature data while the ship was underway. Later, we made a deck installation of STD temperature and salinity sensors in a large container, through which seawater was pumped to give both temperature and salinity.

A daily underway log was maintained on ELTANIN by the contracted scientific support group and it required the full-time services of one technician to do this. Figure 2 shows a sample of the ELTANIN daily log sheet

Figure 2. Daily Log sheet from Eltanin Cruise 12, April 9, 1964.

ELTANIN DATA SHEET DATE: 9 APRIL 1964

CRUISE NO. 12 38TH DAY OF CRUISE (GMT SHIP'S TIME + 2 HOURS)

| NAVIG | TIME GMT | LAT S | LONG W | SHIPS HOURLY TRUE CRS | SPD | TRACK/SPEED CHANGES | DEPTH UNCOR FMS | SFC TEMP oC | WIND BEAU FORT | WIND AZM | AIR TEMP oC | DEW PT oC | SEA STATE CODE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E.P. | 0000 | 58-58.2 | 34-06.1 | 330 | 1.8 | STOPPED - DRIFTING | 1804 | +0.39 | 8 | 160 | -0.6 | -0.6 | 3 | STATION 18 Cont'd: 0000-0 |
| E.P. | 0100 | 58-56.9 | 34-07.1 | 335 | 1.8 | 0138Z MANEUVERING | 1802 | +0.34 | 10 | 161 | -2.0 | -2.6 | 4 | Completion of Plankton To |
| E.P. | 0200 | 58-56.2 | 34-09.6 | 268 | 5.6 | C/C 255 PGC - C/S 5.6 Kts | - | +0.20 | 10 | 162 | -2.7 | -3.3 | 4 | |
| E.P. | 0300 | 58-56.5 | 34-22.2 | 268 | 7.6 | 0242Z C/C 260 PGC, C/S 8 Kts | 1330 | +0.30 | 8 | 148 | -3.6 | -4.6 | 5 | |
| E.P. | 0400 | 58-56.8 | 34-36.9 | 268 | 7.6 | | 1420 | +0.28 | 8 | 158 | -4.8 | -6.8 | 5 | STATION 19: 1500-1920Z S |
| E.P. | 0500 | 58-57.2 | 34-51.9 | 268 | 7.6 | | 1560 | +0.25 | 7 | 178 | -5.4 | -7.7 | 5 | & Deep Hydro Casts (IGO-2 |
| E.P. | 0600 | 58-57.4 | 35-07.2 | 268 | 7.6 | | 1560 | -0.03 | 7 | 178 | -6.7 | -9.7 | 5 | 1602Z Gravity core at 156 |
| E.P. | 0700 | 58-57.8 | 35-21.7 | 268 | 7.6 | | 1560 | -0.42 | 7 | 166 | -7.2 | -11.0 | 5 | (USC-1069). 1936-2114Z Pi |
| E.P. | 0800 | 58-58.0 | 35-35.9 | 268 | 7.6 | | 1365 | -0.75 | 8 | 164 | -7.4 | -10.2 | 5 | Core (FSU-20, 1242 CM, ge |
| E.P. | 0900 | 58-58.4 | 35-51.2 | 268 | 7.6 | 0920Z C/S 8.7 Kts | 1155 | -0.75 | 7 | 167 | -8.0 | -11.5 | 5 | good) 2130-2225Z Plankton |
| E.P. | 1000 | 58-58.7 | 36-05.6 | 268 | 8.7 | | 1048 | -0.1 | 6 | 180 | -8.0 | -11.2 | 4 | (IGO-20, vertical) 2257-2 |
| E.P. | 1100 | 58-59.1 | 36-21.9 | 268 | 8.7 | | 885 | 0.1 | 7 | 178 | -8.4 | -10.5 | 4 | Blake Trawl at 1538 Fms ( |
| E.P. | 1200 | 58-59.3 | 36-35.2 | 268 | 8.7 | 1235Z C/C 255 PGC | 1525 | -0.88 | 6 | 190 | -8.3 | -11.5 | 4 | 1070). |
| E.P. | 1300 | 58-59.6 | 36-48.7 | 268 | 8.7 | | INOP | +0.25 | 7 | 185 | -9.2 | -12.2 | 4 | |
| E.P. | 1400 | 58-59.9 | 37-00.2 | 268 | 8.7 | 1425Z C/C 250 PGC | 1547 | +0.3 | 7 | 210 | -7.8 | -10.1 | 5 | Microbiology (IGO) 1545Z |
| E.P. | 1500 | 59-00.2 | 37-10.8 | 268 | 8.7 | HOVE TO ON STATION | 1557 | +0.45 | 6 | 195 | -7.0 | -10.75 | 5 | chloro-65 and C-14 Series |
| E.P. | 1600 | 59-00.7 | 37-09.2 | 119 | 2.0 | | 1560 | +0.45 | 6 | 220 | -6.4 | -11.3 | 5 | 1555Z Mud-23 and Bact-30. |
| E.P. | 1700 | 59-02.3 | 37-05.0 | 119 | 2.0 | | 1555 | 0.3 | 7 | 225 | -6.5 | -9.7 | 5 | |
| E.P. | 1800 | 59-03.6 | 37-01.7 | 130 | 2.0 | | 1555 | 0.2 | 8 | 225 | -6.1 | -11.9 | 5 | 0000-2400Z Hourly BT's(IG |
| E.P. | 1900 | 59-04.6 | 37-01.2 | 162 | 1.0 | | 1554 | 0.3 | 8 | 215 | -7.2 | -11.0 | 5-6 | 516). |
| E.P. | 2000 | 59-05.2 | 37-01.0 | 162 | 1.0 | | 1550 | 0.18 | 7 | 205 | -7.6 | -11.7 | 6 | |
| E.P. | 2100 | 59-06.1 | 37-00.2 | 162 | 1.0 | 2118Z C/C 185 PGC | 1550 | 0.0 | 6 | 186 | 9.0 | -12.1 | 6 | |
| E.P. | 2200 | 59-07.1 | 36-59.1 | 158 | 0.5 | | 1558 | -0.2 | 7 | 178 | -9.8 | -13.5 | 5 | |
| E.P. | 2300 | 59-08.0 | 36-57.2 | 134 | 0.5 | C/C 045 PGC - C/S 3.7 Kts | 1545 | -0.2 | 5 | 178 | -9.9 | -13.8 | 5 | |
| E.P. | 2400 | 59-05.1 | 36-53.3 | 035 | 3.7 | | 1540 | -0.25 | 5 | 179 | -9.9 | -12.8 | 5 | |

that was originally produced by typewriter. The log shows hourly underway information as well as notations on scientific station keeping. Navigation was by celestial and (mostly) dead reckoning. All course changes had to be noted because of the geophysical program's needs. As the years progressed, more and more of the underway data became automated, but was often recorded on separate systems and on different media. The idea of having a daily record showing the cruise progress seemed to go out of style, especially on cruises where the underway environmental data was not particularly of interest to scientists working single-discipline cruises. The idea of having a log like that shown in Figure 2 always appealed to me and I've worked quite a bit over the years to try and automate the production of such a log to provide daily to the scientists on board.

On our ships, I have developed an underway logging system (Amos, 1994), programmed in BASIC BC7, that acquires data from various sensors, as well as navigation data (GPS, gyrocompass), using a dedicated PC as the acquisition and display system. The system, however, can stand-alone as portable software requiring some modification depending on the number and nature of the inputs. On many ships underway data is recorded at a very high repetition rate and it is impractical, of course, to reproduce that in any form of a log. Those raw data go into computers as a data file or various data files and, on many ships with networked computers, onto the server. For example, on the second cruise of the then new NATHANIEL B. PALMER in 1992, many files (e.g. NAV and IMET) were recorded at different locations with different time stamps and recording rates. For our cruise on the Palmer I devised a method of extracting the needed information, standardizing the time stamp, reducing the number of data points where necessary, and standardizing units and recording formats. This data stream went into a dedicated PC as if it were coming from the various sensors directly and the system then displayed and recorded the integrated data in one file. At the end of each day, a daily log sheet was produced, similar to the old ELTANIN log sheet, and distributed to those scientists working on our multidisciplinary project.

Figure 3 shows a typical screen display. The screen is refreshed once a minute. The program automatically calculates and displays every minute the current ship and UT time, the projected local time of sunrise, local apparent noon, and sunset. Because the ship is constantly moving, the times of the sun phenomena are calculated as they would occur at the present location. When the ship's time and the times of these phenomena converge, the screen displays, for example, "The sun has set now" in case one wants to go on deck for visual verification. The accuracy of this method, calculated from first principles, is surprisingly good, even in the high latitudes where we often work. Local apparent noon (LAN) is calculated as halfway between the time of sunrise and the time of sunset, when the sun should be at zenith. Location of next station or waypoint is displayed and distance, course, and time to the next station are refreshed with each screen. A plotter also records graphically the underway data and ship's track for an entire day.

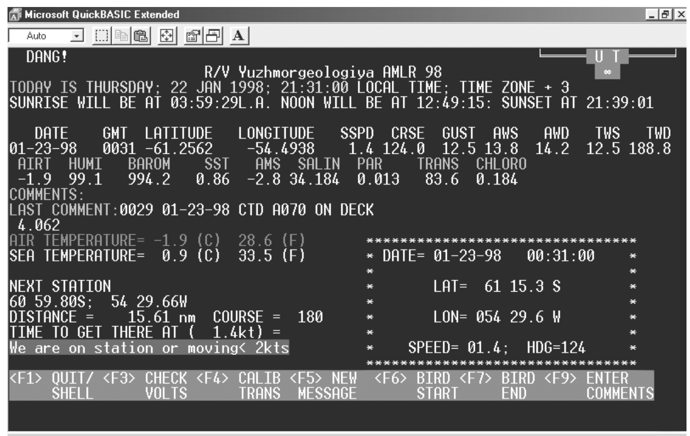



Figure 3. Typical screen display from underway system. SSPD = Ship's Speed (kt), CRSE = Gyro compass heading. GUST = high (true) wind gust during previous minute (all wind speeds are in knots). AWS = Apparent Wind Speed. AWD = Apparent Wind Direction. TWS = True Wind Speed. TWD = True Wind Direction. AIRT = Air Temperature (all temperatures in C). HUMI = Relative Humidity (%). BAROM = Surface Barometric Pressure (mb). SST = Sea Surface Temperature. AMS = Air temperature minus Sea Temperature. SALIN = Salinity. PAR = Downwelling Solar Radiation (quanta). TRANS = Beam Transmission (%). CHLORO = Turner Designs Flow-through fluorometer output (Volts). Air and Sea Temperatures are also displayed below comment line in Celsius and Fahrenheit. The outlined box at the lower right emulates the old Magnavox GPS screen. Next Station information is at lower left. Time to get to next station is not displayed if ship's speed is less than 2 knots to avoid large numbers. Symbol at top right hand corner is an attempt to create the University of Texas symbol, BEVO, the Longhorn.

An on-screen menu identifies the appropriate softkeys that allow interaction with the program. Softkeys permit checking input voltages of various devices, performing a calibration of the flow-through transmissometer, entering a new on-screen message, starting and ending a repetitive observation (e.g. a bird obs), and entering comments. It is the last option that makes the system interactive in the sense that you can enter any appropriate comment during the course of a cruise. Every time a comment is entered, the system interrogates all sensors and tags the comment with the underway data. Although our system is maintained by the CTD technicians 24-hours a day, we encourage people working in different disciplines to enter comments as well. Comments are entered by pressing a single softkey. There is a simple protocol for entering comments: they must be reasonably concise and codes are used for different station activities, such as CTD or IKMT (Isaaks-Kidd Midwater Trawl). Certain keywords (e.g. START, ON-DECK) are used for station operations to indicate the start and end of an over-the-side deployment. I've also devised a method for logging marine mammal/bird observations. Before starting a series of observations, a designated observation number, start time and time interval is entered. Then the observer can go up on the bow or bridge wing and make their observations, knowing that the log is being updated automatically, tagging incremented observations with positional and environmental data.

At the end of each day a file is transferred from the dedicated underway computer (automatically if the computers are networked) to a server or general purpose PC. The watchstander does some editing of the file and launches other programs that produce the hard-copy log sheets. Figures 4a-c show the log sheets that are available to those scientists that request them. One-minute interval ASCII files (usually 200-250Kbyte in size) are also available. The log sheets (Fig. 4a) list data at one-hour intervals and whenever a comment was entered. A summary sheet (Fig. 4b) is also produced listing daily high, low, and mean environmental information. Finally, a graphic representation of the day's conditions, ship's track, and station data is produced (Fig. 4c). At the end of each cruise leg, or at any time during the leg, a concise log can be produced for each of the disciplines involved showing environmental conditions at the start and end times of stations or surveys.

**AMLR 1998 R/V YUZHMORGEOLOGIYA - DAILY SCIENCE LOG; DAY # 23   01-23-1998 ; PAGE # 1**

| GMT | LATITUDE | LONGITUDE | SSPD | CRSE | MILES | GUST | AIRT | RH | BAROM | AWS | AWD | TWS | TWD | SST | A-SEA | SALIN | PAR | TRANS | FLUOR | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0001 | 61 15.13S | 54 29.90W | 1.1 | 168 | 0.0 | 12 | -1.9 | 100. | 994.1 | 12.4 | 017 | 11.4 | 186 | 0.79 | -2.6 | 34.20 | 0.04 | 83.3 | 1.84 | |
| 0029 | 61 15.33S | 54 29.66W | 0.9 | 168 | 0.5 | 14 | -1.9 | 99.2 | 994.2 | 13.8 | 025 | 13.0 | 194 | 0.87 | -2.7 | 34.16 | 0.01 | 83.1 | 1.82 | CTD A070 ON DECK |
| 0039 | 61 15.56S | 54 29.58W | 1.8 | 174 | 0.3 | 15 | -1.9 | 98.8 | 994.2 | 15.9 | 357 | 14.1 | 170 | 0.93 | -2.8 | 34.18 | 0.01 | 83.1 | 1.84 | SUNSET(21:39:02 LOCAL); THURSDAY; 01/22/9 |
| 0040 | 61 15.58S | 54 29.58W | 2.1 | 174 | 0.0 | 16 | -1.9 | 98.8 | 994.2 | 17.5 | 008 | 15.4 | 184 | 0.94 | -2.8 | 34.16 | 0.01 | 83.2 | 1.83 | IKMT A070 START |
| 0100 | 61 16.19S | 54 29.24W | 1.5 | 174 | 0.7 | 14 | -1.9 | 98.0 | 994.4 | 15.0 | 356 | 13.4 | 170 | 0.90 | -2.8 | 34.18 | 0.00 | 83.2 | 1.87 | |
| 0108 | 61 16.47S | 54 29.17W | 1.8 | 174 | 0.3 | 14 | -1.9 | 97.5 | 994.4 | 15.0 | 009 | 13.2 | 184 | 0.88 | -2.7 | 34.18 | 0.00 | 83.2 | 1.87 | IKMT A070 ON DECK |
| 0114 | 61 16.54S | 54 29.50W | 6.8 | 354 | 0.4 | 7 | -1.8 | 97.3 | 994.6 | 0.8 | 097 | 6.9 | 167 | 0.88 | -2.6 | 34.18 | 0.00 | 83.3 | 1.84 | FLOW THRU SAMPLE #13 TAKEN |
| 0200 | 61 8.38S | 54 32.05W | 11.5 | 001 | 8.3 | 12 | -2.1 | 92.5 | 994.4 | 4.7 | 272 | 12.2 | 203 | 0.97 | ---- | 34.15 | 0.0 | 82.5 | 1.80 | |
| 0300 | 60 59.61S | 54 30.24W | 2.5 | 021 | 9.1 | 14 | -1.1 | 85.4 | 994.0 | 8.7 | 172 | 11.2 | 195 | 0.71 | -1.8 | 34.17 | 0.0 | 83.4 | 1.81 | |
| 0400 | 60 59.75S | 54 29.68W | 0.9 | 199 | 2.7 | 11 | -1.7 | 84.8 | 993.8 | 12.1 | 355 | 11.2 | 193 | 0.83 | -2.5 | 34.18 | 0.0 | 83.6 | 1.75 | |
| 0402 | 60 59.80S | 54 29.66W | 0.5 | 200 | 0.1 | 14 | -1.7 | 85.1 | 993.7 | 13.6 | 011 | 13.1 | 211 | 0.81 | -2.5 | 34.19 | 0.0 | 83.6 | 1.76 | CTD A071 START |
| 0435 | 61 0.01S | 54 30.03W | 0.5 | 209 | 0.5 | 10 | -1.7 | 85.3 | 993.9 | 10.5 | 350 | 10.0 | 199 | 0.78 | -2.4 | 34.19 | 0.0 | 83.7 | 1.76 | CTD A071 ON DECK |
| 0442 | 61 0.13S | 54 30.11W | 1.7 | 200 | 0.1 | 9 | -1.7 | 85.2 | 993.9 | 9.9 | 354 | 8.3 | 193 | 0.77 | -2.4 | 34.19 | 0.0 | 83.8 | 1.71 | IKMT A071 START |
| 0500 | 61 0.65S | 54 30.70W | 1.8 | 208 | 0.6 | 11 | -1.7 | 84.7 | 993.8 | 12.6 | 355 | 10.8 | 202 | 0.81 | -2.5 | 34.19 | 0.0 | 84.0 | 1.72 | |
| 0510 | 61 0.93S | 54 31.20W | 1.8 | 212 | 0.4 | 10 | -1.7 | 84.7 | 993.8 | 11.1 | 339 | 9.4 | 187 | 0.84 | -2.5 | 34.20 | 0.0 | 83.9 | 1.74 | IKMT A071 ON DECK |
| 0600 | 60 53.88S | 54 28.58W | 10.2 | 002 | 7.6 | 9 | -1.7 | 83.0 | 994.0 | 2.1 | 046 | 8.9 | 172 | 0.44 | -2.1 | 34.16 | 0.0 | 82.7 | 1.79 | |
| 0700 | 60 44.88S | 54 27.34W | 1.4 | 193 | 9.8 | 7 | -1.3 | 83.5 | 993.6 | 8.0 | 339 | 6.7 | 168 | 1.28 | -2.5 | 33.89 | 0.00 | 80.4 | 2.09 | |
| 0703 | 60 44.93S | 54 27.41W | 1.2 | 197 | 0.1 | 8 | -1.3 | 83.6 | 993.5 | 8.4 | 324 | 7.4 | 156 | 1.24 | -2.5 | 33.91 | 0.00 | 80.6 | 2.08 | SUNRISE (04:03:36 LOCAL); FRIDAY; 01/23/9 |
| 0708 | 60 44.99S | 54 27.43W | 0.6 | 198 | 0.1 | 8 | -1.3 | 83.7 | 993.7 | 8.2 | 326 | 7.7 | 161 | 1.20 | -2.5 | 33.87 | 0.01 | 80.8 | 2.06 | CTD A072 START |
| 0747 | 60 45.36S | 54 27.64W | 0.6 | 209 | 0.5 | 7 | -1.4 | 83.6 | 993.7 | 7.0 | 309 | 6.7 | 154 | 1.13 | -2.5 | 33.87 | 0.02 | 80.7 | 2.06 | CTD A072 ON DECK |
| 0753 | 60 45.48S | 54 27.73W | 1.7 | 210 | 0.1 | 7 | -1.4 | 83.6 | 993.7 | 8.2 | 327 | 6.8 | 169 | 1.16 | -2.5 | 33.86 | 0.03 | 80.7 | 2.04 | IKMT A072 START |
| 0800 | 60 45.70S | 54 27.84W | 2.3 | 209 | 0.2 | 7 | -1.3 | 84.0 | 993.7 | 8.7 | 325 | 6.9 | 163 | 1.17 | -2.4 | 33.87 | 0.03 | 80.7 | 2.05 | |
| 0822 | 60 46.41S | 54 28.30W | 2.3 | 209 | 0.8 | 8 | -1.2 | 83.9 | 993.5 | 9.3 | 324 | 7.6 | 163 | 1.33 | -2.5 | 33.88 | 0.06 | 80.0 | 2.04 | IKMT A072 ON DECK |
| 0900 | 60 41.22S | 54 26.84W | 11.1 | 353 | 5.7 | 6 | -1.1 | 83.5 | 993.7 | 5.8 | 345 | 5.6 | 187 | 1.52 | -2.6 | 33.86 | 0.10 | 79.8 | 2.18 | |
| 1000 | 60 31.30S | 54 29.60W | 7.7 | 000 | 10.1 | 1 | -0.9 | 83.9 | 993.8 | 8.2 | 356 | 0.7 | 309 | 0.97 | -1.8 | 33.95 | 0.17 | 80.7 | 2.05 | |
| 1019 | 60 30.26S | 54 29.78W | 0.8 | 346 | 1.1 | 2 | -0.7 | 83.4 | 993.9 | 2.3 | 311 | 1.9 | 278 | 1.13 | -1.8 | 33.96 | 0.27 | 80.2 | 1.98 | CTD A073 START |
| 1058 | 60 29.92S | 54 30.16W | 0.7 | 357 | 0.7 | 1 | -0.2 | 81.1 | 993.5 | 1.7 | 307 | 1.4 | 282 | 1.18 | -1.3 | 33.97 | 0.51 | 80.2 | 1.97 | FLOW THRU SAMPLE #15 TAKEN |
| 1059 | 60 29.91S | 54 30.17W | 0.6 | 357 | 0.0 | 3 | -0.2 | 81.1 | 993.5 | 2.5 | 284 | 2.4 | 268 | 1.17 | -1.3 | 33.99 | 0.51 | 80.1 | 1.95 | CTD A073 ON DECK |
| 1100 | 60 29.90S | 54 30.18W | 0.6 | 357 | 0.0 | 3 | -0.2 | 80.9 | 993.5 | 2.5 | 280 | 2.5 | 263 | 1.18 | -1.3 | 33.98 | 0.51 | 80.1 | 1.96 | |
| 1106 | 60 29.78S | 54 30.20W | 1.5 | 356 | 0.2 | 3 | -0.3 | 80.8 | 993.5 | 3.7 | 324 | 2.6 | 301 | 1.19 | -1.4 | 33.98 | 0.40 | 80.1 | 1.94 | IKMT A073 START |
| 1132 | 60 29.12S | 54 30.44W | 1.5 | 355 | 0.8 | 4 | -0.4 | 80.4 | 993.3 | 5.4 | 344 | 4.0 | 332 | 1.20 | -1.6 | 33.98 | 0.48 | 80.2 | 2.00 | IKMT A073 ON DECK |
| 1200 | 60 25.57S | 54 30.75W | 9.9 | 001 | 3.6 | 5 | -0.7 | 81.5 | 993.2 | 14.4 | 004 | 4.5 | 014 | 1.22 | -1.9 | 33.96 | 0.65 | 80.2 | 1.92 | |
| 1300 | 60 15.40S | 54 30.00W | 6.0 | 004 | 10.4 | 6 | -0.5 | 82.2 | 993.3 | 11.1 | 005 | 5.1 | 016 | 1.22 | -1.7 | 34.02 | 0.63 | 78.9 | 1.83 | |
| 1313 | 60 14.97S | 54 29.88W | 0.9 | 348 | 0.5 | 6 | -0.1 | 81.9 | 993.3 | 6.4 | 033 | 5.7 | 026 | 1.52 | -1.6 | 33.88 | 0.63 | 79.2 | 1.94 | CTD A074 START |
| 1350 | 60 14.51S | 54 30.27W | 1.8 | 326 | 0.9 | 7 | 0.2 | 80.3 | 992.9 | 7.8 | 039 | 6.5 | 015 | 1.74 | -1.5 | 33.90 | 1.22 | 79.6 | 1.91 | CTD A074 ON DECK |

Figure 4a. Daily Log Sheet 1. Column headers: SSPD = Ship's Speed (kt), CRSE = Gyro compass heading. MILES = Nautical miles traveled in interval. GUST = high (true) wind gust during previous minute (all wind speeds are in knots). AIRT = Air Temperature (all temperatures in C). RH = Relative Humidity (%). BAROM = Surface Barometric Pressure (mb). AWS = Apparent Wind Speed. AWD = Apparent Wind Direction. TWS = True Wind Speed. TWD = True Wind Direction. SST = Sea Surface Temperature. AMS = Air temperature minus Sea Temperature. SALIN = Salinity. PAR = Downwelling Solar Radiation (quanta). TRANS = Beam Transmission (%). CHLORO = Turner Designs Flow-through fluorometer output (Scaled volts ).

**AMLR 1998 R/V YUZHMORGEOLOGIYA - DAILY SCIENCE LOG; DAY # 23   01-23-1998 ; PAGE # 3**

**DAILY SUMMARY**

DISTANCE TRAVELLED TODAY 146.4 nm
TOTAL DISTANCE TRAVELLED 3667.0 nm

| | | | | |
|---|---|---|---|---|
| SHIP'S SPEED (kts) ; | AVERAGE= 6.1 | MAXIMUM= 14.0 | AT 1253 HRS. | MINIMUM= 0.0 AT 0725 HRS. |
| AIR TEMPERATURE (C); | AVERAGE= -0.3 | MAXIMUM= 1.6 | AT 2221 HRS. | MINIMUM= -2.1 AT 0159 HRS. |
| SEA TEMPERATURE (C); | AVERAGE= 1.36 | MAXIMUM= 2.35 | AT 1854 HRS. | MINIMUM= 0.39 AT 0611 HRS. |
| SALINITY (ppt); | AVERAGE= 33.98 | MAXIMUM= 34.31 | AT 0151 HRS. | MINIMUM= 33.76 AT 1849 HRS. |
| BAROMETRIC PRESSURE (mb); | AVERAGE= 993.2 | MAXIMUM= 994.7 | AT 0139 HRS. | MINIMUM= 991.4 AT 2324 HRS. |
| RELATIVE HUMIDITY (%); | AVERAGE= 86.5 | MAXIMUM= 100.0 | AT 2350 HRS. | MINIMUM= 79.8 AT 1334 HRS. |
| WIND SPEED (kts); | AVERAGE= 8.0 | MAXIMUM= 17.8 | AT 0236 HRS. | MINIMUM= 0.2 AT 1048 HRS. |

WIND GUST (kts); MAXIMUM = 18.8 AT 0252 HRS.
MEAN DAILY WIND VELOCITY= 0.9 (kts) FROM 023 DEGREES TRUE

| | | | | |
|---|---|---|---|---|
| SOLAR RADIATION-PAR (quanta/cm^2/sec); | AVERAGE= 0.28 | MAXIMUM= 1.54 | AT 1355 HRS. | MINIMUM= 0.00 AT 0126 HRS. |
| LIGHT TRANSMISSION (%); | AVERAGE= 80.6 | MAXIMUM= 84.0 | AT 0456 HRS. | MINIMUM= 77.2 AT 2157 HRS. |
| CHLOROPHYLL-a (mg/m^3); | AVERAGE= 1.93 | MAXIMUM= 7.35 | AT 0151 HRS. | MINIMUM= 1.63 AT 1444 HRS. |

Figure 4b. Daily Log Sheet 2. Summary sheet of environmental data showing maximum, minimum and mean values. Note that these data are produced on board and are subject to change later when calibration data are examined.

On most cruises where this system has been used, the underway monitor becomes a kind of communal center. We find that both the screen display and plotter output are frequently consulted by both scientific and ship's personnel. Particularly popular are the corrected wind vectors displayed on both. One disappointment is the trend for some groups on board not to take advantage of the ability to tag their operations with underway information or to request the station log files. The key to enter comments is F9. We put up signs saying "F9-It!" It takes seconds to do, but the CTD watch ends up doing most of the logging. In this respect, I yearn for the days when it was required for all scientific personnel on board to do a watch. Perhaps we have become too technical for this to be feasible. Our system is an attempt to simplify this.

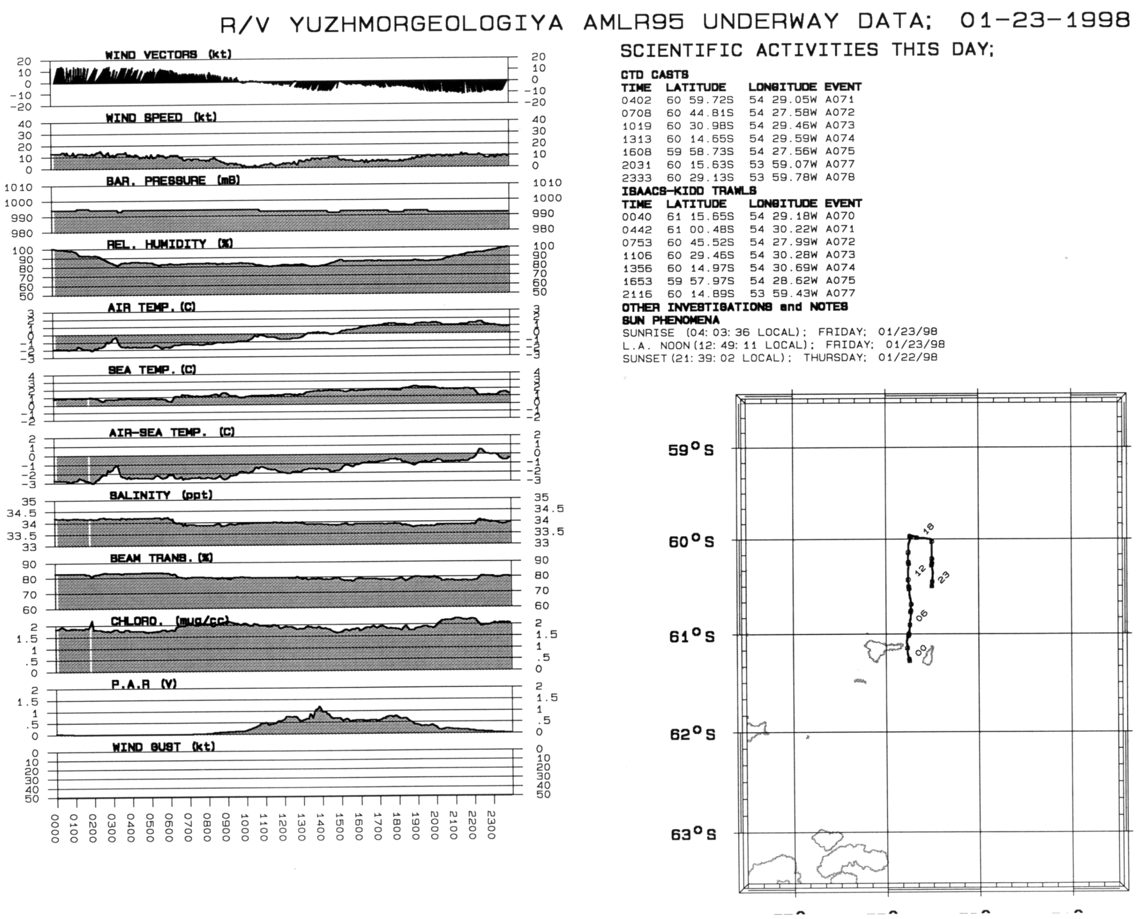



Figure 4c. Daily Log Sheet 3. Graphic representation of underway data and ship's track. Panels on left are self explanatory except AIR-SEA = Difference between air and sea temperature, BEAM TRANS is percent transmission for a 25-cm transmissometer, CHLORO is from the Turner Designs flow-through fluorometer in scaled volts, PAR is in voltage output. WIND GUST was recorded but not graphed here.

References

Amos, A.F. (1994). AMLR Program: The underway data acquisition system. *Ant. J. of the US.* 29(5). 201-204.

Bowin, C.D., R. Berstein, E. Ungar, and J.R. Madigan (1966). A shipboard oceanographic data processing and control system. WHOI Ref. #66-44, August 1966.

NAS/NRC (1973). Continuously sampled oceanographic data: Recommended procedures for acquisition, storage, and dissemination. Ocean Science Committee, Ocean Affairs Board, National Academy of Sciences-National Research Council Report, December 7 1973. 51pp.

# ASIMET
# Air Sea Interaction - METeorology

David Hosom
Woods Hole Oceanographic Institution

**IMET - Improved METeorology - Instrumentation**

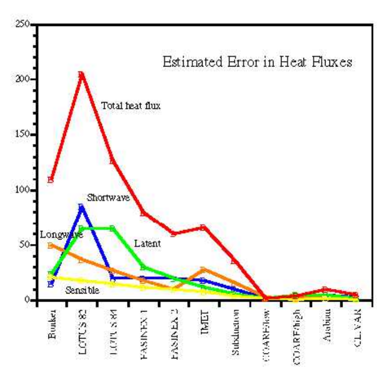
The ocean is critical to inter-decadal climate variability because of its ability to store and transport heat and fresh water and release them to the atmosphere through sensible and latent heat fluxes. Knowledge of various properties at the sea surface is essential to monitoring, understanding, and developing the ability to predict climate change. Vertical exchange across the air-sea interface of horizontal momentum and of buoyancy couples the ocean and atmosphere. The sea surface is the interface through which heat, fresh water, momentum, gases, and other quantities are exchanged. It is the bottom boundary of the atmosphere over approximately 70% of the earth's surface and the top surface of the very large oceanic reservoirs of heat and other properties. Observing this coupling is a fundamental need if we are to both understand ocean variability and its interrelation to climate. This requires the observation of surface wind velocity, humidity, air temperature, sea temperature, barometric pressure, incoming shortwave radiation, incoming longwave radiation and precipitation.

In planning for WOCE (World Ocean Circulation Experiment) it was recognized that moored buoys and ships would provide especially attractive platforms from which to make accurate in-situ measurements of the basic surface meteorological observable parameters required to investigate the air-sea fluxes of momentum, heat, and mass. Accuracy's of 10 Watts per meter squared were sought in estimates of the mean values (averaged over monthly and longer time scales) of each of the four components of the total heat flux (sensible, latent, shortwave, and longwave). Accuracy's of approximately 1 mm per day were sought in evaporation and precipitation.

WHOI (Woods Hole Oceanographic Institution) was funded to evaluate and choose sensors capable of meeting the WOCE goals and to develop the IMET system as a flexible data collection system. Each sensor was incorporated into a module with built-in intelligence that responds to polled commands from the central computer and data recording unit. Each module interfaces to an ADDB (addressable digital data bus) consisting of +12vdc power and RS485 serial ports. A key component of IMET accuracy is that the calibration constants are stored in the module so that the serial digital output is in calibrated units. The calibration constants from each unit are polled and stored on the data file with the data from a specific time period. Modules having non-linear algorithms will output both calibrated and raw data to permit later corrections.

IMET systems are now in use on eight UNOLS ships, six WHOI buoys, one USF (University of Southern Florida) buoy, one NOAA ship and the Rutgers University Field Station. These systems have proven themselves over the last eight years and now provide the baseline for climate quality data.

Data Accuracy

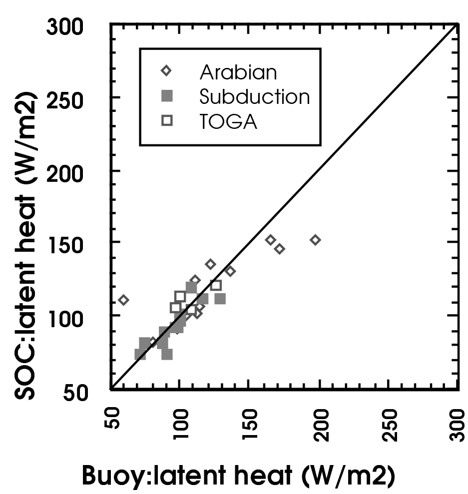



Traditionally, the bulk of surface marine observations have come from merchant ships. There have been numerous attempts to make use of these observations to map the air-sea fluxes and understand the ocean's role in climate. However, these shipboard observations have significant errors associated with the sensors, sensor placement, and flow disturbance. Furthermore, few ships are equipped to measure the shortwave and longwave radiative fluxes. Bunker, in his atlas of surface observations for the Atlantic, concluded that the error in the net heat flux developed using bulk formulae and merchant ship observations was in excess of 100 W $m^2$.

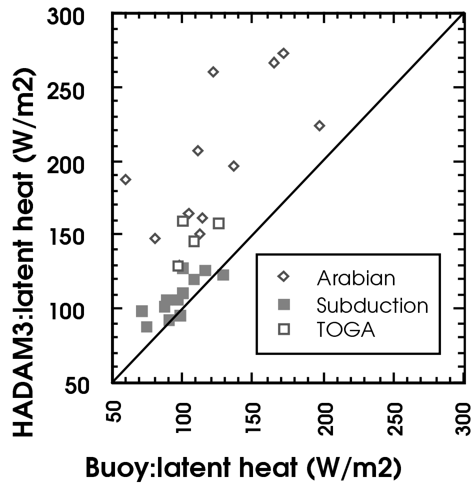
National agencies and researchers have turned to surface moorings in order to obtain time series of surface meteorology at fixed locations and to work toward observations that were both more complete and more accurate than those obtained on merchant ships. In the late 1970's and early 1980's, research oceanographers in the United States began to deploy surface buoys to investigate air-sea interaction. Error analysis of the sensor performance in the Long Term Upper Ocean Study (LOTUS) (Figure 1), which was conducted at 34 deg N, 70 deg W, was discouraging, as the measurement error in the net heat flux was found to be larger than the uncertainty Bunker assigned to his atlas data.

Work to improve buoy measurements continued in association with the ONR-supported Frontal Air-Sea Interaction Experiment (FASINEX), and significant, focussed support by the NSF as part of the World Ocean Circulation Experiment (WOCE) led to extensive sensor testing and development and to the design of the Improved Meteorological system (IMET). This work brought continued improvement. During the ONR-funded Subduction experiment, error in net heat flux was reduced to approximately 40 W m^-2 in monthly means. A major, international collaboration on flux sensors and algorithms and a specific focus on in-situ intercomparisons of methods and sensors during the TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) led to another significant increase in accuracy. In part, the accuracy shown in Figure 1 for COARE results from the benefit of these dedicated in-situ intercomparisons. Further work continued in support of the ONR Arabian Sea experiment, and gains were made in reducing error due to radiative heating of sensors. Work on aspiration, on humidity sensors, on anemometer performance, and on radiation sensors continues; and these gains help make possible an accuracy approaching that achieved in COARE even though in-situ intercomparisons are not being conducted.

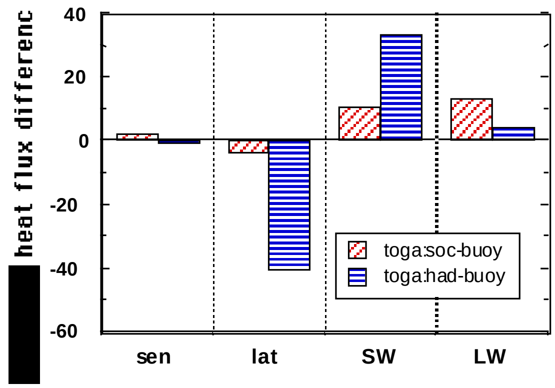
The time series of accurate surface meteorology and air-sea fluxes acquired by the buoys deployed in these experiments is now providing the means to examine the performance of atmospheric models, the accuracy of climatological data sets, the calibrations and performance of satellite sensors, and methods used to improve the data on Volunteer Observing Ships (VOS). For example, Taylor and Josey at the Southampton Oceanography Centre in the UK has worked to correct biases and errors in the data from the VOS; and comparisons between the buoy data and the SOC climatology verify that they have made significant improvement.



In contrast, comparisons between the buoy data and numerical weather prediction models reveals problems with the surface meteorology and fluxes from the models (Figure 2b).




These problems may not be apparent in the net heat flux, as the heat flux components from the models can have biases that cancel. Figure 3 shows that the latent and shortwave fluxes from the Hadley Centre model have biases of opposite sign.




High quality in-situ data is essential to validating models, remote sensing, and climatologies. Figure 4 uses one year of buoy data from the Arabian Sea to show how far off the net heat fluxes from the ECMWF, NCEP, and Hadley Centre models were. The model error approaches 100 W m^-2; during the Southwest Monsoon the NCEP model had the wrong sign of the net heat flux.

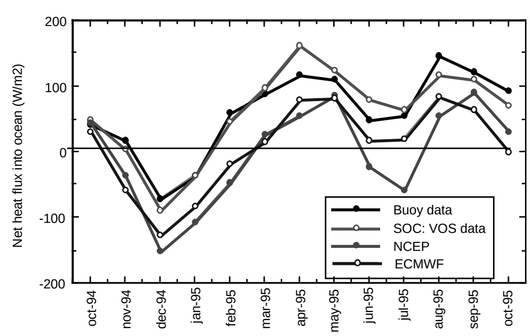
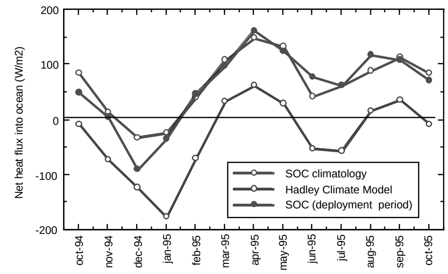


Figure 4, however, also presents a very encouraging result. The SOC developed VOS-based flux data at the buoy site and for the same time period agrees very well with the buoy data. Further such SOC and buoy comparisons indicate the need to make regional choices of the parameterizations used in the bulk formulae. There is both temporal and spatial variability in the fluxes due to things such as atmospheric aerosols that make high quality in-situ observations essential. Taylor's earlier work documented the benefits of a modest investment in understanding and improving the sensors in VOS. Thus, a strategy for moving toward greatly improved global surface meteorology and air-sea fluxes is to deploy surface moorings as flux reference sites and to field improved VOS systems to fill in the regions around the reference sites. The flux reference sites provide the regional tie points, and the VOS calibrated by these sites provide the mapping capability.

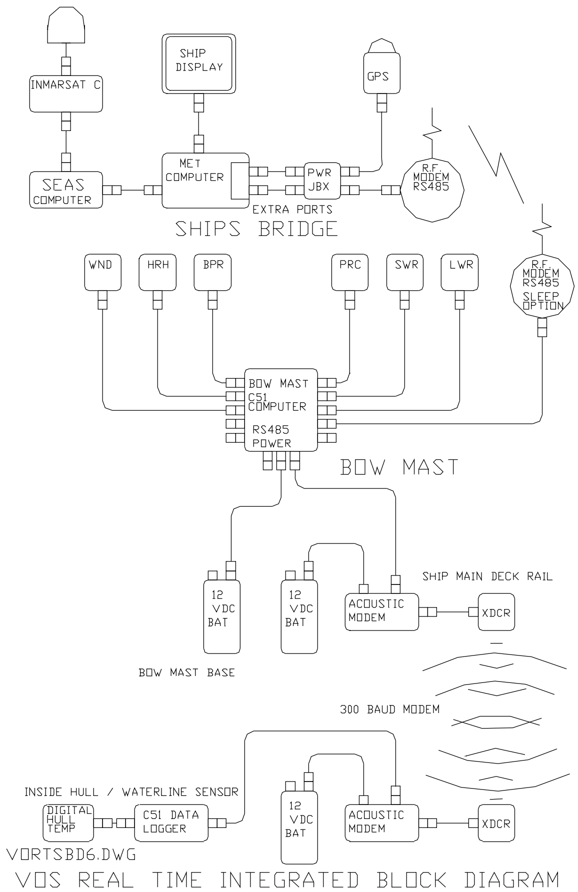



VOS Climate Data Acquisition

Recently, the IMET technology has evolved into new modules designed for use on VOS ships. These new VOS-IMET are self-powered, self recording, stand alone units that also are able to communicate on the IMET Addressable-Digital-Data-Bus (ADDB). These units are being tested on VOS in cooperation with the SIO-VOS Group as part of a NOAA - OGP program. Currently installed sensor modules include Wind Speed and Direction, GPS, Relative Humidity and Air Temperature, Barometric Pressure, and Sea Surface Temperature. This will be expanded this year with Precipitation and Shortwave Radiation. Next year, the addition of Longwave Radiation will complete the flux suite of measurements. These modules are housed in Grade 2 titanium, which provides economical, corrosion-free, and rugged units. Mounting is accomplished by fiberglass channel and stainless steel latches that provides easy installation in a wide variety of ship configurations. The following figures shows the target platform for these systems - large commercial ships that make voluntary observations.


One feature of the US VOS is that they are sold and change routes on a very regular basis. This has severe implications in that it is not feasible to run cables for system installations and it is normally not possible to obtain useable electrical power close to sensor mounting locations. One special problem is getting sea-surface temperature data from inside the hull of the ship at the waterline up to the rest of the modules. An acoustic modem has just been developed that uses the ships steel hull at the acoustic path for 300-baud data. The measurement system for a VOS therefore must be self-powered, self-recording and able to communicate data to the bridge area for both ship use and satellite transmission. This means that the VOS climate observing system uses nearly the same components as a buoy climate observing system.

It is expected that the prototype climate observing system currently being tested on VOS will be available from commercial sources as an operational system. This new commercial system will provide the same data quality and data time resolution as modules used previously to establish better understanding of climate processes. This system or components from this system can provide the same performance from buoys and smaller ships. The following figure shows a block diagram of an IMET system for VOS real time use. On research ships with installed cables, the wireless devices (r.f. modem and acoustic modem) and battery packs may not be needed.




ASIMET MODULE OPERATIONS - 1

The ASIMET main processor board (C51) operates in either RS232 or RS485 upon power up depending on where power/comms is connected and the position of a jumper.

Getting Started

The following equipment should be available:

* Terminal (computer) with RS232 output set for 9600, N, 8, 1, running the terminal program (ProComm Plus), run with cap-locks on.

* Power supply with output of 12 vdc and capacity of 100 ma. Make sure that the polarity is correct otherwise there will be damage. It is recommended that there be a meter measuring the milliamps required in series with the module (3 ma to 6 ma is normal per module).

* RS232 to RS485 converter - Black Box Inc sells 2 converters that work well. The first is a PCMCIA /RS485 port (IC114A, $199). This unit works well on laptops with PCMCIA slots but does not suppress the transmissions (you see two sets of what happens). The second is a standalone (IC108A, $259). This unit works well on the bench. The settings for this are as follows (* indicates the default):

| | | | | |
|---|---|---|---|---|
| XW1A | | DCE * | | |
| W8 | | B-C | 2-wire | |
| W15 | | A-B * RTS/CD enabled | | |
| W5 | | A-B * RTS/CTS delay normal | | |
| W9 | | RTS/TCS delay C* | | 0 msec |
| W17 | | D | 0.7 msectime driver remains enabled after a low-to-hi transition | |
| W16 | | B * | 0.1 msecTurnaround delay | |
| S1 | | OUT * | Normal | |
| S2 | | OFF * | | RS-485 receiver Unterminated |
| S3 | | OFF * | | Line Bias Off |
| TB1 | term 1, Rx | | B+ (connect to 3, Tx, B+) to the +485 (orange) | |
| | term 2, Rx | | A- (connect to 4, Tx, A-) to the -485 (brown) | |
| | term 3 | | Tx | B+ |
| | term 4 | | Tx | A- |

* Connector to power / comms - see drawing of connector / cables next page.
Use Molex connectors - (03-06-1044 male shell, 03-06-2044 female shell, 02-06-5103 female pins, and 02-06-6103 male pins. HTR1719C tool required).

* Module C51 mode configuration. The C51 board is placed into the desired mode upon power up based on the input connector used and the position of jumper JP1. Refer to the drawing of the board for the proper configuration. The unit must be opened up to make this change.

A module should always be powered up and communicated with on the bench prior to connection in a system or when checking operation and trouble shooting. Make sure that the +12 Vdc is connected to the proper connector pin, and that the terminal is running at the proper protocol (9600, N, 8, 1). The current drawn should be in the 3 to 6 milli amps range depending on the module.

Communications

ASIMET (like IMET) has a communications protocol based on the SAIL (Serial ASCII Interface Loop) protocol developed at Oregon State University. The module is interrogated with the following format (always with capital letters):

| prefix | 3 char type | 2 char sn | command suffix |
|---|---|---|---|
| # | XXX | nn | X |

Type of:

- BPR = Barometric Pressure
- HRH = Relative Humidity / Air Temperature
- LWR = Longwave Radiation
- PRC = Precipitation
- SST = Sea Surface Temperature
- SWR = Shortwave Radiation
- WND = Wind Speed and Direction

2 char sn of 01, 02, 03 etc

Command Suffix of:

A = Address acknowledge
C = Output calibrated
H = help
I = ID information
L = Calibration header Info
T = Test data (usually 1 sec rate)
U = EEPROM Update mode
(requires password of "OK")

Operation

1. With terminal running at (9600, N, 8, 1) , the power set at 12 vdc, perform the following sequence, in the RS232 mode without the 232/485 converter.

Send: #WND01A Receive: **WND01<cr><lf><etx>**

2. With terminal running at (9600, N, 8, 1) , the power set at 12 vdc, perform the following sequence, in the RS485 mode and with the 232/485 converter.

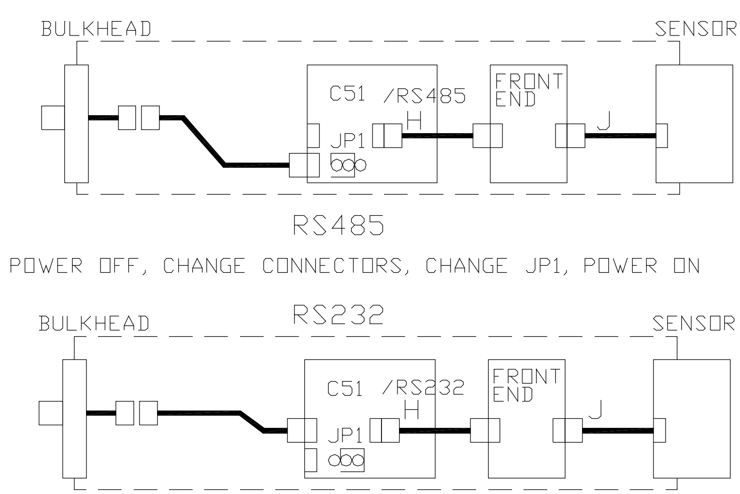
Send: #WND01A Receive: **WND01<cr><lf><etx>**

3. When the module responds with the address acknowledge in both modes, communications have been established. Send the help command:

Send: #WND01H Receive: **(Help Menu)**

Send each command as indicated by the help menu to understand the operation and the data format of the output data. The "I" command will provide detailed information on the data output formats.

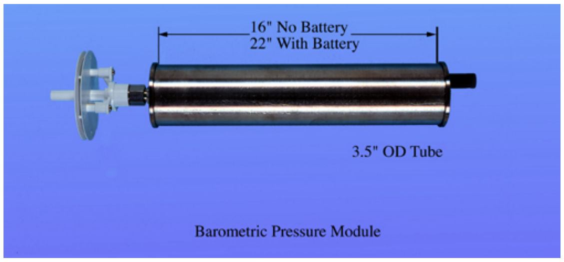
The following figure shows the RS232 vs RS485 configuration jumpers inside of a module.




V232_485.DWG CONNECTIONS - RS232 OR RS485

Individual module data and configuration are in the following pages.

ASIMET BAROMETRIC PRESSURE SPECIFICATIONS




An AIR (Atmospheric Instrumentation Research Inc.) model S2B sensor was selected for barometric pressure measurement. The sensor provides output of calibrated engineering units in ASCII (parallel) for direct input to the processor board. A sample is collected from the ARI sensor every several seconds. Each sample is calibrated in the ARI barometer and is internally averaged from 10 samples taken over the previous second. A Gill static pressure port is used to minimize errors due to the wind blowing over the exposed sensor port.

Specifications:

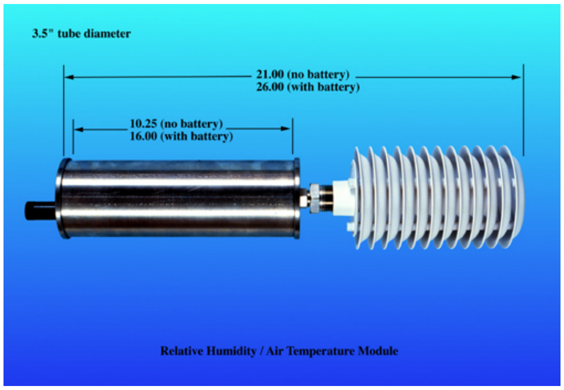
Sensor: Range 850 to 1050 mb
Resolution 0.1 mb
Accuracy 1 mb

Physical: Housing diameter is 89 mm (3.5")
Housing length is 419mm (16.5")
Overall length is 517 mm (20.4")
Weight is 13 kg (6 pounds)

Electrical: +12 vdc to +15 vdc with 2.5 ma average current
Communications : RS485 or RS232 (9600, N, 8, 1) IMET format

Calibration: Calibration is checked using a lab standard electronic barometer and the bias is adjusted as required. If unable to adjust the bia, the unit is returned to the manufacturer for complete calibration. Calibration constants are stored in the EEPROM.

ASIMET RELATIVE HUMIDITY / AIR TEMPERATURE SPECIFICATION




Relative humidity measurements are made with a Rotronic MP-101A sensor. To meet the environmental needs of buoys and ships, the sensor is packaged in a custom housing which is more rugged than the standard housing and with high pressure water seals. The sensor electronics is conformal coated and the sensor housing is packed with a desicant. The humidity-temperature probe provides analog outputs of 0 to 1.0 volts DC for humidity ( 0 to 100% rh): and 0 to 1.0 volts DC for temperature (- 40 to +60 deg C). These signals are amplified and converted to digital in the module. One set of measurements are made every minute and calibrated via a fourth order polynomial for RH% and degrees C. This set of measurements is returned when polled. This probe is placed inside a modified R.M. Young multi-plate radiation shield for standard use. This modified shield has wider plate spacing and a hydrophobic coating on the plates to provide a more accurate measurement.

Specifications:

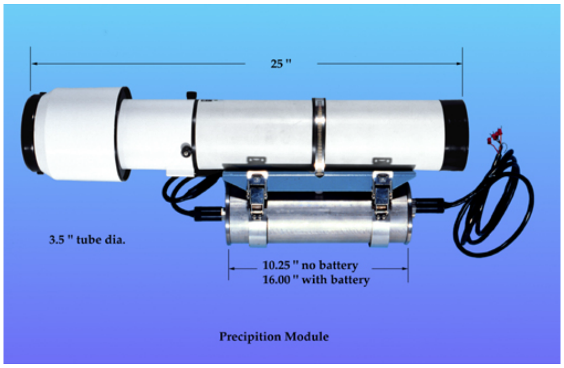
| | |
|---|---|
| Relative Humidity | Range - 0 to 100%<br>Accuracy (77 deg) +/- 2%RH<br>Resolution 0.1% RH<br>Long Term Stability, 1% RH or better over one year<br>Sensor Protection, MF25 membrane filter<br>, RM Young modified shield |
| Temperature | Range - -20 deg to +55 deg C<br>Accuracy 0.1 deg C (if full temp calibration, 0.05 deg<br>Resolution 0.01 deg C |
| Physical - | Housing diameter is 89 mm (3.5")<br>Housing height is 267mm (10.5")<br>Overall height is 535mm (21")<br>Weight is 13kg (6 pounds)<br>Rotronic sensor mounted in passive shield. |

Electrical - +12vdc to +15vdc with 2.5 milliamps average current.
Communications- RS485 or RS232 (9600, N, 8, 1) IMET format.

Calibration: Relative humidity is calibrated over a humidity range of 25 to 95 % RH in a special test chamber with stability to 0.1% RH. The dew point standard has an accuracy of 0.1 deg C and is traceable to NIST. Temperature is calibrated over a range of 1 to 35 degrees C in a water bath with a resolution of 0.001 degrees C and an accuracy of 0.005 degrees C.

## ASIMET PRECIPITATION SPECIFICATION

Rainfall is measured by an R.M. Young model 050201 self-syphoning rain gauge. This sensor uses a capacitive measurement technique to measure the volume of rain water deposited inside a collection chamber. It automatically empties in about 20 seconds when the chamber is full. The output of the sensor is 0 to 5 Vdc which represents 0 to 50 mm of rainfall in the gauge. The sensor is sampled once each minute and the level output. Rain rate is calculated based on average of the last 5 (one minute) samples. The total rainfall for the last hour is also calculated.




Specifications:

Sensor: R.M.Young Self-syphoning rain gauge
0 to 50 mm, with a resolution of 0.1 mm
20 second drain time
Catchment collection area is 100.0 cm2 (15.5 in2)
Catchment outside diameter 140 mm (5.5 “)

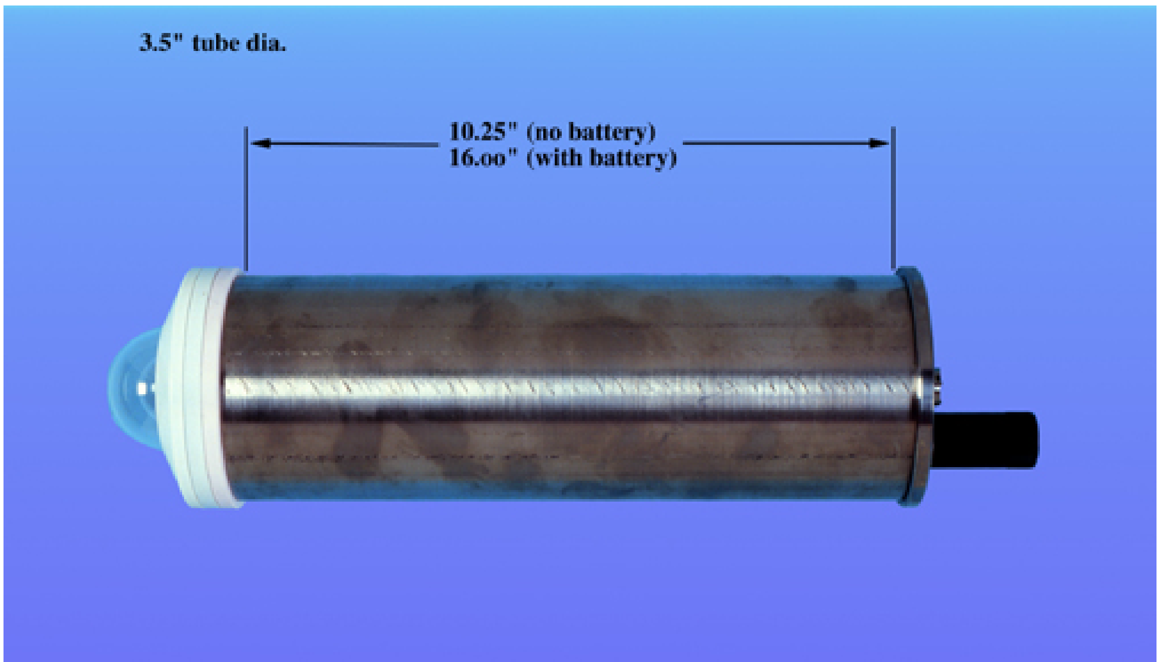
Physical: Electronics housing diameter is 89 mm (3.5”)
Electronics housing length is 267mm (10.5”)

Overall height is 650 mm (25.5")
Overall weight is

Calibration: Recalibrate by adding successive known volumes of water. Perform gain adjustment and calibration of the module electronics. Calibration constants are stored in the EEPROM.

ASIMET SHORTWAVE RADIATION SPECIFICATION

Shortwave radiation is measured with a modified Eppley Precision Spectral Pyranometer (PSP) mounted on an aluminum base which provides a reference mass for the PSP. The aluminum base is mounted to a PVC endcap for thermal isolation from the module housing. The sensor uses a temperature compensated thermopile. It provides an output voltage proportional to incident short wave solar radiation (0.3 to 5.0 micro meters). Sensitivity is approximately 9 microvolts per watt, per meter squared, and has a temperature dependence of +/- 1% over the range of -20 to +40 degrees C. A set of sample is collected, calibrated via a fourth order polynominal, and averaged for the return measurement.




Short Radiation Module

Specifications:

Sensor - Sensitivity approx 9 microvolts per W/M2
Temperature Dependence +/- 1% from -20 to +40 deg C
Linearity is +/- 0.5% from 0 to 1400 watts/meter squared
Response time is 1 sec
Sensor is Eppley PSP.

Physical - Housing diameter is 89 mm (3.5")
Housing height is 267mm (10.5")
Overall height is 310mm (12.25")
Weight is 13kg (6 pounds)

Electrical - +12vdc to +15vdc with 2 milliamps average current.
Communications - RS485 or RS232 (9600, N, 8, 1) with standard IMET format.

Calibration: The sensor is calibrated outside in sunlight against a secondary standard (March to October). If this is not possible, the sensor is returned to Eppley for complete calibration. The gain adjustment and calibration of the sensor electronics are made separately. Combined calibration constants are stored in the unit EEPROM.

ASIMET SEA SURFACE TEMPERATURE SPECIFICATION

A platinum resistance thermometer (PRT) was chosen for sea surface temperature measurement. PRTs have a positive temperature coefficient, are highly stable over long periods of time, and have a very low hysteresis. The electronics consists of an analog front end and an ultra low-power micro processor unit for conversion to a digital signal. The analog front-end uses an Anderson circuit that provides a low noise interface to the PRT that uses a constant current source through the series combination of the PRT and two precision resistors. The resistors are set at the -10 deg C and + 20 deg C values of the PRT. Since the measurements are always made relative to the reference resistors, electronic drift is compensated for and an accuracy of 5 milli degrees C with a resolution of one milli-degree C is achieved over a range of -10 to +45 deg C. The sensor is mounted in a PVC housing that is attached inside the ship hull at the water line. This conforms to the configuration that has provided excellent results from the U.K. Meteorological Office sensors used on VOS ships.

Note that this system can also be used for air temperature with a PRT mounted in a standard 6" probe. For very accurate air temperature measurements, an aspirated shield (R.M. Young) is recommended since the R.M. Young static shield introduces errors in direct sun and with low wind speeds independent of the sensor used. The aspirator uses about 0.5 amps at 12 vdc and is only suitable on a buoy with solar panels or for limited time.

Specifications:

Sensor / Electronics: 1000 ohm PRT
with low noise Anderson Circuit interface.
Accuracy: 0.005 deg C
Resolution: 0.001 deg C

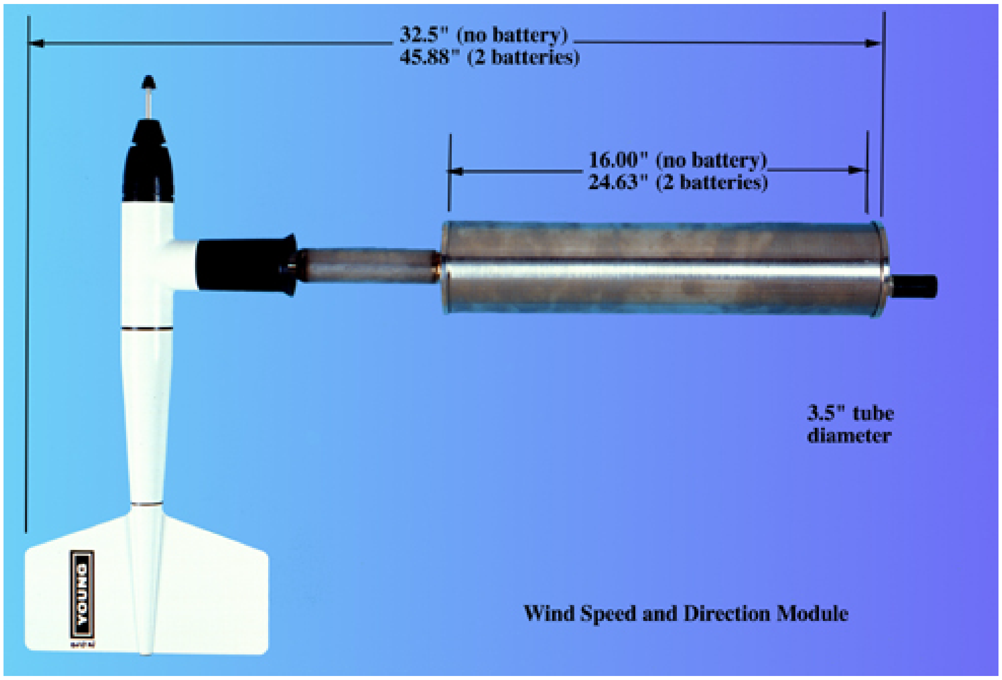
Physical - Data recorder housing diameter is 89 mm (3.5")
Recorder housing length is 267mm (10.5")
Weight is 13kg (6 pounds)
Sensor housing is 1490mm (5.875") diameter x 89mm (3.5") high.

Electrical - +12vdc to +15vdc with 2.5 milliamps average current.
Communications - RS485 or RS232 with standard IMET format.

Calibration: Perform a liquid bath calibration over the nominal range of 0 to 35 deg C. the calibration bath and temperature standard are stable and accurate to better than 1 mK.

ASIMET WIND SPECIFICATION

Wind speed and direction are measured with a modified R.M. Young model 05103 wind monitor. This sensor was selected because of its proven record. It uses a propeller to measure wind speed. The standard vane potentiometer is removed and the vane shaft extended down and coupled with an absolute angle encoder for a full 360 degrees of measurement. A magnetometer compass is used to provide the north reference for use on buoys. This is can be disabled for use on ships (ships gyro and external GPS are then used to compute true wind speed in the data recorder). The propeller generates 3 pulses per revolution which has a calibration of 0.297 meters of wind per revolution. The pulses are amplified and counted over a 5 second period providing scalar wind speed. The vane position is measured once per second and the compass measured once each 5 seconds. This provides a scalar wind speed and direction every 5 seconds that is then vector averaged over the normal one minute sample period. The maximum and minimum wind speeds during the one minute time are also reported for wind gust information.



Specifications:

Speed- 0 to 60 meters/second, propeller with a 0.098 meters/second per hertz, with 3 pulses/propeller revolution.

Direction - Vane encoder has a resolution and accuracy of 0.01 degrees. The compass has an accuracy of 2 degrees and a resolution of 1 degree. There is a full 360 degrees of range with no deadband.

Physical - Housing diameter is 89 mm (3.5")
Overall housing height is 380mm (15")
Overall height is 760mm (30")
Propeller is 178mm (7")
Weight is 17.6kg (8 pounds)

Electrical - +12vdc to +15vdc, with 6 milliamps average current.
Communications - RS485 or RS232 (9600, N, 8, 1) with standard IMET format.

Calibration: The propeller bearings are replaced (on re-calibrations) and the speed checked at several standard speeds using the R.M.Young calibration unit. Operation of the vane encoder and compass is checked by rotating the module and vane slowly through 360 degrees with confirmation of indicated directions for at least two known directions in each quadrant. Vane alignment is checked and adjusted as required.

COST SUMMARY FOR ASIMET MODULES AND ASSOCIATED
**NEW** 15 September 1998

The following is an approved cost list for ASIMET modules fabricated at WHOI with the point of acceptance at Woods Hole. WHOI is a non-profit research and educational organization and all purchase orders are on a best efforts basis. The listed costs include materials, shop time, fabrication labor and engineering support labor. WHOI fee is 15% for non-government organizations. Shipping, agents fees, taxes, and any export costs are the responsibility of the purchaser. Shipping containers are required but not included. If the purchaser does not have a Massachusetts tax exempt number, then the state tax adds 5% to the final cost. Estimated delivery time is 5 to 6 months ARO (since no parts are inventoried, purchased and machined parts can only be started after an order is received). A purchase order should be sent to:

Woods Hole Oceanographic Institution
Attn: David Hosom, MS#30
Account: 1-05-520365.00 (ASIMET Module Fabrication)
Woods Hole, MA 02543

| Item | Description | Cost | Q=1 Calibration | Q=3 Calibration | Total w 15% WHOI Fee |
|---|---|---|---|---|---|
| 1 | Relative Humidity/Air Temp | $6,340 | $765 | 345 | $8,171 |
| 2 | Barometric Pressure | 5,550 | 195 | 145 | 6,607 |
| 3 | Wind Speed/Direction | 7,195 | 270 | 270 | 8,585 |
| 4 | Wind S/D (no compass) | 6,495 | 270 | 270 | 7,780 |
| 5 | Precipitation | 6,510 | 185 | 105 | 7,699 |
| 6 | Shortwave Radiation | 7,130 | 415 | 415 | 8,677 |
| 7 | Ship Sea Temp (hull mount) | 6,205 | 675 | 345 | 7,912 |
| 8 | Longwave Radiation | 8,150 | 995 | 995 | 10,517 |
| 9 | Mounting Bracket | 350 | | | 402 |
| 10 | Buoy Low Power Logger | 7,590 | | | 8,730 |
| 11 | Battery (15v, 98ah /logger) | 200 | | | 230 |

For additional information contact: D. Hosom (phone 508-289-2666, fax 508-457-2165, or email dhosom@whoi.edu)

Since October 1996, prices are up (a few are down). Labor has gone up in all cases, sensors have mostly gone up and experience in fabrication has helped to lower prices.

# Underway Data Collection System Onboard R/V *PELAGIA*; Considerations And Design Of A New System

J. Derksen
Netherlands Institute For Sea Research

My name is Jan Derksen. I work at the Netherlands Institute for Sea Research. I'm planning to give a presentation about a similar system like the previous one, only it's in a much earlier situation. It's in sort of alpha stages at the moment.

This is the contents of my presentation. First of all, I would like to talk about the existing ABC system that we use on the *PELAGIA* at this moment. It's a system that we bought from RVS -- Research Vessel Services -- in England. There are some problems with it. It's not year 2000 compliance. It has a lot of utilities, but they are command line utilities, not graphical user interface programs. So it's a bit difficult to use unless you're really a UNIX expert. Then it's a quite good system.

Because of the problems that exist in this system, we are thinking about either buying a new system or designing something ourself. Well, there are a few options that we can do. I'll talk about that later. Later on, I'll give the specifications of the new system so you know the direction that I want to go in the options. I'll talk about the implementation -- how we did it, something about the status the system is in now, and summary.

This is the sort of diagram of the existing system.

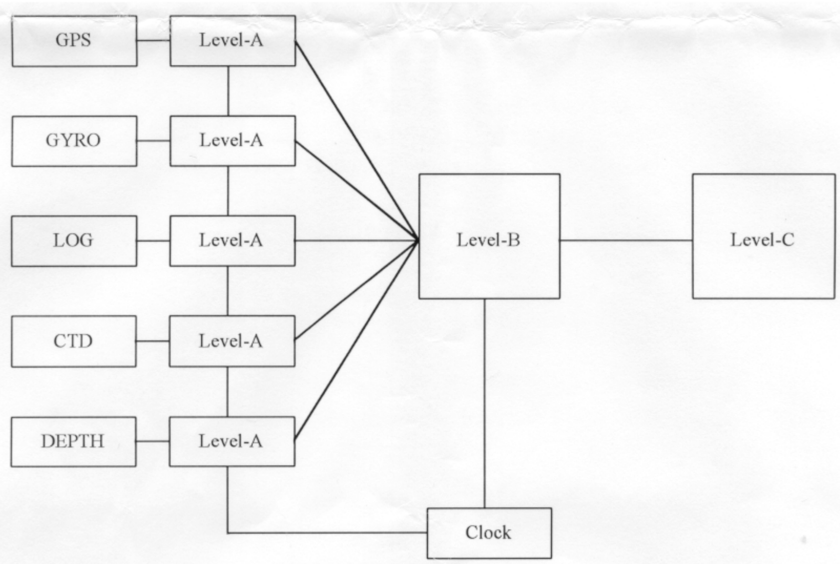



**Figure 1: Overview of the existing ABC System**

The system is divided into three parts -- a level A part, a level B part, and a level C part. Every piece of equipment has its own level A interface that's a physical box with a microcontroller in it, and it's connected to, for instance, a GPS, gyro, log, CTD -- whatever kind of device you want to connect. Every device has its own interface. And all these interfaces are connected to a level B device that's another computer. It's a 68030 microprocessor system. There's a clock system -- a clock with a serial output connect going to the level B and all level A processors. So they all use the same time. So there's no difference in the time stamps that you get on the entire system.

And last but not least there's the level C that's a UNIX workstation. It's primarily used for doing something with the data -- making plots, processing it, whatever you like. This is the existing system. As I said, there are some problems with the system.

First of all, it uses command line utilities. That's no problem if you're really used to the system and you use it a lot, then -- well, you can probably use it fairly well, but not for a scientist who is, as of course every -- well, once a year -- well, then it's not a really good system to use. And second, it requires an operator on board. And what I mean by an "operator" is somebody who knows the system very well to get it, first, to get it started, and once it's started, well, it really needs to be taken care of. Sometimes the logging stops and you have to restart it again. So it really requires an operator -- somebody who knows the system very well.

And last -- actually the most important one -- is it's not year 2000 compatible. It means it uses for the year only two digits, and it thinks that year 00 is 1900. So you have a problem in February 29th. So you can't use it past that date.

RVS, the designer of the system, they said they would fix it in time. They promised. Well, of course, a lot of new hardware, because all the level-As, they have an operating system, called OS-9, and the newer version doesn't fit in it. So we need to buy a new level A system for all the sensors that we have. So it's about a dozen or so, and it's quite a lot of money.

Well, things that we can do are just ignoring it. We could do it, but we don't have a system anymore next year. So that's not really an option. Upgrading -- well, I said it is possible, but we have to replace a lot of hardware.

Another options is buy a new system. Maybe we buy the NOAA system. It might be an option. That's not at the moment the way that we want to go. The way that we want to go now for the logging part is design a new system. I'll tell a little bit about how this new system works.

Of course, you need a list of specifications -- of course, 2000 compatible. One of the most important things is it has to run in the background of the network that's on board the *PELAGIA* without the requirement of an operator. So the software should be stable enough so that a cruise, for instance, of three or four weeks can be done without someone who knows the system. So it should work. Once you've started it, it should work until the end of the cruise. Of course, that's difficult, but I think it will be possible to do.

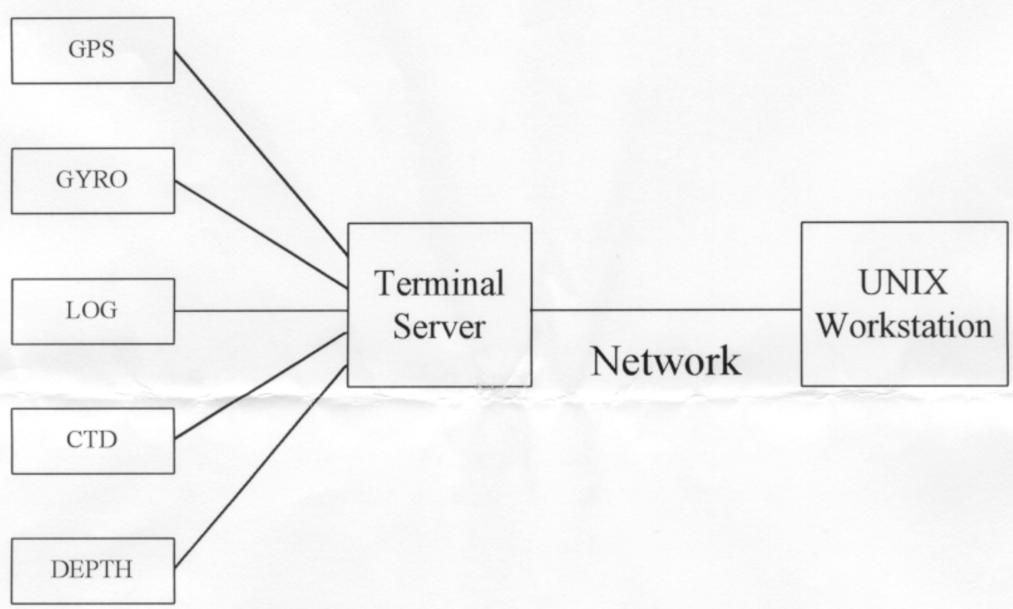



**Figure 2: Hardware overview ABC-1998**

This is the implementation of the new system. We call it ABC 1998 -- of course, with "19". It's basically the same idea as the ABC system that we have, only a bit simpler in hardware. There's only one UNIX workstation and a terminal server. It is a device with 16 serial ports on it and an ethernet connection. All the devices are connected via serial line to the terminal server. So the hardware is really simple. It can be replaced if there's something wrong with the terminal server. You just replace it and put a new one in, and you're up and running again.

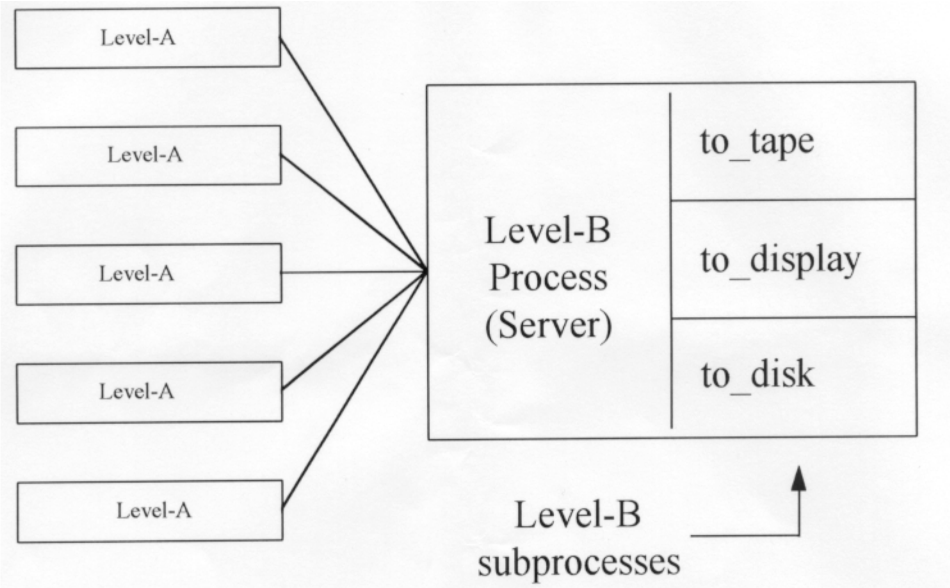



**Figure 3: Software overview ABC-1998**

Since we have the hardware rather simple, the software is a bit more complex. And only in the software you see the ABC part again. First of all, this block here, that's one level A, and it's not a hardware device anymore. It's a piece of software. It's one process that's running on the workstation. It's listening to the terminal server -- to, for instance, the GPS. It reads the data from the GPS, puts a time stamp on it, and sends it to a level B process. It's the server in the software. Level A is the client that connects to a server, and -- well, all level As in this case: gyro, log, CTD and depth can be anything that you want. They all send the data to the level B process.

The level B process, the server itself, is rather complex. Basically, what it does is reads all the data from the level-A processes and sends them to three sub processes. One of them is called "to_tape." All it does is get all the data and stores it on a tape. At this moment, it's not a tape, but a file on the disk. But that can be replaced if necessary. At the moment, we store it on a disk and make a backup of that disk every day on tape.

A second process -- really important one -- is "to_display." All this does is get all the data and send it to a character terminal with the data on it that you want. Say you want GPS position and wind speed and wind direction. It's all sent to this process, and that puts it on a display, and you can take as many displays as you want and move them around the ship.

The last process, that's called "to_disk." That process is for every level-A process that it will be data file generated on disk that contains all the data from that device. So every device will get a data file on disk that you can access and make plots, for instance.

To tell something about current status, it's in alpha status at this moment. Basically, what it means is all the level-A processes are implemented and they're working. The level B process is working. So we get data files on disk, and we have basically, at this moment, one end user utility that's programmed to make a time plot of the data. You need the data files first before you can do anything else. So the level C tools are only partly implemented at this moment

Administration tool. Still in development. We're still thinking on how it should be working and what commands should be in it. This is actually a program that needs to be really simple to use so that everyone can use it. But on the other hand, it must be not so simple that everybody can stop the system or ruin it. So it has to be protected with passwords and things like that. So that takes some time to work on.

Finally, as I said already, although it's in alpha status at this moment -- it's not really distributable -- but it's stable enough, because it's already working for over six months on the *PELAGIA* and a little longer on the ferry from Den Helder to Texel. It's the same system. It's working for over six months, and it seems to be reliable.

There's still a lot of work to do because we're not really finished. The most important part, of course, is the end user utilities, we still have to make them or buy them -- whatever. It doesn't really matter.

In the last six months on the *PELAGIA* and on the ferry, it looks like it's stable enough to run without an operator. So it's probably the design goals that I mentioned earlier will probably be met.

Of course, not yet the GUI part, but the operator actions -- well, they can be simple, because it looks like it's stable enough to work in the background. So the only thing that you actually need is status information and starting and stopping the system. It is year 2000 compatible, that's because we designed it that way.

That's more or less about the system that I -- what I wanted to tell about. I'm wondering if there's still some questions.

PARTICIPANT: Just really briefly. I'm not familiar with the *PELAGIA*. How big is she, and what sort of science measurements does she do, and where?

MR. DERKSEN: *PELAGIA* is 60 meters long and it does scientific research in the North Sea, the Atlantic, Bay of Biscay -- that area more or less.

PARTICIPANT: Could you just say something about the operating systems you're using. Have you changed them dramatically (multiple simultaneous speakers; indiscernible).

MR. DERKSEN: Well, the operating system that we use is Solaris. At this moment, it runs on the Sun workstation. But the logging system itself, it's plain C code. It doesn't really use any Solaris-specific things. So if you want to, for instance, take a LINUX box, you just take the source and compile it, and it works. There are some things that you have to be careful about, but it shouldn't really be a problem to compile it on a different operating system.

PARTICIPANT: I know with the old ABC system that you can't save all the CTD data. Presumably now you can actually store all the raw data from the CTD; you're limited to bits per second or anything like that?

MR. DERKSEN: No. In the original ABC system, the smallest step in time is one second. The smallest step here is microseconds. The way that we use to store the date is we use double. We count days in double. Doubles are eight bytes, so it will be very small time -- no problem at all.

PARTICIPANT: However, we do not do that. We keep -- like in the previous talks, we like to use the software that goes with the specific instrument and store the main data on these instruments, and only take a subset into the central data logging system.

PARTICIPANT: Which CTD are you using?

MR. DERKSEN: SeaBird. There’s also another difficulty. If you use a subset of your data from the CTD and store it in another data logging system, then you’ve got two sets of the same data, and people tend to use one set and forget about the other one, and usually they take the wrong one in that case. So it’s not really a good idea to split them up.

# Underway Sampling Systems Discussion Session

MR. FINDLEY: Rich Findley, University of Miami. Dave, you said that the intake measurements weren't that good, but there were engine --

MR. HOSOM: Similar intake for the engine, yes.

MR. FINDLEY: Most of the research fleet, though, has bow intakes. How are those doing compared to the --

MR. HOSOM: The problem with the seawater intake is that, depending on what the flow is around the ship, you may be getting surface water, or you may be getting 14-feet-down water, or some sort of turbulence. So the seawater intake has a problem of sampling sea surface temperature.

Likewise, if the unit on the inside of the hull is up out of the water part of the time, you're also not sampling sea surface temperature. So the placement of the module on the inside of the hull is subject to the same considerations. But the data from the volunteer ships, as analyzed by Peter Taylor at SOC, says that the hull-mounted sensor provides better sea surface temperature than the seawater intakes.

MR. FINDLEY: Then a regular -- you know, an oceanographic ship designed for seawater intake, as opposed to --

MR. HOSOM: These were volunteer ships, which is -- you know, and one of the things to think about is, when the ship's a thousand foot long and so forth, you have a whole different set of problems than some of the research ships.

MR. FINDLEY: I gave a talk yesterday at -- I've got a thousand-footer.

MR. HOSOM: Okay. Research?

PARTICIPANT: It will be.

MR. AMOS: I'd like to make a comment on that, too. On our ships, we have a system where we have a seawater intake for the thermosalinograph. But at every CTD station, we automatically have recorded the temperature and salinity at the moment that the CTD is stabilized at the surface, both before it goes down and when it comes back up again, to compare, and goes directly in that same system that I was talking about earlier. So you can actually do a comparison. And we get errors in the order of .5 degrees. What you see, though -- is that a problem, other than your point that you may be measuring water from different levels, if you have a system that's off by an amount that you can statistically correct? Do you see any problem with that?

MR. HOSOM: WOCE data quality would like to see .01.

PARTICIPANT: What was that number?

MR. AMOS: Point five. But, I mean --

PARTICIPANT: No, no. What was --

MR. HOSOM: .01.

MR. AMOS: But after -- however, after correction, is this an absolute accuracy that WOCE would like to see?

MR. HOSOM: If you look at the error on each of the variables -- obviously, you're fighting for every scrap you can get from each of the measurements. And .01 was what we used as a goal for sea temperature for WOCE data quality.

MR. AMOS: Any other comments? Yes?

MR. WILLIS: Marc Willis from Oregon State. Dave, when you presented that one graph that showed your improvement and --

MR. HOSOM: Yes.

MR. WILLIS: -- and your error for heat flux, did that include both IMET and non-IMET observations for those terms?

MR. HOSOM: It included IMET and non-IMET and a big chunk of better data processing. Of all of those things, you have to have the basic sensor accuracy to begin with. But the data processing and the analysis which has been -- which has really come from Peter Taylor, has been the primary ingredient.

MR. AMOS: Yes.

MR. POULOS: Yeah. Steve Poulos, University of Hawaii. I noticed on the volunteer ships you put it up in the mast area. How does that -- how do you handle the slip screen or the air flow?

MR. HOSOM: The bow mast on any ship as high up as you can get is the best uncontaminated sampling that you can get. And, obviously, you're only getting good sampling in the forward 300 degrees, which is okay when the ship's underway. The closer you get to the ship, obviously, you start to have heat effects from the ship and flow disturbances. Again, Peter Taylor's group at SOC is doing very extensive ship modeling and using the results of that ship modeling to make data corrections based on where the sensor is on the ship. That's part of the -- I mean, you're really starting to pick at all the details and use every available mechanism to improve the data quality.

Yes?

MR. SCHWARTZ: Dan Schwartz, University of Washington. Amplifying on that same question, then, as far as the height of the sensors compared to, say, the TOGA, tall buoys (ph), or the NDBC buoys (ph), are you normalizing that beta for some ideal height above sea level, or --

MR. HOSOM: I think it's all normalized at ten meters after it's processed. It has to be, because a three-meter discus buoy is like three meter -- the sensors are three meters. The TOTO buoys (ph) are somewhat lower. Most ships, you're up someplace.

MR. AMOS: Tom.

MALE SPEAKER (TOM): Yes. Have you made an estimation -- you have to come up with a ship velocity reference in order to come up with -- in order to correct your MET station. And I presume you're doing that from GPS positions.

MR. HOSOM: Yes.

MALE SPEAKER (TOM): Have you made any estimations on what error contribution there is from GPS position uncertainty when you're doing the analysis?

MR. HOSOM: On the climate data, I don't know the answer to that. The WOCE data is being archived by David Legler (ph) down at FSU. He has been going through all of the WOCE ship data and doing the updating and corrections based on ship speed and so forth, and struggling with making sure that he's got sufficient data to do that.

MALE SPEAKER (TOM): But you’re not trying to do any correction in this when you’re reporting --

MR. HOSOM: No. Uh-uh.

MALE SPEAKER (TOM): -- apparent wind or relative wind, and then later on, you’re trying to take -- use the GPS to take the ship motion out.

MR. HOSOM: That’s correct. The wind instrument that I showed has a compass in it. All of the research fleet the wind instruments do not use a compass; the use the ship’s gyro. Obviously, if you have a magnetic compass upon the bow mast next to the steel bow mast, and I say you start to have correction problems there that are significant. You can’t do correction in the instrument without adding a lot of feedback to the instrument itself. It has to be done after the fact in some computer that’s doing the processing.

MALE SPEAKER (TOM): What’s your sample rate on the wind? How often? Five minutes, one minute, ten minutes?

MR. HOSOM: We take a wind velocity measurement every five seconds. We sample the vane every one second. We sample the compass once every five seconds. We use those scaler readings, then, to generate a vector average wind for once a minute.

MR. AMOS: Let me make a comment. As these vessels are underway most of the time at speeds of -- what? -- how many knots?

PARTICIPANT: Twenty.

MR. AMOS: You can also use course over the ground as calculated by --

MR. HOSOM: And it becomes -- course over the ground becomes, at those speeds, much better.

MR. AMOS: It does. Yes. Right. When you ask a question, could you identify yourself for the recording.

MR. SHOR: Sandy Shor, National Science Foundation. Dave, how extensive is the volunteer observing system now, and what is the plan, or what do you project for the next five to ten years?

MR. HOSOM: The dreams and the discussions, which have not been coupled to budgets --

With that preface, the discussion now is that we have a transition period between now and the year 2000. In the year 2000, we start to put climate quality data systems on 270 volunteer ships. You’re looking at a current cost of the system that I outlined here of about $130,000 apiece. Say that it gets manufactured by somebody besides Jeff and Dave at Woods Hole, and we bring the price down to $65,000 apiece, multiply that by 270. What’s your estimate of the federal budget to do that?

MR. SHOR: Well, NOAA’s a very wealthy organization.

MR. SHOR: Let me just qualify that. NOAA has been the primary sponsor of the VOS program; is that correct?

MR. HOSOM: Yes.

MR. SHOR: Roughly how many ships are outfitted right now? Are you still in test mode?

MR. HOSOM: One ship.

MR. SHOR: One ship.

MR. HOSOM: And we hope to expand that next year to two ships, and then begin to have -- transition this to a commercial system and begin to do more ships.

MR. SHOR: But these similar sweeps of sensors are on a number of NOAA and UNOLS research vessels, as well?

MR. HOSOM: An IMET system, as I had the one slide that showed the IMET system on a number of UNOLS ships, plus the new VOS-type sensors, are on the new NOAA Ron Brown. Dennis Shields, who will be talking later, did the data acquisition programming for that and can comment on that.

Yes?

DR. KNOX: Bob Knox from Scripps. I want to get back to the question about surface temperature. As this program expands and these systems get installed on a variety of ships, some with hull-mounted sensors at various locations on different ships with different flow characteristics -- some may be farther forward where they're up out in the air some of the time -- strikes me the data base is going to be somewhat heterogeneous with respect to the quantity of interest or climate studies, which is probably the real, honest-to-God, no-fooling surface temperature of the ocean.

MR. HOSOM: You really want the skin temperature.

DR. KNOX: In that sense, it's perhaps not too surprising that the Germans got it right by taking bucket temperatures since they do it carefully.

Is there going to be some way to deaconvolve (ph), this or calibrate individual ships, or have canonical mounting places, or something to rationalize this set of data from ships all over the place with regard to your --

MR. HOSOM: I don't know if there's a plan in that direction yet. This whole thing is just being dreamed about.

DR. KNOX: Yeah.

MR. HOSOM: And I suspect that we're going to be buying pens and buckets.

DR. KNOX: I suspect so. I mean, at the very least, you have to keep track of what's done on which ship --

MR. HOSOM: Yes.

DR. KNOX: -- so you can go back into the historical data and work it out, and it may turn into a ship-by-ship calibration against something -- perhaps the bucket, perhaps something else.

MR. HOSOM: The work that Peter Taylor's doing relative to the flow pattern on ships for determining what directions you make to the sensors based on where the sensor is and what the flow characteristics are very probably need to be done relative to where the sea surface temperature unit is. I mean, there's an enormous number of questions of how you take -- I mean, a sensor that's good to five millidegrees is meaningless, depending on where you put it and how you measure it, and what the calibration is, and what the ground-truthing is. And this is -- that whole business of installation, calibration, ground-truthing and so forth, I mean, we toot our horn and say, you know, we're measuring ground-truth. We're not just measuring things with satellites and radar sets and models. But we have that problem of ground-truthing, too -- I mean, big-time.

MR. AMOS: I'd like to make a comment on that. Some years ago, I did an extensive study of bucket temperature methods. I was surprised by the variability. I mean, from a big ship like that, somebody's got to chuck the bucket out of the side, record the time that it went, pull it up on deck, take the reading fairly rapidly or it'll change as you're holding it up over the side of the ship. So I think that data from the Germans was very, very good for that. You have standard buckets, I presume?

MR. HOSOM: We at Woods Hole manufacture buckets, and there must be a standard German bucket that we’ll have to find out about.

MR. AMOS: There’s a question from the back there.

MR. DARTEZ: Steve Dartez, Louisiana State University. I have a question for Dave.

We’re in the process of developing a network along the Louisiana coast measuring meteorology and wave dynamics, and using oil production platforms as bases. One of the things that I’m curious of, when you were looking into your real-time data transmissions from the ships in the future, have you run across what would be the best means of that transmission and what an average cost may be on that?

MR. HOSOM: We’ve been looking at that, and you know there’s the iridium and the yorcom (ph) and all that stuff. We’re just beginning to scratch at that. I don’t have any -- I don’t know. That’s, for us, a serious problem also. I don’t have any --

MR. DARTEZ: That’s our main problem. We’re just outside of cell phone range and just a little too far for the radio.

MR. KRUDELEG: Vic Krudeleg (ph), Netherlands Institute for Sea Research. I would like to comment on your statement, Mr. Amos. The error in the temperature measurement that you stated earlier, on our ship, Pelagia, we have an on-line sampling system which does not measure temperature through the hull, as you assume, but by taking water in. That produces a continuous stream of data, and wanted to calibrate it, too, against CTD measurements, as we also do that. But when the ship is afloat, sometimes we experience very strange temperature spiking on the continuous signal, which I could not lay my hands on right now. But I assume that it is from radiation from the ship itself or perhaps from the axels, the water off the motor outlet that is being partially taken in again, depending on the resisting of the ship, the wind and the stream, and that may account for your half degree of error, because we see a .2, .3 degree error, too, every now and then.

MR. AMOS: Yes. Well, the error -- I’ve always assumed -- most of the work I’m talking about is done in the Antarctic where the outside sea temperature is much colder than the interior temperature of the ship. And so during the passage from our intake to the measuring device, that I’ve always assumed is a warming. We do get some spikes on occasion, but normally if the -- we have a de-bubbler device on it. Especially when you’re on an icebreaker breaking ice, that’s a really big problem because you might get ice actually sticking in the intake area and changing things and making them unusable.

Do you have a comment about that?

In the early days of the Nathaniel B. Palmer, there was a -- we sent an ROV underneath, and you could see streaks of ice all the way under the hull, including in the intakes. We were getting ridiculous temperatures that were just not used -- and salinities, of course.

MR. KRUDELEG: I can imagine. And then two more things. You can either take, let’s say, the bulk (ph) temperature of the upper three meter and the average bulk temperature. But then you’re also very much interested in the true surface temperature. Wouldn’t you not like to go to infrared thermometry to do that? Because that’s what we do occasionally on the ships.

MR. HOSOM: The infrared measurement at night matches the hull temperature perfectly.

MR. KRUDELEG: Yes.

MR. HOSOM: During the daytime, the infrared measurement tends to reflect sun (indiscernible), and you have a problem there.

MR. KRUDELEG: Yes. You need this kind of reference sensor to compensate for that.

MR. HOSOM: Yes. The other thing that’s being done is to actually have a sensor riding up and down a rail so that you always are just sitting at the surface. But on volunteer ships, which is our primary concern right now, that’s -- if we can’t run cables --

MR. KRUDELEG: Yes, that’s my understanding.

MR. HOSOM: Go ahead.

MR. KRUDELEG: Some other questions, please. You spoke about relative humidity measurements.

MR. HOSOM: Yes.

MR. KRUDELEG: Could you explain a bit more on how you do that, and how you do that correctly, and how do you avoid the fouling problem?

MR. HOSOM: We have used for many years a Rotronics sensor for the relative humidity and temperature. In the early days, we made a little frame, and we wrapped gortex around it. Gortex has an interesting property in that it probably gets wet with sea spray, and that when it dries, the sea salt is stuck to the outside of the gortex. The experience we have is that, when it dries off, the salt falls off. And we do not have a nice salt standard cell set up at the measurement.

Rotronics now supplies a gortex shield. You ask for it for their sensor. We have had -- absolutely have not been able to determine any sea salt valley of that sensor at all. We do locate it inside of a static shield, but the gortex seems to be the proper protection in the marine environment.

Did that --

MR. KRUDELEG: What’s the surface like? What’s the sensor like that?

MR. HOSOM: We do calibrations every six to eight months and find minimal drift in that time period. If that same sensor is subjected to hydrocarbons, it’ll foul very quickly -- very quickly. So the open ocean is a good environment in terms of not having hydrocarbons in that, unless the ship’s deck is (indiscernible).

MR. KRUDELEG: Yeah. (Indiscernible.)

MR. AMOS: I have a comment on that, too. A question, Peter (sic). Do you ever get -- what happens when you read more than 100 percent? How do you -- because I’m sure it happens sometimes.

MR. HOSOM: We do. In fact, we’ve been doing comparisons of sensors. The Rotronic and the AIR both will read when saturated more than a hundred percent. The Visola (ph) sensor has had a much faster response time and has never read more than a hundred percent. On the other hand, Visola doesn’t supply in the nice gortex shield, and so we continue to use the Rotronic for that.

MR. AMOS: In the areas that I work -- often they’re in the Antarctic -- I’ve been amazed by the taking of our relative humidity sensor -- 97-point-something percent. (Indiscernible) I’m absolutely sure it must be reading incorrectly. What we do is sling psychrometer (ph) calibrations, I guess you might call them, on a daily basis. Do you recommend that? Do you do the same things, or --

MR. HOSOM: We have, and found that the sensor itself is --

MR. AMOS: Well, in fact, my experience has been that, as I’ve said, this machine has got to be wrong. Then all of a sudden, the wind will change direction and blow in off the ice, and you suddenly see some actual humidity other than the full saturation.

Do we have any more questions?

MR. WALDEN: Barrie Walden, Woods Hole. Dave, what are the -- you just touched on the calibration issues. But what do you recommend as the calibration interval for these sensors? And how do you plan on handling that when you have that number of them out in the field?

MR. HOSOM: We still -- the party line still is six to eight months calibration on things, particularly like humidity. We are currently, based on budget constraints, putting things out for a year with a calibration before and after, and using that post-calibration to process the data. The calibration issue for 270 sensors is a major, major issue. Dick Paine (ph) is the one guy at our institution doing calibration, and I don’t think he’s going to be able to handle it.

If anybody’s interested in calibration, by the way, we don’t want to be in the business -- our guy, Dick Paine, who’s doing the calibration, would be glad to supply all the information you want and tell you how he does it, what he does, what he uses. The more people who can do their own calibration, as long as it’s documented and we have some way of knowing what the calibration history is, please develop your own calibration facilities.

MR. AMOS: At the back.

MR. MULLER: Rich Muller, Moss Landing Marine Labs. We have a R.M. Young relative humidity temperature sensor. We’ve developed some problems with fouling, sea spray, probably hydrocarbons, as well, from the stack. What I’ve done is basically a little filter on the relative humidity sensor. I’ve washed it off with some distilled water. Sometimes it works; sometimes it doesn’t. Sometimes I have to change the little electrode. Have you tried using gortex on a non-standard RH sensor, like --

MR. HOSOM: We use gortex on any kind of a sensor we put there.

MR. MULLER: So you could just apply some gortex?

MR. HOSOM: Basically, if you’re really nice, you call up Gortex, and they give you several eight and a half by 11 sheets as a sample, which gives you sort of a lifetime supply.

MR. MULLER: (Indiscernible.)

MR. HOSOM: You make your own.

MR. MULLER: Okay. Good.

MR. AMOS: There’s another question.

MR. OBER: My name is Sven Ober from the Netherlands Institution of Sea Research. In one of the first sheets you showed a graph which represents the error of the flux.

MR. HOSOM: Yes.

MR. OBER: It varied from 200 watts to nearly nothing -- well, after a few years. I wonder what the term "error" means. Is that an error in a formal way in terms of traceability, or is it an error (indiscernible) the difference between the model and what you measure?

MR. HOSOM: It’s an absolute error.

MR. OBER: An absolute error?

MR. HOSOM: Yes. Yes. As we are beginning to find the models have errors of significant numbers.

MR. OBER: Is it somewhere described this --

MR. HOSOM: Have to do --

MR. OBER: -- calculation in which you -- well, on which you base these error figures?

MR. HOSOM: I can recommend contacting either Dr. Robert Weller at Woods Hole or Dr. Peter Taylor at SOC and asking for their inputs on that.

MR. AMOS: One more question.

MALE SPEAKER: I just wondered if you had any thoughts on using optical rain gauges in (indiscernible).

MR. HOSOM: We have used --

PARTICIPANT: I'm sorry. I didn't hear the question.

MR. AMOS: The question was whether they had any thoughts on optical rain gauges.

MR. HOSOM: We have done testing on a number of optical rain gauges. The first problem we run into is that it's a power problem. The second problem we run into is that the ones that we have and have been trying to test haven't worked long enough. The next thing that comes up is -- and I would refer you to Luce Hossa, IFM Keough. He evaluated the whole rain situation, and he developed an optical distrometer (ph) which actually measures the raindrop size. Most of the optical rain gauges assume a drop size. What you find out is, if you actually measure the drop size, that it varies widely.

Luce's optical distrometer is available from a company in Germany. From what I have seen, that offers the best opportunity for doing really accurate measurements. But in the core experiment, there were a number of optical rain gauges used, and they came back to using the self-cycling rain gauge from R.M. Young as a better measurement. That, you know, you're looking at a 100 centimeter square area bobbing around in the ocean, and now you're going to say that the whole rain is based on that measurement. That's a problem.

PARTICIPANT: And there's enormous distortion due to the flow (indiscernible).

MR. HOSOM: The reason Luce Hossa did the ship rain gauge that he designed was that, very obviously, on a ship, in case it's going someplace, very quickly the rain, even if it is vertical, as far as the ship is concerned, becomes horizonal. And so by switching over the measurement from between nine and 11 meters per second wind speed from a vertical measurement to a horizonal measurement, he's been able to achieve -- again with a point measurement -- 96 percent accuracy based on the testing that he's done. And he used his optical distrometer as the reference.

PARTICIPANT: I've got a question with regard to that, too. How do you actually determine the surface area when you take (indiscernible) from a vertical collection system to a horizonal collection system?

MR. HOSOM: The surface -- the collection area of the vertical collector is the top end of that champagne-glass-shaped thing. So that's a defined area. The horizonal projected area of the cylinder is also a precision surface that's (indiscernible) with the horizonal wind, even though it has five T-bars around it. So the rain hits, runs around to the T-bar and down. But it's a precision area.

PARTICIPANT: But you don't know before hand the actual angle at which the rains fall, do you?

MR. HOSOM: No. No.

PARTICIPANT: So there is a sort of error in --

MR. HOSOM: And he's worked up an algorithm based on wind speed to do some corrections of that.

MR. AMOS: I think we've got time for just one more short question.

PARTICIPANT: I saw the drifter buoys using acoustic -- passive acoustic range sensor. Do you get any good quantitative data out of that, or is it just that it's raining or not?

MR. HOSOM: I don't have any experience. I don't have experience with that.

MR. AMOS: Is that nine to 11 meters per second relative wind speed --

MR. HOSOM: Yes.

MR. AMOS: Well, I think that's it for questions.

# GEOPHYSICAL TECHNOLOGIES

## Chaired By
## Paul Henkart

# An Air Gun Tutorial

John Diebold
Lamont-Doherty Earth Observatory
Columbia University

## Introduction

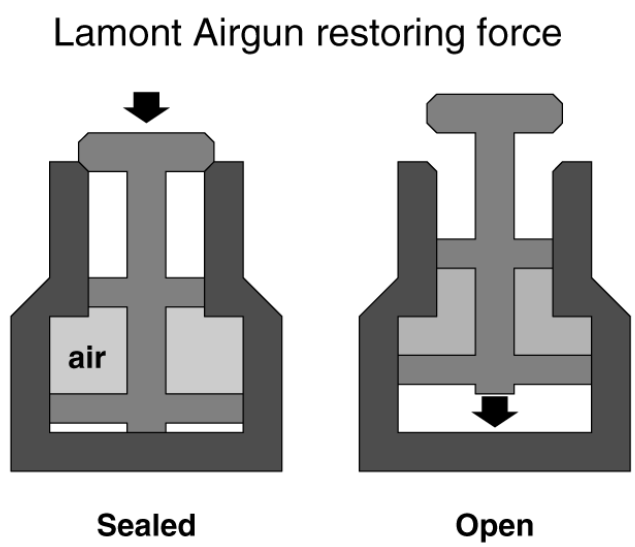
There are three basic types of air guns that are available and in use today. Probably the least commonly seen in the academic fleet is the sleeve gun, originally made by Western Geophysical, and mostly used in commercial employed by seismic contractors. Each sleeve gun comes in a specific size, and if a different size is needed, it is necessary to change guns. That can be a cost issue, but sleeve guns have several benefits, including excellent reliability.

The Bolt 1500C air gun is one of the most commonly used in the academic fleet. These guns have the advantage that the same body can be fitted with many differently sized air chambers, resulting in improved flexibility and a simpler inventory of spare parts. The Ewing, which does most of the multi-channel work in the UNOLS fleet, tows twenty Bolt 1500Cs and therefore, my experience has mostly been with these.

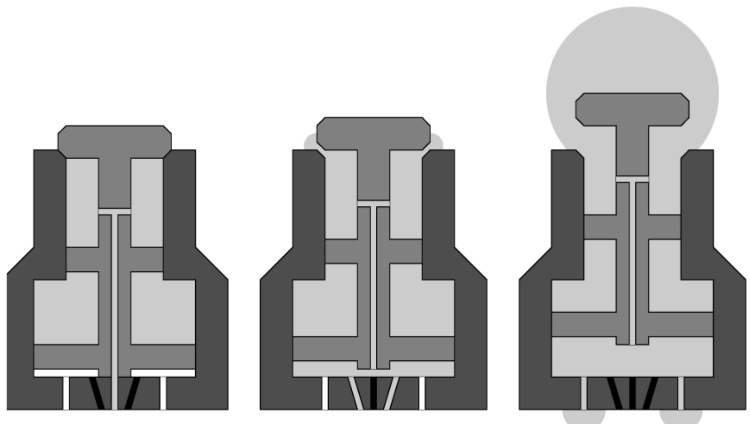
The GI gun is now beginning to take over the role formerly occupied by the water gun. In fact, the same person, Adrian Pascouet, invented it. The GI gun gives you the ability to produce a well-tuned signal with a single air gun.

## Mechanical Principles

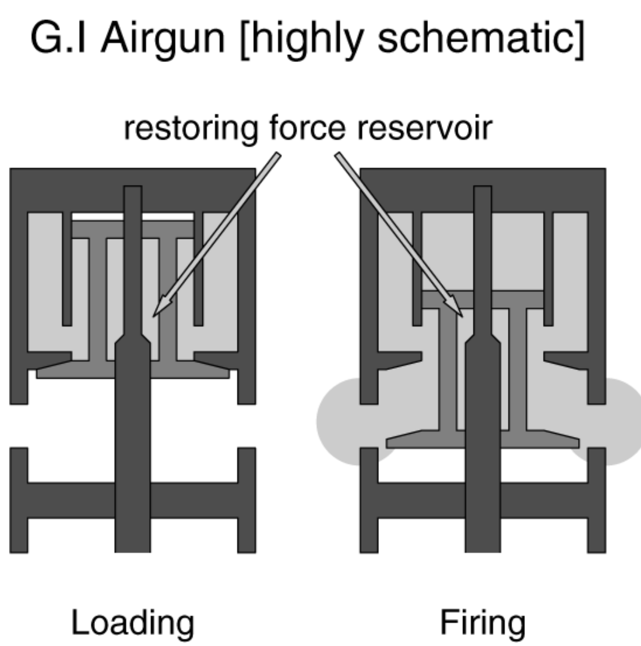
The first thing to talk about is how air guns work: an appropriate subject for a meeting of technicians. . To illustrate the fundamentals, I’ll use what is perhaps the simplest of all air guns, the one developed at Lamont in the early 60s. The background of that development centers around the use of TNT and other explosives as a seismic source. The detonation of an explosive charge under water creates a rapidly expanding bubble of hot gasses. The expansion of this bubble creates the outgoing pressure pulse that we call a seismic signal. Explosives had been used for two-ship refraction work since the 1930’s, and in the late 1950s, a fairly primitive analog reflection profiling system was developed at Lamont. The acoustic source was WWII surplus demolition blocks, detonated with blasting caps and fuses, every minute or two. The stress of doing this work continuously led to a fatal accident in which John Hennion was killed aboard R/V Vema. This accident was one of the prime motivations behind Lamont’s movement toward air guns. In 1964, we started using this gun instead of TNT on Lamont’s two ships for continuous reflection profiling. It turned out that although they are much less powerful than the half-pound blocks of explosive we had used previously, the fact that we could fire them much more often - every ten seconds - made them a better tool for seismic reflection profiling. Air guns are intended to do the same thing as explosives; to create a rapidly expanding bubble, in the case of air guns, by the rapid release of a volume of compressed air.



The Lamont air gun had one moving part, which we called the "piston." Nowadays you'd call this the "shuttle." The Lamont air gun's piston is shaped to form two air chambers. As shown in the diagram, the upper chamber is sealed when the shuttle is in the closed position, but open to the water in the open position. In any air gun, the trick is to find a way to hold the shuttle closed while the firing chamber is being filled with compressed air, and then to slide it open quickly at the desired time. In the Lamont gun, as in all others, this is done by using the pressure of the compressed air. The gun's lower chamber is shaped so that it is sealed at the top and bottom by O-rings around disks of two different diameters. When compressed air is pumped into this chamber, its effect is to force the piston downwards. The effects of compressed air can be thought of in hydraulic terms, and although the pressure on both disks is the same, the fact that the bottom disk has a larger area results in a downward force. Another way to consider the situation is to observe that the volume of the lower "control" chamber is smaller in the open position than it is in the closed position. Therefore, the trapped "control" air acts as a powerful spring, holding the piston in the closed position, and providing a restoring force to close the gun after it is fired.



So with all this force holding the gun closed and sealing it, how does it ever fire? The answer, again, is to use the compressed air. To fire the Lamont gun, you introduce air below the shuttle, which catastrophically forces the piston upward, opening the gun and releasing the air in the upper chamber. In hydraulic terms again, this works because of the differences in areas over which the air has contact, and the relative orientations of those surfaces. Only a small amount of air had to be injected below the piston (this injection is usually performed by a solenoid valve) to fire the gun. As the piston rose, the pressure of the "firing air" beneath it dropped, until its effect was overcome by the restoring force of the control air. Small orifices ("ports") allowed the firing air to bleed out slowly so that the gun could re seal itself without damage, and the cycle began again.




The Lamont gun was very efficient. Its big disadvantage was that you couldn't change the size of the chamber without changing the size of the gun. Lamont guns were built in a range of sizes (volume of the firing chamber) between three and forty cubic inches. A giant, four hundred cubic inch gun was made, but proved to be an extremely heavy and unwieldy beast. There clearly was an upward limit to the useful size of this design.

The GI gun is about the most recent innovation in air gun design, but its basic mechanical principles are very similar to those of the Lamont gun. The GI gun is, essentially, two air guns in one, connected by a central cylindrical rod which pass the air from one to the other. The shuttle of each of the two -- the "Generator" gun and the "Injector" gun -- slides on that rod. The control chamber is actually inside the shuttle, where the central rod has two diameters, generating a restoring force much in the same manner as we saw in the Lamont gun. The gun is fired when the solenoid valve is triggered by an electric pulse, diverting incoming air from the firing chamber to the narrow space above the shuttle, forcing the shuttle down and unsealing the reservoir. As is the case with the Lamont gun, the GI gun has a fixed chamber size – in this case, 105 cubic inches, but sets of plastic spacers are available to reduce the size to 75 or 45 cubic inches.

The Bolt air gun was the first really successful commercially available gun. Since its primary inventor, Steve Chelminsky, worked at Lamont before going on and forming his own company, we know the origin of the company name – Steve's nickname, "bolt."—In this very simplified view, obtained from the company literature, its basic operation can be seen. The actual Bolt air gun has many parts, which don't appear in this drawing, and it is more complicated and difficult to work on. It does have three redeeming features, however. Its purchase cost has been significantly reduced in the past decade, while improvements have become available which increase its reliability. Finaly, a variety of differently sized reservoir chamber can be fitted to any Bolt 1500-C to make a gun with air volumes ranging from 40 to 1000 cubic inches..

The sleeve gun has the unique feature that its shuttle is part of the outside shell of the gun. When it is fired, that entire outer part of the gun slips back and lets the air out much more efficiently than the other guns, with their arrangements of ports.

**The Desirable Seismic Signal**

What do we want in air guns? Usually two things. We want a signal with high resolution, which well do the best job of sampling the sub-sea-floor, and at the same time, we want the power to penetrate deeply and sometimes, to be detectable at large distances. The best resolution is obtained when the signal has a broad, smooth spectrum. This corresponds to a simple, spike-like seismic pulse. The process of achieving such a signal is often called "tuning." The frequency content – the bandwidth – has everything to do with resolution. The larger it is, the better job you can do at discriminating thin layers and fine structures. Penetration, on the other hand, depends most on high power at the lower frequencies, which are the least attenuated by passage through the earth. It is possible to create a seismic source that is both well tuned and powerful, but there is a third parameter – tow depth - that affects both penetration and bandwidth inversely.

Next, we talk about how to accomplish these two goals separately, and finally address the question of whether it is possible to meet both goals simultaneously, or if they are mutually incompatible.

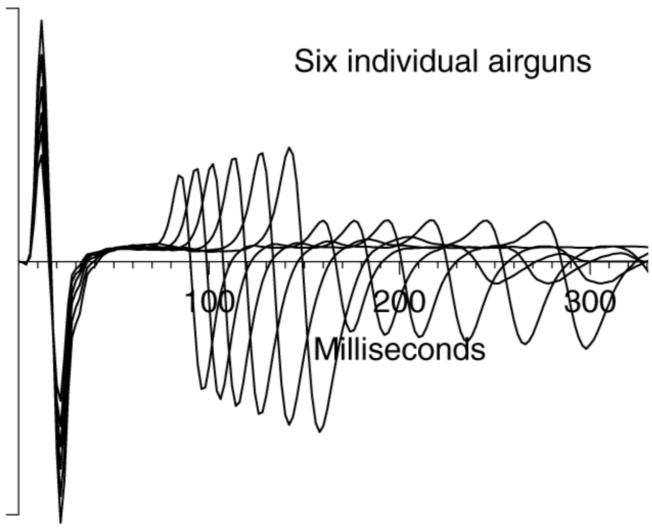
**Tuning**

Good tuning can be arrived at in three basic ways. One is to form arrays of guns of different sizes. Another is to group guns in "clusters", and finally, there's the GI gun, with its two sequentially fired chambers.

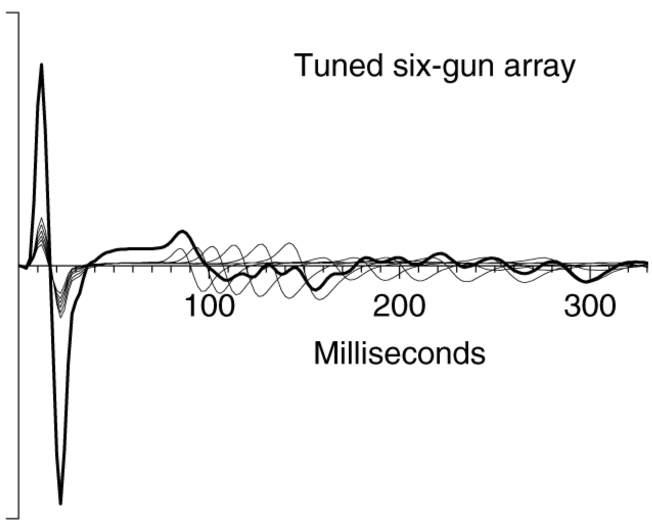
First, why do we need tuning? The answer is: the dreaded and well known "bubble pulse." When the gun is fired and its reservoir is opened, the air forms a rapidly expanding bubble. This produces the sharp pulse that is desired, but then the laws of physics take over and complicate things. An air bubble underwater has an equilibrium size, which depends on the volume of air and the water depth. For example, the bubble from a 500 cubic inch airgun fired at 2000 psi as an equilibrium radius of 65 centimeters at 10 meters. When an air gun is fired, the expanding bubble "overshoots," growing larger than its equilibrium size. Then the water pressure takes over and recompresses the bubble. This process continues, producing a series of reverberations which die out due to thermodynamic effects. The period with which the bubble "rings" depends on the air volume, initial pressure, and its depth in the water. The bubble rises through the water while this all occurs, so the ringing is not periodic. Therefore, it is difficult to remove the ringing by data processing.

The pulse produced by the initial bubble expansion has the characteristics of a desirable signal. Taken by itself, this pulse has a smooth spectrum with maximum power at about 12 Hz. It is interesting to note that the size of the bubble (which is to say, of the air gun) has little to do with the width of the pulse – only its amplitude. This means that the intuitive notion that large air guns produce lower frequencies is incorrect. In any case, the role of tuning is to diminish the bubble pulse ringing.

To form a tuned array, air guns with different volumes are combined and fired simultaneously. The choice of the exact volumes to use is critical to the extent of tuning that is achieved. The usual measure of tuning is the "peak-to-bubble" ratio – a comparison of the amplitudes of the primary pulse and of the residual bubble pulses. A ratio of 10:1 is considered quite good. Trial-and-error modeling is often used to choose the sizes for an array. In my experience, at least five or six different sizes of guns are required for good tuning. In general, a wide range of sizes leads to the best tuning, as does shallow towing. Due to the physical size of the air bubbles, however, larger air guns must be kept below some minimum depth, or some of their energy will be lost – used up in moving water upwards.




Another approach is "clustering" which combines tuning with some physical effects that can reduce the bubble pulse, though they are hard on the air guns. We've seen that the ambient pressure (usually correlated with water depth) affects the amplitude and ringing frequency of a bubble. What happens with a cluster is that the pressure fronts from a pair of adjacent guns firing actually diminish the bubble pulses of both guns. After the first expansion, the two bubbles coalesce, and start to reverberate with a longer period - as if it had been released by a single, larger gun. Different sized clusters can be combined to produce different sized bubbles, so that additional improvement can be obtained by tuning the bubbles. Clusters of two and three airguns are often used. Typically, all the guns in a cluster will be of the same, relatively small size: between ten and 75 cubic inches. Thus, the clustered array can be towed at shallower depths than a simple tuned array, with its larger range of volumes. Clusters have two undesirable properties, however. One is that the pressure interaction results in a reduction in the output peak levels – typically, about a 25% loss. Second, the pressure fronts from the nearby guns create a hostile environment for hoses and fittings. Typically, great care is taken in engineering the mounting arrangements for clustered arrays.




The GI gun works by an entirely different principle. It is really two air guns, in one body. Each "gun" has its own reservoir chamber, its own solenoid valve, and its own exhaust ports, which are located close together near the middle of the cylindrical gun body. One "gun" is called the "Generator", the other the "Injector", hence the name "GI." The G, or generating chamber, fires first, generating the desired pulse. The Injector is fired a few tens of milliseconds later, typically 30 to 40 milliseconds later, just at the time that the Generator bubble has overexpanded and is starting to collapse. The injector air acts like a shock absorber. As the first bubble is collapsing, this air comes in and it sort of just lets it down easy. This all works quite efficiently to give you a nice tuned signal with a single air gun. This is a a great benefit for a small vessel, where it's difficult to tow arrays of air guns. The downside is if you're basically using at least half of your air (maybe even more, as recommended by the manufacturer) to remove the bubble pulse.

## Power

Besides tuning, the most desired characteristic of the seismic source pulse is high amplitude. As we will shortly see, the best way to do this is to increase the number of air guns in the array. The peak pressure output of an expanding bubble, whether it is generated by explosives or an air gun, is directly proportional to the cube root of the volume of gas in the bubble. An intuitive approach to understanding the reason for this is to consider that the diameter or radius of the bubble is also proportional to the cube root of its volume. This means that to double the signal amplitude created by a single air gun, its size has to be increased eight times. Given a limited compressed supply, the output is maximized when that air supply is subdivided into as many air guns as possible. When these gun are fired simultaneously (and unclustered) their individual amplitudes add. In a silly but instructive example, 1000 cubic inches of air released from 1000 1-inch air guns will produce a signal with 100 times the amplitude of 1000 inches released from a single, 1000 cubic inch air gun.

This is an old, old figure comparing various seismic sources. Note that a quarter pound of TNT gives about the same amplitude as a 300-cubic inch air gun. If we take that ¼ lb of TNT as the output of a typical air gun, then R/V *EWING*'s twenty air guns have about the effect of twenty quarter-pound blocks of explosive going off simultaneously. Now, the cube root of ¼ is exactly one twentieth the cube root of 2,000. Therefore, *EWING*'s air gun array is as powerful (in the seismic bandwidth) as a ton of TNT. And, it can be fired every 20 seconds.

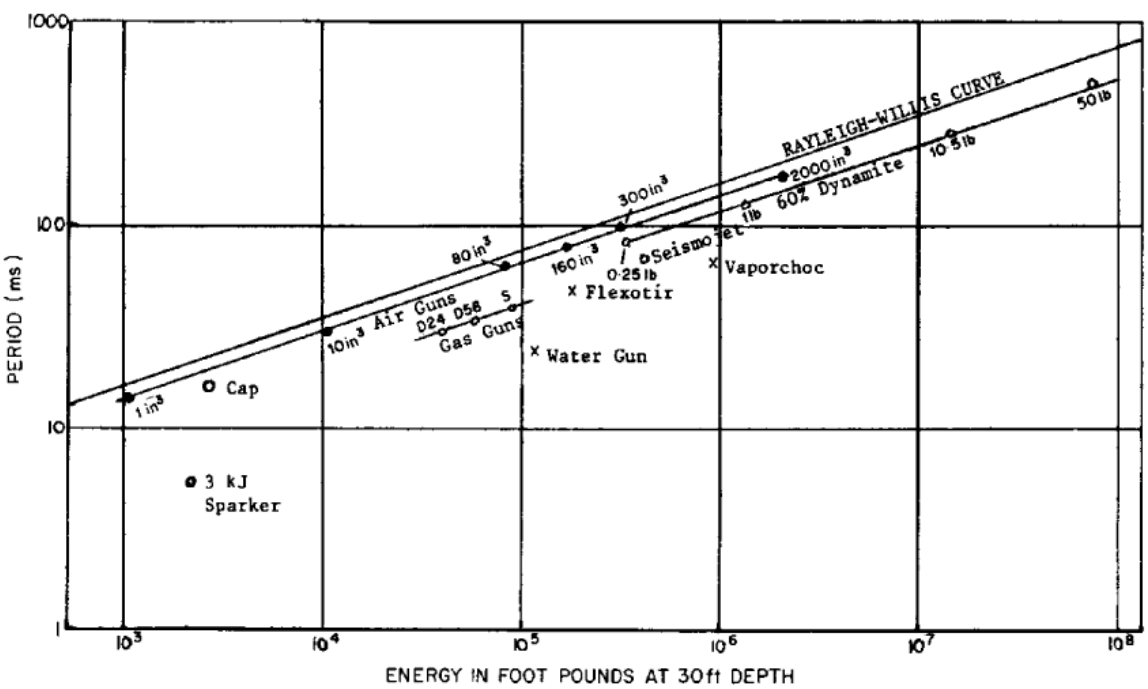
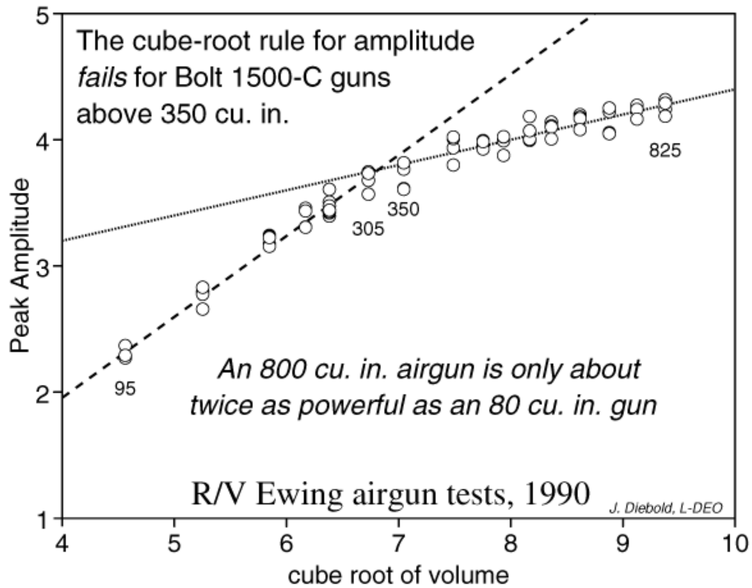



FIG. 56. Period energy points for single unit sources at 30 ft depth.

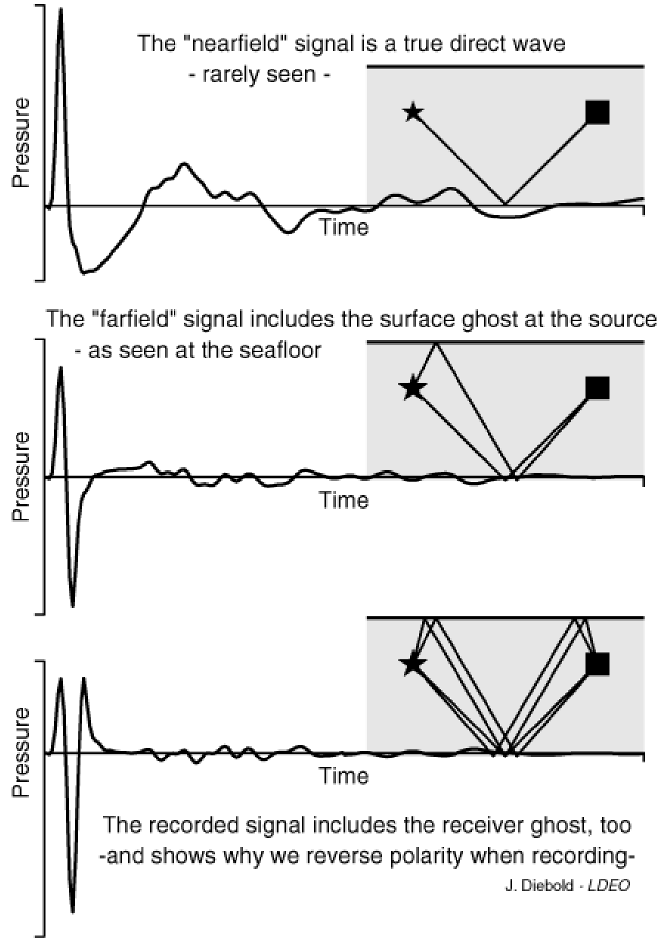
There is another reason that using large airguns is inefficient is the exhaust port design of the most commonly used airgun, the Bolt 1500C, which is incapable of discharging large volumes of air in the time required. To illustrate this, I show the results of some tests carried out during *EWING*'s 1990 shakedown leg. Peak amplitudes are plotted against cube root of air gun volume. According to the theory outlined above, the peak pressures should be proportional to the cube root of the volume, forming a straight line on the graph. Instead, we see that above a certain size -- about 300 cubic inches – the curve starts to fall off. What's happening is that above that volume, those exhaust ports have a throttling effect. No more than 300 cubic inches of air can get out of those ports before the bubble starts collapsing, and the remaining air continues venting into the collapsed bubble. The result is a diminution of the bubble pulse amplitude, at the expense of the peak pressure - just a bit like the GI gun.




The French group at GENAVIR, who run a portable MCS system are now using ten GI guns in their array. In an effort to enhance power at low frequencies, Felix Avedik, at COB/IFREMER in Brest developed a concept he called the "single bubble" technique. The idea there is to time the firing of the array so that the initial pulses are out of phase, but the first bubble pulses line up. The theory behind this is that the width of that second pulse is greater than the first, and should therefore be richer in lower frequencies. The single bubble method has been used with some success, and the results published in several papers. I've investigated this approach with modeling, and found that it works, up to a point. As described in the paragraph above, bubble pulse amplitude is diminished when the air guns get too big. When this is the case, better power is achieved by tuning the conventional way.

**Tow Depth**

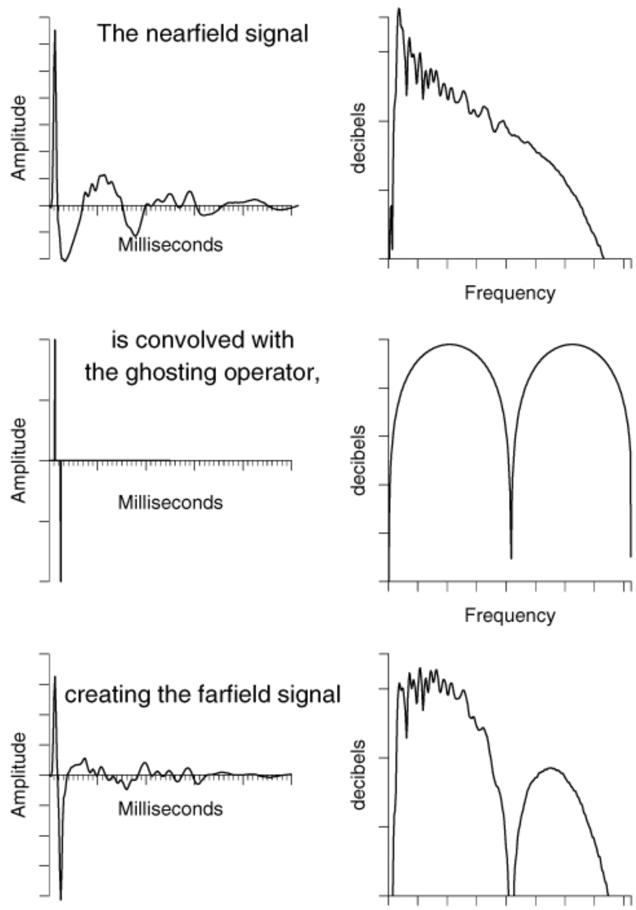
Finally, I come to the subject of towing depth, whose effects are powerful, and, usually, inescapable. In this figure, we return to the output signal of a well tuned array. At the top, is the pressure pulse actually produced by the array. This is called the “near field” signal. This is something that is rarely seen, and is difficult to record, but it’s very important because it has what might be regarded as the intrinsic spectrum of the air gun array. In real life, this signal all by itself is hard to see, because somewhere above the air guns is the surface of the water. While it isn’t a perfect “free surface” as discussed in physics and seismology, the sea surface usually has a very strong but negative reflection coefficient for upcoming sound waves. Therefore, down at the seafloor, the near field signal is closely followed by a second, reflected version of itself, which has a negative polarity and a time lag. The time lag, of course, depends on how deep the gun is. The result is the “far field” signal, which is what is usually shown in airgun literature and advertisements. Note that in fact, the tuning is improved over the near field version!

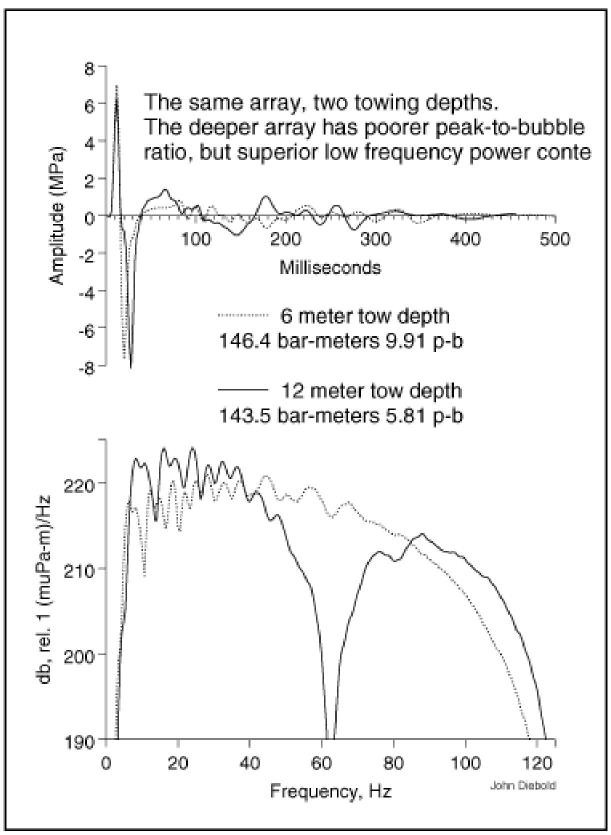



But eventually, unless you are shooting to ocean bottom or land-based instruments, you need to record the upcoming signal using hydrophones somewhere near the sea surface, and the same thing happens again, except that in case the entire far field signal is flipped, and delayed, and added back into itself. The result is something that resembles an upside-down Ricker wavelet, and it is easily seen why the convention for seismic recording is that negative pressures are recorded and displayed as positive numbers. It is also fairly clear that the best looking signature is obtained when source and receivers are at the same depth – this maximizes the amplitude of the central pulse. A “double pulse” seafloor reflection is often (though not always) an indication that the data have been recorded with the wrong polarity, or that the source and receivers are at quite different depths. Analysis of this diagram also shows that the large central peak of the seafloor reflection represents the travel time from the surface to the seafloor and back to the surface. The smaller, leading negative [but positive pressure] pulse represents the time from the source to the seafloor and back to the receiver..

Now let's look at the spectral effects of towing depth, wherein the tale is best told. The sea surface reflections can be represented by a simple little "operator" made up of spikes in the time domain. When these spikes are convolved with the near field signal, the far field and "as recorded" signals are obtained. The time between the spikes depends, of course, on tow depth and water velocity. The surface reflection operator has a characteristic shape over in the frequency domain, too. It is a series of humps (actually a sine wave, squared) with notches, whose spacing in frequency is the inverse of the time domain operator's time spacing. The more shallowly you tow, the farther to the right [towards higher frequencies] the notch moves. When the surface reflection coefficient is near perfect, the amplitude level in the notches is near zero, and it is virtually impossible to remove them by signal processing. Therefore, data should generally be filtered to remove all spectral content above the first notch.

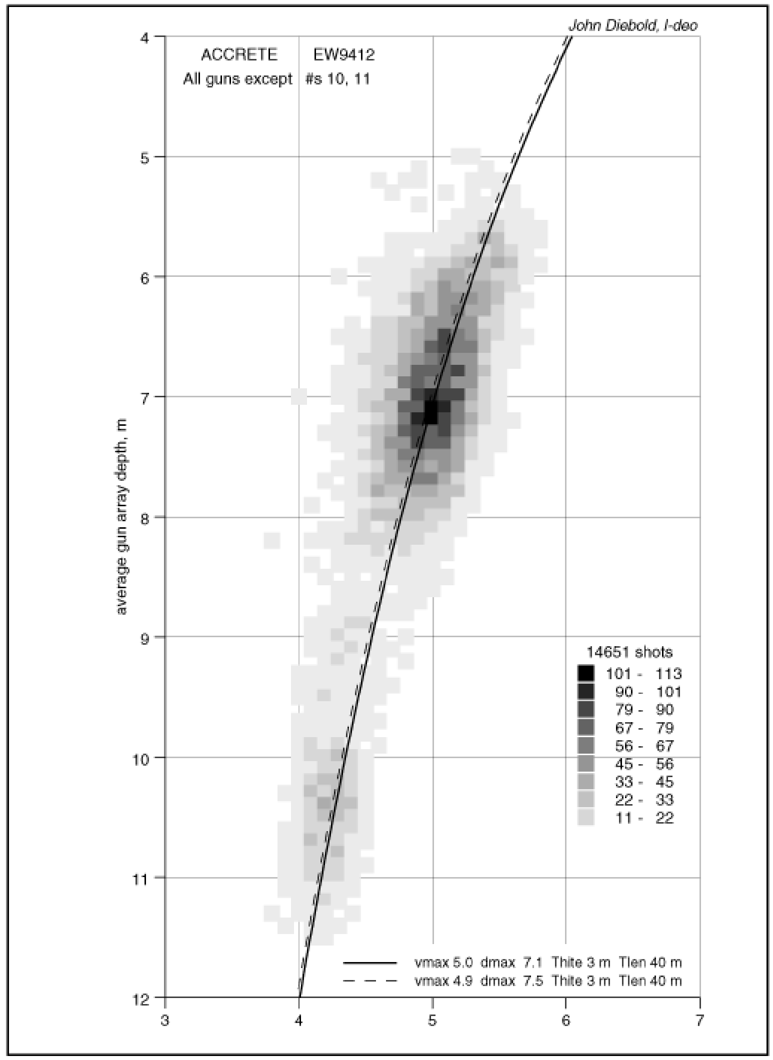
The shape of the "shoulders" of the frequency domain operator is also controlled by the towing depth. The higher the frequency of the first notch, the more sloped they are, cutting out power at low frequencies. This is why deep towing is important for the enhancement of attenuation-defeating low frequencies for large aperture work, and why shallow towing is required for high resolution, broad band profiling..




Unfortunately, shallow towing and high amplitude are difficult to achieve at the same time. The largest gun that you can use in a shallowly towed array is dictated by how big its bubble is. When it's too close to the surface, the larger bubble just blows out, and energy is lost into the air. So all of these things work against each other.

At the other end of the scale, a problem we have with deep towing is -- deep towing. A compendium of air gun towing depths versus towing speeds from EWING shows a strong and predictable relationship, which indicates that deep towing is only possible at low ship speeds. Therefore, the most dependable source of high power is an array with the largest number of air guns, which if properly tuned, will have lots of energy at all frequencies.



# Seismic Receiver Systems

Graham Kent
Scripps Institution of Oceanography

**[Editor's Note: Following is a transcription of Graham's verbal presentation.]**

This is hopefully a complementary talk to the one given by John Diebold a few minutes ago. I guess at some level there's not as much physics involved on the sound receiver end. One thing to note is -- these are some hydrophones in which there's usually thousands in a typical marine streamer. They're probably a buck and a half apiece, or something very low cost. And then when we want to put them in a depth greater than a few tens of meters, they become a thousand dollars apiece. So there's a little economics right there that'll get you going. They will have some implications on what we can do -- whether we have our receivers on the sea floor or towed in a streamer.

At any rate, kind of from a receiver perspective, people tend to group them, and it's somewhat arbitrary. They tend to group them into either single-channel or multi-channel streamers, which are towed at a shallow depth, usually around ten meters. And then there are the on-bottom instruments. Because of the scarcity of instruments for the on-bottom case, people tend to do different types of scientific things, depending on what type of an array you're looking at.

In the conventional multi-channel mode, most scientists are going out there looking at reflectivity structure. This is an example of some seismic reflectivity on the Sedimes (ph) Pacific Rise. The sea floor here is at a depth of about a kilometer and a half -- actually about 1200 meters is the axiomagnachamber (ph). This was shot on the Ewing back in '91. Or one might use, in this case again the Ewing, to look at faulting features in the sediments. And this is near hole 504B (ph), and here's the basement and the sea floor. And again, we're looking at reflectivity structure.

And not to beat a dead horse, but we'll beat it once more. There's obviously more margins implications for shallow water imaging. And again, all these were used with a four kilometer 160-channel streamer.

And here's some structure off the southern tip of Greenland. Here's a nice little sedimentary basin here. Here's some Seawer Dippinger (ph) collectors, which are kind of flep-assault (ph) type of events. But at any rate, these arrays of receivers were used in a kind of imaging mode to look at seismic reflectivity.

Thanks to longer and longer streamers, and especially even two kilometers longer now with the Ewing -- and this is also true in the industry; six kilometers is getting to be kind of a standard size. Not only can you look at reflectivity structure, which typically is behind the water wave up here on the kind of conventional record section, you can also see diving waves or refractive waves that beat out the water wave. They tell you something about the velocity structure. In this case, with only a very short streamer, they tell you something about the shallow velocity structure. Now that the Ewing and other ships are towing longer and longer streamers, it again blurs the notion of streamers, reflectivity, on-bottom instruments, velocity images.

Now that we have a plot with a lot of tracers on it, it should also be noted, on the receiver end of things -- this is not rocket science -- the more receivers, the better. And the more -- or the less distance between the receivers, the better. And that's really because, in the end, the types of things that the end user wants to do to their data will be limited if the receiver spacing is quite large, and also the shot spacing. If you go out and shoot hundred-meter shot spacing, you're throwing away a lot of useful things that you could do with the data. So more is better. But more is more money. So we don't necessarily always get that.

Now, when we -- and I have an on-bottom instrument we'll look at in a few minutes. But when the typical users tend to put things on the bottom, one advantage that you get out of that is you can have almost infinite source/receiver separation, or at least half the circumference of the globe. But at any rate, you tend to get things more than six kilometers, and those types of studies tend to look more at wider angle events -- either reflections -- but typically just the diving fee waves (ph). And then that way, these events are picked and thrown into an algorithm to make topographic images. And this just happens to be from a particular feature on the sea floor.

But we're not looking at velocities. We're no longer looking at acoustic impedence. So at some level, at least in the user community, there tends to be these two different ways of looking at data. As we tend to put more and more receivers on the sea floor, then we can start doing more imaging with actual on-bottom arrays with greater and greater distances. That's something that we're just starting to head toward right now.
But what I'm going to do for kind of the rest of the talk, is I'm going to look at an experiment that is probably atypical of what has been going on recently, but probably more typical of what you may be asked to do. And certainly in industry they've been doing it now for the last decade. We went off Acapulco to look at this feature that is an overlapping spraying center (ph) but it's inherently, unlike these areas, very three-dimensional.

Myself, from the science end of things, at some point, we can no longer apply two-dimensional techniques to look at a 3-D object because of just the physics of sound propagation. It can really get one into a lot of trouble. So industry's learned this a long time ago, but in academia, it's always been kind of the capability. And now, with the Ewing, there's that capability. Workstations are cheap. The software is not really cheap, but it's cheaper. So it's something that the academic community can start doing more often. So you'll probably be asked by more and more of the principal inestigators whether you can do this on your ship, and if so, some of the problems that one might encounter. And that's hopefully what you'll get out of my talk from this point forward is that certainly what the end user's going to want to do is a lot more demanding.

One example of that, although not the only, is going out and doing a 3-D experiment. And here again, we have oval optic spreading center (ph) up close. Here's our imaging box with 201 lines going across, stacting (ph) like this, and then steps along the back and all the little stars were 30 receivers, or ocean-bottom hydrophones. A few of them had three-component seismometers, as well.

So before we get into some details about things that you might find beneficial from doing these types of studies, at least that we learned and in the future -- maybe we can go to the slide projector, and you can see some of these -- I can't bring in the Ewing streamer short of some of the hydrophones we got. If anybody wants one, you're welcome to it. They make great little ballugaphones (ph), as we've -- you can use it to listen to whales. No kidding. We made them while we're out there.

That's the other disadvantage. It's also true the more streamers you put in the water, the better. And we only had one at this point. So we were out there for two months. So we were bored. But you can benefit from our boredom.

Here's another advertisement for the Ewing. Certainly it's been a great ship for what we've needed to do in the last decade and beyond. The first thing we need to do, in some of these three-dimensional surveys, for instance, if you were to put down a lot of receivers on the bottom, you're going to have to need -- you're going to need very accurate navigation.

In some cases, your typical P-code-Y-code receivers may just be on the hairy edge (ph). And so -- and in this case, we had to download the corrections from a differential GPS via the INMARSAT (ph). It's something that -- just doing that additional step would cost you about $20,000 today. But it will give you, in the middle of the ocean, accuracies of a meter or two, as opposed to maybe ten, 15, with the other PY-code receivers. So that's lesson number one.

With all respect to our Lamont colleagues, the other lesson is sometimes these damn things get in the way. So we rotated our survey a little bit. But they were kind enough to give us permission to chop it off. And much to Paul's disappointment, we were not able to. But at any rate, this is a typical streamer, the one that no longer's on Lamont because they've got a nice newer one from Syntronic (ph).

But anyhow, this is a hundred -- typically could be deployed at 160-channel four-kilometer section with 25 metered group spacing. In this case, we only deployed 3100 meters. And again, that group spacing can be very important, depending on what type of imaging processing we do. We probably -- well, you probably never want 50 meter group spacing. But whether you go 12 and a half meter or 50 meter -- you’re going to get twice as much data with 12 and a half. But some of the imaging possibilities that the end user could use would be affected by that decision. So that’s something to always keep in mind, that certain things would require 12 and a half meter, especially the high resolution-type studies.

Of course, it doesn’t lie right there on the surface. We’re bringing it in, and I waited for the thing to strum up (ph) to get the splash. But usually it’s towed at ten meters, and its depth is controlled by these birds. Also you’ll see we get additional information that’s useful.

Here’s a streamer. This was a graduate student at Woods Hole. We did have a Dutchman aboard, but we didn’t think -- we weren’t smart enough to think about it until it was too late, but here’s a hole in the streamer. So we figured, a Dutchman with a hole in the dike. But just to let you know, they put a petroleum product in there that’s kind of like kerosene -- kind of not -- for flotation. There’s Josa (ph), who’s been at Lamont for quite some time -- been very, very, extremely useful.

And another lesson, if you put the streamer out for over 30 days during an El Niño, it's great for growing zebra muscles. That really can be a problem in the end, because you can -- we probably brought aboard something -- we figured out about a thousand pounds worth of muscles. And they don't come off very easily. So it was very problematic.

But here's a digit course bird that both -- with the curving -- the fin angle can control its depth, which is important, as John talked about -- the ghosting both at the source and receiver. And you want to be able to fly your streamer, as well as your source, at the same level, whatever you determine it to be.

And for doing 3-D surveys, there's also compasses in there. It'll tell you what the heading on the actual streamer is at any number of points. In our case, it was 12. That allows you to reconstruct the shape of the streamer. When you're doing 3-D, you have to stop thinking lines and think more about bin coverage. So in that way, you need to, for every shot, know exactly what the position of the streamers is -- maybe 100-, 150,000 times.

And this is a digitization can -- digitizer that sends the data up the streamer. I think nowadays -- maybe John'll prep me -- but most everything comes -- when it's being written out, it's written out in a format that's SEG-D, SEG-Y, but it certainly doesn't need to be D-multiplex. I mean, it's something that the user can grab a hold on and start processing that. So -- that's zebra muscles in there.

And also for if your streamer were to break, having a tail, we might help you recover it. But in our case, and for 3-D -- actually, I think for all surveys, but especially 3-D, it's nice to know where the tail of the streamer is. And so there's a GPS receiver up here. It can be used to precisely locate the tail. You know where the head is, and then use all these compass bearings to reconstruct. Just from the compass bearings alone, you can get about ten-meter accuracy. So again, it depends on what the user needs how high resolution as to whether you really need a receiver on the tail buoy itself.

Here's some of the floats that John talked about here earlier. I think we lost two over a month and some, and 160,000 shots. So I thought that was pretty impressive.

Now we're going to cut to the streamer and go to the on-bottom instrumentation. This is a wet version that's also put together of an LCHEAPO hydrophone. And LCHEAPO -- I wish I could take credit for whoever thought of it -- but low cost hardware earth applications physical oceanography. At any rate, it's a pretty good one. At any rate, in this case, what we're reporting is, well, pressure. And it's a hydrophone. You put a seismometer on there, and you can put some electrical coils and do magnetofluorescent -- it's actually quite, quite versatile.

Instrumentation -- as you're bringing it in, it's floating in the water. You can see some floats over here, and I'll show you those in a second. Here's the actual instrument package with the data logger and the acoustic release beneath it. Here it's being brought up to the surface.

Now, as we tend to do these more densified (sic) surveys, and you start putting lots and lots and lots, and then even more instruments on the bottom, having a single ship there, which runs too much, but it's something like 20,000 a day, seems a little bit ridiculous to go around and pick up one instrument at a time. Right? I mean, that's just -- the economics of that doesn't cut it. And here's Allister Harding (ph) and Paul Zimmer (ph) testing the notion of using a kind of work boat to go around and pick these guys up. I'm not sure that it's ever been done before, but -- so we're taking out the releases and -- the instrument that's used to release the hydrophone from the bottom. Here those folks are out there at a distance bringing home the bacon, as it were.

It actually worked out really great. We used that just for part of one day, but in the end, we were able to bring up 30 instruments in 48 hours, which is actually quite fast. So one could eventually put out a raise of a hundred or 200 on-bottom instruments and recover them probably in four or five days if you used a work boat.

Another beautiful picture. Here's the instrument coming on board, and the work boat, and the atypical day out there, but it ends up in the slide projector.

At any rate, at a sample rate of 250 samples a second with a short battery pack, which you see here, we were able to record for about two months continuous on one channel. These have been deployed for over -- around a year -- I think actually a little over a year. I think it was either -- they were 25 or 50 samples per second. So we can -- and that was looking at more surface wave studies. But at any rate, these things can go down for quite a long time and record continuously. They had a temperature control oscillator right over here. It's about a millisecond of drift a day. So that's quite nice.

But at any rate, the signal comes in from this end. Thanks, Paul. And it's conditioned. In this case, this is a 16-bit recorder. So we play some tricks with the automatic gain control and just gain levels to give it more dynamic range in 16 bits. We've actually designed and tested on that cruise a 24-bit version. So we basically throw this out and just put in a 24-bit digitizer. And then it comes onto this -- it comes over here onto the bus.

This is a Tattletale 8 (ph) processor, and essentially -- and a RAM card, and it buffers the data for however long your RAM card has been -- you know, it's minutes -- and then dumps it to a SCSI drive. I think you can now, obviously, shelve 18-gigabyte drives in here. So certainly the battery is the overall limiting factor. Even at that, it can hang out there -- at least for at-the-source experiments, it can hang out there for a couple months.

At any rate, if you want to look at this in more detail later on, it'll be up here.

The other component, and obviously the more important component -- it's cheap, so don't worry -- is the acoustic release. This guy sits in a similar tube of aluminum that's been anodized. This is time-domain (ph) release where you send it a series of encoded signals.

At any rate, these two then get put into this package here. I'm not very successfully showing you how lightweight it is.

And then there's flotation. And this guy will then send a signal to a Birn wire -- so it's burloir (ph) technology -- to release it from the sea floor. Obviously, doing the on-bottom stuff's a lot tricker at some level than the streamer, because if something screws up, you don't get it back. And they're not that cheap, but relatively cheap.

For instance, this whole getup here, including the extra aluminum anodized tube and caps, just the parts alone run like $9,000. And then with labor, it's probably like 15,000, and that's when you make like ten of 'em. Now, if you were to make a hundred of 'em, it would -- the price would come down. And I believe NSF is going to -- at least they're threatening to -- go to a facility mode more like PASCAL to hopefully, (a), stabilize the finding, and (b), to end up giving the end user more instruments. Again, these things hopefully will grow, or something like this will grow in numbers in excess of a hundred or 200 so you can do these really densified 3-D arrays, or densified 2-D arrays, and in a sense have a streamer that's sitting on the sea floor. That's the goal, and hopefully we'll get there.

So getting back to the -- again, just using this as a canonical experiment -- and I've already alluded to -- again, I think if your users want to do 3-D, at least, and even if they do 2-D, they should notice the position of the streamer. This is a little program we wrote out at sea that grabbed in real-time all the bearing measurements from the compasses along the streamer, and then reconstructed the shape of what the streamer looked like. This one happens to be straight. It doesn't necessarily -- it can be -- you can see it when you go through a turn. It will, obviously, have more arc on it.

This is an exaggerated day because of a passing-by hurricane. But the end of the 3,000 meter streamer is feathering at a thousand meters out. This has a lot of implications for just processing in 2-D. It's critical or of absolute importance when you're doing 3-D surveys. But there are some propagation problems when your streamer's sitting out at this distance -- the intended line. And to date, most people just say, well, the streamer's directly behind me. And then if you don't know any better, then that's okay. But it really can cause a number of problems.

And then when you get done with a survey like that and you've thrown your hundred-and-some-thousand shots and find a unique midpoint between each source and receiver, then you get a bin map showing the full coverage. In this map, white's good, black isn't so good. And the key thing here is you don't want to have a lot of black, and especially you don't want to have black XY. One can certainly -- it gets called bin extension, bin robbing -- but you can take data that's slightly off from any of these empty bins and fill it in. They do this in industry. But it's important to have this all in real-time, because you're out there shooting the survey, and when we were finished, we still a number of days, and this map looked a lot worse than it is right now. So we had to go and use those extra days to fill it in. So this is something that, as you get into this mode, or if you choose to, you have to keep in mind that you can't do your navigation reduction at home, because then it gets pretty expensive to get back out there and fill in any major debts (ph), and we had a couple of them.

This is some real-time processing out at sea. Just to get a look at what things might look in a kind of typical 2-D mode -- sea floor -- here's a reflection from a melt-body (ph), and here's some stuff down at the mo-ho (ph). These are kind of, again, the notion of what things looked like in cross-section.

An advantage of being 3-D -- and I shouldn't show you this because this isn't a real 3-D image. It's kind of a fake. It's not done with 3-D processing. So it looks like hell warmed over. Excuse me, but it does. But you'll get the idea, and I'll show you a better one from an instrument.

Now you're looking at what people tend to do in industry. Hopefully that'll -- and then you start looking at time slices. So now you have your 201 profiles, and you cut it this way. Here's some of the melt from lem-of-the-o (ph) over up in Spring Center (ph) and some of the other. And these are all effects by not treating the data as three-dimensional. Within, I think, about a week, we'll have the right image up. But this came too early.

They don't even denote -- when people are looking at margins -- this is really powerful, because you can start seeing dendritic stream patterns and channels and whatnot. I mean, it's a very powerful way of looking at the geology that you would never see if it weren't for 3-D.

Now, going on the on-bottom receivers, again, this is what a typical geophysicist might show you. Here's the direct water wave of an instrument, say, on the sea floor. And finally, at some point, the rays that are turning the crust beat it out. It's faster. And here are the refractions. And again, this is kind of a typical refraction survey. And also, the shots are quite sparse.

We were lucky enough to, in this survey, see the data also while we were doing the reflection acquisition. Same type of picture. The spaces are more -- or the distance between the traces are better, and again, that's good. But we don't want to look at it that way anymore.

We want to then stack 201 of those together and then take a time slice. And this is what this picture here shows. And again, here's the direct water wave.

The best way of thinking of this, since I'm supposed to talk on receivers, because we have a reciprocity between source and receiver -- there's our link between our talk -- now the instrument on the sea floor is blowing up.

And now we have our array of 120,000 receivers. And this is what the wave field looks like at 3.65 seconds. So if you were to look earlier, you’d just see a point, and the circle would come out, and at some point, you’d see the refracted arrival move out.

What’s really nice about this and why I think you’re going to see more of it from the end user -- at least what they want to do -- is now you capture for just one instrument -- and you have many instruments -- you’ve essentially captured the entire wave field. And you’re able to do so much of just better processing, different techniques that you would not been able to do earlier. Again, I think some of the -- that’s my last one.
Some of the lessons to learn is that, while the receivers can be cheap in the streamer mode, and not so cheap on the on-bottom mode, that the more of them the better. And hopefully, we have lots of them on that end. You also have to accurately locate them. And that’s going to require you to make sure you have differential GPS that’s basically accurate to within a few meters. You’re going to have to be able to reconstruct where your instruments are, both -- not only for the streamer case, but for the on-bottom case. I do think as the numbers of on-bottom receivers start to get in parity with those, you’ll see the techniques -- the kind of the vision between what people do with it too will start becoming more blurry.

So I think it’s actually a very exciting time, because both -- for instance, in the U.S., the Ewing is already has a brand new six-kilometer streamer. Now NSF is making a move, or so it seems, to go towards a facility model where we might have on order of hundreds of these things. So I think the future is bright.

# Chirp Sonar Design for In-Hull Applications

Lester R. LeBlanc & Steven G. Schock
Florida Atlantic University

**[Editor's Note: Presentation given by Lester LeBlanc; Figures not available for this publication.]**

First, I will give you a little introduction of myself. I have been teaching and doing research at the University of Rhode Island for 20 years, starting in 1970. Since 1990, I've been with Florida Atlantic University, Department of Ocean Engineering. I started working on Chirp Sonar back at URI with Dr. Larry Mayer. Many of you may know Dr. Larry Mayer. This program has evolved over the years.

Basically, this first figure (1) is an overview of the different kinds of options that were developed with this system. It started with a tow vehicle that has a separate receive and transmit array. That way, there is good isolation between the transmitter and receiver. And in fact, the system can be transmitting at the same time it is receiving. The Chirp pulse may be as long as 40 milliseconds. So if it is used in shallow water, one must be able to separate the receiver and transmitter signals in this manner.

This option shown in this figure, the hull-mount option, is in fact, the way the Endeavor is set up, using a three-by-four array of transducers. There is a steel plate directly across the face of the transducers, but it'd be more advantageous, of course, to have an acoustic window at this location. This way, there wouldn't be so much airborne acoustic ringing in the ship. This is in fact one of the minor problems with this system. There's a lot of audible acoustic energy transmitted, and it is annoying when you hear it over a long period of time. John Freitag at URI has mentioned this concern to me.

There's a special transformer-matching network in the fluid filled transducer well. There's also a pre-amp in there and a TR switch. Also shown is the receiver and transmit array. It has about 20 degrees of directivity using a three-by-four array of transducers.

Question from audience: I'm curious. Is there an optimum spacing for that -- in your opinion, for chirp sonars?

These are about a quarter of a wavelength apart at the center frequency. It's a broadband system, which is another aspect that I haven't mentioned yet. The system is designed to transmit over a large frequency range. That's one of the advantages of the system. Typically, transmission is from two-to-ten kilohertz. We have recently developed a new system that uses several different transducers to achieve greater frequency range - it operates over a one-to-15 kilohertz range. This represents many octaves – a large frequency range for a sonar system to operate over. Operating the transmitter over many octaves provides a lot of advantage, and we'll talk about that in a few minutes.

The new system shown here utilizes a black box that has an imbedded DSP and a PC. It handles the transmission of user selected chirp pulses at the required time intervals. It interacts with the workstation, which -- in fact, a workstation from a different vendor can be used here. A Triton workstation would work well with this new system.

Also, the black box may be used with a towed vehicle thus supporting shallow water work with the same platform - these two options are very compatible.

This third option, which uses a telemetry receiver – Edgetech now manufactures some systems with cable telemetry receivers. Steve Schock, who is the co-author of this paper, has developed a modem option that transmits three megabits per second over 9,000 meters of UNOLS cable. This was tested on a cable at Woods Hole Oceanographic Institution where this particular system is being used offshore.

This figure (2) shows an overview of the various types of sub-bottom system waveforms. It will give you an idea of what makes the Chirp Sonar system unique. One of the unique aspects we mentioned was the use of a broad bandwidth transmitting pulse that sweeps out over a range of frequencies. This generates a lot of acoustic energy in the water. By transmitting over a long duration of time much more acoustic energy is generated than conventional pulsed CW systems. Instead of trying to operate with one very sharp acoustic peak pulse, the Chirp Sonar spreads the transmission out over a large duration of time so as to provide more acoustic energy in the water.

The problem with long pulses is that resolution of the seabed is lost. However, resolution of the seabed is obtained with the chirp after correlation processing the received signal. This is because the output of the correlation is a very sharp wavelet that has duration of the order of the inverse of the sweep bandwidth. Thus, the more bandwidth used, the sharper this pulse will become.

Another unique aspect of the chirp pulse is the use a tapering function -- this Blackman window tapering function is very much like the Gaussian shape—it is very close to Gaussian. This provides another advantage. Later on, we'll talk about how this improves the appearance of the records, which is related to the attenuation factor of the sediment. The combination of broad bandwidth and near Gaussian tapering provides immunity to loss of pulse resolution caused by attenuation of the pulse in sediment. Attenuation does not cause much broadening of the chirp pulse, however it decreases the peak amplitude of the pulse.

To transmit this form of chirp pulse requires a linear amplifier. Initially, ordinary class AB audio amplifiers were used for power amplification. Recently, a new class D amplifier that behaves very much like a switching amplifier is being used to power the transducers. It maintains 85 percent efficiency and functions very much like a tracking/switching power supply. It can drive a great deal of power without much wasted energy. Yet, it maintains about 40 db of dynamic range (about 1% linearity). The D-to-A is a 16-bit delta-sigma converter –it uses 4X over-sampling which reconstructs the analog chirp waveform nearly perfect. It does this by using a digital filter to fill-in samples. There is not much analog filtering needed to improve the discrete nature of the wave out of this sample D-to-A.

The A-to-D converter component of the chirp sonar system uses a 16-bit sigma-delta. There is a programmable gain pre-amp unit that is used to automatically under software control extend the dynamic range of the 16-bit conversion. The signal from the A/D converter is directly supplied to the DSP processor, which is a TI, based floating-point processor. This processor is more than adequate to perform the required signal-processing task for the Chirp sonar. Again, the workstation has the task of controlling the operation of the DSP including selecting pulse length, bandwidth and power used in the different modes of operation. In addition, the workstation provides a display of the processed sonar information including the function of logging the data -- logging it on storage media along with navigation information.

This next figure (3) illustrates a sub-bottom sonar record that was taken from the Endeavor in July 1995. A three-to-six kHz swept FM; 40-millisecond duration pulse was used. In this example, the sonar is operating in roughly 3,000 meters of water depth and observing 15 meters of penetration. This illustrates the characteristic high-resolution capability of the chirp system, even when operating in deep water from a hull mounted platform.

This data also illustrates another characteristic of the Chirp Sonar. Notice that the layer boundaries do not appear to be widening appreciably with increasing depth – the processed pulse does not appear to be widened as it attenuates within the sediment. As previously mentioned the reason for this is related to utilizing a Gaussian - shaped pulse spectrum. It can be easily shown that attenuation causes the Gaussian shape to shift the center (mean of the Gaussian spectrum) frequency to a lower value without much loss of bandwidth. Since the pulse resolution is inversely proportional to bandwidth, it does not widen appreciably as the pulse penetrates deep into the seafloor.

Using hull mount sonar in deep water does have some shortcomings. Notice the 'crossing' artifact apparent at strong layer boundary intersections. This is related to the size of the aperture (beam width) and is common in most sonar systems. In the Endeavor, the sonar operates with 20 degrees of beam width. This generates a large acoustic footprint on the sea floor when operating in 3000 meter of water depth.

This next figure (4) shows one of our earlier tow vehicles. It contains four line-receiver arrays that are positioned along a line formed by the forward movement of the vehicle. There are four projection transducers in the unit to generate the chirp pulse. The transducer is specially designed using a Toplitz resonator design with tuned head-and-tail masses. They are tuned to handle the broadband requirement of the chirp pulse. This vehicle will transmit chirp pulses in the 1,000 to 10,000 Hz band.

The next figure (5) shows a cartoon drawing of the output of a standard linear FM pulse without any chirp weighting. After correlation processing, the envelope of the compressed pulse is plotted as the red line. In this example side lobes are created by the abrupt nature of the pulse starting and ending. Using the linear FM pulse without weighting to chirp the sonar would result in seismic profiles that contain a precursor of the bottom in the water column. In other words, we would start to see the bottom before it actually occurred.

By using a window function to taper the linear FM pulse such as the Blackman-Harris window, side lobes are significantly reduced and not noticeable in the sub-bottom image. However, the price paid for this is that the peak of the correlated pulse is wider. In this figure notice that the peak correlated pulse is broadened a small amount with essentially no side lobes apparent in the envelope function.

Another advantage of the Chirp Sonar is that it is made of mostly digital components that are under software program control and thus can be modified with software changes. To calibrate the Chirp sonar for a new acoustic transducer, the transfer function of the transducer and receiver array pair is measured in a test tank. The measured transfer function is then used to pre-compensate the digitally generated transmitted signal so that the emitted acoustic signal contains the correct frequency characteristics for broad band operation. This is possible because the Chirp Sonar utilizes linear system components. This is an important aspect of the Chirp Sonar that is related to its high-resolution performance.

In this next figure, (6) the result of matched-filter processing is illustrated. The figure shows the raw signal that was received before match-filter processing. Observe how broad the unprocessed pulse appears. It is not possible to identify closely spaced sub-bottom layers with the raw signal. In addition, noise interference is also obvious in the example. After matched-filter processing, the noise is nearly filtered out because the correlation processor rejects nearly everything that does not look like the signal.

The first arrival is a strong signal and is the result of direct path transmission between the transmitter and the receiver array within the tow vehicle. Notice the surface reflection, and then the first bottom, and then, of course, all of the sub-bottom structures in this figure. In this example the envelope of the signal is not shown. The use of the exact envelope calculation in the Chirp Sonar enhances the display sonar sub-bottom image of the seabed.

The next figure (7) illustrates another positive aspect of using a broad bandwidth pulse. In this model, we simulate the sea floor as a perfect acoustic reflecting plane. The signal that is emitted from the projector is reflected and received later by the receiver array. This model is used to study the broad-bandwidth characteristics of the sonar as the incident angle of the projector/receiver to the seafloor is changed. The result of the model shows that the chirp system contains less side lobes in the angular response function when compared to narrow bandwidth sonar. The comparisons are made between a 200-hertz, 3-kHz and 6-kHz swept FM pulse centered at 6-kHz. The results show that increasing the bandwidth of the pulse results in reduction of side lobes in the angular response function.

The next figure (8) shows the result of using a two-to-ten kilohertz bandwidth sonar for the same ideal reflecting seafloor. In this figure, observe that the main lobe time resolution of the correlated pulse is on the order of a tenth of a millisecond. The angular resolution is on the order of approximately 18 to 20 degrees.

There is a slight dimple in the spatial/temporal side lobe response that is caused by the limited bandwidth of the pulse. Reduction of side lobes is an important performance advantage that the Chirp Sonar has when compared to narrow bandwidth systems. The Chirp Sonar is a spread spectrum system that utilizes weighting functions to achieve superior spatial/temporal performance over conventional sub-bottom imaging sonars.

The next figure (9) is a comparison of the Blackman-Harris window to a Gaussian – this shows that the Blackman-Harris window is a good approximation to the Gaussian window. In the next figure (10) observe the effect of frequency dependant attenuation on the Blackman-Harris window - at higher frequencies, the energy is attenuated more than at lower frequencies. In effect, the mean of the spectral curve is shifted to a smaller value, and the entire curve is reduced in amplitude while maintaining approximately the same width – This is a desirable effect. The next figure (11) shows the effect of frequency dependant attenuation between, two-to-ten kHz chirp waveform and two-to-six kHz chirp waveform. This shows that waveforms with larger spread in frequency produce larger shifts in the center frequency, hence are more sensitive to seafloor attenuation. This phenomenon is desirable and is used to classify sediments. We have observed large shifts in center frequency for sand – Note the appearance of the correlated waveform after the pulse has propagated through 40 meters of sand. In this model, a relaxation mechanism was used to simulate loss in sand. Forty meters of sand is a long distance to expect for operation at this frequency. Because the model does not include scattering of sound from debris in the sand, we expect the model to overestimate depth of penetration. However, even in this case, the amount that the pulse is widened is a very small percentage. A two-to-six kilohertz system is on the order of about a percent increase in pulse width, and a two-to-ten is on the order of ten percent.

At the same time, the center of the Gaussian spectrum is shifting downward in frequency. Measurement of this downward shift provides information for extracting material type. In the next figure (12) you can see that sand, silt and clay all have different attenuation curves. Note that the horizontal axis is labeled in frequency, and attenuation in dB per meter. Sand has a much steeper attenuation curve. So we would expect it to shift the spectrum considerably more than clay or silt.

This next figure (13) is a plot showing the result of spectral analysis of a received chirp pulse transmission as function of depth. The instantaneous frequency (the center frequency of the pulse) decrease in a linear manner until the signal was lost in the noise. By estimating the magnitude of this slope, we can infer the type of material - It turns out that in this case the sea floor material was silt clay.

We have compiled most of the historical data that's available relating attenuation to sediment type – Most of the data was collected from the JASA over the past 20-year to 30-year period. In the next figure (14) we can observe that there is a large amount of variance in the measurements relating attenuation to mean grain diameter. This may be related somewhat to the various methods used to measure attenuation over this period of time. However, this data does provide us with a general idea of the way attenuation varies with mean grain diameter. On the left end of the curve, the materials range from clay, fine-silt, medium-silt, coarse-silt, and down further right to medium-sand. The shape of this curve that we used to 'least squares" fit all of this data does not provide a signal valued function. In other words, a coarse-silt may behave like medium sand; thus the classification using attenuation is not suitable for differentiating between course-silt and medium-sand. However, it does differentiate uniquely between silt and clay.

There are other mechanisms that are used to refine the in-situ acoustic classification process. The Chirp sonar system is calibrated so that the reflection coefficient may be estimated form each acoustic return – and also the reflection coefficient of the reflectors below the first arrival. The next figure (15) shows the relationship between impedance, porosity, and density. We have found a strong correlation between the manner that impedance; porosity and density are related to the depositional environment. Most of the data obtained for this plot is from Hamilton's publications. In this example the depositional environment parameters are; grain density is 2670 and the rigidity of a grain is 1.8 times ten to the eight. These constants are properties of a given depositional environment -- the grain density and the grain rigidity.

By adjusting these constants, we can shape the model to characterize most environments. This next figure (16) shows a comparison between Narragansett Bay, and other sites. This is The Emerald Basin data provided by Dr. Larry Mayer; it is clearly from a different depositional environment. The next figure (17) shows another aspect of our research that utilizes neural nets to track the layers within the image. Basically, this is a learning process. It requires going through two sets of iterations of neural net analysis before the processor is adequately trained so it can be used on other profiles.

This figure (18) shows the training image that was used. The image contains many fine layers that are easily identifiable by eye. A trained observer would know where to draw the lines along each sub-bottom layer. It is a much more difficult task for a computer to achieve the same result. After training the neural net using the previous image, we apply the analysis to an unknown test image, and observe the results. The neural net model tracked most of the layers very well. Later this result is used in our classification model to derive grain density and predict the material type.

The next figure (19) shows the newest Chirp Sonar System developed at Florida Atlantic University. It uses two sets of transducers to cover the frequency range of 1-to-15 kilohertz and utilizes the resource of the DSP processor in the vehicle to generate the chirp pulse. Also included in the DSP is the A-to-D conversion. The digital information is networked to the surface where the display function is handled. Woods Hole Oceanographic Institution is the owner of this vehicle that was developed by Dr. Steve Schock and Dr. Neil Driscoll at Woods Hole. Using this vehicle, experiments are being conducted near-by offshore today. We refer to this vehicle as a sediment classification vehicle. It operates on a much larger frequency bandwidth that spans the range of 1kHz-to-15 kHz.

# Multibeam Bathymetry Systems

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**[Editor's Note: Following is a transcription of Dale's verbal presentation.]**

I offered two stories -- a short story about how I spent my summer. It seemed more appropriate to talk briefly about swath bathymetry. So I spent most of my summer riding around the Arctic on a submarine. We'll see some fragments of that, but not much.

More probably to the point of this group and this audience, a short story about the at-sea business end of swath bathymetry. I suppose the politically correct opening is to say, "Once upon a time" -- swath bathymetry didn't exist. It was really, really simple. Then it appeared, and it was magic, and there was only one kind, and there was only one place to buy 'em, and they only came in one size, and it was awkward initially. Then we figured out how to do it, and we thought we were pretty cool. Then all of a sudden this revolution came along. All the -- prior to swath bathymetry, side scan's been around for a long time. There are really two swath bathymetry tools, and there's what I found to be a pretty helpful paper by Grant Blackinton (ph).

Life used to be simple. Then it got complicated. Grant presented a paper at the ITREGLI (ph) Oceans meeting in Hawaii in 1991, I think -- there's some references at the end that are not stuck in my mind -- in which he proposed that we should talk about side scan swath bathymetry systems and multi-beam echo sounders. They're in the avalanche of new systems that have appeared in the last eight or ten years.

We can lump them grossly into systems that look a little bit like side scans. They make real good image. They make what we used to consider to be pretty good bathymetry, but in the meantime, the form beam sounders got to be radically better. The short story is that form beam SONARs make better bathymetry and not quite as good image data, and the side scan SONARs make pretty good bathymetry and better image data.

For both classes, we are seeing more and more people today who think you just order these up from Sears, or wherever they come from, and a field service guy comes and installs it, and it all works. What we've come to learn is that that part's still awkward. All of the swath mappers depend a tremendous amount on other data. In fact, in the resolution of the screen display thing -- you probably can't read it. It says, "Sound speed profile, position, attitude, heading, sound speed at the keel, META data," which some of us are sacraficing to our eventual displeasure. All feed to the swath mapper in real-time and provide real-time displays and data recording.

I'm not going to talk today about what you do with the data when it's recorded.

We should talk in the briefest sense about some of these pieces. Maybe in the discussion we'll come back to this. The short story is you have to get all those parts right, and then you have to get them right in real-time. And as you migrate from simple old-fashioned deep sea swath mapping to shallow water swath mapping, the definition of real-time gets much more rigorous.

I picked a selection -- there are actually two interesting review papers from the middle 80s, one by Bob Tyson (ph), another one slightly more recently by Christian de Moustier . That survey -- the collection of then-available swath mappers -- and they're both pretty short papers. New systems have been appearing at a stunning rate. I'm not aware of anybody who's had the nerve to tackle a current generation survey paper. It's not going to be me.

I simply rooted around in my file drawers and on the web and collected some example systems where the -- in the simple old days, you had SeaBeam classic that made a 45 degree swath and 15 or 16 beams on a good day. It ran at 12 kilohertz. There are -- 12 kilohertz still turns out to be the nice frequency for deep sea systems.

There's a whole range of additional systems. The HydraSeek DS (ph) was the big revolution -- was the hot-running swath mapper for arguably 18 month -- might make the case that it was only the hot-running system for eight months. In any case, we bought one in that window.

Immediately after that, the SIMRAD (ph) guys came along and turned the world upside-down with a radically better system. Probably lagging behind a little bit these real high frequency, high resolution shallow water systems came, and that all the rage these days. At this end of the spectrum, most of these systems don't work very well in water depths shallower than tens of meters. Some of them don't work very well in water depths shallower than 50 or 100 meters.

The guys up here in this end of the scale are quite happy operating with a meter or a meter and a half of water between the array and the bottom. You get to the place where the draft of the boat is a big percentage of the total water depth that you get to work in. And the error budget changes a lot. When you work in three meters of water, the draft of the ship as it changes over the course of the day as you burn fuel becomes a significant portion of the error budget. In the deep sea, it's not something we even think about.

This is an image borrowed from SeaBeam's web site. It's not my intent to talk about the performance of specific vendors; simply a typical kind of performance curve. For the form beam SONARs, as you get into very deep water, the full swath width decreases.

It's quite typical for the form beam SONARs to generate some narrow swath in very shallow depths -- narrow in an angular sense -- and eventually narrow down as the ocean gets significantly deep. The very shallow water systems do the same thing. They all scale -- the scaling is subtly different.

On the sort of small end of shallow water systems -- this is somebody's house over here. It's a picture from a C and C installation of a SIMRAD EM950, which is one of the early very shallow water swath mappers. Actually, it was a fairly complex array by modern standards. It has a semi-circular array. It has the unique advantage of being able to see out to the side and actually produce bathymetry virtually laterally.

Similar very shallow water systems -- we just installed a 300 kilohertz EM3000 that's on the Onrust (ph) at the moment and likely to move to other ships over time. But the whole array is a third of a meter in diameter. The other end of the spectrum is a picture of the under-hull on the Knorr. This is a SeaBeam 2112. It's a 12 kilohertz current generation system from SeaBeam. This is one side of the receive array, and you can see most but not all of the transmitter ray behind Gus -- these array segments -- the receive arrays and blocks of eight hydrophones, and they're about two thirds of a meter square.

The other class of SONARs typified by these guys -- and there are lots of others that aren't mentioned here. These guys make one beam to each side typically. Sometimes they're actually constructed to make a single very wide beam that covers both sides. They're typically, but not always, used as towed systems. We'll see some pictures that range from very shallow water systems that make swath widths in the small numbers of meters -- I'm not quite sure what one does with a three-meter-wide swath on a towed SONAR where, even under the best of circumstances, knowing where the SONAR is to a significant fraction of the swath width is a problem -- out to nine, ten, 11 kilohertz systems that look out -- that produce swath bathymetry ten kilometers out or more.

From the outside, almost all of these look like typical side scan towed SONARs of one kind or another. There are lots of opinions about how they get packaged. They're all towed. They all have substantial problems in understanding at the pixel level where the pixels go in geospace. They get from the -- what are euphemistically called "hand launch" -- these -- the little guys in the early pictures -- you're supposed to drop over the stern and pull them up by hand -- to enormous SONARs that are -- this is the SISSO-9 (ph) from Sea Floor Surveys.

The previous picture is from Hawaii Map and Research Group. The launch and recovery systems for these guys come in their own 20-foot sea freight container-sized box, and they place pretty big constraints on shipboard installations. You need a lot of deck space. If they don't have their own handling gear, you need more.

The atypical side scan swath bathymetric SONAR is the thing we've stuck on the submarine. It is packaged as if it were a towed SONAR. The pod is this piece right here. This structure is handling the frame to install it underneath the submarine at the pier. It goes in the water on this frame with divers. There's one here, and the other diver is back in there. This is the submarine. That's the pier.

That weighs 9,000 pounds, and we rig it up underneath the submarine and bolt it on to threaded inserts that are there. And that's the front of this pod. It's about 18 feet long. It's about three feet wide and almost three feet high before the bearing covers go on. These are the cables from the sub arrays -- go up inside the submarine from there.

It's the only phase measure that I'm aware of that's actually hull-mounted. Ordinarily, a SONAR like that would be towed in some kind of a tow body.

This is a collection of references. I would strongly encourage you not to write them down now. I'll e-mail them to you if you can't wait until the proceedings come out.

The references -- this is that paper that Blackinton presented in addition to the terminology about differentiating between multi-beams and side scans -- or side scan bathymetric SONARs. There's a fair amount of discussion in there about error budgets and the sources of errors. The two review papers from Bob Tyson and Christian Moustier.

There's also in here a collection of web sites. John Hughes Clark and Larry Mare and others at the University of New Brunswick Ocean Mapping Group have a wonderful web site full of pontification, most of which is pretty well-founded, about the merits of various kinds of mostly shallow water swath mappers. There also is in there, I think new recently, is an outline of the training courses that they run, which are fairly impressive. There's a couple of classic books if you actually want to understand how the acoustics and the data processing work. Urich (ph) is out in a third edition, and there's a book Neilsen (ph), SONAR Signal Processing, talks about the foundations of the commonly used processing beam forming algorithms, and some new algorithms that are not, as far as I know, currently employed in swath mappers.

There's also -- I guess on the previous page there was a URL to NB System (ph). There will be a new release out shortly. There's a catch-up release for us for those of you who care that addresses virtually all of the bug report (ph) we've gotten in the last -- since the previous release.

That's what I wanted to say today. I'll be glad to answer questions. I guess we're at the place where -- maybe Paul's going to answer all the questions.

PARTICIPANT: For instance, does Mare's URL -- does that contain his Bay of Fundi turkey shoot?

MR. CHAYES: There are two extensive data sets in there about their inter-comparisons. I haven't fully mined it. It goes on for a long time. I don't recall seeing anything in there about the Bay of Fundi comparisons.

MR. FINDLEY: Rich Findley, University of Miami. In the beginning, you started out with the problem of interfacing all the sensors and everything. Many of the manufacturers are delivering the systems with all those sensors as part of the system.

MR. CHAYES: Name one.

MR. FINDLEY: Zimmerec (ph).

MR. CHAYES: Not true. I just took delivery of one. It's not all there.

MR. FINDLEY: They quoted me one that way. They promised it would do it; that they would come down and set it up.

MR. CHAYES:  Yup.

MR. FINDLEY:  And it would work, guaranteed, or they would sit there until it did.

MR. CHAYES:  Yup.

MR. CHAYES:  That part is absolutely true.  I've been very impressed with their response to the questions that we've raised.  Somebody has shown up every time, and they've been pretty good about sorting out the details.  But I would argue that they didn't put all the pieces together and integrate them all before they got to us.

MR. FINDLEY:  That wouldn't bother me as long as it didn't cost any more for them to do it.

MR. CHAYES:  Well, what's ship time cost you?

MR. FINDLEY:  Nothing.

MR. CHAYES:  Nonsense.

MR. FINDLEY:  Well, I mean, the ship time wouldn't cost me anything.

MR. CHAYES:  "You" was a euphemism.

MR. FINDLEY:  It's a 300 kilohertz thing up on a 50-foot boat.

MR. CHAYES:  What do you get for 50-foot boat days, or whoever gets the money?

MR. FINDLEY:  It was in-house

MR. CHAYES:  Sure.  But if you were selling those days to customers, it brings --

MR. FINDLEY:  If you're selling the days, that's a whole different issue.  I'm talking about initial installation and setup --

MR. CHAYES:  There are real costs.  Do you just give the guys who come to install stuff on your ship the keys and ignore them?

MR. FINDLEY:  No.

MR. CHAYES:  So you've got somebody tied up there --

MR. FINDLEY:  But you like like to look at it for a while before you (indiscernible).

MR. CHAYES:  I haven't seen a case yet -- and I'd be happy to be proved wrong some day soon -- where the all-seeing, all-dancing box with the on/off test switch came and plugged in per the manual and worked right the first time.

MR. FINDLEY:  Oh, I never would've expected that.  It's just -- I knew that you were going to have to beat them up a little bit.

MR. CHAYES:  All of the vendors will sell you a turnkey package.

PARTICIPANT:  Without the key.

MR. CHAYES:  They charge money for the key.  That's okay.  That's part of the job -- you know, part of their job description.  At some level, there is -- one needs to be cautious and careful and conscious of that expectation gap.  We saw on my fancy lap-top here that's been very reliable for a very long time not do what it was supposed to do. It was doing what it thought it ought to do, whatever that was. But it wasn't what I wanted it to do. Somewhere in between the unrealistic expectations and the unrealistic promises is the reality that we live in every day. At some level, that's sort of our job.

PARTICIPANT: If it all worked out of the box, what would we do?

MR. CHAYES: Collect welfare.

PARTICIPANT: All work at a Radio Shack.

MR. CHAYES: We'd be down there on the beach with the surfers.
(Laughter.)

MR. CHAYES: And we wouldn't have bags under our eyes.

PARTICIPANT: And you just wish you worked at Scripps.
(Laughter.)

MR. CHAYES: I'd be just happy to stay in one place for a few months.

MR. HENKART: Yes.

PARTICIPANT: (Indiscernible.)

MR. CHAYES: Greg Greshan (ph), Arctic survey?

PARTICIPANT: Yeah.

MR. CHAYES: Yeah.

PARTICIPANT: I see on your picture of the transducer installation that things are mounted in (indiscernible). They're not closer to the (indiscernible.)

MR. CHAYES: Yes.

PARTICIPANT: Have you got any experience of (indiscernible) whether that should be mounted to the (indiscernible).

MR. CHAYES: Yes.

PARTICIPANT: And do they work?

MR. CHAYES: They don't work as good as we'd like them to, but they work okay. The Ewing has a flush-mount Hydra-seek (ph) DS. The Polarstern (ph) has a flush-mouth Hydra-seek DS. The Palmer has a flush-mount SeaBeam 2112. The flush mounting itself, I think, is not really a big issue. We've seen some flush mounts go awry where they're actually recessed. So you trap whatever bubbles come by, and then you get a bubble up against the face of your transducer. When you transmit, you make bigger and smaller bubbles like seismic sources. You don't get much energy in the water. That's only an execution detail.

I think part of the bad to mediocre press the flush-mounts get is that they're flush-mounted on ships that have horrible hull forms for moving quietly through the water, because they're maybe the icebreakers. We make them flush so they don't get scraped off. There's a clear correlation that flush-mount systems are somewhat accoustically noisier. But part of that, at least, is the hull form in front of it. One of the things that helps a lot is to make your icebreaker have a ten-meter draft so that the transducers are way down there where the ice doesn't come by very often.

PARTICIPANT:  Too light to break.

MR. CHAYES:  Yeah.  That's -- that one's hard to retrofit.

PARTICIPANT:  And it's five meters already.

MR. CHAYES:  Yeah.  Changing the shape of the bow is a problem.  We've talked about that as an end member of what you do.  I didn't bring with me a picture of the Ewing.  We built a big thing that looks a little bit like a clothesline stuck under the bow of the Ewing that does a fair job of separating bubbles soup (ph) down and keeping it away from the arrays.  Unfortunately, the first iteration of that thing was built with pretty sharp corners.  And we took it back into the body shop and changed that.

There are other icebreakers out there with flush-mounts.  Do you think you're having trouble with a flush-mount?

PARTICIPANT:  Well, haven't got a system yet.  We're looking to the future.

MR. CHAYES:  Anticipating trouble.

PARTICIPANT:  Yes.

MR. CHAYES:  It's good to plan ahead.  I strongly encourage that.

PARTICIPANT:  We've got numerous transducers on the (indiscernible) flush-mounted.  We've got a (indiscernible) system, which is on 38 1.22 kilohertz.  That one's (indiscernible) according to (indiscernible).  So I think we might have (indiscernible) has a very broad range (indiscernible) particular installation or what.  There's definitely a problem, though, with that one.  But it could be any number of factors.

MR. CHAYES:  Are they behind windows?  Are you --

PARTICIPANT:  Yeah.  They're behind this (indiscernible) window.

MR. CHAYES:  Polycarbonate.

PARTICIPANT:  I think that's the --

MR. CHAYES:  Poly-something, or is it really polycarbonate?

PARTICIPANT:  I believe it's polycarbonate.  (Indiscernible.)

MR. CHAYES:  Most of those are polyurethane or some -- but I know that SIMRAD has expressed some concern about polyurethane windows at high frequencies causing problems with the calibration of the EK500s.

PARTICIPANT:  Yeah.  There's a sort of refraction problem (indiscernible) shape.
(Multiple simultaneous speakers; indiscernible.)

MR. CHAYES:  The high end of the EK500 -- I don't know.  You came make it anything you want, but it's a couple hundred kilohertz --

PARTICIPANT:  No.  I just do wonder if you got (indiscernible) or if we're going to purchase a very expensive swath bathymetry system and (indiscernible).  It would be rather annoying.

MR. CHAYES:  Yeah.  Well, --

PARTICIPANT:  All we can do is ask people like yourself and finding out what experiences you've had, I guess --

(Multiple simultaneous speakers; indiscernible.)

MR. CHAYES: -- you know, a million, two million bucks and see what happens. In the end, I strongly encourage you to plan ahead and think out those problems the best you can. SIMRAD has proposed a titanium window for icebreakers. I don't know if there's any operating experience with titanium windows in swath mappers. All of the more or less successful windows that I know about are either polyurethane windows or, in the case of the Atlas DS, the transducer is actually a molded polyurethane block, and it's actually exposed to the ocean.

PARTICIPANT: Yeah.

MR. CHAYES: And well-supported in the back.

PARTICIPANT: (Indiscernible) from UGBO station (ph). We have the the EM-12 (ph) on board one of the (indiscernible) which goes to Antarctica and has six millimeters titanium window on the EM-12.

MR. CHAYES: On Hesparides (ph)?

PARTICIPANT: Hesparides, yeah. It works pretty well. You have some attenuation, but (indiscernible) on the operator unit, and it takes account of the attenuations, but (indiscernible) with reasonable -- see you can get very good results after 12 knots -- between 12 --

MR. CHAYES: So it actually projects below the keel?

PARTICIPANT: Yes. It's --

MR. CHAYES: It's not flush-mounted.

PARTICIPANT: (Indiscernible) centimeters.

MR. CHAYES: Wow.

PARTICIPANT: (Indiscernible.)

MR. CHAYES: Uh-huh. A tear-drop shaped pod.

PARTICIPANT: (Indiscernible.) It's very good. This system is quite good.

MR. CHAYES: Should go talk to them.

PARTICIPANT: Yeah, but theirs is sticking out.

MR. CHAYES: Yeah. I'm surprised that it's sticking out.

PARTICIPANT: (Indiscernible.)

MR. CHAYES: I guess it depends on how much ice-breaking you really intend to do.

PARTICIPANT: (Indiscernible) top of the ship because in certain places we have to use it (indiscernible). You don't want to increase (indiscernible).

MR. CHAYES: Do you have a flush-mount on the Revelle, the flat --

PARTICIPANT: It's the bottom thing.

MR. CHAYES: It's a which?

PARTICIPANT: It's a (indiscernible) to the hull.

MR. CHAYES: It does protrude?

PARTICIPANT: Yeah, a little bit.

MR. CHAYES: A little bit. Yeah.

# Geophysical Technologies Discussion Session

MR. HENKART: So actually, there are a couple of chairs up here and microphones if the speakers want to sit here, or if they just want to use the sides, that’s fine. But just so that it does get on tape, and if anyone has any specific questions that didn’t get them before -- I mean, I asked -- had a couple of questions.

I’m like totally off base here, but I’d like to ask Dr. LeBlanc a question. Could you categorize the differences between the EGG system and the Datasonics.

DR. LeBLANC: You mean the Edgetech (ph) system.

MR. HENKART: I don’t know what I’m talking about.

DR. LeBLANC: Well, there’s a lot of history that goes behind that. That system -- I designed that system early on that Datasonics was using. So they’ve made changes to it, and I don’t know really very much about the way it runs today. I haven’t seen one operate.

We’ve developed all of our technology while in the university environment. This was sponsored under the Office of Naval Research. Edgetech has brought that from the university. So they have an agreement with the university, and they pay royalties, and so on. So it’s an ongoing program. It’s going on today, in fact.

PARTICIPANT: I’ve got a Datasonics. I was wondering if there was any technical differences and, you know, performance differences.

PARTICIPANT: I looked at both before I bought them. I bought the one with the PC because it was easier for us to maintain because we had tons of those around. Support was easier for us to do. That was an issue for us.

PARTICIPANT: But you didn’t see any performance difference?

PARTICIPANT: Nothing that was immediately obvious. We were doing the front -- we were doing one of the first in-hulls at the time. Doing the in-hull is a little trickier. They came up with a solution that seemed to work out. But they’ve gone through a couple revs on the Datasonics, and I don’t know how it really does compare that well. I mean, we tried to do some inter-comparisons between the systems. It’s not as easy to do as you would think, even though they’re supposed to do both kicking out SEG-Y, and you’re supposed to be -- you know, we tried to go over the same areas with two different chips -- with two hull-mounted systems. People sat looking at the data, you know, the printouts, and said, well, what one’s better? This --

PARTICIPANT: Well, I suggest you talk to Neil Driscoll. He did a comparison between the two systems. He hasn’t published that data, but I think he would talk to you as a scientist.

PARTICIPANT: And there’s also some dependency if you’re in deeper water or shallower water, too. I mean, I think the -- in real deep water, you’re going to limit the frequency more because you can’t sweep it as far because the high frequency just goes away. It’s not going to be there. It’s never going to get back to you.

I think you put it in the shallow water, I think is an excellent --

PARTICIPANT: Well, the hull-mounted systems, a lot of these ships already have massive transducers, which are fairly band limited. They’re very efficient, and they work very well in that three to six kilohertz range. They can be swept and generate a Chirp pulse. The records look very good. The Endeavor record I showed you was a Masser (ph) system.

So you don’t have to change it out. But changing it out will give you more bandwidth, and essentially you can realize a little more resolution, especially if you’re doing any work in shallow water, as well.

PARTICIPANT: Right. Like at the shallow end (indiscernible). I think we’re sweeping this Masser up to eight on a regular basis.

PARTICIPANT: They don’t put out very much energy up there, though. I know that because I’ve looked at -- well, I’ve looked at the ones that were on the Endeavor. We calibrated them before we --

PARTICIPANT: Fooled ’em. Sure. And the other -- I have some data from a long time ago when we were fooling around a lot with transducers and things like that. Raytheon did a lot of work for us with arrays and looking things. And they -- we kind of arrived at a -- if you take a four-by-four array, and then take the corner transducers off, it was a very -- there were a lot less side lobes out of that than a lot of the other arrange- -- and this was measured, and that was over -- at a couple different frequencies that they had done that.

PARTICIPANT: That might tend to reduce side lobes, because it behaves a lot like shading. You’re reducing the energy at the edges of the array, which is -- which would tend to reduce the side lobes. You can accomplish the same thing probably by driving the array elements individually.

PARTICIPANT: Sure. It actually had better performance than the full 16 trans-visit (ph).

PARTICIPANT: That’s possible. And they interact, too. When you put transducers next to each other, they interact. They acoustically interact, and they couple energy between them. So their characteristics change. So you really have to callibrate them as a group.

PARTICIPANT: Yeah. That’s what we were working --

PARTICIPANT: Yeah.

PARTICIPANT: -- shuffling transducer (loud coughing; indiscernible) trying to pick the best arrangement and playing with the --

PARTICIPANT: But there are a lot of Masser transducers out there. Most of the ships’ hull-mounted systems have Masser transducers.

PARTICIPANT: Yeah. Under various names. I mean, a lot of them are --

PARTICIPANT: Under the Raytheon name and so on. Yeah.

PARTICIPANT: And there were different series, and predences (ph), and -- yeah.

PARTICIPANT: Can I ask a question very quick before you move on? I’m Dave Summers (ph) with NAV Ocean (ph). Your slide showed three different means of mounting a (indiscernible).

One was hull-mounted version that had the option of putting the shallow tow vehicle into it. And the other one was a deep tow vehicle. So it really gave you three arrangements. What kind of depth range are you recommending for each of these. In other words, a shallow towed vehicle should be in what range -- hull-mounted in what range, and the deep tow in what range?

PARTICIPANT: Well, the shallower tow vehicle, the sediment classification SONAR, normally, we tow that about ten meters above the sea floor. That produces data that you can use for classifying sediments.

PARTICIPANT: Okay. Sediments -- but sediments in what depth of ocean floor?

PARTICIPANT: Twenty, 30 meters of penetration. It depends on the material type that you’re dealing with.

PARTICIPANT: Right.

PARTICIPANT: A lot of people are interested in getting close to the sea floor with the same system. So there are a number of these on ROVs. Edgetech has just developed this telemetry system for deep towing the Chirp. I think the rating there is based on what the transducers will take, and it's about 3,000 meters.

PARTICIPANT: On the deep tow?

PARTICIPANT: Yeah.

PARTICIPANT: Isn't that a little shallow (indiscernible) 300?

PARTICIPANT: It's ten meters from the sea floor.

PARTICIPANT: From the sea floor.

PARTICIPANT: Ten to 20 meters off the sea floor. So, I mean, it depends on the water depth. They can handle a thousand meters of crush depth.

PARTICIPANT: And then with the hull-mounted system, then, you would recommend going to that (indiscernible).

PARTICIPANT: Well, the hull-mounted system can be used in shallow water. You can -- it generates images that are almost as good as the vehicle -- not quite as good.

But, you know, as you get -- the problem is, as you get -- as the water gets deeper, that cone from the beam pattern covers a much larger footprint. As that sound penetrates through the sediment, there are scatterers in the sediment that you pick up. It goes to pot very quickly. You don't get information that you can use for sediment classification.

PARTICIPANT: So if I'm interested in sediment classification --

PARTICIPANT: Or penetration.

PARTICIPANT: Either/or -- and I have a hull-mounted system, I should look at perhaps not using it at any depths over a given value. What would that value be?

PARTICIPANT: Well, what you saw there was like 3,000 meters.

PARTICIPANT: Three thousand.

PARTICIPANT: It's just that it doesn't generate as clean an image. I mean, you could see where things were changing --

PARTICIPANT: Right.

PARTICIPANT: -- because of that crossing-over effect.

PARTICIPANT: Because of the (indiscernible).

PARTICIPANT: Right. But still, a lot later, it was identifiable. We could see the all that fine layering.

PARTICIPANT: In that case, if I were to purchase a system that allowed me to use just -- that allowed me to use the hull-mounted transducers and (indiscernible) shallow towed vehicle --

PARTICIPANT: You could do that.

PARTICIPANT: You could do that.

PARTICIPANT: Yeah.

PARTICIPANT: And use the shallow towed vehicle for -- what? -- a thousand --

PARTICIPANT: You could use the same driver, because it's -- the signal is driven down the cable. Or you can put the whole electronics in the vehicle -- that newest vehicle that you see there that Steve Schock developed with Driscoll, which has all of the electronics in the vehicle. He's networked to it.

PARTICIPANT: But the problem that you have then is the same problem that you have with any kind of towed device, which is positioning the towed vehicle.

PARTICIPANT: Knowing where it is.

PARTICIPANT: Knowing exactly where it is.

PARTICIPANT: Yeah. Navigation is the big --

PARTICIPANT: And then I assume it's the same thing with -- we're having problems with mosaics -- generating mosaics with side scan (indiscernible) which is the other class that you guys are using. Does anybody know of anything that's out there right now that gives us a locus of the towed vehicle reliably versus the mothership? -- the best --

PARTICIPANT: The best (indiscernible) is the inverted tracker from SIMRAD. It actually lives on the remote vehicle and tracks the beacon on a surface ship. It's an HVR-something or other.

PARTICIPANT: HVR?

PARTICIPANT: I can dig up the reference to it, or you can just call Congs Bergan (ph) in Lynwood.

PARTICIPANT: (Indiscernible) hype up on HVR.

PARTICIPANT: And this can attach to almost any towed vehicle?

PARTICIPANT: -- just about the same thing. You put a beacon on the towed vehicle, transducer on the ship. It's coupled to the navigation. You know exactly where the -- you can get within a meter of where it is, and it tracks at the angle from the ship and the -- yeah.

PARTICIPANT: Did we finally get that working?

PARTICIPANT: Yes, we finally got it working.

PARTICIPANT: There was a problem with -- this was a -- my name's Jerry Denhoff (ph) with the Naval Oceanographic Office. There's a problem, I guess, because the track (indiscernible). And there's an orientation problem. We were finding this two months ago -- that we were finding the fish -- the Trackpoint (ph) were saying that the fish was maybe a hundred meters back behind the ship off to one side or the other.

PARTICIPANT: Right.

PARTICIPANT: And so we -- I questioned whether (indiscernible) was, and the engineering guys that we had on board, when we came into port, did some calibrations on it and found out that it was slightly twisted relative to what their initial installation was, and that was over 400 meters back -- 400 meters lay-back (ph). It was causing -- you know, the angle was causing the fish to appear to be way off line. So they got that calibrated in, and we were able to do much better after we went back out.

PARTICIPANT: Those attached transducers, or beacons if you will, on your tow cables have other little problems, such as battery life. So those are some things to consider.

PARTICIPANT: (Indiscernible) is like weeks that they'll last. More than you ever keep a fish out for sure.

PARTICIPANT: Right.

PARTICIPANT: We don't buy the battery packs from ORE. We make them out of (indiscernible).

PARTICIPANT: We've certainly never seen anything close to one meter with Trackpoint. We use it as a backup system for Alvin where we usually have acoustic navigation, and it's more like 50 meters at 3,000 meters --

PARTICIPANT: -- Trackpoint II Plus?

PARTICIPANT: No. In fact -- no, we have not.

PARTICIPANT: We're finding that we're getting three to five meters with Trackpoint Plus. That was 9,000 a unit, I think, to upgrade. I forget exactly how much. But it only takes a couple weeks. Trackpoint Plus is much better.

PARTICIPANT: Question over here.

MR. MULLER: Yeah. Rich Muller, Moss Landing Marine Labs. I had a question about that trace that you had up there, the 3,000 meter trace. Do you recall what sort of power you were using in the transducers?

PARTICIPANT: Let's see. John Freitag would know the answer to that. No, I don't. I think that was full output power, and it was a 40 millisecond pulse.

PARTICIPANT: You didn't see any noise in the water column. It's good signal-to-noise ratio.

PARTICIPANT: Two kilowatt, ten kilowatt?

PARTICIPANT: It's two kilowatt peak power.

PARTICIPANT: Okay.

PARTICIPANT: Peak envelope pulse. So it's a lot less RMS (ph).

MR. FINDLEY: Rich Findley again from the University of Miami. Initially had a foam rubber lining that --

PARTICIPANT: The sea chest, yes.

MR. FINDLEY: The sea chest. I mean, foam rubber's got air in it. Wouldn't you be better off with something -- more of a connec (ph) thing than a foam rubber? I mean, that's almost a perfect reflector.

PARTICIPANT: I recommend corprine (ph), which absorbs a lot of the sound. It's very expensive, though. It'll probably cost you several thousand dollars to cover that sea chest with corprine. And we use layers of corprine and the foam rubber, and that makes up a good impedence baffle. In fact, we use it in that big tow vehicle. The tow vehicle has a corprine layer in between the receiver and transmitter array.

PARTICIPANT: For the ADCPs, which is our higher frequency we've used, it's a rubber floor mat that has tire cord in it. It's like a waffle shape, and that all cut up into chunks. And around the edges and side in there, it will solve a lot of ringing. It probably wouldn't work if the frequencies that -- the 300 that the Chirps run at. And it's cheap.

PARTICIPANT: Yeah. It's inexpensive and it does redirect a lot of the energy downward.

PARTICIPANT: You touched on an earlier subject which actually (indiscernible) mentioned to me earlier. It borders on religion here. But formats of data that you get out, you said you preferred one unit because it was an SEG-Y.

PARTICIPANT: No, it was a -- no. I said because it was a PC base. It was running on Windows and stuff, and that's all we had around. It would've been our only UNIX machine on the ship.

PARTICIPANT: That's a different form of religion, yes.

PARTICIPANT: And this is where you're talking about --

PARTICIPANT: Yeah. SEG-Y versus -- I guess they had a request for (indiscernible) echo sounders being in SEG-2 or something like that. Does anyone in the audience have any -- you know, anything hard about any formats of data that they get out of the unit?

PARTICIPANT: A SEG-something.

PARTICIPANT: SEG-something.

PARTICIPANT: Something that can be post-processed on other commonly, instead of proprietary, formats, which are --

PARTICIPANT: I've seen some of that SEG-y data from some of those machines, and it's --

PARTICIPANT: -- it's kind of Frankenstein SEG-Y.

PARTICIPANT: Amen.

PARTICIPANT: Parts of it look normal, but then you have to -- but then it's not --

PARTICIPANT: Can I offer you the code I wrote this summer?

PARTICIPANT: (Indiscernible.)

PARTICIPANT: I can read -- you broke an ODEX (ph) data filing (indiscernible.)

PARTICIPANT: Right. The format called ODEX.

PARTICIPANT: What's that?

PARTICIPANT: In a format called ODAG.

PARTICIPANT: No. Well, in SEG-Y -- an ODEX version of SEG-Y that drops bytes occasionally.

PARTICIPANT: It's somewhat of a problem in SEG-Y. There isn't any smart way to get these things, but there's real dumb ways that work. I do have a strong preference that all of the operational parameters get imbedded in the data stream. It's not a (indiscernible) profiler issue. It's an issue with all these systems that there are -- in my spare time this summer, I looked at the permutations of the operator interface for two moderately complex SONARs. The unrealistic permutation's in excess of a million. The plausible permutations are hundreds of thousands. There's no hope looking at the data set and looking at somebody's (coughing; indiscernible) in the paper log book to figure out which ping, and the gain actually changed if the gain's not recorded correctly for all of the parameters.

PARTICIPANT: Have you come across this SEG-2?

PARTICIPANT: No. I'm -- my SEG format book stops at SEG-(coughing; indiscernible).

PARTICIPANT: I just finished an archeology project, and it was done in SEG-2.

DR. DIEBOLD: John Diebold from Lamont. I wanted to ask Greg Kent a few questions about the LCHEAPO. I realize he's not responsible for it. Because, you know, we're trying to figure out how to use these things in the field. There's some parameters that are really important. I guess one is: How long does it take to turn them around? If you wanted to redeploy, how quickly could you change the expendables, and reprogram the thing, and dump the disk and all that?

DR. KENT: I guess if you want to do an experiment where you had a lot of instruments you'd want to turn around a lot, then the first thing you'd have to do is make it a little more expensive by bringing more personnel out. Because certainly when you get past about eight hours of that type of thing, I wouldn't trust anything going back over the side. So there's that issue.

But let's say you get beyond that issue. Some of the -- not the one that's there, but some of them now have basically a SCSI connection. So you don't even have to dump the -- or you have the open instrument, and then it's just a matter of how much you can get to the -- however many gigabytes back out of the interface. And I think realistically -- let's see -- it takes -- I mean, probably two, three hours to turn them around and toss it back in.

DR. DIEBOLD: Without opening them?

DR. KENT: With what?

DR. DIEBOLD: Without opening them.

DR. KENT: With -- yeah, exactly. The opening them adds a little more difficulty because you have to worry about condensation and things. So if that were the case, I would try to have one extra, and you could roll them along so you're not trying to exactly deploy that particular one, but -- I mean, I think realistically -- say, you know, three hours if you really -- you know, you can do it faster, but I don't want to sell you something that I wouldn't do myself.

DR. DIEBOLD: Right. When they are recording the -- as I understand it, the disk is normally turned off, and then it spins up the disk when it needs to.

DR. KENT: At 250 mils -- I mean, at four mils, or 250 samples a second, it takes about an hour, or two hours depending on whether the two or four megabyte RAM is in there. We have two different varieties. And that takes about a minute of turning on the disk, which then drains about ten watts. If you look really carefully, you can see that, but, I mean, you'd have to really blow the data up to see that.

PARTICIPANT: See what?

DR. KENT: See the effect of turning the disk on. You get a little bit of feedback or pickup.

PARTICIPANT: So you can still present (coughing; indiscernible) while that's happening?

DR. KENT: Yeah. So it's truly continuous. You used to have to kind of -- if you really want to see it, you have to kind of blow the data up, which might have some bearing on more teleseismic-type studies. But then you're at a lower sample rate. So it's not quite as off.

PARTICIPANT:  What kind of format do they record in?

DR. KENT:  Our version.  No.

Internally, it's our own little header-data, header-data, header-data.  And then we have a program -- at least for conventional shot recorded data, we have our version that goes into SEG-Y.  And it does not violate any SEG-Y.  But we have taken advantage of the empty part of the SEG-Y header to place some additional parameters --

PARTICIPANT:  Sure.

DR. KENT:  -- that someone might want to look at, but rarely ever.  But it's pretty good.  I mean, we have enough different things that read different -- you know, true SEG-Y that so far we haven't found one that hasn't.  But, yeah, so we have just a conversion routine that goes into a records search.

PARTICIPANT:  Well, normally, I guess you'd have to merge the --

DR. KENT:  The shot and navigation.

PARTICIPANT:  -- the shot and navigation.

DR. KENT:  Yeah.  That's a very quick process.  I think one of the more timely things, which is true whether it's this instrument, or ones from Woods Hole, or from Keough, or wherever, is that even if you know where you are within a millimeter on the surface, that it drifts.  Where we had differential GPS to about a meter, some of our instruments were over a hundred meters away on the sea floor.  What you do there is you hopefully have good coverage, and you pick the water width, and then you can invert for the position.  So some of them can drift upwards of a hundred meters, which actually can make a difference.

So that's kind of a -- that takes a while.  So there's kind of like an initial record section you make out at sea to make sure that, hey, I've got data with wiggles, and it looks roughly correct.  But then when we get back to the lab, we have to go ahead and get a graduate student -- no -- pick the water waves, and then relocate them and make a final section.  So it's not total turnkey.

DR. DIEBOLD:  That was my final question:  How do you locate them?

DR. KENT:  Yeah.  So -- but it is difficult, because a lot of times, you just shoot 2-D lines.  And then you go, oh, well, you know, we should really do a little bit of survey around each instrument.  And then you say, oh, but God, we'd have to do half as many lines.  And this is just true pretty much of everyone in academia.  You just run a line over it, and then you get some ambiguity, and it's not quite as good.  But it also depends on what you're doing.  So there's that additional caveat.

PARTICIPANT:  I had another question -- slightly different.  But upon occasion on Scripps, we have a couple of single-channel streamers.  Is there ever any advantage for running the two single-channel systems side-by-side rather than end-to-end?  Can you get a 3-D single channel?  Would that be of any use to anybody?

DR. KENT:  I mean --

PARTICIPANT:  Versus just doing a normal sort of CDP with four channels or something?

PARTICIPANT:  Well, you need a sufficient separation of the streamers.  You'd want them -- if you had one source and two streamers, and the source was in the middle, you'd want the streamers 50 meters from the source, essentially.  You've got to have a hundred-meter wide towing capability to do this right.

PARTICIPANT:  If the screws line up.

PARTICIPANT: I mean, the ACOREs (ph) are getting pretty far apart. See, I guess I'm -- we were talking about real money versus play money here a little while ago -- it doesn't cost 'em anything, but it really costs something. My kind of radical response to your question is: Why would you go out with a $25,000 ship and shoot data that is significantly limited? But there might be those who want to do it because you don't pay anything for the $25,000-a-day ship. But in reality, --

PARTICIPANT: Somebody pays it.

PARTICIPANT: -- you know, the difference between doing a single channel and a multi-channel may be $5,000 a day, or 10,000, or something. It's only maybe ten, 20 percent of the total cost, but because of the way that we decided to charge, 80 percent of it is a freebie, but it really isn't. So I would say I would personally never do it, but --

PARTICIPANT: The cost for post-processing of multi-channel is just so much more.

PARTICIPANT: Yeah. Well, you get what you pay for.

MR. HENKART: Any other questions from the audience?

PARTICIPANT: Well, I was going to ask that side of the table something too.

MR. HENKART: Go ahead, Dale.

MR. CHAYES: Dale Chayes, Lamont-Doherty. I wanted to ask Lester -- I think I came in on the tail end of a discussion about Chirp sub-bottom in very shallow water, or where the distance between the towfish and the bottom is very small. I think what I heard you saying is that the transmit burst has to be over before the bottom return starts. Or maybe I misinterpreted --

DR. LeBLANC: Well, in a hull-mounted system, that's true -- where you have just -- where you have a TR switch for turning the transmitter/receiver. But in the tow vehicle, no. They run at the same time, essentially.

MR. CHAYES: Okay.

DR. LeBLANC: You're receiving a signal while transmitting, in fact.

MR. CHAYES: So -- we're about to jump off the cliff and surveying the Hudson River. It's ridiculously shallow by my standards, and you can see everything all the time, and you're not out at sea. This shallow water boat business is much tougher than going to sea (indiscernible) as far as I can tell. So we can actually still be transmitting the outgoing after bottom return is coming back.

DR. LeBLANC: That's correct. In fact, I've operated it in just a few inches of water, as long as the transducers were covered and the receiver ran covered. I had this graduate student dragging the system along the beach. We got some beautiful profiles.

PARTICIPANT: We're supposed to be doing ground-penetrating radar up in the --

DR. LeBLANC: They were interested in --

DR. LeBLANC: -- finding out how deep the sand was so they could dig a pathway for a pipeline.

PARTICIPANT: Is the surface return as -- I'm anticipating the surface return is as big or bigger a confusing issue, and we get into this water where the distance to the bottom is closer than the distance to the surface.

DR. LeBLANC: Well, in the tow vehicle was a lot of baffling material. There's material for preventing that surface return from coming back in. I haven't noticed it.

PARTICIPANT:  Okay.

DR. LeBLANC:  I suppose you could crank up the gain and see something.

PARTICIPANT:  The operator can always wreck the data by adjusting all those permutations.  That's not our goal.

PARTICIPANT:  (Indiscernible) our background.  We just bought an Edgetech-style tow vehicle.  We did a survey in Louisiana waters over some oyster roots (ph).  We had an excellent return all the way up to the point where we grounded the vessel in the (indiscernible).

PARTICIPANT:  How about right after that?

PARTICIPANT:  But we had to get out and kind of push and pull (indiscernible).

PARTICIPANT:  Well, those kind of boats, if you just get out, then the boat floats, and you walk it into deeper water.

PARTICIPANT:  This is a little 20-foot --

PARTICIPANT:  But we did get some very excellent returns.

PARTICIPANT:  Okay.  That's encouraging.

PARTICIPANT:  This Larry Mare experiment that I was talking about up in the Bay of Fundi -- you know, as you know, the Bay of Fundi has a tidal thing of tens of meters.  So they went out and they surveyed in certain objects in the bottom of the Bay of Fundi when the tide was out.  Then the tide comes in, and they ran the ships around it and played the game of "What can you see where?"  If you can cut across that survey, it's really a true game.

Last week, I was using three geometric units for seismic recording.  Two models had different polarities.  I noticed, John, that in your diagrams you said you had a nice big peak that was going in a negative direction.  And you said, "This one is black."  Does polarity make a difference?

PARTICIPANT:  Yes.  I mean, especially if you're mixing data from two different (laughter; unintelligible).

PARTICIPANT:  If it turns it all to zeros, then you don't have to worry about it.

PARTICIPANT:  No, I think it produces a more -- well, first off, you have to know what you're looking at, because, you know, you go around looking at negatively -- you know, you kind of (indiscernible) is the sea floor really made of always this little pair of -- you know, is there a little skinny reflector there that's causing this doubling (ph), or am I looking at the wrong thing?  And if you really care about the details, you know, the timing's different.  It just looks better if it's right.  And that counts for a lot.

# ROV AND TOWED VEHICLES

Chaired By
Marc Willis

# A Cruise With The ROV Jason

Robert A. Elder
Woods Hole Oceanographic Institution

*Created from a slide presentation given to the INMARTECH '98 conference hosted by Scripps Institution of Oceanography, October 1998. This paper is WHOI Contribution Number 9948.*

ABSTRACT

The Deep Submergence Laboratory of the Woods Hole Oceanographic Institution operates a small fleet of underwater vehicles. This paper describes each vehicle from an operational point of view. A brief discussion of what a ship's requirements are and the process of setting up on a ship will be given. A launch and recovery sequence focused on Jason will be presented along with an overview of the sampling tools with which Jason is equipped. Also, a brief look at some of the data products that Jason has generated over the years will be presented.

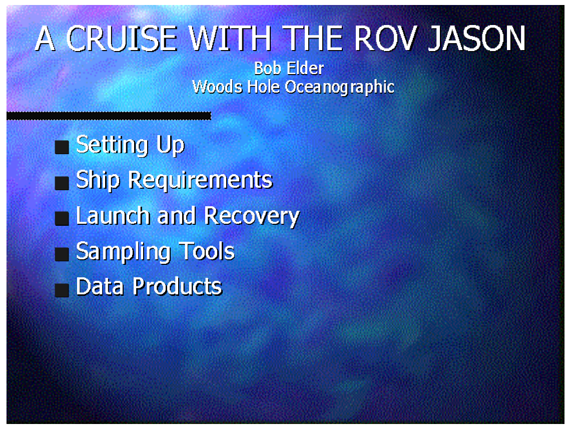



Figure 1: A Cruise with Jason.

DEEP SUBMERGENCE LAB VEHICLES

The Deep Submergence Lab at Woods Hole operates several vehicles. The DSL-120, Figure 2, is a neutrally buoyant side scan sonar sled which is towed behind a clump weight. It is equipped with a 120-kilohertz side scan sonar, as well as a host of other sensors such as CTDs and magnetometers, depending on the needs of the trip. This is a large-scale survey tool intended to survey areas in the order of tens of kilometers, either looking at geology or finding targets to look at with a finer-scale tool.

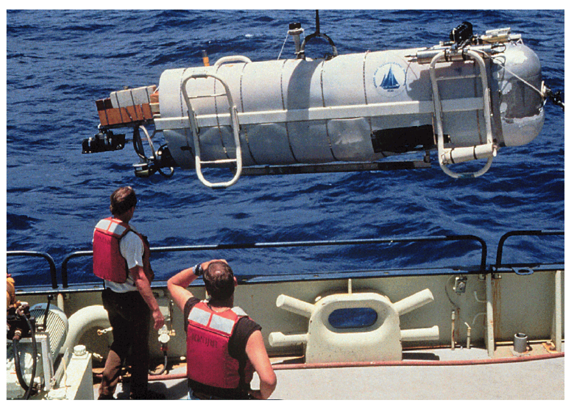


Figure 2: DSL-120

Argo is a heavily instrumented platform that is towed behind the ship using a 10 km Fiber Optic cable. Argo is equipped with an assortment of sensors that can include five full bandwidth color TV cameras, a 200 kHz side scan sonar, profiling and imaging sonars, an Electronic Still Camera, a Benthos 372 film camera with strobes, and thrusters for maintaining heading. Other instruments that have been on Argo include CTDs, transmisometers, and magnetometers. Argo is outfitted with a gyro, compass, altimeter, pressure sensor, and various other sensors that help determine the attitude of the vehicle while cruising along the bottom. Argo is meant to be towed about ten meters above the bottom usually doing photo work with an ESC, or using its video imaging and scanning sonars to record data from the bottom. Argo, weighing about 4000 pounds, is a medium-scale mapping tool.

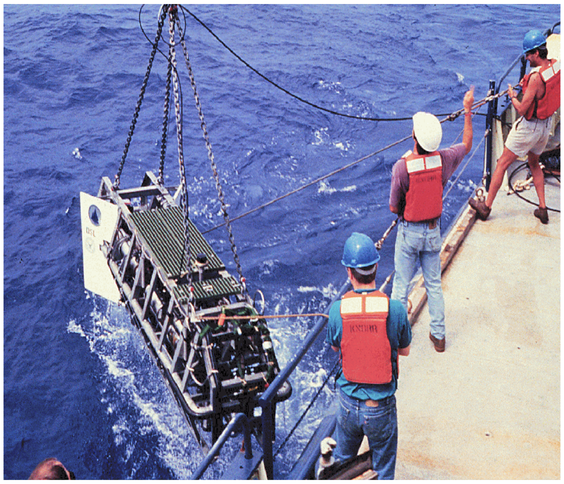


Figure 3: Argo

For fine-scale work, Jason, Figure 4, is the vehicle of choice. Jason is a Remotely Operated Vehicle, weighing 3500 pounds in air but neutrally buoyant in water. Like Argo, Jason is a heavily instrumented platform with much the same set of sensors. Being neutrally buoyant, Jason has the additional capability of being flown in the water using its 7 thrusters allowing four axes of freedom either under the pilot's control or closed loop computer control. Jason also has manipulative capability using an electric manipulator. Jason takes advantage of various sensors to provide auto-heading, auto-depth, and other functions that ease the work load of the pilot, allowing a higher concentration level on the science task at hand. Jason is an excellent tool for fine scale work allowing precise movements and control in delicate environments.

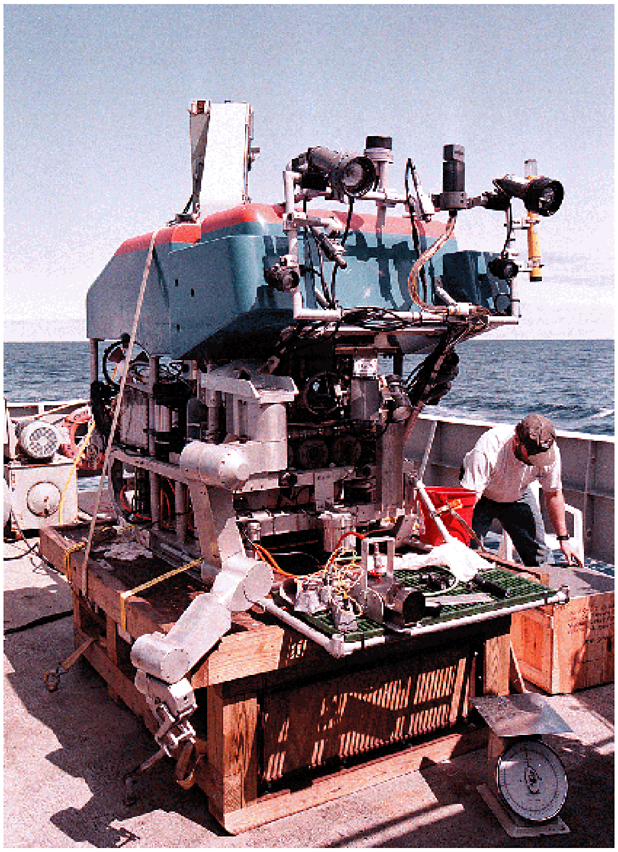


Figure 4: Jason

The Deep Submergence Lab has operated off a number of ships over the last twelve years. DSL has been on ten different ships sailing out of 12 different ports. The operation is considered to be portable, but it takes from four to six ISO containers, each weighing about 20,000 pounds apiece, to field a complete setup supporting all three vehicles on a ship. A considerable amount of logistic work is necessary, especially when equipment is shipped from one port to the next without a stop in Woods Hole.


Figure 5: R/V Thomas Thompson in Seattle

The take up drum for the winch is represented in Figure 6. It is loaded with 10 km of 0.680 fiber optic cable. The winch is classified as portable, but the weight of the wire, drum and traction head exceed the maximum weight that one truck can handle. It takes 2 flat bed trucks to transport this portable winch.

Figure 6: Winch Drum

Setting up the equipment on deck is an all hands evolution. It can take several days to get everything on the deck, maneuvered around and finally bolted down. Most UNOLS's ships have a deck pattern of boltholes that greatly speeds up the operation of bolting down equipment. However, all ships are not the same. Sometimes it takes several attempts to get all the holes in the various deck plates and sockets to line up before things can be secured.

Figure 7: Securing Winch to Deck

Threading the 0.680 cable through the winch, Figure 8, is a major operation requiring careful coordination between the workers and the winch operator.

Figure 8: Threading Wire Through Winch

Once everything is set up and the ship is in transit, the fantail looks nice and orderly. Port side is Jason. Forward of that is the tool van, where Jason rides during shipping. The tool van is stocked with enough parts and pieces to fix just about anything short of a major melt down. Scattered around the rest of the fantail is the DSL-120, Argo, and of course, the winch.

We just finished a cruise, part of the H2O project, about two and a half weeks ago. The purpose of this trip was to recover an old AT&T cable that had been donated to science. The starboard side was left clear to make room to recover the cable, splice equipment to it, test it, and finally re-deploy it. After recovery, the ship stayed hooked to the cable for 4 days while the work was in progress.

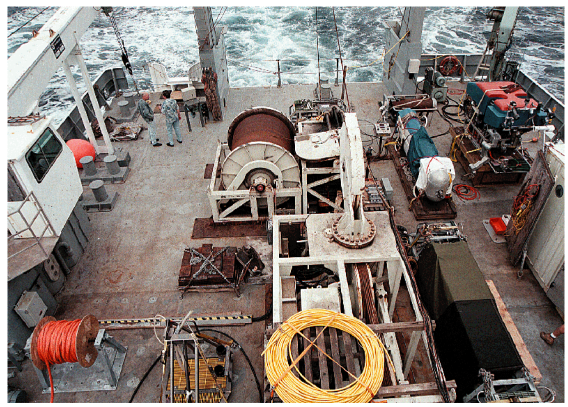


Figure 9: Fantail of R/V Thomas Thompson

Ship requirements have changed over the years. It used to be, back in the "olden days", GPS would be available maybe two hours a day. Transponder launches were planned to coincide with a GPS window. Now GPS is available 24 hours a day, greatly simplifying the act of launching transponders as well as trying to control the ship. GPS coupled with dynamic positioning is an awesome combination. With a well-tuned dynamic positioning system, a ship can be controlled to within a few meters in all but the worst sea states.

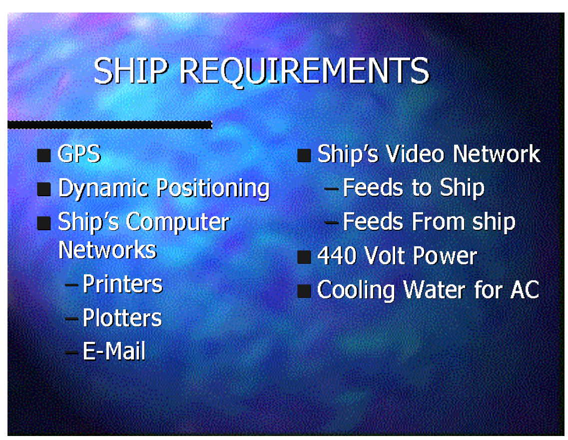



Figure 10: Ship Requirements

The computer networks on ships have become an important service allowing access to ship's printers, plotters, and that all important time sink, E-MAIL. It used to be that breakfast, lunch and dinner were the main things on the ship that you looked forward to. But now that we have e-mail, a new vice exists to vie for our time.

With Jason, it's helpful to have video feeds to the ship. We can supply any number of feeds, with the usual number being 2 or 3. Being able to supply video feeds does several things. It lets scientists set up shop in any of the various labs on the ship and keep track of what is happening on the bottom. It also helps keep "tourists" out of the vans when something exciting is transpiring. We have had as many as 23 people in the vans when Jason is doing work around black smoker vent sites.

Taking video feeds from the ship is an important feature. Today's ships have cameras on pan-and-tilt units that are monitoring the winches, fantail, and various other areas. Part of the safety input into the van is to be able to monitor areas of the ship where people are working, especially around the winch.

Jason and Argo require 440 volt power. Between the vans, winch, and Hiab Crane, the ship needs to be able to supply five 440-volt outlets, the largest service being a hundred amp circuit for the winch. The control vans also require a source of running water for the heat exchanger on the air conditioner units.

Once equipment is set up on the ship, things take on a more orderly appearance. This is the interior of our control vans. Over on the right, with our ace navigator Tom Cook, is the navigation station. In the middle, is the pilot station being manned by Matt Heinz who, incidentally, is also an Alvin pilot, on loan to us to help fill out the watch bill. In front of Matt is a button box used to turn various functions of the vehicle off and on-- things like the cameras, thrusters, lights, side scan sonar, video cameras, the ESC camera, and various other tools. The joystick is used to control an electric manipulator. Also brought into the van is the remote winch handle for controlling the winch. On the far left is the engineer's station where I usually stand watch.

Figure 11: Control Van Interior

Getting ready for launch requires a lot of effort and a lot of paying attention to detail. This is one area where forgetting the tiniest detail, whether it's a cable tie on a wire, or failing to service a connector properly, will come back to haunt you. Figure 12 shows Medea in the process of being launched. The green netting on the side of Medea contains a recovery line. During the H2O cruise we had an occasion to try to recover a piece of equipment that, after about six hours on the bottom, ceased to work. We had to figure out a way, with Jason and Media, to go down, hook a line on a piece of gear weighing about 800 pounds, and get all the equipment back on the surface in a safe and controlled manner.

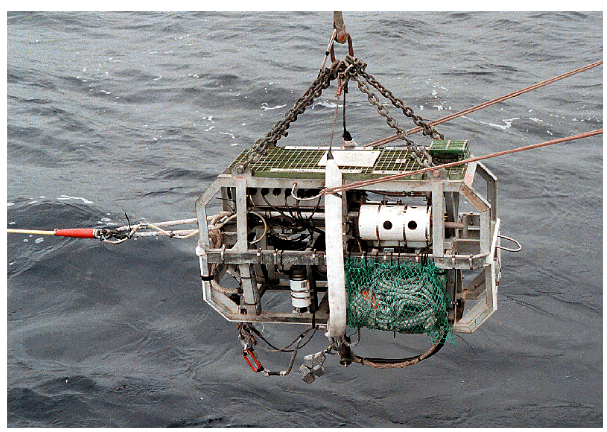


Figure 12: Medea Being Launched

The recovery process turns out to be the most intense operation. The trick is to keep a little bit of headway on with the ship. The stern screws should be disabled to lessen the chance of getting the tether wrapped around them. Once Medea is on board, Jason's tether is brought in hand over hand until the vehicle is close to the ship.

Figure 13: Recovering Jason

Jason is launched and recovered with the assistance of a Hiab crane. It is fitted with a small winch holding 10 to 20 meters of spectra. The A-frame looking device is a swing arrester. During both the launch and recovery sequence, Jason is pulled tightly into the swing arrester, checking the swinging motion, allowing a smooth and safe launch or recovery without the use of tag lines.

Jason is pulled closer to the ship until the lift line that is tied on the tether can be reached. It's already been removed at this point. It's tied onto the spectra from the Hiab winch. With these two lines secured together, the small winch on the Hiab pulls Jason out of the water, snuggling it into the A-frame, checking the swinging.

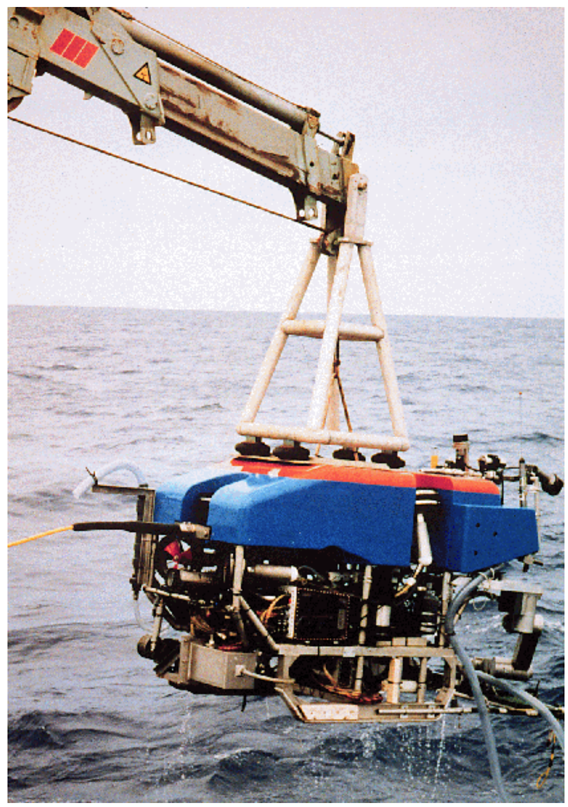


Figure 14: Jason under Hiab

Upon approaching the bottom, the van is transformed into an operating mode, and all the monitors come to life with the various images and data from the bottom. The screen in the nav station on the far right shows the track lines followed to survey the debre field of a bulk ore carrier, the Derbyshire, that sank in 1980. Argo and the DSL-120 surveyed an area roughly 1000 by 2000 meters over a period of 40 to 50 days, taking ESC images and doing sonar work. Jason completed the job by doing some close up work. The middle screen shows a view from Media's downward SIT camera, being used to keep an eye on the tether and Jason. The screen on the left is an Imagenex sonar display--a forward-looking sonar configured on the front of Jason.

Figure 15: Van Interior

Jason, over the years, has had quite an assortment of sensors on it. This configuration is from a trip to the Juan de Fuca Ridge 2 years ago. Figure 16 shows a three-chip color TV camera with a zoom lens on it, real similar to what's used in a baseball stadium. It's a great camera giving great images.

The next camera is an ESC -- electronic still camera -- and it produces an electronic image 576 by 384 pixels. It produces an image that is electronically sent up the fiber optic cable. Jason can bring an image up about once every seven seconds, which includes writing it to tape. During the Derbyshire survey we did, using Argo and Jason over a period of 50 days at sea, 130,000 ESC images were taken of the debris field and wreckage. The cameras near the bottom are two 35 millimeter cameras with film, and they are co-registered to give a stereo image. The two cameras on the bracket are from Deep Sea Power and Light. They are also co-registered to a place about two meters in front of Jason. They were set up to provide stereo TV while flying around and looking at vents and tube worms. Having stereo video while flying around the vent sites gave an added depth to the video data being collected, and also made it easier for the pilot to perform some sampling functions. Up in the middle of the frame, is a pan-and-tilt mechanism, and another Deep Sea Power and Light single-chip color camera that is used as the basic piloting camera for Jason. The pilot has control over it using the pan-and-tilt. It has an electric zoom, electric focus, auto-iris, and a full range of other functions.

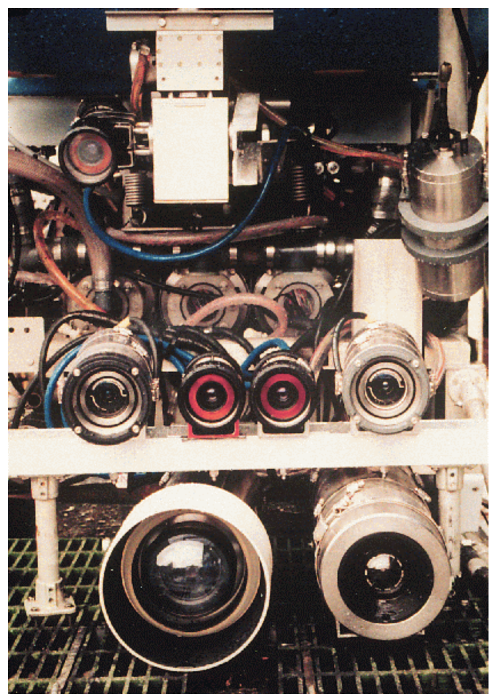


Figure 16: Jason Video Suite

The light bar on top of Jason contains 2 HMI lights, 2 pencil video cameras, the long base line transducer, and the Imagenex scanning sonar.

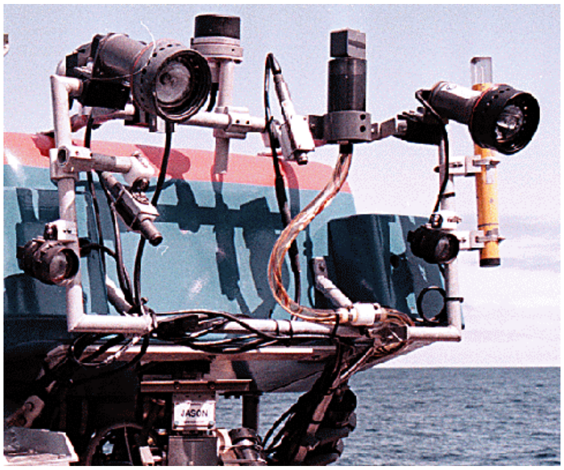


Figure 17: Jason Light Bar

One of Jason's most useful tools is the manipulator. This is a six function electric manipulator that was designed and built at Woods Hole. Its claim to fame is not in brute strength, but in preciseness of control. It can be controlled with various levels of computer assistance from the operator having complete control over each joint to a level of control achieved by defining in space the position of the end effector, and having the various joints position themselves accordingly. Its preciseness is good for trying to insert a water sampling device into a black smoker's orifice, or picking up clams.

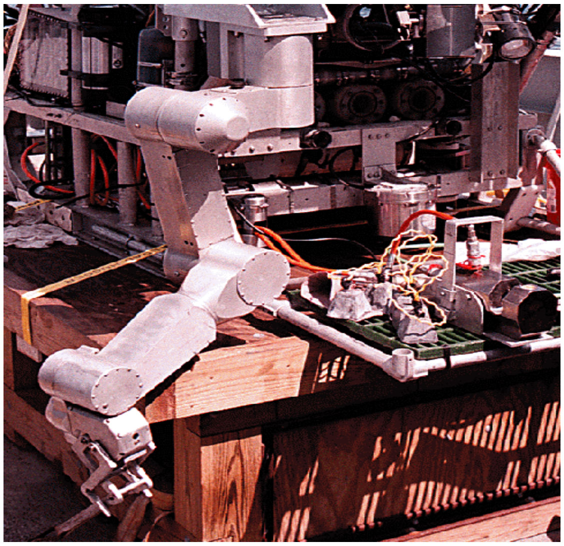


Figure 18: Jason Manipulator

One of Jason's strong points is that it can stay on the bottom for extended periods of time. This feature works fine as long as the data of interest can be sent up a fiber optic cable. However, sooner or later, the scientists want samples. Using an elevator technique, Jason can send up samples several times a day, and likewise, new sampling tools can be sent down to Jason, with Jason never leaving the bottom. Figure 19 shows an elevator that was built at sea. This was used on the Lucky Strike cruise to the Mid Atlantic Ridge two summers ago. It is made with Speed Rail, fiberglass grating material, and has buoyancy provided by Benthos glass spheres. Alvin weights take it to the bottom and releasing the weights allows it to return to the surface. On this particular elevator, some of the sampling tools include small tube cores and bio-boxes, which are basically office trash cans with aluminum lids. One of the major tools for this lowering are double major samplers for getting hydrothermal fluid from the smokers. Other tools include a net for the biologists to gather crabs and other critters. The idea is to be able to deploy the net near a smoker field and hopefully, biology things will crawl into it allowing Jason to retrieve them.

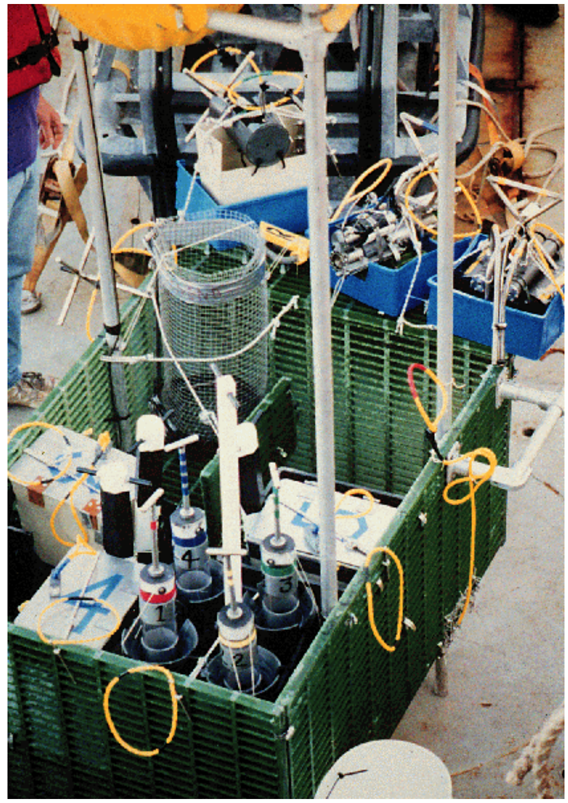


Figure 19: Elevator on Deck

Launch and recovery turns out to rely heavily on the ship's crew as well as the scientists. The ship's crane and an experienced deck crew are definite assets to getting everything over and safely in the water. Once recovery is needed, usually a small boat is used to tow the elevator back to the ship, and then the ship's crane is used to lift the equipment out of the water and get it back on deck.

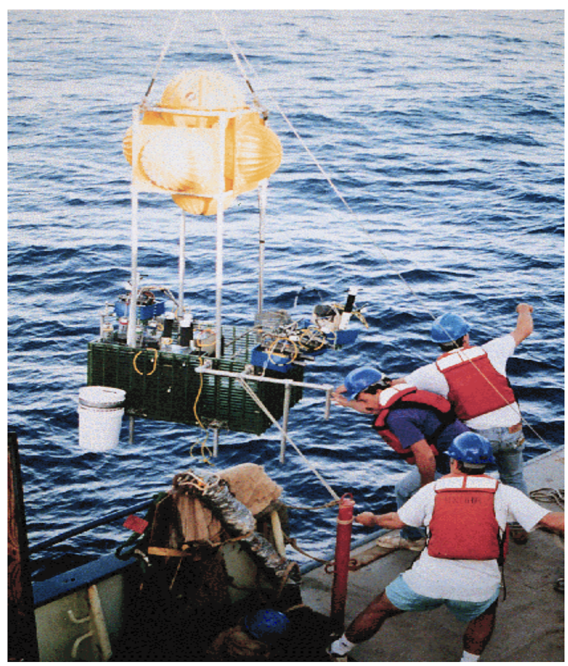


Figure 20: Elevator Recovery

Figure 21 shows a different form of elevator. This elevator was used to recover the amphoras from Roman shipwrecks. Jason's manipulator was configured to gently clutch the amphoras during Jason's short transit to the elevator. This elevator was designed to carry two large amphoras and a host of little ones.

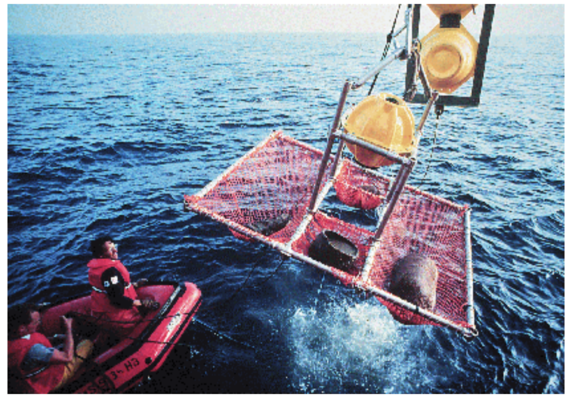


Figure 21: Elevator with Amphoria

While this elevator is being recovered and contents being inspected, Jason can continue its work on the bottom filling another elevator, taking measurements, or doing photography.

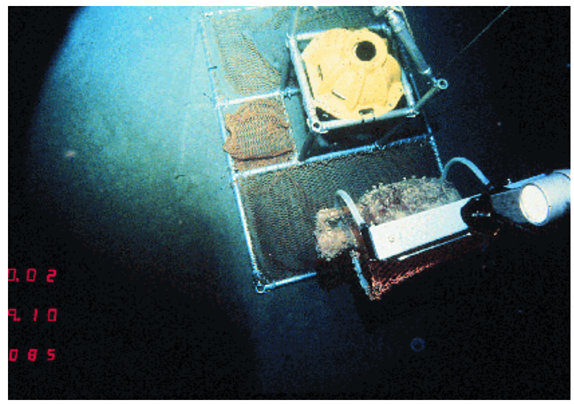


Figure 22: Jason Loading Elevator

Jason can generate a variety of data products. Jason generates basically 2 video tapes per hour of bottom time, 6 ESC tapes per day, one digital data tape per day, plus what ever special sensors need to be recorded. Out of this data, while at sea, we can make a first pass at both photo and sonar mosaics.

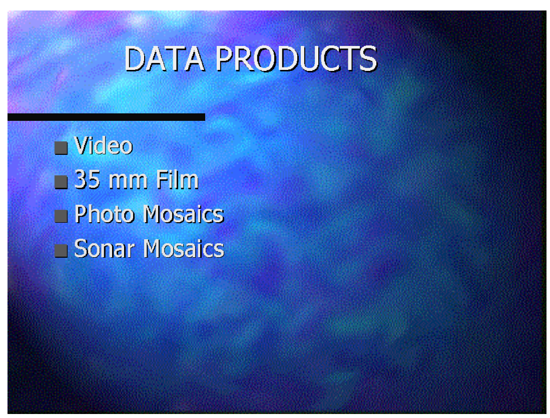



Figure 23: Data Products

In 1980, the Derbyshire, a bulk ore carrier headed to Japan, sank in a typhoon. The wreckage was found by a previous expedition, but for a variety of reasons, not much data was returned. Early last year, the Deep Submergence Lab used Jason, Argo, and the DSL-120 to survey the wreck site. The following two mosaics were made from the data gathered during that trip. Figure 24 shows the bow section. This is a photo mosaic made from about 60 individual ESC images assembled in a computer. Plainly visible are anchors, the windless and an open hatch.

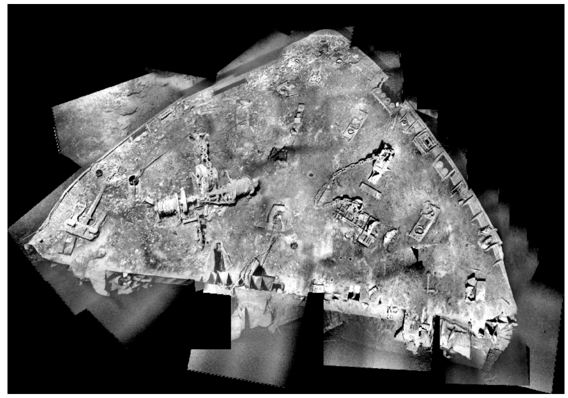




Figure 24: Derbyshire Bow

One of the other instruments that Jason carried on this dive was a HDTV – High Definition TV camera. This camera is outfitted with a 12 to 1 zoom lens allowing incredible detailed views of objects. Figure 25 shows a cross section of a piece of ripped metal from the hull of the Derbyshire. Metallurgists can look at these images, see the grain structure of the metal, and perhaps glean insight as to what failure sunk the ship.

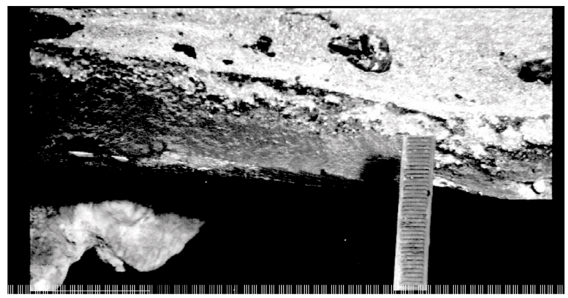




Figure 25: Edge of Metal

A lot of people contributed over the years to Jason. Jason is more than just a piece of hardware full of nuts and bolts and electronics. It's the people and the people working together that make Jason a tool with a great track record of success.


Figure 26: Photo Credits

BIOGRAPHICAL DATA

Robert A. Elder is an Ocean Engineer with Woods Hole Oceanographic Institution. His background is electrical engineering and he has been going to sea doing oceanography since 1981. He spent his first 6 years of oceanography at Scripps and with the balance being at Woods Hole. Mr. Elder states: "To go to sea, put things in the water, make them work, deal with the problems when they don't work, and finally bring home a full bodied data set is very rewarding."

# Recent MPL DEEP TOW Group Seagoing Work

John Hildebrand
Scripps Institution of Oceanography

**[Editor's Note: Following is a transcription of John's verbal presentation.]**

I'm John Hildebrand and I'm filling in today for Fred Spiess. Chris de Moustier has also assisted with this talk. So I'm basically going to describe some of the things that the Deep Tow Group has been doing in the last year or so. This is a list of our expeditions during the last year. Basically, we have tools for doing surveys, near-bottom surveys, and also near-bottom instrument recovery, and placement in particular, in deep-sea boreholes

The first two trips I'll talk about were funded by the Navy. One of them was just a side scan SONAR and photography survey to set up a tracking range off the coast here in the California Borderland. I'll show you some side scan SONAR data that we collected. The improvements of the fish have taken it now to where we have a good kilometer and a half of really nice, quiet side scan SONAR data.

The other things we did for the Navy was to do sediment sampling close to the hull of a scuttled destroyer. This was in the context of the Environmental Protection Agency wanting to see what sort of metals or other materials were leaching out of this scuttled ship.

And then we did a deployment of seismometers in a borehole near Hawaii that's called the Ocean Seismic Network I. It's the first test of what will eventually be a global network of seismic stations. So we deployed seismic arrays in the borehole, and then let them record for 100 days, and then did a recovery.

Also, I'll show some data from a side scan SONAR and magnet survey on the East Pacific Rise.

So to this work, we have a set of tools, the most important being what we call Fish 6 of the deep tow instrumentation package. Each fish -- it's sort of like the hammer that your grandfather owns, where he replaces the handle and replaces the head, and it's still the same hammer. Well, Fish 6 is the sixth iteration of the deep tow package. But it's very much brought up into the -- ready for the 21st century, being a completely digital fish.

We also have what's called a control vehicle, also known as the thruster, which is a deep sea package with the capability of positioning at the bottom of the wife. It's actually -- there are thrusters on a vehicle like Jason, but in that case, it's a more or less neutrally buoyant vehicle. This instead is a heavy vehicle that hangs down on an electromechanical wire, but still have the capability of thrusting. It's niche is more for instrument recovery and placement where the instrumentation can be quite heavy, where the object you're moving can be quite heavy.

We also have a program where we're looking at the crustal deformation of the sea floor. We use what are called precision transponders to make very precise position measurements. We can measure the position at a point on the sea floor to within a couple of centimeters, and also tie that into the global GPS network. So I'll describe some of that work. And then the borehole reentry is related to the control vehicle. That's the vehicle used to place objects into a borehole or recovery from a borehole, or also to make measurements within the borehole.

So this is the generic deep tow instrumentation package. But it's a little bit misleading in the sense that the instrument is very rapidly reconfigured to collect the sort of data that are of interest to that particular PI. So what you see here is -- here's an electromechanical cable, and thus far these have been not fiber optic, but just conventional electrical cables, and then the data are multiplex going up the wire. At this point, we have the digital telemetry scheme, where it's not a -- our conventional -- our old telemetry scheme was as if each channel was a different FM broadcast, but now it's all integrated into a digital telemetry where it's in time sequence, which vastly improves things like cross-coupling between channels.

That's relevant in particular for side scan SONARS. Here's one side scan SONAR, and there's another one on the other side of the fish. With the digital telemetry, you can get very clean and very extended range side scan SONAR images. I'll show you some of those later.

But we also have the capability on this one vehicle of taking photographs. These are a pair of 35 millimeter cameras. There typically are other cameras. I think this is a video camera at the tail of the fish.

Simultaneous with that, we can do penetrating echo sounder. This is a low frequency four kilohertz echo sounder. We have a higher frequency down-looking echo sounder here. Typically now we use a pressure gauge for the instrument depth, but you can also do an up-looking echo sounder to get the instrument depth. There's a sound velocity meter, a transmissometer, and this is the interrogator to do long baseline navigation. So you can precisely position the vehicle within a transponder field to within a meter or so.

And then at other times we've had things like water samplers, or this is a biological sampling net (indicating), although those don't receive as much use as the stuff up on the fish there.

But if you look at the fish as it was in 1970 -- here is an image of the -- this is probably Fish 3 or 4 -- maybe you even know, Bob. But we have a crane, an articulated crane. The basic concept of this cylindrical pressure case with a tail and a protecting frame around it -- so if you compare the 1970s fish externally with the 1990s fish, it's very similar. The basic concept hasn't changed in terms of the configuration of towing. But some of the sensors are different, and certainly the electronics on the inside are different. So the sort of basic concept is very much the same.

You can see the connection here to the wire. There is a fitting that allows us to actually have a positive grip on the vehicle as it comes in and out of the water, and then a set of slip rings here.

If you look at the -- here's what we call a high-ho (ph) crane, is the object we use -- the crane we use to make the lift. This is very helpful in high sea states, as we see here, in terms of not needing a large number of lines on the instrument as it comes in and out of the water.

So here's this articulated crane. Just to show -- here's the typical recovery with the fitting coming up into the crane. It'll be able to hold onto that. So tag lines aren't needed to go from that position outward to bringing it on board because of the mechanical coupling to the crane.

So this is an example of our most recent side scan SONAR data. In this case, it's an image taken near the -- this is just one swath of side scan SONAR. The track of the fish is up through the middle of the image, and you have a left-looking and a right-looking SONAR. Typically, these side scan SONARs ping on a one-second rep. rate, which means that on a one-second rep. rate, you can go out to 750 meters.

This is a two-way sound velocity on either side of the vehicle. What you can see here is that there really is now excellent reflected data all the way out to the edge of the sweep. This is relatively new, and this has to do with the fact that we've gone to the digital telemetry. But those of you familiar with side scan SONAR, that's a really excellent ability to take the reflected image all the way out to one second at this sort of near-bottom configuration.

The other thing that we've focused on lately is doing higher resolution magnetometry. This is a case in 1995 where we wanted to look at the difference between towing magnetometers at various heights. Part of the motivation was to see how well you could upward continue the magnetic signal from a level near the sea floor to a higher level. So we had one magnetometer that was directly aft of the deep tow vehicle, and another one that had its wire going up the .68 electromechanical wire, and then was towed aft of that.

I'll show you an example. Again, there's a magnetometer at the surface that everybody's used to. I'll give you an example of the sort of data we collected with that. This is now a map, and you can see from the latitude it's up near the Juan de Fuca Ridge. It's just south of the Juan de Fuca Ridge off the west coast of the U.S. The red trace is what you'd see from a magnetometer that's towed at the surface of the ocean. You can see that it's very much a smooth version of what you get from towing a magnetometer near the sea floor.

The designations here, the magnetic anomalies -- there are a sequence of polarities in the earth's field where -- we call a normal polarity the same polarity as the earth's field is now, and we call the reverse polarity when the field is generally flipped. People have recognized that within these large blocks of polarity -- they number them, number one being the current normal polarity. So number five -- you go backward to the five. It's the fifth back in time of normal polarity.

People have recognized that, when doing the surveys near the surface, near the -- at the sea surface, that there are these fine-scale fluctions within even the normal polarity. Steve Candy coined the term "tiny wiggles." So the main polarity is the big wiggle, but Steve Candy coined the term "tiny wiggles" for these little fluctuations that he could see in the surface data, and even gave them a series of numbers. So here's 5.1, 5.2, 5.3.

And the purpose of our trip was to see if we could understand in more detail what the origin of those tiny wiggles were. When we put the magnetometer near the sea floor, the signal we see -- and there are a series of tracks here -- is this black line. You can see that several even of the tiny wiggles within the broad normal polarity break up into a series of fluctuations. These fluctuations, especially if you look at the lower figure, you could see that they're very well correlated over quite some distance along the rise axis, which gives you a sense that it's not just a local phenomenon in terms of a particular rock type or change in the magnetic properties, but in fact that you can correlate these, we find now, globally. It's telling us that this is a record for the fluctuations of the earth's field.

And the $64 question that we are still struggling with to some extent is: How many of these things represent actual full-scale reversals of the earth's field, and how many represent a case where the earth's field just diminished in intensity, and then came back in intensity. So something like this you have a pretty good sense that that was a very short reversal. But when there's just a little fluctuation like that (indicating) --

And it's a matter of scale. As you get closer and closer to the source rocks, and also higher spreading rates, then all of these wiggles get spread out so you get a higher time resolution. But this is an example of how -- of the strength of a deep-towed magnetic survey, as opposed to a survey they conducted at the surface -- how much more you learn about the character of the field.

Now, the other vehicle I'd like to focus on today is what we call the control vehicle or thruster. This was developed as a means for putting instrumentation into and getting instrumentation out of boreholes. Its key aspect are a pair of perpendicular saltwater thrusters. These are hydraulically operated. You can see little -- the propeller. There's a feathering of the propeller in these two units, and then there's a hydraulic pump and oil supply.

What this does is this gives us the capability -- you can see it's sort of designed to be a long, narrow instrument. What it does is it gives us the capability of positioning the bottom of even a very long wire. Even a six-kilometer wire, within a hundred meters of the hang-down point, you can, with the use of these thrusters, position the bottom of the wire.

Now, because all of this -- this is a heavy object, and it's supported by the weight of this heavy wire. If you want to pick up something heavy and move it or position it very carefully, this is an ideal object because you don't have the limitations of the neutrally buoyant vehicles like a Jason. So there is a niche for this type of vehicle.

We've also done the same trick of adding a bunch of sensors. And it's a little bit hard to see in this particular image. But, for example, there's a scanning SONAR here at the bottom, and very typically there are cameras near the bottom.

An example of one thing that we've done with the control vehicle is our project to measure the motion of the sea floor, the crustal deformation on the sea floor. Now, we've been working in the Juan de Fuca Ridge area.

And this is a place where, if you -- the Juan de Fuca Plate is a completely submerged plate. So to know how that plate is moving, you can do it indirectly by looking at how that plate moves with respect to the Pacific Plate, and then how the Pacific Plate moves with respect to North America. But it's sort of a circuitous route to learn about what is a really important plate, because its rate of convergence with North America sets our expectations for great earthquakes in the Pacific Northwest along the Washington/Oregon coast. So we wanted to set up a situation where we could directly measure the velocity of the Juan de Fuca Plate.

So the first thing, we developed a set of what are called precision acoustic transponders. A conventional acoustic transponder will give you a range, an acoustic range, that's accurate to something on order of a meter. But because the Juan de Fuca Plate is moving at around four centimeters a year, we needed accuracies on order of a centimeter for acoustic ranging. So the precision transponder has specialized electronics to deal with that, and it has to do with eliminating the latency in the response of the transponder. Transponders will respond more rapidly or less rapidly depending on how close you are to them, and the precision transponder gets rid of that. And the other thing is to use a phase-coated pulse, as opposed to just a normal CW pulse.

So once we have these, we needed to make a very precise measurement of the depth of an object. So we created a package that has a series of pressure gauges. It actually has four pressure gauges that are compensated for dynamics. Those of you who use Parascientific pressure gauges, it turns out that the reading that it gives in a static mode is fine, but in a dynamic mode, there are other effects. And so we've combined a series of pressure gauges to take out the dynamic effects.

But we wanted to be able to calibrate those gauges under pressure during each lowering. And so we created a series of cement benchmarks, and we physically take the pressure gauge and this interrogator, which talks to the transponders, and we put it on a benchmark. The benchmark is about a meter in diameter. So we would use the thruster to really carefully position and set our pressure gauge on the benchmark, let it sit on the benchmark for a few minutes to calibrate, and then go off and do a survey within this field of transponders.

Now, let's see. This is a little bit more detail on our Juan de Fuca project in general. Here's the Juan de Fuca Plate I was telling you about. There are no islands. There's no surface expressions of the plate. Here's the Pacific Plate and the North American Plate, and we're looking at this, the zone between the Pacific and the Juan de Fuca Plate and the spreading access here. This is called the cleft segment of the Juan de Fuca Ridge.

Currently, we have a series of transponders, a trio of which ride on the Juan de Fuca Plate, and another trio of which ride on the Pacific Plate. So the plate boundary comes right down between here (indicating). But -- "Is that really the plate boundary, or is it distributed? -- is another question.

And then we have planned -- we have benchmarks within this, but we have planned to monitor the entire segment, a series of benchmarks, that would tell us also about the vertical deformation of the ridge.

Now, you say, "That's all fine, but how do you locate that in the global coordinate system?" And the really powerful way we have of doing that is with GPS. Everybody knows GPS as used on the ships in terms of precise positioning. But what we've done is we've taken the reception from GPS, and instead of collecting it on a single antenna on the ship, we collect it on a trio of antennas. So now we know not only where the ship is, but the orientation of the ship. And if you do that relative to a fixed station on land, you can actually locate the ship with a centimeter or so error. Then, by knowing the relative position of this trio of GPS antennas to an interrogator that's at the bottom of the ship, and using the ranging to the precision transponders, we can make a connection from the global coordinate system, which is GPS, to the sea floor, which is our fixed transponders.

So with this, we've been able to see the motion of the Juan de Fuca Plate. And, in fact, it is converging with North America. Although what we see is a convergence that's a little bit more to the north than straight east-west, as had been predicted.

This is an image of the New Horizon, the ship we've used so far for doing this work. You can see on the mast of the New Horizon we mount a crossbeam and put two GPS antennas there, and also we use a series of guide wires to stiffen the mounting. Then we have an additional tower with a GPS antenna here (indicating), and that trio of antennas allows us to do the orientation of the ship. And then there's a well that goes through the ship, and at the bottom of the well, we have our acoustic interrogator. So we can stand at the top of the well and simultaneously survey in all three of the GPS antennas and the interrogator to know their precise relative positions.

So the other thing that we've done with the control vehicle, which is in fact the origin of its creation, is to place objects into deep sea boreholes. There are several ways you can go about this. One is that the control vehicle -- we have a tool for logging the hole itself; that is, collecting information about the shape of the hole, about the temperature of the hole, collecting water samples in the hole. And so you can take the control vehicle and just reenter the hole to learn about the state before you put anything into the hole. That's a good idea, especially if you're going to put something expensive like a series of seismometers and a recording package.

The other mode is we can have some sort of objects that's sampling or recording information in the hole, and we can hang onto it and record data directly up to the ship from the hole using what we call a soft tether. And the soft tether is just a pliable -- it's a rope, basically, that we've woven conductors into the rope. And with this, we've stayed on station for as much as a week recording data from instruments down in the hole.

The other mode is to have a package that's a self-contained recording package. This is more like what you would use on a deep sea seismic station that you're going to leave and let record for a year or six months of data -- in fact, what we did on OSN-1, where there's a large recording package and then a series of seismometers that go down the hole.

Here is the scenario that we accomplished on the OSN-1 project. We had the control vehicle with what's called a BIP, or a bottom instrumentation package. It's just basically a large battery and data recording package, 300 meters of space, and then a very broadband borehole seismometer that went down to the bottom of the casing in OSN-1.

Then for some period of time we recorded data directly up the wire. Then we let it go and let it record data on its own for a hundred days. And then we came back and hooked it and pulled it out of the hole. In fact, all of that worked very well.

Here's a picture to show the size of some of these objects. This is the BIP, or the package that actually sits in the reentry cone and has pressure cases to record data and also batteries. And here you see the reentry probe, just the top of it, in the process of being launched. The probe is what we use to do the logging of the whole -- here's a somewhat better picture of the probe. There's a camera at the very bottom, so you could see the cone itself and do the reentry. They're a set of calipers. These are three-armed calipers that open up to measure the diameter of the hole. There's a temperature sensor and a pressure sensor and acoustic transponder to navigate it, another set of calipers. You can break this open and put other instruments, for example, there's a water sampler that Joris Gieskes has developed that goes into that, as well.

Just as an example of the sort of data we collect, this is not in OSN-1, but in the hole in the Atlantic, 534A. In this case, if you look at the temperature profile, here is the temperature in the water just above the hole, and then there's a jump in the temperature, and here's the profiler going down the hole. Now, this is very important to the seismologist, because what this temperature profile screams out is that, in fact, hot water is moving up the hole, which is exactly what they don't want. They want a hole that's very stable. So this is a source of noise for their seismometer.

So this is an example of how the logging of the hole feeds into the understanding of whether it's a good place or a bad place to put seismometers.

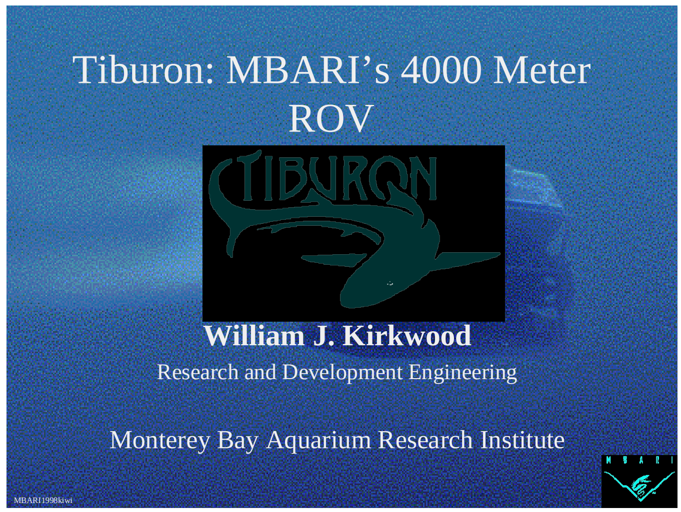
So anyway, that's my sort of quick overview of what we've done in the last year or so in terms of deep tow instrumentation. It's a slightly different niche in terms of the thruster being able to move and position heavy packages, as opposed to neutrally buoyant objects. Anyway, we're open for -- if any of you have heavy packages you want to position or instruments you want to recover, we're open to talking to you about it.

# TIBURON: MBARI'S ROV For Science Research

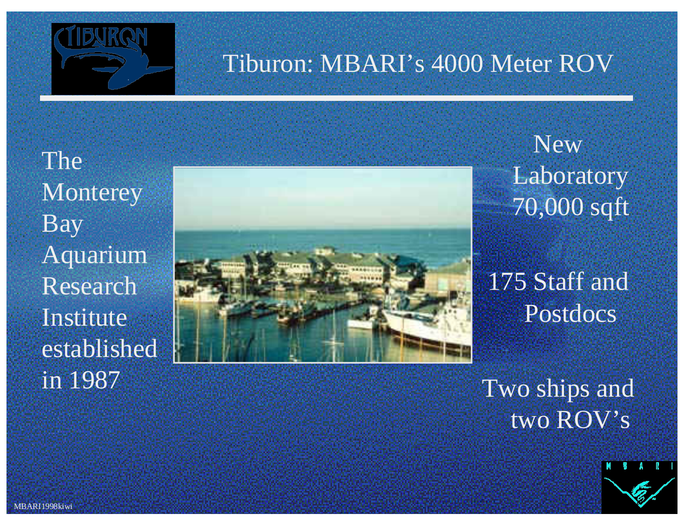
William J. Kirkwood
Monterey Bay Aquarium Research Institute

Hello. I'm Bill Kirkwood. I'm temporarily the director of engineering at the Monterey Bay Aquarium Research Institute. Prior to that, I was the lead mechanical engineer on the design of Tiburon, and the project manager.

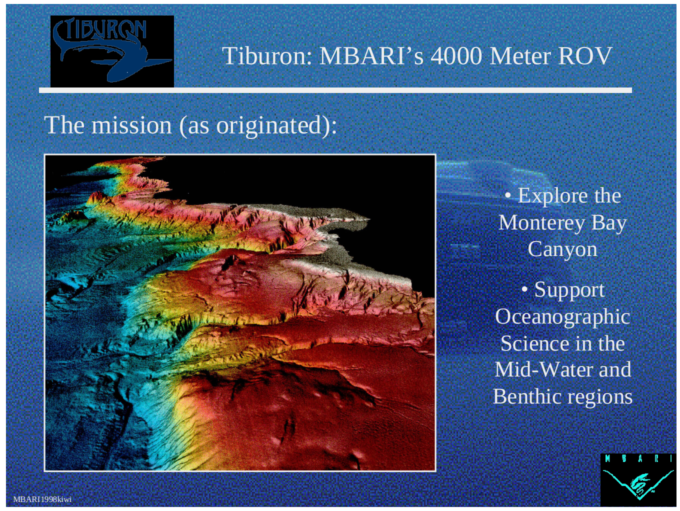
Tiburon, as the title shows, is a 4,000 meter vehicle. It was actually the concept of David Packard. After the aquarium was built, he determined that technology was in short supply for oceanographic work and so he went about creating MBARI.




A little bit about us for those who don't know anything about the history of MBARI. We're located is Moss Landing, which is at the deepest part of the Monterey Bay and at the head of the canyon.

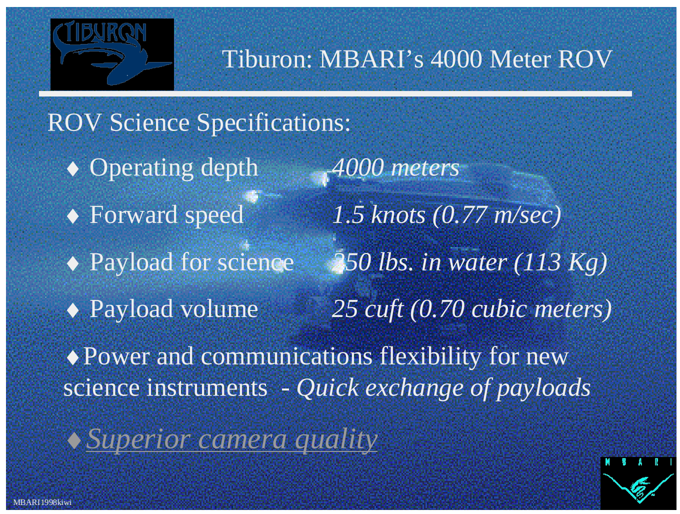


So right up here is Moss Landing (indicating), and this is the Monterey Bay, and so this is the Monterey Peninsula, and Santa Cruz, and so forth. You can see the size of this canyon. It's about equivalent to the Grand Canyon. In fact, if I understand things correctly, it was actually part of the Grand Canyon at one point.



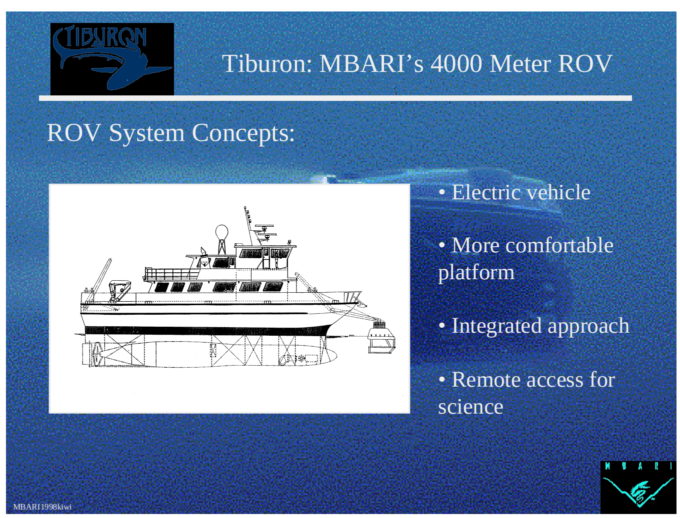

The big difference in why we went to Tiburon was with the industrial vehicle that we started with, and some of you may know about it, Ventana, it's actually limited into somewhere in this pinkish region here, this maybe tan region (indicating). It's not a very deep vehicle. So the idea was we needed to get access out here and see the whole thing. That was where the 4,000 meters comes from, as opposed to 5,000 or 6,000, as many vehicles are rated at.

Today we've expanded our base of operations to actually go quite a bit out of the Monterey Bay, but the full canyon was really the original goal. We've actually done some work out on these sea mounts already.




Here are some of the specifications that were originally set forth, one thing that's different about Tiburon was it was specified by the science staff at the institute, which we had reviewers come from outside the institute and comment on. In fact, some of them were from here at Scripps, also Woods Hole and several other places -- MIT. Many of the Jason crew had a lot of input, and we followed a lot of their leads. So this is some of the information about the vehicle. It's really very general.

The main thing in the requirements here is this camera quality. The main tool that scientists use right now from these ROVs is the video imagery.

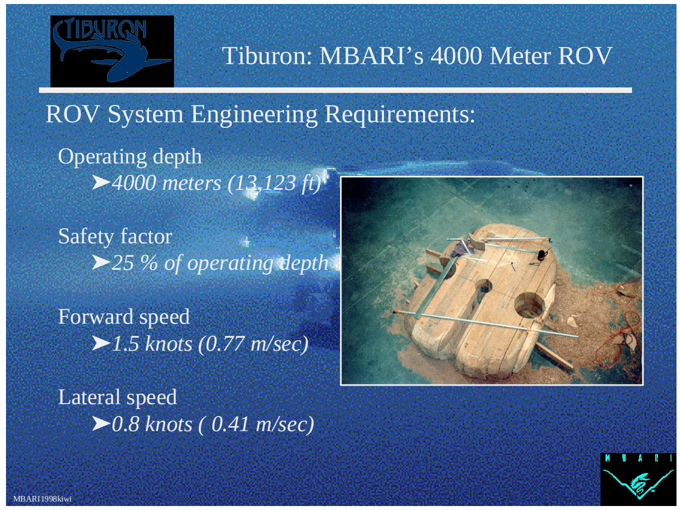



The other thing that we came up with was the use of a SWATH ship -- the Monterey Bay is kind of an uncomfortable place to do business. It's got a long swell to it, and it gets a lot of people seasick. So the other thing that we decided to go with was a swath vessel. Some of you may be aware of the problems we had with ours. But it's an excellent platform, actually.

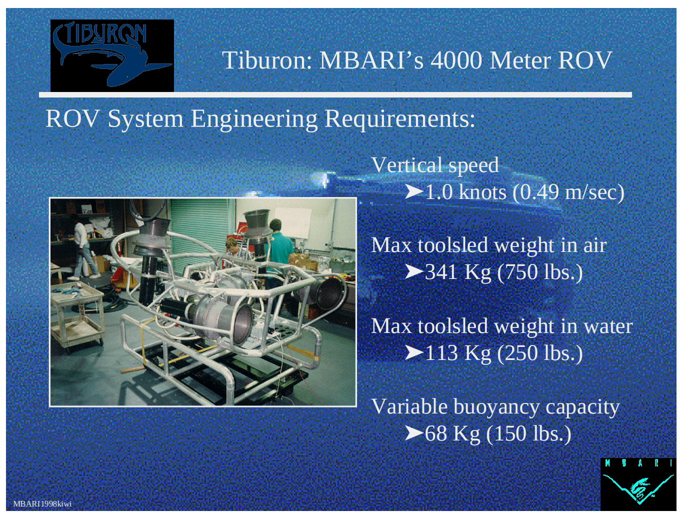
This was the original concept, launching over the bow to keep it out from between the hulls and so forth. And then after the review, we decided actually to launch through the center of the ship, which I'll show you in a bit.

So we went through and we decided what we would do with some of these requirements. For instance one of the things is, everything on the vehicle has been tested to 5,000 meters. So in reality, because we're using titanium, we could go quite a bit deeper. We did change, if I recall correctly, the lateral speed just a little bit and so forth.

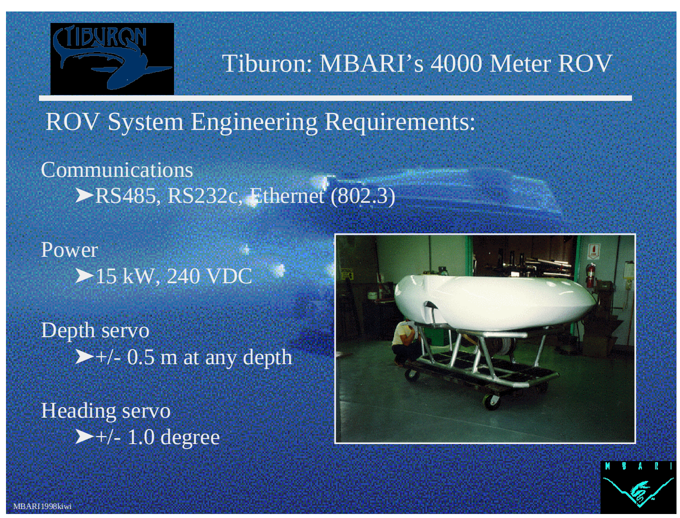
One of the things I've thrown in the presentation is a picture showing these stages of development, because the vehicle was actually quite a bit different than anything that we had done, we built a prototype. So a lot of the key systems were protoytyped in aluminum, and we did a form pack in redwood and so forth, to test it out.




We did a prototype assembly also locating all the thrusters. And what I'm trying to show here is that all the thruster lines actually cross to a center point. So what we did was go to great lengths to make sure that everything is centered off of a key point, which carried over to the final vehicle. Both the ship and the vehicle have points that way for reference and control purposes.



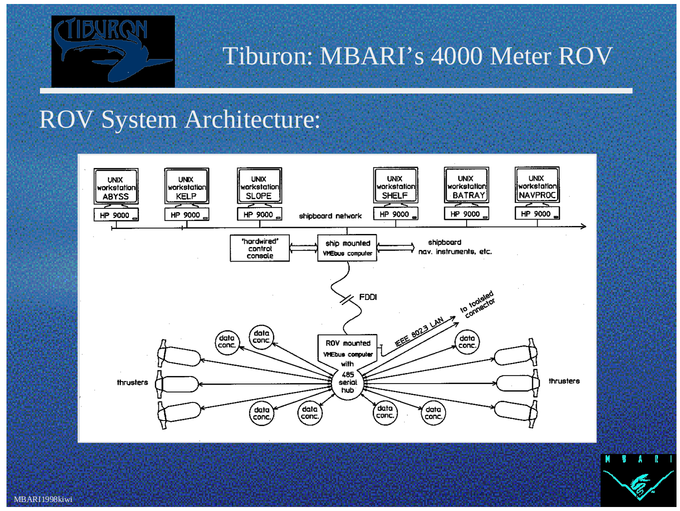

We offer quite a few different communication standards. At the time when we were doing this, instrumentation hadn't been particularly standardized. It turns out that the RS485 is becoming pretty standard across industry. So we offer communications in a lot of different flavors and we do have the others than RS485 available.




The power is delivered to the vehicle by tether. At the top, we actually run about 25 kilowatts, and then we have about 10

Kilowatts lost in the power transmission.

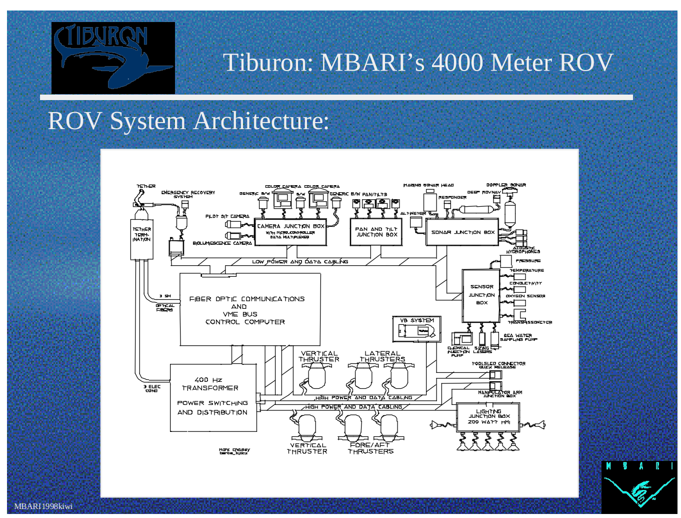
I'm going to get into the technology. One of the other things that we wanted to do was take advantage of the new technologies coming along. This was back in the late 80s and early 90s. The Internet was obviously going to be a big player. The vehicle was actually designed to use an architecture around the computer network concept using a hub and spoke, and then all the instruments and the motors are actually placed as nodes on the net. This has all gone up through our own FDDI, and then we have our own control shipboard network, and it connects to the shore either by copper at dock or microwave over a 20 mile distance from shore in the Monterey Bay. So, for instance, if we had a computer here that was on the internet, and the vehicle was up and running, we could operate the cameras from here. It's actually been a lot of fun and a very helpful way to do things as you have problems to debug.




The major topic from this is as we decided to go with this kind of an architecture, that had an impact on everything else, mostly because the cabling becomes predetermined. Then we had to go through how we were going to multiplex everything going up and down. What we went with was three fiber optic lines. We actually use one and a half right now. Then we have a duplicate system on the top and on the bottom for mux/dmux.

The other thing that's important about this is we decided to go with this VME bus on both ends. We went with that because the cards were standard. You could buy a lot of material at the time, and you could get the computer back-planes and so forth for a real-time operating system off the shelf. So to keep the cost down and to make things work a little bit quicker, we decided to go that way.

We do have several cameras on the vehicle, but we can only run seven simultaneous video channels. You can switch between the cameras and do as you wish, but you can only run seven actual channels at a time.

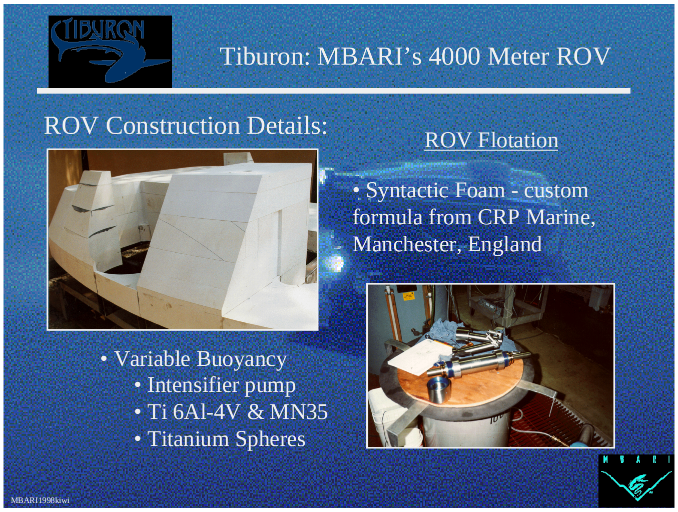



This is the vehicle architecture. The thing that's interesting here is if you look at this picture it looks a little bit different, but it's actually the same star configuration of the network. So we come down through the tether and we actually split out the power and the fiber optics. You can see each of the thrusters is a node, and then these are what we call "data concentrators." I think they were called "De-cons" or something in the previous slide. Each has its particular functions.

What this allowed us to do is have switching and control capabilities on every element in the system. So if a scientist comes and brings in a new component, we then have individual switching capability built right in with the data concentrators. The data concentrators are themselves actually a small computer, and they multiplex everything at that level, then they're polled on a regular basis to transmit the data.

The thrusters run closed-loop. They have a microchip in them, and so you just send them a command, and they send you back a healthy status flag regarding the last command.

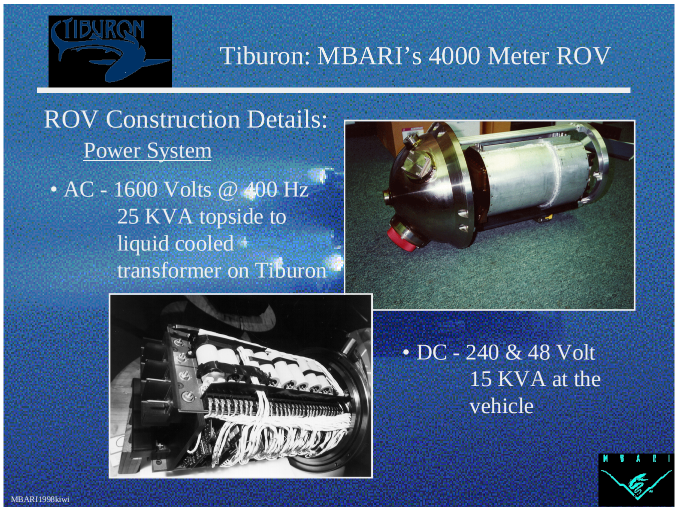
In constructing the final vehicle, we wanted to try and push things a little bit, and so I went to a company called CRP, and they developed a custom syntactic foam. This foam is all done in individual sheets that are built up and shaped. These sheets are each tested and so forth, and they're actually planed down and cored so that they have a very consistent performance capability to them. It's a really nice technique, but it is expensive.




The other thing that we went with was this variable buoyancy pump. I looked in the Alvin documentation and they had a ceramic-type pump, which is prone to cavitation problems, which can crack the pistons. Our solution is actually a an MN35 intensifier design with a titanium housing. You can cavitate it all you want. I've never had the thing apart in six and a half years. It's quite robust.

This allowed us to change the buoyancy of the vehicle and pick up heavier packages. The VB system is used mostly in flying along the bottom where there's silt. You can take away all the vertical thrust for the pilots, and that gives some great imagery.

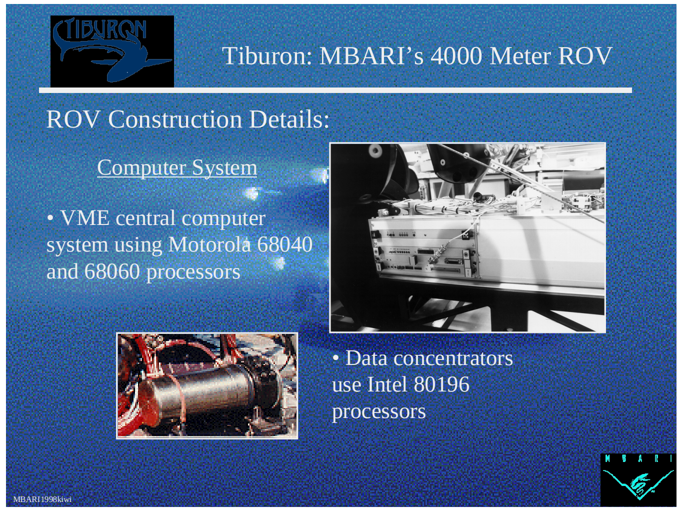
The power system is kind of special, too. It's divided into two halves in about a three and a half foot long can. This side over here is the AC side. What you're looking at here is a tank. Inside that tank there's a set of toroids. There's three for the main power bus and four for the 48-volt bus. They're liquid cooled. We use a florinert liquid which we boil off. It comes out the top here, cools and then flows down the sides. The titanium housing is cooled by the ocean. This black section here is volume displacement, so you don't have a big pool of liquid at the bottom. Then it's pumped back in by these custom built isolated pumps. The whole thing is rubber-mounted so the 800 hertz noise or hum, the result of 400 hertz cycle magneto restrictive problems, is isolated acoustically from the ocean. This was done for a biologist who required having it quiet. As you can see we've gone to some great lengths for the science specificaitons.




The DC side uses a blind connector that goes in the middle. This is a liquid barrier right here that, when you push it in, it seals up. This is the blind connector. On the DC side, this is the filter board. This DC rack is actually a plenum design. So the air is circulated through, out the cards, around and back over the top.

Each of these cards has a various configuration. Some are called high power switches. Some are low power switches. So we have 48-volt, 240-volt DC, 24-volt, and the whole 15 KVA is controlled through here by the computers on the vehicle.

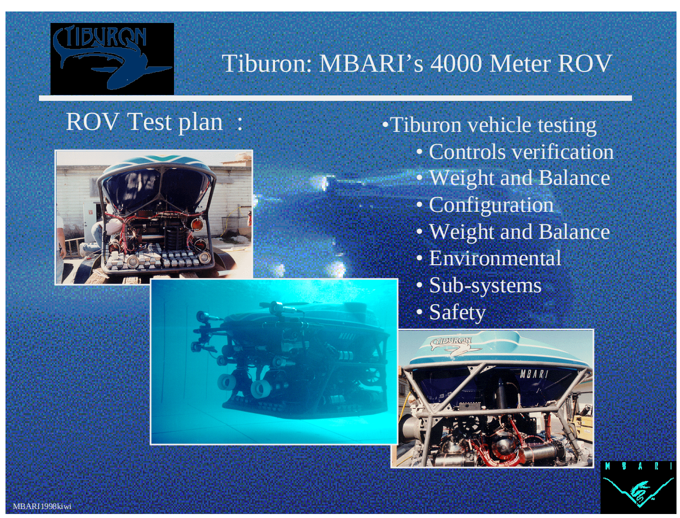
This is a little picture of a VME chassis. We used a 6U European back plane because of the shape factor. You can see we have some expansion still left in the rack. This is where the Grass Valley video cards eventually went.




The thing that's nice about this -- as you can see here, the VME chassis is on a rack that slides out. The other thing that we did, because most failures on ROVs are connector-related, and most of our problems are water somewhere you don't want it, the entire vehicle is able to be pulled apart and worked on without breaking any connectors. So if you have a problem, you can isolate it very quickly.

This is a data concentrator. It's just a standard titanium can with an oil-filled junction box. These little rubber grommets here are where you poke through and put in the cable. So if you come out -- with the card mix that's inside and can be customized, it can have any of the communication standards or power standards available for a scientist. Some of these processors are now out of date, and we have to update them in the future.


Unfortunately, I didn't have a good picture of the cameras, but we do run two three-chip color cameras. They're both Panasonics. We chose those because they do have a high gain margin. So we were able to play some gains instead of having a SIT camera or silicon intensified camera. We did away with the SIT. So we only use these color three-chips for main vision.



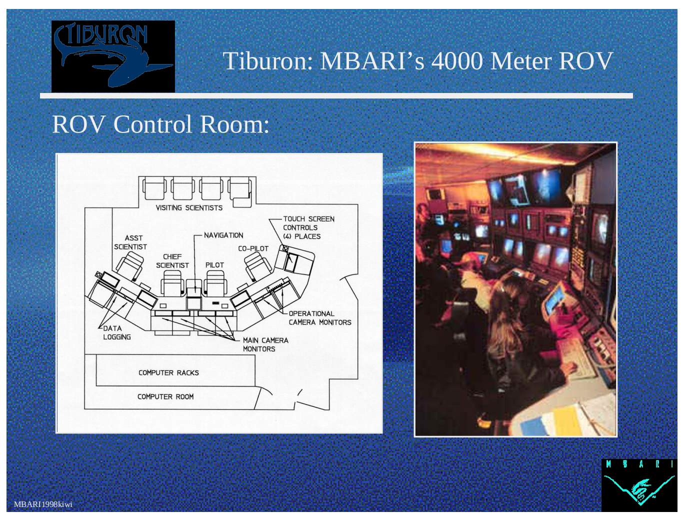

And then we went with Deep Sea Power and Light HMIs. We actually had had some Birns before, but they didn't make depth.

In our test plan, this was the configuration we used for tests. As you can see, it changed over the period of testing. We added equipment, we went through this incremental process. This is one of the nice things about the integrated design, that is things are nodes on the network, and you can just plug them on one at a time and build up the system's complexity.

Here you can see the two color three-chip cameras. Up here are the lights, they're on pan-and-tilts. We have a system called "I-View," which I'll get into in just a little bit here.


The ship, now this is the big one for us, the ship design is a swath ship, as you can see. It's a small water plane area twin hull. Right in the middle here is where we launch the vehicle. That was chosen because that's the active point of the ship. So we have the cable running right through the centerline of the ship's motions. That was done purely for camera work, our reasoning behind it was to take out cable motions.

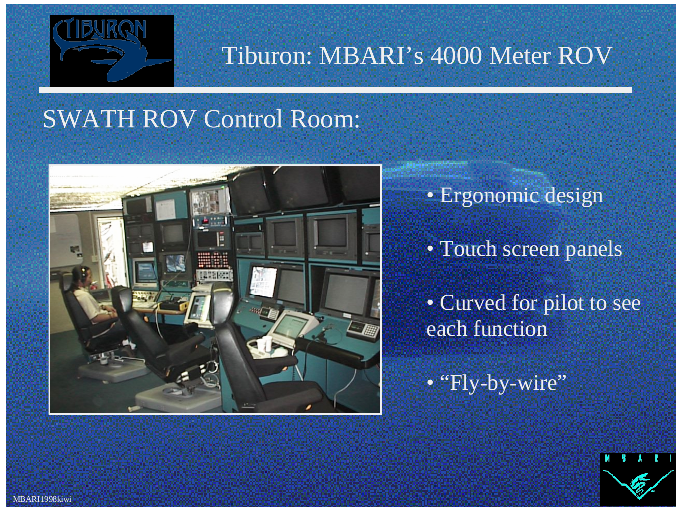
The control room. Notice it looks a little bit like Jason's -- a lot of TV screens and so forth but it is slightly different. We have four individuals working it, so we have a co-pilot located over here. That's about the same function as the engineering function on Jason. They handle tether management and operation systems. There's the pilot sitting here. He actually flies the vehicle, it's a fly-by-wire system which is on the chair, and the pilot just uses a regular flight joystick for that. On the joystick thumb controls is the camera system. Then the chief scientist sits right next to him.



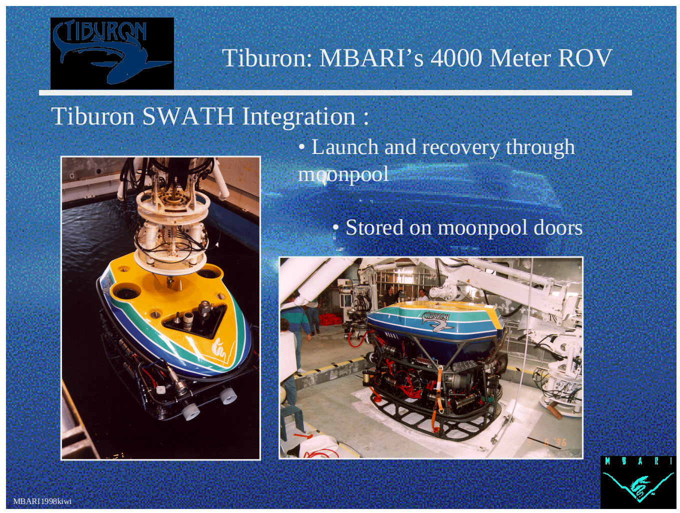

Now, above here, you'll see there's some monitors. We can do a panoramic kind of viewing. That's for the visiting scientists.

The reason that we've done all this is that the I-View system allows some very unique viewing capabilities. We have the ability to have the two cameras operate together, to operate with a permanent offset, or to operate independently and a light will move with each of them. If you remember, in the design of the frame, it looked like there was a large cutback from the nose on Tiburon. That was so the camera can look down the side of the vehicle. So we have well over a 200-degree viewing angle from the front of the vehicle.

Then we have the assistant scientist, which is this position right here.

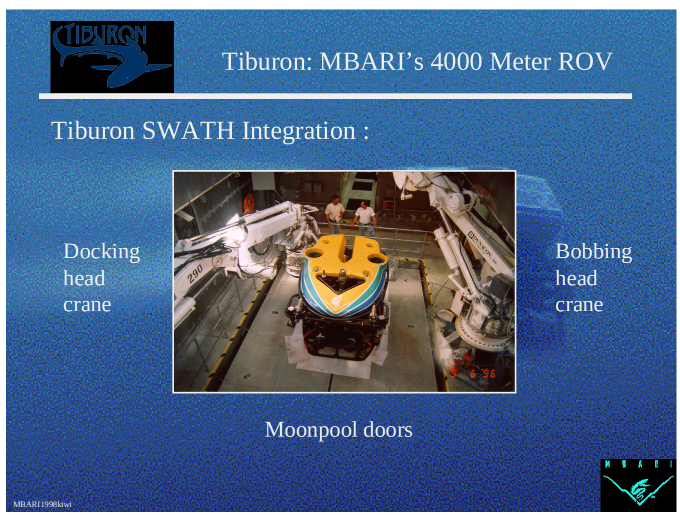



The other thing to look at is most of our controls are done on a touch-screen display. What we have is several GUI pages, and then we have the hard-button panel as a backup, the main computer here and this is that bank of monitors, and then we have the two cameras running side-by-side. In the center here is the NAV system.




For launch and recovery, we use this large docking head. We went with something that was a little more complex than usual so that when the vehicle’s pulled up and snugged, it can be rotated while it’s down below the water line, or down below the wet deck. The reason is if something should get stuck below the moonpool, the moonpool to the vehicle size is very tight. If an arm, for instance, should be stuck out in a position, you really couldn’t get it back in without lowering it and twisting it. The system has been automated and put on here for the operations people.

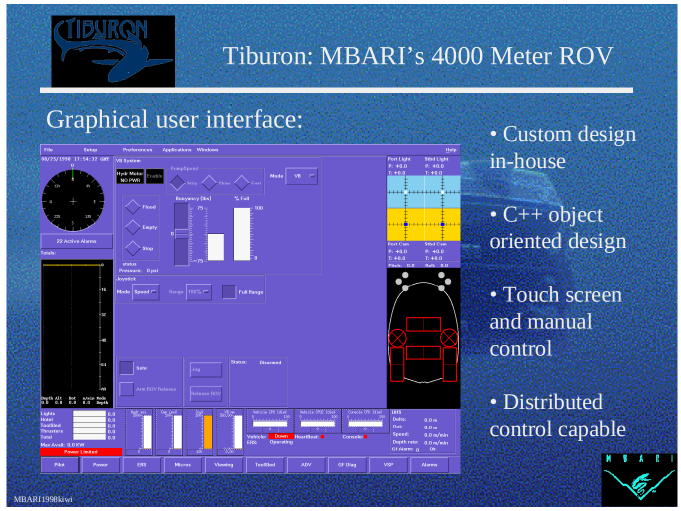
You’ll notice Tiburon sitting here on the moonpool doors, they lift the vehicle up and they accordion out of the way, I’ve got a little bit better shot here in a second.




It’s quite a tight area. This ship is not very big. What we have here is the docking head. This sits on top of the vehicle here, lifts the vehicle up, the doors open, and then this is the bobbing-head crane. If we have time, I have a video that’ll show that in action. The bobbing head crane takes out the vertical heave from the swath ship, which is the motion that’s left in a swath ship.

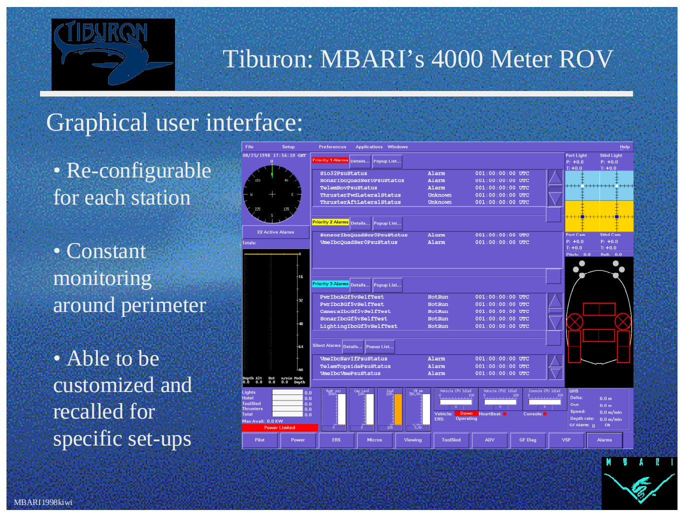
This is one of our GUI pages. The GUI was all done in-house. This outer edge here is the standard operations screen that's always up. The center here is something that changes based on these buttons down at the bottom. You can add your own as a scientist. You can have custom GUI pages for your gear done, and then bring them up and operate them from your station.

Each station -- there are four of them, as I pointed out -- has its own screen, so you can run your own GUI. This one happens to be the VB system showing the levels and the control slider pump in and out water.

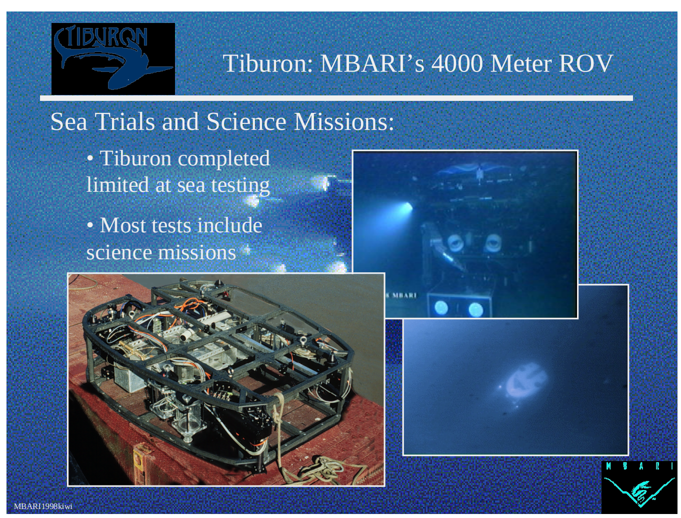



The other thing that we have with the vehicle GUI is quite an elaborate alarm scheme because it's such a long trip to dive depth. It takes about two and a half hours to get down. This is an alarm status page. We have various levels of alarms. We have quite a lot of monitoring on the vehicle so that a pilot can decide whether to cancel a mission. It's a real expense to get down and back, and what's the point of canceling it if you don't need to.

So we have monitors like a constant ground fault detection on all the instruments. Because of the system is constantly working, you can just shut down equipment if it has a ground fault and continue with the mission knowing the conditions.

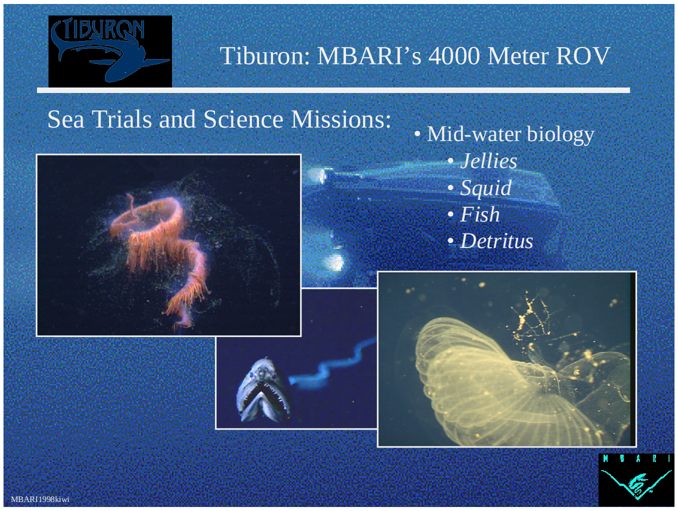



So then on to tool sleds. The bottom third of the vehicle is interchangeable. This toolsled happens to be a mid-water toolsled. You can see some Detritus samplers here on swing arms which swing out. There's a few on each side. This is a carousel in here with 12 vacuum samplers. There's a little pipe that shoots out here, and they vacuum up the animals. If some of you have been in mid-water biology, you probably recognize this from Harbor Branch. It's basically their design.




This notch in the back -- I didn't have a good picture of the back of the vehicle, but we do have an ADCP for Kalman filter work and control. We can do recurrent profiling, bottom tracking, and so forth, for science with this system.

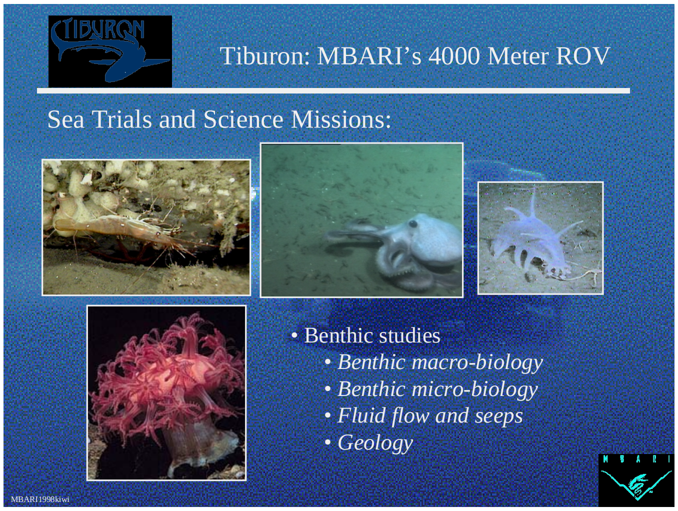
So some of the missions that we've been doing are in the mid-water, we're doing a lot of stuff with the siphonophores in the Monterey Bay. I threw this picture in because he's our logo (Gulpper Eel). There's all kinds of these salps and jellyfish and so forth that are quite interesting.



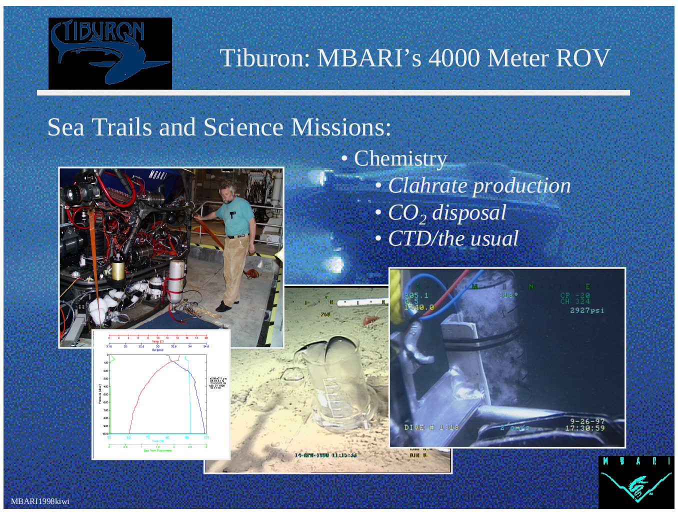

On the bottom, there are all kinds of little animals and critters running around. This is a Carmel shrimp -- "Monterey Bay shrimp" sometimes they're called, some soft corals and so forth.

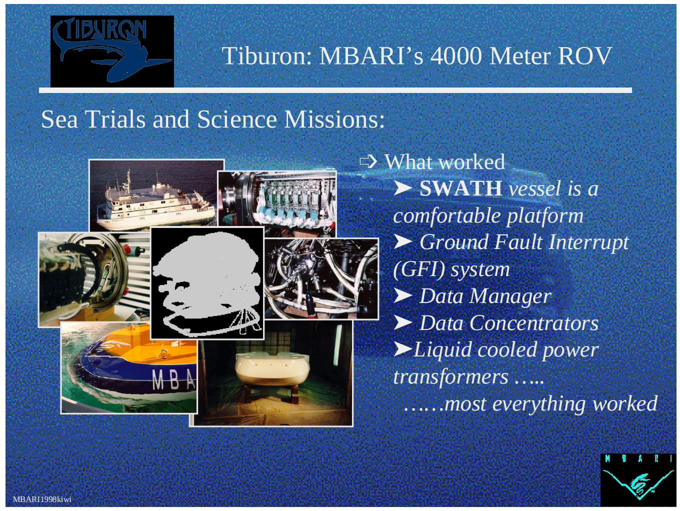
We're also doing some stuff with geology and fluid flow.

This is some of the more interesting work that I've been involved with, clahrates and $CO_2$ disposal. I've got this on the video also. What we did here was the manufacturing of clahrates in situ. It's been done in labs, but nobody previously had actually done it in the ocean that we knew about. So we've been manufacturing those. If you have any questions about clahrates, I'll be more than happy to answer them.




This experiment right here is really a neat one. This has to do with $CO_2$ disposal. One of the things that people have been talking about with greenhouse gases is they would condense them, or liquify, and pump them to the bottom of the ocean, where they would store stably on the bottom. What this experiment kind of proved is that they're not so stable. We poured in some liquid $CO_2$. $CO_2$ is very hydroscopic, and it kept growing and growing, and finally grew out the beaker, rolled off, and several balls of this went rolling away. We chased them for about 19 hours.
(Laughter.)

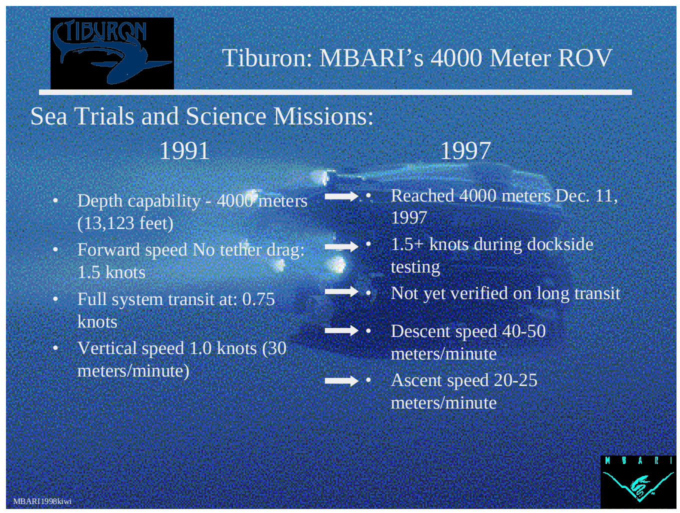




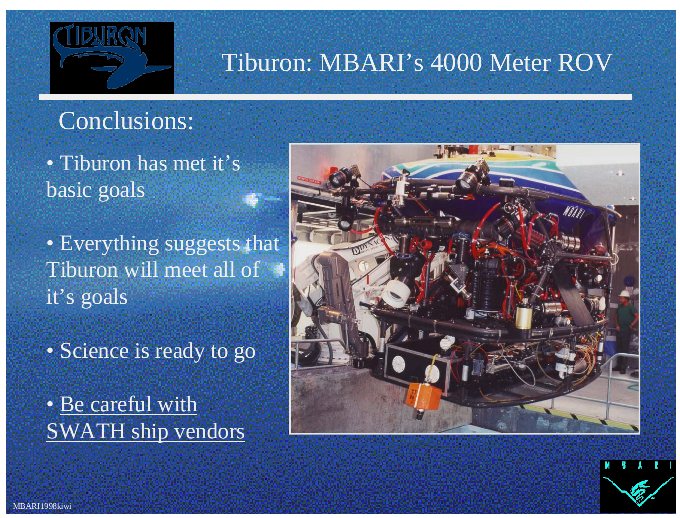

It’s really odd stuff and fun to look at. The scientist that I stole this from is real protective of it until it’s published but I have some of it on the video tape.

Then we have all the usual stuff , the CTDs and all that.

What worked? Well, in actual fact, we’ve done pretty well, I think, against the specs and bringing the newer technology into science here. Now, hopefully what this platform is going to do is not so much be copied by everyone. We’re not going to see everybody have an ROV like this, but hopefully the capabilities that it brings to science (for other scientists coming to or visiting MBARI) are that we can test and develop new equipment and instruments.




So the vehicle has really done very well. We’ve done most everything and it is working. The swath vessel has some issues, and I’ll get into some of those issues, but as a platform it’s highly recommended, a very comfortable ship to use, and they’re not quite as weight-sensitive as I think people might believe. We’ve actually got it in the shipyard right now being modified and some of the ballast tanks that we thought we would need are being removed and turned into fuel tanks to extend the distance.
We’re really proud of the power system. It’s very, very compact, and the liquid cooling has worked out very well. The ground fault system has saved us I don’t know how many times. You can pinpoint a ground fault while you’re running right out to the instrument, turn it off, decide what it’s doing to your data or if the fault is on the connector and so forth.

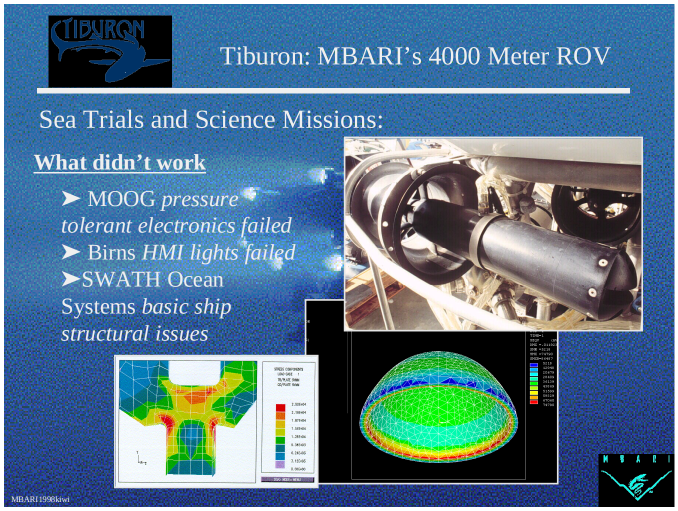



The data concentrators are very, very flexible. We’re using them in other applications, and there are other vehicles hopefully adopting the concept.

We’ve done full-depth to just past the 4000 meters.

The only thing we really haven’t done is a full transit. We’ve done a few transits with the ship dynamically positioned and slave to the vehicle in about 3200, 3400 meters of water, and that’s worked pretty well over several kilometers. But I think we really have to do some more testing to call it a success.

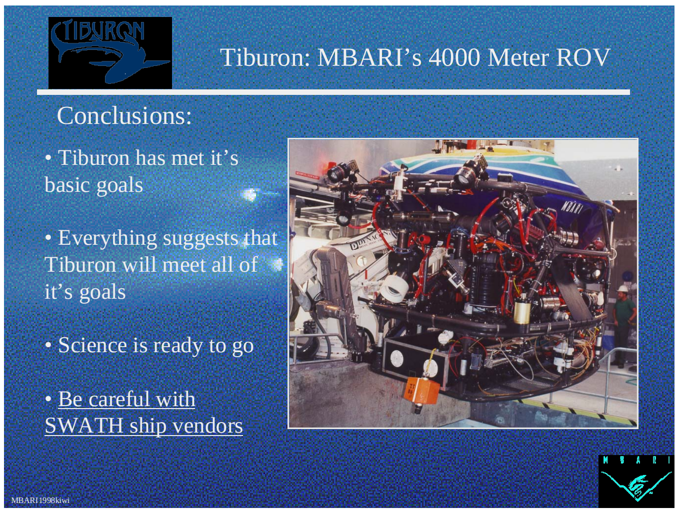
The other weak performance number is the ascent speed coming up. There's so much clutter below the thruster wash that we've blocked much of the area and are wasting a lot of our thrust there. We need to clean that up. It's just a cabling issue mostly, with some smaller items, but it's understandable.




What didn't work. As anybody at WHOI will tell you, MOOG didn't work. In actual fact, I've got to be careful about that. Moog tried very hard. We worked a lot of problems out in the pressure tolerant electronics with them. The inner space thrusters are great, and the DC brushless rare-earth magnet motors are great.

We worked everything out on the electronics, except right in here, there's a large pressure-compensated piece called a power block. We determined it was too large, and the way it's built, the pressure would crack it. So even though we had a lot of dives on them, eventually they would cycle and break. The other problem is that they quit making them , the power blocks that is, and we would no longer get them from the manufacturer. So we went into a scramble, and what we found is a company in industry who has available electronics, about the same size, that do it all. You just run an RS485 signal directly to the electronics. In fact you don't even use a resolver, it uses the magnetic fields of the motor as its own feedback for positioning. So they're very efficient.

Birns, had a lens problem. As you noticed earlier, we now use Deep Sea Power and Light units. I found out they had this design flaw, which we're going to fix ourselves, but we also found you've got to be careful with glass lenses, they are difficult to analyze.




The real big issue is the swath. The design here on the haunch is where they thought they would have deflector for waves to be turned down. I never liked it because it was a step-function to begin with in terms of the boat coming down and hitting the water, but it turned out to be a major stress-riser the way it was designed internally, and so we're having those taken out right now while we're doing some other mods to the ship. This is a really the biggest expense in terms of system corrections.

The boat was designed by Swath Ocean Systems, and I think they're out of business now. The main thing here is be careful with your ship vendors.

# A Comparison Of Single Body And Two Body Shallow Towed Vehicles

Mark Rognastad
University of Hawaii

**[Editor's Note: Following is a transcription of Mark's verbal presentation.]**

I'm from the University of Hawaii, from the Hawaiian Mapping Research Group. Over the last couple of years, we've been involved in a program developing synthetic aperture SONAR. Over the course of the experiments we've been doing, we've tried a couple of different SONAR tow vehicles and different configurations of the vehicles. I thought that would be something of interest here.

I won't be talking to any extent about synthetic aperture SONAR; just the vehicles, and handling, and that kind of thing. But if people have questions about that aspect of things, we could talk about them later.

As I started to say before, this is a project that we've been working on for several years now. It's a joint project between the Hawaiian Mapping Research Group at the University of Hawaii and the company that was once called Reliant Tech Systems. They turned into Hughes Naval and Maritime Systems partway through the project, and they're now called Raytheon Naval and Maritime Systems -- I guess a sign of mergers and acquisitions. But all of this work was funded by CEROS, which is the National Defense Center of Excellence for Research and Ocean Science. They asked us to mention their name.

The very first experiment that we did was with HMRG's mapping SONAR system, with a number of modifications. To give you a little background of that system, it's a 12-kilohertz side scan swath bathymetry system. It maps a swath of up to about 20 kilometers wide -- thereabouts -- in all ocean depths.

This is kind of an old picture of the towing configuration of the MR1. It's what's known as a two body tow -- two bodies in that there's a depressor weight and a clump weight, and then a nearly neutrally buoyant tow vehicle. It's ballasted to be slightly positively buoyant, typically 50 to 100 pounds. That's to allow it to come back to the surface if there's some kind of a malfunction and the towing wire breaks, or some part of the tow rig breaks. There is a pressure-activated release up at the attachment between the tether and the rest of the weight and tow cable. So that allows the vehicle to come back to the surface and be recovered.

This is a picture of the MR1 on its launcher. As you see the vehicle here, I think it's about five and a half meters long and weighs 3500 pounds in air. The launcher is something that was built specifically for launching and recovering both the vehicle and the depressor weight. I have some pictures here that sort of show the process of launching the vehicle. These were taken dockside. Normally, it's launched and recovered out at sea and underway, typically at speeds of six or seven knots.

But as you can see, the launch and recovery system extends off the stern of the ship and tilts down until the end is in the water. Then the tether is paid out from the winch mounted at the front of this tilt frame until the vehicle is in the water. You can see right in here the depressor weight is stored in the trough under the vehicle. So after the vehicle itself is launched, the umbilical is paid out, and then the tow wire is attached to the end of the umbilical and the depressor weight. And then all of that is deployed in pretty much the same fashion.

For this synthetic aperture experiment, we modified the MR1 system. We only operated on the starboard side. We used a hydrophone array, which you can kind of see in the bottom here, that Alliant or Raytheon had built for a synthetic aperture SONAR experiment of their own funded separately by ARPA. And then at the back of the tow vehicle are a pair of projectors that were just hung off the end to act as a sound source. This array was receive only, and then it used the MR1 electronics to collect the data and telemeter to the surface.

This is another view looking at the aft and the two projectors. That's the very end of the hydrophone array.

And this is the ship that we used for that first testing. It’s a work boat. The testing was done just offshore of Waikiki. A target area was set up with a bunch of targets.

I guess I should maybe mention that one of the objectives of this was to apply synthetic aperture SONAR processing to sub-bottom swath imaging; in other words, to be able to see things that are buried beneath the bottom over a swath of the bottom, you know, instead of a normal sub-bottom profile that just looks directly below.

In the picture here, you can see the launcher offset to the side a little bit just to make room for a van that we had the acquisition electronics in. At this point, we were just adjusting the buoyancy, putting some ballast in the vehicle to get it to be about the right attitude and positive buoyancy.

Because the MR1 system is normally towed at speeds of eight to ten knots for its usual survey -- but for this test was going to be towed at much lower speeds. For this testing we wanted to go between two and four knots. We reduced the positive buoyancy to keep the fish from floating up behind the depressor, but still kept it to be positively buoyant. Just in case things go wrong, it’s always nice for them to float instead of sink.

And just a couple of pictures from the testing. Another picture that kind of shows you what it looks like launching -- or recovering, actually. It’s pretty hard to tell from the picture what’s going on. But this is more what it looks like at sea during an actual launch or recovery.

And that first experiment proved to be quite promising. We were able to image objects that were about a foot in diameter and four feet long, I guess the sort of size that you might expect unexploded ordnance to be, which is one of the potential applications. We were able to see those buried in about two feet of sand. So that was pretty promising, and at least CEROS thought that it was worthwhile to continue funding.

So for the next experiment, Raytheon came up with the design that they had used for their ARPA test. This was also a synthetic aperture SONAR. In fact, it uses the same hydrophone array. You can’t really see it, but you can see its reflection in the water. It has that orange front surface. It’s a very broadband hydrophone array. This ARPA testing was being done at frequencies of 50 to 100 kilohertz for high resolution, where the testing that we were doing was being done at 12 kilohertz, just like MR1, in order to get the penetration. The array works fine over quite a wide range of frequency, but it was being shipped back and forth between Hawaii and the Seattle area where Raytheon is located, or this branch of Raytheon.

This towfish design is something that they had spent quite a bit of time working on its design and its hydrodynamics, and had used it for tests in Lake Washington and found it to work pretty well. We had -- I should say I had -- some doubts about how well it would work as a single tow, single body towed vehicle. It’s designed to be heavy. It’s towed from the middle. You can see the tow wire attaching to a bridle in the center here which, for deep towed vehicles, the length of the wire gives you a lot of decoupling of ship motion from the vehicle itself. But this was all being done in quite shallow water. The test range was only about 25 meters deep.

But they were convinced that this would work well, so we built a very similar vehicle, similar in dimensions, but not really in construction. I guess it would take a defense industry contractor to come up with a towfish like this and think it was an inexpensive one. It’s made out of a bunch of giant aluminum castings that were machined to form a pressure hull that makes up most of the body of the towfish. It’s not made out of any standard pipe size or anything. It’s just all made from scratch. It’s about 20 feet long and 14 inches in diameter.

That’s just a diagram of what this towing arrangement is like. The vehicle is just basically right beneath the ship. This really exaggerates the kind of towing angle. It’s usually pretty much straight up and down when you’re only going two to four knots.

The weight of both the ARPA vehicle and the one that we built that more or less duplicated it, in the water was around a ton, maybe 2200 pounds. The one that we built was almost identical in terms of its exterior dimensions, but was built considerably less expensively using pieces of PVC sewer pipe for some of the hull sections. It is using an electronics bottle of the same type that we used for the MR1 electronics, just a six-inch inside diameter aluminum pipe. So the body itself was free-flooding. It was just a place for an electronics bottle in here.

For this experiment, we were using that same hydrophone array and a pair of wings that have projectors and receivers -- transducers that both transmit and receive.

And this is what the vehicle that we built looked like. There's just rolled sheet metal -- sheet aluminum covers to go over the areas that the electronics fit inside and cabling. Again, here's that hydrophone array mounted on the bottom -- not really the most practical place of putting an expensive hydrophone array since the bottom is often what hits something first. But that was the way the array was built.

And so here we are back on Naina again, and getting ready to go out and do the first set of testing with the new vehicle. It's launched and recovered just using this articulating A-frame that was put on the ship for these tests. We picked up and swung astern and lowered into the water.

This is just heading out with Diamond Head in the background.

I should probably mention, you'll notice that sometimes the rings are horizonal, and other times they're up at a 45 degree angle in the testing, depending on whether we wanted to get deeper penetration or a wider swath. We would test it in both ways. And then for storage or for working on electronics in the wings, we could also put them up to vertical and they take up less room.

There it is getting ready to be put in the water. One of the things that we very rapidly changed were these tag lines for controlling it. We came into some very protected water for the first testing. But because of the weight of this vehicle -- in air, it's, I guess, about 3500 pounds -- real similar to MR1, but actually quite a bit smaller in cross-section. It has almost a ton of lead in it to make it have the required negative buoyancy in the water.

Controlling that was a challenge. We very quickly got rid of these light lines and replaced them with much heavier nylon lines, put attachment points on this for the backbone of this system. Even then, it was kind of difficult controlling, even in quite light seas. I guess once you have something swinging around at the end of a pendulum like that, and it doesn't take much to get it going, and it's hard to control.

The end result of that first testing was we ended up with no useful data. The tow vehicle was nowhere close to being stable enough in waters off of Waikiki, even though the weather was actually about as nice as it gets around the Hawaiian Islands. There was maybe a two-foot sea. As we were heading out the first time, some of the people from Raytheon were concerned about how bad the weather was, and I was thinking, Wow, I mean, it doesn't get better than this.

So the folks at Raytheon thought about things for a while and decided on some changes. One of the changes that's sort of illustrated here, for that first test, the tow point attached to the top of the vehicle in the same way as their ARPA fish, but they thought that it might be more stable if the bridle attached more to -- closer to the center point. So we built this bridle that attaches on the sides here rather than up at the top. So the pivot point for the attachment would be more down in this area. Also, they decided that it should be moved further forward. So we made those changes for the next sort of round of experimentation. But probably from -- here's a picture of the vehicle. This actually is a little bit later because this picture was taken on a swath type of ship that we used for sort of yet the next experiment afterwards. I'll have some more pictures of that.

It's a ship known as a slice. It's not exactly a standard swath design, although it is a small water plane area. But it doesn't have two hulls; it has four hulls. It's sort of one hull in each corner of the Morris (ph) rectangular platform. The ship's crews are in the two forward hulls. So the screws are more or less the midships. It worked out extremely well. It was very nice to work off of. You'll see views of what the ship was like further on here.

But the other test that we decided to do was to convert this design into a neutrally buoyant tow vehicle and use a depressor weight much like MR1. It's very much the same kind of arrangement. There's a depressor of about

2,000 pounds, neutrally buoyant umbilical, and then the towfish back here. You took all of the lead out and then added a lot of foam flotation in this blister on the top of the body, and also some in the nose and in the tail to arrange to get the vehicle to be slightly positively buoyant.

Also, like MR1, there was a drogue, although in this case it's much shorter. It is about a hundred feet long of this fuzzy rope that is supposed to have a more or less constant drag as velocity changes. It was just something that the Raytheon people had in the warehouse that they decided to send us.

So here are some pictures of that version of the towfish. Actually, that's the depressor weight sitting there. You can see the flotation blisters, the new nose and the new tail that have the foam filling.

For launching and recovering this arrangement, the tow vehicle was picked up with this four-point bridle and moved overboard with the A-frame, dropped in the water, and then a swimmer would go in and disconnect it. Then we'd put some weight on, stream it aft, paying out the umbilical by hand, and then pick up the depressor weight with the A-frame and drop that in the water.

Here's some of the views from that first test with the neutrally buoyant configuration. This, again, was on Naina, the ship that was used for the initial testing.

And just as a comparison of how the two performed, I've got some of the attitude data that we collected. This is comparing the single body tow with the two body tow. In some things, there's a huge improvement. These bars -- the colored bars give you the range of attitude numbers seen. The smaller ones are standard deviation, and then the dot is the mean.

So not a big difference in roll. There was a static change between the two configurations. But it's dynamic roll that's a lot more important. A vast difference in pitch, and the error bar for the neutrally buoyant one, which is the green -- these are labelled by the times that we did the testing. The pitch is much improved. The depth variation is slightly improved. The variation in velocity is also better with the two body system.

I think that we wouldn't expect to see much of a range in velocity. But one of the things that was going on with the single point vehicle, you can see by the range in pitch that at times it would be pitched quite a bit nose-up. That's what the positive numbers here mean. And when it pitched up that much, the drag increased so much that it would slow the ship down. So as the pitch changed around, it would change the amount of drag on the ship and change the ship's speed.

We also plotted up power spectra for the pitch and -- let's see -- roll and depth, I think. So you could compare the neutrally buoyant fish, which is the blue line, versus the heavy tow. And you can see there's typically a couple orders of magnitude more motion at the same frequency for the heavier towed vehicle. This is frequency here where that's one hertz, that's a half hertz, or a two-second period. Now, these are sort of typical wave periods that you'd encounter out in the ocean.

So just comparing the way the different vehicles handle given the sea conditions, which were very comparable between the two tests, the two body system shows a lot of improvement. This is the pitch. Down at sort of near DC, a very big difference, and then even difference at higher frequencies. And then here for the depth variation, you can see a big improvement there, as well.

That's the end of the slides. I have a videotape of some of the launch and recovery operations that I'd like to show you.

(Pause; video started.)

We didn't take any video of the very first testing that we did with the MR1 system, but the first test that we did with the neutrally buoyant configuration, you can see lifting it up with a lifting bridle. For this we were using a chainfall on the A-frame, and then with a number of people on tag lines. It's a pretty -- "labor-intensive," I guess, is the phrase.

Even though this didn't have all of the heavy lead in it, it was still about a 2,000 pound vehicle. But once it swung outboard, then it would be lowered into the water and disconnected.

One of the problems with the vehicle having wings like this is it would be pretty touch to adapt it to a launcher like the one that we use with the MR1.

After putting the vehicle in the water and putting a little bit of weight on them, you'd deploy this drogue line. One of the things we learned is you should throw it away from the vehicle.

Oh, geez, is it going to tangle? No, it made it. Okay.

But then as you kept some weight on, paid out the umbilical, and then this is where we're getting ready to deploy the depressor, picking it up with the tow wire, going through the ship on the A-frame, and then swinging the A-frame back, then dropping it into the water.

Just some other pictures. You can see some of the attachment points where the lifting bridle attaches to the vehicle.

Now, this is on the slice ship. It's considerably more stable, and also had much better control of speed because it had variable pitch props. It didn't have an A-frame, however. The company that owns the ship didn't want to build an A-frame. They came up with this arrangement that is kind of like an overhead crane. There's another view of it that you'll see a little further on. Basically, again, there was a chainfall -- a motorized one this time -- that would lift the vehicle up, and then the whole chain lift could slide on a trolley back over the stern to be dropped in the water.

This is the overboarding shear for the tow wire, and the tow wire runs down to the vehicle here. So once the vehicle was in the water, you'd slack the lifting bridle and take up tension on the tow wire, and that would transfer the load. And then the swimmer could go in the water and disconnect the lifting bridle.

One of the nice things about this particular slice design was having this recess in the aft end of the ship, because that meant that people going out at the very most aftermost ends on the two sides with tag lines would have a lot better angle controlling the motion of the vehicle -- right here getting underway, and then paying out wire to get down to depth. You can see the sort of overhead crane arrangement and the chain lift in the center there, which would move back and forth.

Then for recovery, it's pretty much the same kind of thing. Bring the vessel up near to the surface, and then have a swimmer go in the water to hook things back up again, and then swing it back under the sling and bring it on board -- not the kind of thing you'd want to do in anything very rough at all. Here it's just being lifted up.

We started out with it fore and aft, but swing it athwartship to get the most distance between the -- you can see the edge of the center part of the back deck. And then once it was up above, swing it fore and aft again.

There's some underwater video here of the test range. These are some corner reflector (ph) fiduciary targets. Then there's some other -- like these little flags mark where things are buried at various depths. But you can just see the vehicle here, and the diver swims up to get a better look at it. He wasn't quite in the right place. But you can a lot of cable strung, which is what you'd expect. It's a little hard to know just how much of the motion is heave being coupled from the ship and how much is the diver swimming around. But I think there's definitely some of both.

There's another pass here which you can see a noticeable nose-up attitude. Vertical is this way, and as it comes by, you can see it's maybe ten degrees nose up. That's actually not too bad. One of the things that we've found was working on the slice improved how well the heavy tow worked. It was almost useable, but --

-- but was never anywhere close to as good as the neutrally buoyant.

Here we are going out to test the neutrally buoyant system on the slice. One of the real nice things about this ship is being able to go places at 25 knots. On the old Naina, we'd get on the ship and start heading out to the test area. We'd have plenty of time to eat breakfast, or a cup of coffee or something. On the slice, you'd get ready to go, and the next thing you knew, you were there, you know, time to go to work.

For the next round of testing, which will be in January and February, I'm planning to put a fixture on the back of the ship here that you can pull the depressor weight up into. For this, we just had to leave it hanging. It worked out reasonably well.

This -- you can actually very dimly there see the slice going by. But there coming out of the gloom is the depressor weight. Again, it's hard to know how much of the motion is the diver and how much is the weight itself.

This is the umbilical line. And then here comes the vehicle itself. Now, I think it's probably pretty fair to say that all of that motion is the diver, because at this point right here, he grabbed onto the drogue line and rode along for a while filming.

We were actually collecting data as they were filming this and didn't see any change in the towfish attitude. Now he's let go, and you can see that fuzzy drogue going by. And then just kind of as another experiment, we had a couple of little drogue chutes at the end here, although a couple of them have collapsed. The material shredded -- but just to add a little more drag to the back of the system.

And that's the end of that.

# SEASOAR Metamorphosis

Lindsay Pender & Ian Helmond
CSIRO Marine Research

## Introduction

13 years ago, we purchased a SeaSoar as part of an ambitious project to develop a towed microstructure measurement system, and as a general towed undulating platform for use with *RV Franklin*. One of the requirements of our SeaSoar system was the ability to reach a depth of 1000m at a tow speed of 8 knots, while obtaining as great an undulation depth range as possible. Our solution to obtaining the required depth was to use 5000m of tow cable. To maximize the undulation depth range, the bottom 400m of the cable was faired with Fathom fairing. The tow cable contains a single coaxial core for communication to and from the SeaSoar, and to supply power to the underwater electronics. In order handle the large data rates anticipated from the microstructure measurement system, an 11mm cable was required to reduce cable losses to an acceptable level.

Fig. 1. Tow winch and cable

As the use of our SeaSoar system became more routine, the requirements of users became more specific. There was a general need to increase the undulation range of the SeaSoar, and for specific experiments there was a need to bring the SeaSoar to the surface for measurements in water unperturbed by the ship’s wake. When operating in shallow water we also needed some form of bottom avoidance for SeaSoar safety, and to ease the stress levels of the operators. Maintenance of the SeaSoar, particularly of the hydraulic unit, was also a concern since it resulted in significant down time while at sea. SeaSoar maintenance was also costly, both from the cost of professional refurbishment, and in the time of maintenance personnel.

In this presentation we discuss the modifications that have been made to the SeaSoar to meet the needs of users and operators. We also discuss the electronic and software developments that have resulted in a reliable and easily operated system.

## Mechanical

Driven by our requirement to increase the undulation range and improve reliability, we undertook four modifications to the original SeaSoar. Firstly, we realised that limiting the tow bridle to positive angles, as on the original SeaSoar, compromised the undulation range. In situations of maximum climb and longer cable lengths, the cable angle at the SeaSoar is negative. With the tow bridle limited by stops to 0°, the cable tension applies a torque to the SeaSoar (since the force no longer acts through the wing axis) which acts to decrease the pitch of the vehicle, thus reducing the attainable minimum depth. However, limiting the bridle to positive angles is an integral part of the original roll stabilisation system. Thus, to attain a greater undulation range by removing the tow bridle stops, we also needed to apply a different roll stabilisation mechanism. We also found that our original system had limited roll stability, particularly with large cable lengths, and we were looking for a mechanism that offered greater stability. The new stabiliser is shown in figure 2. This stabiliser uses a gravity operated aileron mechanism with the weight coupled to the aileron through bevel gears.

To increase the reliability of the system, we decided to replace the hydraulic wing drive with a unit powered by an electric motor. Even though we could have powered the electric drive via a propeller driven alternator, for simplicity and reliability, we chose to power the unit from the ship via the tow cable. This limited the available power, which in turn put constraints on the wing design as discussed below. Mechanically and electronically, the electric drive was designed to be a direct replacement for the original hydraulic unit. The motor used was a 75W Escap motor running off 12V. It powered a 1000:1 gearbox with the final stage being a worm drive. Typical power consumption was less than 10W. A major design concern was the final drive shaft. We chose an O-ring with a teflon slipper seal on a hard chromed stainless steel shaft. The unit has now operated for approximately 50 days of tow time without any discernible wear. A view of the electric drive with the electronics pressure case removed is shown in figure 3.

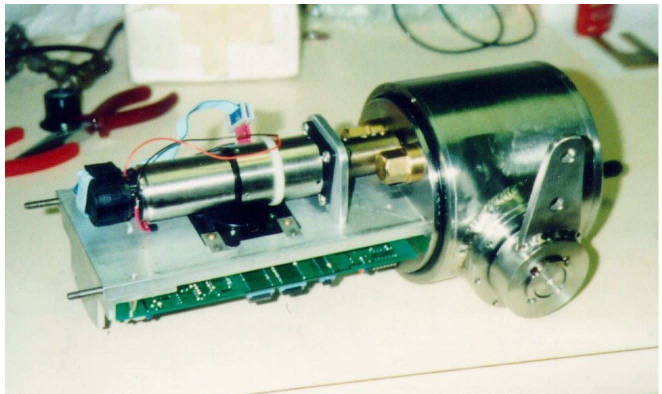


Fig. 3. Open electric drive.

The final stage in improving the performance of the SeaSoar was to upgrade the wings. To increase our undulation range further, we required more lift. From a theoretical study, there was little to be gained through the choice of wing section, so we were left with increasing the wing area. To accommodate the low power available from the electric drive, we required the wings to be rotated with low torque. An asymmetric wing section has the characteristic that, for a fixed axis, it is impossible to find an axis position where the torque is always zero for different wing angles. Theoretically, for a symmetric wing section, an axis can be chosen where the torque is zero within angles of attack less than the stall angle. We thus chose a symmetric section wing. Two sets of wings were designed and built. The first has the same area as the original wings, and is used in situations where the undulation range does not need to exceed 300m. The second set is 60% bigger and is used for larger undulation ranges. By using the smaller wings where possible, we reduce the overall load on the system. Figure 4 shows the SeaSoar from above with the smaller new wings.

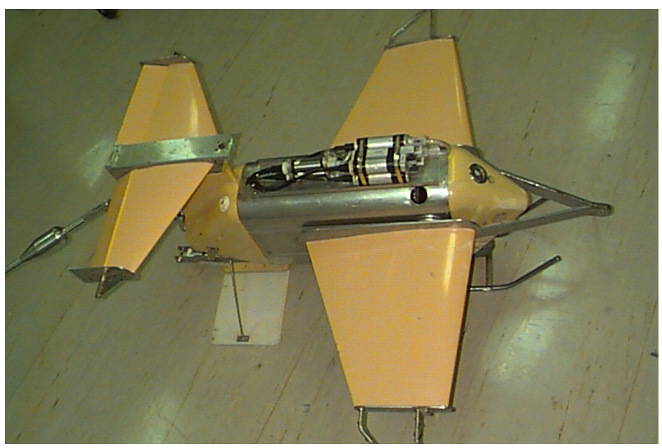


Fig. 4. SeaSoar with new wings.

A comparison of the aerodynamic characteristics of the original wings, and the two new wings is given in table 1.

Table 1. Comparison of SeaSoar Wings

| **Description** | **Section** | **Area** | **Max. Lift Coeff.** | **Max. Lift at 4m/2** | **Pitching Moment** |
|---|---|---|---|---|---|
| Standard | Asymmetric NACA 6412 | $0.5m^2$ | 1.6 Achieved 0.9 | 3600N | 250Nm |
| CSIRO small wings | Symmetric NACA 0012 | $0.5m^2$ | 1.5 Achieved 1.2 | 4800N | 20Nm |
| CSIRO large wings | Symmetric NACA 0012 | $0.8m^2$ | 1.5 Achieved 1.2 | 7600N | *20Nm* |

To compare the performance of various SeaSoar configurations, a numerical model of the system was used. Where experimental performance data was available, it was used to confirm the validity of the model. The performance of different configurations of the CSIRO SeaSoar is shown in table 2. Where available, experimental data is used. Numerical data are shown as italics. Cable tensions are given as a force, and as a percentage of the cable breaking strength.

Table 2. Performance at 4m/s

| Description | **Cable Length for Max. Range** | **Max. Range** | **Profiling Range (1m/s)** | **Max. Cable Tension** |
|---|---|---|---|---|
| Standard SeaSoar. CSIRO cable (11mm cable, 400m faired) | **400m** | **0 – 300m** | **0 – 250m** | **13kN 18%** |
| Standard wings, free tow bridle. CSIRO cable | **600** | **0 – 350m** | **0 – 300m** | **13kN 18%** |
| Small wings. CSIRO cable | **900m** | **0 – 400m** | **0 – 320m** | **16kN 22%** |
| Large wings. CSIRO cable | **2000m** | **0 – 600m** | **0 – 500m** | **20kN 28%** |
| Large wings. CSIRO cable | *2400m* | *0 – 670m* | *0 – 570m* | *21kN 29%* |
| Standard SeaSoar. 8mm cable, 600m faired. | *600m* | *0 – 390m* | | *14kN 33%* |
| Small wings. 8mm cable, 600m faired. | *600m* | *0 – 410m* | | *15kN 35%* |
| Large wings. 8mm cable, 600m faired. | *600m* | *0 – 480m* | | *17kN 40%* |
| Large wings. 8mm cable, 1000m faired. | *1000m* | *0 – 700m* | | *22kN 51%* |

The final significant mechanical change to our SeaSoar, was the implementation of a wake avoidance mechanism. Various devices were tried to apply a force in the horizontal plan normal to the tow direction, some with limited success. These included devices attached to the tow cable, to the wing tips and to the fin. Putting an offset on the roll stabilizer was also used. However, to date, the preferred option has been to place a deflector on the forward end of the tow bridle, while allowing the cable termination to pivot freely in the horizontal plan with respect to the bridle. Our preferred wake avoidance mechanism is shown in figure 5.

Fig. 5. Wake avoidance deflector.

**Electronic**

Electronic developments at CSIRO have focused on reliability and versatility. Recently, we have upgraded the SeaSoar electronics package using an imbedded micro controller. This controller handles all of the internal housekeeping tasks, has A/Ds for sampling status and scientific sensors, and handles the communication with the ship, the CTD, and the electric drive. Integral to this development has been the design of a robust and error free communication system for communication of data and control information between the ship and the SeaSoar via the single coax of the tow cable. Due to the length of cable and concurrent use of the cable for supplying power to the SeaSoar, signal to noise was a major problem in the communication system design. We use bipolar pulse encoding of an RS232 signal, currently operating at 19200 Baud. A token passing protocol is used with data sent in variable length packets. Error detection and recovery is implemented in the micro controller and an equivalent system running on the ship.

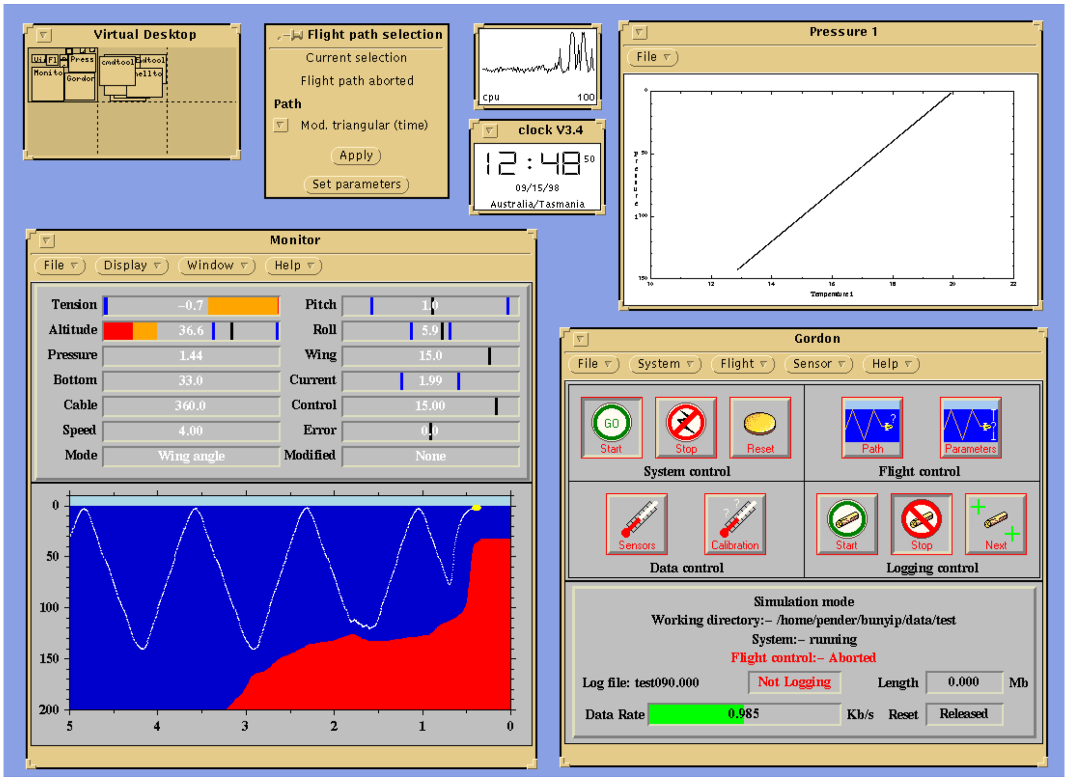
The electric drive uses a microprocessor and dedicated motion control processor to control the wing angle in response to RS232 commands. An incremental encoder on the motor is used to determine wing position. Commands to the electric drive can either position the wings at specific angles, or move the wings at constant rate of change of wing angle. Status information from the drive is sent periodically via RS232. In order to maintain compatibility with the hydraulic wing drive a current mode wing control input is also available.

Currently, we use a CTD with dual Seabird temperature and conductivity sensors, and a Digiquartz pressure transducer. A separate electronics package containing frequency counters and a microprocessor packs the sensor frequency outputs and sends them to the SeaSoar micro controller via RS232.

## Software

On the ship, we use a Unix workstation connected to the cable interface via RS232. A GUI is used to control the SeaSoar and control data logging. A snapshot of the GUI is shown in figure 6.

Fig. 6. Snapshot of the graphical user interface and monitor used to control the SeaSoar.




A monitor frame shows the current status of the SeaSoar, and a scrolling image of the flight path with the sea bottom as given by the ship's sounder. Status information such as pitch and roll is presented numerically, and as gauges. The gauges also show the extreme values for the last 5 minutes. Any number of property/property plots or property/time plots can be displayed with no restriction on the sensor (property) being displayed. Thus the operator can be viewing TS diagrams while checking the SeaSoar behavior by comparing roll and aileron angle as a function of time.

The SeaSoar flight path parameters are entered via a dialog box. There are numerous types of flight path available, both for routine scientific use and system diagnosis. These include options such as the conventional triangular path, triangular paths with parabolic corners to reduce flight instability at the turn around points, constant depth, constant distance from the bottom, direct wing angle control, etc. The servo system for keeping the SeaSoar on a prescribed track uses a PID type algorithm.

We use an active bottom avoidance system when operating in shallow water. This system uses both an altimeter, pointing 30° forward of SeaSoar normal, and the ship's depth sounder. The apparent altitude of the SeaSoar is determined as the minimum of the altitude derived from the SeaSoar altimeter and pitch angle, and a value derived from the depth given by the ship's sounder, delayed in time to correspond to the location of the SeaSoar, less the SeaSoar depth. Two altitude limits are applied. If the SeaSoar approaches the bottom, i.e. is diving, and the altitude becomes less than the first limit, the bottom avoidance algorithm attempts to keep the vehicle at an altitude equal to this limit. If however the vehicle comes closer to the bottom than the second limit, the flight path is aborted and the wings are moved to give maximum climb. Using the ship's sounder has the advantage that it gives us some degree of forewarning. This is used in situations where the SeaSoar is being towed into steeply rising terrain. Using the current depth of the vehicle and the depth of water at the ship, the rate of ascent of the vehicle required to clear an approaching obstacle by a distance greater than the first altitude limit is continually monitored. If this exceeds another limit the flight path is again aborted and the SeaSoar is driven to maximum climb. Figure 6 shows and example of bottom avoidance due to the first altitude limit being reached, and an example of approaching a cliff.

Figure 6 was created after running the SeaSoar software in simulation mode. In this mode a SeaSoar emulator replaces the SeaSoar interface task; all other tasks operate in the normal way. This simulation mode has proven to be an invaluable tool for testing the software.

**CTD**

Each temperature, conductivity pair is connected via a TC duct, and pumped. Routine calibration of the conductivity sensors is performed by placing the CTD assembly in a bucket of well-stirred seawater, and then collecting salinity samples for later analysis while logging data through the SeaSoar system. Samples are taken at two different salinities, with a lower salinity being produced by dilution. For operation in biologically active waters we have implemented a biology deflector over the entrance to each TC pair of the CTD. On a recent voyage, this deflector system dramatically improved our data quality, yet had minimal effect on the response of the sensors. The deflectors - PVC conical cups - are shown in figure 7.

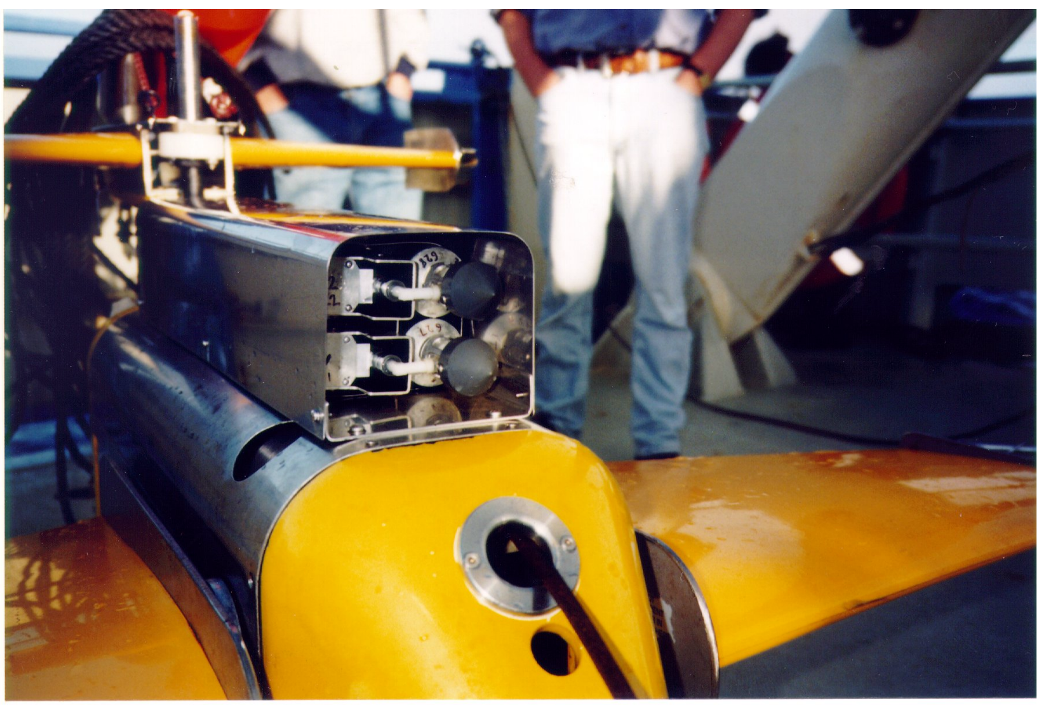


Fig. 7. TC biology deflector

**The Future**

Time and money permitting, we intend to replace the only component of our original SeaSoar still remaining – the SeaSoar body. The new body will have greater depth to enable the placement of heavy pressure cases above and below the wing axis. This will enable us to balance the weight distribution of the new vehicle. The original SeaSoar is very tail heavy and flies with a permanent tail down attitude. For ease of maintenance, deployment and recovery we also intend designing the new vehicle such that it can be landed on its tail. In this upright position on deck all sensors and electronics will be easily accessible. A schematic of the new vehicle is shown in figure 8.

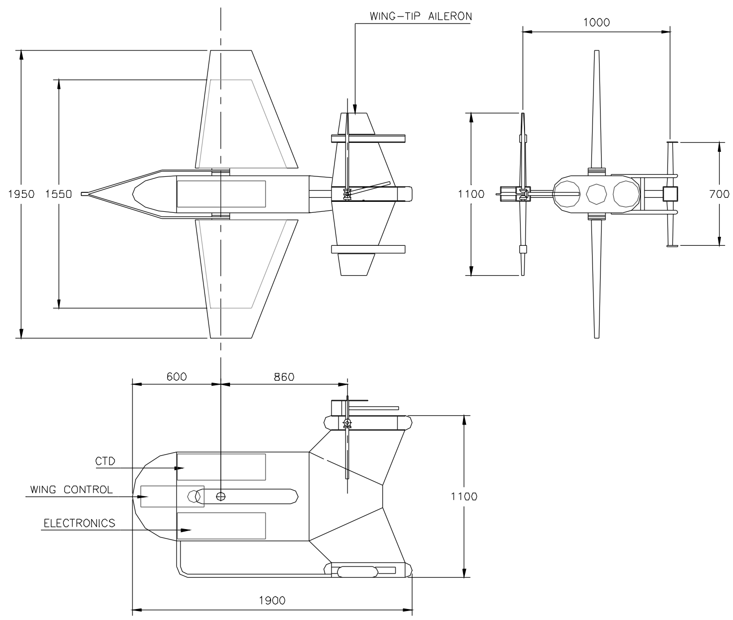



Fig. 8. Proposed new towed vehicle

**Acknowledgements**

The authors acknowledge the significant skill and efforts of the following current and ex CSIRO personnel for making this project a success: Alex Papij, Stuart Swan, Dave Edwards, Phil Adams, Erik Madsen and Bob Driscoll.

# ROV And Towed Vehicles Discussion Session

MR. OBER: My name is Sven Ober from the Netherlands Institute for Sea Research. I have a question about the SeaSoar. There were some figures shown concerning the performance of the improved SeaSoar that were not stated at what ship speed these figures are reached.

DR. PENDER: That was all at four meters a second, or eight knots. They were all at the same speed.

MR. OBER: All at the same speed. And four meters a second is about how many knots?

DR. PENDER: Eight knots.

PARTICIPANT: (Indiscernible) wanting to talk about Jason. You were talking about using GPS reference systems. I presume you were using DGPS.

PARTICIPANT: I was wondering what you used (indiscernible).

PARTICIPANT: Not at the surface. We used along the baseline NAV for both navigating with Jason on the bottom and also navigating the ship. We have another system. It's like a long baseline, but it's a much higher frequency. It's like in the one megahertz range, and it's good for one and two centimeter ranging accuracy. It's only good for about a hundred meters. So if you work within this neck (ph) on the bottom, you're limited to areas you can work in. If you can maintain accuracy -- you know, depending on how the (indiscernible) and how the lines of positions crossed in the order of a couple centimeters.

We also had the Doppler SONAR on the bottom, which gives you a real good tight coupling to the ocean floor. By the time you blend the Doppler SONAR with either the long -- the high -- the lower frequency along the baseline, you can get a really nice tight net on the bottom, which is (indiscernible) and it's what we use for the SONAR scan lines when Jason flying track lines to generate the SONAR images.

DR. SHOR: Sandy Shor from NSF. I had questions both for Marc and for Bill Kirkwood about the small water plane hull toys that they've been playing with. First to Marc, the slice vessel, where did that come from? And is it used for research, or did you just happen to be out there for Hawaii to be looking at.

MR. ROGNASTAD: Well, it's actually been built jointly by Honolulu Shipyard and Lockheed. It was built in Hawaii, and so that's kind of its home port. I understand CEROS funded a little of the development for that, although I think it was mostly funded by ONR. So we found out about it through CEROS, you know, sort of one of these project reviews where you can find out about what other people are doing. It seemed like a real logical thing to do. They had not done this kind of work before, although I gather they've done some sort of experimental testing for the Navy.

DR. SHOR: What's it used for normally?

MR. ROGNASTAD: Well, it's still kind of experimental. We'll be using it again in January and February. I know they're talking about taking it here or somewhere on the West Coast for some experiment that they'll be doing with the Navy, but I don't know the details of that.

There is also talk about using it as a test sort of platform for a passenger ferry -- a high-speed passenger ferry in Hawaii. There's tons of deck space and could easily be enclosed to carry hundreds of people. So it's kind of an experiment.

DR. SHOR: On the MBARI vessel, you showed some stress point figure which shows what the problem was. What was -- what's been done, or what type of work have you done to strengthen that? Is that material changes, or design, or what sort of things?

MR. KIRKWOOD: Material change is we had to add material. What happened is that we went to a boat yard -- in fact, I can tell you more about the other one, because the fellow who did all that, I know. I had him come down and talk to us about swath design. But the people who were in charge of the project at the time had already gotten into a contract with Swath Ocean Systems. The way that it was set up was, you know, we specified a boat; they built it.

What happened is they designed it actually with more of a mono-hull kind of thinking in mind. So the strength members actually run predominantly in the wrong direction. You really want them to go counter-intuitive to what a regular boat would have. So they're missing a lot of material strength going down across the ship.

What happened is, with that, and then of course this little stress riser, the combination was such that we saw some cracks develop. Now, swath vessels crack anyway, particularly on an aluminum structure like ours. They're not supposed to crack that much, or that often, or so soon. So they're a fatigue-type structure.

The thing that we're going to get into is the fellow who designed slice and all the others is a guy named Terry Schmidt. He's at Lockheed Marine Systems, or what's left of it, and he did the stealth ship, and he did the canted strut design in the Navi-Tech (ph) vessel, which is the swath. So he's got a lot of patents and so forth and done a lot of this work. What he proposed to do, and which is what I fought for but we didn't do, was to actually go to a canted strut design that was not a solid wall. If you looked in ours, it's got a solid strut all the way down, and slice doesn't have that either.

PARTICIPANT: Yeah. That's right.

MR. KIRKWOOD: And what happened is it takes out a lot of the shuddering. One of the motions you get in a swath vessel is it feels like somebody's kicking your feet sideways, and it's because of this large wall. So he actually shapes the structure coming down in sort of a wing kind of a section, as opposed to being a flat wall, and it's got a major hole through it. So it's really minimized going through. It's great technology.

The other thing he does now is he puts them at an angle. So what happens is that you don't get the reverse bending. Then the stresses are all pre-loaded in one direction in the boat. It really does away with a lot of those problems of cracking and so forth. You can get away with a lighter structure.

Now, the NaviTech designs -- and I'm not sure about this one -- but they're actually sealed with an aluminum floated house. It's actually rubber-isolated. So Terry -- you can call up Lockheed in Sunnyvale and get a hold of him if you're interested in this stuff. He's a great guy.

DR. SHOR: You have pretty much, I assume, had to stick with aluminum in the modifications made to Western Flyer due to repair type of work.

MR. KIRKWOOD: Yeah. I --

DR. SHOR: So it remains an aluminum structure.

MR. KIRKWOOD: I don't remember the exact number, but it's 5806, or something.

PARTICIPANT: (Indiscernible.)

MR. KIRKWOOD: Yeah. But it's actually an odd one. We had to order the material from France. It's very weldable. You can actually mix materials (indiscernible) inside if you want. You can weld 6061 to it and so forth. You don't want to do that on the outside where you might get a corrosion issue.

Mr. Packard wanted to push the envelope, so he went with the all-aluminum structure, as opposed to the iron for the bottom.

MR. ROGNASTAD: The slice is actually all-aluminum.

MR. KIRKWOOD: It is? Terry -- like I say, he actually -- the other thing that he's doing, too, is he has no rudders on some of them. I'm not sure about the slice one. He uses a differential plane, and he plays with pressures to move the boat around. So really, if you're going to get into that business, you should talk to him anyway.

MR. ROGNASTAD: Yeah. That actually was probably about the only shortcoming is the differential pressure steering doesn't work very well at low speeds. It works great at high speed. I mean, you can just zoom all around. But at low speed, we couldn't turn very quickly.

DR. PENDER: If you're on station, you wouldn't be able to rotate at all.

MR. ROGNASTAD: Well, there are two screws, and they're variable-pitched. So actually, on station, you can rotate in your own length (ph). But either way, it's hard to turn it very quickly. There's sort of a range between near zero speed and max speed where it's not as controllable. In the swath arena, there's a lot of neat things. He's actually got another hull that's sort of Coke-bottle shaped where the fruit number (ph) inverts at a certain speed and you actually get more efficient again, and so forth. Somehow he's convinced Lockheed and other people to build all these things too. It's a talent in itself.

MR. WILLIS: Jim.

MR. SULLIVAN: I'm Jim Sullivan with Harbor Branch. Both Bob and Bill, I believe you mentioned video was one of your outputs, or products, or whatever, and digital video is now the new revolution. It's probably going to be -- impact us much like the internet did. What are you all planning on doing about that?

MR. KIRKWOOD: Several things going. One of the things -- and I'm rushing through this -- if you look at the front of Tiburon, there's several stations for mounting the cameras and rearranging the front end. Most of these ROVs are very flexible for that. The outermost stations are actually positioned along with some hydrophones such that we can do stereo. So we do machine stereo right on the vehicle with precision pan-and-tilts. Right now, we're doing a project and bringing on HDTV. So pretty soon we'll have that running on our other vehicle first, and we'll upgrade them all. So in terms of the video, we're keeping right up with the technology. The big thing is to try and get the data out of the video. So we have several systems going on with lasers. In fact, we're doing some work with Harbor Branch with that where we have the three parallel lasers with the -- calibrated the focal plane -- well, then you have a crossing laser, and so you can get angular positions, and you can tie that back to the vehicle's attitude and get a real reference frame for what we're looking at.

For that, I'm looking into projects where we'll take the polygon created by that system and then texture map the video onto them so you can create these three-dimensional bodies. But that's still a little ways down the road.

PARTICIPANT: We talked about it a whole lot -- (indiscernible) you're not talking about HDTV. You're talking about pure digital signal?

PARTICIPANT: Well, HDTV is a form of digital.

PARTICIPANT: Well, we've got HDTV. It's just a matter of having the fiber optic transmitter it can handle. HDTV's about 30 megahertz of bandwidth; whereas standard NTSC's (ph) about eight megahertz. We're talking about trying to build a new vehicle, and I'm sure we'll incorporate a telemetry scheme to have digital video. But so far, we haven't really broached the subject in terms of the money that it would cost for getting the cameras or anything like that.

PARTICIPANT: Yes, it will.
(Laughter.)

PARTICIPANT: I'm not trying to sugar-dad it, mind you.

MR. KIRKWOOD: The other thing that we've been looking to is the digital still and getting really, really high resolution for a magazine-type quality. They have these cameras with a thousand lines, I guess, or something. They're huge. But the exposure time is too long. So those are areas that I'm looking into also and how to do some of those things. I think a lot of -- both WHOI, and has everybody, been taking all this stuff and integrating it (indiscernible).

PARTICIPANT: The nice thing about fiber optics is the bandwidth is not an issue anymore. So it's just a matter of can you -- how much stuff can you cram into, in our case, a six-inch diameter tube? If you can stick it in a tube, we can send it up the fiber.

MR. SULLIVAN: How often do you have to re-terminate? How often does it break (indiscernible)?

MR. KIRKWOOD: In the early days, we had to do it several times per trip. In the past four or five years, I guess, other than -- well, essentially, once we get set up for a trip and we have everything set up, we don't have to. We've had a pretty good reliability.

A fellow named Mo Sellers (ph) has developed a good technique for terminating the steelite (ph) which is inside the Rochester cables into like an ST-type connector. We mate that up to a Digio-Brian (ph) single-mode feed-through connector. We've had real good luck with that. It's not to say it doesn't happen, but it's not the weak link anymore. It's just an electrical connector to the weak link now. As far as fibers are concerned, it's reliable, they work well, and once you get the system together, it's been a non-issue.

PARTICIPANT: Do you ever get fiber breakage at all?

PARTICIPANT: No. In actual fact, we hockled (ph) the cable, put a pretty tight kink in it, and didn't really see any appreciable change. We monitor -- one of the things we do with the system is constantly monitor all these things. So the optical budget is (indiscernible) all the time for losses. It's quite good. One of the differences, we don't run a soft tether. We run steel to the vehicle and float an S (ph). So we get away with the clump rate instead of having two bodies for recovery. That's how we've had this problem that's going on with (indiscernible).

PARTICIPANT: One of the weirdest problems we've had is fiber is -- there's different wavelengths of windows that you could use. There's basically the single (indiscernible) fiber is 1300 and 1550 nanometers. One of the weirdest problems we've had to solve is when you have one wavelength go dead, but the other wavelength is fine. With our early test equipment, you could launch, say, 1310 (indiscernible) fiber, and you could see it at the other end it's maybe 10 db loss, but yet your system doesn't work. And you can say that your fiber's good, but it still doesn't work. And it took quite a while to sort out the fact that it was actually 1550 nanometer that was being attenuate. So it's the one that goes away first as both pressure increases on the cable, and also temperature, too. We found out at Woods Hole where it's 20 degrees in January that 1510 nanometers would go dark in multi-mode fiber, but not single-mode. So it was kind of early things in the learning game trying to sort all this stuff out.

MR. SULLIVAN: It's written down somewhere; isn't it?

PARTICIPANT: Pardon?

MR. SULLIVAN: This is written down somewhere?
(Laughter.)

MR. KIRKWOOD: The other thing, too, is that steel-life design (ph) -- we pressure test -- we have a very similar construction, this (indiscernible) state, compatible with WHOI and some other people. The other thing is, for some reason, through attenuation, it's a big step after about 4,000 meters. We noticed that when we tested our cable. Now, ours is slightly different, but I think it had something to do with the steel-life construction from Rochester, which is a very good cable. In fact, they were the only ones who could build it to our specs. It's kind of an odd (indiscernible) much past that, it takes this real dip in performance.

DR. PENDER: How do you distinguish between cable problems or fiber problems and termination problems?

PARTICIPANT: How do you mean?

DR. PENDER: Well, if you've got these attenuation problems, how do you know it's not -- it's the cable and not the termination that's the problem?

PARTICIPANT: Sometimes it's hard to tell. Usually, if it's a connector problem, the problem doesn't fix itself as you change depth. If it breaks -- it usually breaks. You can have a connector that might be a 20 db attenuation. Once it does that, it stays that. It doesn't suddenly get better.

DR. PENDER: I would imagine deformation of the termination (indiscernible). You can make an elastic deformation of the termination, add pressure, and then, you know (indiscernible).

MR. KIRKWOOD: The glass usually won't change it.

DR. PENDER: It doesn't?

MR. KIRKWOOD: In fact, we find the performance when it's rolled on the coil will actually be lowered when it's straightened out because of micro (indiscernible) close back up. That's what we've -- I don't know if you guys --

PARTICIPANT: We found as the cable goes in the water, the tension -- there's two factors. There's the pressure on the cable itself, and that tends to increase the attenuation. But there's another factor when the cable gets stretched out. I guess it's like winding up a hose with a bunch of kinks in it. You've got to take all the kinks out. In the micro-bending world, we're talking about nanometer range. So while attenuation is increasing due to pressure, it's actually decreasing due to the stress. In the end, it's the increase in attenuation that wins. You end up with less attenuation at depth than you do on the surface.

PARTICIPANT: So straightening it out, it seems to work better.

DR. SHOR: Another question. You've talked about the internet -- running over the internet back to shore. How do you do that? What kind of -- I mean -- how do you do it?

MR. KIRKWOOD: That's something I didn't get into there. But we run microwave to shore. So within the bay, if you've ever been to the aquarium during the week, you can actually have live interactions with scientists working in the bay on both of our vessels. So we've actually used that from the engineering perspective to prevent having to go out to sea while we're doing something. Because it's multi-tasking, we can actually be doing work in one area while somebody's doing science in another area.

For instance, let's say you're doing a midwater run and so forth, but you're working on the (indiscernible) GUI. You can do that while the boat's within microwave range. We have had problems, though. We have had the boat take off when people were working -- eclipse over a horizon while you're working, so -- and you don't know it. So we've had to install some other learning mechanisms about knowing when the boat's leaving, and so forth, and identifying how you're connected. But on the other hand, it's been -- we have a handy tool. There's times when you get into it with the real-time operating systems and so forth and integrating the hardware, and you just run up against the wall, and you need to get a hold of somebody. We've had guys at WHOI. We call them up. They log in with their lap-top, and they actually can work on it, you know, help you with your problem themselves. So in terms of using that same technology in AUVs (ph) and other instruments that move around the world -- for instance, we had some stuff go to Jamstech (ph) and go to the Mariana (ph). It didn't have any problems, but had it, you know, the way it's set up, the scientist can just plug it in a phone line, and we can log into the instrument, insert (indiscernible) fix the problems. The data comes out the same way, too. So this web browser kind of interface is something we're really shooting after.

PARTICIPANT: What data rate is your microwave link?

MR. KIRKWOOD: You know, I don't know. But I know it can handle HDTV, so -- we checked into that already. The bigger problem we're having is the way it's set up originally, it was kind of on the sly, if you will, because we didn't go that far. So as we're stretching out the distance, if you want to change the tracking scheme, and we're really kind of -- this -- I don't know if you're familiar with monopulse tracking where you use that zero cross-over and the zero pulse.

PARTICIPANT: Uh-huh.

MR. KIRKWOOD: That's what we want to go to, but it's quite expensive. Regardless of what people think, we're not rich.
(Laughter.)

MR. WILLIS: Frank.

PARTICIPANT: Frank (indiscernible), Woods Hole Oceanographic (indiscernible). I have a general question to you, Lindsey. I have a whole lot of questions to you, of course, but this is one. While trying to go deeper with SeaSoar, which we are all of the time, as well, you mentioned the bigger wings. I talked to the Oregon State -- Marc and Linda -- about their -- you guys also had bigger wings, but you also had very high tension and very high dive rates. You also mentioned that you have higher tension, but is it right that your higher tensions strictly come from more cable out, more -- just more drag on the cable?

DR. PENDER: Yeah. The -- I can't remember the exact balance of cable tension due to the cable and due to the fish, but from memory, it's something like 20 percent was due to -- even with the large ones is due to the fish. The bulk of it is, in fact, due to the cable.

PARTICIPANT: Uh-huh. So if you go -- with your wings, you don't see extreme dive rates and so forth.

DR. PENDER: The dive rates are controlled because we have a server mechanism which is driven from the ship, which is basically telling the wings to be in a position such that you can control the rate of ascent or descent. This program will just run from GUI. So typically we run a one meter a second dive rate.

PARTICIPANT: With the electric (indiscernible).

DR. PENDER: That's right. I was just mentioning to Marc earlier, with the large wings, we've had the system in an uncontrolled mode where it was actually climbing at seven meters a second (indiscernible) at four knots -- sorry -- four meters a second. So it would be quite impressive seeing that come out of the water.

(Laughter.)

You know, I have a question regards recovery mechanisms. I was intrigued with your sled for actually getting things out of the water. (Indiscernible) seas other than calm?

PARTICIPANT: Oh, yeah.

DR. PENDER: How do you line things up if your ship’s pitching? Do you have some mechanism for actually adjusting the angle of it?

MR. ROGNASTAD: No. Part of it is choosing a course and also a speed. Another part is the winch that pulls the towfish aboard can pull it aboard pretty quickly. So it takes some operator experience, but we’ve recovered in, oh, I don’t know, 18-foot seas?

DR. SHOR: I have to confess that I was -- I’ve done most of those launches and recoveries in the worst conditions, and if I remember right, the worst was up in the Norwegian Sea in about -- seat state pushing five. We had to go into the trough to do it. The controls were messed up because the hydraulics hoses had been crushed. So we had no visibility. We still got it back. We have lost it occasionally on recovery. In fact, we lost one whole vehicle for those reasons (indiscernible).

It’s a very nice recovery system up to sea state four -- low four. Beyond that, it gets real dicey, and you get smart to bring it in.

DR. PENDER: We contemplate a system of recovering a SeaSoar, and we think it was too treacherous, so we gave up and just wait for (indiscernible).

DR. SHOR: Well, as Marc pointed out, I mean, the wings on that new vehicle are clearly problematical in dealing with a system like that. You got to come up with some way that you can have wings on it, you’re not going to remove them -- a cylinder would be the best shape for recovery (indiscernible). It’s tough.

MR. WILLIS: Any other questions?

MR. SCHWARTZ: Dan Schwartz, University of Washington. Your vehicles represent a really wide -- interesting and wide variety of actual science missions. I’m just curious, from where all of you sit looking into the future, do you see AUVs getting to the state of the art -- and maybe on what time scale -- to where they can do some or any of those missions that these vehicles are doing now?

PARTICIPANT: AUVs tend to be rather power-limited at this point. So they’re probably not going to fill the gap of continuous data recording or recovery type thing. They can certainly be deployed and go into -- take data and go into a sleep mode for a period of time, and wake up, fly around, go into a recov- -- data gathering mode.

So could do video a single shot at a time where you can put a whole lot of data on a single tape, but it won’t be a real-time kind of thing; however, it might look that way if you say, Look at the black smoker groaning from an AUV that takes a picture once every day, or once ever two days, or something like that. So they’re -- WHOI has a couple of these that they’re working on. Dan DeYurik (ph) is working on one that we’ve deployed a couple times now. It goes down to the bottom all by it- -- it has a programmed to a mission. It goes down to the bottom all by itself, slows down when it gets there, does whatever it’s programmed to do, and it comes back. So far, we have a -- it’s a one-for-one relationship between the number of times it goes in the water and the number of times it goes out.

(Laughter.)

But it’s -- in terms of real-time, probably not. But (indiscernible) over the long haul, I don’t see any reason why we can’t take the place of -- they could be the long-term experiment that sits on the bottom. I see perhaps in the future having a docking mechanism where they could keep the batteries charged perhaps -- I mean, to download data into something in an ROV to extract the data out at some time in the future.

MR. SCHWARTZ: That's the concept of some of the observatory systems that are being designed now, whether it be docking stations, maybe cable-to-shore, recharge batteries, download data (indiscernible).

MR. KIRKWOOD: I think there's going to be a whole -- the problem with the AUVs is that they are very custom. They're not as flexible as an ROV in terms of the way they have to be constructed right now. They still, in my mind, take way too many people -- the cost-effectiveness of them for time in the water and so forth is still something that's got to be worked on. I think what you're going to see, at least from our perspective, is there's going to be this docking version where you go between dock stations and you're filling in that temporal-spatial zone. And then there's going to be these custom ones that they're very mission-specific kinds of things. The degree of time that's spent is something that's going to be a question, too. I know that there's some already running where you can acoustically talk to them and change modes. A guy at Lockheed is working on one that changes its mode on itself depending on the environment that it sees. It has some sort of AI (ph) capabilities. So there's going to be this whole sort of spectrum of them, as opposed to the ROVs, where -- and the technology is really proven out in the oil field. When the oil field puts money into AUVs, you'll see a lot of them.

There's a lot of people out there trying to manufacture them right now. I think there's probably 20 different companies starting up. My guess is something on the order of two will survive. Power's the big one, and then this degree of flexibility for science -- the industry's going to just say -- there's a pipe surveyor, and so they'll buy a bunch of these, and they'll be standard, and we'll just maintain them; whereas, our science staff, you know, you'll use it today, we'll use it tomorrow. And if you can't turn it around and make it easy and reliable -- to get them outside of places like MBARI or WHOI to smaller universities, the price (indiscernible) very expensive. I don't know what you think, but I think they're a lot of money. So --

PARTICIPANT: (Indiscernible.)

MR. WILLIS: Do we have any other questions?

(No response.)

MR. WILLIS: Before I let everybody go, Tim Deering brought up a great idea this morning. There's a lot of us now with towed undulating vehicles -- ScanFish, SeaSoar, VanFish (ph), what have you -- and Tim's idea is to set up a mailing list for people who either have those vehicles or are interested in them to exchange information ideas. If you're interested in being on such a list or listening in on such a list, you can see Tim. He's back there in -- raise your hand, Tim -- in the striped shirt, or myself. We'll get your name and your e-mail address and put you on such a list. I think it's a real good idea.

# BOTTOM SAMPLING TECHNIQUES
# And
# DECK OPERATIONS AND ONBOARD SAFETY

Chaired By
Woody Sutherland

# A Large Diameter Piston Corer For Use On UNOLS Research Vessels

Peter A. Kalk
Oregon State University

**Abstract**

Techniques of systematic deep ocean sediment coring began with the British Challenger Expedition (1872-76), and evolved over the years until Kullenberg's invention of the piston corer in 1947. Since then, piston corers have gotten larger and longer but they are still based on Kullenberg's design.

A large diameter piston corer has been developed at Oregon State University's College of Oceanic and Atmospheric Sciences Marine Geology Group that has been used on several UNOLS and NSF sponsored cruises. Core recovery has been generally good but some problems have been encountered with UNOLS vessels and equipment.

**Introduction and History**

The first systematic collecting of marine sediment samples took place during the British Challenger Expedition of 1872-76. While many of these samples came from dredge hauls many cores were gathered. These cores were about a foot in length and were taken by a device called a Baillie Sounding Machine (Fig. 1). The machine's center tube projecting below the sounding weights acted as a small gravity corer. When the sounding machine struck the ocean floor the 150 to 200 kg of weights were jettisoned thus eliminating the need to haul the entire weight package back to the surface. The Challenger carried no geologists aboard and the collected cores were not described until about 15 years later.

After the Challenger Expedition several other efforts at collecting deep ocean sediment samples were undertaken during the late 19th and early 20th centuries. From 1888 to 1920 the United States Fish Commission Steamer Albatross sampled marine sediments from ocean depths of the eastern Pacific and from bays and estuaries along the west coast of North America. The Dutch steamer Siboga during its 1899-1900 expedition to the East Indies gathered sediment samples in large quantities. Expeditions to collect samples of deep ocean sediments were embarked upon by the German Steamers Edi Stephan and Planet during the first part of the present century.

All of the expeditions mentioned, while collecting sediment samples, also made soundings that resulted in charting of the ocean depths which slowly began to reveal the topography of the ocean floor. However, the rope and later piano wire lowerings of weights to the bottom took many hours of time for a single deep sounding. And there was no way to correlate a sediment sample to the ocean floor topography and bottom features. All you had was a sample depth.

Shortly after the end of World War I echo sounding devices were developed thus ending a period of relative inactivity in the study of marine geology. No longer was it necessary to stop a vessel to make a sounding. The German Steamer Meteor was among the first to embark in exploration by the new method. From 1925 to 1927 the Meteor made extensive bottom profiles across the South Atlantic. Over the two year period 311 stations were occupied resulting in 43 3 wire soundings, 74 grab samples, and 359 gravity cores (Fig. 2). With the echo sounder 33,000 depth determinations were made. Core liner was glass tubing.

By the end of the 1920's knowledge of the deep oceans was coming more and more from the work of the oceanographic institutions. Investigations of sediments by Henry C. Stetson began at Woods Hole Oceanographic Institution in 1929 and were followed a few years later by Francis P. Shepard of Scripps Institution of Oceanography on the West Coast. Most sampling was done with grab samplers and gravity

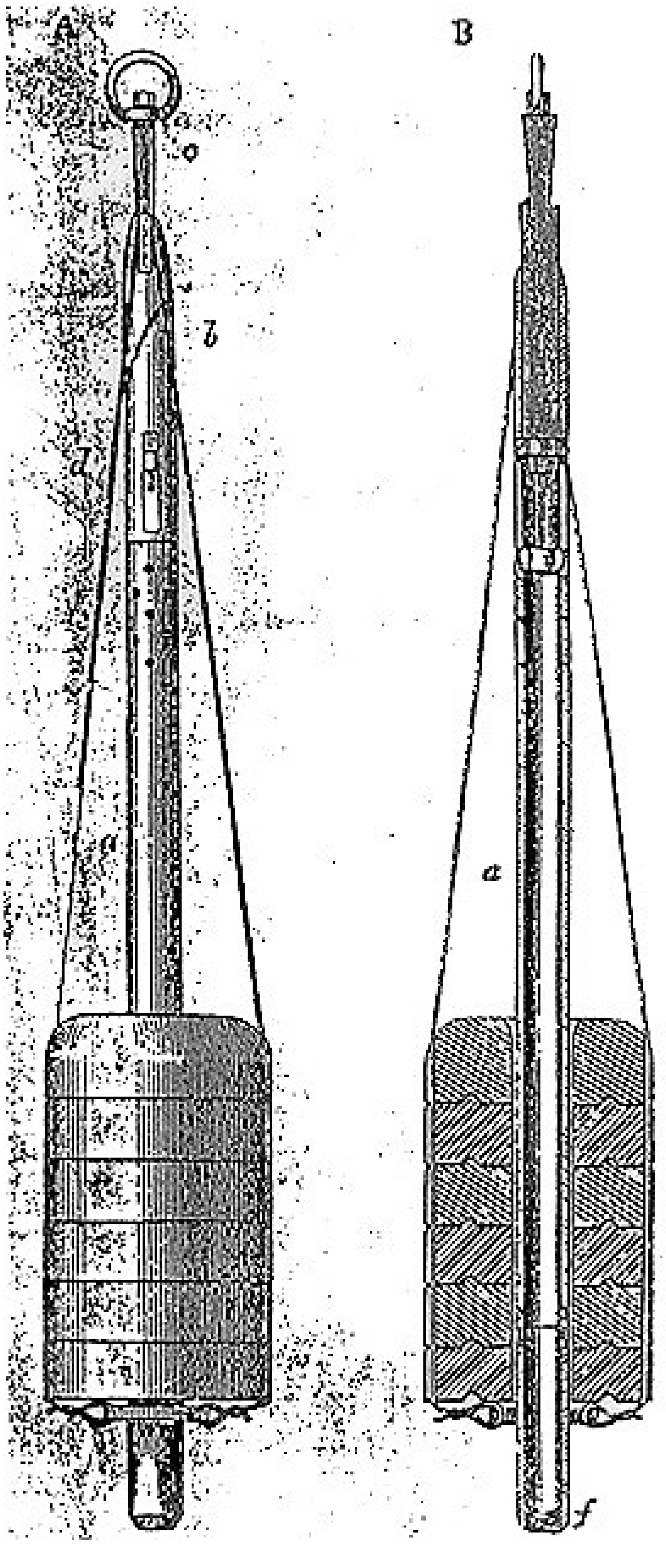



Fig. 1. The Baillie Sounding Machine. The tube (f) was generally made to project 18 inches below the weights (e). From Murray and Hjort (1912).

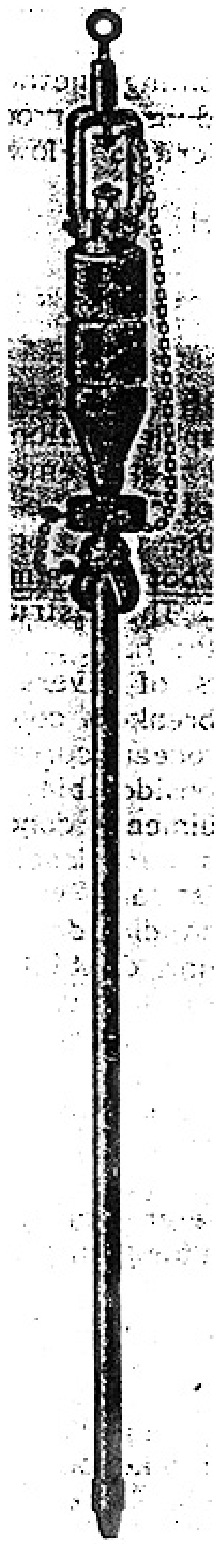


Fig. 2. Mud sampling tube (gravity corer) used on the Meteor Expedition. From Spiess (1928).

corers. In his studies of Scripps Submarine Canyon Shepard sometimes employed the services of a hard-hat diver who would drive pipes into the canyon floor and then signal to Shepard in a skiff above to pull on a line attached to the sediment filled pipes thus bringing them to the surface. As the pipes left the canyon floor the diver would tie rags over the bottom ends to keep the sediments from falling out.

There were, however, problems using gravity corers. Getting enough speed in lowering to drive the corer more than a couple of feet into the bottom was a major problem. Early models of winches were slow and it was hard to tell when the corer was on the bottom in deep water. Wire would pile up and foul especially with some types of the early used piano wire. To overcome the penetration problem Charles Piggot, a student of Henry Stetson at WHOI, developed the coring gun or the core sounding apparatus as Piggot called it (Fig. 3). The Piggot gun was used on an August, 1935 RN Atlantis cruise in which 14 cores were taken. The maximum length of core obtained was eight feet, eight inches. Brass tubing was used for core liner. The explosive charge used one gram of high-speed black powder as a primer and a varying number of pellets of 155 mm. howitzer powder for the main explosive force. Relatively long core samples were obtained using the Piggot gun at stations from Newfoundland to Ireland across the North Atlantic in the late 1930s. Use of the Piggot gun was finally discontinued because of powder storage problems and a few on-deck detonations.

Kenneth O. Emery and Robert S. Dietz, students of Francis Shepard at SIO, developed a very dependable gravity corer in 1938 (Fig. 4). This corer was used on the R/V E.W. Scripps along the California coast and in the Gulf of California from 1938 to 1941. 229 cores were taken with a maximum length of 17 feet. This length core was possible because winch and wire developments by this time allowed for rapid lowerings. The core liner was a strip of 15 gauge celluloid reinforced at each end and rolled into a cylinder before being inserted into the steel corer tube. The core catcher was made of strips of celluloid.

In the summer of 1940, Juul Hvorslev and Henry Stetson of WHOI came up with a way to solve one of the problems of gravity coring-getting a greater lowering speed to increase penetration of the sea floor. They devised a way to let the corer free-fall detached from the lowering wire and winch (Fig. 5). This method is one of the basis of piston coring to this day. The trigger arm design (Fig. 6) with one notable modification is also used in present-day coring. The free-fall coring tube took 21 cores in the summers of 1940 and 1941 aboard the RN Atlantis. Maximum length of these cores was 113 inches using free-fall drops of seven to ten feet. The drive weight (Fig. 7) was 1000 pounds and a brass tubing liner was used. Due to World War 11 the description and operation of the free-fall coring tube was not published until 1946.

Marine sediment research pretty much ended with the start of World War 111, the exception being the compilation of sediment charts from sample notations in the war areas.

Hvorslev's and Stetson's free-fall coring tube addressed one of the major problems connected with coring. However, another major problem existed - how to overcome the friction of the sediment passing the walls of the coring tube or liner as the sediment enters. Emery and Dietz noted with their gravity corer that they never recovered cores that equaled the depth of penetration in the sediment as noted on the outside of the coring tube. Charles Piggot with his coring gun observed this also. The conclusion of these observations led researchers to the fact that once the coring tube or liner fills to a certain amount, the friction between the sediment and coring tube wall becomes so great that filling the stops and the bottom of the tube just pushes the deeper sediments out of the way.

Something was needed to overcome this friction. Böörje Kullenberg of the Swedish Oceanographic Institute in Goteborg had been experimenting with ways to counteract this friction with suction as early as 1940. He started with a vacuum sampler with a piston and finally devised a method of using a piston with Hvorslev's and Stetson's free-fall coring tube. Thus was developed the piston corer (Fig. 8).

After Kullenberg invented the piston corer in 1947 many modifications have been incorporated over the years. In 1951 Maxwell Silverman and Richard Whaley of the Chesapeake Bay Institute of the Johns Hopkins University made a significant modification to Hvorslev's and Stetson's freefall corer release mechanism. Instead of the lowering wire being attached to the top of the trip arm and another, separate, wire running from the bottom of the trigger arm to the piston, the new modification allowed the lowering

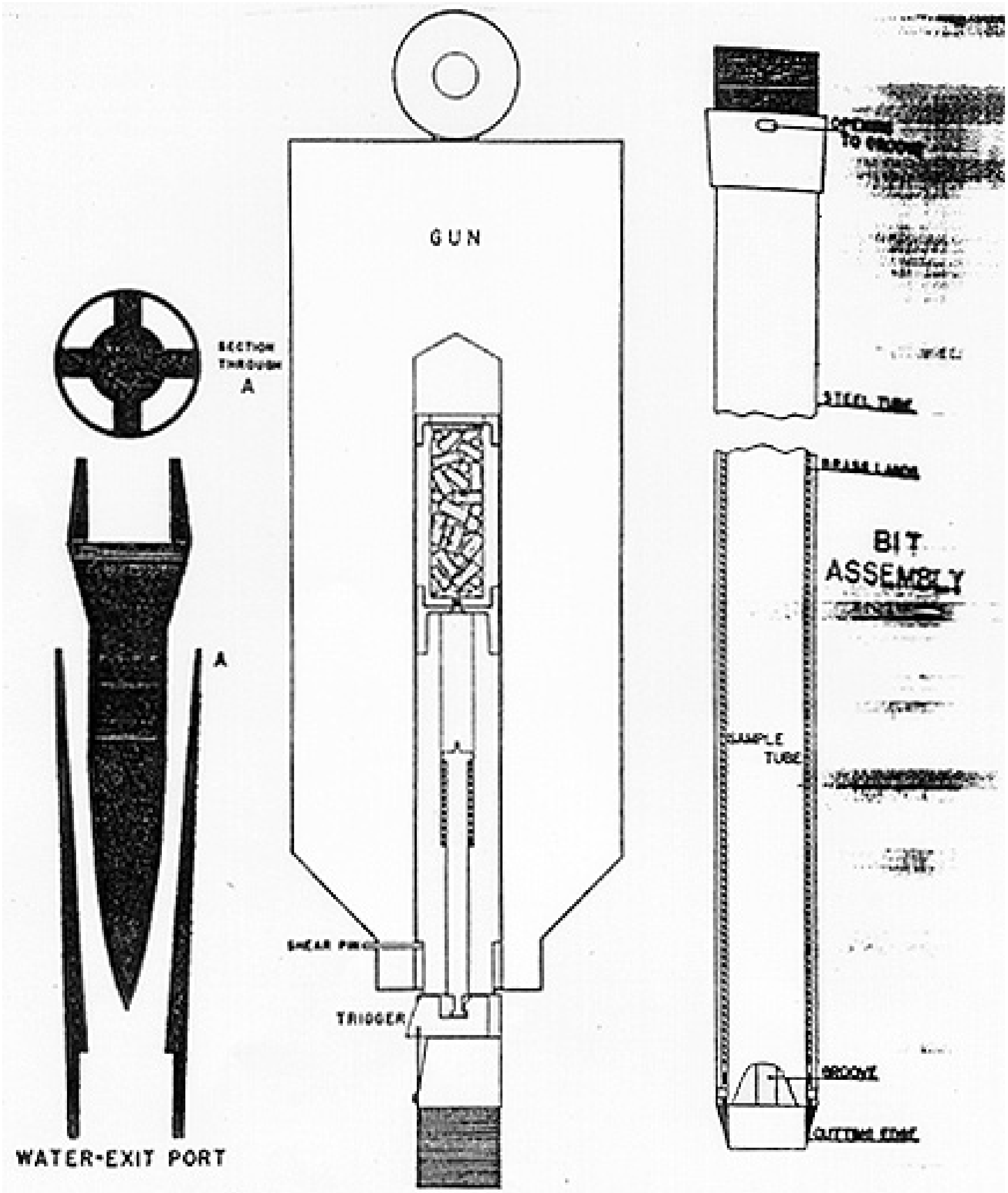



Fig. 3. Principal parts of the Piggot coring gun. From Piggot (1936).

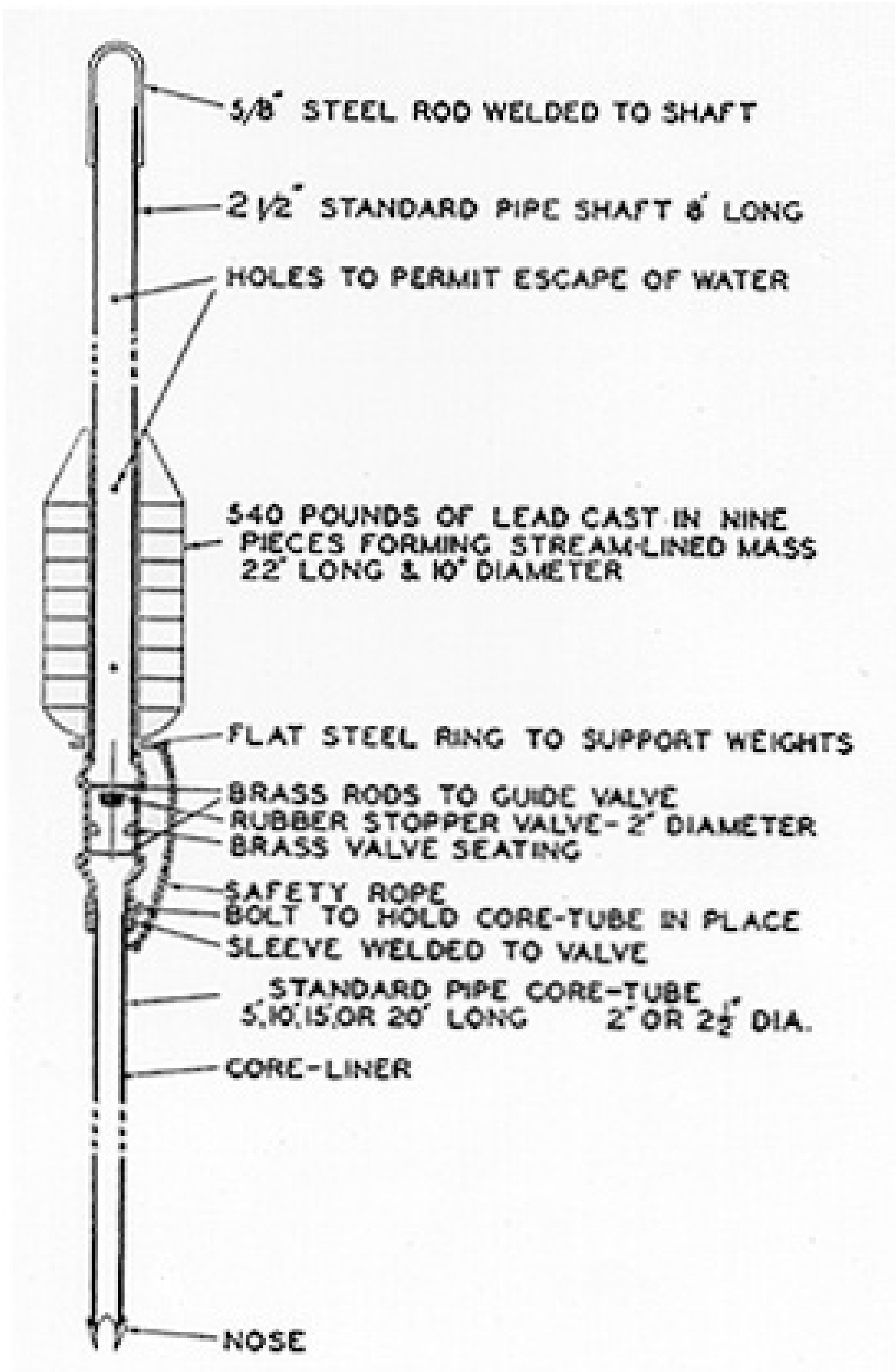



Fig. 4. Emery and Dietz gravity corer. From Emery and Dietz (1941).

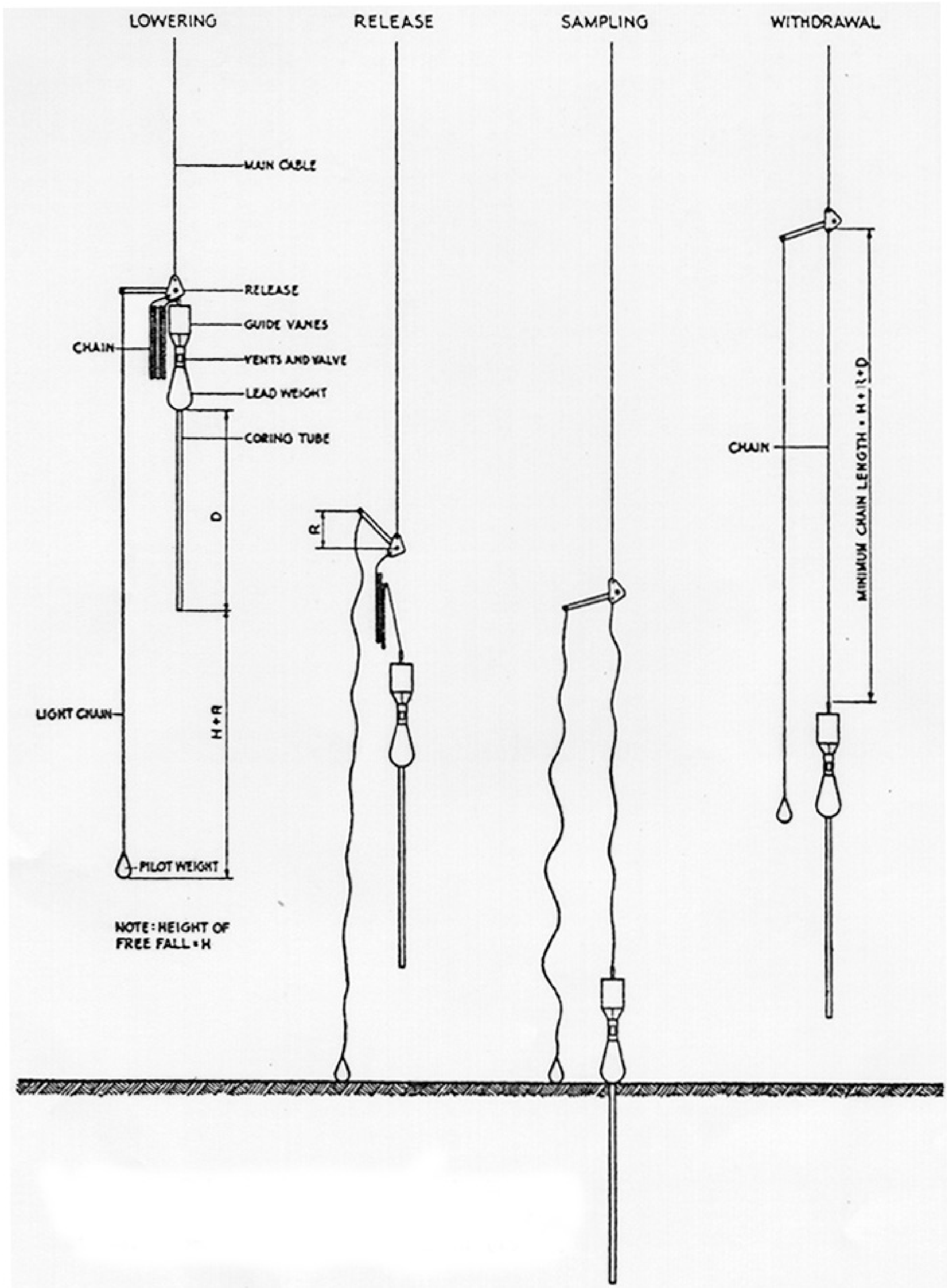



Fig. 5. Principal elements and steps of operation of the free-falling coring tube. From Hvorslev and Stetson (1946).

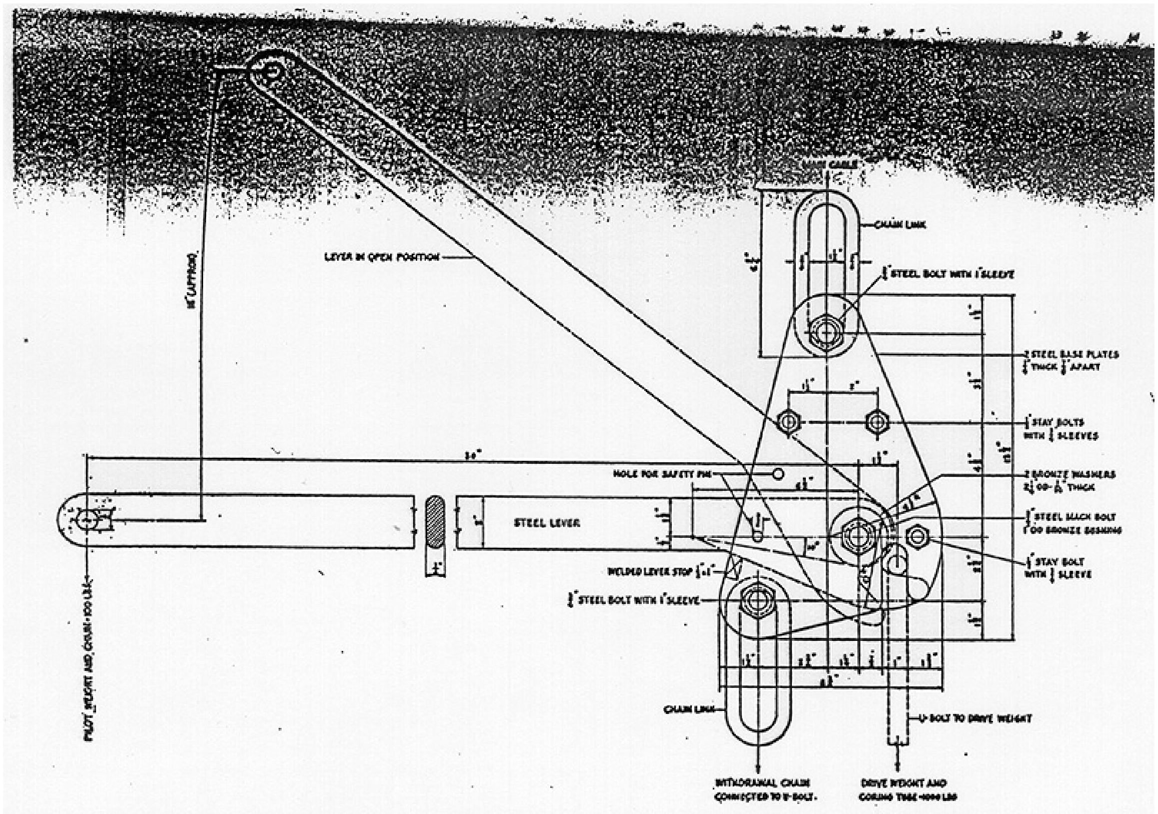



Fig. 6. Release mechanism for free-fall sampler. From Hvorslev and Stetson (1946).

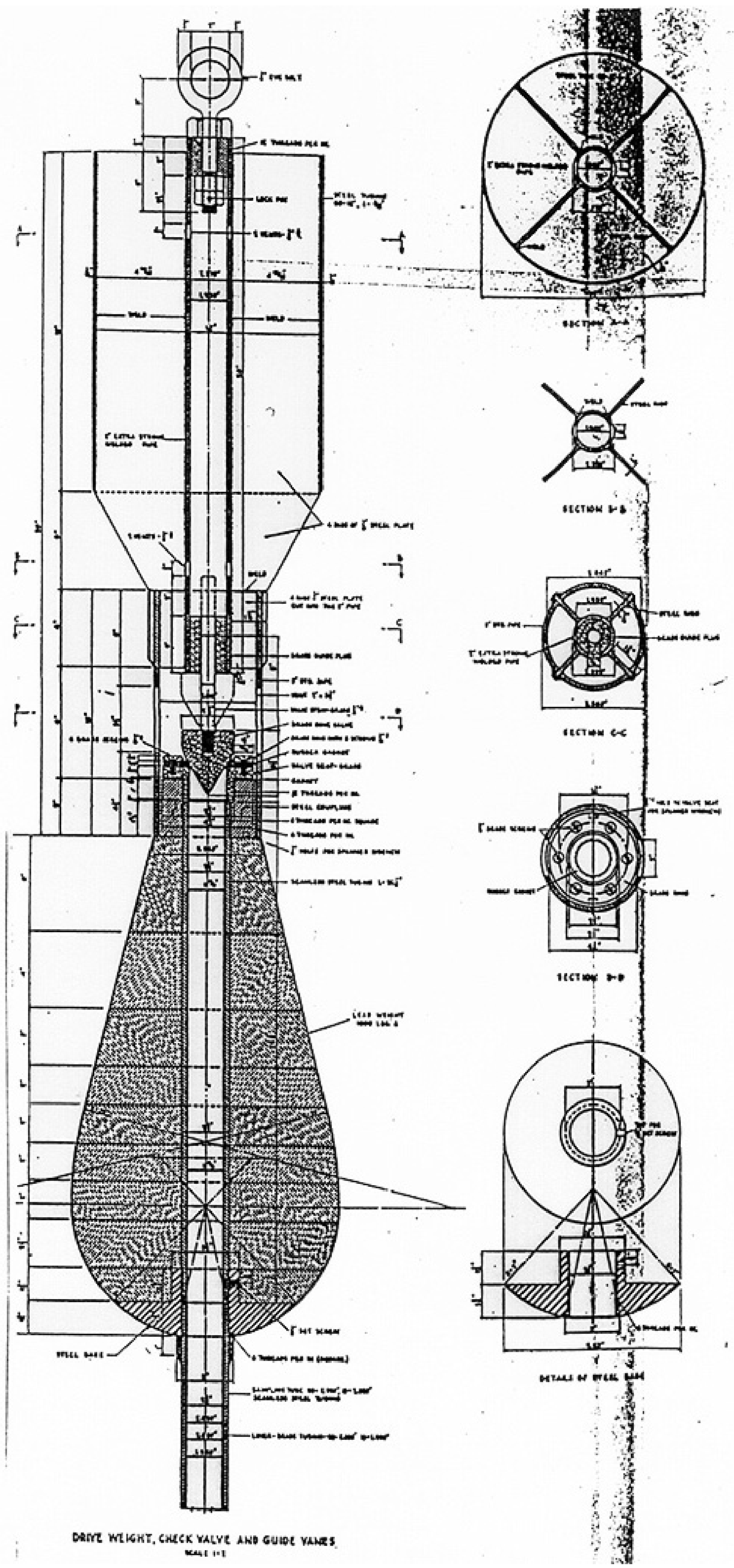



Fig. 7. Drive weight for free-fall sampler. From Hvorslev and Stetson (1946).

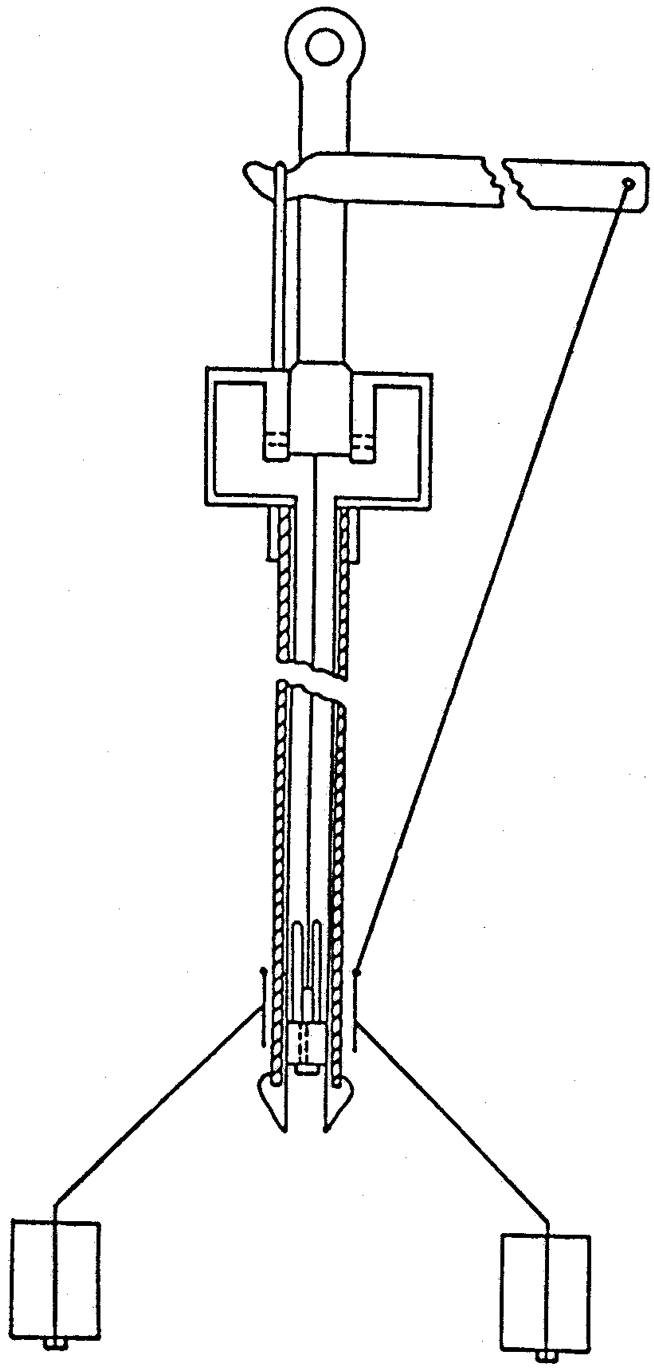


Fig. 8. Illustrating the principle of the Kullenberg piston corer. The trip weights are shown on the side, and the piston in the center of the core barrel. From Shepard (1964).

wire to be used alone. The lowering wire was clamped to the side of the trigger arm (Fig. 9), then after taking into account the free-fall distance, the end of the lowering wire was attached to the piston. This eliminated the need to constantly be changing the trigger arm to piston wire when the free-fall distance or tube length was increased or decreased. The new trigger arm was tested during the 1951 field season in Chesapeake Bay's sands and gravels. 20 foot long cores were obtained with only 250 pounds of drive weight. Anywhere from six to eighteen feet of free-fall was used. Because no core liner was used, all cores were extruded from the core tubes.

Many of the earlier corers and even corers used up to the mid-1960's had no core liners. The sediments had to be extruded. This process resulted in core compression and loss of interstitial water so core extrusion was not an ideal situation. The cores were pushed out of the tubes by extruding rods onto butcher or waxed paper held in wooden or metal trays and then wrapped and labeled (Fig. 10). To get away from the extrusion process core liners started being used in gravity corers as early as the mid-1920's. Glass tubing, brass tubing, and rolled celluloid sheet were materials employed as core liners early on. As the petrochemical and plastics industry progressed with its products more and more plastic tubing was used as core liner. First came Cellulose Acetate Butyrate (CAB) tubing, then tubing from polycarbonates (Lexon), and finally Polyvinyl Chloride (PVC) tubing. Not only did the basic plastic tubing materials change but also the sizes (Fig. 11) as marine geologists were demanding more sediment sample material. Also influencing plastic liner selection is cost. The war between the Arabs and Israelis in 1973 caused oil prices to rise hence a rise in the cost of plastic tubing. Three inch diameter polycarbonate tubing jumped from $1.50 per foot in early 1973 to over $6.00 per foot a year later. Prices for the four inch diameter PVC plastic pipe commonly used today as core liner have remained fairly stable in recent years at about $1.25 per foot.

Besides being heavier, larger diameter, and longer, piston corers from the mid-1950's to the present day still employ the basic Kullenberg concept. A 2000 pound piston corer capable of taking 20 meter cores was designed and built by John Ewing of Lamont-Doherty Geological Observatory. In the early 1970's Charles Holister of Woods Hole Oceanographic Institution and Armand Silva of Worcester Polytechnic Institute designed a "giant piston core". The weight stand carried up to 13,000 pounds to drive over 40 meters of core barrel into the sediment. Five cores were recovered, the longest being about 30 meters – a record length at that time. These corers, ultimately, were all lost at sea due to wire failure.

There are commercially manufactured and available piston corers. Benthos Inc. of North Falmouth, Mass. has a large piston corer that sells for $34,202. This corer has a 2,000 pound weight stand with a polycarbonate liner of 2.65 inches in diameter. It is advertised that cores of up to 15.2 meters length are possible with the Benthos corer. Alpine Inc. of Norwood, N.J. has available a similar piston corer for $18,200.

In the late 1970's, Alan Driscoll designed the Woods Hole Standard Piston Corer (Fig. 12). This design was supposed to have become the standard piston corer for all UNOLS institutions. A few universities accepted the plan but others built their own systems. Today, a lot of UNOLS institutions use modifications of the Driscoll design or use a "jumbo piston corer" which was put together by Jim Broda of WHOI.

Some overseas companies and governments have, in recent years, developed a variety of coring systems. The Norwegians have produced a "vibra-corer" type device that uses hydrostatic pressure to power a motor that drives the core pipes into the sediment (Fig. 13). Selcore reportedly gets excellent results in sand and gravel.

This past summer the French government conducted a series of coring cruises aboard the R/V Marion Dufresne out of Indonesia. This ship is 120 meters in length and was constructed for taking long piston as one of its missions. The coring system deployed from the Marion Dufresne uses a weight stand that can be adjusted from six to nine metric tons. Core barrels range up to 60 meters in length and 55 meter long cores have been recovered. A portable winch carrying a kevlar line with a breaking strength of 60 metric tons lowers and hoists the corer. Because kevlar cannot be clamped, a separate line runs from the tripping arm to the piston in much the same way as the original Kullenberg piston corer. This piston line is wire rope with a breaking strength of 27 metric tons. The trip arm to piston line acts as a safety line if the corer becomes

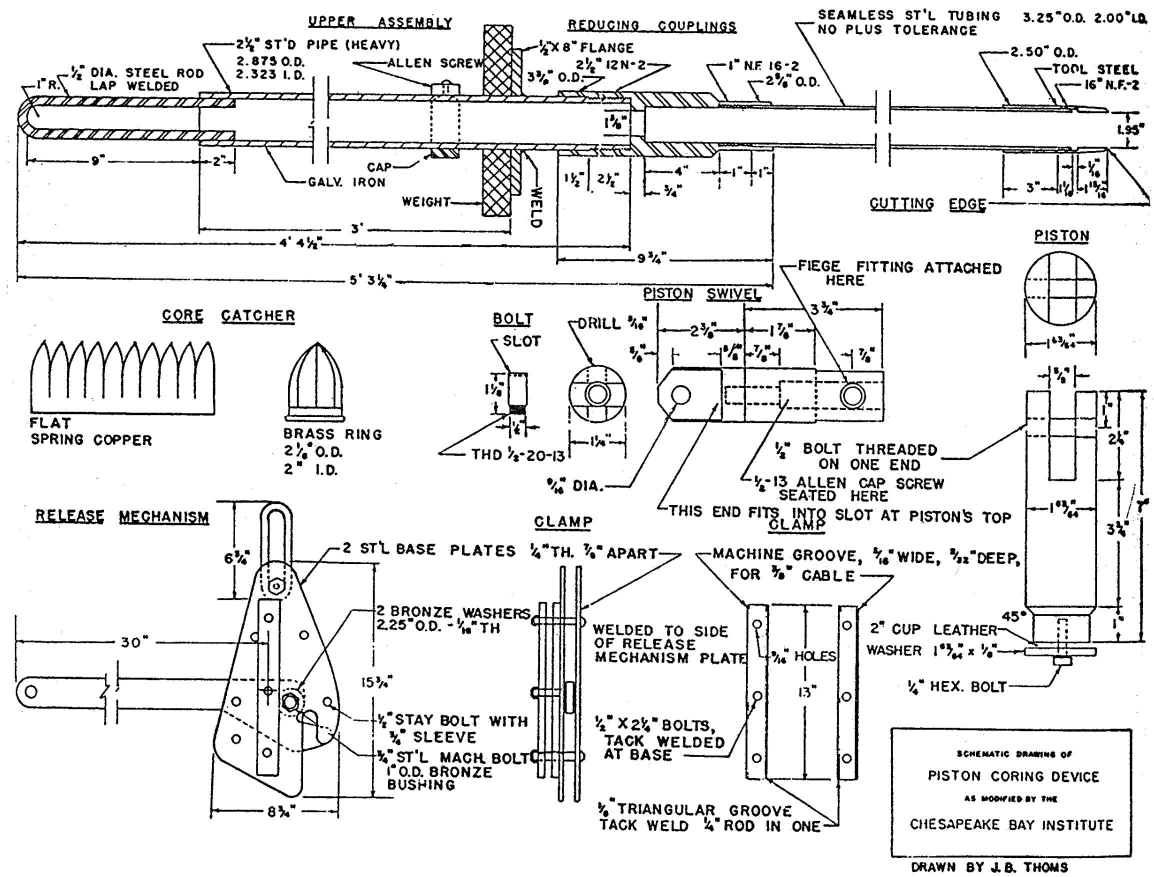



Fig. 9. Modified Release Mechanism. From Silverman and Whaley (1952).

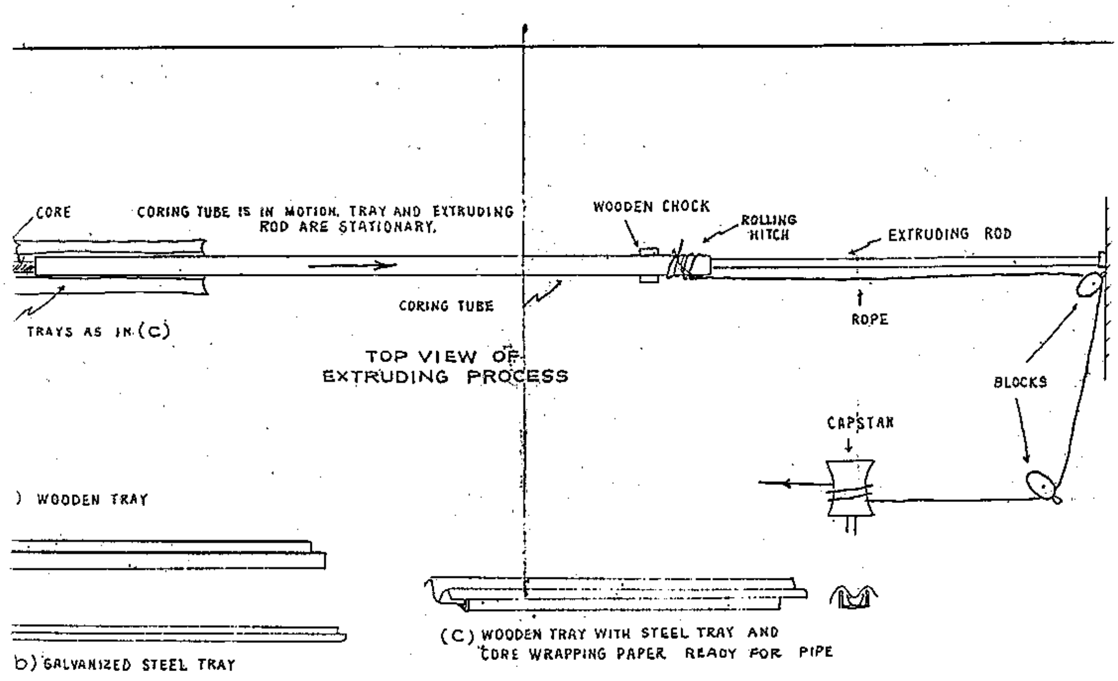



Fig. 10. Typical Extruding Setup. From Alpine Geophysical Associates (1961).

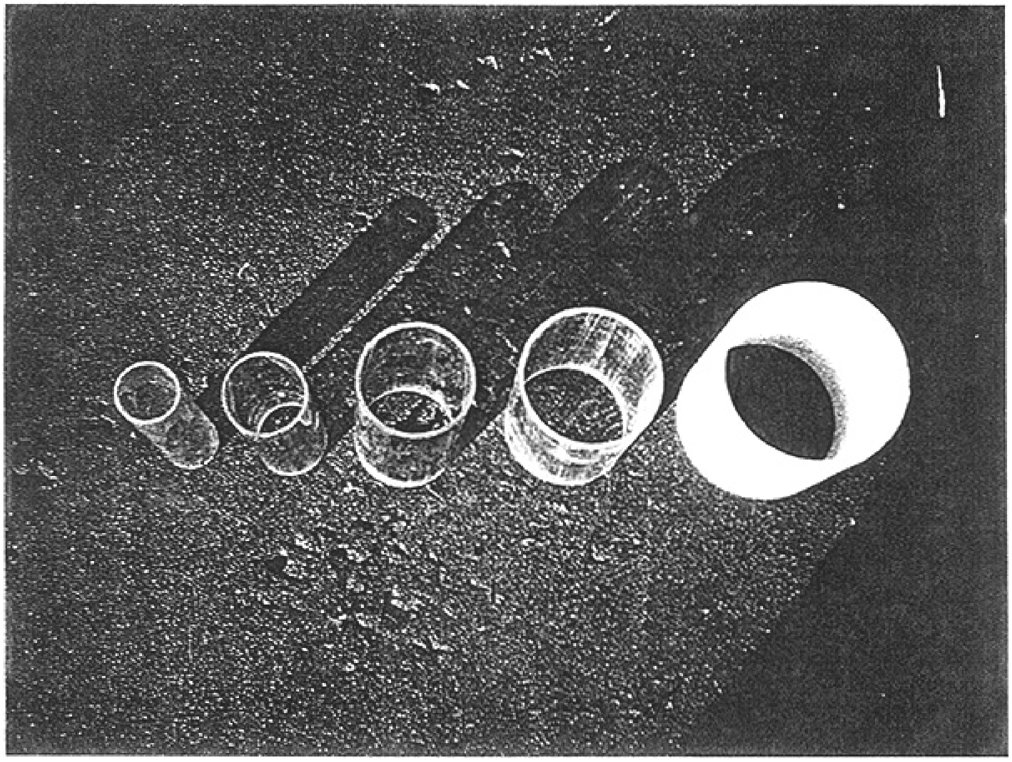


Fig. 11 a.

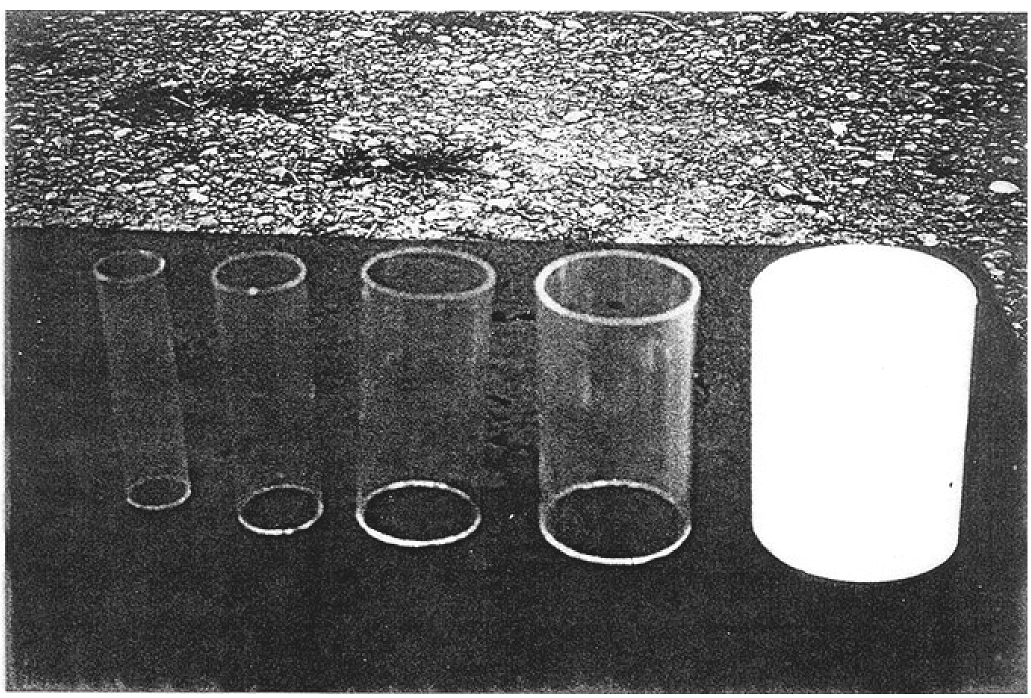


Fig. 11 b. Plastic tubing core liner. Two on the left- cellulose acetate butyrate; two in the center- polycarbonate; on the right- polyvinyl chloride.

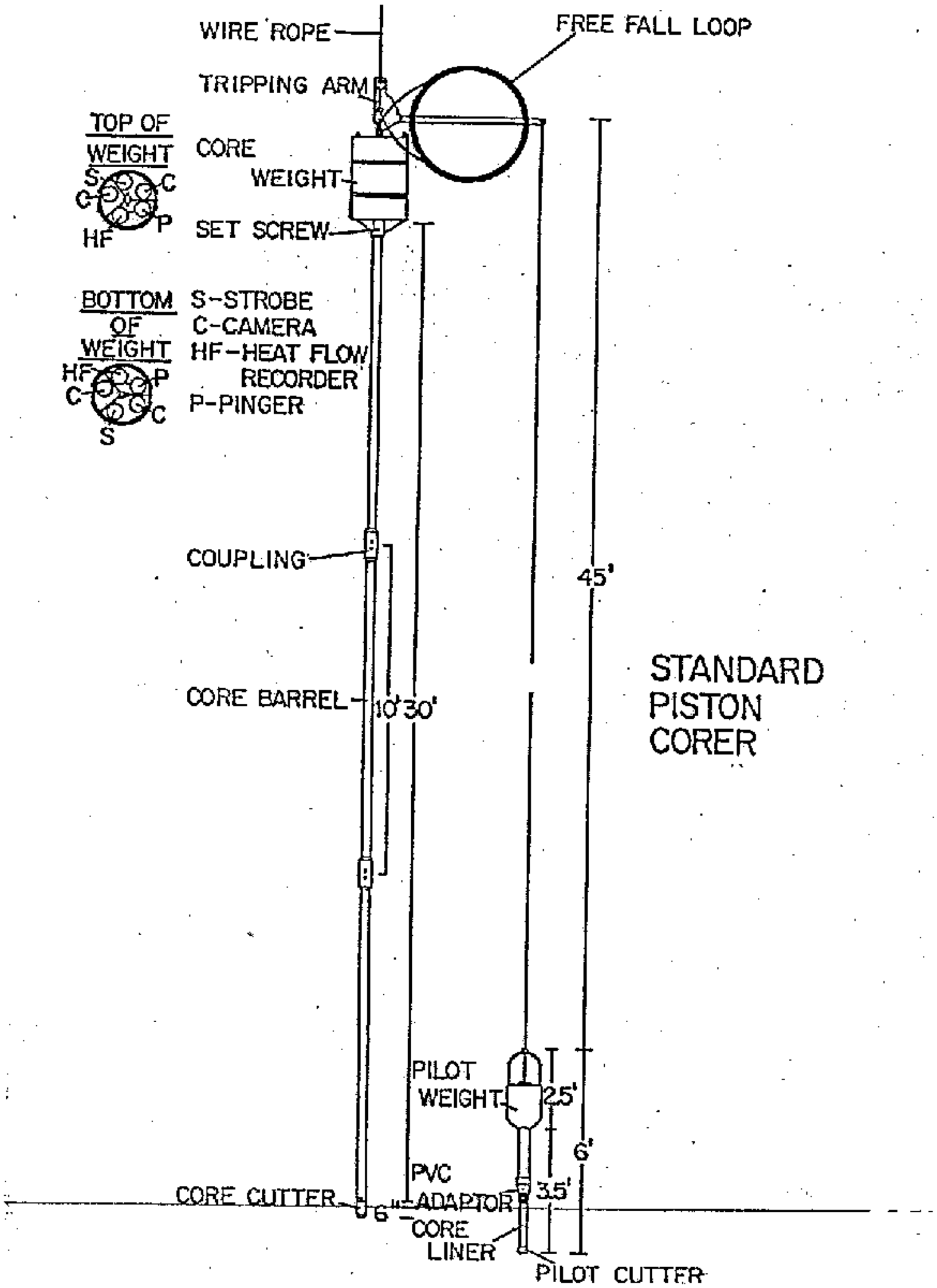
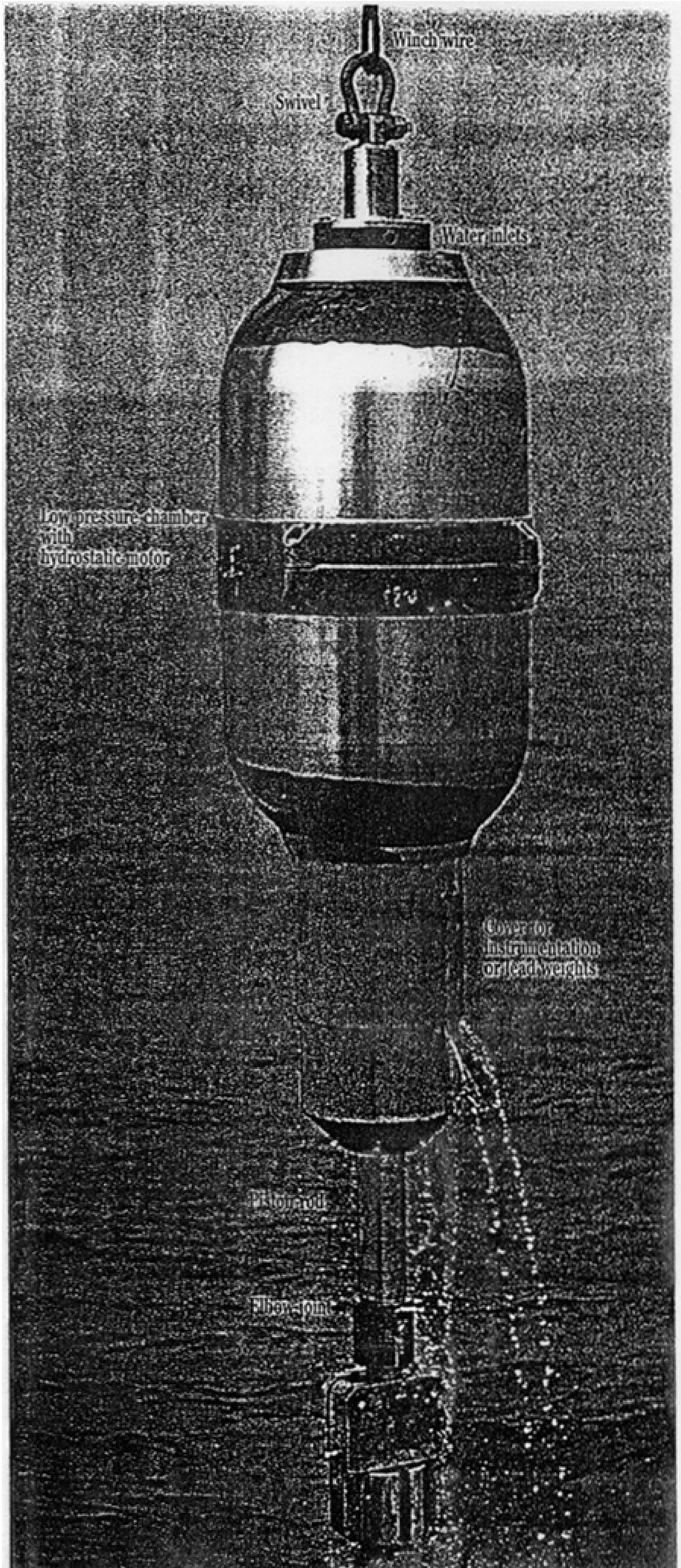



Fig. 12. WHOI Standard Piston Corer. From Driscoll (1977).

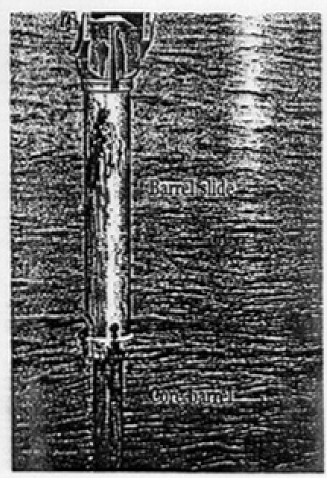



# SELCORE

a new generation of sediment corers capable of MANY TIMES THE RECOVERY OF CONVENTIONAL CORERS.
The heart of SELCORE is the PATENTED HYDROSTATIC MOTOR.
Like a drop corer, SELCORE is deployed free fall at a convenient distance above the sea bed. SELCORE will not tilt during the descent as the center of buoyancy is above the center of gravity. The free fall stabilizes SELCORE without the need for external guidance framework.
The hydrostatic motor is activated automatically when the core barrel hits the sea bed. The energy is derived from the differential pressure between the air in the low pressure chamber and the ambient hydrostatic pressure at the depth where SELCORE is operating. There are no hydraulic hoses, no electric cables and no batteries to be charged[1].
The hammer action will stop when either full penetration is reached, solid bedrock is encountered or five minutes has elapsed.
An elbow joint permits the core head to swing 90° away from the barrel to ease handling on deck.

SELCORE is available in a variety of sizes and weights, ranging from about 500 Kg to 2000 Kg, excluding barrels.

SELCORE may be instrumented for logging of accelerations and penetration per stroke as well as measurement of *in-situ* electrical resistivity.
Other optional equipment is available on request.




SELCORE detail. ▲

◄ **The illustration shows a 1750 kg SELCORE version.**

**[1] At depths shallower than approximately 120 m, the hydrostatic differensial is insufficient to activate SELCORE. In these depths a supplementary power pack**

Fig. 13.

stuck in the ocean floor. It is more desirable to part the piston line and lose the corer than lose the expensive kevlar line. An average of two corers per cruise are lost as a result of “being anchored by the corer”. The French are presently working on a device to separate the core barrels from the weight stand thus saving the more valuable weight stand in “stuck-corer” situations.

**A Large Diameter Piston Corer**

All Components of Oregon State University’s large diameter piston corer are shown in the accompanying photographs taken by June Wilson of OSU. This system has been used successfully on several UNOLS ships over the past six years. A local machine shop fabricated the corer using a variety of drawings and patterns from various sources. This piston corer is similar to the “jumbo” coring system designed by Jim Broda of WHOI and is shown in the photographs as a 30 meter long set up.

The corer cradle (Figs. 14a, 14b, 15a, and 15b) is of all steel construction and is designed to hold weight stands of up to 6,000 pounds. The cradle has three positions for shipboard use. The inboard, vertical position (Fig. 14b) is used for transporting the weight stand from staging areas on land to the ship and for going in and out of port. The outboard, horizontal position (Fig. 15b) holds the weight stand during assembly of core pipes prior to the first deployment. This cradle position is also used during liner loading and extrusion before and after each core is taken. The outboard, vertical position (Fig. 15a) is used as the piston corer is deployed to the sea floor and after sampling is completed.

Fig. 16b shows how a 30 meter piston corer would look sitting in the corer cradle in the outboard, horizontal position down the side of a ship with the core pipes resting on outboard corer racks (Fig. 16a) attached to the ship’s rail.

The weight stand (fig. 17b) is 24 inches in diameter and 40 inches long and weighs 2,700 pounds without the lead slugs or pigs (Fig. 17a) that can be added for increased driving force. Each lead ingot weighs 600 pounds and, with five added, takes the weight stand to 5,700 pounds maximum.

The weight stand bale is one and one-eighth inch diameter stainless rod. The entire weight stand is constructed of stainless steel and is based on a design of Alan Driscoll of WHOI. The instrument wells, if not used for adding extra drive weights, are designed for cameras, strobe lights, heat flow recorders, pingers, and other pressure cases.

The trigger arm (Fig. 18a) is constructed of stainless steel and is based on the Hvorslev and Stetson design of 1946. The brass wire clamp is molded for use with standard UNOLS 9/16 inch diameter, 3x19 oceanographic wire rope. The arm, itself, is the typical unbalanced beam - two inches in length on one side of the pivot point and 45 inches on the other. The hydrostatic safety pin (Fig. 18b) used to prevent pre-trips upon launch and in the upper water column is made of stainless steel and activates at 500 meters depth. If a greater arming depth is desired shear pins may be used. This trigger arm design works well with no pre-trips occurring in over 60 piston cores taken on the Thompson, Revelle, and Ewing.

The core pipe couplers (Fig. 19b) are made from steel tubing 6.000 inches O.D., 5.250 inches I.D., .375 inches wall thickness, and are 18 inches long. The core pipes (Fig. 19a) are also fabricated from steel tubing that is 5.250 inches O.D., 4.625 inches I.D., .313 inches wall thickness, and 3 meters or 10 feet long. The core pipes are fitted together in the core couplers using 16d construction nails (Fig. 19a) that fit into eight machined grooves in the couplers/core pipes. Should a nail head breakoff, the nail is extracted from the fitting by rotating the core pipe in the coupler. The broken off nail is backed out by a weld across the core pipe nail groove.

Four inch diameter, class 160 PVC plastic drainage or irrigation pipe (Figs. 20a and 20b) is used as core liner in the OSU piston coring system. This pipe is 4.500 inches O.D., 4.154 inches I.D., 0.173 inches wall thickness, and comes in 20 foot long belled sections. For use as core liner the bells must be cut off. This PVC pipe is rated at 160 P.S.I. bursting strength which has proven adequate. There has been no imploded liner in six years of use and only a few split liners. The 20 foot sections of liner are taped together (Figs. 21a and 21b) using 3M #3750 clear packaging tape.

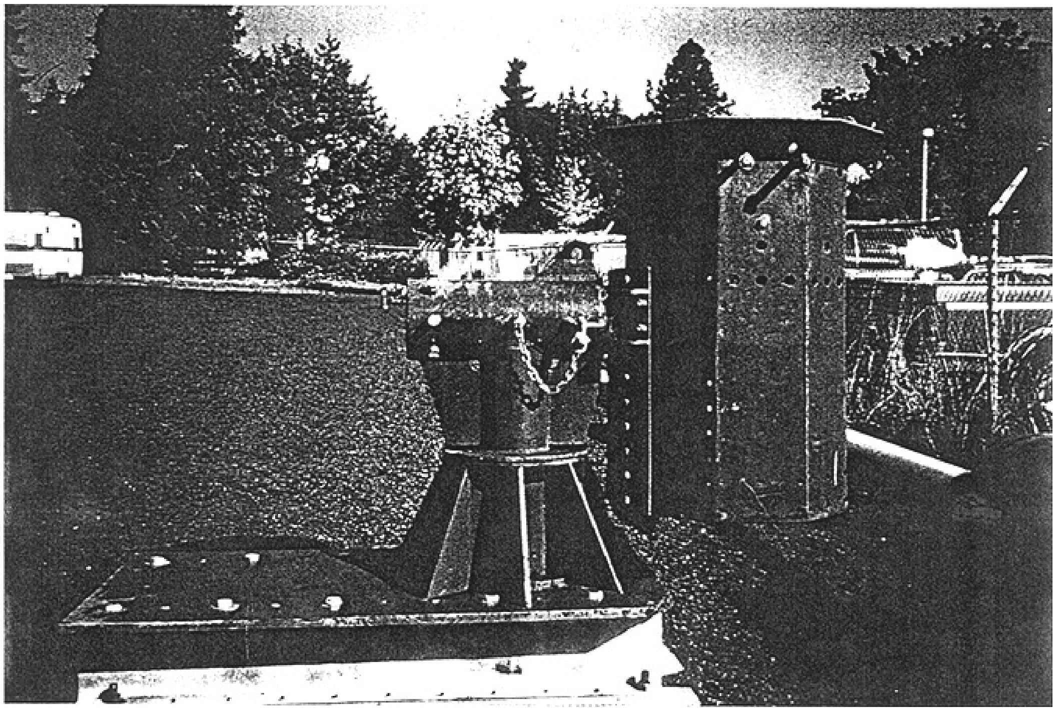


Fig. 14 a. Corer Cradle- outboard position, vertical.

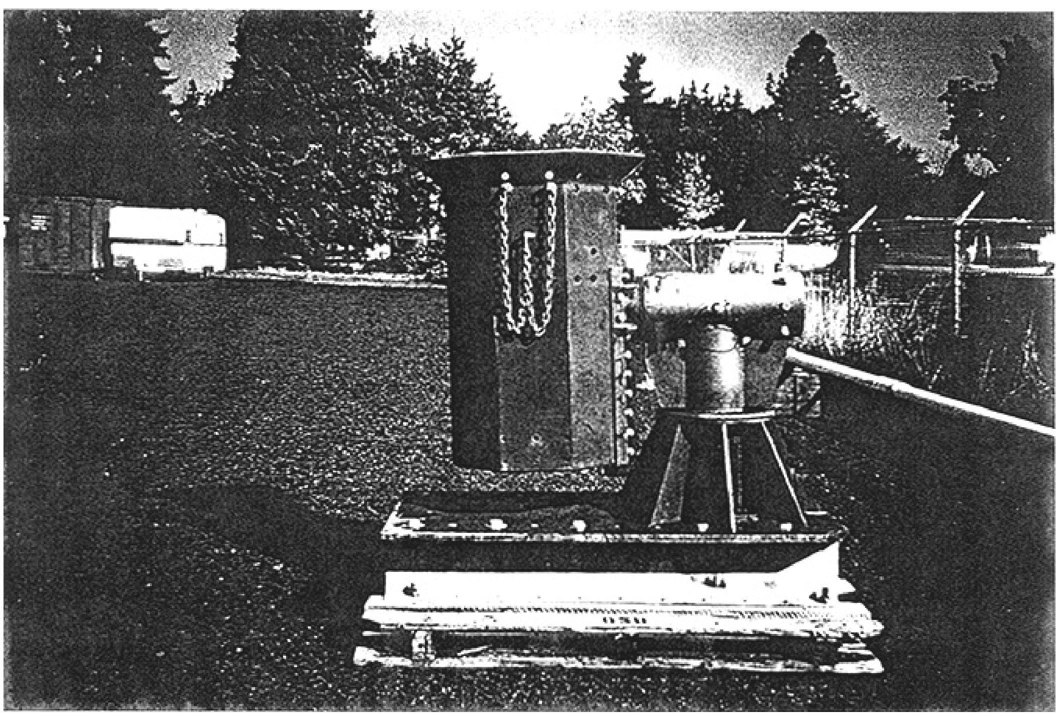


Fig. 14 b. Corer Cradle- inboard position, vertical.

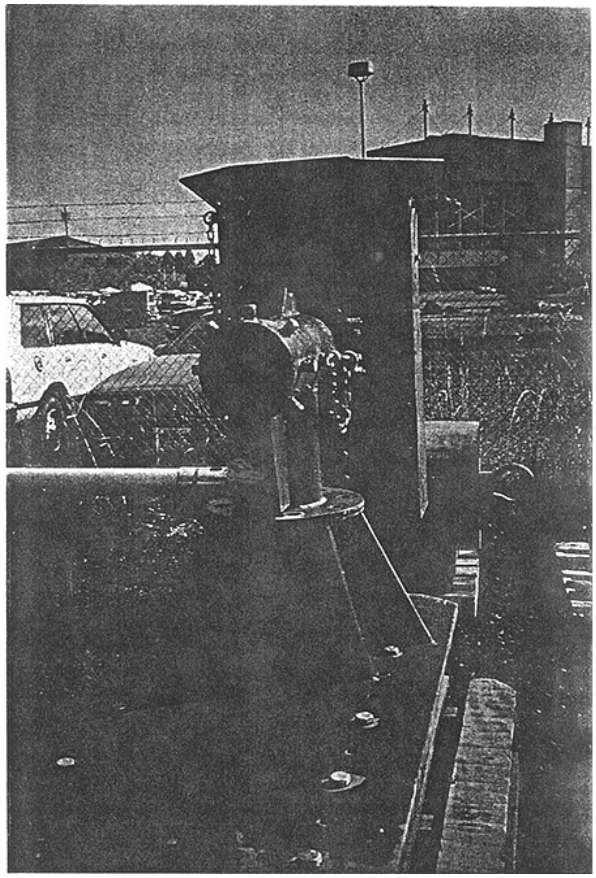


Fig. 15 a. Corer Cradle - outboard position, vertical.

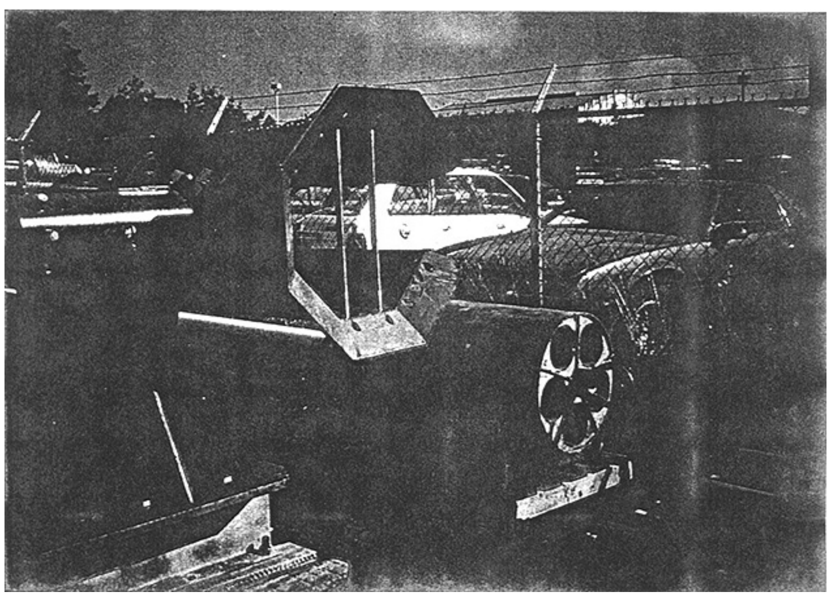


Fig. 15 b. Corer Cradle - outboard position, horizontal.

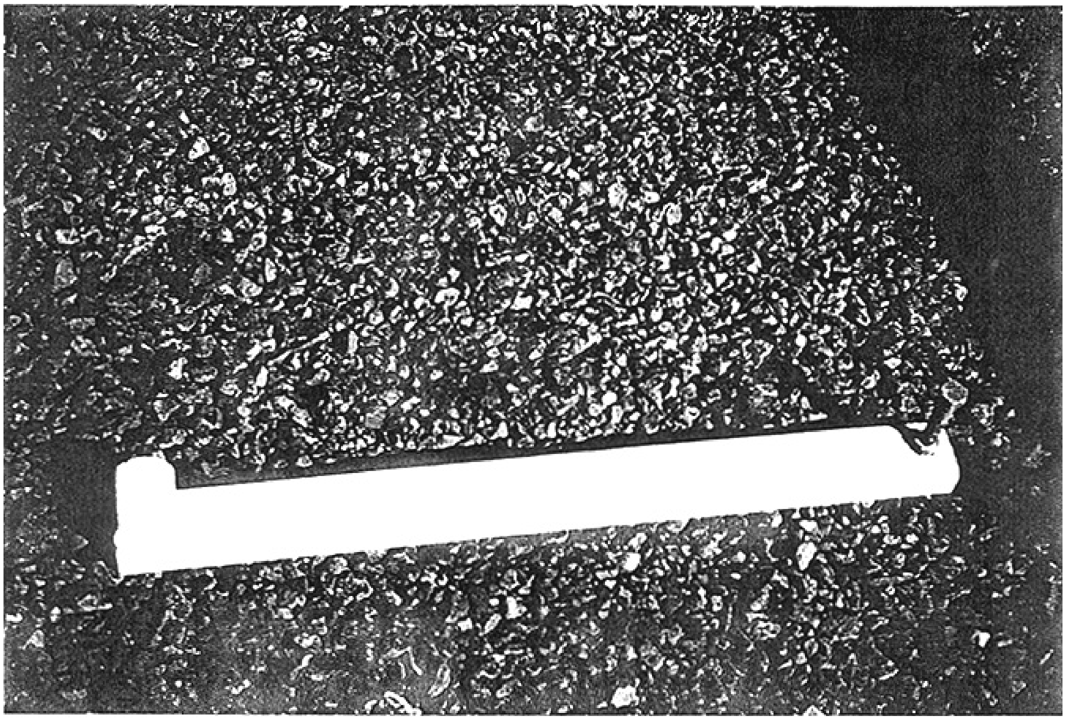


Fig. 16 a. Outboard corer rack.

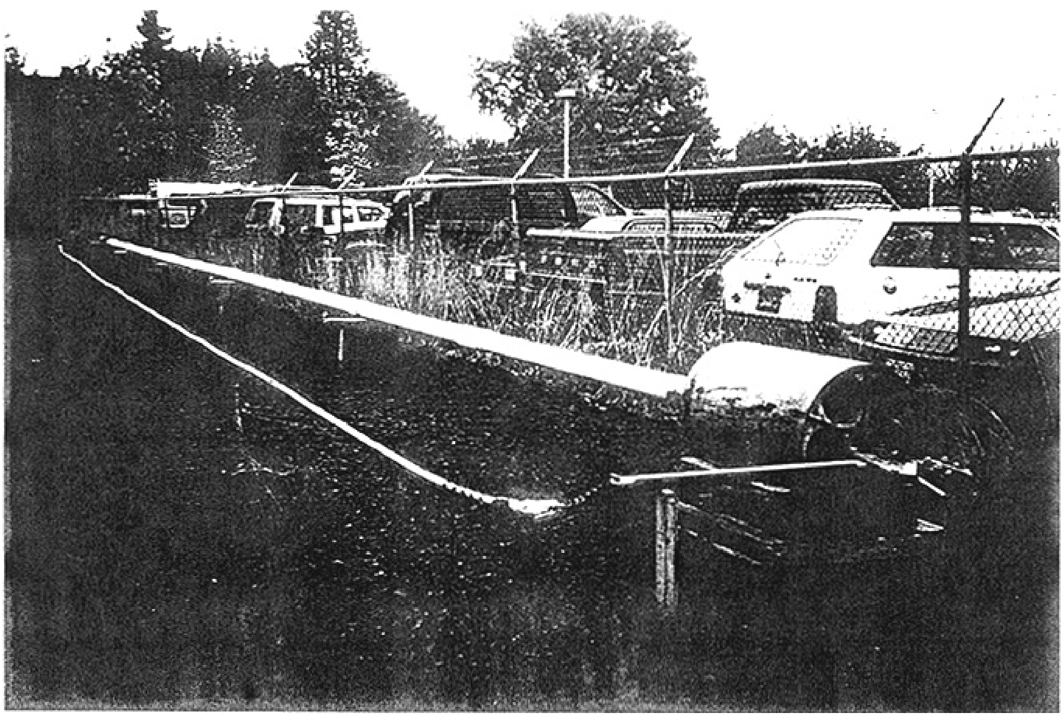


Fig. 16 b. A 30 meter piston corer setup.

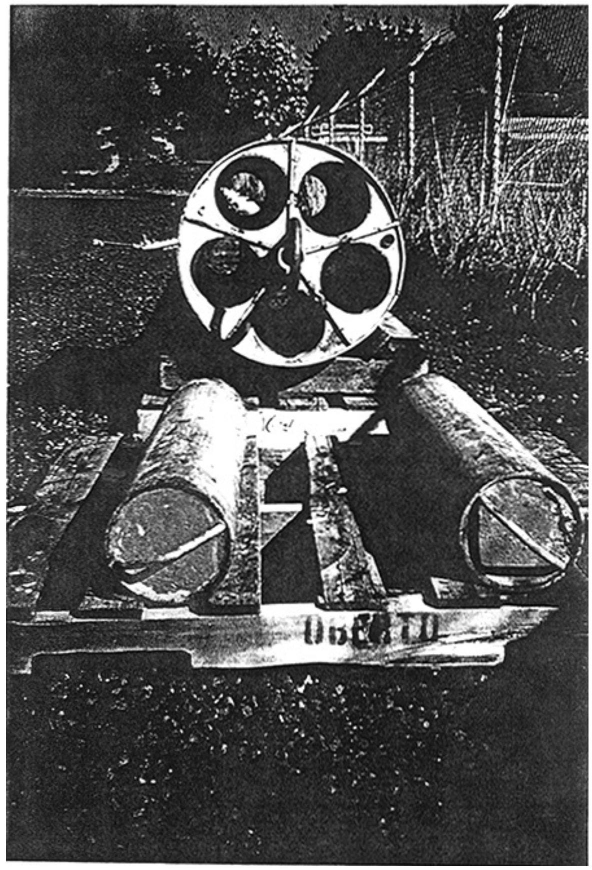


Fig. 17 a. 600 lb. Lead slugs.

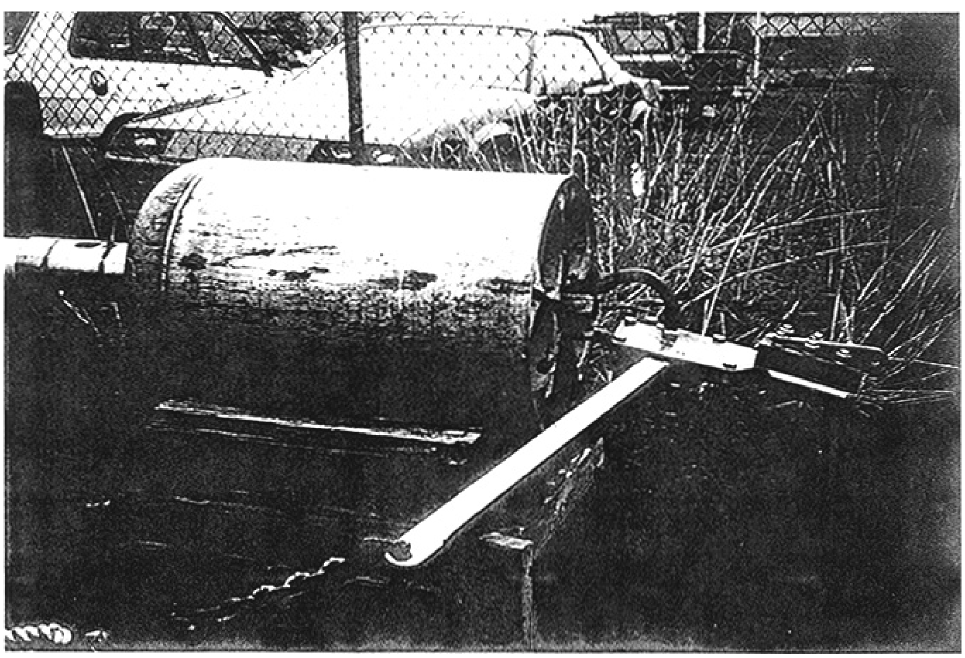


Fig. 17 b. Weight stand and trigger arm.

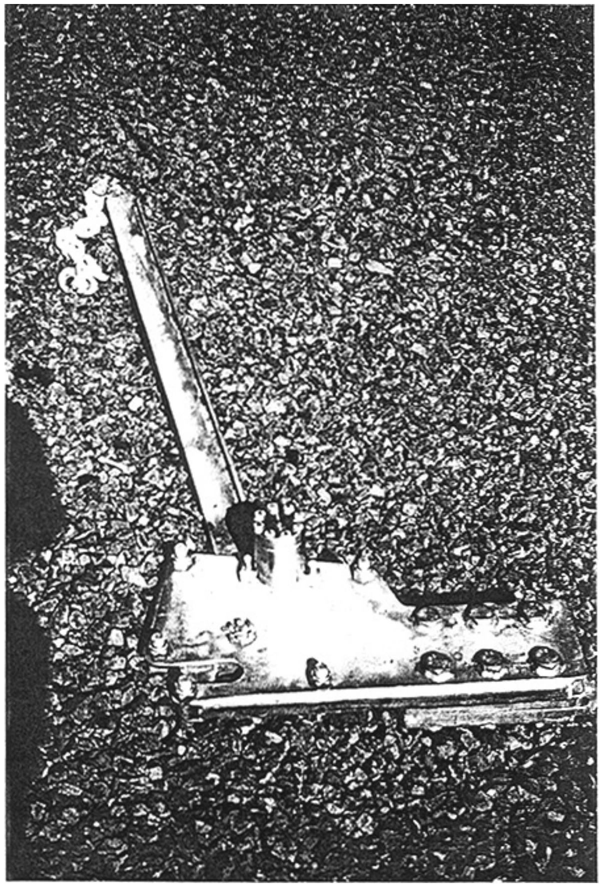


Fig. 18 a. Trigger arm with hydrostatic safety pin.

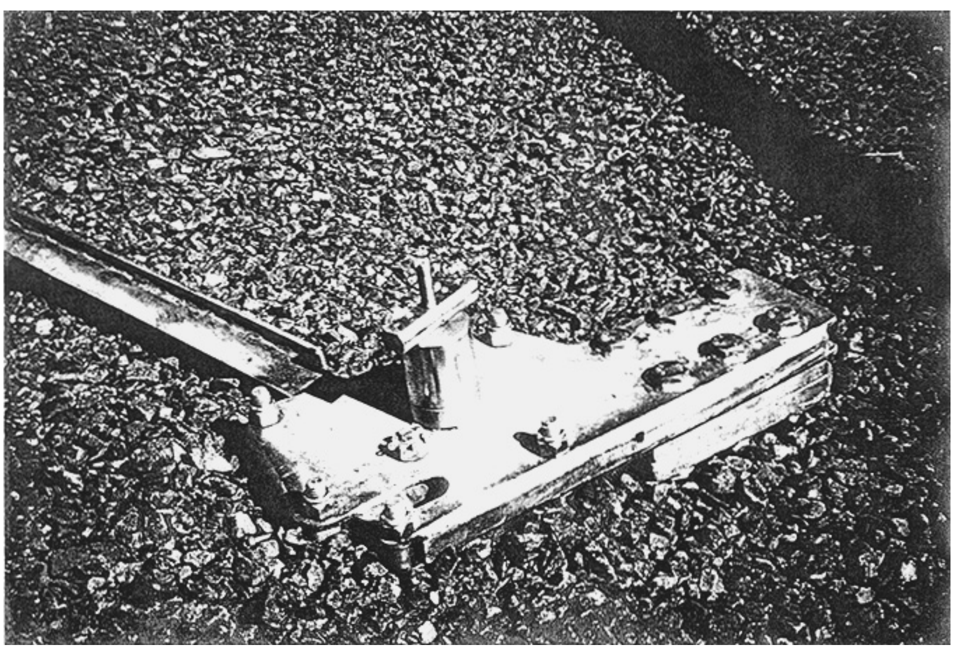


Fig. 18 b. Trigger arm with hydro_static safety pin.

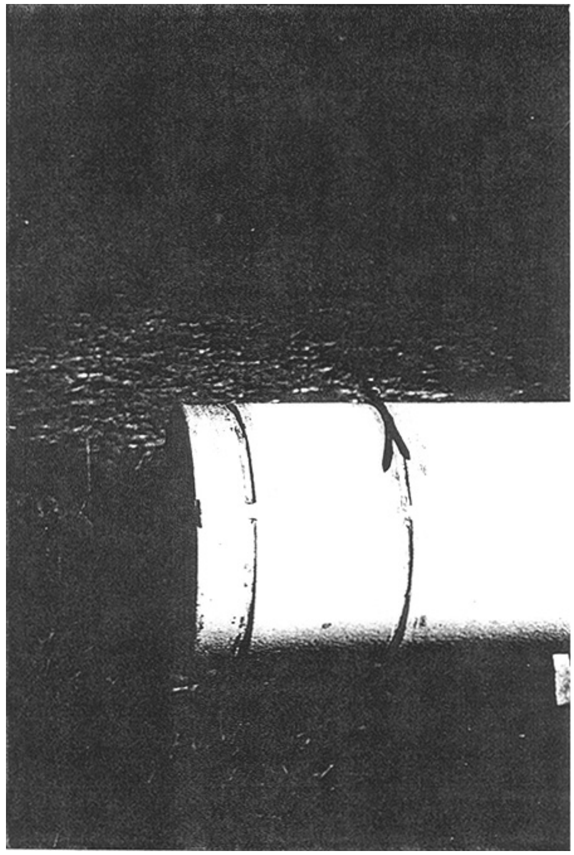


Fig. 19 a. End of core pipe. Note 16d nail grooves and weld across grooves.

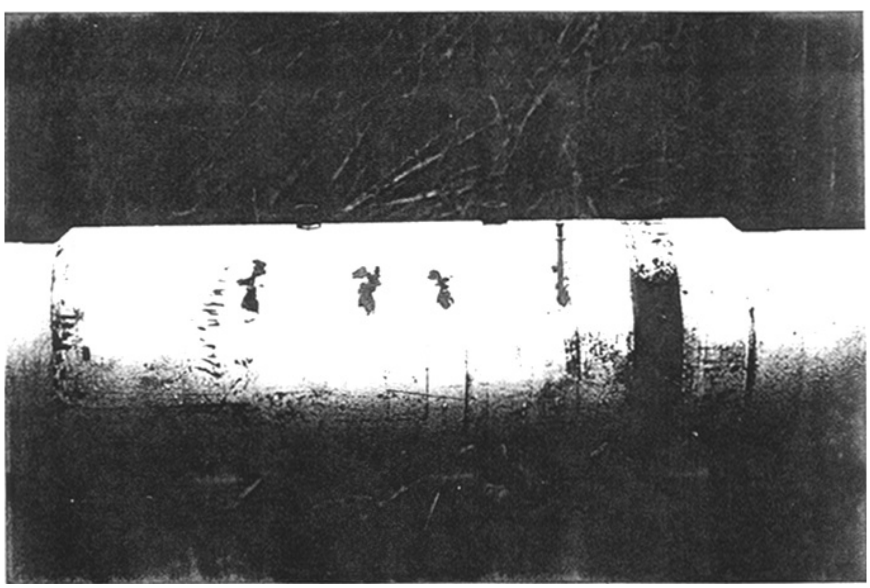


Fig. 19 b. Core coupler with 16d nails.

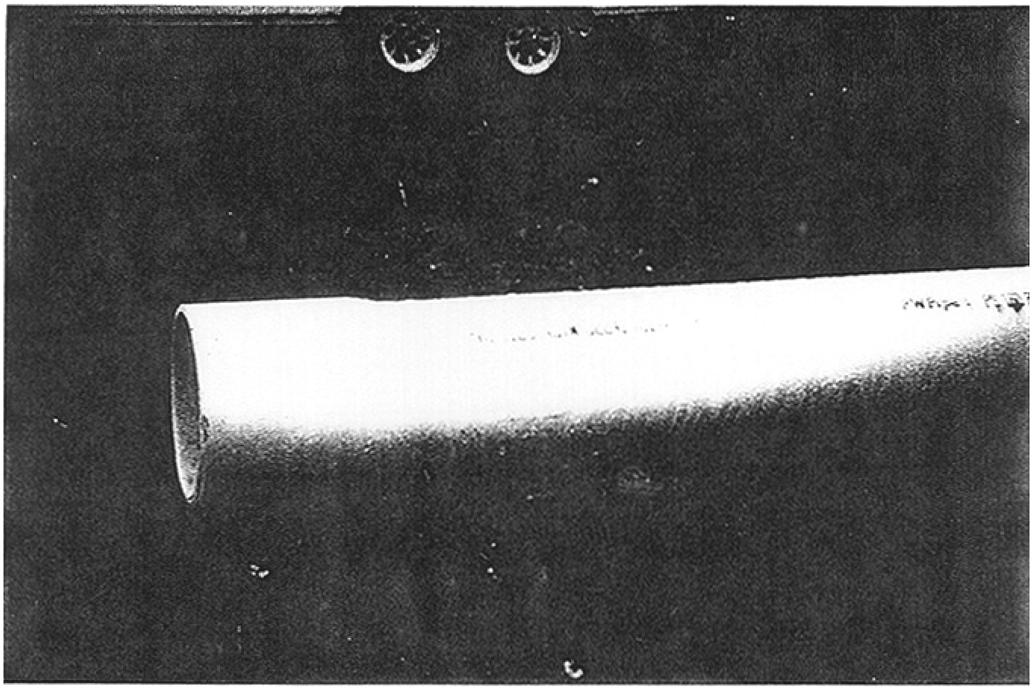


Fig. 20 a. Four inch, class 160 p.s.i. belled P.V.C. plastic pipe for use as core liner.

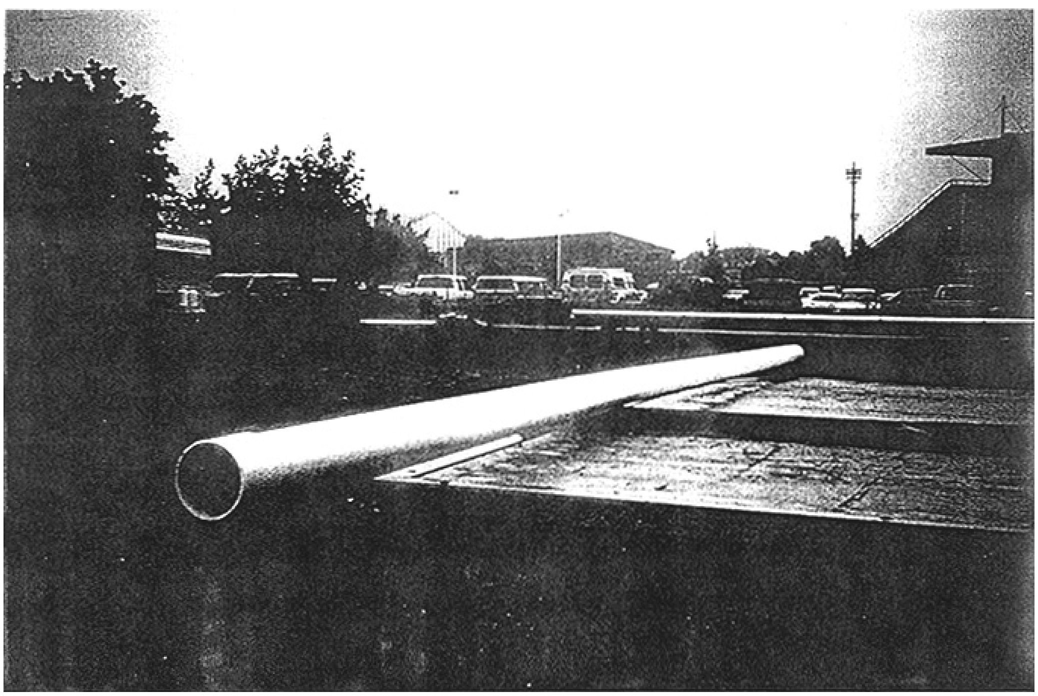


Fig. 20 b. Four inch P.V.C. plastic pipe showing full 20 foot length.

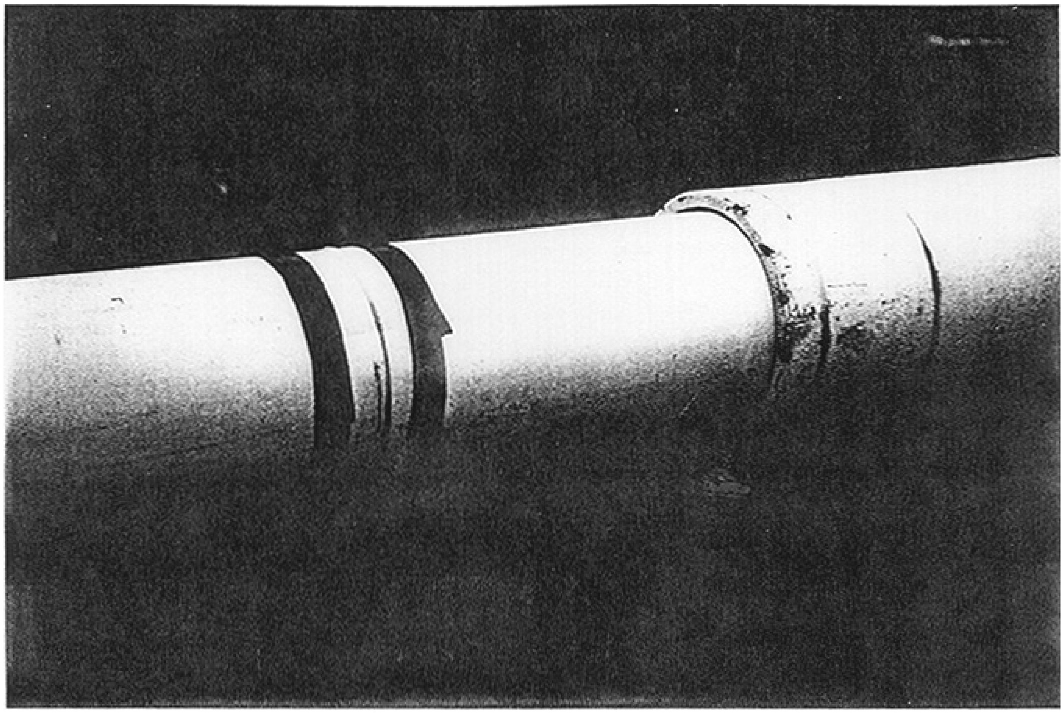


Fig. 21 a. Taped core liner joint.

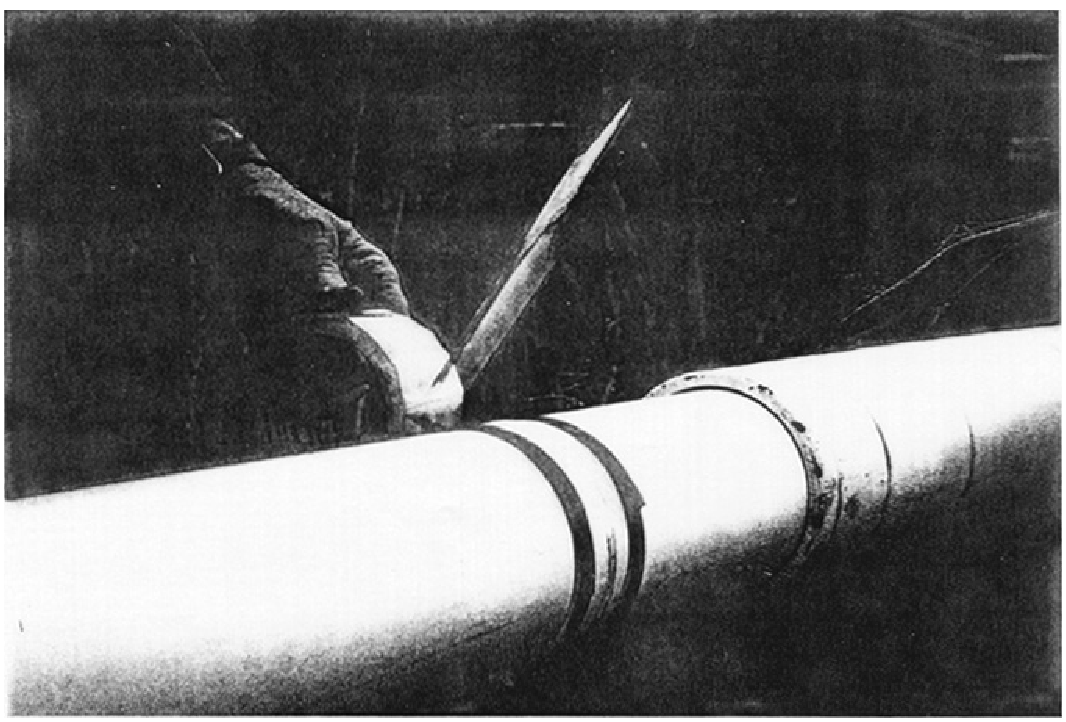


Fig. 21 b. Taping 20 foot sections of four inch plastic core liner together with 3M #3750 packaging tape.

The stainless steel piston (Figs. 22a and 22b) is 4.000 inches in diameter and 7.000 inches long. Old piston washers were made of leather, rubber, or neoprene. Urethane piston washers were chosen because they resist abrasion and compress well against the liner wall thus forming an excellent seal.

Because of the heavy weight encountered with large diameter, long sediment samples in the core liner, two core catchers are used with each corer deployment to prevent sample loss. A stainless steel “Chinese finger” type catcher (Fig. 23a) and a flapper valve type catcher (Fig. 23b) located in the catcher portion of the cutting nose (Fig. 23c) have worked well together in retaining the sediment samples. The cutting nose is heat treated to 45 Rockwell and can be replaced on the catcher component if damaged.

The trigger weight corer (Figs. 24a and 24b) is fabricated from stainless steel and is based on an OSU design. 50 pound lead doughnuts can be added to a base weight of 350 pounds to increase penetrating force. With nine doughnuts added, the total weight stand comes to over 800 pounds. This corer is 13 inches in diameter and 48 inches long. A simple flapper type valve (Fig. 25a) is employed as is a stainless steel cutting nose (Fig. 25b). To prevent the sediment sample from having to be scooped out of the weight stand, the core “pipe” (same PVC pipe that is used as piston corer liner) extends up through the entire weight stand. This “pipe” is attached to the weight stand by a special stainless steel coupler (Fig. 26a) that employs “cannon breech” type threads that allows quick connecting and disconnecting. The trigger corer uses the same stainless steel “Chinese finger” type catcher (Fig. 27b) that is used on the piston corer. The cutting nose holding the catcher is “pop” riveted on to the core “pipe” (Fig. 27a).

A relatively new way to get the sediment filled core liners out of the core pipes of the piston corer has been developed over the past couple of years. Normally, to get the sediment sample from piston corers above the first 20 foot liner section, the core pipes had to be taken apart at the couplers. This was hard and dirty work. Now, a twin cylinder, aluminum air extruder (Fig. 28b) does the work. The extruder bolts to the bale of the piston corer weight stand and, by exerting force on stainless steel push rods (Fig. 28a) extending through the weight stand to a tab pushing against a liner pusher/piston stop taped to the top 20 foot section of core liner, forces the liner from the core pipes. The liner pusher/piston stop is the first component loaded into the bottom core pipe when assembling the liner. The push tab is attached to the bottom push rod inside the head coupler (Fig. 29b). The push tab is then seated against the liner pusher/piston stop (Fig. 29a).

The air extruder is fabricated from two six inch diameter, 26 inch long pieces of aluminum pipe with a 3/8 inch wall thickness. At an air pressure of 100 PSI, over 5,500 pounds of force is applied to the push rods that force the core liner out of the core pipes. The push rods are one-half inch diameter stainless steel and 10 feet long. They screw together with “oil field pipe” type threads. Each stroke of the air extruder comprises a throw of about two feet (Figs. 30a and 30b). The OSU air extruder is similar to the hydraulic extruder used by Jim Broda at WHOI on the jumbo piston corer. A “hero” platform (Figs. 30a and 30b) is needed for the core technician to stand on while attaching the extruder to the bale of the weight stand.

After capping the end, a full 20 foot section of liner is extruded from the bottom core pipe (Fig. 31b). The top end is capped and the whole 20 foot section is brought inboard and placed in racks for sectioning. The 20 foot section of sediment filled core liner is then cut into 150 centimeter long sections, capped, and taken to refrigerated storage. A Ridgid # 134 plastic tubing cutter (Fig. 31a) is used for cutting the core liner into sections. The end caps are #B-629 caplugs made by Cap Plug Division of Protective Closure Co. of Buffalo, New York.

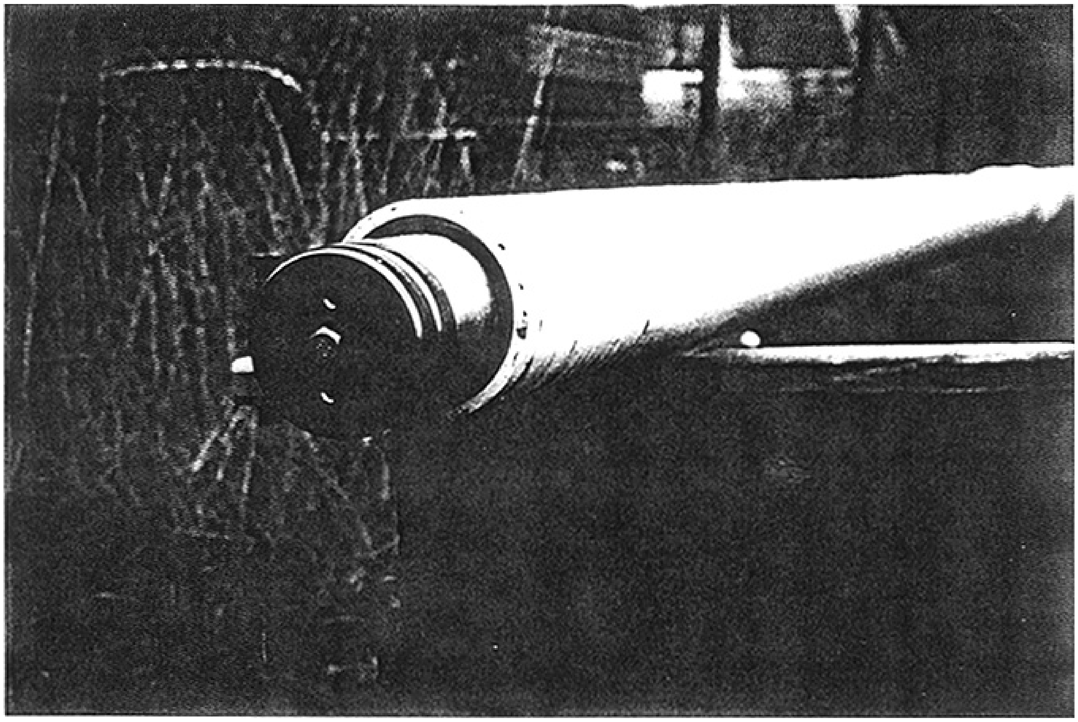


Fig. 22 a. Stainless steel piston.

Fig. 22 b. Stainless steel piston with urethane piston washer.

Fig. 23 a. "Chinese finger" core catcher.

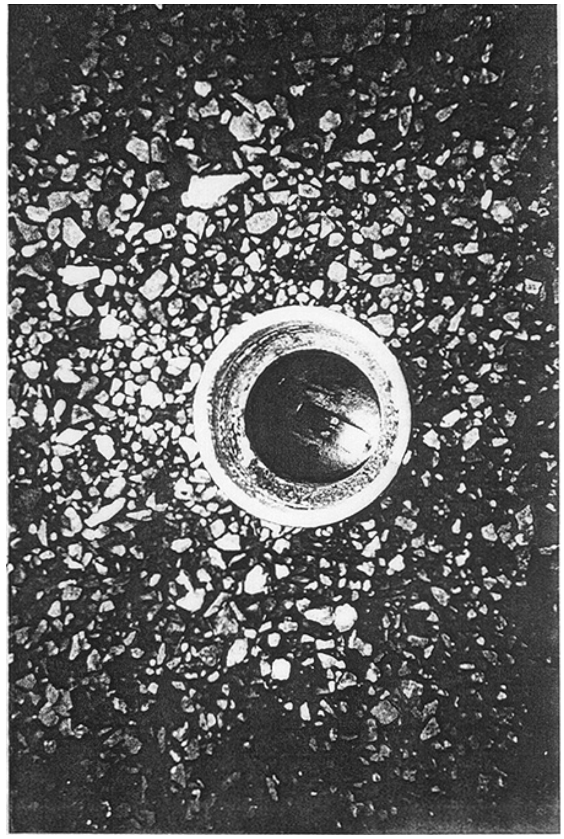


Fig. 23 b. Flapper valve core catcher inside cutting nose

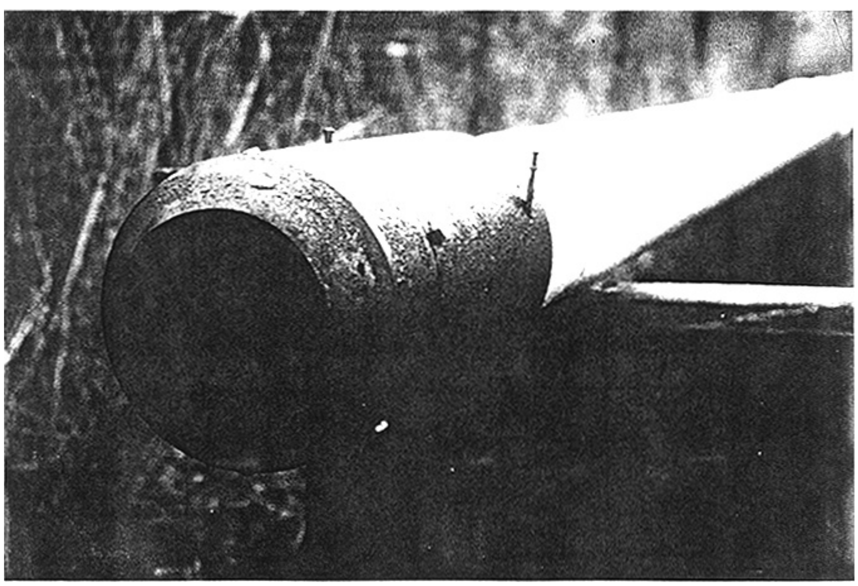


Fig. 23 c. Cutting nose.

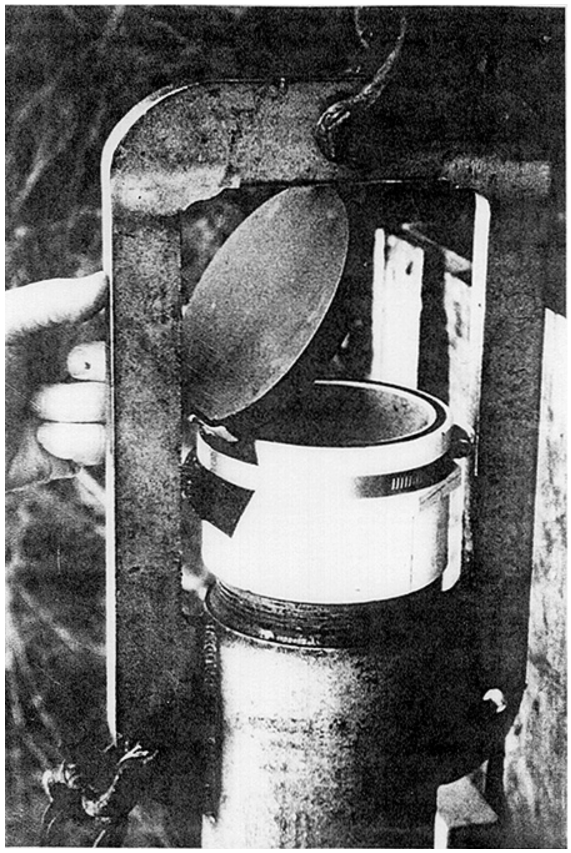


Fig. 24 a. Four inch stainless steel trigger corer.

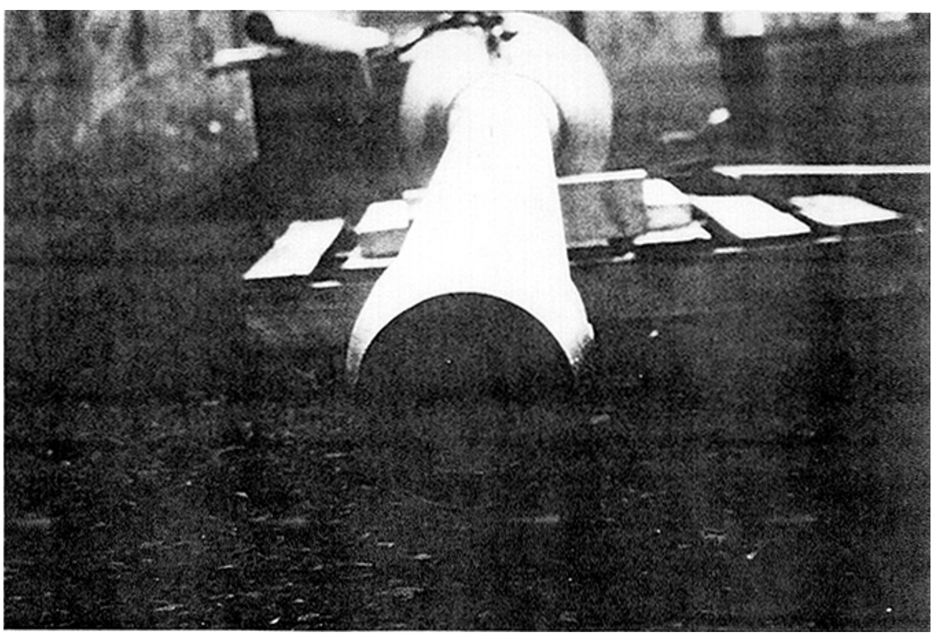


Fig. 24 b. Four inch stainless steel trigger corer.

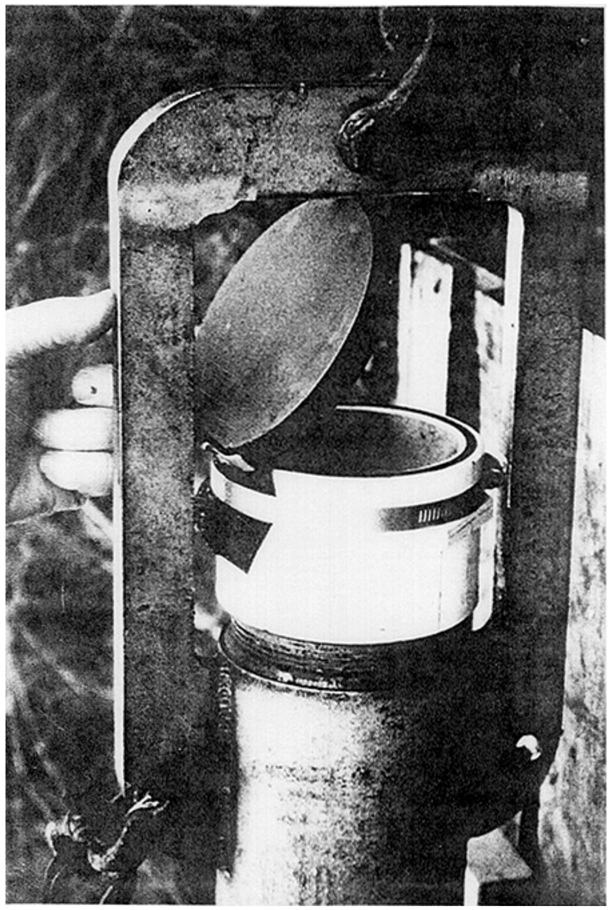


Fig. 25 a. Trigger corer valve.

Fig. 25 b. Trigger corer cutting nose. Note "pop" rivet.

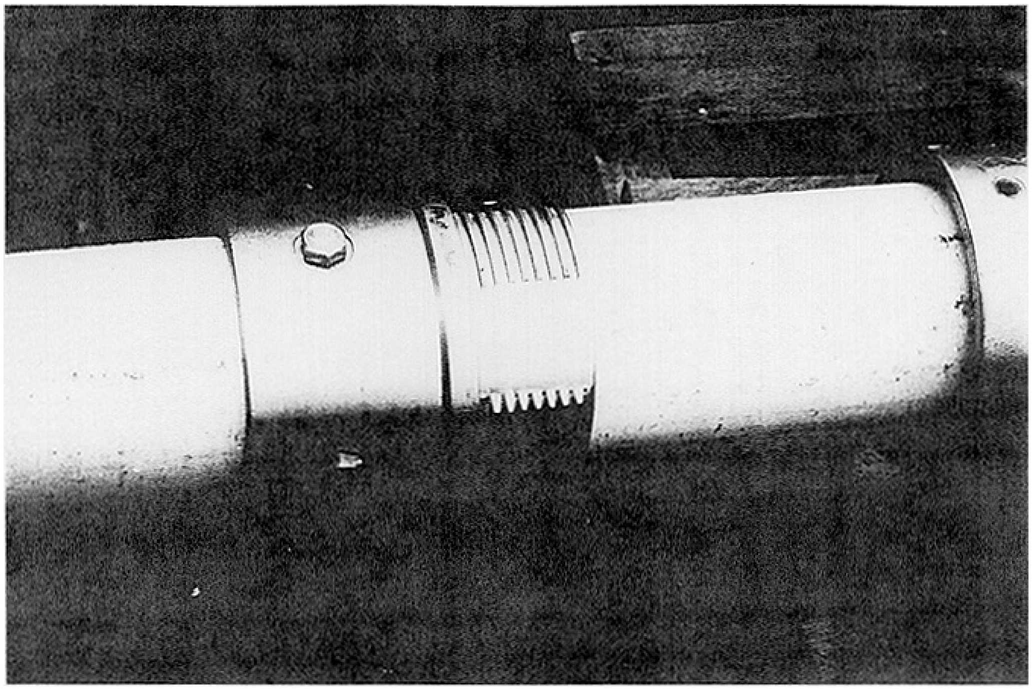


Fig. 26 a. Trigger corer core pipe to weight stand coupler. Note male "cannon breech" type threads.

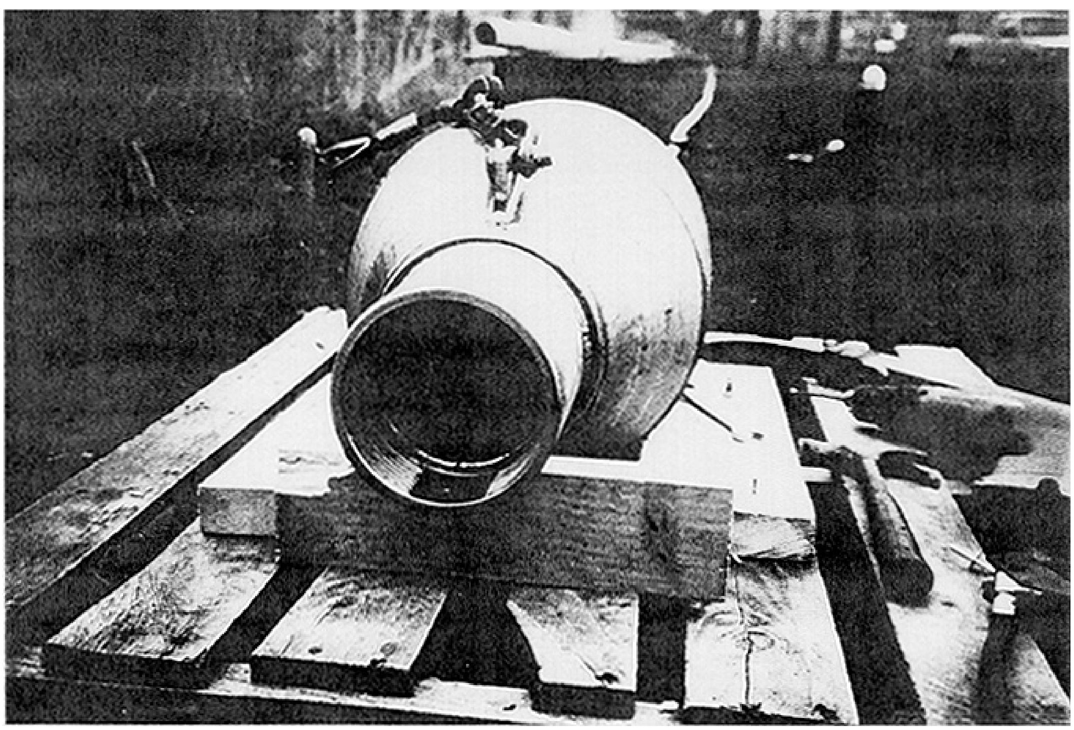


Fig. 26 b. Trigger corer weight stand. Note female "cannon breech" type threads.

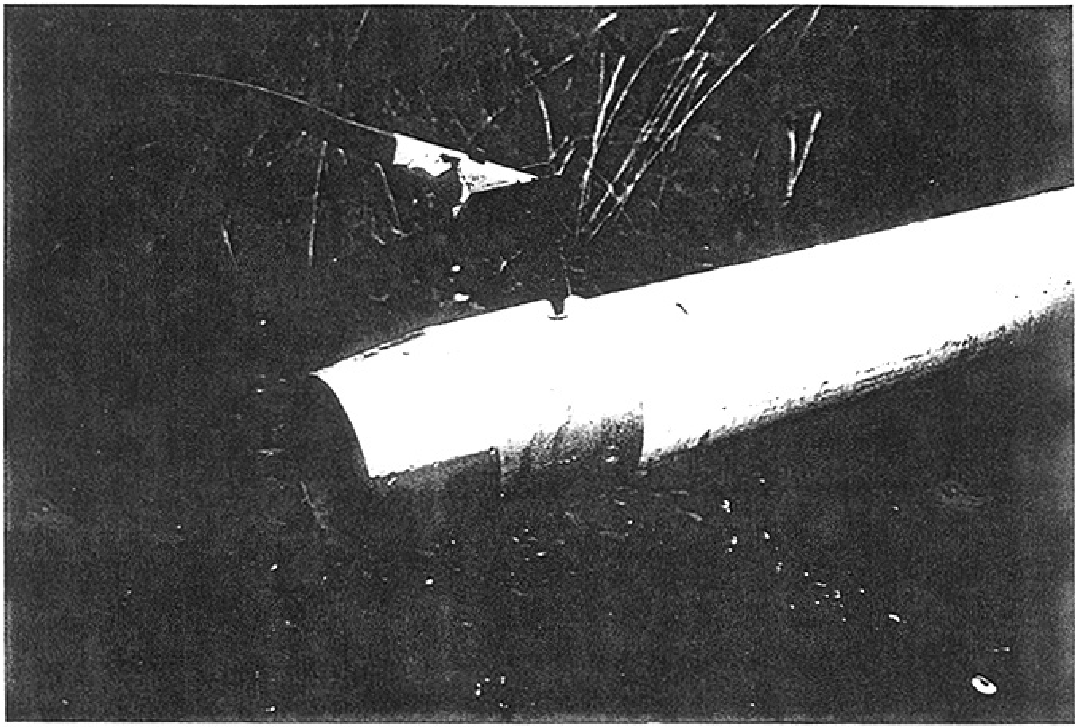


Fig. 27 a. "Pop" riveting cutting nose onto core pipe- four inch trigger corer.

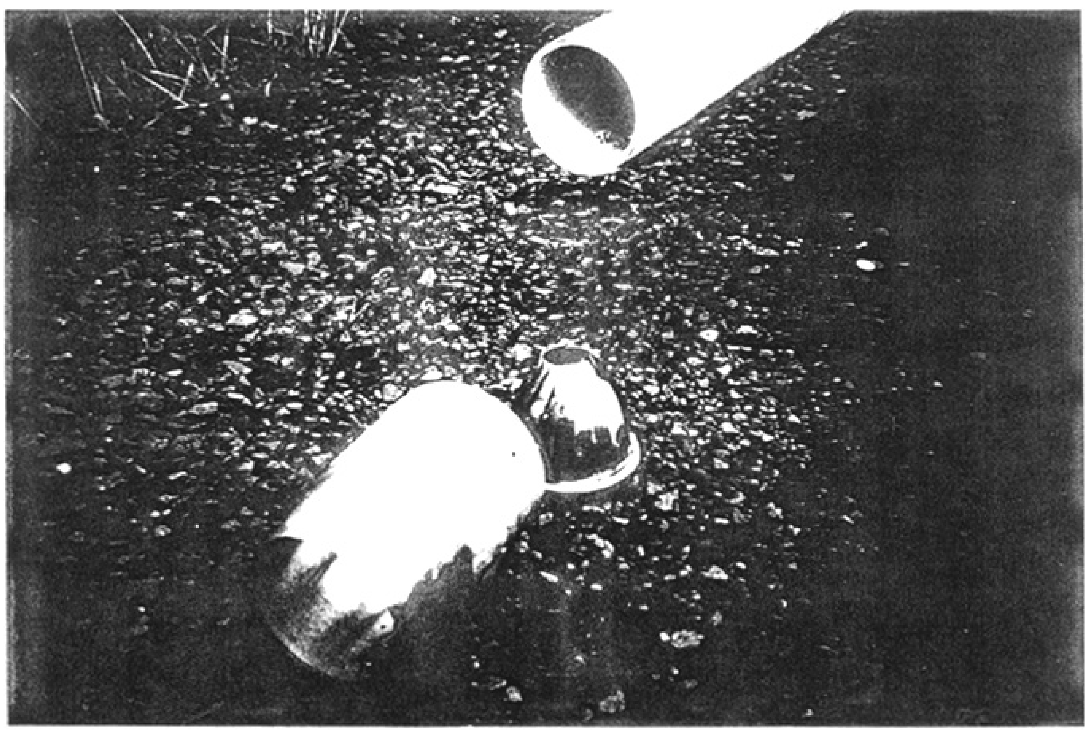


Fig. 27 b. Trigger corer cutting nose and catcher.

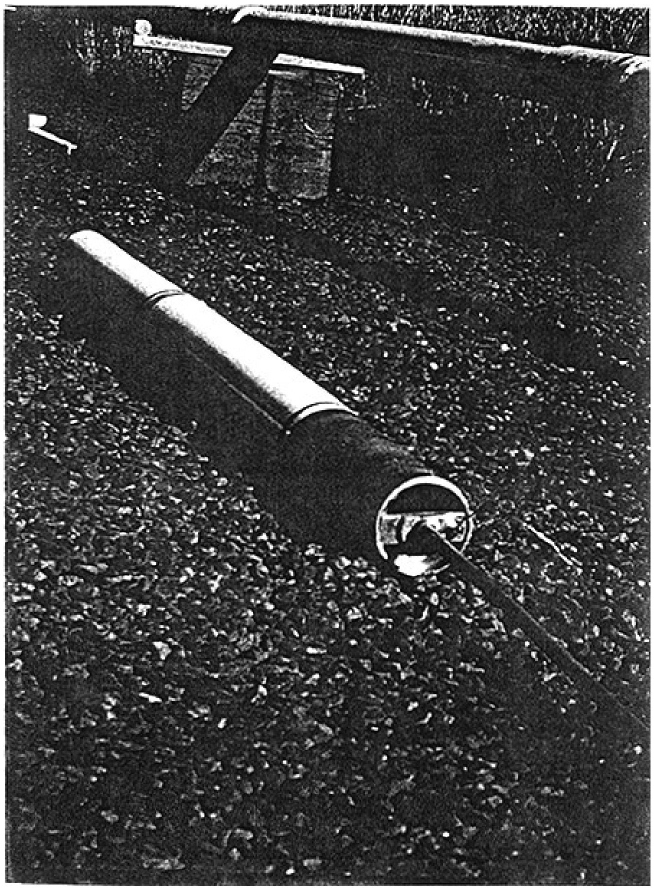


Fig. 28 a. Core extruder push rod, push tab, liner pusher and piston stop.

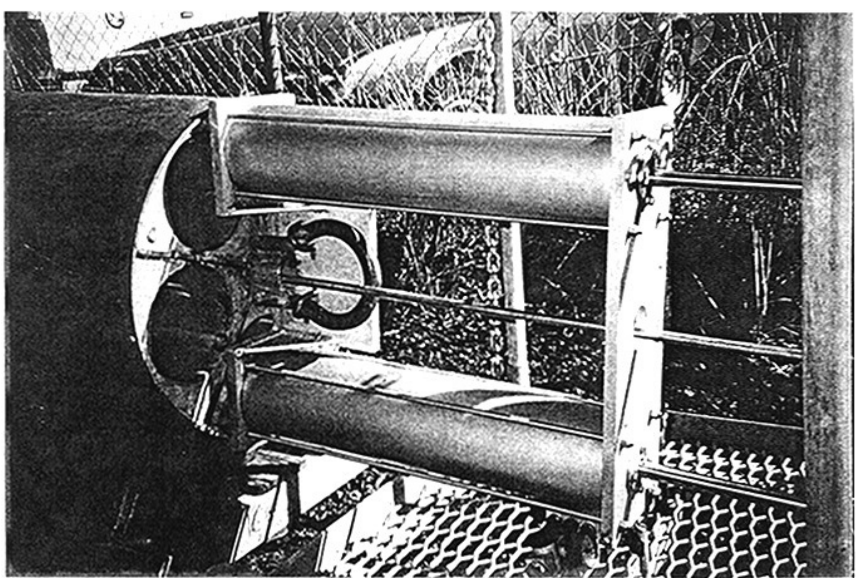


Fig. 28 b. Twin aluminum air cylinder core extruder.

Fig. 29 a. Core extruder push rod, push tab, and liner pusher and piston stop.

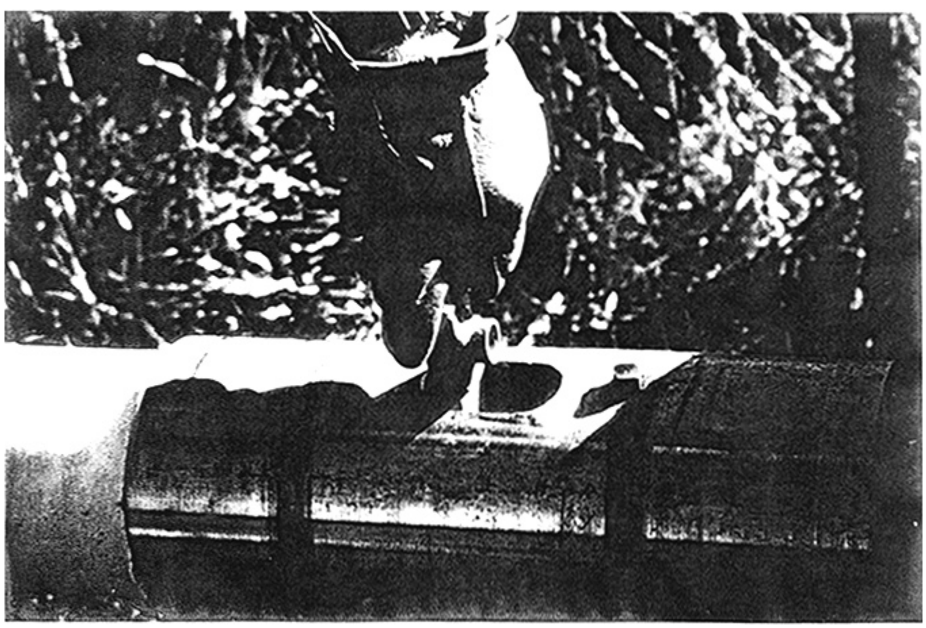


Fig. 29 b. Positioning the push tab through the head coupler.

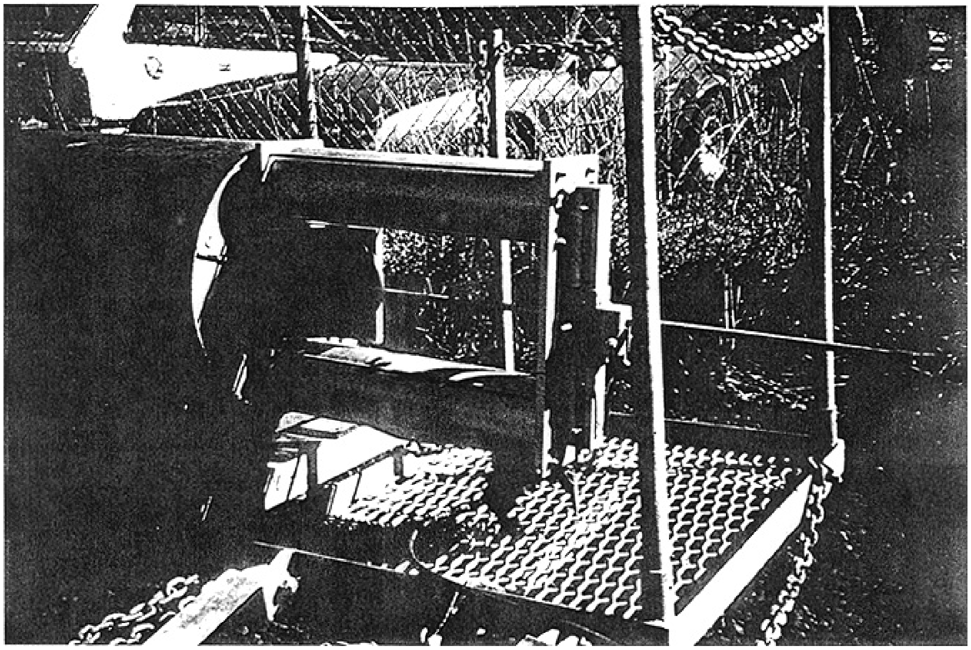


Fig. 30 a. Core extruder attached to weight stand bale. Photo shows extruder at completion of push stroke.

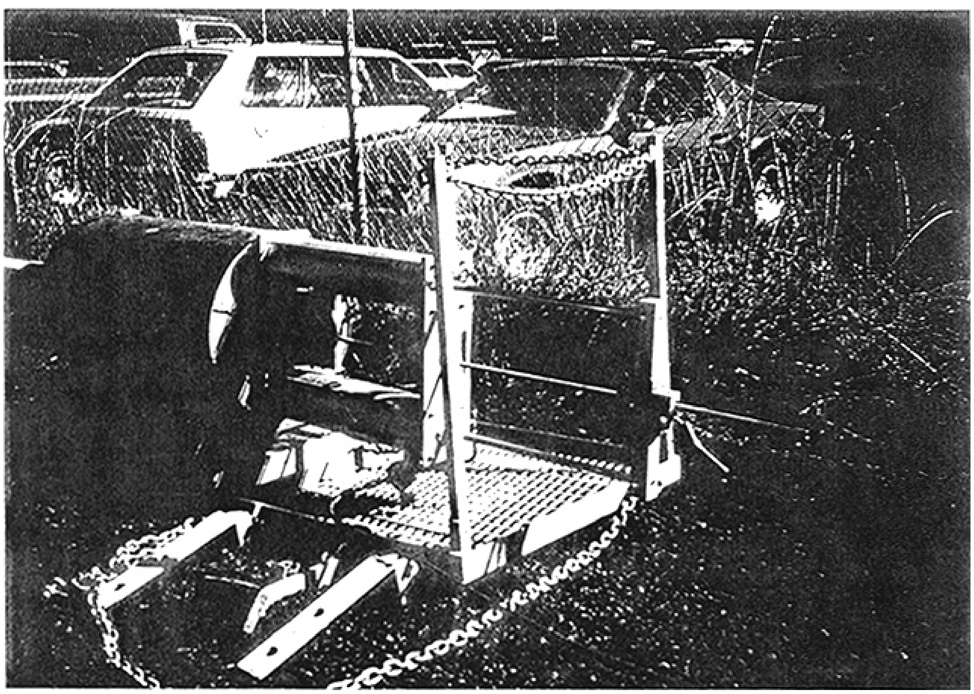


Fig. 30 b. Core extruder attached to weight stand bale. Photo shows extruder at beginning of push stroke. Note "hero" platform.

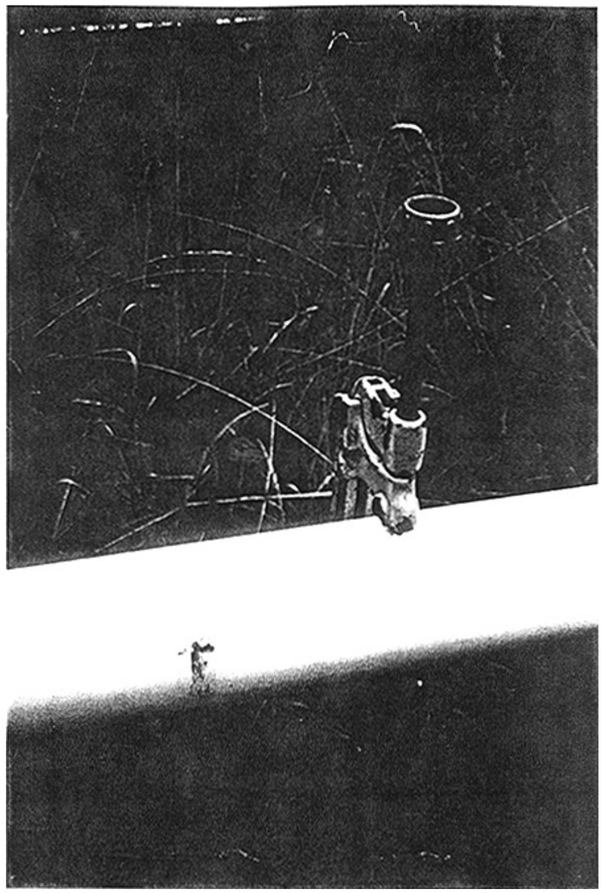


Fig. 31 a. Ridgid #134 plastic pipe cutter.

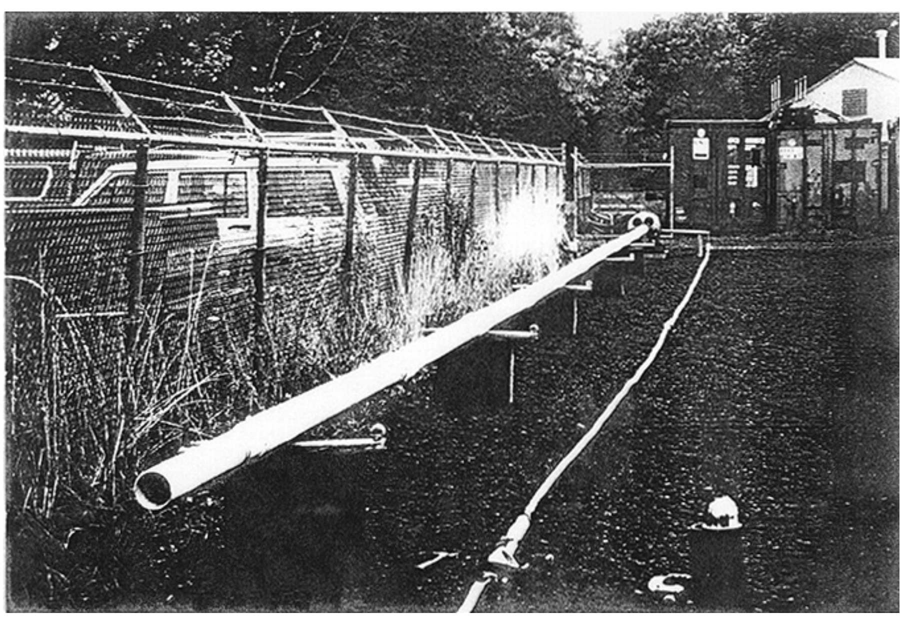


Fig. 31 b. Core liner being extruded from bottom core pipe.

**Ship Requirements for Using a Large Diameter Piston Corer**

Marine geologists are beginning to demand large diameter piston cores that are at least 30 meters in length. If 30 meter long cores are required why not use the Joides Resolution, the deep sea drilling ship. There are several factors that weigh in against drilling ship use. The foremost is cost. The Joides Resolution costs $48,000,000 a year to operate. This works out to $145,000 a day for the 330 days a year that the ship spends at sea. Secondly, a lead time of three to four years is required to schedule ship time. And thirdly, some gaps appear in the sediment at the end of the drilling pipe sections requiring time consuming and costly “triple dipping” to get complete coverage.

In order to obtain long piston cores UNOLS ships, obviously, will need a rail or deck space of sufficient length or size to allow assembly of a corer 30 meters in length. This space is currently available on the new AGOR class research vessels - Thompson, Revelle, Atlantis, and Ron Brown. A little shorter core could be obtained on the Knorr, Melville, and Ewing. 30 meter long piston cores could not be taken on the smaller UNOLS vessels - Oceanus, Wecoma, Endeavor, etc. without extensive platforms of some type being added to the ships. Long piston cores would also be possible on the NSF Icebreaker Nathaniel B. Palmer, the Coast Guard's Mike Healy and perhaps on the new University of Hawaii ship. All ships doing long piston coring must have winches, wire, sheaves, cranes, “A”-frames, etc. of sufficient strength to handle heavy loads and the tremendous pullout tensions of large diameter 30 meter and longer piston cores.

**Problems Encountered with UNOLS Ships Involving Large Diameter Long Piston Corers**

The foremost problem with doing 30 meter long piston cores on UNOLS ships today is centered around the standard UNOLS 9/16” diameter, 3x 19 oceanographic wire rope. The new generation of piston corers are testing this wire to the limits of its capabilities. Pullout tensions of large diameter long piston corers are typically in the 20,000 to 24,000 pound range and often higher - much higher. Three times in the past four years have complete coring systems been lost at sea on UNOLS ships due to wire failure. The commonly observed pullout tensions approach the elastic limit of the 9/16ths wire rope (Fig. 32). By going to 5/8ths inch diameter wire rope additional strength is gained but this increase in load limits is offset by an increase in wire weight.

So, does the solution to the wire breakage problem involve the switching by UNOLS ships from wire rope to kevlar line (Fig. 33) on piston coring cruises? 9/16ths kevlar has the same breaking strength as 9/16ths diameter 3x19 oceanographic wire rope but is 72% lighter weight in sea water. This difference would allow more of the effort of extracting a tripped piston corer from the sea floor to be directed towards actual pullout and less towards supporting wire or line weight. There are many questions that need to be answered before UNOLS makes the commitment of switching to kevlar line. Can kevlar be handled on UNOLS ships’ winches today? Or does kevlar need to be deployed from a special portable winch similar to the French system. If so, does each UNOLS ship have its own kevlar line system to be used on a few piston coring cruises every couple of years or does UNOLS keep one or two kevlar systems to share among the fleet? Perhaps the cost of switching to a kevlar line system is too great and marine geologists should turn their requests for 30 meter long piston cores over to the French.

Some of the corer builders are working on a partial solution to the pullout and wire breakage problems of long piston corers, The French on the RN Marion Dufresne are trying to come up with bolts to attach the core pipes to the weight stand that would be shearable when a certain pullout tension is reached thus saving the expensive weight stand but losing the core pipes and core. Jim Broda at WHOI is developing a similar system only using acoustically activated explosive bolts to separate the weight stand from the stuck core pipes. So, this may be the way to go. The existing UNOLS ships’ equipment could be utilized and those cores that can’t be freed from the ocean floor would be left on the bottom with the expensive wire and weight stands salvaged.

# 1.0 WIRE ROPE DATA

Bright or AMGAL MONITOR AA Torque-Balanced Rope

| Size Inches | Construction (Seale) | Wt. in Air - lbs/ft | Wt. in Water lbs/ft | Approx. Elastic Limit | Breaking Load lbs. | 0.2% Yield Strength lbs | Max. Length ft |
|---|---|---|---|---|---|---|---|
| 3/16 | 3x19Sea1e | .0586 | .0509 | 3,000 | 4,000 | 3,500 | 50,000 |
| 1/4 | 3x19 " | .0997 | .0867 | 3,063 | 6,750 | 5,900 | 45,000 |
| 5/16 | 3x19 " | .153 | .133 | 7,725 | 10,300 | 9,100 | 30,000 |
| 3/8 | 3x19 " | .220 | .191 | 11,100 | 14,800 | 13,000 | 50,000 |
| 7/16 | 3x19 " | .304 | .264 | 115,000 | 20,000 | 17,600 | 42,000 |
| 1/2 | 3x19 " | .392 | .341 | 19,275 | 25,700 | 22,600 | 98,000 |
| 9/16 | 3x19 " | .492 | .428 | 24,375 | 32,500 | 28,600 | 77,000 |
| 5/8 | 3x19 " | .602 | .523 | 30,225 | 40,300 | 35,500 | 62,000 |
| 3/4 | 3x19 " | .879 | .764 | 43,350 | 57,800 | 50,900 | 43,000 |
| 7/8 | 3x19 " | 1.21 | 1.05 | 58,500 | 78,000 | 68,600 | 32,000 |
| 1 | 3x19 " | 1.56 | 1.36 | 75,450 | 100,600 | 88,500 | 24,000 |
| 1 1/8 | 3x19 " | 1.96 | 1.70 | 93,000 | 124,000 | 109,000 | 19,000 |
| | Seale FW | | | | | | |
| 1/2 | 3x46 | .417 | .362 | 19,275 | 25,700 | 22,600 | 98,000 |
| 9/16 | 3x46 | .517 | .449 | 24,375 | 32,500 | 28,600 | 77,000 |
| 5/8 | 3x46 | .631 | .548 | 30,225 | 40,300 | 35,500 | 62,000 |
| 3/4 | 3x46 | .903 | .785 | 43,350 | 57,800 | 50,900 | 43,000 |
| 7/8 | 3x46 | 1.27 | 1.10 | 58,500 | 78,000 | 68,600 | 32,000 |
| 1 | 3x46 | 1.64 | 1.43 | 75,450 | 100,600 | 88,500 | 24,000 |
| 1 1/8 | 3x46 | 2.07 | 1.80 | 93,000 | 124,000 | 109,000 | 19,000 |
| 1 1/4 | 3x46 | 2.60 | 2.26 | 118,500 | 158,000 | 139,000 | 15,500 |
| 1 3/8 | 3x46 | 3.10 | 2.69 | 141,000 | 188,000 | 165,000 | 12,900 |
| 1 1/2 | 3x46 | 3.69 | 3.21 | 166,500 | 222,000 | 195,000 | 10,800 |
| 1 5/8 | 3x46 | 4.43 | 3.85 | 198,750 | 265,000 | 233,000 | 9,200 |
| 1 3/4 | 3x46 | 5.12 | 4.45 | 228,000 | 304,000 | 267,000 | 8,000 |

* Data Courtesy of US Steel

Fig. 32. From Driscoll (1989).

## 2.0 KEVLAR 29 DATA

The following data describes a series or torque balance lines which consist or an elastic center core, concentric layers of "Kevlar 29"* and an overall polyester or nylon braided jacket. Such lines should be considered for applications where long length, small diameter, light weight and flexibility are important. Typical applications Include subsurface oceanographic moorings, balloon tethers and center strength members for electromechanical cables.

JETSTRAN I-A

| Outside Diameter (inches) | Breaking Strength (pounds) | Weight In Air (lbs/1000’) |
|---|---|---|
| 3/16 | 3,000 | 16 |
| 1 / 4 | 6,300 | 28 |
| 5/16 | 10,500 | 40 |
| 3 / 8 | 15,500 | 62 |
| 7/16 | 20,500 | 74 |
| 1 / 2 | 26,000 | 89 |
| 9/16 | 32,500 | 102 |
| 5 / 8 | 40,000 | 128 |
| 3 / 4 | 55,000 | 180 |
| 7 / 8 | 78,000 | 255 |
| 1 | 110,000 | 360 |

JETSTRAN V

| | | |
|---|---|---|
| 1.75 | 215,000 | 0.9 lbs/ft |
| 2.00 | 290,000 | 1.2 |
| 2.25 | 375,000 | 1.5 |
| 2.50 | 450,000 | 1.8 |
| 2.75 | 600,000 | 2.4 |
| 3.00 | 775,000 | 3.1 |
| 3.25 | 925,000 | 3.7 |
| 3.50 | 1,050,000 | 4.0 |

- Kevlar 29 is the trademark for DuPont’s aramid fiber
- Minimum breaking strength for new rope tested in controlled conditions.
  (Actual break strength is up to 10% higher)
- Weight in sea water is approximately 28% of weight in air

Fig. 33 From Driscoll (1989)

## Conclusions

This paper has looked at marine coring devices and how they have been developed over the years. A typical large diameter piston corer that has been used successfully on several UNOLS research vessels was examined. There exists, however, on every geological oceanography cruise a good possibility that one or more of these corers and a goodly amount of wire rope will be left on the bottom due to wire failure from excessive pullout tensions. In the past it has been the dredge technicians that have gotten the blame for stretching and ruining the large diameter wire rope on UNOLS vessels. This blame is now shifting to the marine geologists doing large diameter piston coring. UNOLS and the corer builders need to work together to solve the wire problem or the ships captains will ban large diameter long piston corers from their ships. Then, either shorter cores will become the norm or the long piston coring business will be sent to the French or others capable of handling such devices.

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# Lessons Learned About The Multicore

Richard Muller
Moss Landing Marine Laboratory

**[Editor's Note: The following is a transcription of Rich's oral presentation.]**

Well, my name is Richard Muller and I'm a marine technician at Moss Landing Marine Laboratories. And we've learned about long 20-meter, 30-meter piston corers. Now we're going to learn about 25-, 35-centimeter corers.

I work at Moss Landing Marine Laboratories, like I said, about a hundred miles south of San Francisco on the Monterey Bay, and we operate the research vessel Point Sur, 135-foot, so it can't really do any long corers there. I have a number of overheads and I also have a few slides. What I'm going to do is go through the overheads first and then just go to the slides and sort of use the overheads as an outline.

Why use a multi-corer and what is a multi-corer? Well, a multi-corer has eight of these core tubes on it and these devices that hold the tubes, and they're open and cocked like this. Imagine this cap -- doesn't want to hold it up there. Cut my fingers off -- and they're around a rosette on the multi-corer and they end up getting pushed into the sediment.

And the good thing about it is it actually captures water above the sediment and, after this cap is closed, it's undisturbed.

Well, box corers capture -- a lot of people use core tubes like this and push them into a box core after the sediment is on the surface. Well, why don't we use that? It's a lot cheaper, it's a bit more robust. Well, you never get that sediment-sea water interface undisturbed from a box corer, and that's why these are so popular.

What I'm going to talk about is how we do multi-coring on the Point Sur, basically. The first thing we need to do is tune up the multi-corer before it goes into the water. Otherwise, you waste hours and hours and hours of wire time. We need to make sure the piston is adjusted correctly. We want to clean our release pins on a multi-corer. I'm going to show slides so you know what this looks like. Later, I'm going to go back to this.

We need to make sure the spider is adjusted, it's not rotating or anything like that. And we want to make sure that this particular unit is working properly. We want to make sure there's a good seal at the top of this core cap and also that this seal down here is working properly.

Deployment of the multi-corer has to -- we have to go off the ship very slowly, smoothly, without basically moving the multi-corer up and down. Otherwise, all these core tubes will trip and you won't -- you might have to bring it back up pretty quickly. The lowering rate of a multi-corer depends on the ship swell or the sea water swell and the movement of the ship. You don't want to do one of these movements like this with a multi-corer. Otherwise, it's going to trip. It's much like what a box corer would do.

We put a pinger on the corer, about ten meters above the corer, so we can watch it with a PDR going down. About a hundred meters off the bottom, the ship's bridge crew will maneuver the ship so that the wire is vertical, or as close to vertical as possible, slowly disintegrate down to about 30 to 40 meters a minute, and just monitor the altitude of the corer off the bottom till it hits the bottom.

We quickly increase the wire speed out so that we have a loop of wire while the multi-corer is sitting on the bottom so that the piston on the corer can push -- can have some space to push these core tubes into the -- into the sediment with all the weight that's sitting on the multi-corer.

After about 60 seconds -- the winch operator and bridge crew never like to wait 60 seconds -- but after about 60 seconds or so, we continue -- we sort of reel in the wire. When the winch monitoring system -- when we start to see that we're feeling the multi-corer itself, we sort of goose the wire a little bit, bring it up so that it doesn't bounce on the bottom again, and then start the ascent rate, and the ascent rate is pretty much up to the operator, boat operator, whatever he or she feels the winch can deal with -- 60 meters a minute, 90 meters a minute.

Retrieve the multi-corer pretty much backwards of the way we deploy it, get some tag lines on it, keep it in the water, get some tag lines on it so it doesn't swing around, bring it up, and then bring it on board with a -- the best would be a hydraulically-controlled A-frame, although the Wave has -- Mauna Wave has used it with a rigid A-frame without a problem.

And hopefully that's -- everybody's confused there, so we show everybody some pictures and they won't be confused anymore. How do you turn on the -- please turn on that slide projector.

Here's the Point Sur. You can see the multi-corer here on the stern. We have a -- most of you are familiar with the Ogwalla Juice Company. We were -- Moss Landing was able to sort of finagle an old refrigerated truck/van from them, and we used that as a corer storage facility and extrusion facility and basically a working lab.

Here's a multi-corer on the back deck. It -- we have some dune fence or snow fence; depending upon what part of the country you're from, you'll call it something different. There are eight of these corers or -- these are captured corers already. Inside of this tepee configuration -- and the reason why these are here is -- the reason why this dune fence is here is to prevent any loop from the wire after it's down there getting caught on any tabs or the core tubes themselves.

I've talked to a few people who have multi-corers and some people don't use it at all. Some people use it about halfway and nobody has ever had a problem with any loops getting caught into the corer itself, as far as I know.

Here's a -- what you might consider a picture-perfect corer. Now, a nice capoff at the top, you have a nice capoff at the bottom, and if you look closely, you can see sort of a flocking sediment, and that's what most of the scientists are looking for, that preserved sea water sediment interface and nice clear water above the corer itself.

And here's a box corer. So you can get a pretty good idea of why geochemists -- mostly geochemists and some geologists really like to use the multi-corer over the box corer, although before multi-corer was developed -- I think the first one was made in Germany -- correct me if I'm wrong, anyone --

PARTICIPANT: Scotland.

PARTICIPANT: Thank you.

MR. MULLER: What was that?

PARTICIPANT: Scotland.

PARTICIPANT: Scotland.

MR. MULLER: Oh, Scotland -- I'm sorry. And it was adapted here in the U.S. and manufactured by OI, and -- here's another picture of the box corer, a little bit more of a crude instrument and more robust. But -- and here's another picture of the multi-corer. It gives you an idea of the size of the corer.

And not that -- it isn't always we get a corer that deep. Many times -- this is the bottom end of the spider right here. The spider is that rosette system that holds these corers, and there's weight on the spider that's well-stacked above it. And a lot of times, depending on sediment type, it will go in only up to the bottom of the spider and you'll get a corer about that deep, but that's usually satisfactory for those people using a multi-corer.

Again, sort of a close-up look at the corer itself, flocking -- very flocking sediment. You can see different layers as you go down into the core. And something that I -- I don't have a lot of experience with piston coring. I've seen it done, but I haven't taken part in it. I've done some gravity cores, and I know from the gravity cores, you'll never, ever see anything like this, and I'm not sure about the piston coring.

Deployment of the multi-corer. Again, there's a couple of people on tag lines. You have a -- usually, you have a person in the middle. There's pins right here. This person has them in their hand. Weights stacked on the inside of the multi-corer. The piston tube or -- what would you call it? -- piston tube, and the piston above it, so this whole thing, once it sits on the bottom, will jump and let some slack out on the water, will just move down slowly. This group of weights right here will just push the core tubes into the sediment. And, again, like I say, you want to deploy this thing in ideally good conditions; you know, good sea conditions. But if it's not good sea conditions, you can just take your time and deploy it.

Like I say, this person popped the pins out that hold these weights in place when it's sitting on deck. And once you take up some wire, those weights will get -- will be able to move. You pull the pins out and put it over the side.

Another picture of a multi-corer, and it looks like this one hasn't been deployed. It also hasn't been cocked. So these bottom doors are in a down position. But what I wanted to show by this slide is snowshoes right here. Some 4 x 4s bolted onto the sides of the legs of the multi-corer, and I think this particular setup was done specifically to core into the Santa Barbara basin or the L.A. basin, where there's quite a large sedimentation rate and a lot of very soft, flocky sediments. And what would happen previous to putting these snowshoes on, mudshoes, the whole corer would actually penetrate into the surface without -- into the sediment without tripping, and it would trip eventually but it wouldn't collect any sediment.

And putting these on helped it out a bit, and we actually had to end up -- ended up taking a lot of weight off the stack and it's part of tuning it up, give it a couple of tries. Hopefully you're not in three-, 4,000 meters of water to waste that kind of time.

This is the inside of that Ogwalla van that I showed you. It's basically been set up specifically for the -- to go with the multi-corer. It uses fresh water as a hydraulic core extruder, so you have some fresh water under here. You take the cores out and you put them in this apparatus here. You use an O-ring and some PVC plastic underneath. Inside, there's another O-ring plug. You plug it into the ship's fresh water system. Engineers always like that. You turn on the hose, and you just use a little eight-valve up top here. You just let the water in and it pushes the corer up on -- and you have it going through the tabletop in the van. And the scientists can section the corer as it comes up, do whatever they want to do.

I guess that's it. I'm jammed, I think.

PARTICIPANT: Push real hard.

MR. MULLER: Oh, there it is. Here is a picture of just sampling of the sediment probably for some core water analysis. It looks like they're going to spin that down.

And, again, another shot of the Point Sur. It looks like Port Hueneme or something like that, again with the Ogwalla van. And you can see we don't have a lot of space on the back of the ship, on the fantail of the ship. We have the lab van right here, another van here, and the multi-corer right there, so we really need to make sure we make the best use of space on the ship.

I guess that's pretty much all I really have to say about it, except -- well, I guess what I wanted to do was to -- as the session goes on, I guess there will be more of a question-and-answer period -- is get ideas from those people here in the audience who have used multi-corers and also take questions about -- from those people who have never used it and want to use it.

So that's about it. Again, here's the apparatus that's the heart of the whole deal. Feel free to come look at that as time goes on, and there it is.

(Applause.)

MR. SUTHERLAND: Any questions for Rich? Yes.

MR. RIDOUT: Paul Ridout, Ocean Scientific, U.K. What sort of water depths are you working in typically with this corer?

MR. MULLER: We've used the corer in anywhere from 200 meters -- actually, even less than that. We've tried coring in 50 meters of water, which didn't work because there's too much -- there's usually too much current in 50 meters of water, unless it's flat calm, and we've taken cores over 3,000 meters.

Anybody from U.H. here?

PARTICIPANT: Rich, we've got a 4,000 meter corer.

MR. MULLER: You've got a 4,000 meter corer? Andy Hurd (ph) at SeaBird Electronics, was -- used to be at Moss Landing Marine Laboratories, and he was the guy who initiated the purchase of a multi-corer and sort of got it set up. One of the other things is this is Multi-Corer Serial No. 001, so it's gone through some changes. I saw a small multi-corer at the aquarium last night, and one of the things that we've done that's, although different than what's available with the commercially-available multi-corer, is that these core tubes are attached or inserted into this apparatus and then secured by having a plastic or a polycarbonate band glued to the core tube, and then an aluminum ring that's tightened up against this aluminum apparatus with some hexhead bolts there.

And what's usually -- what's available normally is the -- what do they call -- the kind of snaps that they call it?

PARTICIPANT: Those quick snaps.

MR. MULLER: Yeah.

PARTICIPANT: Yeah, but they were not working real well.

MR. MULLER: Right. So they sort of get -- they stretch out, and so we use this. It takes a little bit more time to set up the corer, but it's insignificant, usually.

PARTICIPANT: That was one of our experiences with the (indiscernible) corer, which is the Scottish one a few years -- quite a few years ago, four or five years ago, when we produced -- when the first one was produced. We had the weights quite high up, the weight stand like the one on the one wigwam corer you showed there.

MR. MULLER: Uh-huh.

PARTICIPANT: And what we found was that to use that arrangement in deep water is that it was very unstable going down through the water, started to --

MR. MULLER: Spin?

PARTICIPANT: -- rotate, and we would then lose a lot of core tubes by the fact the corer didn't hit the sea bay vertically.

MR. MULLER: Oh, really.

PARTICIPANT: And now, the new -- in more recent years, the weights have been brought much lower down into the structure, and the whole thing has never seemed so stable. I was wondering whether you had come across that.

MR. MULLER: Actually, we've had some pretty good luck with it, and I don't know -- what was -- do you remember what the descent rate was?

PARTICIPANT: I wasn't on the actual cruise. It was actually on a French ship. I can't remember. I mean, --

MR. MULLER: Yeah.

PARTICIPANT: -- it would have been fairly fast, typically, --

MR. MULLER: Okay.

PARTICIPANT: -- in deep water.

MR. MULLER: Yeah. You want to make good use of the time.

PARTICIPANT: Well, with box corers, they used to drop them at about a meter a second or so.

MR. MULLER: Yeah. We'll let this down at about -- sometimes about 60 meters a minute.

PARTICIPANT: Second.

MR. MULLER: -- meter a second, and -- but we will stop it about 50 to a hundred meters above the sediment surface, --

PARTICIPANT: Sure.

MR. MULLER: -- straighten out the ship, and then lower it between 30 and 40 meters. Because we've done that, I think we've had some pretty good luck. We did bend it up once pretty badly, and -- but that was in shallow water, and we took it apart and put it under some hydraulic presses and straightened it out, but, you know, we've had some pretty good luck with it.

It's a finicky instrument --

PARTICIPANT: Sure.

MR. MULLER: -- with respect -- sometimes you'll go two or three times -- two or three drops and not get a core and you'll be tearing your hair out, Why am I not getting a core, and you'll just go through the whole setup again and try it again and it will work.

PARTICIPANT: But we used to think we were getting undisturbed sediments with box corers for about 20 years.

MR. MULLER: Oh, and then you saw --

PARTICIPANT: Then somebody realized how much they settle on the way back up. It looks undisturbed when you get there.

MR. MULLER: Yeah.

PARTICIPANT: And we've done a lot of video work with the (indiscernible) corer. Actually, there were video cameras on the corer watching it go down through the water below and then what happens when it reaches the sea bed. In fact, some of this was actually on the Discovery channel, of all places. They used some of the video.

MR. MULLER: Oh.

PARTICIPANT: Because we were doing some work in Loch Ness, and it was -- Loch Ness was attractive to the Discovery channel, but we just happened to have some nice video shots of the corer actually sitting on the sea bed and then watching the actual point where the core tube actually hits the sediment. This is the point that you really know whether you're going to get an undisturbed sample or not.

MR. MULLER: Right.

PARTICIPANT: And it was a similar design -- exactly right. It was exactly what we were doing.

MR. MULLER: Yeah. I guess I missed Nessie on that one.

PARTICIPANT: I could send you a copy.

PARTICIPANT: And what you saw on video -- because we had the same experience. We did some tests with video camera on the tubes and (indiscernible) the first time with the caps close to it. And when it hits the bottom, just before it hits the bottom, you can see it was blowing the fluffy stuff away several times. Then we removed the caps so we have only the tube, and even then it's blowing the very fine material away.

MR. MULLER: Just from the movement of the corer itself approaching the bottom, the way --

PARTICIPANT: Yes, and you can see it go slowly because it's there by the piston.

MR. MULLER: Right.

PARTICIPANT: It goes very slow and even it blow away. And we had the same description you said about the (indiscernible). But when you blow away the (indiscernible) material, of course it's undisturbed. It just comes up -- because you don't know.

PARTICIPANT: Is that a control of the same corer?

PARTICIPANT: It's similar. It's the German one, but it's -- I maybe use it with 12 tubes, four big ones and eight small ones. But even when the weather was very, very calm, you can see it. It goes down fairly slow and it's blown away. It's --

PARTICIPANT: Yeah, 'cause, I mean, one of the things you mentioned was that you hold it above the sea bed 40, 50 meters?

MR. MULLER: Yeah.

PARTICIPANT: And then you let it go.

MR. MULLER: We don't let it go. We --

PARTICIPANT: But you let it go quite quick.

MR. MULLER: No, slowly.

PARTICIPANT: Oh, sorry. You let it go slowly.

MR. MULLER: We let it go quite quick on the way down just to save time.

PARTICIPANT: Right.

MR. MULLER: Get the ship about -- get the ship stable, wires straight. You know, stop it at about 40, 50 meters above the sea floor, get the wires straight, and then lower it slowly, 30, 40 meters a minute.

PARTICIPANT: And then even when it's completely calm, we saw it. It comes out and just before it hit the bottom, the ship moves very slow --

MR. MULLER: Yeah.

PARTICIPANT: -- and it comes back. You just can't tell when it's really on the bottom.

PARTICIPANT: It varies a lot with sediment type, of course. I mean, as you say, if you get in really fluffy sediments, that's an extremely difficult thing to get a sample undisturbed anyway, but I don't know whether yours -- does it have a (indiscernible) piston?

MR. MULLER: Yes. Yeah.

PARTICIPANT: Yes. Because with the (indiscernible) one, it sits right on the sea bed. We used to stop it -- when we had video camera on, we'd just stop it less than a meter before the sea bed and then wait and then lower it down. You'd get a better disturbance from the frame.

MR. MULLER: Yeah.

PARTICIPANT: And then the tubes that go down that control the rate after that.

MR. MULLER: We've taken -- the USGS has used this, and they've mounted a still camera and have taken some still photos just to sort of compare what the sediment was like, and it looked very, very similar to my eye. However, you never know with that very, very tiny little flocky layer however it is captured. But how much more isn't captured? That's what your question is.

PARTICIPANT: I think the big difference between the box corer and the multi-corer is you have only a fairly small part of it, --

MR. MULLER: Right.

PARTICIPANT: -- and I think the disturbance -- the same disturbance is coming (indiscernible) because the box moves a little bit more than the small, cute -- even if you turn it around four, five times, you can see it's very quick. It's very quick back to its original position. I like very much the multi-corer. But I have -- sometimes I think what's real and what's not real.

MR. MULLER: We've brought up cores with relatively clear water above the corer, yeah, and about, oh, an inch and a half or so of what looked to be disturbed sediment, resuspended -- right? -- sediment, so we decided, oh, that wasn't a good core. Why don't we do it again? Well, it will come up just like that. And we leave the corer sit on deck like that for like a half an hour or so. Well, the stuff never settled out. It was just suspended sediment that is so fine above the bottom, and so we were able to capture that.

It seems to me that would have been blown aside because it's so flocky, but we actually captured it. So --

PARTICIPANT: Rich, where you run into a problem is when you put the mudshoes or whatever on because it increases the bow weight. As it goes down, it starts putting pressure against the bottom as you're coming up and will push it aside.

MR. MULLER: Sure.

PARTICIPANT: You never want to use those unless you absolutely have to.

MR. MULLER: Right. Yeah. That's --

PARTICIPANT: The trouble is you use those when it's --

PARTICIPANT: I know.

MR. MULLER: Exactly. We've played with some ideas of using some expanded steel -- expansion steel to make sort of a snowshoe with that so that the water sort of filters through. Actually, the -- we've seen a sediment camera with the same idea from Ireland, where they use some expansion steel around there, and it worked out pretty well with that.

# Rock Dredging And Glass Coring On SIO Vessels

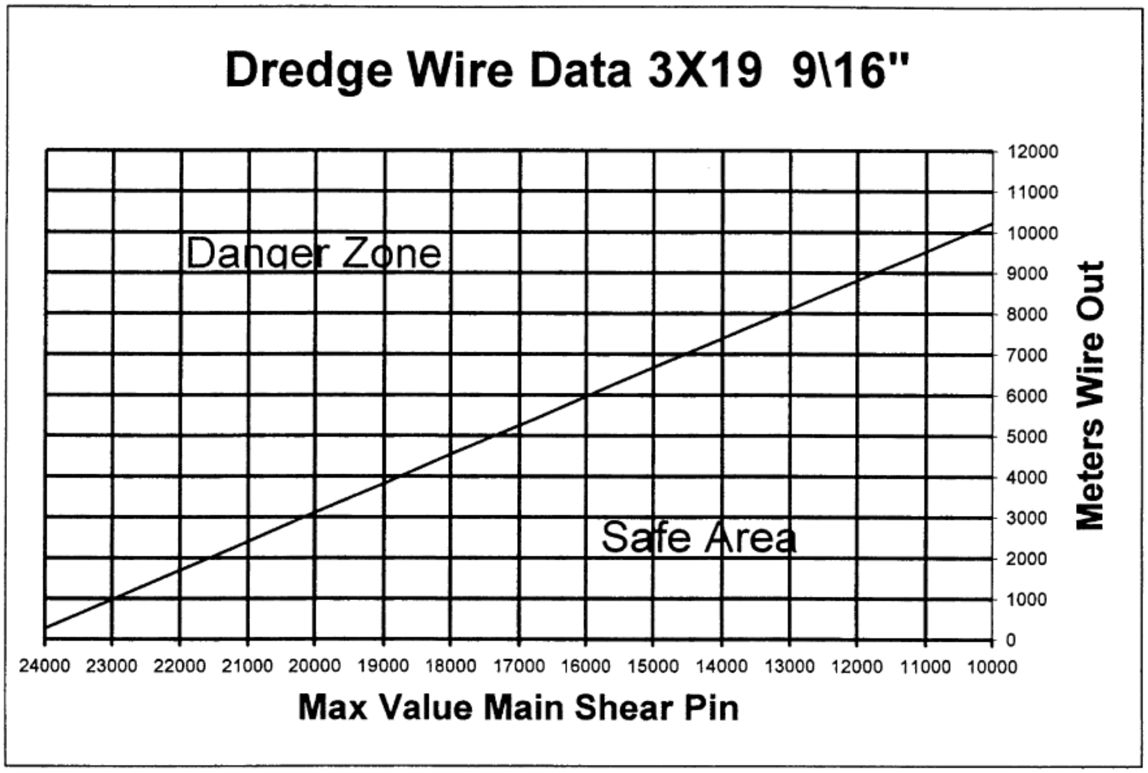
Ron Comer
Scripps Institution of Oceanography

Rock dredging for scientific purposes has been carried out since the voyage of the Beagle and probably on earlier voyages of discovery. The basic idea is still the same. Place some type of gathering device on the sea floor, drag it around for a period of time, bring it back up and see what you have collected. It sounds simple enough, but it is fraught with hazards and danger and can be very expensive. Lots of thought and many ideas and techniques have been tried to varying degrees of success. We at SIO have continually experimented and conjectured on the construction of the dredge, rigging assembly and which techniques work best for different types of terrain. Until cameras are installed on a dredge, no one really knows how the dredge acts on the bottom or what the dredge trajectory looks like. We have tried drift dredging, dredging with large amounts of scope, dredging with large weights in front of the dredge, and different shaped and sized dredges. The current dredges in our inventory and the general description of dredging discussed in this article, we feet, are the best methods of collecting samples from the sea floor in the most safest and economical. SIO dredges today are the culmination of 28 years of sampling, experimenting and learning.

Current dredges weigh about 450 lbs in air and are 13 feet long from the bottom of the dredge to the swivel. The dredge bucket is 36" wide, 18" deep and 12" across, with 3" teeth. The 4 chain bridles are 1/2" Chain, 6 feet in length. Two of the chains have 5/16" weak link bolts installed, rated at 5,000 to 7,000 lbs. Just below the swivel a main weak link, 3/8" bolt, is installed to protect the 3 x 19 dredge wire and Benthos 2216 pinger. This bolt varies in value to the amount of wire payed out to keep the maximum tension encountered to 25,000 lbs or less. The elastic limit of the 9/16" trawl wire is 24,375 lbs. If you exceed this value you will damage and weaken your trawl wire. The collecting part of the dredge is a 1/4" chain bag, 66" long, with a tarred nylon net tied inside of it. We also add a 80 lb weight that is tied in burlap and placed inside the dredge and secured to the chain bag. This weight serves two purposes: 1. It helps keep the dredge from tumbling and blocking off the dredge mouth while lowering and when dredging down slope. 2. It keeps the dredge bag stretched out on the bottom and the burlap traps rock, glass, and sediment particles. (it also proves you were on the bottom in case you were unfortunate in collecting any other material). There are 8 grades of bolts available in each size for the weak links. This is enough of a range to give us a good efficiency in approximating the stretch limit of the wire and still remain in a nondamaging mode of operation. We also employ a recovery system in case the main weak link is severed. It consists of 1, 1/2" chain that runs from the bottom of the swivel to about 18" up from the bottom of the chain bag. It is shackled into a 9/16" girdling cable that will seize up around the net and chain bag trapping any samples in the dredge as the tension is transferred from the top of the dredge, through the chain, to the near bottom of the dredge and hopefully retrieving the dredge in an upside down position. This retrieval system has worked about 40% of the time that the main weak link has broken.

The cost of an SIO dredge is about $2500 dollars. We utilize a Benthos 2216 pinger, cost about $10,000 Dollars, and the 3 x 19 wire is near $6 a meter ($100,000 for 15,000 meters). If you break the wire and lose 3,000 meters plus the dredge and pinger, you have incurred a total loss of $32,500 dollars. As you can realize it is imperative to protect the wire at all times. Not only are losses cost prohibitive but you endanger the rest of your dredging program and other users programs after yours.

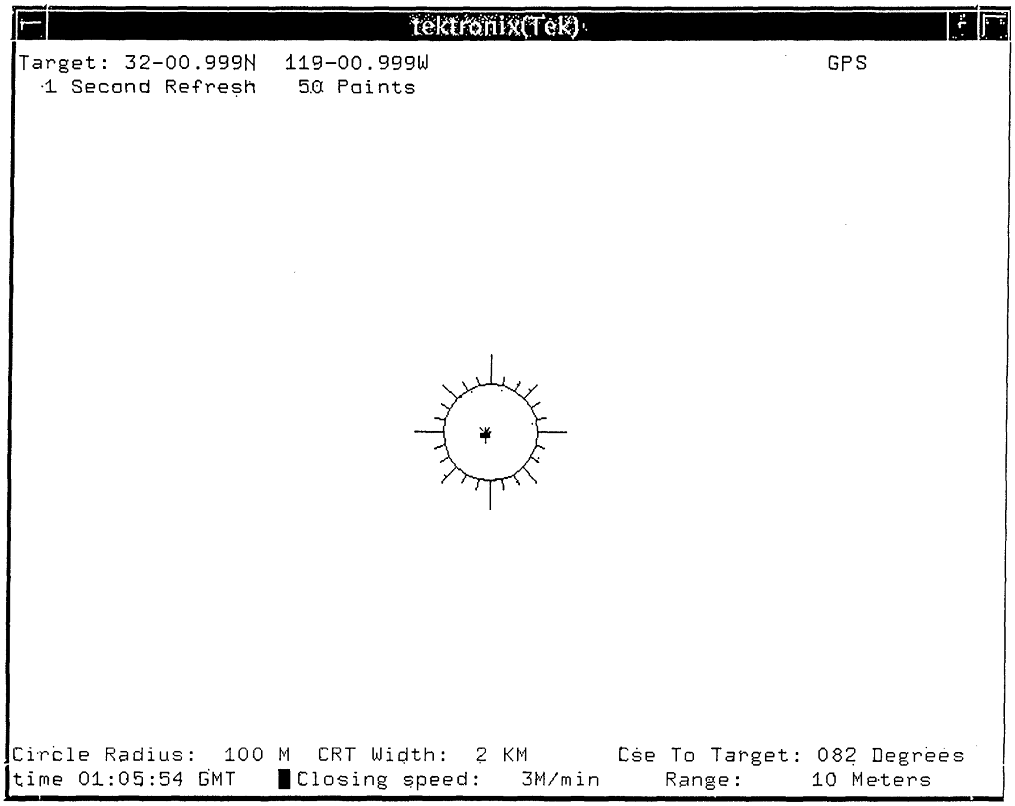
Since 1971 we have done 1458 dredges on SIO vessels with a sample recovery rate of 94.5%. Since installing the weak link system in 1985 we have broken the dredge wire only 4 times as a direct result of the dredge being stuck and have lost 3 pingers. This is a great improvement over the previous years.

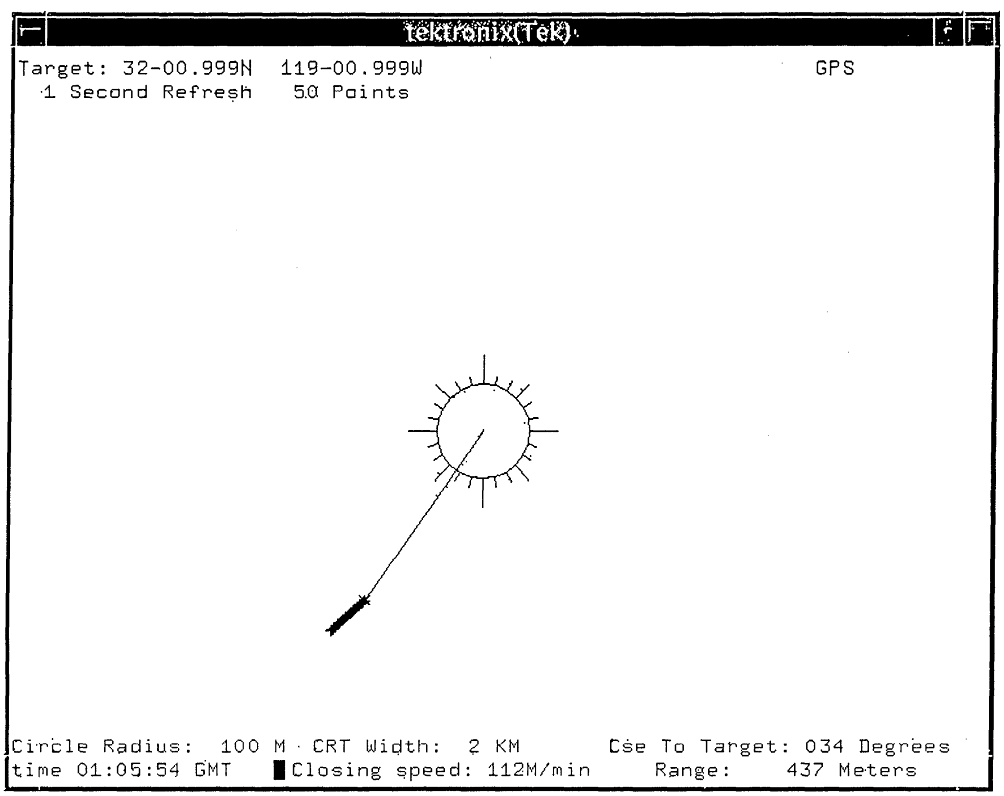

Dredge Wire Data 3X19 9\16"
Danger Zone
Safe Area
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Meters Wire Out
24000 23000 22000 21000 20000 19000 18000 17000 16000 15000 14000 13000 12000 11000 10000
Max Value Main Shear Pin

DREDGES TAKEN ON SIO VESSELS

| YEAR | DREDGES TAKEN | NO SAMPLE RECOVERED | LOST DREDGE |
|---|---|---|---|
| 1971 | 11 | 0 | 0 |
| 1972 | 23 | 6 | 1 |
| 1973 | 15 | 0 | 0 |
| 1974 | 41 | 4 | 4 |
| 1975 | 23 | 3 | 0 |
| 1976 | 18 | 0 | 0 |
| 1977 | 7 | 0 | 0 |
| 1978 | 64 | 4 | 2 |
| 1979 | 25 | 0 | 0 |
| 1980 | 77 | 3 | 1 |
| 1981 | 25 | 0 | 0 |
| 1982 | 36 | 1 | 0 |
| 1983 | 15 | 0 | 0 |
| 1984 | 9 | 3 | 2 |
| 1985 | 150 | 1 | 1 |
| 1986 | 75 | 2 | 2 |
| 1987 | 60 | 1 | 2 |
| 1988 | 173 | 4 | 3 |
| 1989 | 87 | 1 | 1 |
| 1990 | 72 | 6 | 2 |
| 1991 | 84 | 2 | 1 |
| 1992 | 130 | 4 | 0 |
| 1993 | 146 | 2 | 2 |
| 1994 | 64 | 1 | 1 |
| 1995 | 79 | 3 | 1 |
| 1996 | 118 | 7 | 0 |
| 1997 | 93 | 3 | 0 |
| 1998 | 118 | 0 | 1 |
| TOTALS: | 1458 | 59 | 21 |

SUCCESS RATE OF: 94.5%


tektronix(Tek)
Target: 32-00.999N 119-00.999W
GPS
1 Second Refresh
50 Points
Circle Radius: 100 M
CRT Width: 2 KM
Cse To Target: 082 Degrees
time 01:05:54 GMT
Closing speed: 3M/min
Range: 10 Meters


tektronix(Tek)
Target: 32-00.999N 119-00.999W
GPS
1 Second Refresh
50 Points
Circle Radius: 100 M
CRT Width: 2 KM
Cse To Target: 034 Degrees
time 01:05:54 GMT
Closing speed: 112M/min
Range: 437 Meters

We maintain a dredge inventory available for use on all UNOLS institution vessels as well as foreign Countries vessels, on a per lowering rental basis. To date our dredges have been used on WHOI, U. of Wa., OSU, Mexican, Taiwanese, Chilean and SIO vessels. We have had excellent comments from scientists all over the world for ease of use and sample recovery.

We employ the Benthos pinger on the trawl wire 150 meters above the dredge. The top clamp of the pinger is attached directly to the trawl wire and the bottom clamp is attached with an 18" long chain from the pinger to the wire. This enables the pinger to hang in a vertical position at a times, giving a much better echo return to the ship. The dredge is lowered to the bottom, while holding the ship stationary using the ships dynamic positioning system, until it touches bottom. We then stop paying out wire and bring the ship around to the dredge course and get underway at a speed of I knot over the ground, (30 m/m). When the ship starts moving we again pay out wire at 3 0 m/m or slightly faster until the pinger is 10-15 m above the bottom. The pinger is kept at this distance by moving up slope and paying in or out on the wire until you have reached the end of the targeted dredge area. The ship is then stopped and held in position while retrieving the dredge. Our large vessels are equipped with sea beam systems and P code GPS which enable us to create an excellent map before starting the dredge and with the use of the Bulls Eye program we can readily know where the ship and dredge has been and the course of its track. By placing the pinger at the 150m mark we can minimize the amount of scope payed out and the amount of free wire laying on the sea floor. The less wire on the bottom minimizes snagging and damage and cuts the time of dredging. Our experience has shown that the dredge remains in contact with the bottom until pinger separation of 135-150 meters, when using the above techniques. Each dredge situation will present its own set of challenges which will require various alterations to the previous described operation. Experience, practice, patience and thinking before reacting will produce good results.

## GLASS CORING

The idea for glass coring came about from an adaptation of a method of sample collecting on the voyage of the IMS Challenger expedition from 1872-76. They dropped lines encrusted with tallow and drug them on the sea floor when making soundings. Sediment, biota and small rock fragments were usually caught in the tallow. In 1989 Dr. Charles Langmuir of LDEO and I built the first glass corer using a modified 2" gravity core barrel and weight head. We attempted 162 glass cores transversing the EPR and were successful on 159 lowerings. The first corer had a 2" diameter and recovered on average about 3 grams of igneous glass.

The advantages of glass coring versus dredging are: 1. Speed of sampling. Hydro winch can run at 100-120 meters/minute. Time expended is less than 1/3 of dredging time for the same site. 2. Very accurate sample location and a discreet sample. 3. Very close spaced samples are achievable. 4. Cost effective, each glass core lowering costs about $10 versus $150 for a dredge. 5. Sample curating and stowage is much simpler and less costly. Two or three gram samples are enough for plasma spectrometer analysis.

The disadvantages are: 1. Sediment coverage may inhibit corer from reaching a glassy surface, 2. Small sample size, not enough for multiple users or some geologists. 3. At the mercy of the bottom topography and geology, you can't get what's not there.

The best places to sample are ridge crests and spreading center ridges, sea mounts and their calderas. Two thirds of all the worlds volcanoes lie on or within 40 km of spreading ridges, so target areas are abundant. If you have a 3.5 khz echo sounder, use it! Eliminate any area with a suspected high sedimented cover.

Construction of a glass corer does not have to be complicated or expensive. We have found that it takes very little force to break glass off of basalt and have it adhere to the wax in the core head. We currently have 2 types of corer. One corer has stackable weights and can operate from 50 to 600 lbs with a 10" core sampling head that is easily interchangeable for fast turn arounds. Our other corer has a 4" core head and is powered by a 150 weight. Both are lowered on the 1/4" hydro wire at rates of 100m/m until impact. We use a recording tensiometer in conjunction with a meter counting guage to determine impact with the bottom. A Benthos pinger can also be used on the wire at about 75m above the corer for deeper cores. Free fall speeds of the core should be above 180m/m so the winch is actually acting as a brake in keeping the speed at 100m/m. As long as your corer is not extremely long you should not have any trouble with the core impacting in a vertical position. If you construct a core, it should be easy to launch and recover even in rough seas. It should be rugged with an easily replaced core sampling head, Remember heavy weights are not necessary, 100-200 lbs will work just fine. The tool should be cheap, our 4" head corer costs about $400 dollars.

The wax mix for the core head is currently hand made by us out of 65% petroleum jelly (Vaseline), and 35% paraffin wax. Use a double boiler to melt ingredients and pour into easy to use quart containers with tight sealing lids. We use an electric griddle with our double boiler to cut down on fire risk. Once a sample has been collected, hot water can be used to melt wax off of hand picked samples. This solution can then be strained through cheese cloth to separate sample from liquids. Sample can be further cleaned with acetone. Waste wax can be reclaimed by cooling and pouring off water then remelting of wax and straining through cheese cloth again. It will probably be necessary to add more petroleum jelly to the mixture to soften the wax back to the desired consistency. For ease of operations your wax mixtures should be made up on shore. Other tools needed are tweezers, spatulas, sample dishes, sample vials, electric tea kettle and waste buckets.

GLASS CORES TAKEN ON SIO VESSELS

| YEAR | CORES TAKEN | NO SAMPLE | |
|---|---|---|---|
| 1989 | 162 | 3 | |
| 1990 | 8 | 3 | |
| 1991 | 0 | 0 | |
| 1992 | 100 | 4 | #Lost corer on cast 99 |
| 1993 | 28 | 0 | |
| 1994 | 32 | 0 | |
| 1995 | 66 | 3 | |
| 1996 | 56 | 8 | |
| 1997 | 117 | 2 | |
| 1998 | 72 | 1 | |
| TOTAL: | 641 | 24 | |

SUCCESS RATE: 96.25%

## WIRE SPECIFICATIONS

| WIRE SIZE | WEIGHT IN WATER | ELASTIC LIMIT | BREAKING LOAD |
|---|---|---|---|
| 1/4" 3x19 | 0.28 lbs/mt | 5,063 lbs | 6,750 lbs |
| 9/16" 3x19 | 1.39 lbs/mt | 24,375 lbs | 32,500 lbs |

# Oceanographic Research Vessel Deck Safety

Daniel S. Schwartz & George White
University of Washington

**[Editor's Note: The following is a transcription of Dan and George's oral presentation.]**

MR. SUTHERLAND: We wanted to get some presentation on general deck operations and safety issues, from both a large ship operator and a small to medium ship operator. We fished around and got representatives from the University of Washington to talk about large boats. We have Captain Dan Schwartz and George White, both from the University of Washington, talking about oceanographic research vessels and deck safety on large ships.

CAPTAIN SCHWARTZ: Thanks, Woody. Before I start, I just want to acknowledge one other person from our team. Bill Martin's back in the corner there. He's head of our Marine Technician Group and, Bill, if you could just wave your hand -- if anyone wants to talk to him about our operation, too, you're welcome to afterwards.

I think in order to have any credibility on a subject like this, it would probably help if I just take a second and George takes a second to talk a little bit about our backgrounds before we begin.

I've just started, two months ago, at my fourth UNOLS institution in my career, joining a team at UW. Over the last 20 years, I've spent most of that time in command of research vessels at sea, with a year off to graduate school at URI and another year and a half at Washington, D.C. So, needless to say, I've seen the good, the bad, and the ugly when it comes to deck safety and operations.

George, when he starts, I'll let him give a little of his background.

I'll just start by outlining some aspects of the topic and then George will go into the details with his slides.

Why are we even thinking about this here? These are some of the reasons why deck operations and safety on research vessels are important. And then, again, looking at it as Woody said, we're going to start from the large ships. Obviously, the extended nature of our deployments, the fact that often the areas of the most scientific interest are those farthest away from any sources of assistance or help or medical care; the necessity to operate in all kinds of weather, which was a drive in the design and size range of the large agors (ph); as we've seen just at this morning's session, the size, shape, and weight, and bulkiness of the gear, occasional need for using small boats and divers; and the day-and-night issue gets into human factors, which I'll talk about in a moment in terms of fatigue; and -- and then on top of all of that, we've all often encountered the fact that many of the people on the research team, this is their first experience at sea. It's important for their careers that they be good scientists and, fitting in there, becoming good seamen, seawomen, is often not something that's within the constraints of their time. So we have to do it for them.

Wearing one of my other hats, which is as an aviator, I've read innumerable NTSB accounts of aircraft accidents, and there's a whole science of aircraft accident investigation. And one of the things that the aviation investigators have found out is that in every accident, there's always a chain of circumstances, a number of incidents, hazards present, judgment calls that were maybe poor judgment calls. But if you removed any single one of those factors from it, the accident would not have occurred, even though all the other hazards and bad decisions and things might have been there.

They've also found, of course, that the easiest links in that chain of circumstances to break are the human links, the ones associated with human error. We can't control the weather. Often, we're confronted with pieces of equipment to history and construction and strength and metallurgy we don’t know. So the things we have to concentrate on as technicians and ship operators are those concerned with the human factors.

This bulleted point of the shared responsibility, that gets back to the fact that, again, so often we see participants in these expeditions who have never been on a ship before or have only occasionally been out -- maybe a month or two every few years. So this becomes a shared responsibility of the ship’s crew and very often the technician group onboard. And I say that because, often, a ship’s crew is up on the bridge looking the other way or watching a RADAR or holding station or monitoring DP equipment, and the people where the tire meets the road are the technicians out on deck. It’s very important that the lead technician of an operation, for example, putting in a large coring -- piece of coring equipment -- is clearly in command of that operation and that he or she makes the calls, watches out for everybody, looks at the footprint of where there’s hazards of equipment breaking off or falling or snap back with wires, and that involves zooming out; in effect, not just concentrating on pulling the set pins on a CTD rosette but actually, you know, looking around for other hazards on deck.

So these are -- these are the responsibilities that we all share.

I’ll make a final point here before turning this over to George, and that’s that, again, why are we thinking about this? Safety’s cost-effective. One of the things that’s -- I guess this is a sort of macabre thing to find enjoyable, but one of the things that’s really enjoyable about the RVOC meetings, which some of you go to, the Research Vessel Operators Committee, is that we often get into some fairly lengthy sea stories and land stories about lawsuits, litigation, Jones Act cases from injuries onboard ships.

Dennis Nixon, who’s the legal consultant to UNOLS, has lots of good stories about this. I think we all know enough about the subject that these are very time-consuming. They cost our institutions a lot of money. Unfortunately, it’s money that’s wasted that could have gone to doing good science or buying better equipment.

Obviously, safety contributes, thus, to mission accomplishment. We’ve talked about the excellent statistics Scripps keeps on, you know, loss of gear. We all have similar records. Some of it’s irreplaceable, especially when it’s prototypes, new equipment.

So with that in mind, as I hand off to George here, again, we’re not going to attempt to provide today an exhaustive inventory of what can go wrong on a ship and what risks are presented to the personnel. Rather, we’re just going to outline a few areas of recurring concern, areas that Sandy has mentioned he wants to talk about to, thinking in terms of when there’s these incredibly heavy pulls on wire. It’s not just the wire but how was that pad eye welded to the A-frame and how is the winch bolted to the deck, items like that, so these are all -- these are all areas that I think we’re going to have to concentrate on more in the future as the size and weight of the gear goes on.

After George is finished, we’ll come back with some tools that maybe we can take away from this talk and some beginning points at which we can generate a healthy discussion on.

So, George, with that, it’s all yours.

MR. WHITE: I’ll have to get the gear.

CAPTAIN SCHWARTZ: Yes.

(Pause.)

MR. WHITE: Well, I’m George White and I’ve been at the University since the early ’80s. My background is civil engineering. And I went to work for a mining company after finishing school and worked for International Nickel in the early -- during the ’70s in ocean mining. And once that came to a close, I ended up at the University, and first worked as a supervisor for the technician group and then am the technical manager for marine operations at the University of Washington.

And, basically, today what I'm going to go through is just give you some overviews and ships, large ships, the deck layouts, and we'll sort of talk through this as I go along about various safety items and issues that are going to come up onboard a vessel.

As most of us are familiar with research vessels, there's a lot of gear brought on and off the ship. We have some residual equipment -- winches, cranes, capstans, various handling gear -- pretty much permanent to the ship. But in each operation, we see new equipment. And it all relates to the mission that we are involved with, which is the sciences.

And the science missions are varied, and so the equipment is varied. And this happens to be a CTD operation. I believe this is an SIO unit here, a Scripps unit. You can see -- here's a trolley located. It's bringing the package out onto the deck. There's an overhead boom, and then the ability to put this unit back inside for sample-taking.

And you see a lot more and more equipment like this coming onboard ships. Packages are getting heavier. We're starting to stretch some of the limits of our -- of our wire capability.

And also you'll notice through here -- and this is kind of a good picture here because you have an operation there and you also have people in the background. Most of the big ships, they've got their multiple disciplinary vessels. You're doing -- there are several groups onboard doing different things, and this is one of the hassles for the marine technicians and for the ship's crew, is those people not involved in the over-the-side operation, you've got to make sure these other people are out of harm's way. Because everybody likes to watch what's going on but, a lot of times, you've got heavy loads, the weather is not very benign, and you don't need a lot of bystanders cluttering up the deck, getting in the way.

And here's another example of what you're going to see onboard a deck at times. You've got these multi-disciplined groups onboard that are doing a variety of experiments, and the deck -- I mean, there's sediment traps, there's incubator. They're filling your deck full of equipment. And so trying to make order out of this and then also trying to keep control of which experiments are going on at what times and where people are located, it's becoming -- it becomes a more and more difficult proposition.

These are just some of the lowering equipment, CTDs, people preparing them for over the side.

Here's another example of what we like to talk about on deck, is that there's one person in control for any operation on a deck. You know, you've got -- usually, you've got a winch operator or a crane operator moving some gear, having it -- lowering it or moving it. You can't have a bunch of people all at the same time giving different directions. We usually assign one individual as the person on deck that's going to be doing the directing.

And those can easily be done ahead of time. It's either one of the ship's crew, one of the mates. A lot of times on our ship, we don't have boatswains. It's the chief mate or one of the technicians that's in charge of the deck at that particular time. And there are some groups, especially doing moorings, there are groups -- Woods Hole, Scripps -- other institutions have groups of people who have done this a lot, and they many times will run their own operation. And the ship's crew, the technicians, we'll assist them. They will need the work to be done on deck. But that's all assigned ahead of time so you know who's in charge on the deck.

Here again, this is a Scripps CTD, just giving you some idea of some of the stuff that goes over the side.

Now, here's -- here again, you see, this is more weight on the deck. I can tell you -- see, and the weather's bad is why you see more of this, but hard hats and life jackets and proper clothing worn on board the ship is another big problem. I don't know how many slides I had to go through before I could find one that might demonstrate the fact that we do -- you know, people do use the proper equipment.

(Laughter.)

Most of you know that on any type of -- especially in any kind of tropical weathers, you normally find the safety thongs and shorts and T-shirts is the common fare on the decks, and it's very hard to find anybody wearing a hard hat. And -- but this is what is incumbent on all of us now. We've got to start dressing harder, from -- both from shore to the ship to start complying with the rules and regulations that are coming -- that are being made more and more efficient.

We've all known we should be doing these things, but it lacks in a lot of cases, but with ISM and the ships' -- and IMO regulations that we're all starting to face -- and our community is just now, on the ship side, are going to start having to deal wit this -- these regulations are going to start having more bite and teeth to them, and we're going to start enforcing safety. And it's not that it's a bad idea, but it is something that we need to pay more attention to in our community.

Here again, they're lowering. But that's the other thing we notice in this business. It's never the same. You're not just doing one thing at a time. You know, we've always done this. You're getting new things every time. For the ship operators, especially, and the technicians, every cruise there's something different. Science is changing. Our missions are changing. And so you're continually having to be -- be cognizant of the gear that you're going to get onboard.

And a lot of times, we try -- I know the operators try and technicians try to get all that information ahead of time, but more than often, it will show up and here it is. "Well, we didn't know we were going to have this piece of gear to deal with." So this is what takes place a lot more
-- your pre-planning, even after the scientist shows up with his trailer loads of gear, to get a plan made and who's going to be in charge and how are we going to handle this stuff.

And the first thing that arises is deck layouts. Where are you going to put all this stuff and get it all secured before you go to sea? That's usually the first thing you've got to do -- is where is this going to locate so we can move it once we're at sea, if it does need to be moved, and what locations do they go into, and get it secured.

Here again, some more examples -- and you see some of the operations. The weather here is not the greatest, but you've got high abs., A-frames involved, moving equipment and gear on deck.

And during this operation -- this is a mooring -- so -- and any of you who have been familiar with those, there's a lot of things going on out there at once. You've got people back up here running winches, feeding out equipment. You've got people on the sidelines bringing equipment to be attached and stopping lines up. And in these kind of operations, fortunately for our community, the guys involved in this have been doing it a long time and are very good at it, and they are the ones that typically run these decks, and we fill in. You know, "You run that winch."
"Okay." Or, "You move this" or that. They're the ones usually directing traffic.

But as you can see, just from what you see through this picture, is there's a lot of things going on and the potential for something to go wrong. You're going to have a lot of trouble in a hurry.

There again, there's more weights. You see all the lines across the deck. And any of you who have been to sea, I'm sure -- I don't care how long you've been out there -- sooner or later, you've heard someone screaming at you about getting out of the bite of a line, getting out from in between a line, and usually it's not very nice what they say to you at the time.

(Laughter.)

But this is why. I mean, you can see. You've got heavy loads under a lot of tension, and it's not static. You're on a rolling ship that -- the large ships, they're 3,000 gross tons pumpin' around in the ocean. And you've got packages over the side, obviously, that weigh a lot less and that ship is moving.

And these are just -- I'm just giving you some sort of feel of part of the operation of deploying some of these packages. Yeah, see all those life jackets on and hard hats? Here again, they seized up streaming out. And, again, the deck, all this equipment. It's loaded onto the deck. It's got to be spotted. You've got to have people who -- you know, in places. You just can't have people knowing about the deck that aren't involved in the operation.

And the other thing that comes up is small boat ops. Many times, you have to use small boats. There again, the people have got to be trained. The ships' crews are trained to launch and retrieve these vehicles and get them onboard and back but, again, the training again to people who are new to the ship or new to small boat ops. -- and small boat ops. are not taken lightly. I mean, you've essentially removed a few of your people from your vessel. Communications are extremely important, and people knowing what -- and having the proper gear onboard.

See, they're having fun out there; right?

Here they're -- the weather is pretty lousy.

Now, this -- and that's the other thing I've noticed in my ten -- the last ten years, especially -- loads are getting bigger and bigger. CTD packages are bigger. This happens to be ROV boats, the Canadian ROV. It's a monster. And it lives in a garage and it's deployed from that garage on an umbilical, and these things are starting to get real heavy. And, again, you've got ship's crew and the team involved with the ROV itself trying to launch and retrieve these vehicles.

And in good seas, you know, that's not so bad. But weather can change on you in a hurry and it can get pretty nasty.

Here's a picture over the side. But, see, the sides are -- now, that's pretty flat calm out there, but they did try to retrieve this in 70-knot winds and lost that. They got the cage onboard, but the -- because of the heaving of the ship, the little ROV couldn't get back into its garage, and so they brought it up in two lifts. They got the main garage onboard and had moved the ROV around to the side of the ship to try to pick it up with a crane, and 70-knot winds and -- they're pulling in the umbilical, they short the umbilical to the point there. The little ROV weighs so much and the Thompson's 3,000 tons, and it went one way and the vehicle went the other and the umbilical parted, but these are the kinds of things that happen -- big-time loads on -- and weather can change.

These vehicles are down for -- as we know in this business, oh, just a little more. Just a little more. One more cast. One more. Oh, the weather will hold. We can make it.

There again, here's another example of deck -- this is before things are getting settled out but, again, it's a lot of equipment on board.

Some of this is from (indiscernible). I don't remember -- I think this was (indiscernible). But, you know, there you have a full ship with maybe a dozen different scientists with different projects that they're doing, so they've got all their gear onboard.

Now, this is part of the rowpost. This is -- they're bringing their own winch. They have their own winch for their ROV. This is collecting some of these smokers off of the Pacific Northwest.

Now, this is -- what I'm going to get into here now is some of the things that we as operators and technicians can look at, is look at better handling gear as far as safety. We try and -- as you saw earlier from Peter Kalk on the coring, where his core was -- you know, it's outboard, because of his core cradle, and we've designed up at UW one that's on hydraulic lifts. And I'll just -- so you can get an idea.

This is the position that you saw where Peter had his corer. But we can now bring that inboard instead of having people hanging over the outside, just bringing it -- getting it on -- get it inboard. And that's something that we've got to look at, too, greatly incumbent on some of the funding agencies, is looking at -- you know, when we're asking for deck handling equipment -- winches and air tuggers or hydraulic handling gear -- I don't know about a lot of you, but I'm getting older and I just am not as robust and as cocky on the deck as I used to be and not as strong either. And a lot of this gear is very heavy and one reason we use a lot of guys to manhandle this stuff around. Hydraulics is available. Some of it, you know, you can reduce the number of people involved, which helps, and you've got a better capture system of it. Hydraulics on ships is something that is a really easy tool to use for most of the large vessels. They have the capacity. They certainly have the technology. It's -- and they do cost more, obviously, and a few more pounds of chain and some comealongs, but they will make your life a lot easier.

Some of the other handling gear -- this happens to be a sled that we use to move the CTD. You saw the one before. This is the one we had built at the "U" and it primarily uses -- instead of a chain drive or cable drive, it's on a worm gear. This is just a long worm drive here that's attached to the front of this slide that drags it in and out. And the one advantage to that is it doesn't matter if you have a power failure or just a mechanical failure. You're just stopped. You haven't got something loose that's going to take off on you on a rail. It's captured. It's -- and even with a failure.

Here again, some more deployments, nets, and what have you.

Now, here's -- these are the things -- you know, in most of the operation plans that you go through, there's, "This is how we're going to do it," and -- but -- and then they add on. This is what happens. It doesn't come back quite the way you envisioned that it was going to. The wires and nets tangle. Moorings -- and these are the times when, you know, you really have to be on your toes as to what you're doing. There's a -- there's usually a frantic, "Oh, we've got to save my instrument. I have to ..." -- you know, "We've got to take care of this equipment." But the thing you've got to take care of is those four people standing out there first, and that's one of the things that I guess some of us have learned a long time ago. We can get new equipment, maybe. You know, maybe Santa will be good and give us some more equipment. But we can't get new people. And so one of the things you always want to look at is you want to come back with the same number of people you started with and you want them to have the same number of digits that they left with when they get back, and that's the overriding concern from the ship's ops. and from the technicians. The science -- I mean, we all know why we're here -- it's to support scientists and to make their mission successful -- but part of that is bringing them back. And those are the things you just cannot emphasize enough onboard a ship, is -- is the safety.

And the biggest part of all of that is the training. And the ships are being forced out. Crews have to be trained. There's more requirements for them. And we're going to -- and that's going to get passed on down. There's never enough training, and especially with safety. We tend to take it for granted onboard a ship, but, I mean, like the techs themselves, you know, it's -- it's amazing how from one, you know, bolt drill to the next, you know, we listen the first time and it's sort of like getting on the airplane, you know, with the spiel the stewardesses give at the beginning. They're safety people. I bet half of us never even listen to it anymore. Still readin' books or --

But on a ship, the best safety device that's on there is you. You know, that's the best safety device on those ships, is the individuals out there. And I can't overemphasize it enough. And if anybody takes anything away from these -- the day about safety, it is that big. It's something you've got to pass along and you've got to review it.

And for the techs, I know onboard ships, it's -- it's -- next boat, you'll ask some of these guys, "Where was that eyewash station?" You know, ask them that question. Let them tell you where it is. Then it will make them start to think, "Well, maybe I'd better pay attention because a guy's going to ask me this and embarrass me in front of everyone."

Somehow, we have to get that across -- that the training and going over these things is important.

There again, there's another -- things don't go well.

But, again, that takes coordination on deck. And the most important thing, again, is the people.

And that's all I have for right now.

(Applause.)

CAPTAIN SCHWARTZ: All right. Based on what we've looked at, what can we carry away from here as maybe a starting point for future discussions and thinking about? As George said, training is really important. I'm sure everybody has their own procedures. On our ships, Bill or his technicians often are -- actually serve, in addition, as the training officer for the oncoming scientists and then conduct training drills.

There is often an enhanced communication at that level rather than having a member of the crew reading through a checklist to the oncoming scientists.

We talked a bit about communications, the important points of how directions are given for the handling of heavy lift gear, common terms, hand signals, the importance of a chain of command, making sure the person on the spot where the greatest hazard is is in charge of that operation and has the authority to stop it and restart it. All those pictures that we showed were taken in daylight but, as we know, an equal amount of work usually goes on at night.

Bright lighting is important, so there's not shadow areas and dark areas, especially with all the hazards strewn about the deck as we saw in those pictures -- cables and things.

Contrasting color on hazard points. Did you notice the moving machinery associated with that Canadian ROV was very bright orange painted, things like that. You want to keep people away from.

And then, finally, proper safety apparel and protective gear and underline enforcement of that. I'm sure it's bewildering to some of our guests from other countries the way the U.S. legal system works but, in the United States, you are never responsible for your own stupidity or mistakes. It's always somebody else who is responsible.

(Laughter.)

And so since that basically means us as operators of ships and the people that conduct science, somebody that neglects the safety apparel, makes the mistake of getting under the hazard zone of heavy lifts, will not be responsible for their action, at least financially; we will be. So we must all enforce that and not delegate that to someone else and hope somebody else will say it.

So, with that, that's a good point to start discussions. Woody, I don't know how you want to do this. I might suggest if people want to add things -- I remember yesterday, we were saying your name and institution so that, in the course of recording, we can get where that's from.

# Small Research Vessel Deck Operations

Steve Hartz
University of Alaska

**[Editor’s Note: The following is a transcription of Steve’s oral presentation.]**

MR. HARTZ: Do we have a VCR -- I don’t know if we have a VCR hooked up here.

MR. SUTHERLAND: It appears Steve brought a videotape, and we didn’t know. That was a surprise to me. So we don’t have video set up in this room. Tomorrow afternoon’s session is on CTD operations. By chance, I’m chairing that as well. It’s going to be a combined session. And I’m going to continue the discussion session on safety issue and deck operations following the CTD session. So we’ll have the formal presentations, and then we’ll continue with safety and deck operations in that session as well, so we can show the tape then.

MR. HARTZ: Okay. Small deck operations. As you can see, we have a small deck. This is the Alpha Helix. It was actually a Scripps vessel before it came to the University of Alaska. Scripps used it as a multi-purpose biological research vessel. And when it came to Alaska, they converted it to a multi-purpose oceanographic vessel. They added a large oceanographic winch, and that’s actually in the hull, and then they had a crane center ship, extended the wings out. They used to have a fly bridge out there. That was open to weather, and we of course enclosed that so the -- to keep the deck officers happy.

And they also added a winch house on the back because the first year it came back from the Arctic when they were using it, the guys built this plywood shack so they didn’t have to sit outside running the controls on the winch. So I think Dolly Dieter at that time didn’t like to see the wooden shack on her boat, so they built the doghouse, and it’s rightfully named.

The Helix is based in Seward, and that’s actually our town, if you believe it or not. Here’s the town here and it runs along actually the bulk of it. It’s about 3,000 people, so Scripps is a little bit bigger than Seward, Alaska.

And this is Alaska. And that’s how it normally looks from the air. This was done with a AVHRR that we collected onboard the Helix. This is a composite of three bands off the NOAA-12, I believe. It was bands one, two, three in the visual range. And Seward is actually located right here under the big sphincter. That’s our normal-looking weather.

And, unfortunately -- I did have some -- on the video, you will see some of the conditions we operate on, and that will give you a good idea what the Helix is about. Some people call it "The Ralph of Seasick." I’ve heard it called "The Blue Canoe," many other names.

Probably the best thing I could start out with is come back to the ship. We do things a little bit different. One is our deployment. We do work in a lot of rough water. And it’s a single screw and it has an omnidirectional bow-thruster, but the bow-thruster is just like a little fire hose under there. It really doesn’t do much when the wind starts blowing. We’ve got about a 14-foot draft in a 30-foot house, so it’s a lot of sail on the vessel. But we use that to our advantage. And we actually back down into the season into a CTD deployment.

Now, that sounds kind of strange to most people, especially if they have a mud-boat type design or anything that -- whoops! -- but you can see they call it a Blue Canoe 2, and the stern is rounded in the aft end, so it’s -- it actually rides quite well that way. They run it at about 20 percent pitch idle back on the prop. And if it gets away from them and they (indiscernible), we just weather cock and sit really nice in the seas.

Problems with working on a small vessel. I think some of them are space and motion and so, with that, especially the motion, the big problem is complacency. We’ll be running downhill. With the seas on the stern, it might be a nice ride. People have all their signs here out not tied down, and the boat turns to go on station and, all of a sudden, it looks like a bomb goes off and the lab cameras are hitting yourself in the head and people are losing a lot of money.

Actually, we have a quite extensive briefing before the scientists go to sea so they’re pretty good. We usually don’t have any problems because we drill it into their heads prior to the -- prior to going.

Right now, this boat, we do -- probably 20- to 30-degree rolls are normal. So in any type of deployment, even in flat calm, I think she’ll roll about ten degrees tied to the dock here.

So -- so that’s a -- and it’s a quick -- sometimes it’s a real quick roll. It’s usually about eight seconds, I think, from side to side, but it can all of a sudden just dump on you and you’re walking on the side of the boat.

I think we should incorporate some of the flick technology from Scripps, but they didn’t work that into the Alpha Helix when they had the Alpha Helix designed. And it’s actually the oldest research vessel in the fleet. This was -- this picture here was taken this year in the spring, prior to the real start of our season.

We’ll give you a little walk around the deck here. I don’t have a real good picture. I have better footage on the video of the deck space. That’s our Alaska crane, and it’s slightly off-centered in the deck. That’s used primarily for loading and offloading and we use it for towing things on the side. This one is a bioacoustics package. It has four transducers. And we can tow that in conjunction with doing mock ness operations on the deck. We’ve been doing quite a lot of that lately -- running those two in tandem.

We also use it for shallow Van Veen grabs, also tows. It’s quite versatile, nice crane.

One thing here is -- probably into deck safety -- I do have ten years’ time on the Helix. So some people might say I have ten years of experience. I think sometimes I have one year of experience ten times, but -- but I’ve had all kinds of things happen, and things evolve.

One time in Hawaii, we were working pretty rough weather recovering the Goliath buoy, this thing from Honce (ph), this 30-foot long, which is our beam buoy with 300 pounds of weight on it. And -- actually, it wasn’t even that. It was in the recovery of the sediment traps underneath that buoy. So we were using the working wire to bring the spar buoy onboard, and then we would convert over and run the tether to the sediment traps on a block underneath. Well, what we should have done was probably take the headache ball off the crane prior to running the -- running the slip through the -- through one of these blocks. Because they decided to ram out. And part of the headache ball, which landed four feet from me -- without my hard hat, but I don’t think it would have done much to the hard hat. I think the headache ball weighed about 80 pounds. So the point being is that, you know, take the time to strip down and get the gear prepared. And, in that case, we didn’t which, if I would have been four feet over, it would have probably been pretty brutal.

So enough said there.

A little bit more of a tour here. That’s looking forward, of course. You can see the large step here. This is -- the stern is ramp down. We have a large wash area right here along the house, so that’s what you have to go in and out of to get into the Helix. We had one chief engineer that was older than dirt onboard, and he could have had a (indiscernible). So you’d look for a different way to get out of the door when he was in the doorway. It might take him 15 minutes to throw that leg over.

On the davits here, we have two small craft that we can deploy, semi-rigid, which is actually really nice -- a real nice skiff and puts the Boston whaler to shame for a lot of overboard rough weather work. We did swamp a skiff in Nome coming out of the river with scientists onboard, and they were fairly lucky to get out of the situation. And since that time, that’s what prompted them to go to the semi-rigid, which would not shovel a wave like they did coming out of Nome, so --

Here's one of our CTDs. This is a small rosette system, and actually it's no longer. On my last cruise, it went to the bottom. So -- we had a lot of rough weather this year. I think this hopefully appeased the sea gods for at least next year.

We are using the PMI grip and the CTD was at the surface and, because we do have a lot of motion and we do deploy that by hand, we -- I don't weight it down as heavy as some people may, just because I wouldn't be able to control it when it came back onboard. And so we have a little bit of floating at the surface. And in the video, you can watch how it will slap the cable, and so it pulled the PMI grip right out right at the surface, one of those quick snap rolls, and I got back the wire and that was it, so we did a little bit of dragging for it. It was not the best place to drop. It was right on an embankment.

So we actually were fortunate we were close enough to Seward that we could run back and I rigged up an old geo rosette and had a backup CTD, so we were able to finish the cruise and the scientists were able to get all of their data, and we weren't far away on (indiscernible), so it was fortunate.

If anybody has any of these diatom blocks, we did have problems with that this year. We're working in 25- to 30-knot winds, which is pretty brutal to us. And we actually -- the seas were building and it was -- the seas were -- the wind and the seas weren't even matching at that point, so we couldn't work the gears, so we pulled the plug and we were cruising to another location.

The next morning, the chief came up smoking a cigarette on the deck and noticed the block wasn't there anymore, and so I got a call. I was in the electronics lab. Sure enough, the block's sitting on the deck. The -- we do check the hardware every year for ware, but we didn't -- this particular block has a -- this is an I-bolt with a nut on it, has a roll pin. The roll pin was crushed inside and the nut backed off. So -- and you can't -- you can't see that on just a visual inspection so, from now on, we'll tear it down every year and check that. So, again, we're rocking and rolling and I had to go up there and get the block down and we got it repaired and back up in -- we're back in business.

This is our mock ness system. And oftentimes on a small vessel, because of the motion, we come up with ways to try to better handle the gear, at least be able to get blocks on it to bring it onboard.

Here, we use -- actually, these are the -- you see these -- these are tag handles we put them on. They actually were the door handles for the skiff that I robbed off one time because I couldn't get the line into it. So -- we also -- the cradle for the MOCNES we had built is probably the one reason that we're able to provide this piece of gear routinely without problems because this really protects it and we shored up the side here with a piece of channel so that we could -- so it could set in the cradle. And we can work on the instrument packages in this -- in this configuration, and we can also cock the nets in this configuration, so it's worked well. It prevents the keeter (ph) from being beat up. And, also, we stow it in this cradle, so we have forklift skids here and also we have tags for a bridle to pick it up off the deck.

We use a happy hooker -- I don't know if people are familiar. You'll be seeing it on the video -- to put a line around those. And, actually, they've worked quite well. They're a little tricky. You have to hold the line in. There's a little bit of an art. But I've been able to put a -- pass a line around an MK-3 box corer and actually tag it in the water, which is crucial for us because we have so much swing. We had people -- we did a HOTS (ph) program in Hawaii, and I don't think they've ever been on a small vessel before, and they had all types of ideas how you're supposed to bring a CTD in on a small platform, and they were all wrong. And so the first time they put the CTD on, the first thing they did was they -- they sucked the CTD up to the center of the block, and this thing was up there like a helicopter. And we had a bunch of guys with pipe pulls on there with hooks on them that they're trying to hook, so it looked like some savage ritual dance underneath with these pipe pulls and this swinging helicopter up top. It was quite comical.

And everybody I passed was telling me, "We have to minimize the pendulum. Minimize the pendulum." I was ready to knock the next guy who told me about minimizing the pendulum. But, ultimately, they started to tag the CTD in the water, and then actually they came up with a -- I don't know if it was their idea, but they started using a pendulum weight, and actually I use that now in my stern deployment on the large rosette to dampen that type of swing.

So on the large CTD, I had put a 24-place CTD overboard with a pendulum weight with very, very few people onboard and very -- you know, I don't need the big deck ape out there, 300 pounds on the tag line. I can -- it saved me a lot of headaches. And we use the hookers to pass the lines around. So if anybody hasn't seen them, I -- most of the people have probably seen them but, if you haven't seen them, I would recommend getting the hookers.

Here's something you can do with a visual photo if you make it look like a water color drawing. Actually, it looks better. You can make posters of it. Another view of MOCNES from the other side.

Well, this was about video time. I don't have a video but I'm going to -- because of that, you're going to be subjected to some other parts of the Helix that you didn't want to see.

This is -- we had some talk about data acquisition systems.

PARTICIPANT: So that's the (indiscernible).

MR. HARTZ: That's the HP reverse Polish notation version.

(Laughter.)

And this is a crude but this -- we use a program similar to Daisy Lab to produce this, or similar to Lab View, so it's all modular and we just plug and chug. Actually, I programmed this in transit time, going out to Dutch Harbor, and so it's a very simple mock-up to make a data acquisition system with very little effort.

I don't -- my problem on the Helix was I'd had a programmer and then I had another programmer, and then nobody likes the other programmer's program, so you end up not having a program on the Helix. So I brought it down so that -- and, also, there was no way I could modify or update or add new equipment. This year, I added a (indiscernible) to the instrument. It's right here. That took me less than day to plug in and actually to mount the hardware and to get it up and going. So that's one reason I would recommend anybody to looking into a modular-type program if they're trying to build a data acquisition on the chief.

And, also, you've got a lot of flexibility. I can set up the screens however I want. Here, I'm just plotting temperature, salinity, and chlorophyll. I printed this out while we were hiding from weather so, if it looks like we're in the same water, it's because we were, so it doesn't look very good. The barometer is still falling. It's 997 there.

I'll give you a little quick look at our electronics lab. This is actually a quite old picture. It's getting a lot more crowded. I have a lot of monitors down there. We added several -- several computers this year and, right now, I'm looking at -- thinking about getting air conditioning back on the Helix just to keep this room cool. You have to wear your lead underwear when you go in just from all the CRT radiation.

We'll go back. This is the type of real time contouring plots that people are doing on the Helix. And it's not -- this is rough data, but they're just using it as an idea to -- this is from our Auto. Analyzer and the CTD data, and they're just going -- trying to figure out sampling techniques on the fly by having a little bit of a look at what the data looks like onboard.

Other than that, I think I'm done until -- until the video.

(Applause.)

# Bottom Sampling Techniques and Deck Operations And Onboard Safety Discussion Session

MR. SUTHERLAND: Thank you, Steve. I think what I'd like to do now is -- we have some invited panelists, and I'd like to bring them up, pull some chairs out here, and take a few questions from the audience. Let me do the introductions. We have Michael Markey from Markey Machinery. I think most of us know about his winches that are on a lot of the UNOLS vessels. John Hedrick from Ocean Instruments, that builds most of the box corers, the multicorers that we're using on the UNOLS vessels. Is there anyone else? I think that's it.

So if anyone has any questions about the bottom sampling equipment or the winches that we can direct toward these two gentlemen to begin with, and then we'll take general questions just on deck operations and safety.

Yes, Sandy?

MR. SHOR: There's one question. In addition to your panelists and the speakers, we also have Greg Beers, who's from Jamestown Marine here. He's involved with all the UNOLS ship safety inspections. And we've gone through a series of discussions here about instrumentation which gets up at or above the safe working loads and the breaking strength even of the cable, and there's no question that NSF research is proposing to us in the programs to push for larger and larger, longer and longer piston corers, in particular. It's flat out a science requirement. And I guess the question I would throw out is: How can we do it? In terms of constraints, we've got breaking strengths up in the neighborhood of 20- or 30,000 pounds. How can we get 30-plus meter piston corers of adequate diameter, the larger diameters, safely? Is it a wire problem, equipment problems, winch problems, ship deck problems? What are the weakest links -- what are the most important problems with all of this?

MR. HARTZ: I think Michael can talk about winch-related issues.

MR. MARKEY: I'm Mike Markey from Seattle, and I need to say that, once in my life, it was a thrill to see my name listed Dr. Michael Markey. My senior differential equations prof at Stanford would be laughing himself into his next grave if he even considered issuing me anything beyond the first-level exit ticket.

(Laughter.)

On the question of getting more strength, I've heard a lot of discussion about Kevlar and its various commercial put-togethers. And we have to recognize that Allied Fiber controls the supply of the basic Kevlar strands that are made into ropes by people like Samson, Puget Sound Rope, et al.

And there seems to be no shortage of it to make 800-foot lengths of 12-inch braid for the ship-assist and escort business. But when you're talking about making 6,000-meter lengths or 10,000-meter lengths, the way Donny has built a pool of standard wires, actual supply will mean that your sources are being -- your requests will be qualified and people will question your usages, and you may find that whether it's Spectra or the 150 percent stronger Plasma or its other commercial names, the sellers may be reluctant to enter into supplying as much as you folks need. We're fairly close to Puget Sound Rope, and that's one of the questions we had asked them.

If you do run into Kevlar, you're going to repeat the experience of the tugboat industry of the last five years, where every finish, every turn that that rope runs over, had better be stainless and mirror-polished and -- if you want any life out of it at all. Abrasion eats it.

There's another fact that I can share -- although it's not a metal bender's specialty. The Kevlar lines -- Aranitz (ph), Kevlar -- I'm not enough of a scientist to make the distinction. I'll leave that to you and the people you work for, but those lines have an accumulative creep phenomenon. Every peak load induces a little creep, and it's not a yield like steel that comes back.

At ten percent of ultimate, the Kevlar lines may work for thousands of hours. At 20 percent of ultimate, they may work for hundreds of hours. At 50 percent of ultimate, they may work for fives of hours. And so when you're looking at Kevlar as a hopeful replacement in the search for stronger lines that I've heard a lot about, you maybe have to go bigger than you'd like to because of this creep accumulation that is built in.

I think that's all I have to say on -- or offer on our side experience into the soft lines.

Would you like a few random thoughts that I've picked out, or how would you like --

MR. SUTHERLAND: Sure. I have one more question.

MR. MARKEY: Yeah.

MR. SUTHERLAND: Let's say that we can get the Kevlar line. Are there any considerations for the winches that we already have in inventory to handle Kevlar rather than the wire rope that we're using now?

MR. MARKEY: All right. Are we talking strength members only, like coring 3 x 19? Lord knows all of us winch builders would love to see anything replace the 3 x 19. Anything to get rid of that nightmare to a winch maker would be wonderful. Are you talking composite, where the Kevlar is the strength and you've got EM members? Or are you talking composites with fiber optics?

MR. SHOR: For the moment, I think we're mostly interested in just the flat out wire rope question was the one I asked, but there certainly is interest in both of those other questions.

MR. MARKEY: At the strength member point, there are a thousand constructions in the Kevlar. Every supplier has his own braids, with braid angles, with bulk, with lay angles, with rope lay, and you really have to go to your friendly local rope supplier with your own requirements. They are still early in their life. They're custom-designed tension member. And Phil Gibson, I'm sure, would back me up on that.

So it's hard to generalize, but it would be equipment handling other than having to be smooth, glass smooth. From the machinery viewpoint, we can spool it. I think the Leba (ph) shell -- the bending radius remains the issue and, of course, with a soft line, you could wrap it around your wrist, theoretically.

But since fiber optics lurks, I think that any equipment consideration should leapfrog. And as you're trying to replace your 3-2-2 as an industry with something stronger and your 9/16ths 3 x 19 with something stronger, it would make sense to me to try leapfrogging clear to the fiber optic horizon.

And some existing winches can be lagged and remain hell for stout doing it right. You don't want 2 x 4s with banding, please. Leba shells don't sit well on top of that. But a drum can be lagged if you can -- if you don't need your 10,000 meters. And I heard some conversation last night wondering if the magic 10,000 meters is something that your ships all need. So it might be that a lot of the present machinery could be lagged up on the barrels. You're going to need larger sheaves on the level winders.

I know that the AGOR traction machines were all set with 48-inch barrels, and the fiber optic fairlead(ph) sheave and all the outboard sheaves were at 48-inch to handle .681 fiber optic. And so that was leapfrogged.

Bending radiuses is what we need to know. The other thing -- any machinery you build, you've got to go to a breaking strength of whatever you could possibly put on it and have it stay there.

I made a note, looking at the sheave of opportunity information here. It's -- I don't know of any instances where winches have flown off. I watched Max Silverman pull a headache ball through an overboard J-frame on the Argo (ph) about 35 years ago, one of my first and few experiences offshore, and he was quite embarrassed, but he was very impressed with the high speed he could get coming up. And he was -- the water was clear and he could see it, but he didn't -- he could see it down there and then it went back, and everybody was startled. It was a good thing Max's hand was on the winch control.

Let's see. I did make some notes about the safety angle, and George is absolutely right. We all face vultures from the legal profession that we didn't used to have to face. And it's not only the PI or the port captain or the director of the institution; there's a whole chain, and they will all be on the list of the subpoenas. And so safety is an issue that you have to address when the ship is the gleam in the naval architect's eye.

You are probably the most ingenious group of people on the planet and you make things work where there's no excuse for them to work. If you'll go hell for stout to start, your lives will be easier. I think that's a disguised sales pitch. I'll try to avoid that.

Machinery controls should be simple and as intuitive as possible. We've seen some machinery controls, and I've talked to a Coast Guard gentleman, where the control people have gone berserk because the tools we have now allow it.

Twenty years ago, we were all excited about a computer controlling the winch, where you could program a profile, and we talked it up to our friends, provided it on a number of systems, and we don't think it's ever been done.

So the "KISS" theory and simplified controls, just because we can do all these magic things with touch screens, there's a certain beauty to a big red E-stop button that even has a glow-at-night feature if you're in a dark shack so that you don't have to hunt for an icon for the E-stop.

I wanted to make another safety point, since I seem to have the tag here. Watch out for strangers. Sometimes there will be strangers who have access to the ship, for one reason or another and are sort of accepted, and they will do stupid things because they really don't -- even if they have built machinery, and designed it perhaps, they really don't know its operation. They haven't had their hands on the controls onboard a ship.

And I'll close off with a small story. It's too long ago -- I can't remember the ship -- but a piece of 3-2-2 was over the stern -- it was a test -- and there were -- the winch was up on an 01. Down on the main deck under the A-frame, there were about seven people. And I had always wondered -- I was alone just watching -- and I had always wondered if the stern's brake manual release button on an electric winch actually would release. They only release about 85 percent, by the way. You can burn the stern's break with the pull -- the knob pulled all the way up. Anyway, the winch was in the "off" position, and they were doing things down by the rail, and like a damn fool, I reached up to see what would happen if you pulled on the stern's brake that I had spec'd and designed in. And all of a sudden, I'm watching the drum start to turn. Well, I start to freeze up my spine, and I hit that button to push it back in, and it hadn't gained any momentum, and I don't think anybody on the after-deck even saw the wire move, but it put out about four turns of the drum before I got through my "Oh, my God" and reset the stern's brake.

So beware of strangers on your ships. And I hope to maybe have a few other comments tomorrow as we go. Thank you.

(Applause.)

MR. SUTHERLAND: Well, since we have John here in the audience, one question that did come up from our Norwegian friends was the bow effect of the tube in the multi-corer. And is there another instrument or can there be another instrument that will preserve that flocculent layer better than the multi-corer or --

MR. HEDRICK: Well, if you have an idea, please let me know. I'd be more than happy to take it under advisement. It seems to me that multi-corers, as opposed to box corers or any other kind of equipment as it comes down, I think it's a matter of landing and operation of a piece of equipment the way you can do it.

If it's 3,000 meters deep, it's pretty difficult to do. But I think with time and experience, people will become more and more adept at landing this unit and catching more and more of the flocculance. If you've never seen a picture of the Soutar box corer or even a Mark III or any of the other box corers, as it comes down, everything just goes like this. And it goes in, it shakes it all up, it becomes a turbulent mess. And surely after 3,000 meters, it comes up, it comes onboard, a scientist opens it up and says, "The water is absolutely clear." Everything has resettled again.

And as the gentleman from Moss Landing said, that hopefully the sediment that you can see using a multi-corer is actually what you're getting. There always will be bow wake, no matter what you do. Anything that comes into the presence will push it away, but you should design something so that it's round, that it's open as much as possible to cut that bow wake down as much as you can.

PARTICIPANT: Just one point on that, is that when you get to this flocculent layer, you're then drawing the distinction between sediment and water. One of the things that -- we modified one of the multi-corers, the SOC, to use it for actually taking gas type samples in the Black Sea. But one of the things we did was put a single -- actually, I think there were two NIO waterfalls on the frame which would sit in that layer. It was a very ill-defined sediment interface. And so we were actually taking liquid samples as well as taking core samples in that. And that worked quite well. I mean, that's another way around it. You know, is it liquid? Is it solid? They're just single waterfalls triggered by the mechanism of the corer going into the sediment.

PARTICIPANT: Yeah. We've done that also just as a double-check on that.

MR. SUTHERLAND: I just remembered one announcement I need to make. The shuttles will be leaving here and staying down at MarFac. If there's anyone that needs to go to the hotel and not go to MarFac, then we've got at least one shuttle that will be leaving very soon, so you'll need to hurry down to the shuttle to pick up there if you want to do that.

Yes?

PARTICIPANT: I (indiscernible). I understand that people around here haven't used Kevlar very much. On our ship, we actually have 8,000 meters of 29-millimeter Kevlar which we've had to use for eight years, so we've had a pretty lot of experience with it. What I would like to say is I don't agree fully with your comment about the sheaves. They happen to be very clean sheaves. Clean is not the overriding problem. The biggest problem is actually getting reverse bands on the K. And we have a traction winch, a cock traction winch, and that is a severe problem because it has many reverse bands. And what actually happens is that the inner sheath that holds the cable in fact separates from the outer PVC, the little plastic coating. What then happens is that you actually get ripples in that. It splits away. You then get water inside the cable, and then you get the salt when it dries out actually cutting through the cable.

And we now have 6,000 meters of cable because it broke about seven or eight times. (Indiscernible). It's readily available (indiscernible) quite readily. To give you some idea, I have 8,000 meters of 27-millimeter cable. It costs about $250,000.

PARTICIPANT: Is that the same cable that (indiscernible) or same vendor?

PARTICIPANT: Yeah.

PARTICIPANT: That's the Marion du Fresne. Is that --

PARTICIPANT: Marion du Fresne.

PARTICIPANT: -- du Fresne is the ship they use that on?

PARTICIPANT: What they -- we have traction winches in the U.K. We've got traction winches on the (indiscernible), and they have proved totally a waste of space, and we are looking at replacing them. What they have on the Marion du Fresne is a band winch which comes from Clay, France, which is a (indiscernible). So you, in fact, get traction on the winch. But I would say to you if you go with it, a standard (indiscernible) winch is probably the best for actually pulling cable.

PARTICIPANT: We -- maybe I might say something about getting cable because we are experience -- we have experience from 1978. And I was just writing a little bit about the list cable because what you said, that it's never very fast, that's true. In 1989, we bought a new cable, 20 tons. In one year, it goes down to 12 tons. The next year, it goes down to ten tons. In 1991, it was ten tons. But now, in 1989 (sic), it's still ten tons. It was decreasing fast and then it stopped. And we work now for about nine years with this cable. We have lost not one equipment. We did a lot of piston coring, box coring, and I can say, and I mean it, it's much easier to work with skiffer cable on the deep sea -- especially on the deep sea -- than with steel cable.

My first experience, we were on the Melville on Scripps Institute. That was my first trip. It was in 1977. And I was wondering if you take a piston coring, we take a box coring, there are I think three or four people -- they were in charge. People (indiscernible) pinger and all the things like that.

We start one year later with the Kevlar cable. In our institute, only one person is really the whole thing because you are working with Kevlar cable. When you touch the bottom, the tension meter is completely down to zero. It comes up. You can almost set before it comes up how many -- what's the -- what's the -- what's in it, what is in it, and it's -- I can say it's working very, very well. The only thing is -- okay -- can it be phased out?

But when you buy what you said, you have to buy an oversize cable and then you have problems because when you can work ten years this cable, I think it's not a real problem. It's fairly expensive, but --

MR. SUTHERLAND: Yeah.

PARTICIPANT: -- I think you -- you're winning a lot of ship time because it's -- the results by us, they are better than with the steel cable.

PARTICIPANT: What kind of winch are you using? Is it a --

PARTICIPANT: We use bent winch. We use double-capsuled winch and they call it a cable killer. And maybe that's the reason. But even the bent winch of Clay, France, it's not sure if it's the solution because they also have troubles. It goes very fast down and then it's more or less stable, but it's very difficult to ask the French how is now the cable because you have pulled to them for some information about that.

PARTICIPANT: Are there maintenance issues with Kevlar cables that you don't deal with with a steel cable?

PARTICIPANT: I'm sorry?

PARTICIPANT: Are there maintenance issues? Do you just leave it out in the sun uncovered? Is salt --

PARTICIPANT: Yes. Yes.

PARTICIPANT: -- washing, that sort of thing?

PARTICIPANT: We have a big problem with the jackets. We have high-tail jackets. And I think ten years ago, there became gaps like this into -- it was broken and you had to gap it in the high-tail jacket. And we were very afraid about that. We got in contact with the company, (indiscernible), in French (sic). They come to look and they said, Yeah, that's not good. But you can't repair it. It was impossible.

But three years later, the gaps are a little bit bigger, but that is inside the brake jacket and that's much more -- that's enough protection, and it doesn't have problems. Not at all.

MR. MARKEY: I'd like to impose a real semantic discipline in the subject of Kevlar cable.

PARTICIPANT: Right.

MR. MARKEY: There are hundreds of different kinds of cable using those fibers. And so please be specific when you're asking those questions. Different answers apply to different -- the smoothness is open, unjacketed fiber on tugs around bits. There's where you need --

PARTICIPANT: I was going to object.

MR. MARKEY: I wanted to make one other statement about traction winches. We're all waiting for the cable people -- the Kevlar EM and optic people -- to do something where you won't need traction winches. The bends are killers. But if the geometry of the wheels is correct, you can put out any given number of metered -- thousands of meters without twist.

PARTICIPANT: Yeah. Unfortunately, our ship is a multi-roll ship where we have some -- we have a ten-ton and a 30-ton traction winch. The ten-ton is very good, but the 30-ton, there are problems. And what I would say to you is that as we have the wide range of cables -- you've actually got something like 15 different cables on the ship -- it's in fact a job to try and put all those on traction winches and not have too many sheaves. So what we're have to do is we refine them.

# ACOUSTIC DOPPLER CURRENT PROFILERS

Chaired By
Eric Firing

# Fundamental Components Of Shipboard And Lowered ADCP Systems

Eric Firing
University of Hawaii

I will introduce the topic of Acoustic Doppler Current Profilers (ADCP) with a broad overview of aspects common to two particular applications: lowered, in which a self-contained instrument is lowered with a CTD on a wire to make a velocity profile over the entire depth range of a CTD cast; and shipboard, in which the instrument is mounted permanently on the ship's hull. I'm going to go over some aspects of ADCP systems in the broad sense that are common to both of these two applications. Later, Martin Visbeck will talk more specifically about the lowered application and I'll talk about some shipboard issues.

It's important to view the ADCP system as a whole for both of these applications because each requires more than the instrument alone. The system components can be categorized as follows:

* The profiler itself-the transducer and electronics that send out the sound pulses and process the returns.
* The data acquisition system (DAS), which can be a mixture of software and firmware.
* The data processing software. The distinction between the DAS and the processing software is that the DAS is used in real time or near real time, whereas the data processing is something that's done maybe a day later, maybe a week later, maybe a year later. But we hope not a year.
* In addition to these software components, an important part of the system is the platform: the ship and transducer well, in the case of the shipboard system, and typically the rosette frame in the case of the lowered.
* GPS navigation. Both lowered and shipboard systems require very accurate determinations of platform velocity, either instantaneously or in an averaged sense. Rather than just giving a general category of navigation, I specify GPS because that's what we all use. There's no reason to think much about any other type. Note that we are mainly interested not in the position at which a measurement was made, but in the platform velocity, which we must add to the measured velocity of the water relative to the platform to calculate what we really want to know: the velocity of the water relative to the earth.
* Attitude sensors. In addition to knowing the velocity of the platform, we have to know the orientation of the profiler so that we know whether we're measuring a north velocity or an east/west velocity. We may also need to know the tilt, more critically for lowered than for shipboard systems. So, the last component of the ADCP system is the suite of attitude sensors. For shipboard systems, that now means a gyrocompass and, whenever possible, a GPS attitude measuring system. For a lowered system, the heading normally comes from a flux gate (magnetic) compass, and the tilt comes from a bubble or pendulum-type tilt sensor.

So those are the system components. Now, let us consider some of the criteria that one might use to select a profiler, the first part of this system, for either of the two particular applications that we're interested in. Since we're trying to make vertical profiles, it is obvious that a primary criterion is vertical range. And that's equally true for the shipboard and the lowered application. Range is always good; the more, the better. We also want vertical resolution and, again, the more resolution, the better. Of course, there can be a tradeoff between range and resolution and, in fact, there are tradeoffs among many of the relevant criteria; that's where the difficulties come in.

Another good characteristic is a high sampling frequency. Sometimes the sampling frequency--the number of pings per minute--is fundamentally limited by other aspects of the system. For example, you don't want to be hearing returns from two pings in the water at the same time. You have to wait until the return from one ping dies out before you send out another ping. That's a fundamental limitation; but actual systems are often limited by their design so that they cannot achieve the theoretical maximum ping rate.

Single-ping accuracy--again, accuracy is always a good thing. We have to be careful in thinking about accuracy, however, because it can't be characterized by a single number. The accuracy that matters is not just an idealized single-ping, single-bin standard deviation. In real life accuracy, there can be random components, which are often well-characterized by a simple standard deviation, but there can also be biases. Especially as the signal-to-noise ratio goes down near the limits of profiling range, the likelihood of a bias increases. There are many potential sources of bias in the ADCP system as a whole, not just in the profiler itself.

So, we have to distinguish between short-term random errors and biases, and among different types of bias. For example, is a given bias identical in all depth bins, or is it a bias in the deeper velocities relative to the shallower velocities? It makes a big difference. For the shipboard application, depth-independent biases tend to cause the most trouble; the water velocity over the ground is the small difference between the large ship's velocity over the ground and the large ship's velocity relative to the water, so even a small percentage error in the latter can cause a large error in the estimated current. The lowered ADCP is not quite as sensitive to range-independent bias--the velocity of the water past the package is much less than the speed of a ship underway--but is extremely sensitive to any range-dependent bias. Any tendency for the velocity estimate from deeper bins to be biased relative to the estimate in shallower bins is devastating. The requirements of the lowered application for low bias in the velocity shear measurement are so stringent that I am always amazed the method works at all!

We also have to consider real world conditions. Backscattering strength, for example, is not uniform; layers of strong and weak scattering are interleaved. Strong scattering layers can introduce rather huge biases in the velocity estimates from shipboard ADCPs. The bias can come from either or both of two causes:

1) Swimming: Sometimes whole layers are moving relative to the water , and you're stuck. The best you can hope to do is detect those cases and edit them out.
2) Beam width: A scattering layer can act almost like a hard reflector such as the ocean bottom. The outgoing sound beam hits the surface at a range of angles; first the part of the beam that is more nearly vertical, then the middle of the beam, and last the more nearly horizontal part of the beam. The horizontal velocity of the ship relative to the layer therefore causes a smaller Doppler shift during the first part of the return from the layer than during the last part. This range of Doppler shifts causes the velocity to be biased low in the depth bins just above the scattering layer (or ocean bottom), and high in the bins just below the bottom, causing a characteristic "S" in the velocity profile.

This second source of bias suggests that narrow beam widths should be preferred to wider widths, other things being equal.

Another ADCP selection criterion may be interference, so the instrument can be used as much as possible in conjunction with other acoustic instruments, neither interfering with them nor being subject to interference. This tends to be more of a problem for shipboard than for lowered systems. Narrow bandwidth, both on the receive and the transmit side, helps to reduce interference. The ability to synchronize different instruments can also help.

It's desirable to have a good backscattering measurement to maximize the usefulness of ADCP profiles for biological studies. Both in shipboard and lowered ADCP data sets, we see all sorts of interesting geographical and vertical structure in the distribution of scatterers. The relation of this variability in scattering to biogeochemical processes remains mostly unstudied, as far as I know.

Another selection criterion is instrument size--smaller is better. Smaller instruments are easier to handle, easier to mount. Ease of use and maintenance is another obvious criterion. We want instruments that are as easy to use as possible. We want reliability and long lifetime. That's certainly not a trivial requirement, by any means. We want instruments that are easy to fix when they break or when something goes wrong. So you want things like fuses that are located in a sensible, easy-to-get-to spot. You don't want to have to tear the whole instrument apart if a fuse blows.

Cost--you have to remember that it includes two components. There's the initial cost, which of course has to be low so that you can afford the instrument in the first place; but then we also have to consider the annual cost, and that's related to the reliability and serviceability issues. For a shipboard system, for example, how often do you have to take the transducer out and have it rebuilt? The less often, the better.

Now, let’s consider the basic types of profiler. One way to categorize ADCPs centers on the type of acoustic pulse that is used to estimate the Doppler shift, a very small difference between the frequency of the transmitted pulse and the frequency of the sound scattered back that is proportional to the along-axis component of relative velocity between the transducer and the scatterers. Pulses can be coded or uncoded. An uncoded pulse is just a gated sinusoid: the sound is turned on, it continues with constant amplitude, then it is turned off. Such a pulse has the narrowest possible band width for any switched signal of the same duration. A coded pulse is typically generated by periodically reversing the phase of the signal, thereby broadening the bandwidth and adding structure, or information, to the pulse. It would be incorrect to say that uncoded pulses are good, coded are bad, or to say that coded pulses are good and uncoded are bad. Each has its advantages and disadvantages , and either method can be implemented well or badly for a particular application.

The commercial instruments that we’ve used the longest are so-called narrowband (NB) devices using uncoded pulses. The uncoded pulse method is simple and tends to be fairly robust and easy to set up--there is not a lot that can go wrong with it. Short-term accuracy is moderate; it is not as high as it could be with coded pulses. Narrowband instruments tend to have the best possible range; because the signal bandwidth is narrow, the receiver can use a narrow filter, which rejects more noise than a broad filter would. Hence the signal-to-noise ratio is higher at a given range than would be the case with broader bandwidth. For uncoded pulses, bandwidth is inversely proportional to pulse length.

The use of coded pulses, or broad bandwidth, in commercial ADCP systems is more recent, although the fundamental ideas were developed for radar a long time ago. Coded pulses add a problem that uncoded pulses don’t have: an inherent ambiguity. Where narrowband systems measure frequency, broadband systems measure phase, and phase can only be known to within an integral multiple of 360 degrees; a velocity corresponding to a phase difference of 190 degrees can’t be distinguished from a velocity corresponding to -170 degrees, or from one corresponding to 550 degrees. There is a tradeoff in the coded pulse systems: if you push for higher short-term accuracy, then you will introduce an ambiguity corresponding to a smaller velocity interval. Velocities greater than this interval, or less than its negative, will wrap around.

There are two ways of dealing with the problem. One is to avoid it by simply letting that ambiguity interval be larger than any range of velocities that you expect to see. That’s the simple way. The tricky way is to try to use an algorithm or sequence of different types of pings to resolve the ambiguity. By using a small ambiguity interval, you can get very high accuracy, but you’re laying yourself open to the possibility of making a big mistake, getting that ambiguity wrong. That does happen in practice.

In general, broader band width reduces range. It turns out to be difficult to empirically quantify the range loss because we rarely have the opportunity to directly compare, under identical conditions, instruments that differ only or primarily in their pulse coding or lack thereof. Broader bandwidth also inherently increases interference with other acoustic devices by occupying a larger part of the frequency spectrum.

In addition to pulse coding, there is another fundamental way in which ADCPs may now differ: the type of transducer. The basic types are monolithic, in which a single ceramic disk (or an array of smaller disks wired to act as a single disk) generates a single beam, and phased array, in which a whole array of little ceramics is wired so that alternate rows and/or columns can be driven with different phases or time delays, thereby generating two or four beams simultaneously.

For any transducer, the angular beam width varies inversely with the product of the frequency and the transducer width. At a given frequency, a larger transducer makes a narrower beam; and the lower the frequency, the larger the transducer you need for a given beam size. This is one of the factors that limits our ability to take advantage of low frequencies; the transducers get so large as to be unwieldy and expensive. The phased array is an attempt to reduce that problem by generating two or four angled beams from a single flat transducer.

As with bandwidth, I’m certainly not going to say that one style of transducer is good, the other is bad. Either can be implemented well or badly, and each has its advantages and disadvantages. The monolithic design is simplest and cheapest, and is likely to have the best beam pattern and efficiency for a given aperture (defined as the diameter of the ceramic for a monolithic transducer, or as the diameter of the projection of a phased array on a plane perpendicular to a given beam). In a phased array, any variations among the ceramic elements will degrade the beam pattern. The disadvantage of the monolithic transducer is its size and bulk, particularly at low frequencies. It is not only wider than a phased array, because of its four separate elements, but it is deeper, because each element has to be mounted at the angle of its beam. The flat panel of a phased array is a much nicer shape to mount on the bottom of a ship.

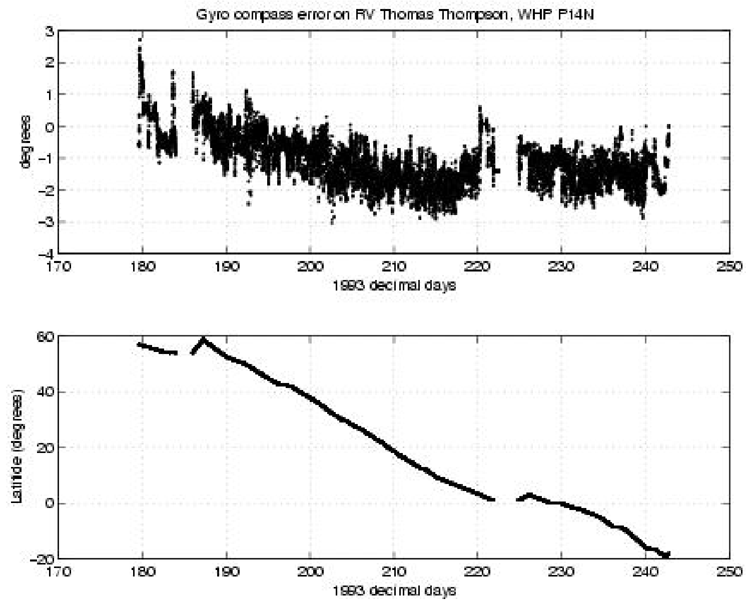
Changing now from the instrument itself to the platform: the first aspect to consider is its motion. There's often not much you can do about it and, for the most part, both shipboard and lowered systems are fairly robust against platform motion. The worst motion-related problem is the wraparound in recorded velocity when a maximum velocity magnitude in any beam is exceeded; both in shipboard and lowered systems, this is often triggered by the ship's wave-induced transient motions, which tend to be larger in magnitude than the ocean currents or the average platform speed. As noted above, broadband systems are much more susceptible to this problem than narrowband ones.

Another important element of an ADCP installation is the protection it affords the transducer, especially in shipboard systems. You would like to protect the transducer against ice, barnacles, and so on. Protection generally means putting the transducer behind an acoustic window and, unfortunately, acoustic windows in shipboard ADCP installations have had mixed success, at best. In many cases, they have not been very satisfactory; they have reduced the profiling range and increased the ringing problem. A related shipboard installation design criterion is accessibility. You want to have easy access so that if something goes wrong with the transducer, it's easy to pull it out and replace it.

The overrriding acoustic aspect of an installation is its noise level. In the case of shipboard systems, the worst routine noise source is propeller cavitation; sometimes reverberation, or ringing, is also a big problem. A quick fix when the ringing problem is mild is to increase the blanking interval. This may be necessary sometimes also in lowered systems, because of the very low backscattering signal encountered below 1000 m; even a weak reverberation in the instrument case or rosette frame may cause interference at the top of the profile if the blanking is insufficient.

An obvious installation requirement is that the acoustic beams have a clear path; apart from the difficulties with acoustic windows on shipboard systems, this is mainly a problem with lowered profilers that have to fit in an existing rosette sampler frame. Because the transducer geometry of self-contained (lowered) profilers is convex, as opposed the the typical concave geometry of shipboard transducers, lowered profilers require a large opening in the bottom (or top, if upward-looking) of the rosette frame if they are to have an unobstructed view. Shifting our attention to other aspects of ADCP systems, we find that the attitude sensor is a key to both shipboard and lowered applications. Until a few years ago, the single biggest, most common source of uncertainty in currents measured by shipboard ADCPs was uncertainty in the true heading of the transducer. That uncertainty was mainly brought about by gyrocompass uncertainty, and we really didn't know how large or small it is. It's very hard to measure the absolute orientation of a ship at sea. So until the advent of the GPS array technology for attitude measurement, we really didn't know just how big this heading problem was.

If a ship is underway at a typical speed of five meters per second , you get about eight centimeters per second error in the cross-track velocity component per degree of heading error. We are often looking for ocean signals averaged over a long distance that are much smaller than that, and this heading-related error is one of those insidious types that can show up as a long-term bias; even a fraction of a degree of systematic heading error can be devastating in a calculation of transport across a section. Errors that fluctuate rapidly and cancel out on average are much less important.




Once GPS attitude sensors became available, we found out what sorts of heading errors we had been living with. Here's an early example from the Thompson. You can see that there are short-term fluctuations of +/- 1.5 degree or so, and there are also long-term changes as the ship went south along the cruise track. Without the GPS attitude sensor we would have been able to detect and correct some of the large-scale trend, but certainly not all of it; and we would have had little idea of how well or badly we were doing. It is hard to overemphasize the importance of GPS heading measurements in modern shipboard ADCP work.

Heading errors are also a source of velocity measurement error in lowered systems, but unfortunately there is no magic bullet like the GPS heading sensor. We are at a very early stage in detecting and dealing with LADCP heading errors. When particularly large and consistent, as in a recent WHP cruise in the North Atlantic, they can be evident as a systematic bias in the difference between LADCP and SADCP velocity estimates on station, and in such cases can be at least partially corrected.

# Routine Shipboard ADCP Operation: Benefits, Problems, Methods

Eric Firing
University of Hawaii

Shipboard ADCP systems are standard equipment on most research ships, but they are used to varying degrees. I believe that on most ships, they should be operated routinely as much as possible; the benefits outweigh the costs and difficulties.

There are two main benefits of routine operation: 1) With frequent monitoring of system performance, problems can be found and fixed early, so it is more likely the system will be in top form on those cruises for which it is a primary instrument. 2) Interesting and scientifically valuable observations can be made at low marginal cost.

I will show some examples of the second benefit; the first is obvious and self-explanatory.

The first example (Figure 1) is presently no more than a nice picture; I have not done anything with it, other than show it to people, but some day it may find its way into a study. It shows currents in the Agulhas retroflection region south of South Africa. The land at the top of the figure is the very southernmost tip of South Africa. The observations were made from the Nathaniel B. Palmer at the start of the WHP S4 Indian Ocean sector line. The three transects are all just transits, not part of the official S4 line; there are three because the ship had to drop off a crew member for health reasons shortly after the start. Note the strong currents, approaching 2 m/s, and note the very sharp peaks of the current maxima. I think these sharp peaks, which I have seen in other measurements of strong eddying currents, are particularly interesting and will turn out to have dynamical significance. A numerical model would need a very fine grid to resolve them well; indeed, few observation methods other than the shipboard ADCP resolve them.

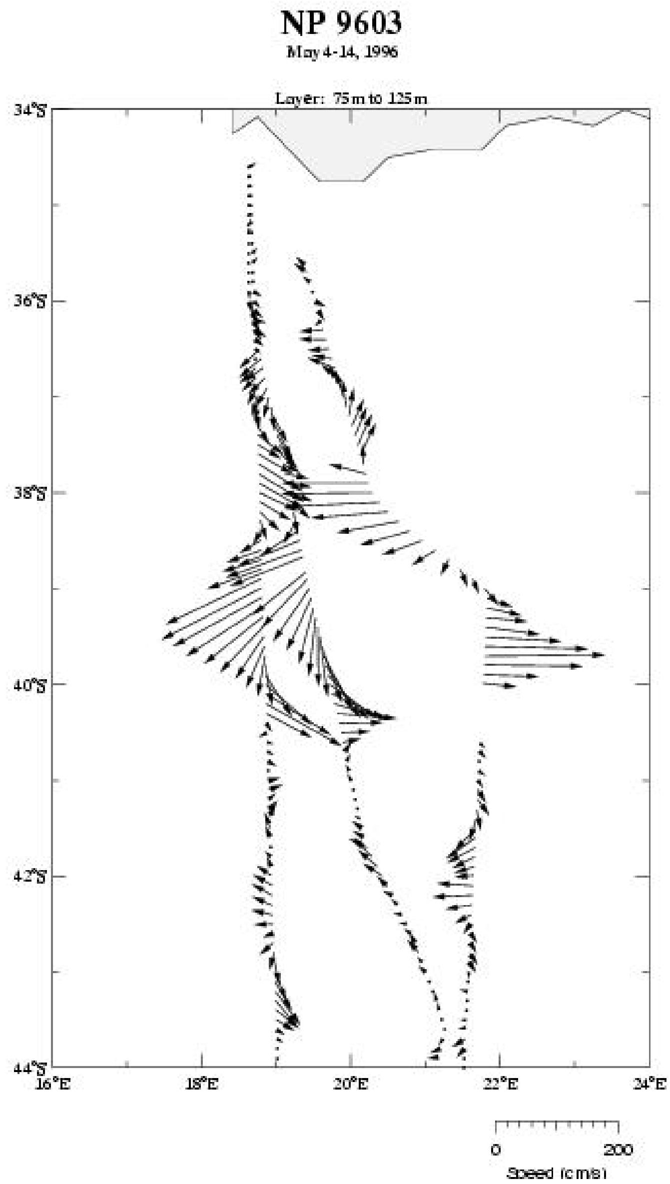



Figure 1: Currents in the Agulhas retroflection region, south of South Africa, from the WHP S4 Indian Ocean sector cruise of the Nathaniel B. Palmer. The average from 75–125 m is shown.

Now let's look at a different sort of current survey that was entirely a byproduct of a geophysical cruise (Figure 2). It was not planned to provide data for physical oceanography, but it turned out to give a unique and fascinating picture, and the material for a major chunk of a master's thesis (Mao, Ming, 1997: Analysis of three-dimensional current structures using ship-mounted ADCP. M.S. Thesis, Department of Oceanography, University of Hawaii.). Here we see a snapshot of the meandering and eddying flow through the Woodlark Basin on its way to Vitiaz Strait, after which some of the water will cross the equator. At 100 m depth (not shown), the eddies are more pronounced, and surprisingly strong for anticyclonic eddies at these low latitudes. Again, the current structure is uniquely well resolved by the shipboard ADCP observations.

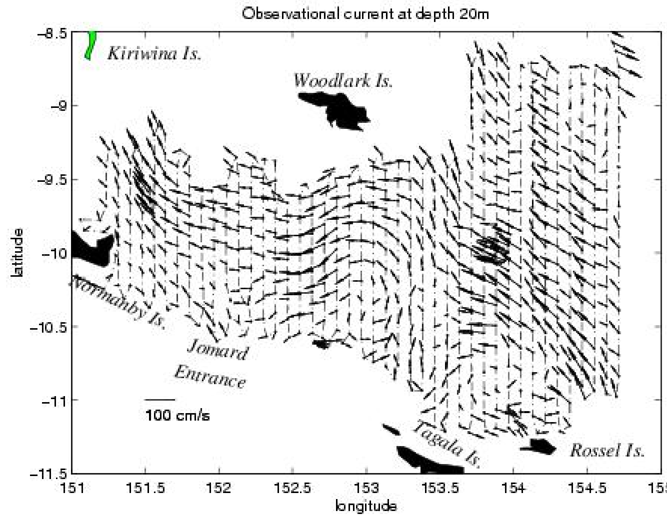



Figure 2: Currents at 20 m in the Woodlark Basin from a seafloor mapping cruise of the R/V Moana Wave, superimposed on the ship's track. The current field is extraordinarily well resolved.

Another geophysical survey resulted in a current map in Luzon Strait, near the southern tip of Taiwan (Figure 3); this dataset was also used by Ming Mao in his thesis. The picture I am showing here differs from the previous one in that it shows not the raw current measurements, but the result of a de-tiding analysis. The raw measurements (not shown) look like a mess, but it turned out that, because of the dense grid of observations, it was possible to figure out the tidal contribution as a function of position (horizontal and vertical) and time. The dataset ended up providing two products: a unique 3D map of the Kuroshio and nearby flows in this region, and a similarly unique picture of the complex combination of barotropic and baroclinic tides.

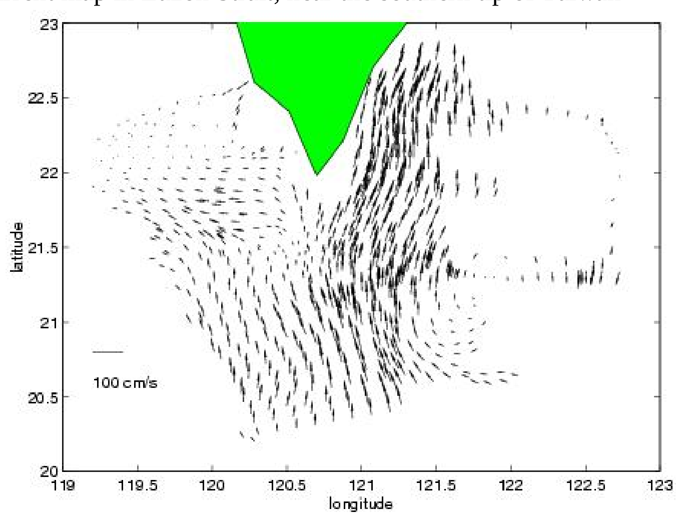



Figure 3: Filtered mean current pattern at 20 m depth in the Luzon Strait, south of Taiwan. Very energetic and complex tidal currents have been estimated and removed.

Tropical storms can generate strong transient currents, but because the storms are unpredictable, these currents have been observed more often by accident than by design. Here is an example (Figure 4): near-surface currents approaching 1 m/s in the wake of Tropical Cyclone Ofa in 1990 (Firing, E., R.-C. Lien, and P. Muller, 1997: Observations of strong inertial oscillations after the passage of Tropical Cyclone Ofa. J. Geophys. Res., 102, 3317–3322). Again, these observations were made on a geophysics cruise as a result of our policy of running the shipboard ADCP system on the R/V Moana Wave whenever possible. I have another example (Figure 5): the NOAA Ship Ka'imimoana, which also keeps its ADCP system running routinely, crossed the wake of a hurricane in the eastern Pacific in 1997, and recorded currents exceeding 1 m/s.

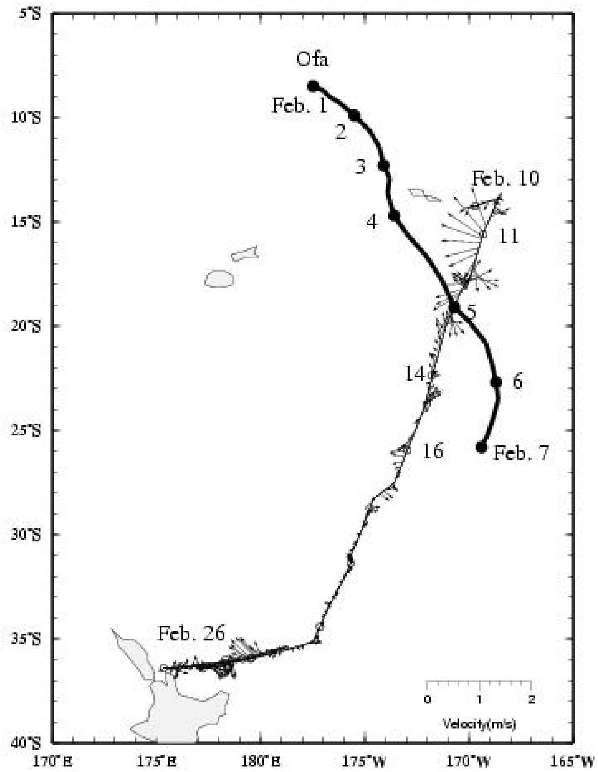



Figure 4: (ofa_fig1.eps) Currents averaged from 25-75 m as observed from the R/V Moana Wave in February 1990, shortly after Cyclone Ofa (thick line) passed.

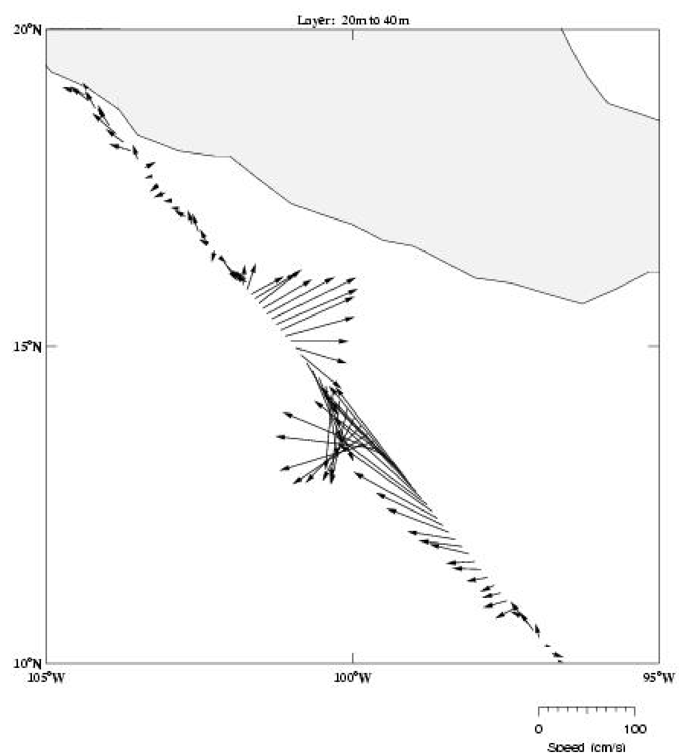



Figure 5: Currents averaged from 20-40 m observed by the NOAA Ship Ka'imimoana, showing strong near-inertial oscillations in the wake of a hurricane.

Routine current observations can be valuable individually, as in the examples above, or in aggregate, to provide a climatological picture. The shipboard ADCP in this sense is something like a modern version of the old set-and-drift method of estimating current, on which most of our large-scale picture of ocean surface currents is based. Of course, the shipboard ADCP adds information in the depth dimension while vastly improving accuracy and resolution in comparison to set-and-drift estimates.

The climatological shipboard ADCP dataset plays a central role in a recent study by Dail Rowe, Greg Johnson, and me (Rowe, G. D., E. Firing, and G. C. Johnson, 1999: The velocity, transport, and potential vorticity of the Pacific Equatorial Subsurface Countercurrents. J. Phys. Oceanogr., in press). The subject of the study is a fascinating pair of currents with typically cumbersome names: North and South Subsurface Countercurrents, also known as NSCC and SSCC, or the SCCs for short. Another name for them is Tsuchiya Jets, because they were discovered and extensively described many years ago by Mizuki Tsuchiya. The SCCs are narrow eastward currents found 2-6 degrees on either side of the equator and at depths of 100-500 m, just below the tropical thermocline. They flow most of the way across the Pacific, and they are quite consistent; look at a velocity section that crosses the equator, and you will almost always see them, regardless of season or of phase in the El Nino/La Nina cycle. Here is one example of a section that shows them, on 140W (Figure 6): they are regions of eastward flow (yellow in the top panel) centered at about 250 m, 4 degrees N and S. Although they may not look impressive in this picture, they transport quite a bit of water in their density class, so they are a significant part of the general circulation. What makes them even more interesting is that until very recently they did not show up in numerical models at all, and there has never been any satisfactory theory of why they exist.

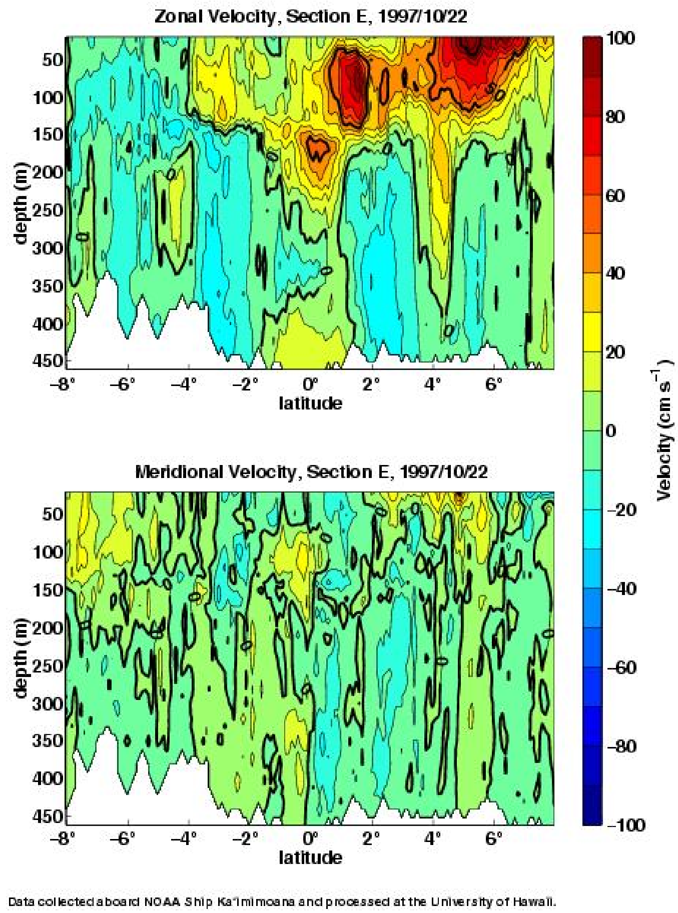



Figure 6: Contoured section of currents along 140W measured with a 150-kHz narrowband profiler on the NOAA Ship Ka'imimoana in October 1997. The Tsuchiya jets are the regions of eastward flow (top panel) centered at about 250 m depth, 4 degrees on either side of the equator.

Dail Rowe gathered all the shipboard ADCP sections crossing the equator from the NODC/UH Joint Archive for Shipboard ADCP (http://ilikai.soest.hawaii.edu/sadcp), and started looking in detail at the three-dimensional velocity structure of the SCCs and the neighboring flow. The sections came from 44 cruises, on most of which the ADCP was run routinely rather than as a primary scientific tool. They included 93 crossings of the NSCC and 77 of the SSCC. A plot of current core positions gives an idea of the data coverage, as well as a picture of how the cores rise and diverge from the equator as they flow east (Figure 7). The point I would like to emphasize is that this extensive data coverage, with high-resolution velocity measurements, could never have been obtained deliberately; we could not have gotten funded to make these cruises for the purpose of these ADCP measurements. But the dataset has been very valuable for the study of the SCCs; it is still growing, and as it grows we will learn more and more about them, and about other aspects of the equatorial velocity field. The effort to acquire and process the ADCP data from all these cruises, regardless of the main purpose of the cruise, is paying off scientifically.

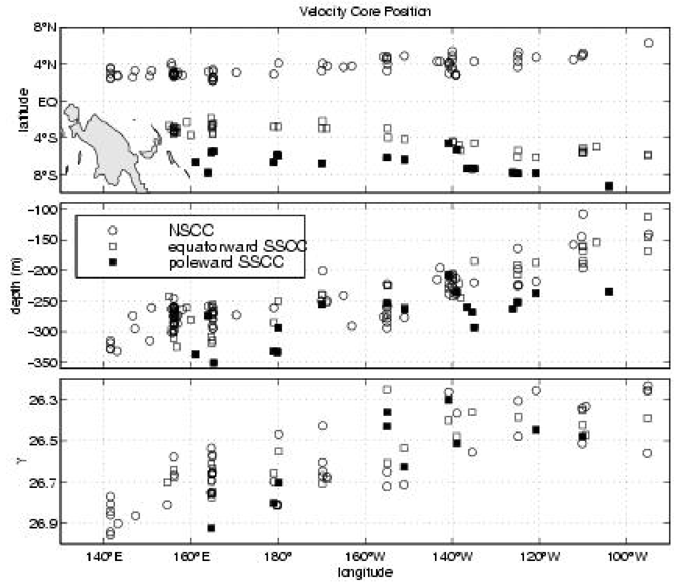



Figure 7: Tsuchiya jet velocity core positions from all available ADCP sections. The top panel shows the core latitudes, the middle panel shows the depths, and the bottom panel shows the densities.

The SCC study brings us to the question of what are the most important characteristics in a shipboard ADCP system for routine use. Note that the core depths of the SCCs in the western Pacific are generally below 250 m, and the bottoms of the currents are much deeper than that--so the depth range of the instrument can be critical. The differencebetween broadband and narrowband instruments is noticeable. For example, one may compare two section on 140W made by the Ka'imimoana, the first in September 1996 with a BB-150 using mode 7 for maximum range (Figure 8), and the second about a year later with a NB-150 (Figure 6), both made by RD Instruments. The range is generally 50-100 m better with the narrowband instrument. Although it is dangerous to make such comparisons based on non-simultaneous measurements, since range is strongly affected by sea conditions, we have data from three Ka'imimoana cruises with the BB-150, and from many with the NB-150; the particular comparison shown here is reasonably typical. Data from all cruises can be viewed at http://currents.soest.hawaii.edu/kaimi/. It should be noted that the effective range after data logging and processing is not the same as the raw range of a single ping. The BB-150 effective range is reduced in our plots by requiring 4-beam solutions and by using a higher percent-good threshold than we use for the narrowband instrument. These editing choices are made to minimize contamination by the erroneous ambiguity resolution that we have observed with mode 7, and to compensate for the lack of a reference-layer-based averaging mode in the Transect data acquisition program used for the broadband.

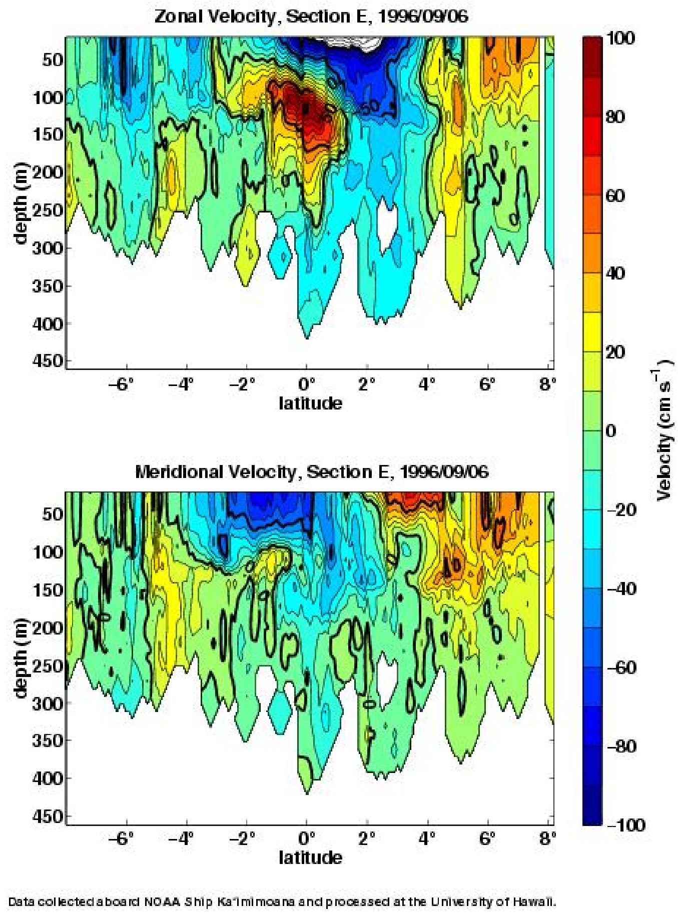



Figure 8: Currents along 140W measured with a 150-kHz Broadband profiler on the NOAA Ship Ka'imimoana in September 1996. Compare the depth range to that in Figure 6.

Now I would like to briefly note some other desirable characteristics of a shipboard ADCP system for routine use; this is not intended to be an exhaustive list.

* It should be simple to set up and to monitor. A glance at the screen of the main data acquisition system display should be adequate to determine whether the system is functional, or whether there may be a problem with any of its main components.

* There should be little need to change settings based on ambient conditions. Ideally,any instrument configuration changes should be automated. For example, it would be good if the system could use the amplitude profiles from the water track pings to determine whether the bottom is in range and bottom tracking should be turned on, if a separate bottom tracking ping really is required.

* The system should not interfere with any other instrument systems. For example, it may be necessary to synchronize the ADCP with other sonars so that either their pings are interleaved at adequate intervals, or they ping simultaneously.

The instrument system is in some ways the simplest and most tractable problem of routine shipboard ADCP operation. After all, it is just a matter of engineering and technology, and technology generally improves with time--although commercial shipboard ADCPs have been an exception during the last decade. Other problems of routine operation may be categorized loosely as diplomatic, procedural, and financial.

The diplomatic problem results from a huge flaw in the United Nations Convention on the Law of the Sea (UNCLOS), which gives each country jurisdiction over Marine Science Research (MSR) within its Exclusive Economic Zone (EEZ). Although the US has not ratified the UNCLOS, and does not claim this jurisdiction, official US policy is to comply with the research clearance requirements of the countries that do claim jurisdiction. Each country seems to have established a bureaucracy to handle these clearance requests with as much fuss, delay, and annoyance as possible, regardless of how innocuous a particular type of measurement may be. But not all measurements at sea are covered--for example, routine meteorological observations and set-and-drift surface current estimates can be made and archived without clearance. Instrument testing and calibration do not require clearance. The defining characteristic of MSR seems to be the intent to use the result for scientific research; if routine met obs are used in an operational weather forecasting system, they don't require clearance, even though they may also be used eventually in a research mode as part of a climatological data set. But if the primary purpose of running the shipboard ADCP is to provide information for scientific study, then clearance is required. I think this is a grey area, and I have argued that routine shipboard ADCP observations should be treated as simply a technological update of the old set-and-drift current estimates, but so far my opinion has not prevailed. In many cases, therefore, fully routine operation of the shipboard ADCP (with logging turned on) may require additional effort to obtain foreign clearance beyond that which would be required for the primary activities of a given cruise.

What I mean by the procedural aspect of routine ADCP operation is, Who is responsible for carrying it out? And how big a burden is it? The answer to the "Who"" question is generally the shipboard technical support groups--and they certainly have many tasks to juggle as it is, so the question about the size of the burden is important. Ideally, the burden should be small: turn the system on at the start of the cruise, look at it occasionally to make sure everything is working, turn it off at the end of the cruise, copy the data to a transfer medium, and transfer it to someone who will process, archive, and distribute it. Whether these tasks are as easy as I would like to make them sound depends largely on the characteristics of the entire ADCP system. All present systems benefit from the additional tasks of turning bottom tracking on in shallow water and off at the start of long periods in deep water. When a typical narrowband system, with the old DAS 2.48 supplemented by the ue4 user exit program, is running normally, it is capable of running for an entire cruise with no adjustment other than turning bottom tracking on and off; it can be monitored with an occasional glance at the screen, and/or via a speed log data stream into the ship's main navigation system, and/or via transmission of all data over a serial line to another computer where it can be logged independently; and the data logging rate is typically about 0.5 Mbyte per day, so the data transfer at the end of the cruise need not be onerous. Although such a system is far from ideal, it can be used routinely, and has been on several ships. The larger burden is fixing whatever problems arise, such as transducer failure; but this is a cost of having the system installed and used at all, and is not increased by routine as opposed to occasional use.

To whom should the routinely acquired data--that which is not claimed by theparticipants of a particular cruise--be given? This raises the question of organizing and financing the routine processing, archiving, and dissemination of shipboard ADCP data. The US NODC now archives and distributes such data (http://ilikai.soest.hawaii.edu/sadcp), but understandably does not have the resources or the mandate to process everything that might come in. I have at times had explicit funding for some such processing, and some can be done under the umbrella of related projects. In general, however, the funding problem remains open; the oceanography funding system is geared primarily towards focussed short-term projects, not toward routine data collection. To minimize the funding problem, we need to minimize the cost/benefit ratio. The formula is simple: a good instrument system plus good data acquisition procedures yields a clean data set; a clean data set plus good processing software yields the best possible product at the lowest possible cost.

# Lowered Acoustic Doppler Current Profiler: From an Experimental Instrument to a Standard Hydrographic Tool

By Martin Visbeck
LDEO Columbia University, NY

During the last decade lowered acoustic Doppler current profiler (LADCPs) have matured from an experimental instrument to an almost off-the-shelf standard tool for deep hydrographic programs such as WOCE (Firing, 1998). The first LADCP profile was taken in 1989 at a site near Hawaii by Firing and Gordon (1990). The way the LADCP system works is that it relies on the fact that short current profiles can be 'pieced together' to obtain a full ocean depth velocity profile (Fig. 1). The initial results were not too encouraging since systematic errors of the order of 10 cm/s were expected, much too large to be used for quantitative purposes such as top to bottom transport calculations. However, proof of concept was given and some first steps towards a useful processing algorithms were realized. A year later in 1990, Fischer and Visbeck (1993) used a similar system during a cruise in the equatorial Atlantic. They had the advantage of simultaneous LADCP and Pegasus velocity profiles. The Pegasus is an acoustically tracked free-falling float that can be used to accurately measure top to bottom ocean transports; however, it requires bottom mounted and navigated acoustic beacons. Consequently, each station takes several hours of extra ship time plus the expense of a pair of acoustic beacons to obtain one Pegasus velocity profile. In comparison, the LADCP is much more attractive: no extra ship time is required and the running costs per station are minimal. However, when care was taken during the data processing of the LADCP system both velocity estimates agreed. In particular the close comparison allowed us to develop a method to compute the barotropic mean flow given accurate GPS ship navigation.

During those first years self-contained ADCPs, typically used for moored applications, were mounted on the CTD/rosette frame. Most of the early designs replaced two bottles in favor of the large ADCPS. In particular the narrow band 150 kHz full ocean depth system was very difficult to mount and handle due to its weight of app. 140 pounds.

The next generation of broad band technology ADCPs promised much increased single ping accuracy, however, the range of useful data was reduced despite an effort to boost the power level of the transducers. The instruments themselves were more compact and easier to handle, however, the power requirements increased by almost an order of magnitude. Consequently a rechargeable battery pack hat to be added to the system in order to run an intense hydrographic program without unmounting and opening the ADCP every few days. Better rosette designs emerged that were able to accommodate the new ADCPs in the center of the package. Such configurations were used throughout the WOCE and provided a wealth of useful top to bottom velocity profiles.

The latest generation of ADCPs is much smaller instruments with a frequency of either 300 kHz. The new instruments have no internal batteries and hence are extremely compact with a dimension of only 9x8 inches and a weight of 30 pounds. Moreover, the price dropped dramatically and one can now purchase two transducer heads for the price of one of the traditional 150 kHz BB systems. In order to make up for the reduced range of the higher frequency systems we have recently started to mount two heads on one CTD frame, one looking upward and one looking downward. This LADCP2 system has several other advantages (Visbeck, 1998): no complete loss of data when the CTD is close to the bottom, view of sea surface for an improved initial depth estimate and some built in redundancy. While mounting an upward looking system is not always easy to do, the small size and much reduced power requirements make the new LADCP system very adaptable to small CTD frames and towed vessels. Today there are two commercial vendors who both have promised to sell complete LADCP2 systems in the near future.

Over the years the community has learned how to process the data and we are beginning to understand how instrumental and system errors affecting the final velocity profiles. We have discovered regions in the world's ocean with dramatically reduced instrument range due to low abundance of acoustic scatters. One of the surprises on the way was what initially seemed to be the hardest problem, i.e. to obtain the vertical mean velocity, turned out to be a very robust estimate for reasonably deep (long) CTD stations. We have learned how to use the 'water' bins for acceptable bottom tracking (Visbeck, 1998). We still have not fully understood why sometimes the up and down cast velocity profiles differ dramatically, which ADCP beam angles are most versatile and what the tradeoff between accuracy and range is.

We envision that in the very near future the LADCP system will be available on most hydrographic vessels. In conjunction with an easy to use processing software this will allow even the inexperienced user to obtain full ocean depth velocity profiles at every CTD station.

PRODUCTS from the LADCP system:
- full ocean depth relative velocity profile
- with GPS full ocean depth absolute velocity profile
- accurate absolute velocity profiles within 300m of the ocean floor
- profiles of acoustic back scatter
- pitch, roll and heading of CTD/rosette
- absolute position in X, Y and Z of CTD/rosette
  measure distance of CTD/rosette off the bottom

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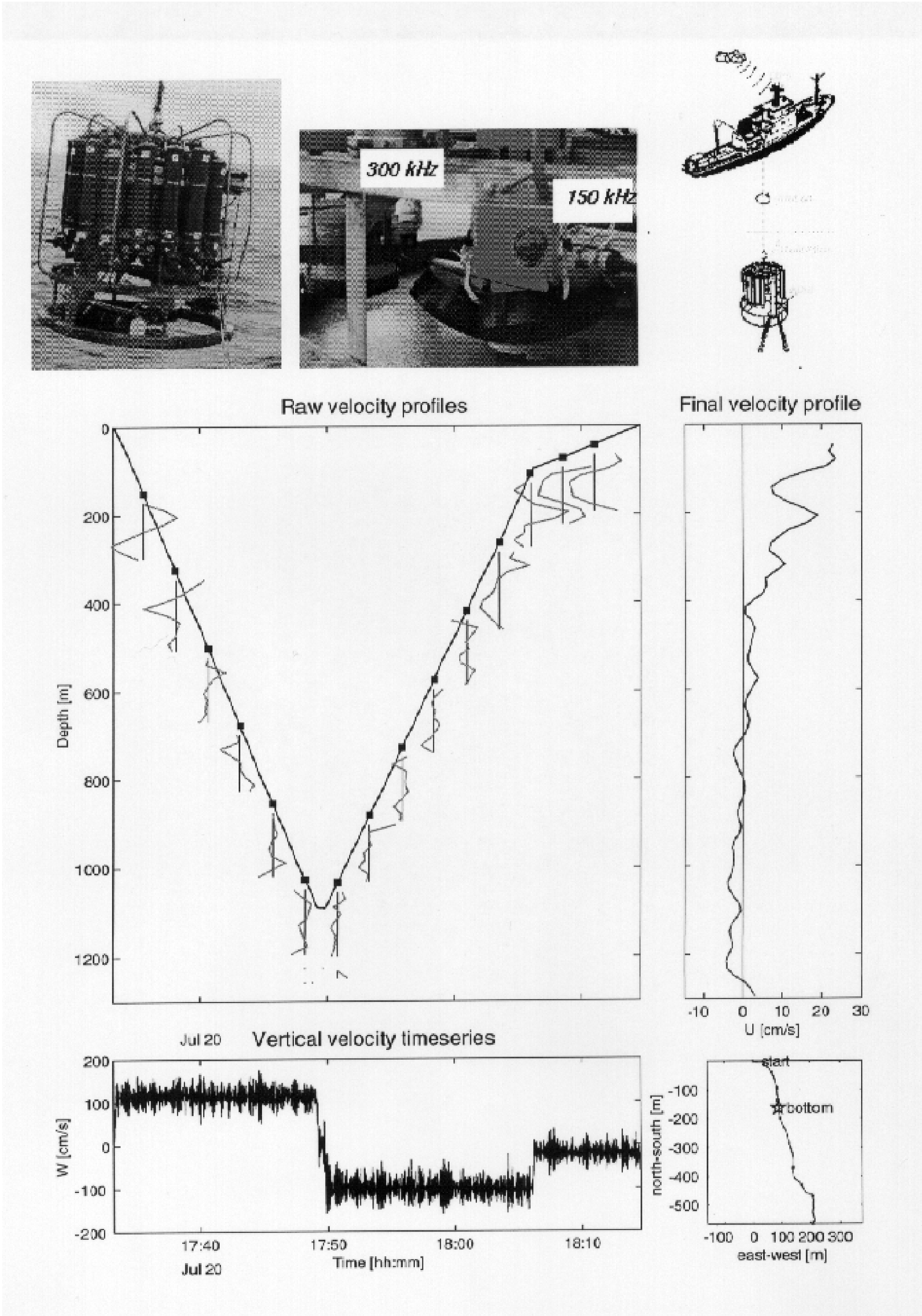
300 kHz
150 kHz
Raw velocity profiles
Final velocity profile
Depth [m]
U [cm/s]
Jul 20
Vertical velocity timeseries
W [cm/s]
Time [hh:mm]
Jul 20
start
bottom
north-south [m]
east-west [m]

# ADCP DISCUSSION SESSION I

PARTICIPANT: Yes. What do you do about -- do you stop when you encounter problems, or do you fix on the run, or --

MR. VISBECK: No. We can stop -- the LADCP doesn't require you to move. You can wait a while and trip your bottle and then continue to hydrocast.

PARTICIPANT: That doesn't interfere with the --

MR. VISBECK: It doesn't interfere with it at all. No. That's no problem for us. I was looking for a figure where you can see it, but we usually -- so this cast, for example, whoops! -- here it is. You go down -- you go down, here's the bottom, and then you stop one bottle, two -- here your bottle stops. No. It's not a big problem for us.

The -- if you were to just stop at the bottom and not at the top, then what you're losing a bit is the cancellation effect I was talking about earlier. The sheer profile has some arrows to it and, in order to complete a very accurate top-to-bottom velocity estimate, you want those arrows to cancel.

And, formally, you can show -- if you spend the same amount of time in the lower part of the water column as you do in the upper part, this cancellation's pretty good. If you happen to spend a lot more time at the bottom as you do at the surface, that doesn't help you then all that much anymore, but that's a secondary effect. Primarily, there's no constraints on what you do with your CTD as you go.

There's one -- there actually is one. When you are close to the bottom, we don't like to spend much time down there, the reason being is, you know, we don't see much of the ocean. With the double system, we have more success. We actually see -- the upper-looking gets some data but, in general, we don't like to spend 20 minutes very close to the bottom.

So in an operational point of view, I encourage my guys, Well, tilt your bottom bottle quick and then come up and wait there.

PARTICIPANT: We don't like to spend a lot of time on the boat.

MR. VISBECK: Well, I know that, but scientists -- I know. I know on the other side of -- there's a lot of interesting physics going on close to the bottom, and people like to measure oxygen precisely, and one thermometer is the adjustment.

PARTICIPANT: Have you considered using a USPO transponder or the CTD package to fix its position?

MR. VISBECK: Yeah. We considered that, and I think Eric did much more research on that than I did. It turns out that the accuracy you're getting out of these systems out of, you know, three-kilometer depths, is not sufficient to what we want -- what we need to know, although one could use it.

We -- we looked into it a little bit. The off-the-craft systems are just not accurate enough to do the job, what needs to be done here. You need to know -- in order to get the velocities right, and you want to maybe get it right over ten minutes, you need to have an accuracy of a few meters, which they really don't deliver. But, yes, we thought about that.

PARTICIPANT: Our sample -- (indiscernible). I was just going to tell you that. Never mind.

MR. VISBECK: All right.

PARTICIPANT: I'm not familiar with self-contained ADCPs.

MR. VISBECK: All right.

PARTICIPANT: Is the flux gate compass actually built into the --

MR. VISBECK: Yes. The flux gate compass is inside of the unit.

PARTICIPANT: And is there any sort of external input to it that you prefer, an external instrument?

MR. VISBECK: You mean, could we use an external compass?

PARTICIPANT: Could you use, for instance, one of these gyro-based references?

MR. VISBECK: Yes. Yes, and I've thought about that. And if you have some experience, I would like to talk to you afterwards. I'm trying --

PARTICIPANT: But it's something which we're able to get out for another project and, --

MR. VISBECK: Yes.

PARTICIPANT: -- you know, there are these nice self-contained things, which are very small.

MR. VISBECK: Yes. I'm looking -- I'm trying to find somebody who actually owns a gyro that I could put in a pressure case, because I do want to do at least a couple of casts to see how bad the problem really is. Right now I know there's a deviation problem, some of which has to do that there are magnetic parts on a CTD frame, you know, as this pinger is and there's all sorts of other things there. Not all CTDs are non-magnetic, so we have a problem right there. And I think if there was a system out there for -- let's put a number out here, let's say 20K -- that you had a self-contained gyro, we could use it; no problem. We don't need to use the internal flux gate compass.

So if you had a separate time series of heading of the CTD package, it would be just fine.

PARTICIPANT: Well, the system I -- or the form -- reference system I looked at recently was about $5,000, though, obviously, that's not in a pressure case.

MR. VISBECK: Right. And then there's a question of how much current it draws. Some of these are pretty power-hungry. But I think -- I'd like to look into this because it happens to be one of the problems.

Another problem that came up, some folks I work with are actually interested in lowered ADCP profiles right on top of the Salzman-Eddy pole (ph). Well, so far I told them, Well, good luck. I mean, I can't help you. So there's a desire for many reasons to get a better estimate, and a self-contained gyro would be great for this application.

MR. FINDLEY: Yeah. Rich Findley from the University of Miami. I'm currently the chairman of the UNOLS Wire Committee. We're looking at a new wire for the CTD wire. We're looking at possibly a single -- changing from the three-conductor, which is really a leftover from trying to operate the rosettes and the CTD simultaneously, and we're looking at a single-conductor cable and fiber optics for the data transmission, so that would allow probably a lot more current through that single-conductor if you didn't have to worry about data transmission.

So I guess that would go very well with data communications down to the -- mix everything down there and --

MR. VISBECK: Yeah. I think this -- the systems are certainly set up for this. They -- even the off-the-shelf systems you buy have -- spit all the data out a serial port if you'd like to.

MR. FINDLEY: Sure.

MR. VISBECK: So even if you had a -- have a modern CTD that has a modem to it, you could actually do that readily but, in particular, if you had a fiber optic table, you could probably transmit all the data off the wire.

MR. FINDLEY: Sure. That's what I was getting at. If we could do that and combine that with the CTD and the whole --

MR. VISBECK: Right. And now if -- and, also, if you can supply a significant amount of currents down -- and the new system is actually not that bad anymore -- we -- I'm running my double system on an alkaline battery pack and I can get two and a half days' continuous operation out of it.

MR. FINDLEY: I mean, like how many watts is it drawing, or amps? What volts?

MR. VISBECK: Well -- I knew those numbers. I have to look them up again. I can give them later to you. I was using a 400-amp hour. That's a package. And I can do the math for you.

MR. FINDLEY: Probably running an amp --

MR. VISBECK: Right.

MR. FINDLEY: -- at 24 volts or something.

MR. VISBECK: Something like that.

MR. FINDLEY: It shouldn't be a problem to step down.

MR. VISBECK: Yeah. But right now it's --
MR. FINDLEY: The problem's always when you've got the signal coupled to it, you've got all these D-coupling transformers --

MR. VISBECK: Exactly.

MR. FINDLEY: -- that can't take the current through them --

MR. VISBECK: Right.

MR. FINDLEY: -- and pass the signal at the same time, so --

MR. VISBECK: Right. I think this could be easily done nowadays. So it would make this even easier because it's one piece of equipment less to worry about; i.e., battery pack. And then you're really closer just setting a sensor there.

But the self-contained operation so far has been pretty workable. We've done a lot of data and, typically, anywhere between ten and 25 minutes depending on how deep the cast is. So it's not too bad, but it's certainly nice if you have it on the real time.

MR. FINDLEY: Well, I remember we were doing tow op- -- we were actually towing a lower ADCP, fill gallons -- it's got to be ten, 12 years ago.

MR. VISBECK: Right.

MR. FINDLEY: And we get it down and we were profiling -- we kept it bottom track all the time, just doing spillovers over shelves.

MR. VISBECK: Right. Right. Yeah. Well, then --

MR. FINDLEY: That would have been nice if we -- it was always try to configure the thing, get it down there, and say, Hmm, I guess we've got to adjust some parameters, bring it up, adjust some more things, and send it down. It would have been much easier to deal with it in real time.

MR. VISBECK: Exactly. So certainly this would be the way to go. The reason why I haven't -- it's -- what I found out -- and this -- you know, I've been working with probably about now seven different ships, and they're all so different in the whole setup. I'm almost pretty glad I come with my self-contained system here. I just say, you know, Tell me where I can put it on your rosette and then I'm okay. You know, I don't have to bother about all the wiring.

But, on the other hand, for UNOLS' perspective, if you have a certain -- setting up certain systems on the UNOLS fleet, this would probably be the way to go. Then you'd just interface it once and forever.

MR. FINDLEY: Yeah.

MR. VISBECK: But for university setting, where you hop ships all the time and you're on foreign boats and Russian ships and whatnot, I mean, sometimes it's actually kind of nice to have a self-contained unit. But I hear you. I mean, this would be a nice way forward.

PARTICIPANT: I have a question for Eric. The notion of recording data, we have several ADCPs that the P.I. is often not interested in. Some of them are narrow band, yield narrow band. The ping data piles are very small. We have no trouble recording and archiving that data. The broad bands, we have not ever gotten a satisfactory answer about how do you want to report this data, so we just report raw data, which is typically 30, 40 megabytes a day, and throw it away because we don't know what to do with it.

Do you have any suggestions on how we might record broad band data in a reasonable manner?

MR. FIRING: Well, the best hope for that might be in Helen's talk -- I don't know -- because the usual Transect software is -- well,

PARTICIPANT: We know that, Eric. Everybody knows it. It's very bad. And there is -- there simply is no equivalent good way to set it up, especially with an Ashtech data stream included that allows you to record the compact sorts of data files that you have.

MR. FIRING: So, no, I don't have any solution to that, short of a complete replacement for Transect, and presumably, Helen, for example --

MS. BEGGS: I have a question about that. Has anyone talked to RDI and said, Look, it's really important to us. Can you fix the bugs in your system?

MR. FIRING: RDI has certainly known for many years that I had detested Transect, and I've been completely unable to understand why they haven't been able to do any better in all that time, why it was a step backwards from their previous task, things that they knew how to do correctly in the previous one and then forgot in Transect.

PARTICIPANT: Let me make a comment on that. I left RDI a few months ago, and one of the reasons that -- let's say one of the sources of conflict was software. You know, I've taught over software for a decade. Transect was written to measure discharge in rivers, and it was given to people to run broad band systems because they didn't have anything else. And then it started to try and do both, and it didn't do either one of them very well.

So, you know, that's why we -- that's why Eric doesn't like it. I mean, it wasn't written to fit the software programs of an oceanographer. And why does -- why do the owners of RDI not want to invest in software to run their broad band (indiscernible) systems? You know --

MR. VISBECK: Yes?

MR. AMOS: Tony Amos, University of Texas. I have a question for Eric. In running this continuous data, have you ever run into a problem of getting permission from countries when you’re running in their territorial waters of whether you can use that information or not?

MR. FIRING: That -- well, that is a problem and, in fact, I have a transparency about that, and I talked yesterday morning to Tom Cock at the State Department about exactly that. It’s -- the problem is a potential conflict between common sense and law, bureaucrats, letters, and so on.

The common-sense position would be that the collecting -- the routine collecting and scientific use of shipboard ADCP information within EEZ poses absolutely no threat whatsoever to any country’s valid interests and, therefore, there should be no objection to it.

But the reality seems to be that the law of the sea has given jurisdiction for an undefined something called marine scientific research to the countries -- to the coastal states for that work in their EEZs. And so the way -- now, one of the interesting things about that, of course, is that the United States has not ratified the law of the city, and the United States does not claim this jurisdiction for themselves.
So any foreign ship is entitled to go into U.S. EEZ waters and collect shipboard ADCP or just about anything else, except maybe fish -- maybe even fish. I don’t know -- without requesting clearance.

But the State Department seems to be taking the relatively conservative view that we need to get clearance from countries -- from all the countries in whose waters we work and so, rather than try to push the interpretation, they would rather say, Well, if there’s any intent whatsoever that the observations be used for science, then please try to get clearance first.

If the observations are for calibration -- so, for example, if you need bottom tracking over a shallow section in order to determine the orientation of the transducer, that would not be covered under the law of the sea because that’s not research; that’s just checking out your instruments.

But taking the most conservative viewpoint, if the information is something that you would later want to use in the compilation of statistics for currents in an area, then that clearance should be obtained in advance.

So, yeah, it’s a problem. I don’t have a solution.

MR. VISBECK: And sometimes it’s tricky because it’s actually an acoustic device.

MR. FIRING: Yes.

MR. VISBECK: And some countries are concerned about, This looks like an echo sounder or even a sediment penetration device, and they really are concerned about these.

MR. FIRING: There is one way you can get around it. If you make an expendable device, if you -- you know, say, floats and drifters and things can -- they can go anywhere, send the stuff back up by satellite, and that doesn’t seem to be covered.

So, you know, I guess we’ll just have to make expendable research ships and send them off.

PARTICIPANT: Tough luck.

(Laughter.)

PARTICIPANT: A lot of these same countries may well have required that the ships have Doppler velocity logs. Doppler velocity -- they don’t sound any different than profilers.

MR. FIRING: In talking with -- yeah. In talking

-- what I was hoping to be able to get Tom Cock to say -- I didn't succeed -- was that if -- say, if the ADCP is used as a speed log, which on the one wave, it always has been. It has been the ship speed log -- that we can consider it as a navigational device, that the measurement that we're getting is simply an update of the old set-and-drift observations, and that -- or set-and-drift navigation, a simple speed log that's standard, routine is not a problem, but I couldn't get him to say that.

PARTICIPANT: Well, surely then when you publish, that's when they will cry foul, the people that you --

MR. FIRING: Well, I think, in practice, most of the time it's not actually going to be a problem because I don't think that the lawyers and the bureaucrats in the countries concerned are very busy, yet anyway, poring through the literature for infractions. I think they're too busy just processing the applications six months in advance and taking six months to do it.

PARTICIPANT: Given that you admittedly hate the Transect software, --

MR. FIRING: Yes.

PARTICIPANT: -- is there still a best set of settings that you could provide us? I mean, you know, other than saying, "I hate it," could you --

MR. FIRING: Well, okay.

PARTICIPANT: I mean, I think we talked about this some time ago, --

MR. FIRING: Yeah.

PARTICIPANT: -- about providing a -- maybe a little short paper that could be -- or instruction manual on all the UNOLS ships on how to set up for routine data collection when there is no scientist --

MR. FIRING: Right.

PARTICIPANT: -- that's saying, "I want it set up this way" and maybe even provide the --

MR. FIRING: Yeah. Okay. For the -- certainly for the narrow band, the answer is usually, Yes, use UE-4. And, yes, any time I can give an example (indiscernible) as I've done many times on many ships.

For Transect, I have used that -- I have worked with that from the Kaimi Moana. I've seen some from other places. And it's -- you know, I can come up with something, but it's really hard. I can't come up with anything decent that includes Ashtech information and is compact because the problem is that, to use the Ashtech information correctly, you need to, as nearly as possible, on a ping-by-ping basis, be comparing the Ashtech heading to the gyrocompass heading.

And so, well, to really do that with Transect, you have to record every ping, to do that ping-by-ping comparison with Transect.

So -- okay. You back off from that a little bit. So maybe you average -- over 30-second intervals, you get average heading over that period -- you can credit an average Ashtech -- if the Ashtech data coverage is reasonably good, then those averages will compare fairly well and you're not in such bad shape.

PARTICIPANT: But that's just worrying about the amount of data. I mean, I'm not concerned about the volume.

MR. FIRING: Yeah. If you're not concerned about the amount of data, then the issues are the other aspects of the setup. And that has been an area of great confusion on RDI's part and, to some extent, correspondingly therefore, on everyone else's part, including mine.

MS. BEGGS: Yes.

MR. FIRING: And so what the upshot of that seems to be coming down to is that if you want routine, reasonably robust operations under a wide range of conditions, the -- what you’re left with is mode one, band width zero; in other words, broadest band width, mode one, and a WB of 600 or something like that, and then, you know, probably something like the generic eight-meter bings and whatnot.

Because everything fancier that tries to push for a little better performance seems to go haywire sooner or later.

PARTICIPANT: I mean, basically, you talk about monitoring, but there’s -- really nobody’s going to be paying that much attention to it, so it needs to be as generic as possible.

MR. FIRING: Yeah.

PARTICIPANT: I mean, you can get somebody to watch and make sure that you haven’t run out of storage space, but --

MR. FIRING: Yeah. Right. But I think that on a routine basis, those voluminous data sets are rarely actually going to be used because they are -- they’re just more expensive to handle, much more -- they’re more difficult to handle.

PARTICIPANT: I mean, I wouldn’t mind telling -- we wouldn’t want to do anything on them, but we could send them to you. You don’t want them either; right?

MR. FIRING: I don’t want ’em. No. I don’t have the resources to deal with that, especially, I mean, since I have essentially now no funding officially for working with -- for acquiring processing these data sets. I still try to get some, but I have to be fairly selective and try to get the ones that look to me the most interesting for a given amount of effort that it will take to work with them, and so that immediately rules out broad band data sets for me at the moment, because of lack of funding.

PARTICIPANT: How about phase -- I mean, the phase (indiscernible). Is the software coming out of RDI for that going to be --

MR. FIRING: Well, I don’t know what it’s going to be because, for many years, about once a year, I talk to somebody at RDI and they say, "Oh, yeah. In six to nine months, we’ll have a new data acquisition system. It will be modular as code. You can put in your own pieces. It will do this, that, and the other thing," as I’ve always requested, and I’ve yet to see anything emerge from that pipeline.

PARTICIPANT: And that’s supposed to drop back actually and handle the old -- handle the broad bands, too, I thought.

MR. FIRING: It always has been supposed to be probably. I don’t know. But, again, I -- there’s no point in my trying to comment on --

PARTICIPANT: Vaporware.

MR. FIRING: -- that vaporware, right, which it’s always been. Some day it may not be and, at that time, you know, we can talk about it.

PARTICIPANT: Okay.

MR. FIRING: But no point until then. Helen?

PARTICIPANT: Go ahead. Go ahead. Sorry.

MS. BEGGS: Yes. Quite a lot of these I’ll be dealing with in my talk, so I’d like to come back to the discussion on settings for broad band eddies and things after --

MR. FIRING: Right.

MS. BEGGS: This is -- but I’ve got a question for Eric. I don’t understand why you need to compare the gyro compass -- the gyro heading to the 3DF heading in real time. We don’t. And I just take the 3DF heading and I use that. What do you mean by

MR. FIRING: The reason that I never use the 3DF headings in real time as the heading for vector averaging is that once you vector-averaged, you can’t go back.

MS. BEGGS: Yes.

MR. FIRING: Okay? So it’s crucial to have something reliable.

MS. BEGGS: Right. Yes. Yes.

MR. FIRING: And I have seen a wide variety of behavior in 3DF systems, from very unreliable, all kinds of problems, to very reliable. The very best systems I’ve ever seen have still never been a hundred percent. They still have had their periods of dropouts.

MS. BEGGS: Yes.

MR. FIRING: Or maybe occasionally actually went haywire in the readings.

MS. BEGGS: Yes. Yes.

MR. FIRING: And so if you were trying to use it in real time or near real time, you would -- you could do it with suitable -- I mean, I could write software that would do that.

MS. BEGGS: Yeah.

MR. FIRING: But what it would have to do is collect an ensemble and then not only do some editing of the velocities, which past other commercial software has not done very well, but also do some editing and checking with the headings, and only use the headings that pass some tests.

MS. BEGGS: We --

MR. FIRING: So if you do that, then that’s --

MS. BEGGS: Yes. Well, I chose to go down that route.

MR. FIRING: Uh-huh.

MS. BEGGS: However, I also collect the raw data just in case, so I can get the gyro heading at the same time as the Ashtech heading --

MR. FIRING: Right.

MS. BEGGS: -- so that later on, if there’s a problem, I can do something about it. But because we’ve only just started to do this over the last 12 months, you know, I haven’t seen the problems except on the Southern Surveyor, about twice a cruise suddenly some really stupid data was being set by the 3DF, and we’ll actually take account and tell us why that is. And the other way to stop it is to power it down and power it back up; then it seems to be okay.

MR. FIRING:  Well, --

MS. BEGGS:  So apart from that, it has been pretty reliable.

MR. FIRING:  So -- well, okay.  Let's -- we can return to that and other things after your talk, which should be after the break because it's time for a -- I believe it's time for a break.

MR. FIRING:  Okay.  It looks like we're all set for the remainder of the session.  We have one more -- one more speaker and, following that, we'll continue with questions.  But with the slight change in format that any -- as I said at the beginning, any industry representatives, including if there's a defender from RDI who is present, be invited to come up here and ask and answer questions.

# ACQUISITION OF VESSEL-MOUNTED NARROWBAND AND BROADBAND ADCP DATA USING A SUN LOGGING SYSTEM

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**Abstract**

In early 1998 an RD Instruments BroadBand Acoustic Doppler Current Profiler (BBADCP) and Ashtech 3DF ADU2 GPS were installed on CSIRO Marine Research's FRV Southern Surveyor. The existing RDI NarrowBand ADCP (NBADCP) acquisition software from the ORV Franklin Data Collection System (FDCS), written in C for a Sun, was modified for a BroadBand ADCP and installed on the FRV Southern Surveyor Sun computers. The RDI BBADCP data acquisition code (Transect v. 2.80) was installed on a PC and used for testing the BBADCP.

The Sun-based ADCP data acquisition system is described and its advantages outlined. The quality of data and performance of the BroadBand ADCP on the FRV Southern Surveyor is compared with the NarrowBand ADCPs on the ORV Franklin and RSV Aurora Australis.

## Franklin Data Collection System

On ORV Franklin, FRV Southern Surveyor and RSV Aurora Australis, CSIRO's Franklin Data Collection System (FDCS) operates on Sun SPARC stations running Solaris 2.5.1. FDCS has two components, the data acquisition and operational code and the user analysis and display utilities. The FDCS acquisition system is primarily written in C, with the analysis software written in a mixture of C, Fortran 77 and MatLab.

The acquisition system logs data to file and publishes instrument data to the FDCS Shared Memory System (sms), to make it available to other processes on the master logging Sun or on Suns running as FDCS "slaves". Shared Memory System data can be used for generating event logs, driving real time displays or passed on to other data acquisition programs. Data acquisition is controlled and monitored from the X-windows based, Unix user interface program (ui) (see figure 1(a)). The ui can also be used to modify the configuration of some instruments.

All instruments with serial output are interfaced to the network via Micro Annex terminal servers. They are controlled using input controllers, programs which control and log data from an instrument and/or the FDCS sms. All the input controllers (eg. GPS, Gyrocompass, ADCP) regularly publish their current data in the sms.

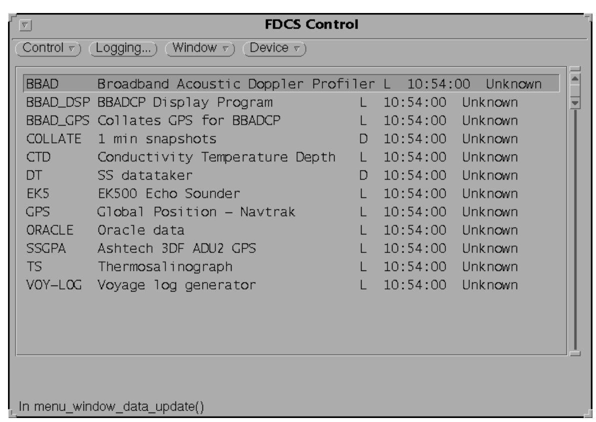


Figure 1(a). The FDCS user interface control window on FRV Southern Surveyor, which controls the overall operation of each input controller, including starting and stopping data logging.

**ADCP Data Acquisition using FDCS**

The original code for logging RDI NarrowBand ADCP (NBADCP) data on ORV Franklin was written for CSIRO in 1985 by Len Zedel and rewritten in C for the Sun-based FDCS system by Jeff Dunn in 1992. In 1994, Jeff Dunn modified the software to operate a NBADCP using the FDCS aboard RSV Aurora Australis. In early 1998, the NBADCP acquisition code was modified by the author to operate the RDI BroadBand ADCP (BBADCP), newly installed on FRV Southern Surveyor.

The ADCP logging system collects pings into 1 to 3 minute averages (ensembles). At the same time, GPS data is collected and processed into mean position and ship's velocity. The ships's attitude (heading, pitch and roll) and navigational data are stored in the FDCS shared memory system and after each ADCP ping the most recent of these attitude data are used for calculating water velocities, in addition to being stored with the raw and ensemble ADCP data. The full resolution GPS and EK500 acoustic depth recorder data are seperately logged, and potentially used in processing the ADCP data.

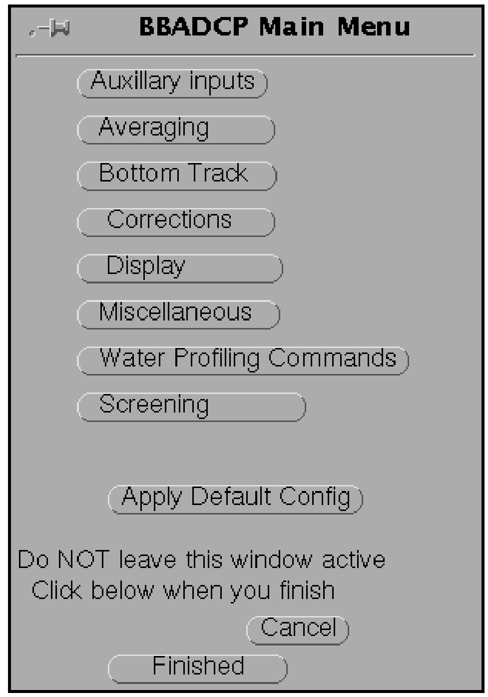


Figure 1(b). The "BBADCP Main Menu" window, which is accessed from the "FDCS Control" window and used to modify the configuration of the BroadBand ADCP either before or during data acquisition.

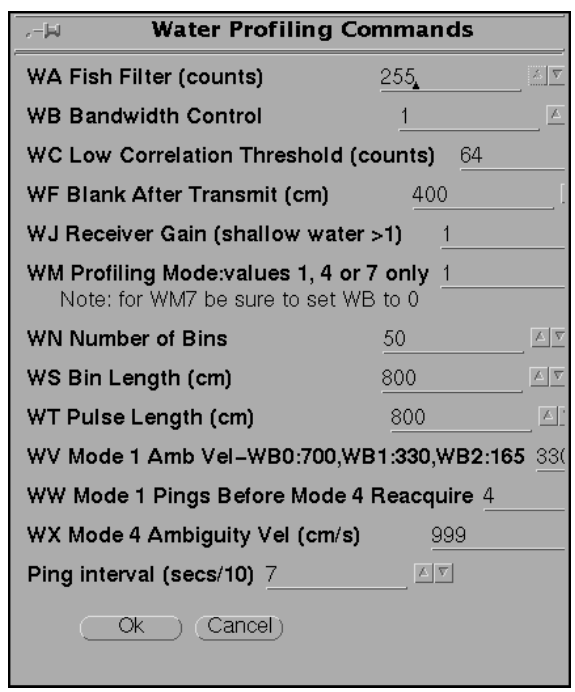


Figure 1(c). The "Water Profiling Commands" window is one of the windows which may be accessed via the "BBADCP Main Menu". The window may be used for changing the BBADCP water profiling configuration parameters.

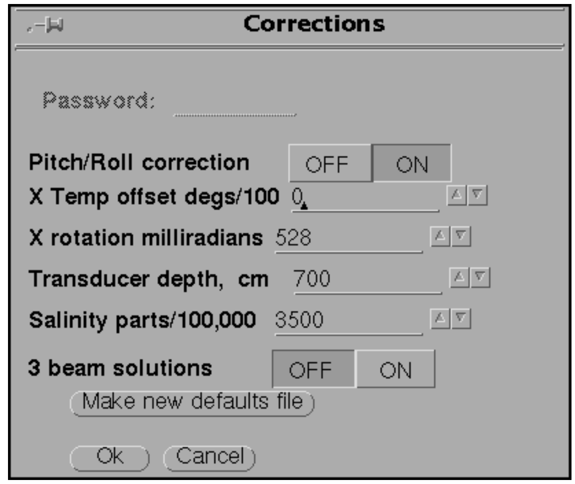


Figure 1(d). The "Corrections" window, accessed from the "BBADCP Main Menu" is password protected and used to alter, among other parameters, the transducer misalignment angle. One can also store the current configuration to a new defaults file.

## ADCP Data Acquisition using RDI's Transect

During the testing of the new BBADCP on the FRV Southern Surveyor, we experienced several problems with RDI's Transect software. Although Transect is excellent for use with moored ADCPs it has several limitations for use with vessel-mounted ADCPs (VM-ADCPs), where navigation and attitude readings are required and large amounts of data are gathered.

Fast Microprocessors: Transect will not at present run on fast microprocessors such as a Pentium II because the Borland Pascal compiler is not compatible with Pentium microprocessors.

Backing up of data: Transect is reliably run only in DOS mode on a pc. To back up data, acquisition has to stop.

Reliability of settings: Although the user may elect to use a particular configuration file, that file may be up-dated by Transect without the user's knowledge. The list of direct commands may be truncated, with potentially unreliable results. Operators using Transect for data acquisition should check the configuration file after making any changes to it from within Transect.

Stability and memory problems: The software will crash when there are too many files in a directory that Transect is accessing. A Transect crash may corrupt the configuration file.

Rigid data stream inputs: An Ashtech 3DF GPS can feed all the data required for navigation and attitude in a single stream. These data must, however, be sent through two separate comms ports on the PC.

Rigid data formats: The options for feeding navigation and attitude data streams into Transect are somewhat limited. Transect will accept only pitch, roll and heading in that order. Therefore, a second PC is required to re-format the attitude data string from an Ashtech 3DF GPS and feed it to the Transect PC.

## Advantages in using FDCS

The advantages we experienced in using the FDCS software for logging ADCP data were:

Hardware and software reliability: The Sun computing system on the Franklin has been very reliable, with no hardware failures and very few software crashes in the 5 years since it was installed.

Ease of operation: It is relatively simple to change logging parameters in the ui either before or during data acquisition, and these changes may be stored as defaults.

Integration: ADCP data acquisition is integrated with the other instrument logging on the vessel, which simplifies both acquisition and post-processing.

Flexibility: All code is written in C in a modular style and is flexible and relatively easy to modify, with all constants stored in header files.

Understanding: Developing our own code means we know exactly how the data is manipulated.

Backing up data: On ORV Franklin and FRV Southern Surveyor all data is automatically backed up hourly to the other networked Suns. Backups may also be performed manually at any time to exabyte tape without ceasing data acquisition.

**Differences in performance between RDI's NarrowBand and BroadBand ADCPs**

The range of an ADCP system is affected by the concentration of scatterers in the water, the absorption in the water (which changes with temperature), the energy transmitted into the water (which varies with bin size), and the background environmental noise (including sea state and speed of vessel through the water) (Symonds, 1998).

In a BBADCP, profiling range is sacrificed in favour of greater single ping accuracy, allowing higher accuracy in shorter averaging times. This is because the BBADCP has a wider bandwidth that causes the signal-to-noise ratio to be lower than that for the NBADCP (Gordon, 1996). For example, the 150 kHz BBADCP will generally have about 2 cm/s standard deviation for a single ping compared with 13 cm/s for the 150 kHz NBADCP (pers. Com., Darryl Symonds, RD Instruments).

Unlike the NBADCP, the BBADCP implements a variety of transmission modes with varying time-lags and pulse forms. Some water-profiling modes are more robust for use in turbulent water, while other modes produce hightly precise measurements but will not work in rapid or turbulent flow (RDI Application Note FSA-003, 1997). The following three BBADCP profiling modes may be used in vessel-mounted applications.

Mode 1 (WM1): This is the most robust profiling mode and will work in all environments, including from a vessel. The Mode 1 profiling range can be increased through the WB command, which selects the operational bandwidth of the system. However, a narrower bandwidth increases the standard deviation in the measured water velocities and reduces the maximum ambiguity velocity.

Mode 4 (WM4): This mode has the lowest standard deviation of any mode but will not work on vessels moving faster than 5 knots, or in water which is turbulent or has high shears, low backscatter, or high noise floors.

Mode 7 (WM7): This "extended range mode" provides a standard deviation about three times that of the equivalent Mode 4 setting. It will only work in calm to moderate seas where the vessel is moving at less than 3 knots.

In order to compare the performance of vessel-mounted RDI ADCPs, Wilson et al. (1997) logged 150 kHz BBADCP and 150 kHz NBADCP data in a time-interleaved fashion aboard the RV Seward Johnson. It was found that in generally calm seas, with a constant ship speed of 6 knots, the profiling range of the BBADCP in water profiling mode 7 was equal to that of the NBADCP. In broadband modes 4 and 1, profiling ranges averaged 78% and 75% of narrowband ranges respectively.

Table 1 summarises the differences between the ADCPs mounted on vessels used by CSIRO Marine Research. ORV Franklin and FRV Southern Surveyor are owned and operated by CSIRO Marine Research, whereas RSV Aurora Australis is chartered and operated by the Australian Antarctic Division. It is important to note that on all three vessels the ADCP transducer is mounted with beam 3 at approximately 45° to the bow ("transducer misalignment") to reduce as much as possible the effects of pitch and roll on the data quality. In the case of the BBADCP, the maximum permissable ambiguity velocity (Gordon, 1996) is optimised when the transducer misalignment angle is 45°.

| | ORV Franklin | RSV Aurora Australis | FRV Southern Surveyor |
|---|---|---|---|
| ADCP type | 150 kHz RDI narrow-band | 150 kHz RDI narrow-band | 150 kHz RDI broad-band |
| Purchased | 1985 | 1994 | 1998 |
| Mounted | moonwell - flush with hull | behind acoustic window | moonwell - 1.5 m below hull |
| Beam Angle | 30° | 30° | 20° |
| Navigation | Ashtech differential GPS | Ashtech 3DF GPS | Ashtech 3DF GPS |
| Attitude Sensor | gyrocompass | Ashtech 3DF GPS | Ashtech 3DF GPS |
| Pitch/Roll Sensor | none | Ashtech 3DF GPS | Ashtech 3DF GPS |
| Synchronised? | no | yes | yes |
| Interference | none | interferes with echo sounders | interference from fish sonar |
| Typical long-term error per m/s of ship speed | 0.6 – 1.1 cm/s | 1.0 cm/s | 1.0 cm/s |

Table 1. The differences between ADCPs on vessels used by CSIRO.

The 20 minute averaged ADCP profile data from three recent voyages of the ORV Franklin, RSV Aurora Australis and FRV Southern Surveyor were compared for data quality and profiling range (Table 2). Profiling range was determined as the point where percent good pings dropped to 30. It should be noted that the Franklin cruise was over a different region of the ocean and at a different time of year to the other two cruises, although the values for profiling range were typical for this vessel.

ADCP profiling range on all three vessels was reduced when the ship was underway, possibly due to bubbles underneath the hull inhibiting the transmission of sound (Gordon, 1996). When stationary, the Southern Surveyor BBADCP (set to Profiling Mode 1, medium-band) had 87-89% of the profiling range of the Aurora Australis NBADCP, and 100-156% of the profiling range when both vessels were steaming at around 10 knots. In calm seas, the Southern Surveyor BBADCP set to Profiling Mode 7 matched or exceeded the range of the Aurora Australis NBADCP. RDI expects that in similar sea conditions and on the same vessel, that a 150 kHz BBADCP set to Profiling Mode 1, medium-band, with a beam angle of 20°, would have the same profiling range as a 150 kHz NBADCP with a beam angle of 30° (pers. Com., Darryl Symonds, RD Instruments). It is therefore surprising that the profiling range of the Southern Surveyor BBADCP was consistently less than that of the Aurora Australis NBADCP when both ships were stationary, especially considering that the NBADCP is mounted behind an acoustic window. Bubbling underneath the hull is obviously more of a problem for ADCP profiling range on the Aurora Australis than on the Southern Surveyor when both vessels are cruising at 10 knots. The Aurora Australis NBADCP had a smaller profiling range than the Franklin NBADCP both when the ship was steaming (42-90%) and when it was stationary (68-100%), most likely due to the acoustic window over the Aurora Australis transducer and bubbling underneath the hull.

| | ORV Franklin<br>NBADCP<br>30 Nov – 6 Dec 1997<br>36-44°S, 143-150°E | RSV Aurora Australis<br>NBADCP<br>14-20 Mar 1998<br>48-54°S, 141-142°E | FRV Southern Surveyor<br>BBADCP<br>14-20 Mar 1998<br>49-52°S, 140-143°E |
|---|---|---|---|
| Rough seas | | | |
| ship speed 10 kn | 200 m | 180 m | 180 m (WM1, WB1) |
| ship stationary | 290 - 400 m | 270 m | 240 m (WM1, WB1) |
| Moderate seas | | | |
| ship speed 10 kn | 280 m | 135 m | 210 m (WM1, WB1) |
| ship stationary | 330 m | 335 m | 290 m (WM1, WB1) |
| Calm seas | | | |
| ship speed 10 kn | 310 - 360 m | 150 m | 220 m (WM1, WB1) |
| ship stationary | 400 m | 325 m | 290 m (WM1, WB1) |
| Calm seas | | | |
| ship speed 10 kn | | | N/A |
| ship stationary | | | 340 m (WM7) |
| Calm seas | | | |
| ship speed 10 kn | | | N/A |
| ship stationary | | | 360 m (WM1, WB2) |

Table 2. Profiling range of the vessel-mounted ADCPs, with the BroadBand ADCP set to various profiling modes (WM1 - profiling mode 1, WM7 - profiling mode 7, WB1 - medium-band, WB2 - narrow-band) (See RDI’s Application note FSA-003 - Broadband ADCP Water-profiling modes.)

**Summary**

The advantages in using the FDCS for logging vessel-mounted ADCP data include reliability, ease of operation and processing, flexibility and a clear understanding of how the data is manipulated.

ADCP profiling range on ORV Franklin, FRV Southern Surveyor and RSV Aurora Australis is reduced when the ship is underway, possibly due to bubbles underneath the hull. The ORV Franklin NarrowBand ADCP gives the greatest profiling range in any sea state, does not experience interference from other acoustic devices on the ship, and the data quality suffers least in rough weather. The FRV Southern Surveyor BroadBand ADCP appears to have close to the same profiling range as the RSV Aurora Australis NarrowBand ADCP.

At this stage, improvements in single ping accuracy for vessel-mounted ADCPs are less important to CSIRO scientists than optimising profiling range in a variety of sea states.

**Acknowledgments**

I would like to thank Mark Rosenberg of the Antarctic CRC in Hobart for supplying processed ADCP data from the RSV Aurora Australis, Bob Beattie of CSIRO Marine Research for his comments on FDCS, and Pamela Brodie for her work with Transect on FRV Southern Surveyor.

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# ADCP DISCUSSION SESSION 2

MR. FIRING: It's getting a little late. In fact, I obviously mismanaged the time here. It slipped away from me, and I apologize to the industry people who are left with extremely little time. I'm very sorry. I did screw it up.

But with what time remains, if each of you would start with a brief introduction to everyone so that those who don't you can find out who you are, who you represent, and what solutions to our problems you can thereby provide. We'll start with Jim Christensen.

MR. CHRISTENSEN: My name's Jim Christensen. I represent Sunwest Technologies. I've noticed throughout this meeting that one would get the impression that the only current profiler company in the world is RDI. I'm here to dispute that perception. We make a line of shipboard-mounted Doppler current profilers which have been mainly sold in Asia and Japan, Korea, and places like that. They're produced and their frequency range is from 300 kilohertz through 75 kilohertz. And they are narrow band instruments.

Our 75-kilohertz system, which we recently tested, did achieve 700 meters range. And I guess that's about it. Move on to the next one.

MR. WARD: Yeah. I'm Chris Ward. I'm with Sontek here in San Diego. Some of you may recognize my name because I formerly worked for DDO Acoustics out of Salt Lake City when they were involved in a current profiling program, which I think they're now pretty much out of. I've been here in San Diego for about six months.

Sontek is a company that manufactures current profiling instruments as well, and I'll probably defer to Jerry talking about instruments and things.

MR. MULLISON: Thanks. Yeah. My name is Jerry Mullison. I'm also at Sontek. And for anybody who's curious, it's actually colder up here than it is down there. We do make profilers. Our profilers are strictly narrow band. We haven't gone into the full vessel-mount-type systems that have been discussed here. We do -- we are going into the lower profiling systems. And we're hoping to put together complete-type packages, as Eric and Martin have been talking about, systems that are ready to go onto the CTDs and be lowered and come back out and use data processing that will actually come from Eric or Martin.

MR. GORDON: My name's Lee Gordon. I'm starting up a little company here in San Diego with a friend of mine in Norway called Nortek USA. And we make neither long-range scientific profilers nor lowered ADCPs. But I was with RD Instruments for 13 years, until just a few months ago, so maybe I can -- I may be able to answer a question or two on RDI stuff.

MR. FIRING: Okay. Thank you. So questions? Frank?

MR. DELAHOYDE: A general question that I thought (indiscernible) by -- regarding shipboard ADCPs. I use the narrow bands mostly, but -- I use the 75 kilohertz and the 300 kilohertz broad band usually. In both cases, I just found the profiles to be, in general, more noisy than narrow band, and I'd like to hear -- we have two columns. Perhaps then there are others (indiscernible). With broad bands apparently taking over, at least as far as RDI is concerned, will this be a problem or am I just using the wrong settings for my broad bands?

MR. CHRISTENSEN: I have not studied standard deviations in great detail, but I have done a cursory survey, obviously, and it seemed to me that one of the major factors affecting the standard deviation of Doppler data is the fact that these instruments all assume that the flow field is identical on all four beams.

And, of course, it's not. And as you go deeper, the spatial distance between the sample volume increases. And I'm sure that the flow field deviation increases also.

So the studies I did, comparing broad band to narrow band, showed, at best, broad band was only like 50 percent better than narrow band.

MR. DELAHOYDE: Well, I find it's not better and not only having a smaller range, but it's less -- it's more noisy.

MR. CHRISTENSEN: It's more noisy.

MR. FIRING: Frank, there are two things that can come from but, first, what profiling mode were you using?

MR. DELAHOYDE: Mostly one.

MR. FIRING: With what band width?

MR. DELAHOYDE: I don't know. Default.

MR. FIRING: And WV. Okay. There are two ways that -- yeah, the default doesn't work. That's one point.

PARTICIPANT: Default band width.

MR. FIRING: Oh, default band width would be zero. Okay. There are a couple of ways that it can be -- it can very easily be noisier. One is if you're getting wraparound. And the noise that you're talking about is probably in some sort of averages.

MR. DELAHOYDE: Right.

MR. FIRING: Right? So if you're getting wraparound errors, that will show up as noise -- as obvious noise in cases where you're having -- you're averaging pings with different depth extents. So you have one ping that gets deep and has wraparound error one way, and another one that doesn't have wraparound and it's shallow, and you average them together and you get a profile that looks like that. I have a sample here of that.

Another is that Transect does not do a reference layer sort of calculation in its averaging and, so for somewhat similar reasons, but even without wraparounds, you can have noisier averages not because of broad band but because it's Transect.

MR. GORDON: I would suspect that that's more than likely the reason for the noise. Given mode one, I think that's more likely. Mode one, zero band width default, I think that's a more likely reason.

MR. FIRING: Yeah. Depending on how the WV is set.

MR. GORDON: Yeah. That's a good point. You know, if you have your -- if you have your ambiguity velocity set at a number you think is okay, one of the things that happens if -- you know, you may not be thinking of is the fact that you get a sizeable velocity from the heave of the ship.

MR. FIRING: Right.

MR. GORDON: And that can cause you a sizeable error.

MR. FIRING: Yeah. In fact, the setting with -- the maximum setting with the mode one, band width one, that intermediate band width -- well, okay. The Instrument Field Service Bulletin 109, or whatever it was, is not quite correct and quite misleading. It turns out that if you set WV-330, that does not actually give you the maximum that it can handle. You have to go a little bit over 330 to get -- to do that.

Second, for reasons that they never quite explained, there's some bug that if you set it -- it's said that if you set it at more than 425, you get garbage. I'm not sure if that's true or not. The business that it wouldn't go over, effectively, about 330 is something that was actually pointed out to them about two years ago, and it took them until September, I guess, for it to register and -- to the point where they sent out this somewhat misleading field service bulletin.

If you set between, say, 350 and 425, things seem to work. The value of 330, however, I think is a dangerous one for many shipboard systems. I think that it gives a significant danger of wraparound occurring as the weather gets rough, for exactly the reasons that we gave -- that the regulable velocity component is going to be dominated by the heave of the transducer associated with the heave of the ship, to the hull and with the pitching.

So depending on where it is and what the sea state is, you could very easily be hitting wraparound, I think, with 330 when the ship is going fast and bouncing around.

Tom?

PARTICIPANT: Yes. There's a couple of things. We can give a history to anybody that doesn't know where I'm coming from. We've had at Marine Sciences Stoneybrook University an experience with both broad and narrow band machines over a number of years, and we have a number of years honed a broad band. We did the inter-comparison study in Barbados.

From a blue water perspective, certainly the narrow band has advantages in terms of being more robust in bad sea conditions and giving great profiling range when you're in deep water.

From -- I would say that those are -- that those particular advantages are somewhat less -- should be weighted less when you're looking at operations on the continental shelf and certainly operations in estrian environments where you're trying to run very complicated tracks and you're running in shallow water where the range of the instrument really isn't a factor. You're running in 50 or 60 or 70 meters of water, and there's an awful lot of oceanography that goes on in those areas.

By the way, the inter-comparison we did, we were able to run the instrument on mode four and mode seven at six knots, in relatively calm waters, but this was -- you know, this was open water, 500 meters of water off Barbados, so not entirely -- not entirely mill pond either.

And if anybody wants some suggestions on broad band settings, please get in touch with me.

MR. FIRING: A quick comment on mode four. Mode four, if it thinks it's running into problems -- to the extent that it thinks -- it drops back to mode one. And with whatever WV happens to be -- command happens to be sitting around. And I think the only way to find out whether it's done that would be if the raw data are recorded -- I don't know how the averaging was done. You might find in the raw data files, by looking at the lag and the mode, maybe you'd find whether it actually had gotten back or not. I'm not sure. Not even that? Okay.

MR. GORDON: Sorry.

MR. FIRING: So mode four -- yeah -- maybe under ideal conditions may be fine but, boy, it's hard to know what you're getting.

MR. GORDON: RDI may have included some way of telling you within the last year or so, but --

MR. FIRING: Highly unlikely -- if it wasn't in before. Highly unlikely that's been changed.

Are there other questions, comments? Frank?

MR. DELAHOYDE: Yeah. A follow-up. You showed these great pictures of having a lot of (indiscernible) from cruises where there is not really an operator (indiscernible).

MR. FIRING: Well, actually, let me clarify one thing. That was a combination of everything we had, some of which were FIO cruises, and there's a whole variety of things in there. So it's not all opportunity data, but it's being used in a climatological sense for one of the first times, I think.

PARTICIPANT: Explaining the comment -- I had a lot more luck with getting data from narrow band without babysitting it than from a broad band. And it sounds to me like the broad band data that I had problems with could have been better with better settings. So henceforth, if we have more ships now that do have broad bands, perhaps we can have some sort of, I don’t know, library or better exchange of what the good settings are, because I get asked by people, "When you go out and when you use the broad band, what are good settings," and, obviously, I’m not giving them the right advice.

Is it just such a bigger pool of possibilities that that is not possible, or what? I --

MR. FIRING: No. I think it is, but I think it all just boils down to just kiss range goodbye and set it to WM-1, WB-0, WV-600, eight-meter bins, and whatever blanking you need to take care of however much ringing problem you have.

MS. BEGGS: So you still think that WB-1 is a bad idea because of the ambiguity?

MR. FIRING: I would not use it unless I knew because of the characteristics of the ship, or the operating region or whatever, that the regulable velocities really were not going to exceed that threshold.

Now, this is another area, though, where if you have control, as you do over the processing software, you could -- you may be able to put in -- if you’re looking at things in ensemble all the time, you could put in some reasonableness checks. And so if you were getting an occasional wraparound, you might be able to detect it and knock that out of the average. It’s not necessarily trivial to do it; it can be rather tricky to detect, but at least you have a chance of doing that, which we don’t have with something like Transect.

MS. BEGGS: Yes. But wouldn’t that just be a spike? I mean, wouldn’t you just see that as --

MR. FIRING: Not necessarily.

MS. BEGGS: -- a bad bin?

MR. FIRING: The example that I have buried in here somewhere of a wraparound occurring with mode seven, it’s showing up in the vertical velocity component, not on the horizontal components. And the reason is that if it’s caused by vertical velocity excursions and you wrap all four beams at the same time, that doesn’t give you a spike in U or V, in the horizontal velocity, but it does in W. So that’s -- you know, the wraparound is not always easy to detect.

Yes?

PARTICIPANT: Yeah. One additional comment about recording data. We record an average data and we, frankly record raw data just to back ourselves up because, you know, frankly, disk space is cheap. For us, it runs about 50 megs a day but, in today’s world, that’s ten percent of a two-Doppler CDR, so it’s really -- luckily, because of the advance of storage technology -- it’s -- recording and saving the raw data is not that big a deal; I don’t think it is -- and will become less so as time goes on.

MR. CHRISTENSEN: I’m kind of confused. I hear all this agony and problems over the broad band, and I’ve been hearing it for years. Yet, as I say, we make a narrow band system based on an FFT, which means that we’re looking at the whole spectrum and making an estimate of where we think the real frequency really is. Yet it’s virtually impossible to convince anybody that they should go narrow band, in spite of the fact that we get maximum depth -- as I said, 700 meters at 75 kilohertz, and we get 500 meters at 115 kilohertz. It’s a very robust system.

So what happened to narrow band? I mean, where did it go?

MR. FIRING: Jim, if I could comment on that. I think the -- well, people are still trying to go with narrow band and, in fact, RDI's arm has been twisted various ways to keep building some of their ancient, creaky, old but still functional original designs.

With respect to the Sunwest system, one of the concerns that Kerry Dreskin (ph) and I had with the -- using the FFT algorithm is the issue of the amount of -- the number of samples that get edited out.

So what kind of an actual profile do you have ping by ping to average together? And our -- because -- we have a problem of sampling a very time-variable ocean field, given the super-position of wave motion, ship's motion, and whatever else is going on. And so having lots of samples and having uniform sampling is a criteria.

And our impression was that that was a problem, but that may not be the case. Please address that.

MR. CHRISTENSEN: Well, one thing -- our code -- you know, we have digital signal processors. The code in the DSP is of course written in C. It's fairly simple. The code in the host is written in Pascal. Everybody said, "Ooh, Pascal," but Pascal is very nice and is very heavily typecast, so it's hard to make a mistake. You can't just freely interchange images and words.

And it's available to the user. If the user doesn't like what the Pascal is doing, change it. Make it what you want. If you don't like the editing that it's doing, make a change.

We do -- we, of course -- we build what we think is the most robust system that we can and the most highly accurate system but, obviously, our whole environment is 12 miles off the San Diego coast, plus whatever information might filter back from the Orient. So we do make ourselves -- we're available, and I would think that would be an advantage.

MR. FIRING: That is a huge advantage. That's a very commendable thing. One of the big problems with Transect and with the firmware in the RDI systems is that they've both demonstrated themselves to be bug-ridden and typically not very well-understood by -- even by RDI. Witness the amount of time it's taken them to find the bugs. And the frustration has been that since we haven't had the source code, we haven't been able to find them ourselves and find out just what on earth the systems are really doing.

Are there questions or comments? I think we're beyond our time allocation, slightly.

# RD Instruments Response To The Proceedings From The 1998 INMARTECH Symposium

Darryl R. Symonds & Harry Maxfield
RD Instruments

**[Editor's Note: RD Instruments was presented the ADCP Session document and given the opportunity for comment since they did not participate in the INMARTECH Symposium.]**

In response to the issues concerning RD Instruments (RDI) products and software discussed during the 1998 INMARTECH Symposium, RDI felt clarification and input of relevant information would be beneficial to all parties. Unfortunately, the staff transition at the time of Symposium did not allow us the opportunity to participate directly. RDI acknowledges that this symposium was an excellent opportunity for users to share experiences. It is these types of functions that have given RDI valuable input and has contributed much to the development of our products in the past and will continue to do so for future RDI products.

RDI values all input from our customers and has made significant strides to include the end-users in the product development process. During our development process RDI incorporated changes to software, firmware, and hardware to implement requests from our users such as improved accuracy, better software graphical representation of the current data, more flexible data formats, and easier setup routines.

A few examples of what we have incorporated are as follows:

Dr. Firing's input was instrumental in providing the feature of reference layer averaging in the original NarrowBand Data Acquisition Software (NB DAS).

Users input stating that both the ADCP's raw data output and the NBDAS pingdata file format were difficult to access was the impetus for RDI to create a new data file format which is incorporated into the BroadBand, WorkHorse, and OceanSurveyor series ADCPs.

Users input on the need for contour plotting and shiptrack plotting were incorporated into the TRANSECT program.

Users input on the need for flexible schemes to input NMEA devices were incorporated into the NAVSOFT and TRANSECT programs.

Users input on the need for simpler user setup interface were incorporate in the TRANSECT program.

RDI acknowledges the ability to incorporate all of these features in the initial release of one product or one product family is not an easy task. We further acknowledge that the initial BroadBand ADCP systems and software did not incorporate nor duplicate all of the features previously available in the NarrowBand systems and its software.

It should be noted that the RDI product development process for products, such as BroadBand, Workhorse, Ocean Surveyor, WinRiver and VMDAS are in conjunction with the end-users. The goal of these development processes is to provide acoustic Doppler technology for a much broader spectrum of the research community. The increased hardware and software capabilities of these products have provided the coastal and inland water research and commercial communities as well as the open ocean research and commercial communities with valuable tools for their research and survey requirements.

RDI has received a great deal of positive input on the advantages that the broad bandwidth processing added to ADCP systems. RDI has also received some customer feedback concerning the lacking of some features that are considered either mandatory, or basic in nature. RDI has been and will continue be open to any and all comments.

RDI has incorporated this customer-generated input in the development of the latest ADCP series the Ocean Surveyor. The Ocean Surveyor ADCP provides the capability of both narrow bandwidth and broad bandwidth processing features that are available separately within the NarrowBand and the BroadBand ADCP products. The Ocean Surveyor utilizes a WINDOWS based data acquisition software package. This software package incorporates all of the core functions that were omitted in the TRANSECT program (such as user-exit software capability, and reference layer averaging) as well as the features that were incorporated in the TRANSECT program (such as shiptrack plotting, independent averaging, recording, and display intervals, and NMEA interfacing). This WINDOWS package also incorporates screening capability and 2 independent averaging intervals allowing the user the most flexibility of any RDI software package to date.

The research community worldwide has employed the Ocean Surveyor product line for the past 2 years (mid-1997-2000). All of the features that have been mentioned above are now field-test proven. Even still, customer input, remains a big part of improving our products. Features are being added now and will continue to be added as our users needs, requirements, and expectations are assimilated in the product development process. We value our customers, they’re input, and intend to continue to use their input as a major part of our development process.

# SHIPBOARD NETWORKING AND SEANET

Chaired By
Barrie Walden

# Data Collection and Distribution

Barrie B. Walden
Woods Hole Oceanographic Institution (WHOI)

This presentation is actually a lead-in to the five that follow; it's a long-winded introduction. I'm going to talk about the some of the things which precede data collecting, logging, transmission around the world and E-mailing your friends for help when there are problems. I have recently been able to design and, to a large extent install, a Science Information System (SIS) on a new vessel, the *Alvin* support ship *Atlantis*. This proved to be more challenging than I expected because a design existed and was well on its way to installation before I became involved. Actually, there was little wrong with what was done - it simply didn't go far enough and it completely ignored some of the more practical aspects of how a shipboard installation needs to work.

Before becoming involved with *Atlantis* I had done similar installations on WHOI's other two ship's, first *Knorr* and then *Oceanus.* This was a real advantage because even though this is not rocket science, it is very difficult to get it right the first time, or the second. I haven't even done it correctly the third time so my presentation today is not intended to be of the "here's how to do it" variety. Instead, I am simply going to talk about how we have done things at WHOI and what considerations went into our decisions. Our system has worked extremely well; it's both versatile and reliable. Best of all, it has proven to make the job of an onboard technician much easier.

Today there are a number of choices available for ship-board data transmission which were not even considered just a few years ago. Fortunately, ships are not the only place where data needs to be moved around so the data system component vendors have had plenty of incentive to stay abreast of advancing technology. This is both good and bad - we can enjoy the benefits of technological improvements and we get to share in the pain of their learning curves. One of the first lessons I learned was not to go along with the adage "out with the old, in with the new". Even if I wanted to, there are a lot of vendors making essential instrumentation and struggling to keep up with advances. Using their equipment in the most reliable manner frequently means using it in the way they originally intended rather than trying to force it to perform in conjunction with the latest data handling technological advance.

One of the first things I did for the *Atlantis* installation was make a list of the interconnection requirements for some of the instrumentation I knew I would be dealing with. I could see that the ship would be ready for retirement before I could say this list was complete but it was quickly obvious that there was a good case for needing practically all the commonly used data transmission schemes. Figure 1 provides a limited example of what this list looked like. The requirement for RS232, RS422, RS485, and Ethernet is probably not surprising to anyone but Ethernet is rapidly becoming the communications method of choice and many people believe we have reached the point where it can replace all the others. Perhaps it can, but for a lot of the existing instrumentation that would be the hard, expensive way to do things.

# Figure 1

**Information Transfer**

**RS232**

- **Instrumentation Data Input (i.e., Navigation)**
- **Dynamic Positioning System Input**
- **Precision Time Output**
- **Winch Monitoring Systems**
- **Terminal-Based Data Display**

**RS422**

- **NMEA Instrumentation Output**
- **Bridge Electronics Input**

**RS485**

- **Sensor Communications (i.e., IMET)**
- **Interface Module Communications (i.e., MetraByte)**

**ETHERNET**

- **Data/Image Transfer**
- **Instrumentation Control**
- **Intranet and Internet (E-Mail)**

**BASEBAND and Multiplexed Video**

- **Closed Circuit Video (i.e., Camera Outputs)**
- **Video Distribution**

**MISCELLANEOUS**

- **Gyro Synchro**
- **Precision Time (Pulse and IRIG-B)**
- **Video System Control**
- **Audio Distribution**
- **SVGA Computer Video**

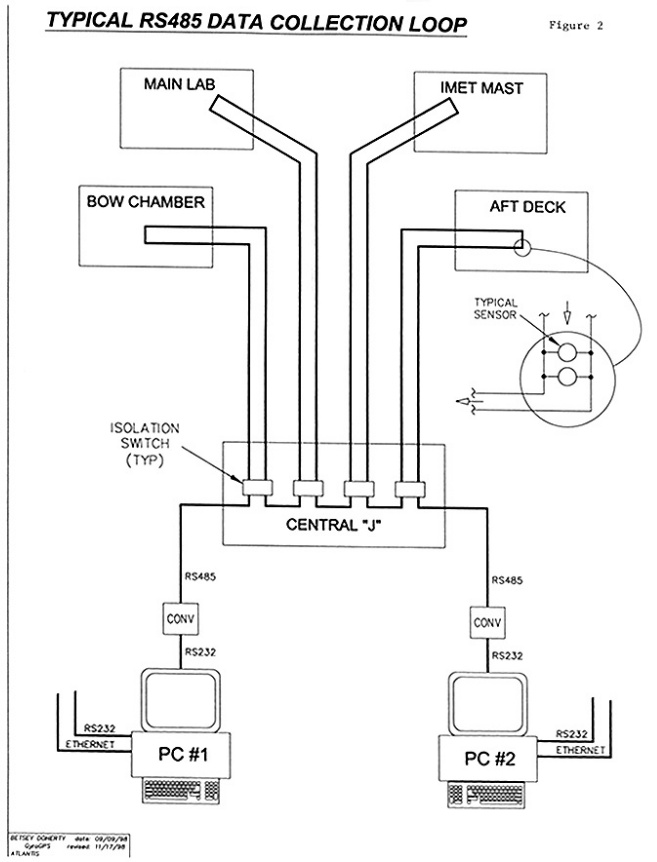
The most important thing I gained from my "interconnection list" was clearer idea for how open ended it really was. I expected there to be a requirement for dealing with new equipment in the future but I was surprised by how difficult it was to obtain the necessary information for the equipment planned for installation during construction. Not only was it hard to obtain details for the equipment itself but in many cases I couldn't even learn where the equipment was going to be located. There was also a lot of confusion about who had the responsibility to meet some of the interconnection requirements. In a number of cases I found instruments appeared to require a data input which could only be obtained from the system I was installing but the shipyard seemed to have total responsibility and planned to be finished long before I was. As one would expect, the lesson here is to make the installed interconnection system as flexible as possible. Minimize the number of special purpose wires and add all the redundancy you can reasonably afford.

I decided upon a standard pair of cables to be run between all "suspected equipment locations". One cable contained 15 twisted shielded pairs for "clean" signals and the other had 8 twisted shielded pairs for more abusive applications. My "interconnection list" also provided a way to identify cable termination points. Again, after putting down the locations for everything I knew about, it was necessary to go back and add more to allow for future expansion and compensate for lack of knowledge.

The next step was to decide on a cable run topology. I selected a "star" for three important reasons: it appears to provide the greatest flexibility, it facilitates trouble shooting, and it's what I've used in the past. There are some down sides: it probably requires more cable than many of the alternatives, some of the interconnection runs are much longer than necessary, and the central hub ends up with an incredible number of wires which need to be terminated in an organized manner. These negatives are not trivial but I feel the central hub provides over-riding benefits.

Further consideration of my "interconnection list" showed that for the most part the equipment locations could be divided into a small number of categories. Some were "heavy use" areas where additional cables of the standard type were likely to be needed, some had a special purpose requiring additional cables of a different type, and a very small number proved to have technical reasons which demanded point-to-point wiring. The initial tendency was to agonize over the number and type of cables to pull to each location but the requirement differences turn out to be small. I ended up pulling almost the same set of cables to all termination points. Some exceptions were extra 15 pair cables to the major laboratories and extra coax cables to locations I knew were likely to generate a substantial amount of baseband video - the ROV control room location for example. The end result of this effort was a cable list specifying a minimum of three coax, one 15 TSP and one 8 TSP cables to be run from the ship's computer/electronics laboratory to approximately forty other locations on the ship. This wouldn't have been hard to do except the work wasn't started until after the ship's joiner work had been completed. The central hub was a challenge because of the number of cables but we managed to get them into a single large junction box where each wire ends on a terminal strip. The far ends of each cable set are terminated in smaller "standard" junction boxes, each having the same internal terminal strip arrangement and wire log-out.

So far I haven't mentioned Ethernet runs. The original ship design specified a fiber optic Ethernet installation with a central hub in the computer/electronics laboratory. The specified drops were limited to places you would expect to find a computer five years ago; they did not include sensor locations. Fiber optic cable had been specified for both bandwidth and electrical noise immunity. *Atlantis* is an electric drive ship and major SCR related noise problems were anticipated. *Knorr* has the same type of drive system and has both fiber optic and twisted pair Ethernet runs installed. The twisted pair installation has worked so well that we have never activated the fiber. Because of this experience, I ran an entirely new set of twisted pair Ethernet cables on *Atlantis* duplicating the existing runs and expanding the system to include spaces I thought had been overlooked. These included the majority of my standard cable drop locations and all of the ship's crew staterooms. The hub is in the originally intended location which turns out to be right next to the hub for the conventional cables. The installation has been certified to 100 mbits/sec and tested to 300 mbits/sec. We have not found the need to activate the fiber which I suspect has saved us a lot of trouble and money.




At this point we have cables running all about the ship - how do we use them. This is where the star topology flexibility comes in. Almost all data routing can be done with jumpers on the main J box terminal strips. You can do point to point, series connections, and parallel broadcasts from this one location. Best of all, you can also do problem isolation from this location. The RS485 data collection loop provides a good example (see Figure 2). Many of our standard sensors are RS485 instruments and they are all connected to a single ship-wide RS485 data loop. However, the cable system's star topology makes this loop look more like the pedals of a flower; a pair of wires go out from the hub to a sensor location terminal J box where they are jumpered to a second pair which returns to the hub. Jumpers in the hub interconnect these pairs so that the whole installation is continuous. The data collection and logging computers are attached to the two ends of this loop using 232 to 485 converters. One of these machines is doing all the work while the second is monitoring performance since it can "see" all of the loop traffic. In theory the second machine could provide some "watchdog" intelligence but we haven't gotten that far with our programming.

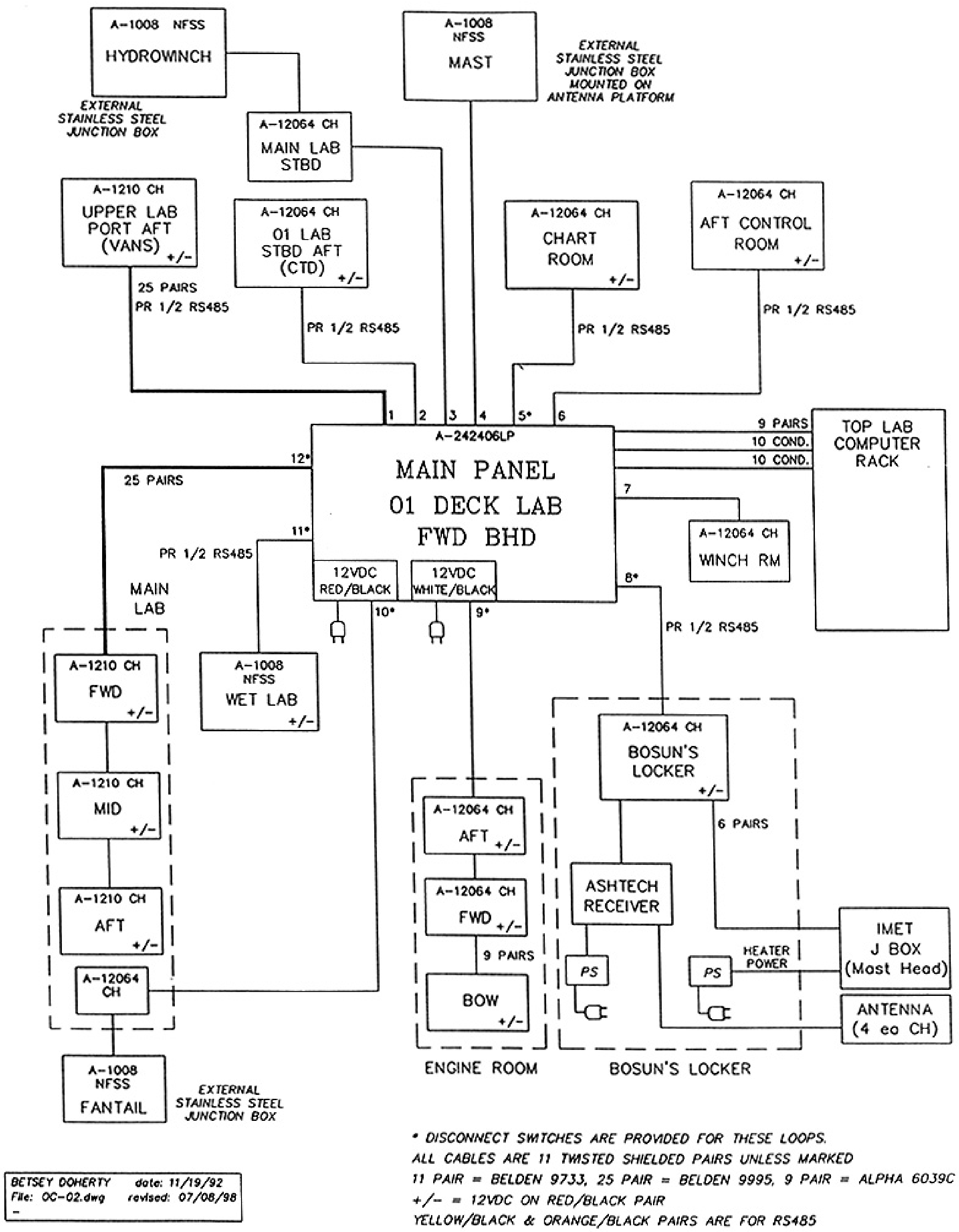
This is a case where the star topology has undoubtedly made the length of 485 cable unnecessarily long but there is a real maintenance and troubleshooting advantage. Instead of simple jumpers in the main J box we have used isolation switches to interconnect loop segments. When a technician notices problems with the 485 loop data he can use the second computer to quickly determine if the problem is within the primary computer or is being caused by loop and/or sensor hardware. If it's a loop problem, he can determine which segment is causing the problem by using the isolation switches. Frequently loop problems of this nature are caused by a sensor which needs to be reset. We have made the technicians life a little easier in this regard by powering most sensors from a 12 volt supply located at the main J box. This allows all sensors to be reset with one switch in a central location.

Beyond this you start getting into requirements specific to particular instruments and sensors. Again, the central hub frequently simplifies the interconnection process but it still turns out to be a complicated mess. The only advice I have to offer here is in the area of documentation. We all know it's needed and we probably won't have it if it's not done in conjunction with the installation. I have discovered that there is no single correct form for this documentation - what you need always depends upon what you're trying to do. For our system we have found three document types to be extremely helpful: 1) an overall interconnection diagram [Figure 3], 2) signal routing diagrams or documents [Figures 4 and 5] and 3) junction box terminal strip definitions [Figure 6]. There are others but this is a good start.

As I mentioned originally, our system is not the only good way to provide shipboard instrumentation interconnections. What we have done works well and if I had to do it again, I would do it the same way.

Figure 3

# R/V OCEANUS INSTRUMENTATION
## Science Cable Runs



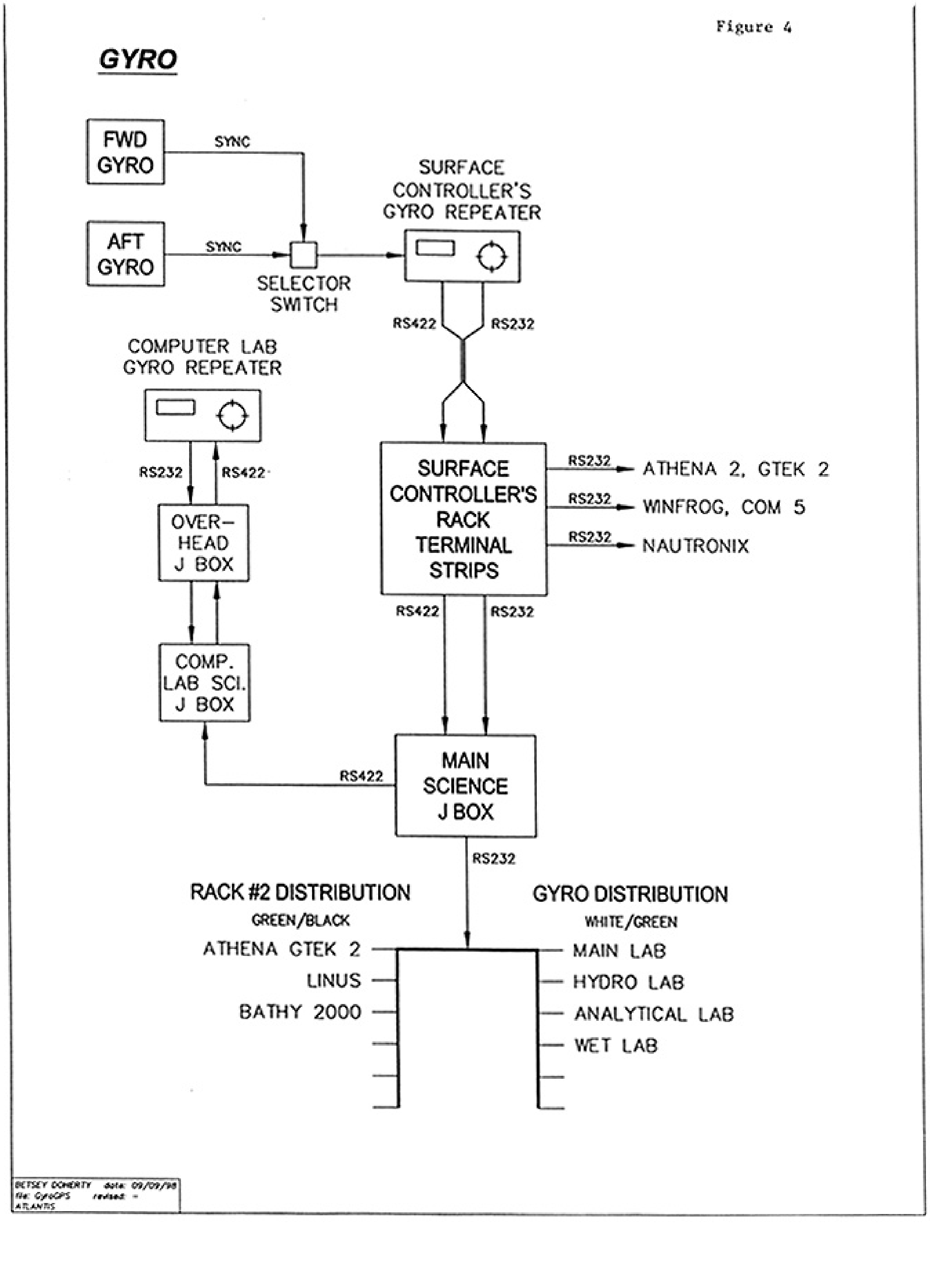

GYRO
FWD GYRO
SYNC
AFT GYRO
SYNC
SELECTOR SWITCH
SURFACE CONTROLLER'S GYRO REPEATER
RS422
RS232
COMPUTER LAB GYRO REPEATER
RS232
RS422
OVER-HEAD J BOX
COMP. LAB SCI. J BOX
SURFACE CONTROLLER'S RACK TERMINAL STRIPS
RS232
ATHENA 2, GTEK 2
RS232
WINFROG, COM 5
RS232
NAUTRONIX
RS422
RS232
RS422
MAIN SCIENCE J BOX
RS232
RACK #2 DISTRIBUTION
GREEN/BLACK
ATHENA GTEK 2
LINUS
BATHY 2000
GYRO DISTRIBUTION
WHITE/GREEN
MAIN LAB
HYDRO LAB
ANALYTICAL LAB
WET LAB

Figure 4

## Figure 5

OCEANUS Wire Assignments
OCWIREWPD Rev. 07/01/98

**Standard Assignments:** (Mn Lab, Mn Lab Rack "J", Wet Lab, 01 Vans, 01 CTD, Chart Rm)

| | | | | |
|---|---|---|---|---|
| Red/Black | 12vdc | J Box DB25's | 01 Fwd DB25's | |
| White/Black | Power (Not active) | Blue - pin 2 | Port: | Red (2) |
| Orange/Black | 485 outgoing | White - pin 3 | Purple (3) | |
| Yellow/Black | 485 incoming | Black - pin 7 | | Black (7) |
| (Green)/Black | Signal ground* (Green is unused) | | Mid: | Orange |
| Blue/Black | Gyro RS232 | | | White |
| Brown/Black | GPS NMEA, TxD/Gnd (Aft DB25s in Main Lab) | | | Brown |
| | (Port DB25 in Top Lab) | | Stbd: | Yellow |
| | | | | Gray |
| * Athena I/O, Ashtech, DB25's pin 7 | | | | Green |

**Standard Assignments for Main Lab & Vans only:**

| | |
|---|---|
| Yellow/Blue | Athena I/O (GTEK7) |
| Brown/Blue | Athena I/O (GTEK6), Forward DB25 (pins 3/2)* |

* Mid DB25's are frequently used for Wyse terminal data displays. Pin 2 should only be connected for single terminal having a keybd available for station annotation input.

**Pairs available at most locations:**

| | |
|---|---|
| Yellow/Red | (Except Bosun's Locker & Radio Room) |
| Green/Red | (Except Radio Rm) |
| Blue/Red | (Except Radio Rm) |

**Pairs available in Main Lab & Vans only:**

| | |
|---|---|
| White/Green | Orange/Green |
| Yellow/Green | Blue/Green |
| Orange/Blue | Yellow/Blue |

**01 Rack Spares** Red/Black, White/Black
Cable #1; Orange/Yellow/Green/Blue/Violet/Gray/White/Black
Cable #2; Brown[Red/Orange/Yellow/Green/Blue/Violet/Gray/White/Black
Note - Cable #2 is not terminated in main J box

Figure 6

# COMPUTER LAB J BOX

## 15 - PAIR

### DISTRIBUTED PAIRS

BRN ┐ RS485 DATA +
BLK ┘ RS485 DATA –

RED ┐ RS485 DATA +
BLK ┘ RS485 DATA –

ORN ┐ –
BLK ┘ –

YEL ┐ –
BLK ┘ –

GRN ┐ –
BLK ┘ –

BLU ┐ –
BLK ┘ –

### POINT–TO–POINT WIRES

BRN ┐ TRACTION WINCH DATA + WHT ┐
RED ┘ TRACTION WINCH DATA – GRN (TO BRIDGE RPTR)
ORN ┐ HYDRO WINCH DATA + RED
RED ┘ HYDRO WINCH DATA – BLK ┘

YEL ┐ RM YOUNG WIND RS232 TRANSMIT
RED ┘ RM YOUNG WIND RS232 GROUND

GRN ┐ GYRO RS422 ┐ (TOP LAB RPTR TO
RED ┘ GYRO RS422 ┘ ELECTICAL LAB RPTR)

BLU ┐ MARKEY DISPLAY SERIAL DATA XMIT ┐ (TO MAIN
RED ┘ MARKEY DISPLAY SERIAL DATA GRND ┘ J BOX)

WHT ┐ –
RED ┘ –

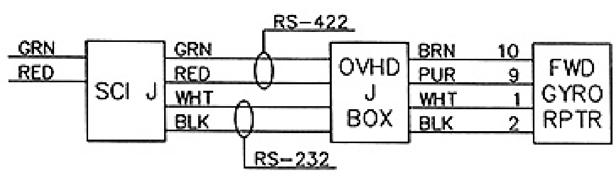
### DATA BROADCAST WIRES

BLU ┐ GPS P–CODE RS232 SIGNAL ┐ (TO NEAR SAT–B
GRN ┘ GPS P–CODE RS232 GRND ┘ VIA RS232 JACK)

WHT ┐ GYRO HEADING RS232 SIGNAL ┐ (SOURCE FROM
GRN ┘ GYRO HEADING RS232 GRND ┘ REPEATER)

WHT ┐ ATHENA DISPLAY OUTPUT
BLK ┘ ATHENA DISPLAY OUTPUT

NOTES:




## 6 - PAIR

### POWER PAIRS

RED ┐ IN RS485 LOOP PWR +12VDC
BLK ┘ RS485 LOOP PWR GROUND

WHT ┐ IN GEN PURPOSE PWR +12VDC
BLK ┘ GEN PURPOSE PWR GROUND

### GENERAL PURPOSE PAIRS

BRN ┐ IN/OUT +24V FROM DK BOX (BRN)
BLK ┘ IN/OUT GRND FROM DK BOX (RED)

YEL ┐ IN/OUT TRANSMIT FROM DK BOX (YEL)
BLK ┘ IN/OUT RECEIVE FROM DK BOX (ORN)

GRN ┐ IN/OUT GRND FROM DK BOX (BLU)
BLK ┘ IN/OUT –

BLU ┐ IN/OUT –
BLK ┘ IN/OUT –

NOTES:

SEE PROPULSION ROOM WIRING
FOR PIGTAIL COLORS TO FANTAIL

BETSEY DOHERTY date: 10/20/98
file: CompLabWireList rev: –
ATLANTIS

# SEANET – Extending The Internet To Oceanographic Research Platforms

Andrew Maffei & Steve Lerner
Woods Hole Oceanographic Institution

**[Editor's Note: The following is a transcription of Andy's oral presentation.]**

I'm Andy Maffei. I work at the Woods Hole Oceanographic. I work with Steve Lerner. Steve and I are both giving this talk, although I'm the one that's talking. I'm going to talk about the SeaNet Project, which is a project designed to begin bringing internet-type capabilities -- shoreside internet capabilities out to ships.

There are five organizations that are the SeaNet partners. It's funded by an ONR National Ocean Partnership Program grant for two years, starting back in August -- last August -- '97. The five partners are the Joint Oceanographic Institutions who are handling the administration of the funds and then also acting as liaison with the various agencies and the other ship operators -- academic research fleet operators. Ellen Kappel is at JOI.

Steve Lerner, myself and Cindy Sellers are working at the oceanographic to develop what we call the SeaNet communications node, which ends up being the building block for building our SeaNet network. It's a piece of software that I'll talk a little bit more about.

Lamont-Doherty Earth Observatory with Dale Chayes and Dick Perry -- some of you may have seen Dale at the RV Tech meeting where he gave a little bit different presentation about SeaNet. But Dale and Dick are responsible for installing systems on board the five ships that have been funded to have systems.

The Naval Postgraduate School -- Rex Buddenberg -- Rex is the liaison with the Navy fleet. He does the forward planning for new wireless technologies -- forward-looking, really. And he also has a test bed there with a bunch of graduate students that can run little projects on it.

And Omnet, Incorporated is the commercial entity that is playing the role of internet service provider for SeaNet, and also looking at commercial opportunities. The idea behind SeaNet is that we would like it to become self-sustaining at some point.

This has kind of been the ongoing vision for SeaNet; the idea that you could have AUVs, buoys, ships and shore all tied together with internet links where you could get easily to these different platforms. The SeaNet project -- the idea was envisioned back at WHOI back in 1990, actually, when I was doing some work with Ken Stewart where we just ran a 9600 baud link out to a barge. It's progressed through a pilot program where we installed the SeaNet system on the Thompson, and then on the ocean drilling ship. And then most recently, back in August of '97, we got the NOP funds, and we've been working the last year on getting the systems ready, and just beginning to get them deployed now.

Current status -- the five UNOLS vessels have been identified. We currently have a beta system running on the Atlantis. We're gathering statistics on the satellite system. COMSAT has been helpful in doing some free time for some of the system testing. We can thank Carol Olson for that. We're also in the process of installing the other systems -- doing the planning of getting the NERA INMARSAT-B systems installed, and we're hoping to be operational by the end of January '99.

This is a SeaNet communications node. It handles -- its functions are to handle -- where did that -- Bob Elder -- well, I'll have to look for my pointer. Oh, here it is. All right. So it does the wireless link management. This is the first time I've used one of these [laser pointers]. It's kind of fun. -- provide tools for cost-efficient use of the link. I know they're banning them from schools these days because kids are blinding each other. It also does the accounting. One of the major parts of the SeaNet -- all of you have dealt with INMARSAT accounting and such -- but being able to provide some information back to users about how the link is being used, by which investigators. It's designed for modularity. The idea behind the SeaNet project is that we wanted a system that others could add to.

We're hoping that after the initial infrastructure is there that it also -- the SeaNet communications node will provide the foundation for future science applications. I'll talk a little bit about that, but not much.

As far as what's delivered to the ship, there's a UPS, which is part of the system, a SeaNet communications node, which is a PC running LINUX, and also with our web-based software built in Pearl actually, a Sisco (ph) router, and then these are the wireless communication devices that are part of the SeaNet project right now -- a NERA INMARSAT-B high speed data system, an AMSC unit which runs at 4800 baud -- this runs at 64 kilobit -- and then a cell phone interface. The idea is that you should be able to do the same functions no matter which of these interfaces you're using. And we're hoping to expand that.

PARTICIPANT: Can you just tell me what AMSC is so that I know?

MR. MAFFEI: What is AMSC? American Mobile Satellite Corporation. It's a satellite vendor that sells time on a geosynchronous -- yeah, sells time on a geosynchronous --

PARTICIPANT: So it's INMARSAT compatible?

MR. MAFFEI: It's continental U.S., so it only goes 200 nautical miles out of -- it's for coastal applications.

Now, the SCN, one think you realize early on is you're paying all this money for this internet link, and you're not going to be doing a whole lot of browsing on it. So there are three different modes that this SeaNet communications node, this box that sits on the ship, provides.

One is a batch transfer mode, something we call "data pipes." The idea is that you identify a source directory and a destination directory. Those sources and destinations can either be on the shipboard LAN or on the shore, and you match them up. And you can have several of these. The idea behind the link is that you configure it at the beginning of a cruise so you've got these directories matched. When it comes time to do a transfer -- the system on the ship -- you initiate it from the ship -- the system on the ship gathers together all of the information from the source directories, packages it all up together, compresses it, brings the link up, and transfers it back to shore to another system sitting on shore. And then it terminates the link. And then that system on the shore redistributes the data out to the internet, because you don't want to take -- affected by the internet latencies. And the same thing happens in the reverse direction, as well.

WebMirror is an idea where you can, if you had a shipboard web site, that you could mirror it back on shore so that folks back on shore can take a look at a web site, and they don't have to actually connect to the ship in order to see the web site. And again, the same thing can happen from the ship back to the shore. So that's another mode.

And the other one, the third one, is the interactive IP. And then we just rated these in terms of cost-efficiency. It's best if you package everything up, ship it over fast. It's somewhat worse, but better than this to do the WebMirror, and the interactive IP is the worst in terms of cost. In terms of convenience, it's the opposite.

This is an example of the data pipes, just identifying the sources and destinations -- how it would be set up on the ship -- and then the link would come up and transfer the files between the two.

This is an example of the SeaNet operations screen. This upper corner is where the main menu is. When you touch on these buttons -- it's all web-based -- then you get the secondary menus down here, and then these are your two operations screens. This is showing a queue of files that have to be sent out, and this shows the output as those files are being transferred back to shore. But that's a little bit complicated for normal operations.

So normally when you're doing a batch transfer or an interactive IP session, you're using one of these simpler screens where you get some feedback in terms of what link you're using, the VHSD -- it's state is up -- telling you how much money you've spent so far. The data rates are actually wrong. Data rates tend to run for the INMARSAT-B somewhere between 55 -- 55 kilobits, something like that -- 55 to 60 kilobits per second when you figure in the overhead. So in normal operations, you're using one of these screens to do your daily operations.

One of the things we're particularly excited about, and I'll be able to show you some information on it, is we've set up some benchmark tests -- some standard-size files and pings that get done so that every once in a while you can run a benchmark test on your system. In fact, that can be done automatically, so you can gather your statistics regularly. So that's something that came out of a workshop that we held a while back, and that seems to be working quite well.

In terms of wireless links, these are the three that we're implementing as part of SeaNet right now -- the NERA INMARSAT-B. American Mobile Satellite -- there's a Canadian company called MSAT (ph) that provides a similar service -- cellular telephone -- these are two -- the 915 megahertz spread spectrum technologies that we're doing in other projects, particularly for coastal -- short-range coastal applications.

And these are things that we're interested in, as well. I'm particularly interested in finding out if there's some way someday for us to find a shared use satellite channel where oceanography could have a single channel that could be shared among many ships. We're still looking to find that, but once these SCNs are on board, you have a common platform that you can begin implementing that sort of thing on.

This is the NERA systems that are installed -- the above-deck equipment and below-deck equipment.

This is -- we've had the system running out on the Atlantis for the last month or so. We've been collecting satellite statistics every 15 minutes, and then two or three transmissions a day sending the information back to shore, and then gathering it in a system that we've developed to analyze some of that data.

So this top plot has signal-to-noise here, and has time and days across here. What it shows -- the top one -- is the signal-to-noise ratio. So it starts out very high, drops down low, and then it ramps up. And then you begin to get this chaotic action here.

PARTICIPANT: Do those figures on the scope refer to the ones you get on NIMOS (ph) -- on the NERA handset?

MR. MAFFEI: That's right. The output from the handset, or in this case, we're able to do it through the data port -- get the information out of there.

And the if you take a look at heading -- this is a plot of heading. We're sending back heading information, as well. There are a number of parameters that are getting sent back regularly. You can see it stays low, and gets pretty stable up in here, and then it goes chaotic here. And this is, in fact, showing the effect of obstructions on board the deck. What we're beginning to do is gather the statistics. And what you're seeing is -- you know, as you get obstructions, then your signal-to-noise goes to crap, and then -- you know, that's what happens here.

But the more interesting char- -- see, because this ramp up -- and we were wondering what that was all about. What we did was we plotted -- in this package we have we were able to plot the signal-to-noise on a TUTI plot. And what you see is the signal-to-noise steadily gets better as it gets towards the reds and oranges. It's higher signal-to-noise. And what it's doing is heading towards the equator. And as it heads to the equator, the elevation raises, and you have less atmosphere between you and the satellite, and your signal is improved.

So that was kind of reassuring to see that -- that we’re getting some consistency out of the data. And the particularly exciting thing for us is to think about having five ships. This is just one month’s worth of data. But if we get systems installed on five ships and we begin to gather statistics, for example, on file transfer rates and such and can easily plot them, then we’ll begin to get an idea of what the performance on some of these satellites are and what type of -- you know, and how that’s all working.

Now, in terms of future possibilities for SeaNet, there are some ideas we’ve had. As I said, one of the main ideas is that we’re going to create this infrastructure that people can use and begin to do these things pretty regularly. What we’d like to begin to do is to begin moving science applications over to some of the -- Barrie was talking about his data collections systems -- the Athena system, and such -- getting those types of data systems integrated, as well, so that data can be regularly transferred back and we can begin to get a shore-side presence of what’s happening on the ships -- more from the science side -- I know -- there have been a lot of projects recently, for example, where newsletters have been put together and you get an idea for what’s going on in words. But it’d be nice to get some of the data representation back on shore, as well.

We’d also like to investigate the possibility of a shared access communication satellite. We’re also quite interested in identifying more cost-effective wireless options as they become available.

I mentioned the science applications. In other projects that we’ve worked on, we’ve been working on things like a data logger, an event logger, and a data logger (sic). These tools put out the data in the same way that we’re collecting our signal-to-noise data and all that -- other things. So you can use the same tools to plot it and to access that information. We’d like to see ourselves and others developing these same sorts of tools so that they can add to these shipboard web site type ideas.

This slide shows what the -- at Omnet, which is acting as our network information center -- that’s a key to the project, as well, is the idea of having 24-by-seven coverage there being a network operation center, so it’s someone to call when things go wrong. They’ll have someone on call all the time. They provide the shore-side internet connection. They also -- the way the billing works is that any calls that are made from the satellite, in the case of the NERA, any calls that are made from the NERA unit back to the SeaNet site get billed to Omnet. Then Omnet does the detailed billing out to either investigators or to institutions. Any calls that aren’t made to that SeaNet site get billed directly back to the institution itself.

As I mentioned before, Omnet is also looking at SeaNet expansion, finding commercial entities that are interest, also other agencies that are interested in similar systems, similar capabilities. And for more information, there’s the web site, which is www.seanet.int. You can also contact Susan Covaney (ph).

And there’s an internet at sea mailing list that we just started up. There are actually several internet at sea programs. I know NOAA has one. Dennis Shields is here. He’s been involved in that. The Navy has an ADNS (ph) program. It’s interesting to share information with those folks. So we’re putting that list together, as well.

So that’s it.

MR. WALDEN: As Andy said, Steve Lerner is also here. Steve, would you stand up so that people can take a look at you. If you have any questions during the break, for instance, you can talk to Steve just as easily as Andy.

MR. MAFFEI: The talk feels a little bit dry, too, after having given it, too. The other thing is that if there are folks that are interested in seeing the front end and seeing how it works, we do have a working system on a notebook. If people wanted to take a look at it this afternoon or something, perhaps we could find some time to get together with a few of you. So just talk to either Steve or myself. We’d be glad to do that.

# The National Oceanographic And Atmospheric Administration (NOAA) Scientific Computer System (SCS)

Dennis Shields & David Benigni
Office of NOAA Corps Operations

**[Editor's Note: Following is a transcription of Dennis' oral presentation, with submitted graphics.]**

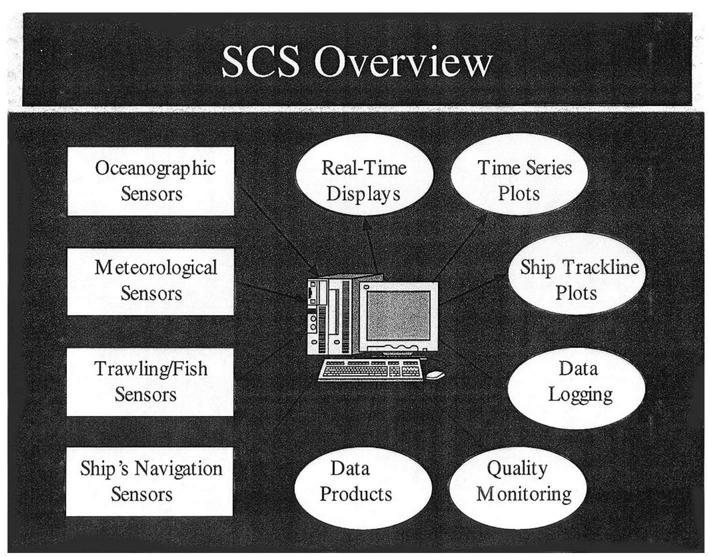
My name is Dennis Shields. I work for NOAA, for the office of NOAA Corps. I've been in the data acquisition business probably for about 15 to 20 years working for NOAA, building systems for them, starting on PDP-11s and working through our current generation, which is in Windows NT.

What I'd like to talk to you today about is a system we call the scientific computer system that has its origins back in 1989 when we put the first system on the NOAA ship Researcher based on a MicroVax computer. The objective of that system was to design a system that would be flexible enough so that, without writing any additional software, we could interface sensors on any given ship, bring the system up, and have it function, and be able to propagate that system to all of the NOAA vessels out there.

So we started this process back in 1989 using a MicroVax. And as time went on, we've kind of improved it and changed the way it looks and feels, specifically trying to make it a lot more user friendly.

Again, the objective is basically to be able to acquire data from all of the ship sensors -- the standard suit of sensors, if you will, that exist on a vessel. This includes the meteorological navigation and oceanographic-style sensors that are available.

This is a basic overview of what the system tries to do. Here's the basic computer center, at the acquisition, if you will, and the various kinds of sensors. We use this system a lot on fisheries vessels, as well. So we have a lot of trawling and fisheries sensors that interface to it. All basically are acquired by the primary system, and then from there, the system provides real-time displays, time series plots, track lines. Obviously, it logs the data in a variety of different ways and does real-time quality monitoring of the data to look for range and delta-check kind of problems, or time-outs where a sensor goes out to lunch, and then produces finally data products for the user. So that's kind of an overview of what SCS tries to accomplish.




Its primary function is to acquire real-time data. The acquisition process is based on the concept of what we call the sensor configuration file. When the system is brought to a new vessel, you accumulate all of the various kinds of sensors you want to install, and you build this configuration file, which I'll show you later, telling it what port the data's going to come in on, what its name is, how you want the primary message broken down into components, or "children," as we call them. And then after you've built this configuration file, when you bring the system up, it basically self-configures and is able to acquire data.

We log data to the system in -- we've kind of changed the method we've done that over time. Originally, we would accumulate data from a whole bunch of different sensors of a type, like a navigation type, and log it. But we've gone to a simpler system now where every parent sensor, if you will, the data that's received from that sensor is acquired, and time-stamped, and placed in a single file. The files accumulate over time with time stamps for when the system starts.

So at the end of the cruise, you end up with maybe five or six different files of your tuned out (ph) GPS navigation systems and a gyro file. We found that this is a simpler way to organize the data over a long term as you acquire the data for a whole cruise.

The real-time displays and graphs, basically, have been around since the beginning. That's the concept that -- and at some point on the vessel, wherever you're working -- the labs, or on the bridge, or wherever -- to be able to bring up a customized display of the information you're interested in watching or being able to glance at while operations are underway. So every component in SCS is basically broken down into what we call a sensor ID. Latitude, for example, would be an ID -- longitude or sea temperature. And so the user can customize what pieces he'd like to look at at any one time and on any display.

The same concept is used for the graphics -- to be able to track over time time-series of data to compare multiple temperatures or wind parameters or air temperatures, what have you, the time series are used for that.

We have a kind of a unique -- or at least it's kind of new to us -- method of logging data we call event logging. This came about with a lot of brainstorming we did with our northeast fisheries folks up in Woods Hole. In terms of -- the data sets that they were interested in sometimes dealt with particular times during a cruise. They really weren't interested in data for a whole 30-day cruise, but they wanted to have a very active data logging process underway when, say, a net went in the water, when a tow was underway. And then when the tow came out of the water, they wanted to stop the data collection.

As well as getting the automatic data for that event, they wanted to be able to log information that dealt with -- the net went in the water, the tow began, it's at depth, it tore, it twisted -- to be able to track everything that occurred during an event. And so we built this system, and I'll try to show you that later on in the presentation, where a scientist or the manager of the system can basically configure an event from scratch, tracking certain metadata information about the sensors he's interested in, as well as building live buttons that allow you to trigger time stamps and put information in to track an event as it's underway.

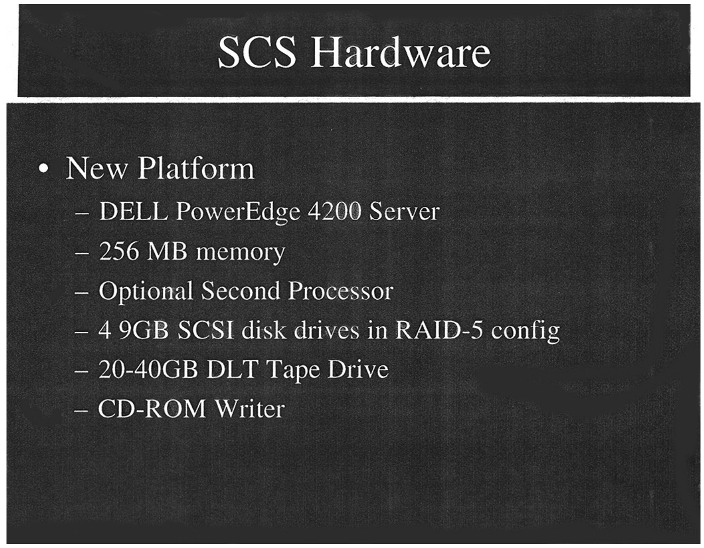
Of course, after you've corrected all this data, other people want it. One of the methods that we provide the data to people in real time is we basically feed information back out to them with serial ports. So a PC, or a Mac, or a Sun System can basically just have a serial hose where we -- they tell us what information they want us to send, and we go and send that information to them.

At the end of our day of logging, we want to do some QA processing. Typically, it's basically to do some -- what we call "newspaper plots." On a daily basis, we try to plot out the time series for the given day or for the whole cruise, and have them typically ready in the morning so people can view them and see that the system is functioning and all the data is being collected correctly.

And then, of course, at the end of the cruise, PCs make things a lot easier, and the technology's changed. We try to be able to put data out on writeable CDs, so a scientist can walk away with one or two CDs that would have all its data on it, possibly a ZIP drive or a JAZ drive is also supported. That's kind of the basic things that it tries to do.

The current hardware platform we're using is basically a dual configuration of Dell Power Age 4200 servers. These are 300 megahertz servers that have a rate controller in them with about 27 gigabytes of disk space. We actually had a cruise where a scientist at the University of Washington didn't have enough disk space even with the 27 gigabytes, which was amazing.

So we're using that server as the primary acquisition system. We have a second system identically configured similar to Barrie's so that, if one system goes down, the other system is available there to be able to use as a hot spare.

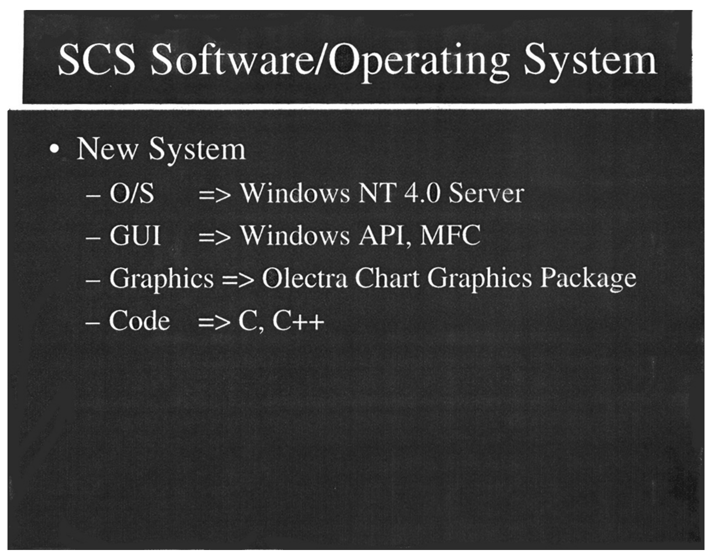


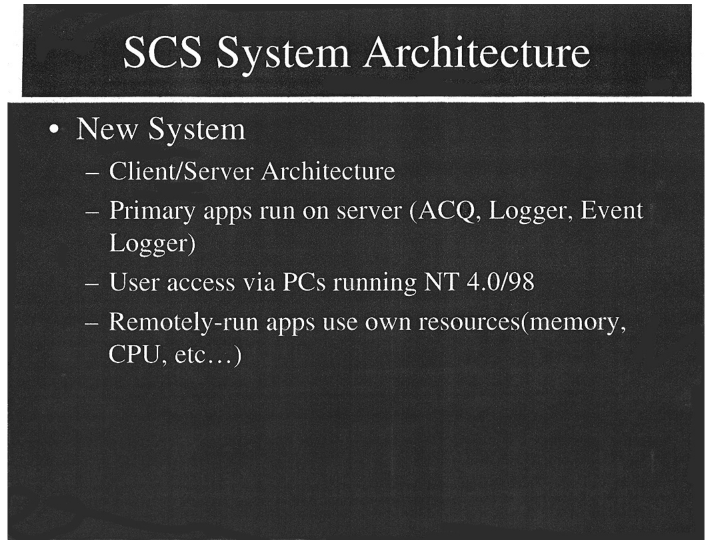

We haven't installed the second processor yet because we really don't need it. The acquisition system takes about five or seven percent of the CPU when it's fully running.

We use the DLT tape drive as a backup method to be able to pull the data off the system on a daily or weekly basis so that we can capture the data and ahve it someplace safe. That's basically the hardware configuration.

The minimum platform that you can run on is -- I designed the system on a 166 megahertz Pentium, with 64 megs of memory, and enough disk space to be able to store the information, and a simple serial port device of some type. As you'll see in a few minutes, we have two kinds of devices we use, either a port server which hangs on the network like a terminal server, or directly connected instruments. So that would be about the minimum configuration. I was thinking on the way in when I was setting up that actually this Dell 266 portable and port server that hung on the network would effectively be an entire system. You really wouldn't have to have too much, as long as you could get a large enough disk drive in here to be able to collect the data.

The operating system of choice -- we started back in 1989 with VMS and Digital, and we moved through to X-Windows and Motif, and we've finally made the port over to Windows NT. We're using the Windows generic API with -- the foundation class calls for making the windows happen. We use a package called the Olectra Chart, which is made by K&H -- K&L? -- K&H industries, which basically runs on NT and allows us to get our graphics up and running a little faster than doing it from scratch. All the code is based in C and C-plus-plus.



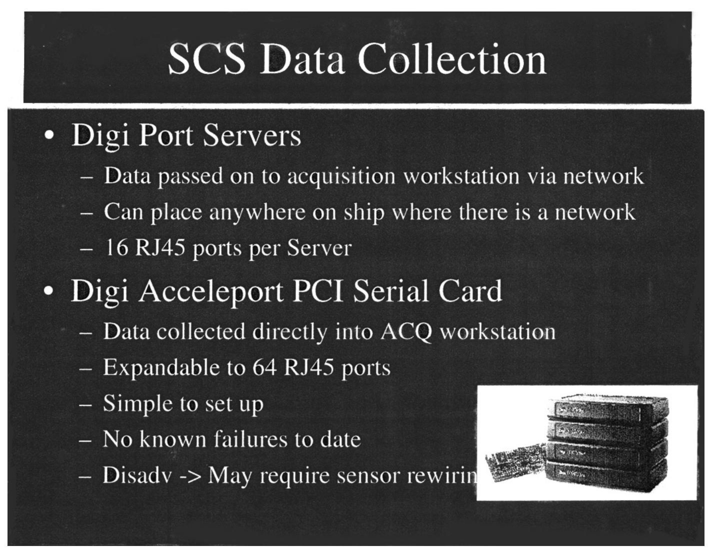



The system architecture is basically a client-server architecture, where what we try to do is have the data acquisition system be acquiring the data. In the old days, on the VMS world, everything occurred on one box. The worry there was, if you had an ambitious user of some type who brought up ten or 12 times series plots and was doing a lot of things on the system, you could affect the acquisition process itself over time. You really wanted to get away from that. So client-server seemed to be the way to go.

In the current configuration, the acquisition system basically acquires all the data. It has the ability to do all of the display functions and rendering of graphs, but instead of having it be the primary source, it provides a thing we call the data server. The data server is available to anyone on the network who sets up his PC, essentially makes a pipe into the data server, and has the data automatically sent out to him. So all the applications run out on the PCs. What we find that way is if you go to crash a machine, it's going to be some client PC, and it's not going to be the one that's doing the real work. So that's been a big thing.

I'll look at that again in a different way with the acquisition system. You can see the configuration file that's critical to describe how these sensors are going to be interfaced. The logging occurs, and the quality checking occurs off of a log file. So we're not just looking at data as it comes in; we want to make sure the data is actually on the disk. So we have this process that kind of follows behind acquisition, reads the data files, and determines whether or not the data is there and is valid or not.

And then the real-time display -- the real-time memory share is basically where all the data is dumped. The client-server -- the data server basically provides all these applications out on the network on somebody's PC.

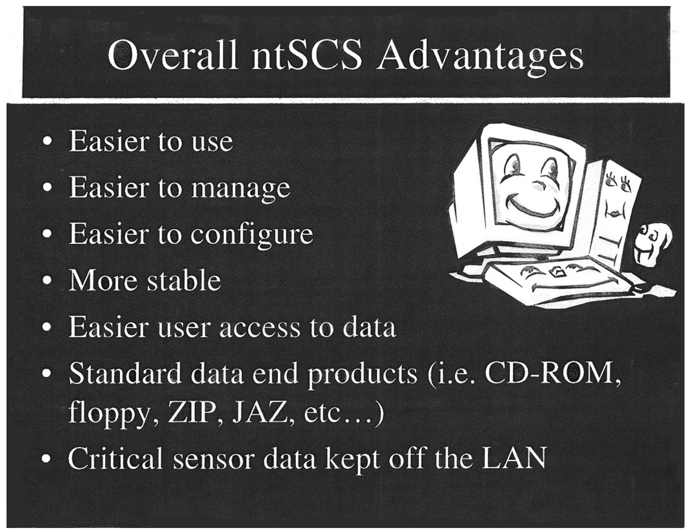



We use two kinds of serial interface devices, if you will, to acquire the data. The first is the Digi port server. These are both made by Digi Data, or Digi International, I guess, is its new name. The port server basically hangs on the network. It has a TCPIP address. There's a piece of software you install in NT, and then it has its own protocol between that and the port server. To the programmer or the coder, it basically looks like 16 COM ports, and you really don't know where they are on the net, but they're out there.

It has some inherent advantages in that, if you don't have a lot of ability to run wiring, you can just plug one of these servers in there where your sensors are -- plug them in and go. We have also been doing the terminal server business as a method of interfacing since 1989. Over the years, we've found, though, that if you put your entire system out on the network, then the network becomes part of the complexity of the system, and then over time that complexity will eventually bite you. It won't happen the first month or the second. It may not happen on a given ship. But with five or six ships out there, if you have everything dependent on the network, sometimes you can get hit.

So the other method we use is the direct connection method. And here you see what we call the black boxes, which are basically 16 port interface devices that plug into the card directly inside the machine, and then we run all of our sensor information directly into that. So it eliminates the network as a possible source of failure. But both methods are available, and certainly in a small configuration, one port server and a small PC get you up and running.

Here's just an example of that where, if you were on a vessel that had a network connection to the bridge but it didn't have any real wiring, and you didn't want to run a 15-pair cable from the bridge down to the computer room, you could plus the port server in, interface whatever sensors you had there, maybe drop another port server down in lab area, and then connect your computer on the network, and you'd be up and running. The preferred method, like I said, is to put -- for permanent installation -- is to put as many of the connections in directly as possible. It limits the amount of complexity.




Our overall objectives of what we try to do with SCS is ease of use. Over the years, we've constantly tried to make it easier. The graphics interface helped a lot. And Windows NT, we've found, has been incredibly successful, and that users that come out, they pop onto a PC, they log onto Windows NT, and all of a sudden they're at home. They're familiar with a PC and its environment and how to make things work. So we have a lot more interest in using this system because it's not a foreign platform to them. So that's been a good thing.

It's easier to manage with NT in the way we've configured the data sets. This ability here to be able to interface new sensors without any code -- we've had people call us up and say, hey, I have this light sensor I'd like to interface. I hear we can do it on your vessel. I would ask them questions -- basic questions -- about what type of data is it? They would say serial or NEMA. And I'd say, well, you should just be able to interface it. Where's the sensor now? We can check it for you. Well, it's on a barge heading to Alaska. It'll be there two days before the system is -- the ship leaves. We've been successful with that, where sensors arrive the day the ship leaves, be able to plus them in, and actually be able to acquire the data from them for the whole cruise.

Stability. The system's been running now operationally for a year on the Ron Brown. We have had no failures of either hardware or software out there. It seems to work well. Currently, we have it on six vessels, and we plan to put it on four more.

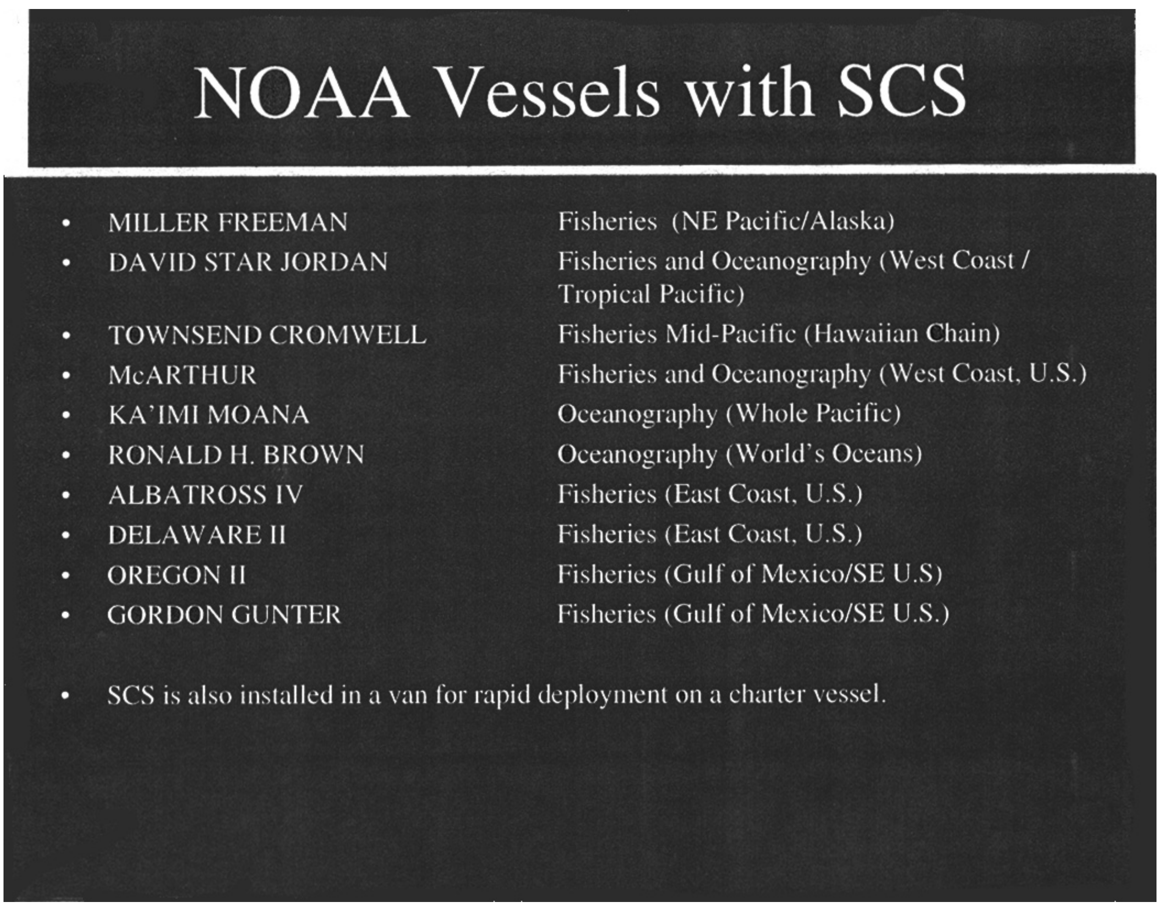
The user access to the data is basically through Microsoft Share. So it's a PC-based system. But we also have the ability to use the NFS capabilities, so UNIX boxes can map to those shares and be able to pull the data over. All the data is ASCII, so it transitions from system to system without any kind of problem. And then the end products, I've already mentioned, are CD ROMs.

We try to keep a backup of the critical data after it's been acquired. So we use that backup system as a -- every day we move the data from the primary acquisition system to the secondary, and we allow the users access to that data set as a standard way of getting to the data. That way, there's always two backups on the system at a time. You can tell I'm kind of paranoid about data.

The real-time plots basically come in three varieties -- time series plots, where you can plot up to four sensor values at a time. The track line program, which can -- you can run your track line, as well as your coastline, as well as your satellite information. We have two kinds of track line programs -- the one that's built into the system, and then we're also using ARC View and building it -- we have a GIS track line where -- we're just starting in that world with the GIS, but we can upload and overlay satellite images, or if you've had some contours of the bottom and you can get them into the right kind of file, you can upload the contours and basically have your track line run across those layers. So we view the GIS as a growth area where more and more of the data can be displayed and the GIS environment become a good management tool and a good information tool.

The event logger I'll show you when we do the little demo. This program here is called the "send SCS message." It's basically the one that allows you to send data out to other PCs. That can be done in either an automatic method where it's updated -- you ask them to send you data or every second -- or polled, where you've written an application to where it'll go out and request data at a certain time during your -- whatever acquisition you're doing on your PC or your box. So you would send a command in to the system. The system would then respond where the data was collected -- effectively, a poor-man's network, if you will, of sharing information.

These are the NOAA vessels that the SCS system is on. Some of them have been in the system since 1989/90 time frame. Miller Freeman's on the SCS system from way back. A couple of our new vessels, the Gordon Gunter and the Ronald H. Brown, are also running the Windows NT. You can see it's a mix of both oceanography and fisheries vessels, and vessels that do both.



Because of the portability of it, we've also been able to install it in a van. NOAA gets involved in charters where -- pretty rapid staging to go out for a vessel and (unintelligible) pop the SCS system in and at least be able to collect a few sensor at a time.

I kind of made it -- that part of the presentation pretty fast, and probably talked pretty fast, too -- the idea being that I'd maybe give you a few examples of what the system looks like. This is where Murphy may strike. This is large software, so it's hard to tell.

The program I'm bringing up now is called a configuration file editor. That's basically the program that -- well, let me stop talking for a minute so I can concentrate.

That's basically the program that configures all the sensors in the system. This is a new program written by one of my co-workers, Tom Stepka. It's object-oriented, and it uses all the latest bells and whistles in NT.

You can see there that the sensors are -- the ones with the plus signs are what we call "parent sensors." So a Trimble GPS, you'd be describing what you wanted in the GGA message, and then you would maybe extract out those particular pieces of information that you wanted to track separately in either logging separately or being able to display them separately. For the parent, you would fill in information dealing with communications, what COM port it was on, its parity, how long the record was going to be, how it was terminated, and what the sentence label was. And SCS basically can handle any NEMA 183 format quite easily, or anything that even looks like a NEMA 183 by using this sentence label to discriminate between messages.

And then the amount of samples you want to keep in memory, which we call "history elements," the logging rate -- we built some support files, as well as the primary parent files, one of these being the lab file. A lab file is basically, hey, I need a quick and dirty file that I can plot easily to look at some of my data without waiting ten minutes for Windows NT to load in the megabytes of information. So we have the ability to say, well, I want you to decimate that by 30 so that it's a smaller data set so I can get a quick look at the data.

We also have some other log data files that we call "compressed" which take critical pieces of information -- I guess I'll move over here. You would pick a piece of information you wanted and include it in the compressed file. And then these small ASCII comma-delimited files would be available to the user right away. All that information is sharable on the net so that you can look at the data effectively as it's being collected.

So the NEMA information is one type. These are actually the large sensors installed on the Miller Freeman right now -- I just pulled its file up -- a variety of different kinds of sensors -- Ashtech 3DF (ph), EK500, depth sensors, gyros, barometers, thermosalinographs.

In terms of CTD, in the early days of SCS, we used to actually have interfaces directly to SeaBird. So we would do the same work that SeaSave is doing in terms of acquiring the data. And we decided over time that it was much better to let subsystems do their thing, because subsystems work better, and they're supported by the manufacturer directly. But we felt it was useful to everyone on the vessel to be able to get sub-samples of that information. So in the case of CTD, we use one of those extra serial ports on the back, and we pull out a sub-sample every second, acquire that data, and then, of course, that's available for display in graphics around the vessel. It's used a lot when you're towing CTDs and you want to get them close to the bottom. You can be tracking on a time series two or three depth sensors on the bottom, and then watch your CTD come close to the bottom, and then go back up.

In the world of nets, when we were first testing this technology, we'd watch the MOCNES net drag right through a small little rise in the bathymetry. We'd draft it out, ran down to the fantail to find out, and sure enough, everyone was unhappy because they tore the nets. But we were ecstatic because we had proved that they were going to tear the net.

They weren't real happy with us that day.

So for sub-samples ADCP, we basically try to take the NEMA messages that are out. In the old days, we used to work with getting the ensemble messages in from the narrow bands, and building structures, and using them in that way. But we've kind of fallen back from that, and felt that subsystems are appropriate and leave the data on the subsystems and collect everything else. There's certainly enough available.

PARTICIPANT: How does it work when you've got to interrogate an instrument in order to (indiscernible)?

MR. SHIELDS: A polled sensor? Yeah. Let's see. I have one of those here. They're becoming less frequent, but they -- basically, there's a sensor-type -- that's a NEMA -- but basically there's a sensor type we call "polled set serial." One of the items in the polled serial was the window down here called "command prompt." You plug in the command prompt and how often you want the data to be output, and then it shoots it out and gets the data back. That's called "polled serial."

PARTICIPANT: So how do you place to analog -- things you analog -- outputs? Do you use something like in-pattern (ph) module, or --

MR. SHIELDS: Right. We use a device that converts it from analog to serial. It's either a poll device where you would actually go and request the information when you wanted it, or it would be one that would just stream information to you. We also cheat. RS485 -- we use converters. BCD -- we'll use converters into kind of a poll thing using a kinetic box or something. We try to keep everything in the serial world.

When we first started, we had A-to-D cards and all those other things -- synchro cards inside the system. And over time, we realized that simplicity is good. It keeps the system from breaking -- hardware and software. So that's the configuration file.

We use the standard menu. So if this was a PC on the vessel, everyone on the vessel would basically get this menu. And the menu would have -- is basically controlled with password controls. So if you were just the standard user that wanted to look at some displays or times series, certain items on the menu would be blocked out to you and you couldn't get to. If you were the manager, then you can go in and enter the appropriate password, and the system would then be available to do things like starting acquisition or stopping it.

We added voice to this so that -- what typically happens is this system runs all the time. If you have an error that would occur in one of the windows, you may not look at it because you're not -- you know, there's a lot of other things going on on the vessel. You're not really paying attention to your sea temperatures all the time. So when an error occurs or when the system detects a decoding problem, it would make a sound for you. Of course, we have these original sounds -- "Warning: Please have the EQ look at this information. There may be a problem." And what happens is, since we made them little audio files, people immediately change those files out, because they don't want those. They want things like, "Bud-weis-er."

So you get some really unique sounds. But you sit at the computer doing something, and all of a sudden the computer starts talking to you. Maybe you've had some rough weather, and your GPS is not quite coming in as well as it's supposed to, and you'll get the computer start talking to you. You can really freak people out if you don't tell them about that until the error occurs.

So we've done that, and we haven't added it or propagated it to a lot of our other software, but we're hoping that our data monitoring software will also talk. And it was quite simple to do using threads in NT. You could just say, well, just launch that thread and go say some sounds, and leave me alone because I'm doing real work.

The acquisition system comes up and basically shows you what logging data is being acquired. These are the raw data files that I mentioned. For each kind of sensor, there's a data file that's created with a time stamp. Any messages would occur here.

This is our -- what we call our logger control. Basically, it lists the raw data that's being logged to the system. I'm running this using a built-in simulation so that I don't have to have any sensors attached. It's one of the traces in the configuration. But the red lights mean I've never received data from this sensor. So I've never really touched a file and logged anything. So that's obviously a concern.

The yellow means that I have received data at some point, but in the last second, I didn’t receive any data from the sensor. So things are probably okay, but make sure that I turn green at some point. And, of course, green means that I’m a data-hungry sensor, and I’m logging once a second, and I’m always acquiring data.

The record size and the total number of bytes acquired is listed there, the free disk space, which doesn’t look quite like a right number, but is supposed to be listed up there so you can kind of monitor what’s going on in the system as it acquires data.

So these are your basic displays that come up when acquisition starts. These are errors that occur because I don’t have any COM ports attached. I’ll get rid of those. So a basic real-time display -- if I wanted to go in and -- I was a new user but I wanted to track individual pieces of information, I could pick the -- you know, latitude, longitude, maybe both lat-longs, the wind direction, sheer wind speed, pop ’em over into window, save it as UNOLS, and then pop up to display, and find UNOLS, and up would come the display. And of course you could look at any pieces of information in the system. If they have an ID number, they can be displayed, and you can customize these screens any way you want.

The whole system tries to use the same look and feel that I just went through where you basically get a list of all the ID numbers, you select the information you want, pop it over to the right, and then save it as a file, and it becomes a configuration file.

One of our programmers did something that we thought was really cool and decided to build gauges into the system so that you now had the ability to look at gauges. It’s just another way of rendering the information. It comes basically in two types. It looks like -- I don’t know if that’s a temperature sensor or not -- yeah. So it’s possible to now build like electronic instrument panels, if you will, of some of the information you want. Instead of looking at a number -- you may not have time -- you can just look up and say, yeah, that’s where the wind’s coming from, and make it as large as you want.

The time series stuff is pretty standard. It’s all using this Olectra Chart Graphics as the tool that we used to build it. I’ll just try to show you one real quick if I can get one to work. I think "demo" works. I’ll give that a shot.

It’s going to plot two GPS sensors on the single curve. I’m trying to go fast so I don’t mess up on the time here.

Let me go over and show you a little bit about event logging, because in some ways I find that that’s one of the more interesting areas. This is called an event builder. So you come on the vessel, you go to do some kind of experiment. You could be wanting to do -- you want to track that experiment while it’s underway. So you go in and -- I’ll pull one up that already exists. You decide that, I want to track this header information. So you add information in there -- I’d like to know the serial number of the TSG, the CTD number. I want to be able to track who the captain is, what the crew’s ID is, what kind of GPS sensors I have on board. And you plug all this information in the header, and when the event is run, the user sees a presentation of this and has the ability to either fill it in or verify that it’s correct, depending whether you’ve made it -- you’ve filled it in up front as a default.

In addition, you can plug in these buttons. I’ll go ahead and add a button called "hello." You can make the button a modifiable repeating, meaning that -- you know, maybe you want to allow the user to only hit this button one time, or maybe it’s an event that’ll occur multiple time.

Then, of course, you log data. I’ll just show you kind of what they look like. Similar to the same -- hours, minutes and seconds, the amount of data that’s going to be logged, the name of the file. And now you’re events-ready, basically. So you go off and run the event and be able to make these statements.

We’ll go ahead and save this. No, can’t think of any reason why I shouldn’t. Still waiting for Murphy to strike.

Okay. So the event logger -- we’ll go ahead and start it. What you see are all the events that have been built that are already available to you. And there’s way too many here. It’s all the demos and testing we’ve done. We’ve been working with Brookhaven.

So go ahead and initialize the event. And the first thing you see is the presentation of the header. Now, typically, you would go in and you would put all the information you could right up front at the beginning of the cruise and have it available, and you would see it in a greyed-out fashion. But you’d also have the ability to modify it if you wanted to. It comes in both a list and a yes/no and a text-box thing. And you may have more than 50 items. This particular event is run for us that sends data to NODC at the end of every cruise. So that’s a sparse data set that goes to NODC. Then NODC has just recently built the ingestion routine so that, as NOAA vessels finish their cruises, you’ll be able to start seeing small data sets on the web directly from NODC. There won’t be the whole data set, but they’lll be small.

And then you hit START. And when you hit START, up comes the event. All the metadata information is written to a file so that it’s available to you. You can see I’m like a normal scientist. I ignore the metadata and don’t put anything in. Then the IDs -- the actual formats of the data files are listed so that you know what data’s going to be in what file. And then a snapshot at the beginning -- all the data you decide to log is snapshots of the file. And now the event is running for 27 seconds, and I can go in and say, "Hello."

And there’s the default message I have. I could change that message if I wanted to. When I push the button, it also gets written to the file. So now I’m tracking whatever that event was. And that’s kind of how the event logger works. So I’ll go ahead and close the event down. When you stop the event, the event stops, but you have the ability to go back and look at the information you plugged in, and you can still make an annotation into the file, but the event is effectively stopped.

The red, green, yellow lights are the same. So when you’re managing your events, you can see which one’s running.

The events can be run on the client. So you don’t have to run down to the computer room, find the acquisition machine, and run event logger. You can run that out on your own PC. In order to grab the data for running SCS on a PC that you bring on a vessel, you simply drag in the SCS menu -- executable -- and map to a couple of shares, and you’re up and running, and everything runs off the client server. So you don’t have to have anything polluting your system that you don’t really need.

So I covered acquisition. Of course, there’s an input manual data capability so that, if all you want to do is type some information into the system, it’ll time-stamp it for you and log it to a file.

Under displays, we’ve covered everything. We have the ability to do remote displays to small little VT terminals in various parts of the vessel if we’re not into PCs.

The quality processing was mostly the plotting, as I mentioned, and the monitoring errors deals with minding the errors.

Here’s a program, again, that would just render you the list of information so you can look at what information you’re logging on this vessel.

And that’s probably the fastest SCS talk I’ve ever given.

# E-Mail On WHOI Ships

James Akens
Woods Hole Oceanographic Institution

Well, John Frietag gave a talk on the general state of ship’s email systems in an earlier session on Monday. It convinced me to change the focus of my talk today, because it appears that email administration is a real sore spot with most people. In fact, it's something that we don't even think about. I think we've got a good solution. So I'm going to concentrate a little bit more on that level.

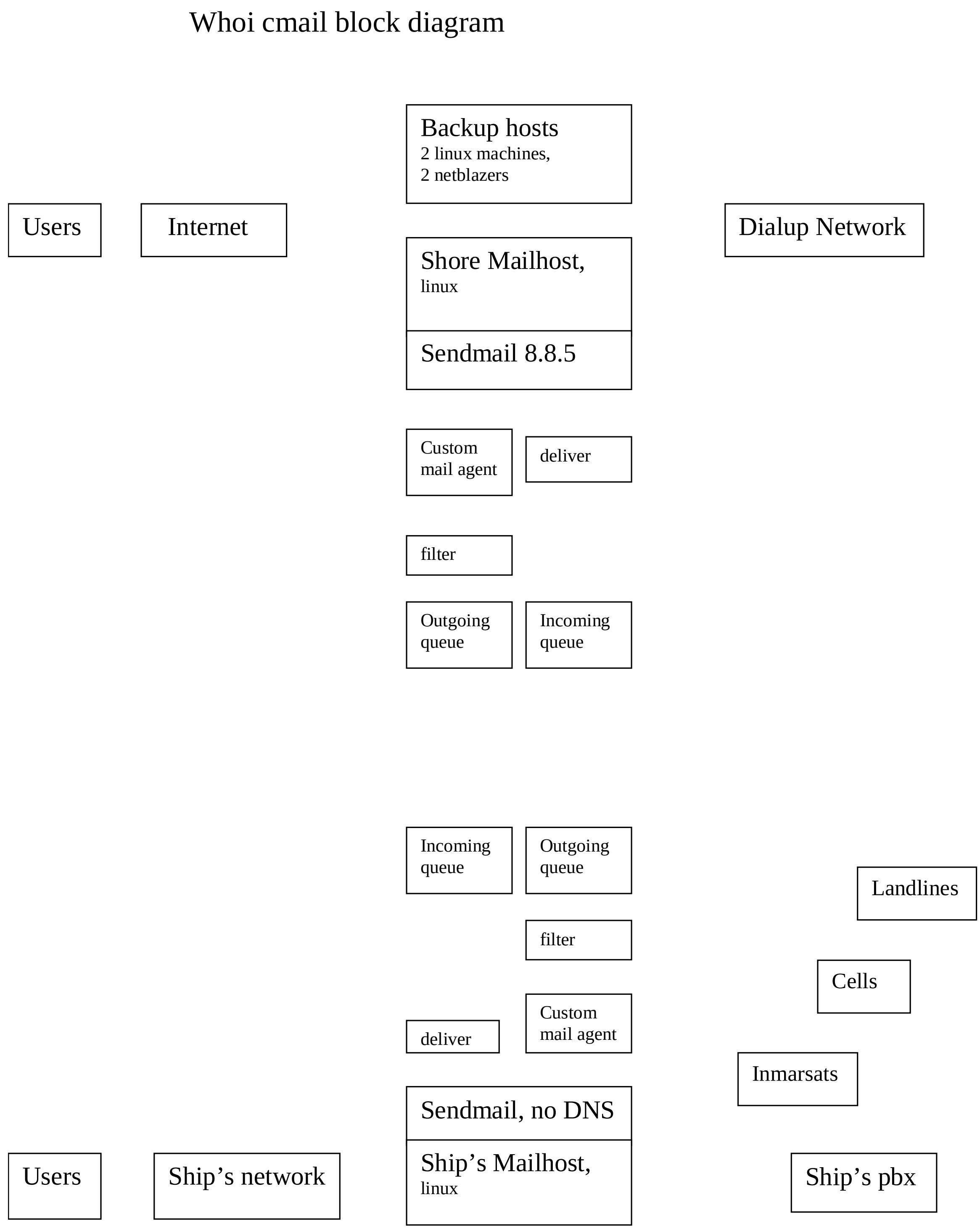
This is a simple block diagram (Figure 1). It's a totally symmetrical system, based on RFC 822 UNIX mail, operating on LINUX platforms. I started out on Solaris platforms, and ran it on Solaris for a little while, but I had a lot of minor problems, and so I abandoned Solaris totally as an email platform.

The only real difference between the ship and the shore installations are the SendMail configurations. We're using the standard SendMail 8.85. We're up to 8.87 on shore now. The ship side has a special problem in that there's no DNS, at least worldwide DNS -- domain name server -- system available on the ship. So we had to get a hacked version of SendMail. That, along with the SendMail configuration file, basically says, if the mail is not addressed to a local host, a host or a user on the ship, just pass it off to our Cmail package. Other than that, it's really standard SendMail.

We've defined a new mail agent on both ends, which is totally within the rules with SendMail. SendMail, if it finds mail that it doesn't know how to deal with, just passes it off to our Cmail package. The entire system is set up as a bunch of queues. Each stage pushes mail along a little farther. Once a stage is completed, it then deletes files from the queue. But reliability was a big issue, and so we don't delete any files from any queues until we've verified that the mail has arrived at the next step. That results in very occasionally duplicating mail, but we don't lose mail. That's obviously more important.

When we actually do a mail exchange, all that happens is that we exchange the contents of the outgoing queues. This can happen with any method that we choose. We only use low speed data on our ships. We are not yet using high speed Inmarsat B. But the whole point is that, from one system to the other, mail goes from the outgoing queue to the incoming queue, and vice versa.

Figure 1


Whoi cmail block diagram
Backup hosts
2 linux machines,
2 netblazers
Users
Internet
Dialup Network
Shore Mailhost,
linux
Sendmail 8.8.5
Custom
mail agent
deliver
filter
Outgoing
queue
Incoming
queue
Incoming
queue
Outgoing
queue
Landlines
filter
Cells
Custom
mail agent
deliver
Inmarsats
Sendmail, no DNS
Users
Ship's network
Ship's Mailhost,
linux
Ship's pbx

This dovetails nicely into SeaNet, and its notion of data pipes. When SeaNet is up and running, we actually expect to turn this part over to SeaNet. We’ll just stick our data in a data pipe and be done with it. Easily the biggest headaches of this system for us are the COMSAT COMs. We often operate it in moderately high latitudes, often 50 degrees north or more, where there’s such a low horizon angle that we waste a lot of time just trying to get the mail through that one step. Everything else works well. So if we can turn that over to a more automated process, we’ll save a lot of technician time.

Whoi Cmail user interfaces

| | | | | | | |
|---|---|---|---|---|---|---|
| synopsis:call | [striker] | | | | [landline] | [landline1-4] |
| | | [sssg1] | | [comsat] | [comsat1,2,b] | |
| | | [sssg5] | | [cell] | [cell1-3] | |
| | | [remacc] | | [ptt] | [ptt1-2] | |
| | | | | | [ip] | |
| | | [-v] | [-d] | [-I] | [-p alternate.pin.number] | |
| synopsis: | collector | [-v] | [-d] | | Normally run as cron job | |
| synopsis: | cmailfilter | | [-v] | [-d] | Called by collector | |
| synopsis: | checknewdb | | [-v] | [-d] | Called by cmailfilter | |
| synopsis: | deliver | [-v] | [-d] | | Called by call | |
| synopsis: | newfilter | | [-v] | [-d] | Operator | |
| synopsis: | mq | [-a] | | | Diagnostic called by operator | |
| synopsis: | cbill | [-l] | [-s] | | Bill reporting program | |
| synopsis: | msg | | | | Show status of hold directory | |
| synopsis: | msgbill | | | Client; show message stats | | |
| synopsis: | mailbill | | | Client; show projected bill | | |
| synopsis: | td | | | | tail –f /var/log/debug | |
| synopsis: | tm | | | | tail –f /var/log/maillog | |

This is, from an operator's point of view, such a simple system that there's no point in building a GUI. There'd really be one button, and that's it. The button is "call" -- the top word here. Normally, the syntax is such that you can just execute call , although we have four different hosts that you can call. The principal host is striker, and that's where the mail normally lives. That's also where DNS directs all mail bound for the ships.

There are four different hosts to call but there's a default, usually striker. There are also four different ways to call each host, but the default is usually comsat. The configuration file has all these options set up in advance, and they're normally never touched. You set them up when you set up a ship, and that's it. You set up the default land line. You set up the default host. So in fact, the operator, all he does is type "call." That's really good.

If one of the modems go down, he might type "call SSSG1," or "call SSSG5." Those are all just different machines that have modems. "Remacc" is the WHOI modem pool. But they're actually on another campus. So we're separated by an ethernet link there, as well. We use remacc as a last resort.

I'll get into billing later.

Collector is run as a cron job. The operator normally never sees that.

"Cmailfilter" is the actual filtering part of the process, and I'll talk about that more.

"Checknewdb" -- these are things that are never run from the command line. "Deliver" -- same way. Checknewdb looks at cmail's mail to see if a new filter database has arrived. Deliver is run at the end of each mail transfer.

"Newfilter" is run once a cruise. The whole mail system is based on the cycle of the single cruise leg. It's hard to know where to start talking about it, so I'm going to start at the end.

"Mq" is the other diagnostic that is used a lot. It's somewhat analogous to the UNIX command "mailq," which shows you what's in the normal SendMail queue. But "mq" shows you what's sitting around in cmail's queue. That one I use a lot because that lets you see how much mail you've got sitting around waiting to go out. In some cases, that's the criteria for doing a mail transfer, which are always initiated manually. Once we get a mail queue size larger than 50K or so, it's time to start thinking about doing a mail transfer, because that translates to several minutes of satellite time. We have trouble maintaining a data connection much longer than that reliably on a really consistent basis at high latitudes. Most of the time it works fine, but it doesn't always.

"Cbill" is the program that is run at the end of the cruise cycle. It just tabulates all the billing and mails a copy to Barbara Martineau, where she has to deal with the real mess. "Cbill" is also used as the basis for two utilities, "mailbill" and "msgbill," which are available to all the users. Any user can type "mailbill" and see what their current charges are. They can type "msgbill" and see a list of time and length of all the messages that have come in or out to them in case there's ever any squabbles. In fact, there never have been so it hasn't been an issue.

I've got my lap-top, which I will use for a demo to show you what happens. At the beginning of the cruise, the root operator has to run a utility called "newcruise." It basically puts in motion all the steps for archiving that particular cruise's data. This moves data to the archive directories and it cleans out the science accounts. That's a very critical part of this as far as cmail is concerned, and ultimately billing and accounting.

The most important thing is that it zeros out the names for all the science accounts. One of the things about filtering is the way the filters are built automatically. But an entry is not built if there's no name in the name field of the password file. It's a very simple trick. The reason that accounting works, is because there are a lot of silly tricks like this that, if you exploit them, you don't have to think about things much.

I've got four different terminal screens. One is a root operator, which I actually won't use. One is myself, Akens. That's the typical interface that a user would see to the system. One is cmail, which is the operator that actually does the processing on the ship. And the other one is Atlantis, which is meant to simulate what's going on on shore.

So here we are sitting at the mail operator's console. We'll execute "mq". "mq" shows the time. This is what we like to see. The queue is absolutely empty.

I'm going to run the first utility. Let's pretend this is the start of a cruise. We'll just run "newfilter." So this just greps through the password file. This will create the file that will be sent to the remote machine to determine whether or not anybody can get mail onto the ship. What it does is go through the password file and look for the users who satisfy certain criteria in the password file. It excludes everything with a user ID below about 15, which are all the administrative accounts. There are a few others that are selected or actually just chopped out by hand because I know they're invalid.

The first column is the user name. The second column is the alias that's constructed automatically. Aliases are kind of a big part of this. This is the style we use at WHOI. An alias's is always constructed with the first initial and last name of the user. What this means is that user Akens can get mail addressed to either "akens@atlantis.whoi.edu" or "jakens@atlantis.whoi.edu".

I'm going to stop for a second. I forgot to mention that the other big part of this thing is getting domain name serving working. This is a problem no matter what kind of mail system you have. But you've got to get it working. In our case, I chose to just use the idea of the ship name in front of our institutional name. That's worked out well. The whole goal is that if you know someone's name and you know the ship they're on, you can very easily make up an address that will get mail to them. Because I got tired of answering the phone and saying, What's this person's e-mail address?

So this is a pretty small filter. This kicks you into VI. Everything, by the way, with the one exception of the mail agent, is written in Perl 5. The mail agent is written in C just because couldn't quite figure out how to do it in Perl three years ago when we didn't know much about Perl. Now it'd be easy to change it, but there's no point to it.

So what happens here? Again, I ran this diagnostic called "newfilter." This is what happens. For the operator's benefit, this filter will be written and mailed unless you interrupt it. I also construct two aliases for the ship's purpose only, simply crew and science -- based on some very simple criteria so that you can send mail to "crew@atlantis.whoi.edu" or "science" and so forth, and get it to them.

I built two separate alias data base called "aliases." It's in cmail's home directory --/user/local/cmail -- separate from the normal alias file. The "aliases.cmail" is very dynamic. It changes every time you run newfilter. The other alias file is the one that you build on a system-wide level, and that we don't want to touch. That's the reason I made two alias files.

So now that thing has been presumably mailed off. If I type "mq," what I see are -- now in the "msgout" subdirectory, there are two files. This is, again, standard UNIX mail stuff. Every mail message has a control file and a data file. I think of them as "cf" and "df" files. I'm not sure if "df" means "data file," but that's the way I think of it. The control file is the one that's actually used throughout the mail system. The one that you read is the data file. So it doesn't matter what the "df" says, it's what's in the "cf" that counts. This is one of the ways that mail is spoofed. You alter the "cf" and nobody ever sees that. The "df" says it came from someplace. What the real mail message says has nothing to do with where the mail really came from.

Okay. I'm going to now pop over to another screen. This is the screen for user Akens. What I should've shown you earlier is that, in the filter, there was a number after the name and the alias. That's the size that you're allowed to send per message. That defaults to 10,000 characters. Everything, including all these defaults, are set in a single configuration file that once installed on the ship, are never touched. So a normal user can send 10,000 bytes without any trouble.

I'm going to just invoke a little shortcut. So I just sent a mail message off the ship, which was this 23,000-byte file. If I come up here to cmail's screen, and again type in "mq", it shows the file that I just sent. It hasn't been processed yet. Normally, what happens here is there's a cron job that sweeps these things up every five minutes. I disabled that just so it wouldn't surprise me. So I'm going to run that program with the verbose switch -- it's extremely verbose -- and we'll see what happens.

The long and short of it here is the sender was okay. Akens was on the list, but the message was too big. What happens over here, on akens screen if I do look at my mail, I get a little message saying, "Try again." Essentially, if you've got some mail that really has to go through, all you have to do is go talk to the tech and he can edit the filter, and the mail will go through. I won't go through that. Just take my word for it that it's really that simple.

At this point, even though I don't have a phone line, I can try to make a call. Really all I'm going to try to show you here is that this system takes care of itself. I don't have a phone plugged in, so it's going to figure that out here in a minute. This pause is just so that the operator can verify the call destination before actually starting the call.

Okay, it didn't get the "okay" string it expected from sending an initialization command to the modem. It just quit -- the connect time, as calculated by this program, was two seconds. Nothing was lost however.

There's this business of fudge factors. Our accounting is all based on two files, called "calls.dat" and "messages.dat." We log every call and every message, basically add it up and divide it at the end of a cruise, apportion to each user, and that's the bill. The only real problem in this is that there is no real simple way that I know of to actually determine the call time. All we can do is measure the time between when you started the call and when you finished the call. But, in fact, as far as COMSAT is concerned, there's 30 or 40 seconds there -- you're not charged until the remote phone picks up. And there's no way to get that simply. So I invented this thing called "fudge factors," which you calculate by comparing connect times with calculated times. These factors are then part of the configuration. There's a fudge factor for each type of call.

Let's just go down here. I'll show you -- now, this is -- suddenly, we've jumped back to the shore. This is an account on the shore. I ran "mq" -- and "mq" here shows lots of stuff which is not good. All this "message hold" stuff are files that have been trapped by the filter. We save them for a period of time, typically a week. The idea there is that we notify the sender immediately, in a similar fashion to the way we notified the user on the ship, so that if they've got some big file that they feel is really important, they can take some action. The typical action is to send a short message to the ship saying, "Do something about this."

Cmail is designed to be administered totally from the ship. It can be tweaked from shore, but in fact, I had no interest in doing this. So the operator on the ship really has complete control of it. And this control is all in the file filterdb, the filter file. The shore side constantly looks for a new filter.

We have another little loophole in the system that allows any message less than a thousand bytes to go through unchallenged. This is a way to establish communication of some sort, even if you've got the user name all wrong.

Any message that's been trapped by the filter shows up in the msghold directory, and you'll see the last message there is a megabyte and a half. That's somebody trying to send a megabyte and a half as an e-mail message. That would cost many hundreds of dollars.

The small ones that you'll see, like that 2345-byte, are for a user that doesn't exist, or more often than not, the name's misspelled, or they were on a previous cruise, or something like that.

I will say that this filtering has made all the difference in the world as far as keeping our costs in line. I initially resisted the idea. When we did it, I was really surprised to see how smoothly it makes things operate.

So in the outgoing queue there is a file. The collector process takes the "cf" and "df's," it tars them and ZIPs them, or compresses them, and makes a single file out of it. So each mail transfer is just an exchange of a single file, unless the process has failed somewhere along the line. We just sweep the directories clean when we do a mail transfer.

Since I can't do a real mail transfer, I'm going to fake it. All I did is copy an old cmail file into the incoming queue. Now if I type "mq," we should see that file in the incoming queue. So I'm going to run "deliver," which is the program that normally is executed as part of a call. It's the last thing that is executed by the program call.

This is a real mail file. I just pulled it out of the archives. But in fact, all of the mail in this file is addressed to users on the Atlantis. So every single one of these mail messages is going to fail. I picked it for that reason, to show you how the system works.

Normally, these programs run in the background and generate no output. All these programs have interactive or a verbose options so that you can see what's going on if you choose to run them manually.

Okay. The very first message fails, and they're all going to fail. This was addressed, in fact, to our tech, Dave Sims at Atlantis. And what we have are three options here -- to view the message, postpone delivery, or just delete it. That's really the way it works. I'm not going to bore you with this. We could go through the whole list, but I'm just going to quit now.

Now, I'll show you another thing. If I run "mq" now, it's very unhappy. There's, in fact, enough information there to say that something's probably really screwy. Well, what happened was I stopped the delivery process in the middle. I can start it up. The beauty of all this stuff is I can run "deliver" again and it will pick up where it left off for the very simple reason that the whole structure of this program is to just deal with files in a subdirectory. Anything that's in this subdirectory, this is what happens to it.

It's proven to be pretty bulletproof. You can interrupt virtually any process in the middle, which is not untypical on a ship, and the next time around, it'll realign itself.

That's really it as far as the delivery stuff is concerned. I'm going to again cheat and copy of pair of accounting files. The accounting files here are basically empty. The fact that there have been no successful calls, it's a divide-by-zero problem at this point.

So in order to show you what really happens, I'm going to copy a pair of files that are real files from a cruise that I was on about a year ago so I can demonstrate this. I was on the cruise; therefore, I show up in the data base.

So now I will run the command mailbill; normally, this is quick, but this is a tired old lap-top. Okay. I had 183 messages, 381,000 bytes, for a cost of $63.71. The next command I will run is "msgbill". The first column shows the user id; the second column shows the user id number. The third column is UNIX time, which is about as useless as you can get if you're looking at it. The fourth column shows whether the message came in or out. The fifth field is UNIX time translated to readable time.

These files are usually only read by the accounting programs, so I don't really worry about making them pretty. So that's it from the user's side.

At this point, I'm going to run this cbill program. This shows that we're down to an average cost of about 8,000 bytes per dollars now. This is the bill that goes to Barbara. And this is the breakout that she gets. Essentially, these 43-cent ones are not really worth collecting. In fact, I think perhaps the threshold is somewhere around $20 or more. If the bill is not at least that big, it's not worth collecting.

So that's billing for us. This all happens in the background as part of the program newcruise. We typically send a copy of this bill to the captain and the SSSG tech so they can kind of keep an eye on what's going on, but without having to worry about it too much.

Thank you.

PARTICIPANT: I just wanted to know how much operator time was involved in sending the message in?

MR. AKENS: I'm sorry?

MR. WALDEN: She's asking how much operator time is involved in sending the message in. By "operator time," do you mean technician time?

PARTICIPANT: Yes, per day.

MR. AKENS: Oh, maybe a half hour on the bigger ships where we tend to do about four transfers a day.

PARTICIPANT: Total, even with the launching?

MR. AKENS: Yeah. I mean, you'd sit there -- we had very explicitly chosen not to make this an animated process because of some horror stories we heard about satellite -- you know, not logging off the satellite properly. In the end of my call program, I verify three different ways that we're, in fact, logged off, and yet I still don’t trust it, because if you lose once, you’re out $10,000 or more. So it’s just not worth trying to automate it.

It’s become something of a social event, as well, when the mail comes in. So the technician -- we also print out a list of mail mess- -- or recipients for the last 24 hours and post that a few places around the ship. So it’s a little ritual that the technician runs the mail, and then walks around the ship posting the message in -- you know, sometimes somebody has told them, boy, I’d really -- you know, I’m expecting some mail, and I haven’t gotten it. And if they get it, you can go find them, and that sort of thing.

PARTICIPANT: So all the connects are initiated from the ship?

MR. AKENS: Absolutely.

PARTICIPANT: And typically how many do you do a day?

MR. AKENS: Four. It’s also -- there’s a great economy in keeping the number of connections down, because there’s almost 45 seconds typically at the beginning of each call just to allow the modems to negotiate.

I can’t wait until we go to high-speed B-data. We’re very close. I should’ve said that. I expect the cost to drop at least by a factor of two as soon as we can get onto high speed B-data.

PARTICIPANT: Do you bill both ways?

MR. AKENS: Oh, absolutely. We make no distinction.

PARTICIPANT: Can you also send formatted files? Can you send like an Excel file or something?

MR. AKENS: Oh, yeah. We do it all the time. We just do it as mail attachments. MIM is perfect for that. In fact, that’s really gotten to be the bulk of our traffic. The earlier meeting, John was saying he thought a lot of mail was personal. I’d say the message count, that’s still true, that most of the number of messages are personal mail. But in fact, as far as byte-count is concerned, they’re absolutely in the noise level, because so many people are sending spreadsheets, executable files, you name it. In fact, our port office has started to use this on a regular basis to exchange their NTC -- their ship’s inventory and control program. Those are big files and they go every day. At this point, I’m very comfortable with the fact that all that stuff is really subsidizing the personal mail, and you can’t even detect it on the map really.

PARTICIPANT: A couple of questions about the big file and how to deal with big files. Can you -- if someone comes on the ship and says, you know, I’m going to be getting 150K JPGs every day, can you set their user name so that it will allow those through?

MR. AKENS: Oh, certainly. We can. And what I didn’t show you is there’s an asterisk option in the number column of the data base. They’re allowed unlimited --

PARTICIPANT: In a situation where, for example, I send a big file, it gets bounced, and then I send a little message that says, "Please let that big file go through," the shipboard guy can -- seeing that queue on the land-based machine, the shipboard guy can point at it and say, "Bring that over next time."

MR. AKENS: It’s not even that hard. You run newfilter again, stick an asterisk in that user’s column, do a mail transfers so the newfilter gets to the shore -- I should’ve talked a little bit about how the -- that’s done totally automatically as part of the -- every time a call is received, you look to see if there’s a new data base. And we do that with a few key words in the data base. So we scan, for instance, "user Atlantis." Atlantis nor Oceanis are just another user as far as that particular machine is concerned. They’re a domain as far as DNS is concerned. But they’re just a user as far as the mail machine. So if user Atlantis gets some new mail, we look, if the two key words are in the file, that’s a new data base, and you use it, the mail goes out. So again, I said, I’m not interested in lifting a finger from the shore. And that --

PARTICIPANT: And you get a -- and there is a list of all the messages that have been rejected and held in queue until this ship --

MR. AKENS: It's not a list per se. It's just that it shows up in that thing "mq". And there's another -- there are a couple of other utilities I run as weekly -- or daily chron jobs. You delete all the mail in the mail hold queue that's longer than seven -- it's a variable, but we set it to seven days. We also, for reasons of privacy, we keep copies of the incoming and outgoing tar files. But there's a chron job that runs that deletes them after they're a week old. We're really only interested in keeping them in case there was some screw-up somewhere along the line so we can resend them.

PARTICIPANT: So you do have a listing of the shore-based whole directory. So you could look at that on the ship and say, "Hey, wait a minute."

MR. AKENS: No. The ship does not see that.

PARTICIPANT: Okay.

MR. AKENS: Barbara.

MS. MARTINEAU: In the case of the big file transfers, though, before the cruise, generally, we'll know who -- someone is going to want to download weather satellite pictures (indiscernible) or something like that. You could be sure the accountant wants to know who's going to pay for it. And generally, the tech will e-mail me and say, So-and-so said they're going to download this stuff every day. Have they made arrangements for paying for this? Because we've had some chronic 3-, $4,000 users.
(Laughter.)

PARTICIPANT: When you're in range of the Canadian AMSET (ph), can you use that rather than going through INMARSAT?

MR. AKENS: We just don't have the hardware. We'd like to, particularly on the OCEANUS, which is mostly a coastal ship, within the footprint of AMSAT, we'd like to get the hardware.

PARTICIPANT: It's about a tenth as much -- it's only a little over a dollar, little under a dollar; isn't it?

MR. AKENS: Yeah, I know. We just haven't gotten there yet.

MR. FINDLEY: Our INMARSAT rates aren't ten dollars. They're considerably lower.

MR. AKENS: Yeah. We're getting them as much as -- through PTT, another carrier, I guess, is the proper term -- getting it for about $3.30 a minute at this point.

# Direct Connection Network Sensor Interfaces

Richard Findley
University of Miami

**[Editor's Note: Following is a transcription of Rich's oral presentation.]**

Well, I'm giving a talk on a couple things. I really didn't know what I was talking about until earlier when it was described to me what I was giving my talk on. So I've been sort of editing it along the way. So it might be a little strange in some places. But we'll start it off and see what happens.

When you're interfacing sensors -- analog sensors and things like that -- you really need to digitize right at the source. RF is going to get in there and trash things up. You're also going to have -- which means, actually, distributed measurement system. You've got voltage drops in RF.

You want the system to be modular, because you don't want to have to shut the system down to replace anything. Sometimes for your really highest accuracy, you want to calibrate the interface, which is going to take the analog sensor, and digitize it, and do them both together so that they're sort of a set. That's just sort of like Dave Hosom was talking about, the original IMET concept where it was a -- grab the whole thing and go with it at once.

Other requirements are high accuracy, high resolution, easy configured, and all the other standard ones, like reliable, year 2000 -- dun-dun-dun -- they're just -- I don't think we need to go into those. Everybody else has stated that we've got those sort of things.

Love those touch pads. Okay. Some of you from RV Tech might remember this talk, because I gave sort of a revised version of it from last year. I got the same phone call that almost everybody else did from our friend back in the UNOLS office and said, How about giving a presentation on something? I liked that one before, so we're doing it again. So if it seems repetitive, it is.

We found -- these little modules are called SmartLink. Some of these slides are from some of their advertising. So they might seem a little overbearing in some ways. It was easy to use them. I don't get anything out of it. I'm not a salesperson for them, but they're a nice little module.

To make their graphics line up with the way the module's laid out, it's sort of laid out backwards from right to left. But you have your sensors, and signals coming in can handle things -- microvolts, femtoamps -- da-da-da -- you can read them as well as I can. Those were all signals that are brought in through some signal conditioning, isolation. Then there's local processing for a limit, scaling, logging.

And then there's a network interface. Various types are available. This is really talking about using RS232 -- I'm sorry -- ethernet, and in particular, we're really big on fiber optic ethernet.

Again, this is the list of the different types available. The stuff that are grey aren't quite available yet, but I think everything else is available.

So what's typically done on the ship are these type of things. Everybody's mentioned them. There's the Keithly Metrabyte (ph) modules out there, an Omega, or maybe IMET -- I would be a little careful about saying low accuracy slow speed there, but some variations on this theme.

And you can read the vendor's advertising on it there. Other things you'll see, there's a multiplexer board in the PC, or maybe some signal conditioning out there, and then another multiplexer back on the computer. Those are typically -- this little converter box at the top typically take the sensor signal and convert it to -- what is it? --

four-to-20-milliamp current loop stuff. Again, all the wonderful reasons why you should use these sensors as opposed to the ...

Our next solution is the data logger. These are pretty expensive. I don't think you see these too many times on the ships, but maybe.

The nice thing about these modules, they're scalable. I mean, you can go ahead and hook it up to a port, which I have right here. Actually, I hooked to an RS232 port because I sheered off my ethernet connection dangle yesterday. That was a -- don't you love dangles on laptops?

Anyway, so the next level up is hook it to an ethernet with a single computer or internal LAN and interrogate multi-ones (ph). But really what's most exciting for a shipboard application is the final one. Maybe you could call that intranet -- wider. If Andy Maffei and the boys get their way, maybe it does mean internet-wide.

But if you could think about the top computer there being sort of your data logger computer that's collecting the data and logging you on a regular basis like we always do, and then think of the other computers as other instruments needing the information on the ship, like ADCP or -- I don't know, whatever you want to pick -- that needs to know one of these other sensor inputs, it can interrogate it directly. You're doing this at ethernet speed, so these things don't really bang into each other too often. So this is really one of the main advantages of these type of sensors.

There's like an example application. These are solar radiometers. You put those up on the top of your mast, and you typically run the copper wires right down by the radars and the radio -- thousand-watt linear radio antennas, and proceed to measure those signals much more than you do these little microvolt signals coming out of those.

We put the interface in a waterproof box, run fiber right up to it, and some power, and interface them right up there at the sensors. It makes a major difference in signal cal.

This is a typical sensor. This is a DC volt one. There's others. You can sort of read through that. I don't know that there's any reason for me to read it to you.

Again, some more specifications on these. They draw about five watts, and that's in the ethernet modules, because what they have on them is there's an AUI interface on all of them -- all the ethernet versions. Then you plug a little converter on it if you want twisted pair, fiber optic, or whichever. And it comes with the converter when you order it.

Notice they are -- I don't know if it's here or on the other page -- but it's a 20-bit A-to-D. They can have various configurations of the channels. It'll do four-wire resistance, two-wire resistance, single-ended. And the number of channels obviously varies as you start using up the number of pins on it.

This is sort of a block diagram of the system -- input multiplexers, some protection circuitry, a voltage generation for driving -- for measuring resistance, some ranging A-to-D into the CPU, where all kinds of things are done to it, and then there's the configurable network interface. And up on the top, you'll see there's a local interface, which is the RS232, for configuring. And that's the one I'm currently running on. It's got some status LEDs. Down on the lower left there, you'll see there's a digital output. There's two pins coming out for controlling stuff.

This is the specs on the accuracy. Four-wire resistance -- I don't know how you do 24-hour accuracy. I mean, by the time you get it in and out of the box or something, it's dead. But it's pretty good right out of the box. I think if you calibrate it as a sensor, like if you look at the four-wire resistance, you'll see it's 24 hours, .019 degrees C, or .13 in five years. I mean, in our calibration schedule, we're typically doing once a year. So I think we can hang in close to that 24-hour when we calibrate them together.

These are the other modules available. Some of them are high-speed, like the first one is a high-speed bridge module that runs at 33 kilohertz. It has a little less bits. All the modules are like an 11 -- the first one is an 11 and a two. The 11 means it's a single-channel unit, and the 12 means it's a multiple-channel unit.

There's high-speed DC volts, precision DC volts, which is primarily what we're using, which is a 16- or 20-bit, iso-precision isolate it, which can provide a little more decoupling between signals, high-speed dynamic, which provides power for accelerometers and things like that -- one that is particularly dedicated to platinum probes, or one that's for thermocouples, or ones for thermistors, and then there's also a -- one that has a built in temperature and humidity sensor. These are sort of what the layouts of those look like. It's all the same package. I just changed the software in them, really.

This is a dynamic -- applications support it. I mean, you got a sensor, you got to get it somehow into your computer. They supply drivers and things for programs like TestPoint, LabView, Lab Tech Notebook. You can just work them with an RS232 -- terminal program if you're running through a terminal port. NEDAC -- you can do DDE links to things like Excel, run them on visual Basic, and your standard programming language for those that want to venture.

This is not meant to be a readable slide, but it'll give you an idea of the type of the command structure and the number of commands you can give to it. I'll break down into some more detail in the ...

This the syntax -- typical types of things you can choose. May not need the argument. You can choose from A, B or C. There's a normal response, a valid command, invalid command, command in process. They have the ability to store -- if you need to do a burst on something, you can go ahead and store a couple -- depends upon how many bits you want and how much other stuff you want to record -- a couple hundred or tens of thousands of samples -- and then you can pull that average back out, or you can pull them all back out as individuals.

The most important one is measure. You say which channels you want to read and the number of readings you want from them. If you do -- if you put a question mark after most of the commands, it'll spit back all the options for it. So it's obviously a fairly intelligent sensor out there all on its own.

Configurations -- some of these are like -- there's -- the first one's for an accelerometer. There's dewpoint digital inputs, digital outputs, horsepower, humidity. The stuff in the lighter is supposed to come out in a later revision. Some of that's actually been done already.

You can see for temperature down low in there, there's RTD -- there's the 385 versions and the 3916 versions.

More configuration. We'll run through these pretty -- you can filter with a moving average so that all these -- like the last five or ten or 15 readings. You can apply scaling in two different forms -- slope and offset, and spans and zeros, use both at the same time. You can really confuse yourself sometimes.

You can set limits. You can tie those limits to the digital outputs if you want to sound a buzzer from them directly. You can pick up the minimum and the maximum out of a set of readings.

Scan -- you can go out there and start a scan, and store it to memory, and then pop them back out. You can do it a lot faster if you store it as bits, and then you can read it back out as callibrated data later. These provide fully calibrated data with the information behind them. Throw a flow diagram on them, bring readings in, you measure and average them, then filter them.

Above that, the auto-calibration and the super M and super B are the factory installed slope and bias on it. You can cal them yourself. And then we go through some linearization and scaling to units. And then there's non-linear for thermocouples and platinum probes, filtering, more scaling, limits checking, and finally some statistics on them. And then you can see where they can come back and go into memory and loop back and be rescaled if they -- just in memory as binary data.

This has to do with all the memory things. We don't need to go through this. I'm just sort of -- kind of give you an idea of the richness of the ...

Price. There you go. They're obviously not cheap. When you get out in the ethernet end, they're a couple thousand dollars. Now, if you're looking at multi-channel one and you're putting eight signals into that, you can see the price per channel is not much different than we're paying for the current single input Metrabyte 485 sensor -- sensor interface, I should say.

Live demo. Let me tell you, a lot of these things -- this thing's running 98, and I'd never run some of these things on it. I started doing this on the plane over and in the room, and some of this has not gone as well as one would hope. But what the heck. So a program called Net Acquisition, which ships with it -- you've got a simple operation, you can use this all by itself.

Select a device or add a new device. Call it "test." Since I snapped off my connector, we're doing this in RS232, COM 1, 9600. It'll time-out after five seconds, and it'll try three times. It goes out, talks to the device, and down here is the confirmation, and it's pulled back all the serial numbers and things like that -- firmware.

Now I'm going to try to configure some of the channels. It went out and read what the channels are -- are available. This list will vary and the options on it will vary according to the module.

On channel one, I happen to have a two-wire platinum probe where I measure temperature. All that changed as it read what the capability -- it's a platinum probe -- 200 -- and it's a single-ended measurement. We could have single-ended zero-compensated where it goes back and every once in a while re-zeros itself -- four-wire -- four-wires zero-compensated.

And you can see that, as I've changed those, it's all updated here. And we'll call this -- oh, let's pretend it's something real -- SSTEMP -- so it's sea-surface temperature. And it's -- change it here, and you can see that has been configured, that channel.

I didn't want that one.

This is for setting the time and date. If I go in there, hit that -- boom, it'll go back -- and if I were to pull that module up again -- the time's different because that was the last it read it because it just went through. But as you can see now, this is the computer clock running in the clear window, and the grey one is what it read out when I went back to look at the time again. You can globally set all of them on the ethernet to the same time.

Data fields. When you ask for a measurement, this is what you can ask for it to put out in a single measurement -- just the reading with the units, the channel number, the channel tag, time, date. So it will time stamp every measurement by itself. So you can go out and set the clocks once an hour, globally, and pull back all the data, calibrate it, and time-stamp it.

These are units. Just to give you an idea -- temperature -- we can set the thing so that it reports back in something that makes sense in your world -- in degrees C, degree F or calvin.

This has to do with averaging readings across the whole unit. You can do that across the unit or you can do it in an individual channel.

This is plotting filters to each individual channel, setting up limits. Last time I clicked this one, it crashed. Look at that. This is for setting up things like the number of digits it reports for each of these things and the functions formats.

This is if you want to talk to the thing directly. And you can see that it read back the temperature. This is prized as really a troubleshooting tool or something like that if you want to use it, but it does have some -- if we wanted to read that channel -- ten times, I'd say -- when it's connected to ethernet, this is a little snappier. And then just for a -- make that a little down and dirty -- it has a plotting temperature on a pretty expanded scale. So it's just air temperature fluctuations out of that temperature sensor -- well, it adds five millidegrees between divisions. Drop in a cup of water, it'd settle out a little bit, but ...

So that's a pretty basic little tool you can use at any time to configure one of the modules. That one hasn't crashed too often on me.

This one is a DDE server. This basically goes out and places the -- requests information from the module, makes it available to other programs -- DDE clients -- direct data exchange clients -- on the computer. There's also network versions of this. And this is just one way of dealing with this. This is not to say the only way for sure.

So we're going to call this "test" and the topic name is the -- what the sensor will be referred to as a DDE client later. We have our COM ports and everything selected. That's very nice. I've got it being polled twice. If I don't crash it with this, I'll be impressed.

I don't see how to get rid of a sensor, but okay, we'll see what happens next. There you go. Now, here's the magic part when it always crashes. Boom. Okay. Got that far.

So now we're going to copy a DDE link to the clipboard. If you look at it, you'll see at the top there "MMagic," which is the program running -- Measure Magic, the topic name, which is the sensor itself at this point, and the parlance of this stuff is "test," and the item number name is "measure," and we want channel one. Note that this has some intelligence of what's out there on that sensor, because it can measure -- take a measurement -- minimum, maximum, output, capture, time, beat (ph), and then -- you can get all kinds of different things out of it.

So we're just going to take channel one to keep this simple. Then we'll just open up Microsoft Excel. We'll past it in there as a live link. You can see we're now putting it with an Excel spreadsheet in real time, and it's updating -- that's text, because I left the degree C attached to it. But if I pulled that off, I could've put it in as a number.

Another thing we can do is we can bring up LabView. I'll just pick an example program they have, and we'll do it dynamic data exchange. I had a nice little demo on using tcpip and going to the sensor directly, but again, oops. And this is all on graphical user inter- -- graphical program. I'll show you how that works a little bit, too.

So we've said, Pull things from the DDE client -- I'm sorry -- DDE server, Measure Magic. We want "test," which we've assigned to that sensor. And we want to measure channel one. And it hasn't blown up on us. Let's see. We've got to change the temperature scale a little bit, and there we are, running, bringing that into a data acquisition program. And I can show you some of the -- how this thing is constructed.

These are all just little icons you drag off of these pallettes over here and plot them down. You can there was the service, the topic, the item. These are just little text strings. Some of these are carried through because they relate to everything.

So this opens the DDE client, requests the data for it, and does it a close on it, some error checking, this little wave chart. You just drop it right into there. These are all fairly simple things to do.

So you basically construct an entire shipboard data logging system out of these things. That's our current -- we're currently doing that on most of our ships. The hardest thing to deal with in these programs, oddly enough, is things like the GPS, where you have all these different strings coming out where they don't repeat. Like GLL (ph) will come out, and something else, then something else, and then a fourth item will come out every ten minutes or something like that. And people changing the number of digits of precision and everything up on the bridge throws you every once in a while.

So actually, it looks like I got through all those live demos. Look. See? I got down to the bottom of that list.

So the next thing is about fiber optics and why we use them on our ships. Florida is arguably the lightning capital of the world -- well, maybe -- but in Florida, lightning strikes down there are -- I’ve just sat there in the ship in port and just watched lightning hit a tree, hit a power pole, and strike the ground next to the ship within 15 minutes. So you really start thinking about things like, gee, I’ve got this GPS antenna sticking up way higher on this mast, and it’s got this copper cable coming down, and it’s hooked to the GPS. And then you’ve got this RS232 copper cable coming from there, going into a server, and then it’s connected by copper to your computer network. And you say, this could be real exciting. Three days before a cruise, or three hours before a cruise -- doesn’t matter -- you’re just -- everything will probably go if you really get a -- you know, if it hits you right.

So realizing that glass fiber doesn’t carry electricity, we have sort of leaned very heavily towards fiber optics for our ships. The Seward Johnson (ph), which was one of the first ones we did start using fiber on had cad five copper through it and fiber. We have just recently started putting instrumentation on the Edwin Link, another Harbor Branch Oceanographic Institute ship. That one we did not run any copper networking at all. We looked at what we could with fiber these days and said, forget it, it’s not worth the aggravation. We’ll learn to use fiber and do it for just about everything.

Obviously you can’t avoid a couple things. Moving a synchro signal around on fiber is a little tough. You could probably digitize it and undigitize it, but I don’t think that’s what we want to do.

This is the fiber optic. We’re also doing a -- we’re working on a cruise ship where we’re doing some things. This is the network fiber map for that ship. We’ve got two pieces of copper you can there between the transducer pod and the oceanographic lab, and those are ADCP cables only. And there’s some from one of the masts that we just didn’t think it was worth the trouble. That’s all the way up on the bow, and it was only about a 15-foot run. So we decided to just leave some copper up there.

This is a thousand-foot ship. You can’t run things this far on copper. So you actually have to start worrying about if you can run it this far on fiber. But you can see the high fiber counts. These are 24 pairs to the oceanographic lab, 24 pair to the bridge. These are just not networked. This is what, when we’re talking to the shipyard, they didn’t understand it. It’s about $50,000 -- I mean, half a million dollars worth of fiber in that ship -- not the fiber itself, but labor alone.

So I went through this -- the one module -- and these are other things we were running on fiber optic things, and I’ll go into a little more detail on those.

Port servers. A couple of people have talked about port servers. Same thing, except most of them have an unshielded twisted pair interface. We just convert that to fiber, run it into the ship’s network, goes down to the data collection CPU.

GPS distribution. This one gets a little strange, but we bring the GPS into a NEMA to RS232 converter. They’re fairly inexpensive. NEMA doesn’t put out a legitimate RS232 signal. Every once in a while, we run into a problem with it. We just convert it to RS232 and forget it.

We convert that with an RS232 to fiber optic converter and shove that into the ship’s fiber optic network. That doesn’t -- when I say "network" there, it’s a fiber network, but it is not necessarily like an ethernet network. It is just a fiber pair, or in this case, since we’re only going one way with the communications, we’re only using a single fiber, the transmit fiber.

That jumps into the network, comes back out into another converter, and it gets actually converted back to copper again, where it’s really just plugged into an RS232 splitter. That’s an eight-channel splitter. We convert all those back. This is again the star -- things that were being talked about where it all comes to a central place and goes back out. This is actually repeated about four times. I think there’s four GPSs on the ship. Typically, one -- is there a pointer? Who had those pointers? Who was the magic guy with the pointers?

I keep pointing at the screen, and I’m -- it’s a lot clearer to me.

So it comes in here, it comes back out this splitter, jumps back into the ship's network, and then goes out to all these clients. So if we have four -- typically, we'll have four GPSs. There's two differential GPSs, there's the 3-D GPS, and then sometimes there's a P-code on board. So all those come down and get to -- are brought into a splitter. So we have a rack of four splitters, plus one spare, and in fact one of them we're double-splitting because we need more than eight outputs.

So if somebody says, I need this GPS, or one of those GPSs dies, all we have to do is change this connection right here, or actually change it back here, and we redistribute through the whole ship again.

And then these are -- typically, when we say GPS clients, there's the ones we're normally using, and then some scientist always comes along and says, I need GPS. We do it with one of these RS232 converters. They're self-powered, run off the port, and there's never really much question about why his computer blew up -- you know, like, You connected that wire to my computer, and it doesn't work anymore. Again, it's hard to destroy a piece of equipment through a piece of glass. I mean, maybe if -- a powerful enough laser at the other end, you might do it, but I don't think we're gonna. So this is a real argument-ender.

There is no interference. You don't have anything trashing up your signals.

ADCP over fiber. Again, it's a deck unit -- 232-to-fiber converter, in and out of the network, back to copper, and that convert is plugged into the CPU. Typically, we'll locate the deck units -- the ADCP deck unit very close to the transducers and convert. We'll throw a network connection down there also and run a SmartLink module down there measuring temperature, because bioscattering -- you need a temperature measured off of that deck unit also.

The second version of this, if you're running one of those with a 488. There are 488-to-fiber optic converters. There are SCSI-to-fiber optic converters. You can put your disk drives down in the nicest place on the ship and run SCSI out of your computer anywhere on the ship and hook up to those drives.

Web cameras. There's a company called Axis that makes a camera. It's a black and white one. It has a twisted pair output. Convert that to fiber, jump it in the network, and it has an http address. You just put that into your browser and you get a picture of what's on that camera. You can have a web server interrogate that on a regular basis and build up little videos out of that thing.

Web cameras two. There's another one that's a -- has a four-input, and it can handle external cameras, color or black and white, and again, the same -- well, that's wrong. That's UTP-to-fiber in the same sort of arrangement.

The other thing you can do here is actually take a -- let's say you have a computer up on the bridge, and you want to get the display from that computer down to somebody's stateroom. Let's say it's a radar. You could convert the 15-pin cable in the back, put a splitter on that, send it in to the same sort of box that people use for these presentations, and convert it into video, plug the video into here. That has an IP address. Somebody can be down in there room with a browser, and as that updates, he can set the browser to update that. They can take snapshots of the radar on the bridge. Somebody can walk in and say, I want to do this in 15 minutes from now, and you can accomplish this -- most of the time.

Obviously, we talked about SmartLink sensors. That was the beginning of the talk. That is how they fit into the whole thing.

That's all I've got.

PARTICIPANT: SmartLink, does it expose a tcpip socket so you can actually get to the sensor and read it over the network, or --

MR. FINDLEY: It's an IP address.

PARTICIPANT: Okay. But, I mean, how do you actually get to the actual sensor? Do you use a socket? -- a send/receive socket?

MR. FINDLEY: Yeah.

PARTICIPANT: Okay. So you don’t have to use one of those applications to --

MR. FINDLEY: Nope.

PARTICIPANT: Okay.

MR. FINDLEY: Anybody else?

PARTICIPANT: Splicing. Since we’re all familiar with soldering, what tools do you use for splicing when you get breaks?

MR. FINDLEY: Break? It doesn’t break.
(Laughter.)

I mean, you don’t splice -- well, typically, you don’t splice fiber optic. I mean, it doesn’t break -- I mean, if it’s installed properly in the ship, you know, it runs from point A to point B. Somebody may drive a screw through it or something like --

PARTICIPANT: No, I’m not -- not the end -- or let’s say you have to make a break somewhere at one time. Can you break off your (indiscernible) connector?

MR. FINDLEY: Basically, you terminate it and put a barrel in it -- is the easiest way to field-deal with that type of problem. You can splice them, but that’s not -- I mean, you just put a connector on there -- on it -- put a connector on the other half, and run them together. You can put a termination on the end of a fiber in about an hour. It’s not something you want to do on a regular basis. Say you want to lay 50 percent fiber is dark (sic). All of us have run wires through the ship, and you sit there and say, Oh, I’ll never use all these. And later, you’re running another 50 pair. You know, it’s the same sort of thing.

# CTD PACKAGES

Chaired By
Woody Sutherland

# WOCE Style CTD Operations

Frank Delahoyde
Scripps Institution of Oceanography

**[Editor's Note: The following is a transcription of Frank's oral presentation.]**

Hello. My name is Frank Delahoyde, and I work for the Oceanographic Data Facility here at Scripps. The Oceanographic Data Facility is sometimes known as ODF, and it is in the business of making hydrographic measurements.

I'd like to talk to you today about ODF's involvement with the World Ocean Circulation Experiment, which we will shorten to WOCE, and about our CTD data collection and processing methodology. This talk will probably contain a lot of acronyms.

This picture is a salinity section from CTD data collected during one of the WOCE sections. You'll notice that the cruise name has been obliterated because the data, at this time, was still proprietary, and there is no data on it either. But this is a deep section, and it covers approximately 70 stations or so of our final data product. This is generated shipboard, and this is indicative of the level and quality of data that we routinely produce on a shipboard basis for WOCE expeditions.

The World Ocean Circulation Experiment, or WOCE, includes the WOCE Hydrographic Program, or WHP, a global hydrographic survey that map the world ocean at unprecedented sampling densities. This program is international in scope and includes about 22 participating countries, including the U.S. and the United Kingdom and New Zealand and Australia. The WHP surveys ran from 1990 to 1998. The data center and office of the WHP is still very much active and is here at Scripps.

The major goal of the WHP is to construct a global high resolution CTD hydrographic and tracer data set of uniform composition and highest quality. To this end, the WHP have had to ensure that the data collected by different groups and at different times were comparable, and that all measurements are consistently of the highest achievable standards.

This has been done by setting standards for the overall precision and accuracy of hydrographic measurements by recommending standard methods and techniques to be used for data collection, processing and recording, and by requiring complete documentation of the work actually performed.

ODF has participated in some 28 WOCE cruises. Our responsibilities have usually included providing, operating and maintaining the water sampling and CTD hardware, providing equipment and techniques to make salinity, dissolved oxygen and nutrient measurements, and providing equipment and technicians for data processing.

The WOCE requirements for CTD data accuracy and precision include three decibar accuracy and half a decibar precision for pressure, two millidegree accuracy and half a millidegree precision for temperature, .002 practical salinity units accuracy, and .001 practical salinity units precision for salinity, and one percent of full scale reproducability and precision for dissolved oxygen, which typically means about .05 milliliters per liter.

Achieving this level of data quality requires careful attention to detail. Any aspect of the seagoing data collection operation that affects the traceability of instrument response to calibration standards affects the measurement accuracy. Maintaining this level of data quality requires careful planning and adequate backup instrumentation. Shipboard data processing is essential to quickly diagnosing and resolving problems that affect data quality.

Sustaining this capability requires techniques and methodologies that encompass both shipboard data collection and processing operations, and shore-based support. Some of the key technical issues that should be addressed include:

Selection of CTD instrumentation and appropriate calibration and maintenance procedures: It's essential that you know how the sensors respond and how to keep them operating that way.

Sampler system deployment and maintenance methods: Check samples are necessary for calibrating CTD salinity and dissolved oxygen. Good check samples and CTD comparison data are required.

Provision for appropriate levels of system redundancy and backup capability: If equipment is lost or damaged, it is essential to quickly get back to the program.

CTD data acquisition and processing methodologies and shipboard data processing and quality control: It is essential that the CTD data quality be assessed as the data are collected. Data problems can't be allowed to go unresolved.

ODF uses Neil Brown Mark III CTDs for WOCE operations. This has been a pragmatic choice based on our experience with the instrument and sensors. And we also have used SeaBird and FSI CTDs, but haven't had as much experience with these instruments.

We maintain our own calibration facility for pressure and temperature sensors. The CTD pressure and temperature sensors that we use are sufficiently stable that we calibrate a CTD immediately before and after a cruise. Pressure sensors are calibrated to a Ruska piston gauge pressure reference in a temperature-controlled bath. Temperature sensors are calibrated to an NBIS -- that's a Neil Brown Instruments -- resistance bridge with a Rosemount standard PRT.

Actually, I'm not sure if we're still using the NBIS resistance bridge for temperature.

ODF STAFF MEMBER: We are.

MR. DELAHOYDE: Are we? Okay, we are.

Conductivity sensors are not as stable as pressure or temperature sensors and are also subject to fouling and contamination problems. For these reasons, CTD conductivity is calibrated to salinity check samples taken during the CTD upcast. The precision and accuracy of the CTD salinity data depend on the precision and accuracy of these check sample data.

Dissolved oxygen sensors are also not very stable and are calibrated to check samples. Again, check sample precision and accuracy determines the CTD dissolved oxygen data precision and accuracy.

We deploy two temperature sensors on an instrument for reliability, and most recently have had redundant conductivity sensors, as well. We have used various temperature transfer standards as cross-checks, and currently use a SeaBird SBE35 temperature reference. This device is internally recording and connects directly to the pylon on the underwater package. It records the temperature each time a bottle is closed. So this gives us three temperatures on the underwater package that we can use for cross-calibration purposes, ensuring that temperature, if it has changed, hopefully all three don't change in different ways at the same time.

We have made some modifications to our CTDs. We've revised the pressure and salt oxygen sensor mounts. The pressure sensor is insulated and not directly connected to the end cap to reduce dynamic thermal response effects. The pressure sensor temperature signal has been disabled. We have a separate sensor holder for dissolved oxygen so that sensors are more easily replaced. We also designed our own sensor interface for dissolved oxygen. We provide an elapsed time channel and power supply voltages so that some operational characteristics of the instrument can be monitored better.

Standard CTD maintenance procedures at sea include soaking the conductivity and dissolved oxygen sensors in distilled water or saltwater when there's danger of freezing sensors between casts, and protecting the CTD from exposure to direct sunlight or wind to maintain and equilibrated internal temperature. Any extraordinary maintenance to an instrument is documented.

ODF designed and built a 36-sample, ten-liter rosette system for WOCE. A SeaBird SBE32 pylon currently serves for tripping samples. The CTD and auxiliary sensors are located at the bottom of the rosette. This package is deployed from a .322 inch conducting wire, providing for real-time CTD data acquisition and interactive sampling. An altimeter on the package typically provides distance above the bottom in a CTD data stream. A pinger is also used in conjunction with the shipboard 12-kilohertz PDR as an additional safeguard. This package is routinely used to sample within ten meters of the bottom.

The shipboard deployment and retrieval of this package requires a coordinated deck team. Air tuggers are typically used to stabilize the package during recovery. A complete examination of the sampler precedes and follows every cast. Bottles on the rosette are maintained daily to ensure proper closure and sealing. O-rings are changed as necessary, and valves are inspected for leaks. Any problems discovered during these regular inspections or during water sampling are documented.

On WOCE cruises, we attempt to provide redundant backup for all key systems. This includes complete duplication of the underwater package, rosette system, CTD, and underwater electronics. We also provide spares for key shipboard systems, sampler electronics, CTD deck unit, CTD data acquisition computer, and analytical equipment such as salinometers.

ODF CTD data collection and processing methodology attempts to perform as much processing as possible at sea. Although CTD data cannot be considered final until post-cruise sensor calibrations have been examined, near-final data can routinely be made available at sea with some confidence limits placed on how stable the sensors have been.

There is a pragmatic side to ODF's methodology. Our CTD processors are also seagoing technicians. Much of the business of CTD processing is bookkeeping and documentation. If this happens at sea when the problems occur, much time and effort are saved. More attention can be given to data quality assessment.

ODF's CTD data acquisition and processing system runs on Sun computer workstations. The CTD and hydrographic data processing software that we use at sea is identical to what we use on shore. Our shore-based systems simply have more disk space and memory. We normally use two or three shipboard systems that are networked together. One of these systems serves as the CTD data acquisition console, and is also used for interactively closing bottles on the rosette. Another of these systems serves as a hydrographic data management system. The data are transparently available on all of the systems.

A VCR is used to make an analog backup of the CTD signal, a secondary backup that must be replayed in real time in the unlikely event that it must be used. One or more color inkjet printers are provided on the network for a color hard copy from any workstation.

The real-time CTD data acquisition system is also the processing system. Calibration data, sensor response models and filters are applied during the cast, and the data are filtered to a two-hertz time series. These data are available for interactive and hard-copy plots and displays during the cast. Both the raw and the processed time series CTD data are stored on disk. Bottle trips are initiated by the console operator, confirmed by the underwater package, and detected by the acquisition software.

At the end of the deployment, various calibration and consistency checks are performed. The CTD data associated with each sample trip are entered into the hydrographic database. Standard hard copy reports and plots are generated to serve as a reference and as an additional data quality check. A two-decibar pressure series of the downcast is created, which is subsequently used for the shipboard data reports, plots and data distribution.

Since CTD conductivity and dissolved oxygen are calibrated to check samples, variability and errors in the bottle data must be identified and not allowed to bias comparisons. Large gradients exist in the thermocline and can result in large differences between the CTD and check sample. Good techniques and documentation for every bottle analysis is an essential tool for accurate CTD calibration.

The CTD conductivity sensor calibration involves fitting conductivity differences to conductivity from one or more rosette cast to determine a calibration correction, then to determine when or if the calibration has changed. The stability of CTD conductivity sensors varies from sensor to sensor and can be affected by environmental factors such as freezing conditions or extreme heat.

The CTD conductivity calibration process is iterative and is refined by examining potential temperature salinity overlays from successive CTD casts and by comparisons with historical data. The CTD dissolved oxygen sensor calibration is somewhat simpler than the conductivity calibration in that the sensor is less stable and must, therefore, be fit cast-by-cast to check samples.

There are a number of problems with the response characteristics of this sensor, the major ones being a secondary thermal response and sensitivity to profiling velocity. Since we don't control the flow across the sensor by pumping, we can't directly calibrate the sensor check sample data. Instead, downcast CTD dissolved oxygen data are derived by matching the upcast bottle trips along isopycnal surfaces.

Differences between CTD dissolved oxygen modeled from these derived values and check samples are then minimized using a non-linear least squares fitting procedure. The differences can be selectively weighted, and are normally conversely weighted by maximum pressure.

Additional filtering is occasionally required for CTD data, particularly conductivity and dissolved oxygen, as both sensors are subject to fouling. Any filtering that is performed on a data set is carefully documented. WOCE CTD data sets have quality flags identifying filtered values for every level.

The WOCE rosette, because of its size and lack of streamlining, has a noticeable wake that can affect the CTD data. We mount the CTD on the bottom of the rosette for this reason. Normally, the ship's motion transmitted to the package breaks up this wake. But under certain conditions, such as deployments in the ice, the effect is significant. At bottle stops, the weight catches up with the package, resulting in anomalous CTD temperatures and conductivities in high gradient regions. This effect is minimized by carefully examining the CTD temperature for stability at each stop before closing the bottle.

This top illustration is a CTD downcast and upcast. This is time series data. The red is the downcast; the blue is the upcast. These bottom two points are bottle stops. The bottom illustration is the same data, the bottom two bottle stops, blown up and thought of as a function of elapsed time. The black line on this plot is pressure. So you can see when the pressure becomes constant, the bottle stop is occurring. And you can see the variability occurring over the temperature channel and contaminating the CTD data until the package begins being raised once again.

The final CTD data processing steps include calibrated data checks and comparisons, as well as comparison to other historical data sets. This is just a sample shipboard blowup of calibrated CTD salinity for a series of stations that are delineated at the side of the plot. If you notice the scale at the bottom, this is a fairly extreme blowup.

We routinely provide complete documentation describing all methods and procedures used on a cruise, together with the preliminary CTD data, at the end of a cruise leg. This includes a shipboard CTD data processing summary and calibration reports on CTD conductivity and dissolved oxygen.

This is an excerpt from one of our reports. At the top is part of the calibration summary on CTD dissolved oxygen. At the bottom is a description of our numerical methods associated with our model for converted CTD dissolved oxygen to engineering units.

ODF CTD data collection and processing methodology continues to evolve as better instruments, equipment and processing algorithms become available. Key to our success with WOCE has been putting our resources to work at sea in integrated CTD and hydrographic data processing with data collection. The result has been an improved data product.

Thank you.
(Applause.)

MR. SUTHERLAND: We have time for one question if anyone wants to ask about WOCE in specific.

MR. DELAHOYDE: Sure.

MR. AMOS: When you do pre- and post-calibration of your conductivity sensor, for example --

MR. DELAHOYDE: Okay. We don't. With the Neil Brown, we do a pre- and post-cruise temperature and pressure calibration.

MR. AMOS: I see.

MR. DELAHOYDE: But the internal field three-centimeter cell on the Neil Brown is not really stable enough to warrant a pre- and post-cruise calibration with any hope of sustaining that calibration over the course of time of a WOCE leg.

MR. AMOS: Well, then I could direct my question to, say, temperature.

MR. DELAHOYDE: Sure.

MR. AMOS: Do you then -- after you've done all this on-board processing, do you then -- when you've got to a post-cruise calibration, do you then take these to endpoints and apply some linear or non-linear --

MR. DELAHOYDE: We may. Generally, we have enough information. Certainly, we have typically three temperature sensors on the rosette. Assuming that we have a stable conductivity calibration, we know the pressure hasn't changed. So, typically, we don't have to go through and attempt to interpolate either pressure or temperature corrections over the course of the cruise. If there is a calibration shift, it's usually quite apparent in the data exactly when and where it's taken place, and we're able to adjust for it.

# Sea-Bird 911 CTD Operations

Kristin Sanborn
Scripps Institution of Oceanography

**[Editor’s Note: The following is a transcription of Kristin’s oral presentation.]**

MR. SUTHERLAND: A couple of year ago, when the Navy Oceanographic Office decided to use UNOLS vessels to start doing some coastal surveys across the U.S., they came to ODF because of its excellent track record in doing CTD, and in particular WOCE operations, and asked us to become involved in the data processing of the CTD data that was collected on those NAV-O cruises.

The next presenter is going to be Kristen Sanborn. She’s going to tell about the trials and tribulations we had gaining experience with Sea-Bird CTD data collection and processing.

MS. SANBORN: Like Woody said, I’m part of the Shipboard Technical Support group here at Scripps Institution of Oceanography. We have been contracted to help out on the processing of the NAV-O CTD data. We started this -- or the NAV-O started this in the beginning of 1997, and we have acquired 3500 -- approximately 3500 -- CTD stations to date. The data was collected on four ships. Three of them were on the East Coast -- Cape Henlopen, Cape Hatteras, Pelican, and here on the West Coast, the New Horizon.

The data acquisition included pressure, temperature, conductivity and light transmissivity. The sampling was to -- and a lot of the waters was no deeper than ten meters. The maximum sampling was no further than 1,000 meters.

For our group, this was very different. We felt that this was a great opportunity for our group to gain experience with the Sea-Bird data. We had visited the web page. We had CTDs of our own that we loaned out to the oceanographic community; however, we were always told that they didn’t need a data processor. Everything was easy enough they could take care of it themselves.

As Frank has suggested, we have gone out on expeditions with Mark IIIs, with the FSIs, with the Sea-Birds, but we’d never really made a final result on which instrument we would like to go with. Our boss decided that we were going to start learning about Sea-Bird CTDs. We took on this project and are having a great time with it. Really. Honest.
(Laughter.)

It is. It’s really nice.

However, with the Sea-Birds, there were some things that Sea-Bird was saying that we didn’t completely agree with. They had claimed that calibrations didn’t need to be done pre- and post-cruise. We took our experience with Neil Browns and we decided we want to see a pre- and a post-cruise calibration on everything that we go out with. We have a calibration facility in our department. We’ve picked up many sensors from a lot of different organizations all over the world and have seen the results. We have seen how people treat their sensors. And we felt that, if this calibration were done, depending on the reports that we heard about Sea-Bird and the dealings that we had with them, that if there was any problem with the sensors, Sea-Bird would let the people know they had a problem, and they’d fix the sensors. So our people would return with data that we were fairly confident was -- we were able to get good numbers out of.

Salinity check samples. We also, based on our experience with the deep ocean water, we felt that check samples -- salinity check samples -- would also help with coming up with a good data set. Again, keep in mind this is coastal water. They’re on the beach. They’re on the beach. These guys are on the beach, especially compared to someone that’s used to deep ocean water.

The changes that -- another change that we had made to Sea-Bird's method of data acquisitions, that we decided that we would like the data acquisition to start on deck. With the Neil Browns, we wanted to see when the sensor went into the water, if there was any kind of a pressure effect. So we decided that this is what we want to do with the Sea-Birds, too. It was our experience with the Neil Browns, so we're going to take it into the Sea-Birds.

We found a lot of reluctance from a lot of people to do this because this wasn't in the Sea-Bird's manual to do it this way; however, we were able to review the offsets in the pressure. We also had information on on-deck readings which were necessary for calibration of the transmissometer data. We also ran into a lot of trouble because of starting the acquisition on deck, because we were not rewriting any of the Sea-Bird programs. We were using exactly what came with their package.

The data acquisition on deck was not easily removed through the Sea-Bird software. There is an option for it to start -- to keep the -- to convert the original data and eliminate these on-deck readings or anything else that you want from the beginning of the cast, but it was kind of a difficult endeavor. What we started out with was using the program and scanning through the data looking for a pump status, which is just another variable in their programs. And we then also had to watch for the conductivity when it went from zero, which is what you get before the water is pumped through the cell. And we had to also look at this tabular data when the cast actually started down, because what we found, these --

By the way, if you're not familiar with these ships, they're also kind of small. They're 20 to 51 meters and close to waters. They're kind of rough, kind of bouncy. Some of our more seasoned technicians made their reports back and said to make sure to take your dramamine with you.

So in the deployment, the people on deck were taking the CTD and the package further down the water column -- five meters, and they're almost to the bottom. So this also caused a problem in the programs -- not all the time, but sometimes -- because the technicians started the data acquisition -- they went down to the five meters, and then they came back up to the surface, and we found that the program that takes out roll -- the ship's role -- was eliminating not only coming down to the five meters where they stopped to wait for the pumps to come on, but as they went back up, it took out all of that and then back down. I mean, in five meters, you know, evidently this was -- the software was looking for that kind of roll in the ship, and this is where we're starting the pumps to come on.

So we have a -- there's a support staff at our facility. One of our electronic technicians wrote a program for us to pick out that beginning scan number. It took us a while to come out with the correct equations in order to do that, because the data acquisition wasn't always started at the same place. We also found that, if we found a problem in the data, that, yes, it would, in fact, show up in modulo air counts.

I hope all of you are kind of familiar with the Sea-Bird data acquisition. If you're not, they have a wonderful web site. They have great documentation. I don't want to tell all of you that they have a terrific support team, because then if I need help, Andy -- Andy Hurd from Sea-Bird -- may be on the phone with you. But they do. They are very cooperative. They are very receptive to any of our questions, any of our suggestions. I just think the world of Sea-Bird. I think that in itself is really good for us.

The tabulation of the modulo word errors, this is really -- we found this to be very helpful, and as a matter of fact, the gentleman that wrote this program passed this on to Sea-Bird. It gives you a lot of information about each and every cast. This modulo word error usually is an indication in the Sea-Bird data that you've had some kind of a problem. Now, the problems that can occur are usually because of telemetry -- you have some kind of slip-ring problem, there's some kind of noise from your winch, the interface from your deck unit to your computer -- you have a problem there. The problem is diagnosed in this modulo word error. It's great.

We also had in place some tabulation of bottle data versus the CTD conductivity differences. And as I said, we have a program that gets this beginning scan number for us. So we've now eliminated all of the problems for the Sea-Bird software that we caused by starting our data acquisition on deck. We found that that has given us a lot of information. Then along with the programs that were written to find this beginning of the cast, we have programs that now take that information and set up configuration files, so we can just run through all of the programs very easily.

If I can back up here a minute. I have some sea stories for you guys, but this -- that's what I was told you like to hear. But first of all, this is something that I thought you might find real interesting. This is a bottle -- the top one is a bottle conductivity minus the CTD salinity. In this shallow water, it's also very hard to get a salinity check sample in a well-mixed area. But when we first looked at this information here, even though it's a little bit sparse -- it's certainly a lot sparser than what we would do on the WOCE data -- I thought that at first what we had was a slight offset at the beginning of our cruise.

Then at the end, there was some kind of jump in the data. And we went back and looked and tried to figure out if anything had happened between any of these stations here. Then one of our technicians decided, well, she'd just go ahead and apply the pre- and post-cruise calibration information. We've spent enough time on this. Let's see what's going to happen. And once that happened, we found that, on the bottom plot, that we had a very good fit. This, in my opinion, also shows another reason for a pre- and a post-cruise calibration. If you have any questions, to us, it was now obviously answered, where before that, we had spent a couple of weeks trying to figure out what was going on.

PARTICIPANT: Was the bottom slide done with the post-cruise calibration data?

MS. SANBORN: Yes. Sea-Bird recommends that what you do is that you use their pre-cruise coefficients. If from the post-cruise information they give you a slope on the conductivity -- and they have an equation in there -- documentation to correct the data from your pre-cruise calibration to your post-cruise. Does that answer your question?

And again, a lot of the methods that we are trying to employ here for the Sea-Bird CTD processing we picked up from what we had done -- what our group had done over the years with the WOCE data. Documentation is absolutely a must. A lot of our technicians that went out and collected the data are also now processing the data; however, there are cruises where this isn't always possible. Notes and the way the equipment is set up is so useful to a data processor. Sometimes being on both ends, acquiring data and processing data -- I also realize how difficult it is to say exactly what it was that you did out there. You think you're going to remember. Okay, I'll just jot this little note down. When it comes to, later on, someone else, or even yourself, looking over the data, the notes that you keep are the most valuable.

So now to tell you that I think a lot of the Sea-Bird software -- their documentation, again, is really great. Some of it is a little bit hard to understand. But as I said, any time we question anything, that the next release of software or the documentation, our questions are usually resolved in the next manual.

We have talked about deployment of the package, what the proper thing to do is. In the training session that Sea-Bird would give you if you went to their class, they tell you if you see any noise in the data, it's in your slip rings or your -- you have some kind of electrical noise -- they give you a path to follow if you have a problem.

However, in real life, this is kind of some of the things that we get: Someone started data acquisition and the pumps weren't on. So this being the start of the downcast, over here is where the pumps came on. Water started flowing through it, and we finally got some saltwater in here, and then we started getting some kind of a realistic trace.

I expected more of a reaction than that.
(Laughter.)

PARTICIPANT: We've all done it too many times.
(Laughter.)

MS. SANBORN: And I told one of our technicians, "Don't worry about cringing when I show these, because I think a lot of people are." It's not uncommon. Like I say, we've seen 3500 expeditions, and these people are very talented people. They know what they're doing. Things like this happen.

This is data that's been run through the Sea-Bird software programs -- all of them. What happened here was that they hit the bottom. However, if you notice, you're -- well, my scales are kind of -- yeah -- never mind. Never mind. But our transmissometer data never did recover on this one.
(Laughter.)

The spiking that you see in the salinity -- I was going to point out in temperature that it didn't look so bad, but I now see that I have 20 degrees here. But there is some spiking, and this did happen on the upcast. But we can still recover from this.

But when you start data processing, when you start looking at the data, this is what you're going to see. It's going to happen. As I said, this isn't all on Scripps ships. Even though our group, our technicians, are fairly new with the use of the Sea-Birds, there's still a lot of experience behind all of this.

This one is on the up-trace. This is actually on the up-trace where we see these spikes, dips. The technician didn't really think this was too much of a problem. It was at the surface, almost onto deck -- you know, what they thought, okay, a few spikes may be coming up. There was some kind of electrical noise. However, what we found was that, if you see anything like this, anything small like this, then you do have some kind of electrical problem, and that it can -- I guess what I'm trying to say here is that it can be taken care of before you get too far into your data collection, because your data shows you what's going on.

Here, another -- this actually is the same expedition -- a few little glitches in it. And this is happening on the upcast. So perhaps they were just watching it on the down and, okay, let the winch man bring it on up.

Here's some more data. It really looks pretty good, except this cast is only to 10,008 decibars. So what we have down at the bottom here is some kind of electrical noise.

One thing that is really nice about this is that we could find out from our technician what was going on with this.
(Laughter.)

This is the same data as the other where in your down-trace it didn't show, but in the up-trace, it started having problems. This could be a lot of different things. It could just be -- it could've been from your winch. It could've been your termination. You know, because as this is coming up, you have a lot of weight on your wire. But we don't think that was what it was. There was another piece of equipment for another part of a program, and they didn't have the right connector. It fit, but it wasn't real tight. Then after many examinations -- probably right after this station -- they took it apart and found that the plugs on it were corroded and that when the package sat on deck and there was no movement, they didn't see anything, but once they started through the water column and back up, that the connection kind of wiggled, and we got saltwater in there.

Okay. I'm done.
(Applause.)

MR. MULLER: Rich Muller, Moss Landing Marine Labs. How does Scripps mount their temperature conductivity sensors? -- vertically, horizontally? And if you do mount them horizontally, do you bother doing the ten-meter dip anymore, or what?

MS. SANBORN: We do ours horizontally. Ten-meter dip? I'm sorry, I don't know what that is.

MR. MULLER: Andy'll tell you. Well, we would normally -- like you said, you go down five meters before the pumps come on.

MS. SANBORN: No. We start acquisition on deck, and we just take -- we take the CTD to a safe point, wherever the on-deck technician feels that it's low enough in the water not to come out on a roll, and not to cause any kind of problems hitting the ship or anything like that.

MR. MULLER: Okay. And the second part of the question was, do you -- in the post-processing, when you're looking at WOCE quality, do you routinely find any shed wake or bow wake problems in the temperature?

MS. SANBORN: In the what?

MR. MULLER: Temperature data or conductivity data?

MS. SANBORN: Oh, yes. Yes, we do. I didn't show you this plot. Yes, we do, and --

MR. MULLER: How do you deal with it?

MS. SANBORN: How do we deal with it? We use the Sea-Bird software, and we go through the processing steps that way, yes.

MR. MULLER: All right.

MS. SANBORN: Yes. Yes.

MR. MULLER: What I really meant was, even after you use the software, (indiscernible) and all that, do you still see a shed wake problem, and how do you deal with it?

MS. SANBORN: This isn't WOCE quality. We're not doing that. We're not handling it that way. Most of the Sea-Bird software takes care of that problem, and especially in these coastal waters. Does that make sense?

MR. MULLER: Yeah. We do the same thing.

MS. SANBORN: Okay.

ODF STAFF MEMBER: Kristen, you might want to mention on the first question that we mark the wire above the rosette, so no matter if you do a ten-meter dip, or a five-meter dip, or whatever, when you bring the rosette back to the surface to start the cast, and you always start it at the same point, it's important with the processing to have a relative pressure figure. So we mark the wire, say, exactly three meters above the pressure sensor, and we note that in the log that the rosette -- the cast starts always with the pressure sensor three meters below the surface. So we put a mark on the wire so the cast starts at the same point every single time.

# CTD Data Quality Issues

James Swift
Scripps Institution of Oceanography

**[Editor’s Note: The following is a transcription of Jim’s oral presentation, edited by himself.]**

"My perspective on this topic comes from observations during 25 years of experience as a seagoing oceanographer. Data quality control is the key to my scientific work. And that means sorting out the real from what isn’t real. It’s not always easy to tell. Doing this, I’ve learned a lot from working with ODF, and that’s what I’ll bring to you today.

"Much of my own work has been with bottle data, and I apologize for that emphasis. But I will bring CTD data into the discussion.

"I came up with what I call the three cardinal principles of data quality evaluation.

1. **documentation**
2. **documentation**
3. documentation

"This arises from my own experience where I cannot actually separate the activities of data quality evaluation from the preparation and examination of the documentation that should accompany the data themselves. It’s difficult to evaluate a data set cold – i.e., as some remote person take the data, and do a meaningful job of data evaluation -- except for noting various outliers in the data, or differences with other data. But some or all of those outliers or differences could be real. How do you know? It's the documentation which enables one to determine the cause of a problem and to solve the problem.

"To think about data quality evaluation it's best to arrange to think about documentation in the same sort of hierarchy we use to organize our data. This isn't any profound point, except that it's very useful to think of your record keeping to match the way that you carry out your other activities. That way, you'll have records of all your activities. This means, for example, at the system level, you would have information such as your CTD configurations -- what sensors are on which CTDs, the calibration histories of your different sensors, your oxygen flask volumes, whatever else.

"For each cruise, you'll have some of station cast descriptions, like positions, times, and depths. You'll have various log sheets that you accumulate, information about the ship, the winches, the wire used, which instruments were actually taken to sea. You'll generate directories for the raw data and for the processed data, and you'll start developing what I call a doubtful data directory, which is a cruise level directory of data problems and observations. At the station or cast level, you'll have the files for the raw and processed data, and perhaps you'll have additional data quality information at that level of the documentation hierarchy.

"The general principles involved in record-keeping and the data quality control are intertwined. These include generating complete records at sea, beginning your data evaluation at sea, correcting repetitive problems at sea before they can further mess up your data, using appropriate and consistent standards for the techniques at sea and for quality control both, identification of suspect data values with the probable cause, and correction of data problems. That's how you would intend to do it anyway. But you have to start thinking of how you organize your work, and then the documentation will naturally organize itself.

"Most important, you must document your evaluation of the data quality. You have to write it down. It's not just an activity -- a secondary activity, but it's an integral part of the data acquisition and processing stream. It must be documented, just as you document any other part of your work at sea.

"These days, a data report doesn't mean what it used to mean when I started out. We don't print our data in data reports very often anymore. We just distribute them electronically. But this in no way reduces the need for a data report, whether it's printed or electronic. And so I mean that the data report is the documentation that's required to understand the origin, nature and condition of the data.

"The elements of the data report are cruise information, methodology, summaries, data quality information, and a way to contact the investigators. This data report or these elements must be included with your data in a form that can be downloaded or otherwise available at any time, or you're not meeting your obligations to your program, your funding agencies, or your scientists. Again, you all know this. But you have to keep this in mind as you structure your own record-keeping.

"Keeping complete records is not really all that hard, so long as you recognize what are your most critical elements in your information tree, and have redundancy in that. You recognize the errors in your documentation and in your data are going to be everywhere. You all know that, that we make mistakes all the time. And so do the mistakes show up in the electronic semi-automatic records also. And you have to have enforceable procedures that are consistent throughout your cruise, throughout your group, so you have something to fall back on when you need records.

"I'll give you a couple of quick examples of the kind of information we're talking about. The CTD operator should keep track of the header date, such as the station, cast position and time. We all do that, but I mean writing it down in addition to some electronic recording. You should record information, including time and winch information, every time you try to close a rosette bottle, whether it's successful or not, for every attempt. This can become very important later on in processing. I'm emphasizing the fact that time data are necessary with CTD data acquisition and processing because it's a time series you're dealing with, not a pressure series.

"One of the most important log sheets that I use in my work is the -- for bottle data work -- is the sample log sheet. This is where all the sample serial numbers are written down. They're matched to the bottle IDs. All problems with the rosette bottles are noted. And we designate a sample cop here at ODF to see that all bottles are sampled in the order specified and with the properties specified, and to write down all of the observations of unusual problems.

"When you're armed with all this information, plus the data, it makes data assessment much easier. Now, what do I mean by "data assessment"? There are four basic questions. Have the appropriate standards been met by the bulk of the data? By this I mean that you follow the paper and file trail for each parameter. You see if the methodology was followed. And you see if the standards were applied correctly.

"Another question you ask is: Which data are suspect overall? You're looking for -- are there big groups of suspect phosphate data? -- something like that. Can this problem be corrected? And then for individual data values for each parameter, what are the apparent outliers and the cause for each outlier? That's a really tricky issue because many data outliers are incorrectly plotted due to some other problem. For example, a bottle salt could look bad when you plot it against pressure, but it could be the pressure that's wrong. You thought that it actually was a correct analysis, but from a different depth than your records indicated. So that's not a bad salt; that's a bad bottle depth. We find that that sort of problem in the older 24-place GO pylons. That's largely gone away, but we have still seen pylon problems with all pylon models.

"Some of the biggest headaches later on come from problems in the header data. In other words, we want to look for data entry errors and omissions. Errors in station positions you can see on station position plots. A vertical section with a mark for each bottle will help show you gaps in the data and maybe show you where it's something you should look to. So a little time to get the station numbers, dates and cast times correct is worthwhile.

"I guess this is what I meant where some of the big problems come in, and that’s identifying the sampling level with the sample ID. That’s as opposed to the one you thought you were sampling, like the one you wrote in your log sheet. The actual sampling depth at which a bottle closed must be verified by the data collection and processing group and examined by the person assessing the data. The sample ID is not automatic -- even if we think of it as automatically assigned to the sample depth. But if you look through the process involved, you’ll see that there’s places where mistakes can be made.

"You never want to index bottle data by their depth. You use only some other unique identifier. This is very important but widely overlooked. Pressure is a measured value for rosette data. Pylons may not actually release a lanyard when you think they did, despite what the deck unit tells you. The computer printout of P, T and S and bottle trip time may not, then, actual match the real time that the bottle lid closed. Even NODC makes this mistake. In fact, we recently pointed this out that their new master data base indexes water samples by depth, and they’re now busily correcting that. That’s really my main point of the whole talk: please do not index bottle data by depth.

"After that, many problems with bottle data are actually related to problems with the water in the bottle, not necessarily with the analysis. And you’re familiar with most of these -- warming, air leaks, water leaks, contamination from the bottle itself, aerosols or precipitation -- if you’re sampling in the rain, it can mess up the salinity sample, and there can be contamination from the salinity bottles themselves.

"The depth log and the sample log sheet provide a lot of clues in this. Were the lids tight, air vents closed? Was it raining? Whatever -- like that.

"I said I wouldn’t talk much about the data quality control methods for individual parameters, such as salt, oxygen and nutrients, but there are a few things to note about CTD data that may not be so obvious. These are related to CTD data errors which may not be generated by the CTD, but instead by the methods that you used to process the data.

"For instance, pressure reversals -- if the pressure reversals due to ship roll are handled by a technique which includes averaging of up and down scans, this will introduce false data and instabilities into your record. The spiking is of great interest to CTD data processors. They’re always taking out the spikes one way or another. But the method must follow the physics of the sensor. Any technique which includes averaging, or alternatively, interpolating through spikes, will produce problems. In general, it’s better to leave a data gap or use a bad quality flag than to interpolate through a spike.

"As we all know, the station grouping that’s used for CTD conductivity corrections must match the changes of the conductivity sensor or you’ll get errors there. More secondarily, the order in which you do your CTD processing steps can change the data, and the means used to correct surface pressure can introduce a constant error in the whole data set even with the highest accuracy sensor.

"The techniques of data quality assessment, then, are simply to assemble the records and files from the expedition, to generate a data report if one isn’t provided, to review the records of the expedition, to examine the standardizations and the CTD bottle comparison. The data assessor reads through all this documentation, puts it together, and gets a picture of what’s going on.

"Next you plot the individual station data against pressure, maybe plot against historical data, but that’s dangerous, so you have to be careful. You want to plot your vertical profiles or other property-property plots. To look for consistency, you ought to plot and examine vertical sections of the various parameters. Unusual features in any of this should be checked out in the original data and in the original calculations.

"Finally, you must write a report which includes a summary, discussion of problems, and suggestions or actions on corrections, and you must archive the report.

"Ideally, the primary data quality assessment work should be done by the data originators, and as much as possible, at sea. As everybody has mentioned and we all know, much more can be accomplished at sea than ashore, especially ’way after the cruise by a data quality examiner not involved at sea. If there’s no probable cause for an error or an odd value, it’s often best to leave the value unflagged, but with discussion of that odd value in your data analyst report.

"Two things to remember: First, the data you are examining are interdependent. And so what looks like an error in one parameter might actually be an error in a different parameter. And second, some anomalies, including some very puzzling ones, are real features of the ocean. There’s a lot of sea stories about real data that have been thrown out.

"This makes data assessment a real puzzle, and it also makes it a lot of fun. One rather obvious point is that it’s easier to identify problem data when there’s only a few problems. Remember that excessive noise and errors indicate a failure in your methodology somewhere along the line and call for a careful examination of all relevant events and procedures, and possibly for changes in training, or even personnel assignments.

"Finally, I remind you to never again index water sample data by depth.

"Thanks."

# Marine Instrument Calibration: “You Know It Makes Sense”

Paul Ridout
Ocean Scientific Internationsl, Ltd.

**[Editor’s Note: Following is a transcription of Paul’s oral presentation, including submitted graphics.]**

MR. RIDOUT: Good afternoon, ladies and gentlemen. I hope I don’t regret this step into high technology presentation. As you can see, it’s taken us most of the tea break to sort it out. It struck me this morning with the talk on the Woods Hole management of sensor data from the ship, which I thought was most impressive, particularly the recreation of dials and meters, but now on a computer screen instead of the real thing. The only thing I felt that was missing there is that -- apart from the lovely addition of WAV files, and sound, and these lovely meters, is that we’re going to need a little icon that you can move with a mouse that has a finger that comes along and taps on these dials to make them move.
(Laughter.)

And then we know we’ve made it.

Just to give you some background while we get this up, my name is Paul Ridout. I’m director of Ocean Scientific International. My background is I started my career as a research technician with Imperial College in London doing mainly chemical analysis, and moved to the Institute of Oceanographic Sciences in Wormley in 1977 where I spent the next 12 years doing a lot of work which included sediment coring, animal trapping -- midwater trawls mainly, and water sampling -- all cruises of which were from the RRS Discovery in her older, shorter form.

In 1989, we set up Ocean Scientific International to take over the operation of the IAPSO Standard Seawater Service, which I was managing on a day-to-day basis with Fred Culkin (ph) in those days.

Since 1989, we’ve expanded our activities, particularly in the field of standards and calibration -- now developed nutrient standards kits, which is a combination of nutrient concentrates in low-nutrient seawater. We also operate a CTD calibration facility which operates commercially and is also contracted to Southampton Oceanography Center. For the last three years, we’ve been doing the U.K. WOCE calibrations. Now that the WOCE field program is finished, we’re now contracted again by SOC to do the high precision calibrations for the Physical Oceanography Group -- the James Reynold (ph) Division.

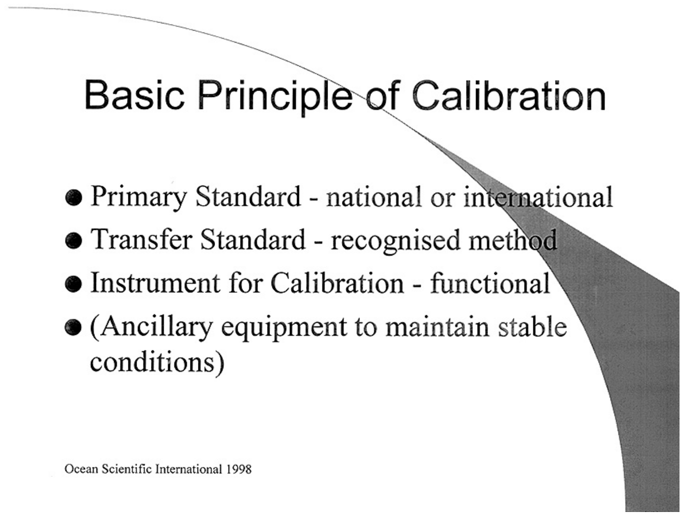
It won’t be long now. I’ll have to go down to jokes soon because I’m going to run out of introduction.
(Laughter.)

Some of our other activities involve doing commercial calibrations for customers all over Europe. So we get involved -- we’re not a CTD manufacturer, so we get -- we’re sort of independent in that respect, and we get to see a whole load of different makes, and we do all the ones that you will commonly know. We particularly do a lot of work calibrating the O’Brien CTDs, which are still commonly used in the WOCE program, of course, and the SOC. But we do Sea-Birds, and we do Applied Microsystems, and Chelsea Instruments, and any other -- FSI, and most of the commonly used CTDs. So the guys in our cal lab have to learn all the intricacies of the different software types. And I must say, the earlier talks about the helpfulness of Sea-Bird and so on is that we would support that, too. And the other manufacturers, too, are very helpful in giving us information to allow us to do the calibrations for customers in Europe.

And Microsoft, a very important company, I’d like to --
(Laughter.)

But not as quick as you’d like them to be.

What I'm going to do is run through fairly quickly what we do in our calibration lab. As other people have said before, it isn't the only way to do things. It is, I hope, one of the right ways to do things. I'll just explain the fundamental features of how we do CTD calibrations in our facility in the U.K.



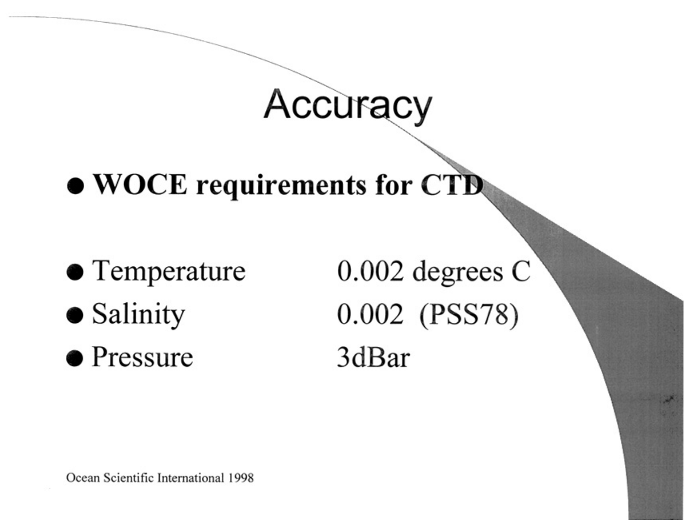

First of all, the basic principle -- oh, I should point out here that I took another radical step. I thought, I'll do some slides on blue because everybody in oceanography, and myself included, that have always done a presentation, and it's in blue. So there's no blue on these slides. I'll probably find out that the type won't show later on.

The basic principle of calibration is that you have a primary standard. The primary standard has to have some national or international status -- the whole point of it being we all want to be able to compare our data in terms of time and in terms of geography. So recognized standards are absolutely fundamental to any calibration. But you need to be able to transfer the information from the primary standard to the working instrument, and that is where the transfer standard comes in, which has to be linked with a recognized method. If you have a transfer standard which is approved, but then don't use it properly, then it's still a waste of time.

Other things which we look at during the cal lab, which is a fairly fundamental thing, is that the instrument that you're calibrating has to be functional in terms of operating properly. We get sent instruments quite often where it has just been sent for a calibration, and in fact when we start to do the calibration, it doesn't work, or it certainly doesn't work properly. And then, of course, we have to go back and inform the client that -- as to what action to take.

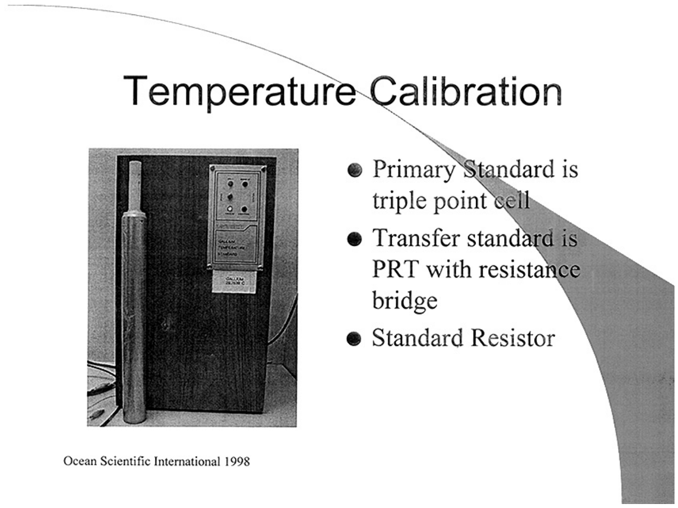
One or two, amazingly, say just do the calibration. We only need the certificate, which --
(Laughter.)

That's true. I say that's not normally oceanographic institutes. It's survey companies who are having to fulfill some documentary requirement. It's a bit alarming. Trust me, I'm a biologist, is another one that's come up quite often.
(Laughter.)




I am a biologist originally, so I can say that.

We've all seen the WOCE requirements. It's been up many times. We work to the WOCE standard, but many of our instruments, particularly the server instruments, the WOCE standard is better or more demanding than needs be. It's very difficult to downgrade a cal lab. You have the equipment there -- the water baths, the transfer standards and so on -- it's very difficult to say, well, I've got a cheap water bath that I use for the less instruments. We use the same stuff for all of them. So if it's a .1 degree accuracy or a .001 degree, actually, we use the same equipment. The difference we make is how we interpret the data in that we will accept bigger errors in a calibration fit, obviously, for a less accurate instrument. But we don't have a lot of different equipment for different standards of instrument.



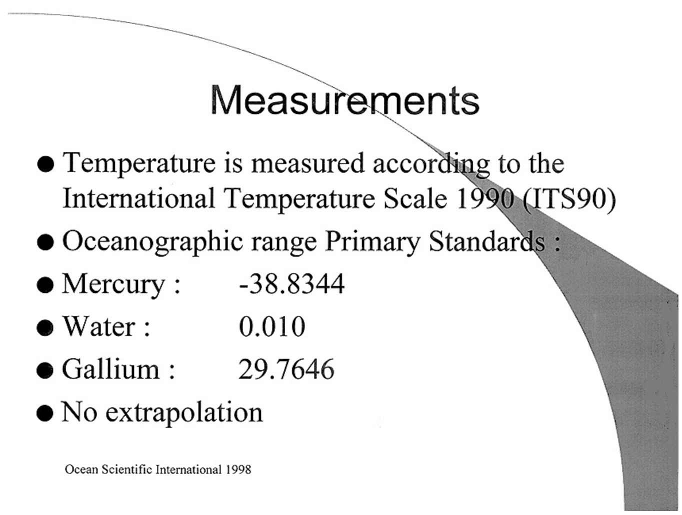

So I'm going to run through each parameter fairly quickly. Temperature -- the primary standard is triple point cell. Some cal labs keep their own triple point cells. Other cal labs rely on some central laboratory -- for instance, in the U.K., it's the National Physical Laboratory -- keep a whole range of triple point cells. So you can have your transfer standards calibrated there and sent back.

We keep triple point cells in our lab when we do them ourselves. The three that we use -- gallium, water and mercury.

A transfer standard is normally the platinum resistance thermometer, which is couple to, in our case, an AC resistance bridge -- a DC resistance bridge can be used -- and a standard resistor which is used really, in effect, to calibrate the bridge.

Measurements that are made for temperature according to the International Temperature Scale of 1990. This is a revision of the temperature scale -- previous one being the IPTS-68 -- International Practical Temperature Scale of 1968 -- which ITS-90 actually brought in a few changes that had already been happening during the period after IPTS-68, but formalized them. One or two other points, particularly at high temperature, were revised.

Having said that, it did have an effect, and certainly if you're calibrating in laboratories at room temperature, the difference between IPTS-68 and ITS-90 roughly is about five millidegrees. When you're doing measurements at sea surface -- I'm sorry -- the sea bed, around about four -- three or four degrees is actually no difference, or no measurable difference. Those are the three triple points that we use.



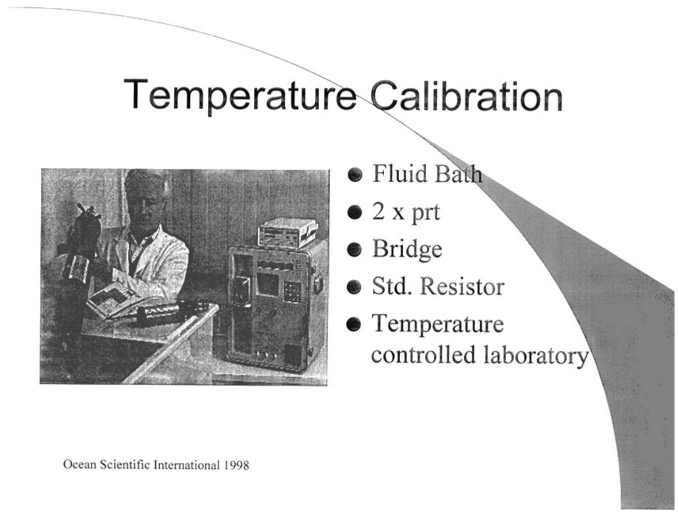

And the no-extrapolation rule which I've put at the bottom is actually an ITS-90 stipulation, and that is that you can't -- if you strictly follow the rule of ITS-90, you can't extrapolate beyond the triple points that you use. So the theory of that is that if you want to do calibrations below zero, you should have a mercury triple point cell. You should calibrate your PRT on a mercury cell as well as the water one.

It gets a bit more difficult, though, because some of us do make measurements above 29.8. That's the biologist coming out in me, by the way, calling it 29.8.

PARTICIPANT: At least you didn't call it 30.
(Laughter.)

MR. RIDOUT: If I were an engineer, I’d say, to be on the safe side, we’ll call it 35.
(Laughter.)

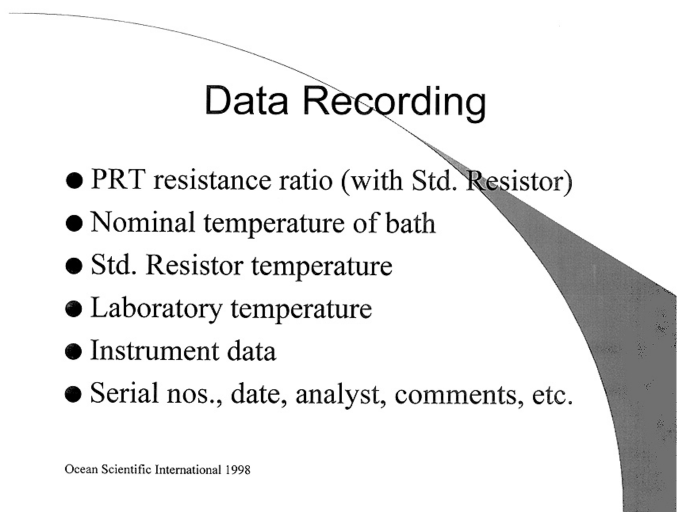
We do have to make measurements above 30. The next point -- I can’t remember -- it’s a long way. It’s in the hundreds. And so we have to make that exception.




To carry out a temperature calibration, we have a stable fluid bath, and they’re all shapes and sizes. I’ve been to many cal labs around the world. There are some of them which are as big as the swimming pool at our hotel. Some of them are, well, as small as the sink in my bathroom in the hotel.

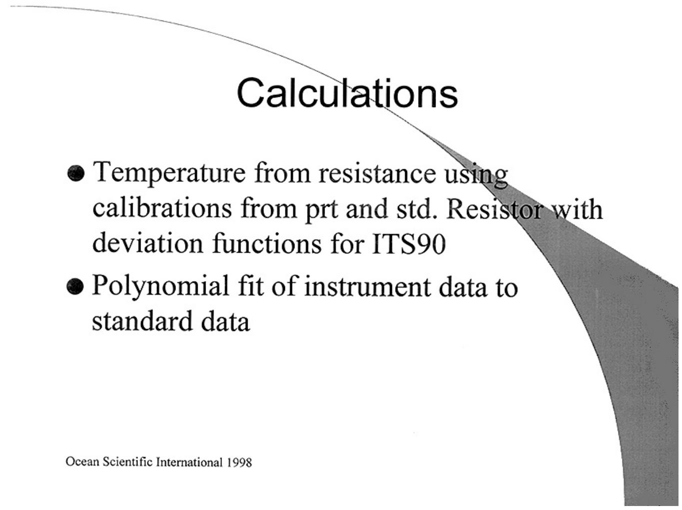
They each have benefits and each have disadvantages. Obviously, very big baths, you have problems of controlling the temperature and keeping it stable. Because if you’re doing a calibration to three decimal places of temperature, you need to have some stability over the period that you make the time -- the period that you make the measurements.

We always run two PRTs. We run high precision PRT which is used to make the calibration, and we run a second high precision PRT as a redundant probe to make sure that, if something did happen during the calibration, we’d at least have some check on that. We have an AC bridge and a standard resistor, and it’s in a temperature controlled room. If you’re trying to maintain a bath, you need to maintain the environment too.




The data we record for temperature, then, is the resistance ratio, or whatever -- some PRT bridges will give you temperature. They’ll do the calculations and put the coefficients in, and so they’re easier to use. We require the nominal temperature of the bath. The temperature of the standard resistor that we use, which is the balancing resistor -- in some -- again, in some bridges, you will have an internal resistor which is maintained in the temperature bath, which you then calibrate against an external resistor. But the resistance is temperature dependent. So we keep ours in a nice stable bath and record the temperature.

Then going in tune with other comments today and yesterday about documentation, keep notes. And it’s the little notes that usually make the difference, like, "Dropped something in the bath during the calibration." It’s the little things that might even seem insignificant that sometimes can make the difference between -- well, at least salvaging a calibration.



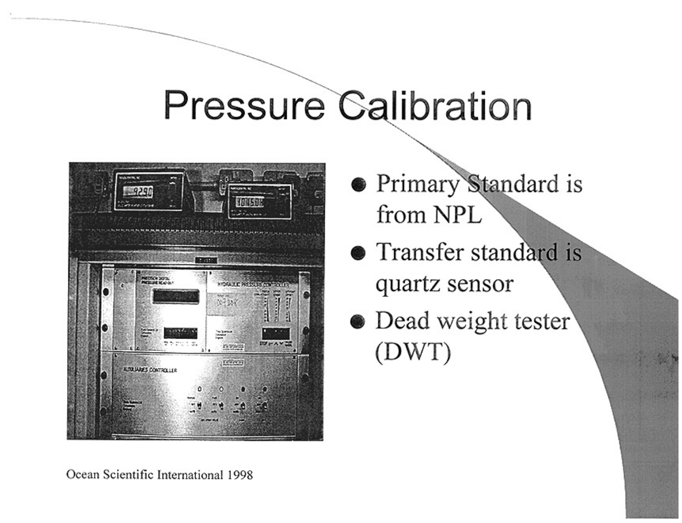

And then the calculations that we make is that we measure the temperature from the resistance, and we do a polynomial fit of the instrument data to the standard data, and then the first thing we look at are the error bars, assuming we've used the fit that's recommended for that particular instrument to see whether we think the calibration is within our specification.

And in line with something that Jim mentioned about real data, real effects being missed sometimes in the field, I don't know what it is about calibrations, but if you get a bad calibration, you always blame yourself first. So you always say, oh, I must've done something wrong with this, or -- so our cal manager will spend all this -- if he gets a bad cal, he'll spend most of his time then checking out all the equipment that he's used, what he did, and he'll probably do it all again. If he gets almost exactly the same bad cal, then he starts to think it might be the instrument. And sometimes it is, of course.

Certainly, though, the big differences in the way modern instrumentation operate and -- how did I do that? Oh, "end show," that looks like a good one.
(Laughter.)

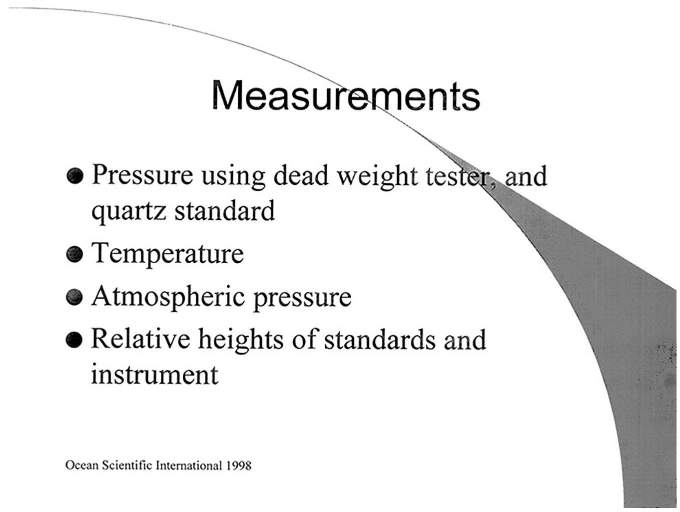
I'll just go down there and click -- see what happens.

Different instruments have different degrees of fit. I think -- and I might be wrong here, because I'm sort of up in the thick carpet bit upstairs now, so I don't get down into the cal lab as much as I used to -- is that something like a Neil Brown is probably a second degree -- a quadratic fit for the polynomial, or even linear fits we get for a number of instruments. Some instruments have very complex fitting programs and the software is used to give a good working range for the instrument, in which case, that's where the dialogue between a lab like ours and the instrument manufacturer is essential. We must be kept up to date with the latest developments in their software and calculations.



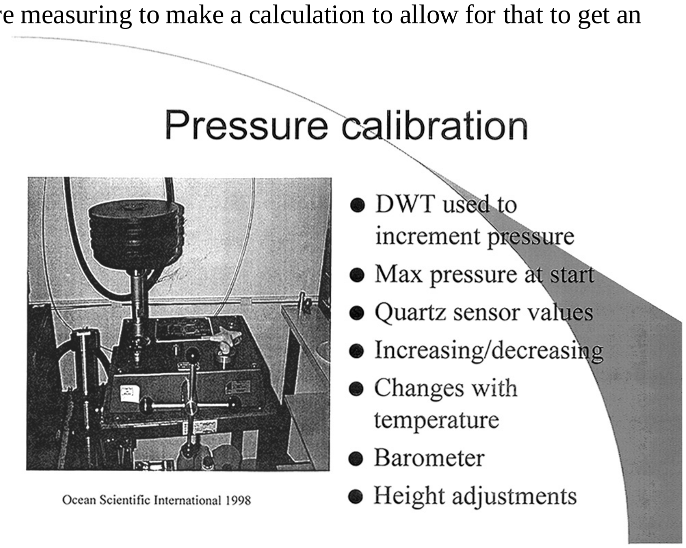

For pressure -- we use a dead-weight tester to generate changes in pressure, and then we use a paroscientific quartz sensor as our transfer standard. The primary standard is -- well, it's very easily waved away as being something from the National Physical Laboratory because it's based on standard piston areas and so on -- complex issue which I can't pretend to understand. So we send our primary standard to NPL and they calibrate from the primary. But we use the quartz sensor, which is the one on the left at the top, as our transfer standard, and that gives us better accuracy than using a -- well, we use a Bedenberg (ph) dead-weight tester.

More recently, which is the box below, and it's the top of what essentially looks like a large filing cabinet, is a Theta Systems (ph) automatic pressure calibrator. We actually run that -- we can run pressures overnight in that it increments the piston system through a pre-program. We use LabView. Our cal manager's written a program in LabView to generate it. So we do a pre-program pressure cal. And you can do up and down pressure cals and so on automatically overnight. Being a commercial laboratory, in that respect, we're always trying to save time but not lose quality. So one of the things we're trying to do, certainly with the mid-range calibrations, the sort of .01 instruments as we call them, is to run things overnight using programmable equipment.



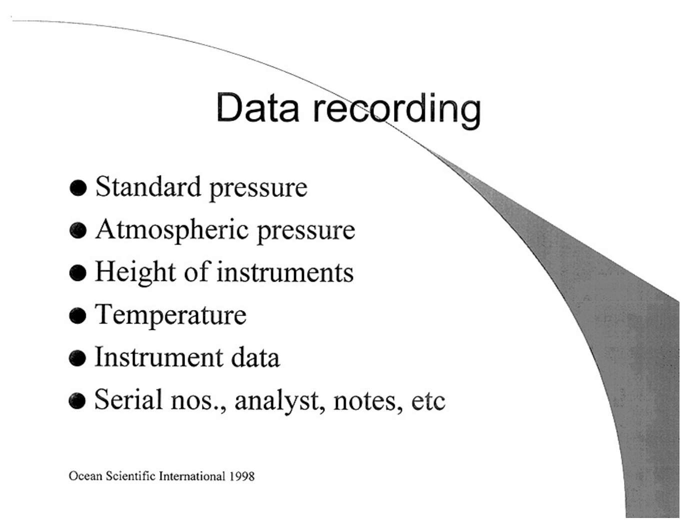

Okay. Some of the measurements we make: We measure pressure from the quartz sensor temperature, and we need to know the atmospheric pressure because atmospheric pressure obviously has an effect on the pressure. We also need to know the relative heights of the instruments that we're measuring to make a calculation to allow for that to get an absolute measure.

I've already explained that now. So there's an example. That's the dead-weight tester that we use. We increment the pressure with that.



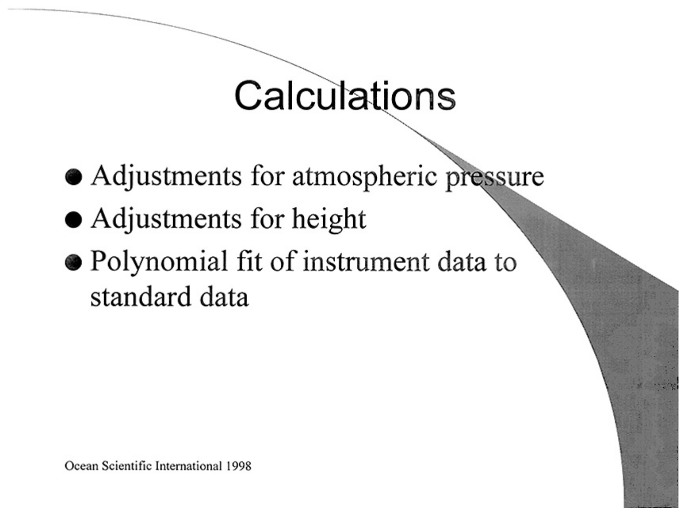

One or two little things we do is we always give them maximum pressure at the start to -- sometime you get sticky pressure sensors. So we sort of whack it a couple of times to make sure it's all going to respond properly when we start a calibration, making sure that we've checked, first of all, what the maximum operating pressure is.
(Laughter.)

One of those areas of -- hot on the back of the neck when you read it after you've just pumped it up to 10,000 psi and you realize it's a coastal instrument.
(Laughter.)



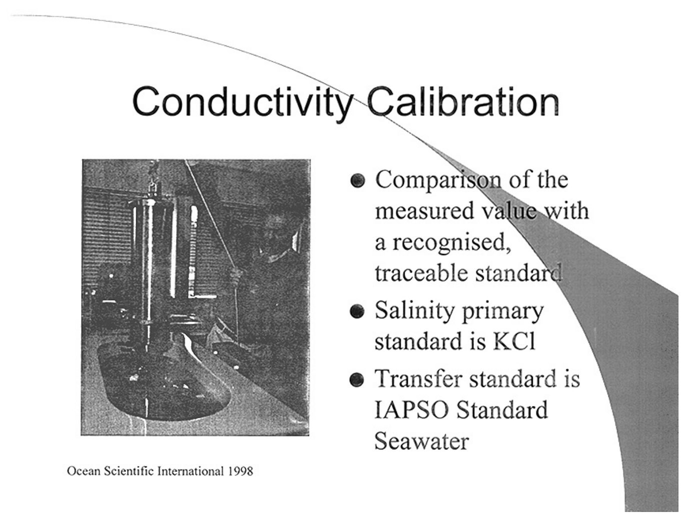

We do things like increasing and decreasing pressure cals, of course. For WOCE particularly we've been doing experiments and carrying out pressure cals by looking at particularly the Neil Browns, changes with temperature, how it affects the temperature calibration, and dynamic temperature changes like plunging the unit in from room temperature into five degrees and looking at the effects on the pressure cals.

And these are the things that we record -- standard pressure, atmospheric pressure, height of the instruments, and so on. And in the same way as temperature, we then have to make calculations, the adjustments for atmospheric pressure and height, and then another polynomial fit.




Conductivity. This is what I probably know the most about because I've been running the standard seawater service for so long now at IOS and at Ocean Scientific -- that's rather a dark picture. For conductivity calibrations, the primary standard is potassium chloride solution, as defined by the practical salinity scale 1978 -- PSA-78. This is my opportunity yet again to remind you all that you all, of course, know there are units for salinity, not even a PSU -- which I think Woods Hole invented it because I'm here in Scripps. And when I'm in Woods Hole, I say you invented it.
(Laughter.)

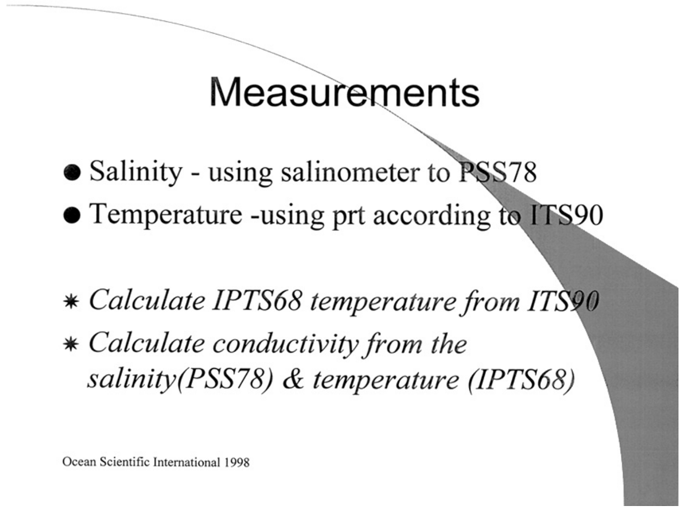
There are no units. The practical salinity scale is a scale, and it was introduced in 1978 based on a series of experiments that were carried out at various laboratories around the world. It's like the pH scale. That's the only analogy I can draw there. You don't say normally it has pH -- you know, pH is 14, seven -- when it's a scale, it's not -- it's very difficult with salinity because it used to have a concentration. It's obviously difficult. Even now I have to say it's the same as three and a half percent salt. But no units.




So the primary standard's the KCl, but the transfer standard is IAPSO standard seawater. I'm often asked the question, why don't we have KCl as a transfer standard so we can all use the primary standard? There are a number of reasons, but the main reasons for that is that KCl has a completely different temperature coefficient to that of seawater.

And of course it's always better to standardize on the same matrix in most measurements, and particularly chemical measurements. It's much better to measure on the same matrix that you're -- calibrate on the same matrix that you're measuring on. And there's obviously a very long historic link with the Standard Seawater Service, which is coming up for its centenary soon. So we'll probably have to do a special colored batch or something for that.
(Laughter.)

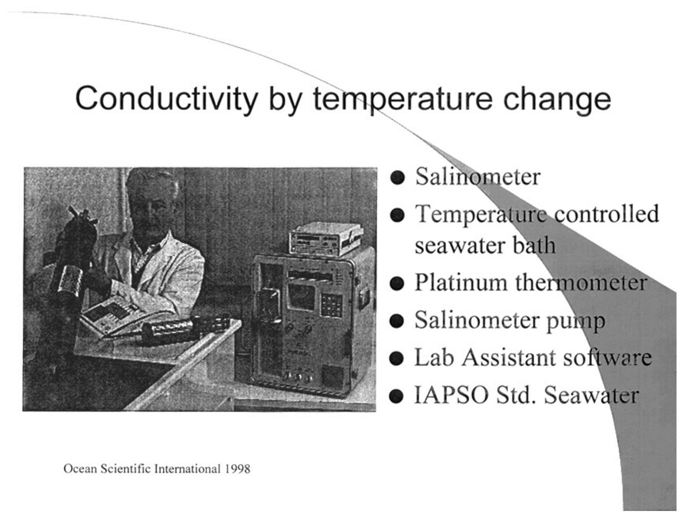
So the measurements we make -- we measure -- when we're doing a conductivity calibration of a CTD, we measure salinity and we measure temperature. We measure salinity by having a salinometer next to the water bath, and we measure temperature in the same way as the temperature cal, using a PRT and a bridge. But we measure temperature on ITS-90, and the definition of salinity is still related to IPTS-68. So on low and deep water measurements, it doesn't make any real difference. It does make a difference in the lab, because you do most of your calibrations at 21 -- well, in lab temperatures -- or above zero anyway.




And so you have to convert your ITS-90 temperatures to IPTS-68 when you make the calculation from salinity to conductivity. Your salinometers (unintelligible; mumbling) conductivity.

That may change, and in fact I had a meeting while I've been here this week. Fred Culkin and Joris Gieskes , who were involved with the original JPOTS committee that defined the last definition of salinity, discussing now how we're going to deal with perhaps bringing ITS-90 to become the standard for the salinity measurement. So something may come out, I hope, in the next 20 years or so.

In our laboratory, we have two ways of doing conductivity cals. For the mid-range instruments, the .01 instruments, we use the quicker method, which is to use a seawater bath, and we get changes in conductivity by changing the temperature. So we use the same seawater, and we use it in the temperature controlled bath. We obviously monitor the salinity because there will be a little bit of evaporation. So we're interested in the salinity changes. But the big changes in conductivity take place because we run the bath from zero to 30, something in that range.

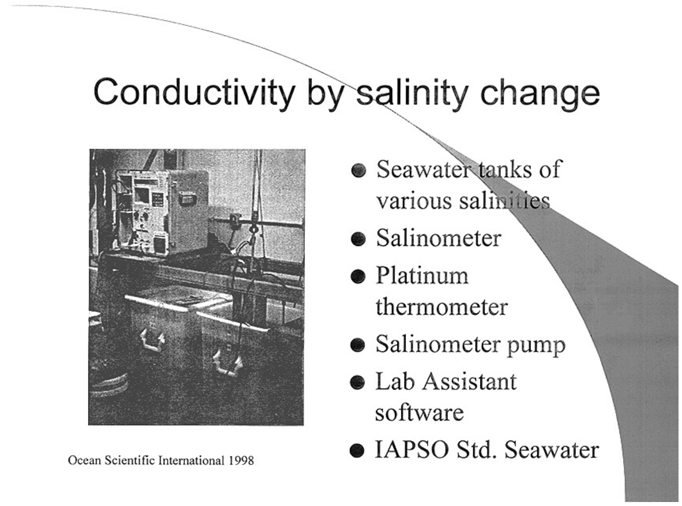



The speed advantage of that, of course, is you can do temperature and conductivity cals at exactly the same time. For all the mid-range instruments, I think that's a perfectly valid way of doing it.

To get a really big range of conductivity, you really need two baths to have -- to get up into the higher end and the lower end. You need sort of like one bath at salinity 35 and perhaps one down at about 20 -- something that order to give you a nice range.

All the equipment, then, is temperature controlled -- seawater bath, platinum thermometer, salinometer pump -- I'll mention in a minute -- and some software, and the standards, of course.

The other way to do it is by changing the salinity, which is the way we were doing it for WOCE. We've got a whole series of baths -- seawater baths -- which contain natural seawater. Natural seawater is the best way to do it, again for temperature coefficient reasons. We have a range of baths at all different salinities, and we just lift the CTD up and drop it in, one into each bath, and the salinometer is there monitoring the salinity accurately to three places, along with the PRT for the temperature.

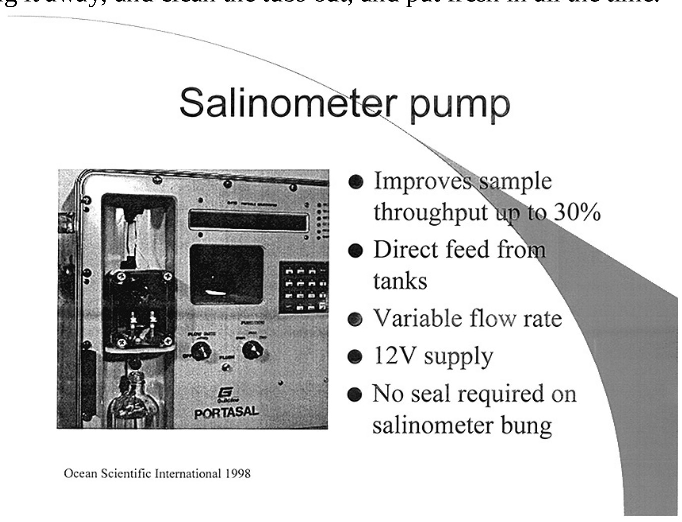



The principle's the same. There's a lot more moving around. We get slightly better cals that way.

You've got to be a bit careful. There are little, little things to do, like always go from high salinity to low, or low to high, but don't jump around, because that way the flushing of the sal is constant. You obviously have to take care to make sure the whole thing's equilibrated. And these baths, although they look fairly simple, there's quite a lot of work that had to go in, one, to make sure that the way we pump the water in the bath that we get completely even circulation; two, we didn't want the temperature of the bath to change dramatically during the period of the calibration measurements. So we used magnetically coupled pumps where the blades of the pump are a long way from the motor, so we don't get a lot of heat being put in from the circulating motor. We keep the baths clean.

Some places we'll filter the water, or even poison the water, which I don't like because it changes its chemistry. We're bringing in thousands and thousands of gallons of seawater all the time for the standard seawater service, and so we just keep throwing it away, and clean the tubs out, and put fresh in all the time.

One of the things that we have done that's made a huge difference to our calibrations, but it also makes a big difference in the lab, as well, is that we came up with this little pump idea to go on the Guildline Autosal or Portasal, either salinometer. You know, the Guildline salinometers are sort of an industry standard now for laboratory salinities -- very nice and stable, been around a long time. They're well characterized.




But they have a few weaknesses. The one weakness that we found difficult to cope with was the pumping system. They've got these little -- got little aquarium pumps in there that are laboring away to just about get a sample in if all the tubes are on tight. We've found that slow and inefficient, and of course with ampules, it's even more difficult to get a good seal, or you shred the bungs and so on.

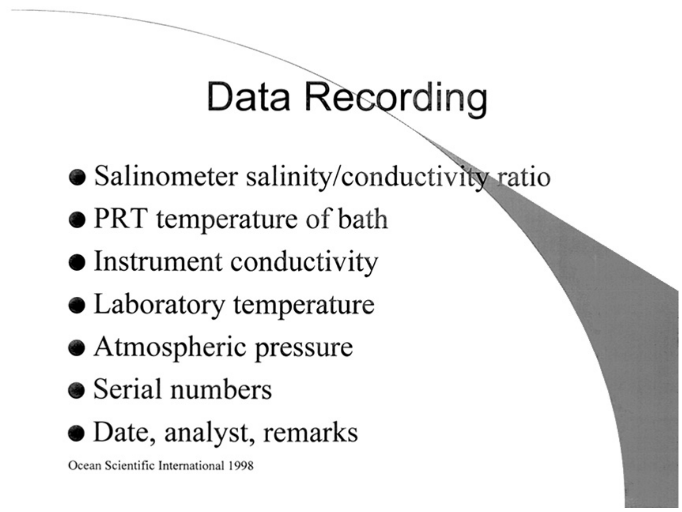
So quite a few years ago now -- four or five years ago -- we came up with this little pump, and we put it in a water-tight housing, made it -- designed it so it would fit on the platform, which is the other weakness in the salinometer is that platform keeps -- you can sort of put holes in the back of the thing trying to use the same position. So once we've put it up, it stays there.

Now you don't have to make a seal anymore. So you've just got a tube coming out the bottom of the pump, and you break the top off the ampule and put it straight in, and it just draws it out as a positive peristaltic action. And what are the lasers (ph) to do of course is to pump water straight from a cal tank straight into the salinometer. So we don't mess around with siphoning water into bottles and then transferring them and all the error -- potential errors that can come into that part of the calibration.

I produced one of these myself five years ago because I thought -- I fed up with these pumps. And then, of course, the inevitable happened. These people came, oh, I'd like one of those. I'd like one of those. So we started manufacturing them. We started manufacturing them, and I did sort of calculate that we might break even if we sold 20. So I thought, well, we'll work on that basis. And we've sold 200. But it's not -- they're not that expensive, so I'm not driving a Ferrari or anything on it.
(Laughter.)

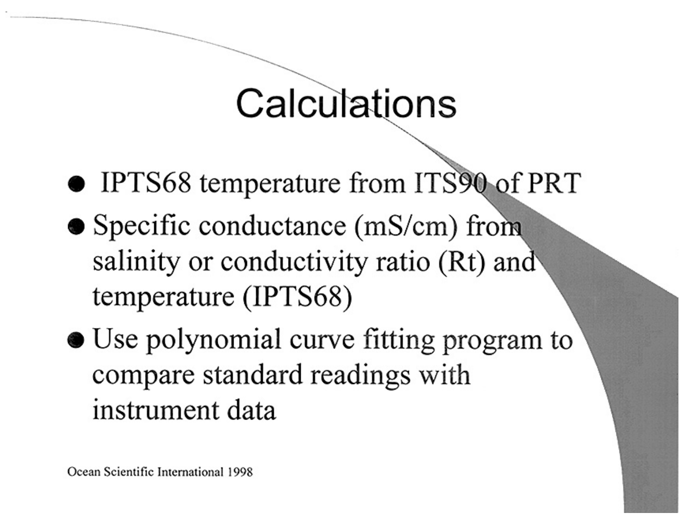
PARTICIPANT: Not yet.

MR. RIDOUT: Not yet, no. There's not many more salinometers left, unfortunately.




Data recording. Then we record the salinometer salinity or the conductivity ratio, the temperature in the bath, the instrument conductivity and laboratory temperature. And then, again, we take detailed notes. Who did the analysis is always a good one. And then we calculate IPTS-68 temperature from ITS-90. Specific conductance, which I think is actually the proper term for what we call CTD conductivity -- millisemens (ph) per centimeter -- has to be calculated, and then the polynomial curve fit.

So that's a brief overview of how we calibrate CTDs in our laboratory. I've got a few papers here which you're welcome to take away. One of them was an article that was published in International Ocean Systems Design last month, which perhaps (unintelligible) little bit more detail, but it's a summary of what we do in our laboratory. And there's a copy of our newsletter if anybody's interested.




Perhaps more interesting for some people who are doing salinity work is we've recently published a paper in Journal of Atmospheric and Ocean Technology on the stability of standard seawater. It's an age-old question. What is the shelf life of standard seawater? And a number of papers, two or three particularly good ones, from Arnold Mantyla here, but a number of subsequent workers also have written papers on so-called offsets -- differences in salinity ageing properties of standard seawater.

It's quite an important subject, and it's one not to get too confused over, and one that worries Fred Culkin and I some of the time, which is one of the reasons why we've published this paper, is that you have to be very careful when you make assessments on the changes in standard seawater.

What do you use as a reference? A number of papers have come out where they’ve taken the latest standard as the reference. We know there are changes in standard seawater after it’s bottled. And we know they’re small. Certainly in the first 12 months they’re very small, within the noise of the measurement normally.

But if you then, two years on, take a standard reference and then compare other bottles with that, you may actually be looking at changes in the standard that you’re using -- the reference point that you’re using -- rather than the changes in the more recent standards. I certain have seen work where claims have been made that so-and-so batch has gone off, or whatever that means. And in fact what it is is that the reference that they’ve used is much older than the standards that are being measured now. So it’s probably the other one that’s changed. We’re talking very small changes, and so you have to be very careful on how you interpret so-called offsets in standard seawater.

Our paper is not the same necessarily as these other papers. It’s a different approach. It doesn’t invalidate anybody else’s work. But what we do when we calibrate IAPSO standard seawater, we calibrate it against the KCl, which is a defined solution of 32.4356 grams of KCl per kilogram of water. And so that’s an absolute reference point, or as near as you can get with a chemical standard. So we use that as our reference point when we look at offsets. And every time we calibrate a new batch of standard seawater, we run two or three or four of previous batches, some of which can be up to 18 months old by that time. So that gives us an indication of changes. Admittedly, we’re only doing small numbers of ampules, so you would not describe it as a definitive experiment in that respect. But it’s quite important data, and so we felt that we would publish that to give an idea.

I have to say, of course, that it’s between -- I think 96 weeks was the longest period that we showed, and many of the other ampules that we tested were a lot younger than that, and the differences have been extremely small, less than .001 in salinity in all cases, which is another important factor. You know, we’ve got batches that go right back to 1901. We’ve got the original ampules that Martin Knudson (ph) made, hand-signed by him, with "Please return the ampule" on the label, which shows how things have changed.

We’ve gone back, and you can look at previous batches 30, 40, 50 years old. And they will be different. They will have changed. You get interactions between the water and the glass, and you get microbial action.

But with some of these more recent studies, you’ve got to be very careful, because three years on, you might see an offset of, say, 001, or even 002 in salinity. But was that offset there when you used it? You know, you might’ve used that batch when it was 12 months old, or six months old. And the chances are that those changes, which are very slow process changes, have been taking place.

There are a few copies of that for anybody who’s interested. If they run out, or if anybody wants to talk to us about how we do things, we run training courses in CTD calibration. We’re quite happy to give free advice to anybody that asks. By all means use my e-mail, or you can access us through the web site.

Thank you.
(Applause.)

MR. SUTHERLAND: We have time for one or two questions for Paul. Anyone?

PARTICIPANT: Do you have a plot of the difference between IPTS-68 and ITS-90?

MR. RIDOUT: I do.

PARTICIPANT: Is it up --

PARTICIPANT: It’s pretty boring.

MR. RIDOUT: Not on my machine, but I've got it in a book. Happily, you can photocopy it if you wish. The National Physical Laboratory produced a very nice paper on the subject summarizing the stuff that we really need to know, the practical aspects of it.

I got off lightly.

# Insitu Pressure Calibrations On WOCE-Level

Sven Ober
**Netherlands Institute for Sea Research**

**Introduction**

The NIOZ-CTD systems are based on Seabird CTD’s. A lot of time and money is spent to calibrate the sensors properly. This is done mainly for 2 reasons. The first is quality assurance. Good science starts with high quality data. The second reason is perhaps a bit unexpected. It is an economical one and it is called speed. A few years ago it took months to process a CTD data-set up to WOCE-level and that is very expensive in terms of labor. Main reason was doubt about the calibrations. They were carried out as good as possible, but the remaining uncertainty was still too big. In order to tackle this problem it was decided to invest in better calibration-equipment as soon as it appears on the market. The first big jump forward we made was the use of one of the first reference thermometers of Seabird: the SBE-35. During Inmartech 1996 in Southhampton these results were presented. All doubts and discussions about temperature-calibrations were killed in one single action. With an Autosal Salinometer it was already possible to calibrate the conductivity-sensor easily and onboard, but for the calibration of the pressure-sensor it was necessary to rely on the pre- and post-cruise laboratory calibrations. In principle this is good enough, because the Paroscientific pressure is a very good and very stable sensor, but the wish to have an independent calibration (independent from Seabird, Paroscientific or NOAA) on board during our cruises remained. We used ERPM’s manufactured by SIS from Germany, but the accuracy of these instruments was too low for a proper calibration. It monitors the Paroscientific sensor for malfunctioning only.

It was pleasant to hear from SIS that they were developing a new generation ERPM’s with a much higher accuray. Perhaps it was possible to calibrate from now on all CTD-sensors in situ so during the cruise on WOCE-level. That is the ultimate speed goal: CTD-measurements database-ready on board.

## *Pressure-sensors*

The WOCE-requirement for pressure measurements is 0.02% of the reading. This figure originates from the WHP-manual, but in terms of metrology it is poor defined. Not stated is whether this is based on 1, 2 or 3 s.

Inside of most Seabird CTD’s (SBE-9) a Paroscientific pressuresensor is mounted. This sensor has an uncertainty of 0.02% of the reading. So it meets the WOCE-requirement. This figure is based on personal communication with Seabird and is conservative. In earlier days the Paroscientific pressure-sensors were calibrated at NOAA, but due to budget-cuts the NOAA calibration facility was closed. Seabird is developing a pressure calibration facility now and it is almost ready. The expected uncertainty by then is about 0.01% so twice as good as today.

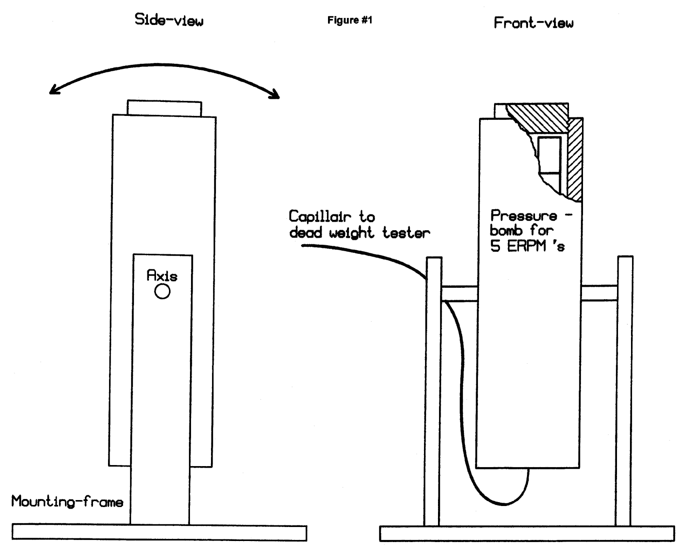
Mentioned above is the use of electronic reversing pressuremeters for “checking” purposes and the hope that the new generation of pressuremeters could be of use for real calibrations. The accuracy specifications of both types are:

| | |
|---|---|
| RPM-6000 (traditional type) | 0.3% of full scale |
| RPM-6000 X (new generation) | 0.1% of full scale |

Earlier experiences with the traditional ERPM’s learned that 0.3% was very conservative. The instruments appeared to be better then specified. The expectancy was that the 0.1% of the new ones was too pessimistic as well. There was a small concern about the pressurecalibration-facility from SIS. It was developed to calibrate the traditional type so it may be not good enough for the new generation ERPM's. Therefore it was necessary to develop a calibration-method for these new ERPM's. Two problems had to be solved. The first problem was a proper pressure standard: a socalled dead weight tester. Dead weight testers are very expensive both to buy them and to keep them OK. The Dutch laboratory of standards, the Nmi, was able to solve this problem. They had (and still have) a pressure calibration facility with an uncertainty (based on 2 s) of 0.008% available for a reasonable price. The second problem was how to attach an ERPM to the dead weight tester and how to initiate a measurement. This was solved by developing a pressure-container that can be reversed exactly like a rack mounted on a watersampler.

**Facility and procedure for the calibration of ERPM's**

Figure #1 is a drawing of this container. It can take 5 ERPM's. The calibration procedure is straightforward. Load the container with armed ERPM's. Fill the container with water, close it with the lid and de-air it with the (small) de-air valve. Increase the pressure with the dead weight tester. Enforce an overshoot to simulate an upcast so a calibration point is always reached from the high end. Turn the container upside down and wait for a minute. Turn it back and depressurise it. Open the container and read the values from the displays of the ERPM's. With the same dead weight tester the Paroscientific pressure sensor of the CTD was (re)calibrated, because of the lower uncertainty of the Nmi-facility.




## *Calibration and field results*

In figure #2 to #4 field results obtained during a cruise in the Bay of Biscay in August 1998 are presented in 3 different ways using the original factory-calibrations and the Nmi/NIOZ calibrations. Presented are ALL the measurements, there was not a single rejection. In figure #2 the "raw" results show a systematic difference between the sensors of about 2.5 dbar at high values. Figure #3 shows the contribution to the quality by the Nmi/NIOZ-calibrations of the ERPM. In figure #4 the combined result is presented: a difference between "standard" and "sensor" of far less then 1 dbar for ALL in situ calibrations. This result is obtained onboard, meaning during the cruise.

**Figure #2**
**(Psis,p6538 factorycal. - Pctd, factorycal.) vs. pressure**

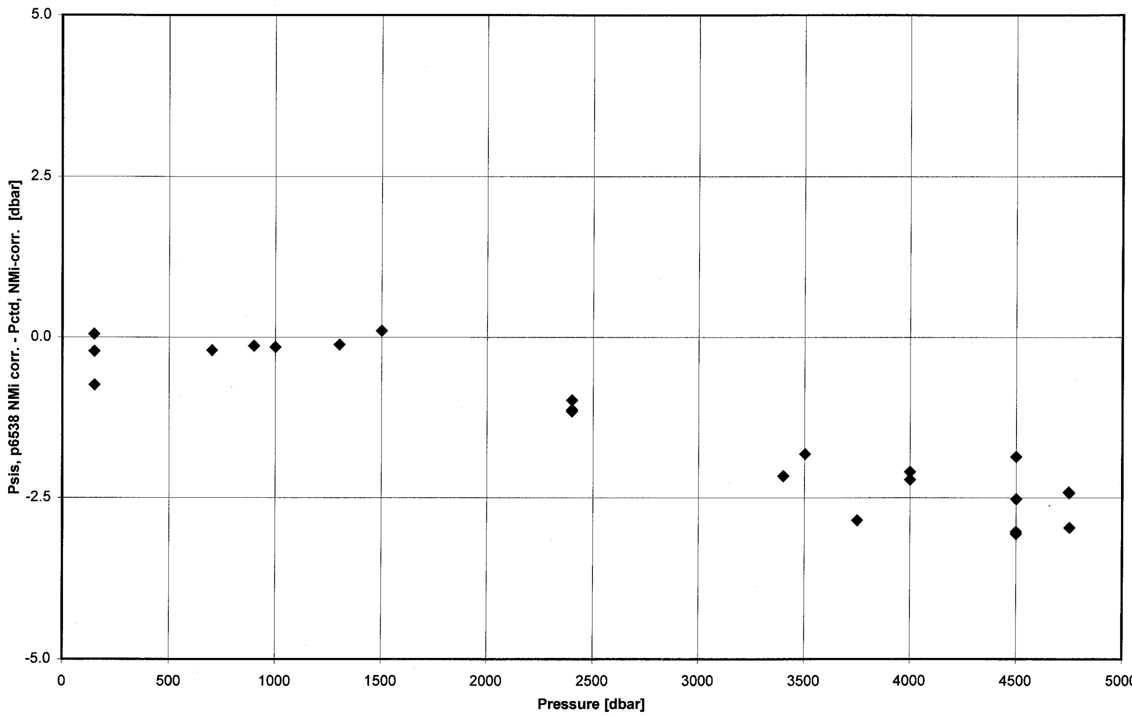
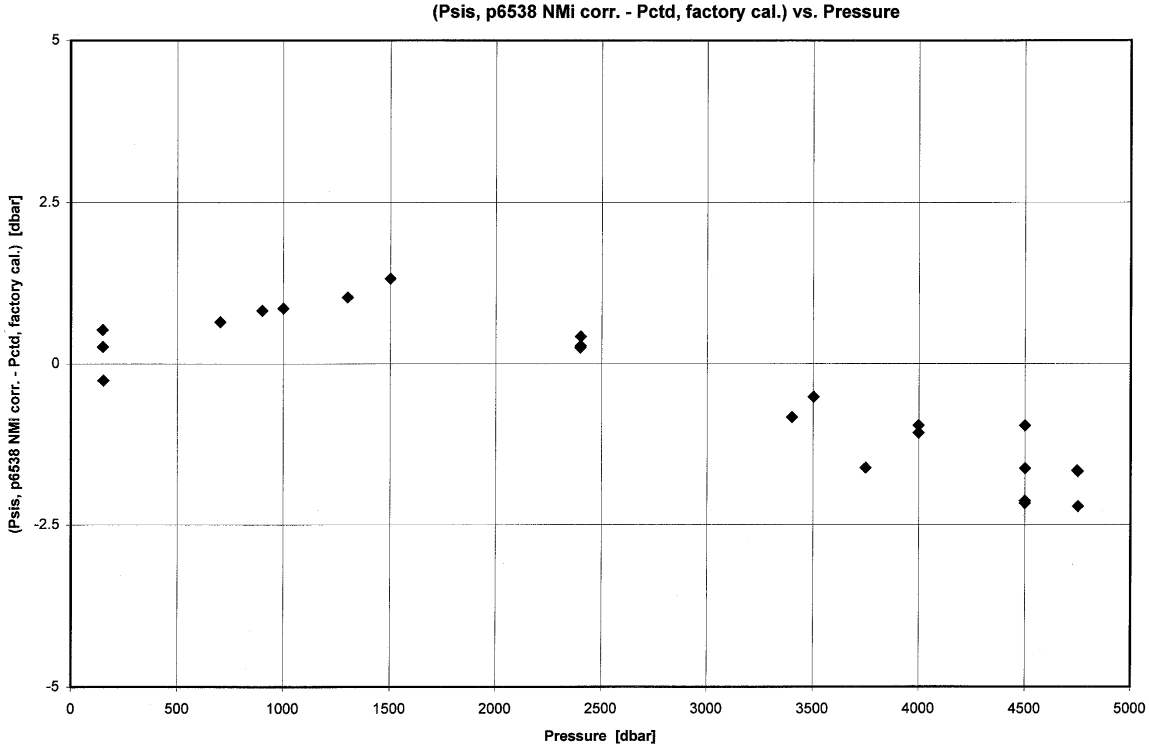
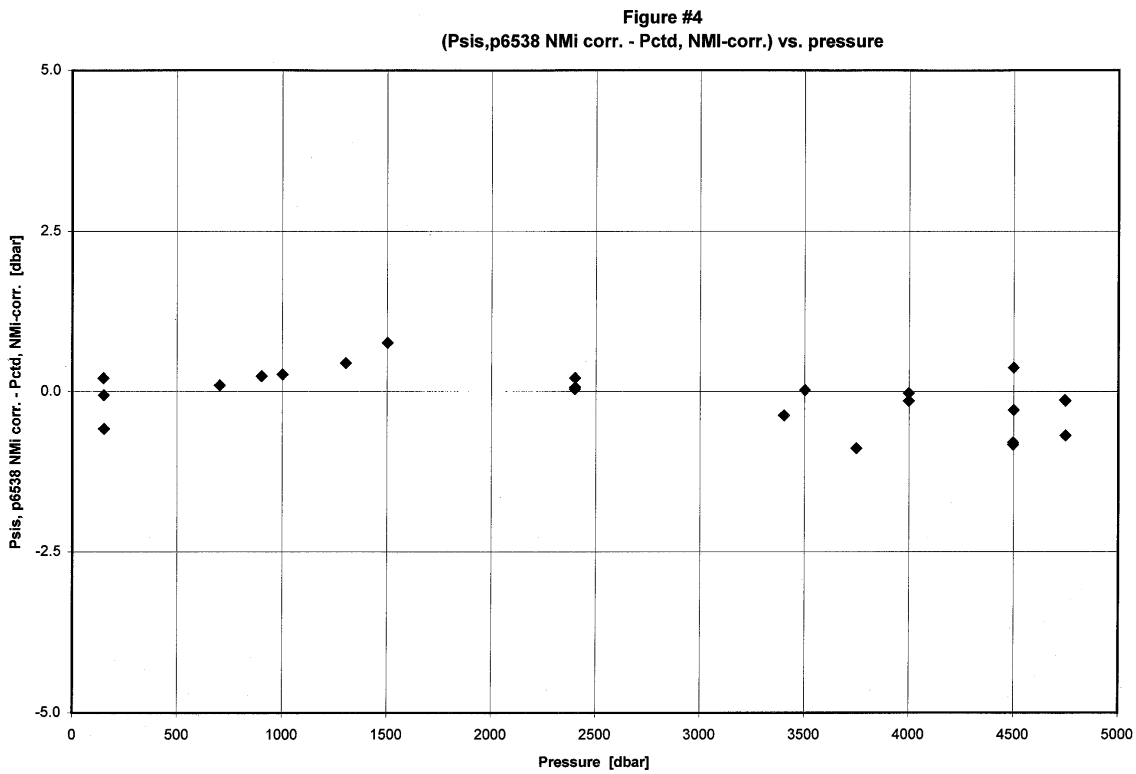



**Figure #3**
**(Psis, p6538 NMi corr. - Pctd, factory cal.) vs. Pressure**






## Conclusions

- Both the Paroscientific pressure sensor and the RPM-6000 X meet their specifications.

- With a careful calibration it is possible to increase the performance of both sensors.

- It is possible to meet the WOCE-requirements already onboard during a cruise.

# INMARTECH '98 WRAP-UP DISCUSSION SESSION

Chaired By
Woody Sutherland

# INMARTECH '98
# Wrap-Up Discussion Session

MR. SUTHERLAND: An issue that was brought to my attention during the week is -- Helen Beggs from Australia is interested in anyone that's doing work with current meters. I'll let her speak up and see if there's anyone that can answer her questions.

MS. BEGGS: Yes. I've been asking around -- Scripps anyway -- and it seems that Scripps doesn't use them anymore. Perhaps they're too old-fashioned or something. But unfortunately, we still have Pelandra (ph) type four, five, seven and eight current meters, plus Dietman (ph) current meters and Neil Brown acoustic current meters. We're really desperate for some good processing software, because the stuff I've got is just terrible. I don't really have the time to sit down and write the new software at the moment.

So I was wondering if anyone knows of anything at all.

MR. FINDLEY: There are people at the University of Miami using ANDRES (ph). I don't know what they're doing with it.

MR. SUTHERLAND: So why don't we leave it if you have any contacts, then go ahead and talk to Helen either after this break or at dinner, or either get her e-mail address or somehow get the two connected.

MS. BEGGS: I'd really appreciate it.

MR. SUTHERLAND: Okay. I want to go back to this issue about the future CTD package being just a telemetry module. This sort of has come during the Indian Ocean WOCE Project that ODF was concerned with.

MR. FINDLEY: I'd rephrase that.

MR. SUTHERLAND: What's that?

MR. FINDLEY: I wouldn't call the CTD the telemetry package.

MR. SUTHERLAND: Well, the center of it. Okay.

MR. FINDLEY: Think of it as a sensor attached (unintelligible). It doesn't make sense to tie a sensor to a telemetry. I mean, that's a classic problem with CTDs for years has been that you'd make an advance in telemetry that then would allow you to make an advance in the sensors, or vice versa, and for too long we've tied those together. I think the next biggest advance in CTDs is get -- take all the telemetry out of them and make them just sensors that go to something else. A SmartLink CTD-type thing would be so much simpler than having it deal with all the telemetry.

MR. SUTHERLAND: I stand corrected.

MR. FINDLEY: Well, not correct -- re-opinioned.

MR. SUTHERLAND: During the WOCE project, we had 36 ten-liter bottles on the frame, the CTD -- often a separate conductivity temperature pair, which really doesn't matter -- but we did have transmissometers, a large lowered ADCP, and the packages got bigger and bigger and heavier and heavier, and we're still working with the .322 cable. I forgot what the timing was, but I remember -- if my memory's correct -- that in the middle of the WOCE project, Rochester lowered the safe working load on the .322 wire -- just sort of under the table in the back corners and said, oh, yeah, well, that wire's not built to work at that load.

After we investigated, the reason was is because we were seeing conductor failures inside the wire, and not necessarily the strength -- the breaking strength of the wire was going down or was being lowered, but they didn't want to have to mess with the liability issues of the conductors going bad inside the wire.

So at that time or shortly thereafter, the U.S. contingency of the technicians started talking about, well, maybe we need to investigate a new standard for the EM cable, some sort of electrical/mechanical cable to take these bigger packages. One of the major concerns is going to be the cost. We already have all the ships outfitted with winches, and LEBA(ph) shells, and level winds for a .322 EM cable. And if we go to a different size cable, then we're going to have to change all that at a large expense.

DR. SHOR: Woody, that is assuming -- this is Sandy Shor -- that .68 is too big.

MR. SUTHERLAND: Right.

DR. SHOR: And .68 is not too big. They're all outfitted with that, as well -- or not all, that's certainly true -- but a large number of them. I would like to hear whether you're going to be pushing that standard in a while with CTDs or similar. Certainly there is a big financial impact in reconfiguring a fleet for a different size of an EM cable for CTDs if it's not the step to the larger one we're using now.

MR. SUTHERLAND: But I think the first question I have to the audience, which hasn't come up yet, to my knowledge, the .322 wire we're using now has three internal conductors -- and whether anyone is using each one of those three conductors individually so that we will need to maintain that number of conductors, or if we can go to a smaller number of conductors as we're thinking about new cable.

MR. FINDLEY: Well, since I'm like the chair on that new UNOLS committee -- or reformed committee -- I mean, that's the next issue I'm going to be starting to deal with.

MR. SUTHERLAND: While we've got quite a few people here, I wanted to hear who's using -- who's using more than one conductor in that cable, essentially?

MR. FINDLEY: Or not tying them together.

MR. SUTHERLAND: Yeah. Yeah. What are you using the other conductors for.

UNIDENTIFIED FEMALE SPEAKER: Optics package -- AC-9 (ph).

MR. SUTHERLAND: Okay.

MR. FINDLEY: And that's just a failure of not having enough bandwidth in the single conductor.

UNIDENTIFIED FEMALE SPEAKER: Right. Or you -- I mean, bypass that and go with the low-depths (ph) (indiscernible).

MR. FINDLEY: That's a 500 (unintelligible) long cable.

UNIDENTIFIED FEMALE SPEAKER: Right.

UNIDENTIFIED MALE SPEAKER: That's a 500 meter wire.

MR. SUTHERLAND: You’re limited by the resistance of the wire, too, so you have to use a short wire.

MR. FINDLEY: I mean, here’s the part of the discussion on this cable, too, is if you go to, quote, the core of the problem and the core of the cable. Where Woody, I assume, is heading, if we go to single conductor, we can reduce the inner core.

MR. SUTHERLAND: Right.

MR. FINDLEY: And then by doing that --

UNIDENTIFIED MALE SPEAKER: Getting more steel.
(Multiple simultaneous speakers; indiscernible.)

MR. FINDLEY: Well, what we can then do is actually put two inner lays (ph), because the current wire is not torque balance, and not being torque balanced, what happens is the outer layer unlays, and the inner one stretches. You’re not really carrying equally on each half, so your strength is way down because of that factor. If you just could get them balanced and not even increase the cross-section of the steel, the cable would be much stronger. But if you go to two inner lays in the same direction, you might be able to balance it against an outer lay. You can’t just reduce the strands in the outer lay, because then you start to have too small a strand that will then wear and break, and then you have flying strands, and they get real ugly fast when they ball up in a block.

So that’s kind of the basic idea. If we reduce the number of conductors in the center, and one of the thoughts was using -- to carry it even further -- would be use possibly a stainless tube in the center as the conductor, copper plate it, and use that as a power conductor, and then run fibers in that tube for high speed communications. And then if you wanted the cheap version of that cable, you’d leave the fibers out and put maybe just a regular conductor. But you could pump a lot of power down that center and not worry even if leakage became a problem, because (unintelligible) you would never put any signal through it.

UNIDENTIFIED MALE SPEAKER: Isn’t that center part going to be shorted to the inner steel?

MR. FINDLEY: Well, no. There would be an insulator over that. I mean, it would be -- I mean, these tubes are small. I mean, they look like wires.

UNIDENTIFIED MALE SPEAKER: No, I’ve never seen that.

MR. FINDLEY: And then there would be an insulation over that, and then the -- that is like one of my first approaches to the problem. Maybe somebody else has got some other ideas who’s been using it.

MR. SUTHERLAND: Well, as a take-home message -- the take-home message to Rich in his position as the chair of the committee, it sounds like no one, in this audience at least, would be -- would have heartburn over the idea of going to a single conductor EM cable that has higher bandwidth so that you can get more throughput; is that correct? Would anyone --

MR. WOODROFFE: Can I just ask, just for my own information, because I’m not familiar with the equipment you use over here. I just wondered why you have multi-colored cables and what instruments you have that have such high bandwidth that you require things like fiber optics for the CTD cable.

MR. SUTHERLAND: If I remember -- I think I can answer the first one. If I remember correctly, when we started with the CTDs, we needed separate conductors -- one to go to the pylon and one to the CTD.

MR. FINDLEY: It was actually for the old Plessy (ph) 9040 STDs and the -- wherever you came into the history of it, Plessy or Tetratech (ph) -- STD and the original General Oceanics rosettes, they actually reversed -- on a single conductor, they reversed the polarity and shut the STD down, which, you know, there was all the stability in the sensors gone. So originally, the additional conductors were added so that you could run the STD and the rosette on a separate conductor. So that was two conductors, and to make it a round package, you added the third conductor.

MR. WOODROFFE: But you've stuck with that over the years, because, I mean --

MR. FINDLEY: Yeah. Well, that was -- this was sort of a double check on that. We'd assumed everybody had done that, but it wasn't positive.

MR. SUTHERLAND: At least everyone has here --

DR. SHOR: For those --

MR. SUTHERLAND: -- and they're the important people. So --

DR. SHOR: For those not from the U.S. and maybe not familiar with how we do things -- this is Sandy SHOR again -- another reason is that, in the U.S., the 28 ships, plus or minus over the years, we have determined that it's a lot cheaper and a lot better to buy about four types of cable, period, for the whole fleet, and buy those in bulk, and through a separate wire pool. So we pretty much force commonality on the ships throughout the fleet with very few exceptions in what we buy. So there's a momentum that remains in the system long after the requirements may change and the standards.

MR. WOODROFFE: And what about the bandwidth issue?

MR. SUTHERLAND: And in buying in bulk, it means that you buy a whole lot, and so you have to wait until you use it all up before you get to go to something else.

DR. SHOR: That's only a couple years lag.

MR. SUTHERLAND: You want to answer the bandwidth, Rich.

MR. FINDLEY: I mean, the bandwidth is -- people want to put things like video systems down there, ADCPs at the end of that cable. There's very bandwidth instrumentation that could possibly go down there, but we can't accommodate it. Right now, everything is tried to be channeled through the CTD, and why make that do it?

There's no reason why you can't have ethernet at the end of that cable. And once you have ethernet at the end of the cable, then you can do tons of things. You know, you can put a little PC down there and communicate with it, have an X-Windows terminal on the top running it, or PC Anywhere running it. You could have these network ports that people have been using. You can have an RS232 connector down there, and you can run multiple things in, and a video camera. So all of that kind of -- things you can do at the end.

It makes interfacing simple because then you can run up the instrument connected to a network in the lab and test it. You don't have to build any telemetry. It's all -- once the telemetry's established, that's a non-problem anymore. And no matter how much bandwidth we build, in ten years, then somebody'll say, gee, this is not enough bandwidth. So data always grows to fill the bandwidth.

UNIDENTIFIED MALE SPEAKER: It goes back to Mike Mark Markey's point yesterday afternoon. If you're going to make a jump, make a big one so you aren't making small jumps all the time. Another point is there is no technical reason why we all have to buy new LIVA shelves and level lines. It's merely a challenge to the wire manufacturers to say, within this form factor, what can you do? It's highly impractical at this point, now that almost every ship has been standardized on this size wire, to go in and spend millions of dollars to refit all those winches again.

MR. FINDLEY: We almost have just gotten there. We just got a brand new Markey just installed -- you know, the perfect (indiscernible). But there is another question -- is that -- in the same line -- we keep buying these 10,000-meter reels. Do we need 10,000? Would 8,000 be -- I mean, we lop off pieces all the time, but do we really lop -- how much do we actually put in the water, 7,000 at most? Anybody have a feel for that? Woody?

MR. SUTHERLAND: We have 8500 out.

MR. FINDLEY: You do get 8500? Bad wire angles.

MR. SUTHERLAND: No. Deep, deep water.

MR. FINDLEY: I mean, the CTD won't go that deep, will it?

MR. SUTHERLAND: Yeah, it will.

MR. WOODROFFE: It has a different shape when it comes back, but it's --
(Laughter.)

MR. SUTHERLAND: Who was on Nan's WOCE trip? How far did we go?

UNIDENTIFIED MALE SPEAKER: You can do a 6800 meter cast and have 8,000 meters of line out.

MR. FINDLEY: Well, I know you can do it.

MR. SUTHERLAND: We went deeper than we were supposed to.
(Laughter.)

For the last cast, yeah. We decided to see what it looked like down there. We took off everything that was essential.

MR. FINDLEY: Well, I mean, it might be possible that you only have to change the gear ratio on the level line and put a new shell on. And, yes, there's a cost with that, but that's like 10- or 20,000, not a quarter of a million dollars a winch. So -- and if you could give up ten percent of your length, drop to 9,000 meters, that might be something else we have to look at. And then retire the wires that are no longer for the deepest ocean at 9,000, and send them down to the intermediate ships, and then send them down to the --

MR. SUTHERLAND: Yeah. That'd be politically correct.

MR. FINDLEY: We do it within our own institution where we have a variety of sizes of ships.

DR. SHOR: Woody, it might be useful to get some ideas on the standards that are used in Europe --
(Multiple simultaneous speakers; indiscernible.)

UNIDENTIFIED MALE SPEAKER: I was going to ask, what is the breaking strain in your eight millimeter CTD cable?

MR. FINDLEY: Somebody just did the math. It's 11,000 pounds?

MR. SUTHERLAND: The .322?

MR. FINDLEY: Yeah.

MR. SUTHERLAND: I didn't think it was that high.

MR. FINDLEY: Ten-five?

UNIDENTIFIED MALE SPEAKER: What did you say it was, Scott?

UNIDENTIFIED MALE SPEAKER: Ten thousand.

MR. SUTHERLAND: Yeah, that's what I thought.
(Multiple simultaneous speakers; indiscernible.)

UNIDENTIFIED MALE SPEAKER: We use -- in the U.K., on the research vessel services ships, we use ten millimeter Rochester CTD cables -- the sixternal (ph) 5.95 ton breaking strength, which is obviously more than what you were using.

MR. SUTHERLAND: What did you say it was? I'm sorry.

UNIDENTIFIED MALE SPEAKER: 5.95 -- ten metric tons.

UNIDENTIFIED MALE SPEAKER: Ten metric tons.

UNIDENTIFIED MALE SPEAKER: But you're using eight mil; we're using ten mil, I think.

UNIDENTIFIED MALE SPEAKER: I'd have to get a calculator.

UNIDENTIFIED MALE SPEAKER: So we've already got a high breaking strain than yourselves. The cables we use are also single conducting core. We've actually surpassed the limits of these cables. We're in trouble with these cables as it is. So if you're thinking of trying to improve the breaking strain of your cables -- I mean, the gentleman next to you suggested that, if you're going to make a jump, make a proper jump. I'm wondering -- I mean, the ten-millimeter cables that we're using currently are too small. Scientists want to use increased weight packages, bigger packages. We realize that the cables we're using have a finite life. We're already in trouble. So I'm thinking that the jump that you're looking at may have to be bigger than what you think.

MR. FINDLEY: That's another -- yeah. The question is, what can we --
(Multiple simultaneous speakers; indiscernible.)

UNIDENTIFIED MALE SPEAKER: -- materials we're looking at.

MR. FINDLEY: The problem is that there's 20 -- I don't know -- they don't all have these large winches on them -- the winch for those -- but there's probably 15 of those winches in the fleet, and most of them were bought within the last seven years, and are a quarter of a million dollars each. So --

UNIDENTIFIED MALE SPEAKER: If you look at alternative materials such as kevlar (ph) (indiscernible) very early stage of development. I mean, these could give us vastly more loading capability. But they're in very, very early development stage. They don't work --

MR. FINDLEY: We went through -- we had -- two years ago at one of our RV Tech meetings, we had what's probably considered one of the biggest experts in tension member technology, which happens to be the name of their company -- isn't it?

UNIDENTIFIED MALE SPEAKER: Phil Gibson.

MR. FINDLEY: Phil Gibson. And he pretty much said, at the current time, that all these arramed (ph) fiber-type technologies were really not very suitable for --

UNIDENTIFIED MALE SPEAKER: They’re not there yet.

MR. FINDLEY: No. We could always use the Japanese one. I think they’ve got a titanium wire.

UNIDENTIFIED MALE SPEAKER: They did one drop (indiscernible) Mariana’s Trench (indiscernible) been there. (Indiscernible). We operate on the RRS Discovery -- we have a subrum almay (ph) cable that we use for giant piston core operation. (Indiscernible.) And it works. How long (unintelligible). But it’s a hell of a thing to operate with. I mean, it’s very, very expensive (indiscernible) and all sorts of troubles of trying to look after the cable. I mean, it’s actually come off the drum now to be -- if we have the skin repaired and the end parended (ph).

UNIDENTIFIED MALE SPEAKER: I was interested in this gentleman’s comments the other day in the wire workshop. He was talking about reduced loading levels of the cable. These new materials are in a very early development stage. I wonder whether there’s a lot of people that are going to have this same problem over the next half a decade or so with scientists wanting to increase the large-already packages. I mean, a lot of pressure could be brought to bear on these manufacturers to let them know that the next generation are going to be significantly higher spec. than what we’re working with now.

MR. FINDLEY: Sandy’s --
(Multiple simultaneous speakers; indiscernible.)

UNIDENTIFIED MALE SPEAKER: -- materials we’re using steel is actually coming to the end of its life.

MR. FINDLEY: Sandy’s point about, well, gee, we’re already -- a lot of the boats are already carrying .680 wire, which is -- you know, maybe that’s --

UNIDENTIFIED MALE SPEAKER: But the thing is, increasing the size of the wire is not necessarily going to be the answer. The wire will reach its factor of safety by virtue of its own weight in the depths we’re working to. So it doesn’t matter. You could chuck yourself a 20-millimeter wire over the side and you’re only going to gain yourself a few hundred meters. The bottom line is this material is actually the fundamental governing problem -- it appears at the moment, in my experience anyway. And I’m not sure whether increasing the size is going to be (indiscernible) is going to solve the problem.

MR. SUTHERLAND: I want to make sure that we limit our discussions now to the smaller diameter EM cable, because we’re going to jump to the piston core and learn the strength numbers later.

Michael, did you --

UNIDENTIFIED MALE SPEAKER: To hammer on the obvious, holding onto the .322 OD is very appealing, and the idea of a stainless tube up the middle of a single conductor -- if you can use it, great. But don’t forget bending radius. That eats to your existing winches as much as does diameter.

MR. SUTHERLAND: Yes?

UNIDENTIFIED MALE SPEAKER: We just bought a kepla (ph) cable -- a namred (ph) cable with a conducting wire in it. We are in the process in rebuilding our winches in order to have the larger diameter wheels in order to (indiscernible). So we bought the cable, but we are -- not used it yet on our winch system. But we’re experimenting with it.

MR. FINDLEY: As a quick question to Mike Markey back there. What would happen if we put that kevlar on the existing -- let’s say it was exactly the .322 cable (indiscernible)? Do we have drum-crush problems?

MR. MARKEY: No. Not on a Markey, at any rate.
(Laughter.)

MR. SUTHERLAND: I've got a couple questions here. One is just a clarification. In the U.K., they're already using a larger diameter single conductor wire, and all it's giving you is a slightly larger breaking strength; is that what I hear? -- or working load?

UNIDENTIFIED MALE SPEAKER: (Indiscernible) from Research Vessel Services. I want CTD cables at ten mil -- standard ten -- Rochester cables, which I (indiscernible) 5.9 -- call it six -- metric ton breaking strength. We tried to keep that cable somewhere down around the 2.2 metric ton loading to protect the internal -- the electrical core in it. Increasing -- I mean, the point I'm making is that we're already having trouble with -- loading troubles. We have -- the standard CTD we operate is 800 kilograms in air. The safe working loads -- we like to significantly reduce the safe working loads of the cable to do 6,000-meter CTDs. If scientists require that that package increases by 200 kilograms, we're in real trouble. I mean, this wire is going to wear out very quickly or the integrity of the electrical (indiscernible) electrical core is going to be under severe strain.

So I'm wondering -- you know, you're looking at improving the effectiveness of the eight-mil cable, and the point I'm making is we're using the ten mil, and we are in trouble already.

MR. FINDLEY: Is that a fully torque-balanced cable?

UNIDENTIFIED MALE SPEAKER: Yes, I believe it is. It's a two skin contra one.

MR. FINDLEY: I mean, that's the way ours is, but it rotates like crazy. There's a rotation spec on ours that'll tell you how much it'll rotate per pound.

UNIDENTIFIED MALE SPEAKER: I'm not really sure. I believe it is. It's the standard one the baths also use. (Indiscernible). I believe it is, but I wouldn't put my life on it.

MR. WOODROFFE: It certainly doesn't rotate (indiscernible) or do anything like that, except the one we've had at the moment which got damaged anyway.

MR. SUTHERLAND: Does your standard package have any just weight on it to keep it from sailing, so you could replace the weight with instrumentation, or --

UNIDENTIFIED MALE SPEAKER: Well, yes, it does. But this is another sort of area of discussion. I mean, the people who are desailing (ph) these packages were not necessarily the people involved in the deployment and recovery of these packages. They're not (loud coughing; indiscernible) significantly more interaction between the two parties. As we're reaching the limits -- the operating limits -- a (indiscernible) some of these pieces of equipment, it's bloody important that we have much more interaction between the people who actually chuck 'em into the water and bring 'em back and the people who want them chucked in the water and brought back.

Simple answer to your question, yes, there are weights on it. But the reason is that you need the weights because the package -- one package particularly I'm thinking of -- is so draggy if you deploy anything over a three. I mean, you can have your sandwiches while you're waiting for it to sink the first ten meters. It just floats (laughter; indiscernible).

MR. GROENEWEGER: Rich Groeneweber at Netherlands Institute of Sea Research. We too have a pre-weighing on our CTD frame of about 300 kilograms. So a full package bringing back 24 bottles of water will weigh about 800 kilograms, too, just like your system. And we are using an even smaller cable, 7.4 millimeters, and we're not experiencing any difficulties in using that. That is because we're trying to streamline the CTD package, because drag is a major issue. As you already pointed out, it's not very useful to go to larger diameters. It will just mean you need larger drums, stronger winches, or else the next payload won't increase very much. If you make a curve of what the cables can do for you, you will see that it is -- it rolls off to be rather flat above a certain diameter, and I believe that's around ten millimeters. It's not very useful to go any higher.

MR. SUTHERLAND: You're not getting much conductor failure in your packages? Does it just have one conductor?

MR. FINDLEY: How deep are they going? I mean, most of our problem's the weight of the wire.

UNIDENTIFIED MALE SPEAKER: If you're going to 6,000 meters with our package, you're up over two metric tons. The point is, the mechanical integrity of the cable is no problem. It's safe as houses (ph). You have to ask the question about the wear and tear of the electrical core. But there is another major question here which should be considered, is what is safe? I mean, what factors of safety do people operate their wires at? I mean, we don't have to international waters. We can get away with murder.

UNIDENTIFIED MALE SPEAKER: It probably will be that.

UNIDENTIFIED MALE SPEAKER: That is the exact point.

UNIDENTIFIED MALE SPEAKER: Within the international safety management code --
(Multiple simultaneous speakers; indiscernible.)

MR. FINDLEY: How deep are you going?

MR. GROENEWEGER: We very rarely go to 6,000 meters. Just over five is -- but rarely see that.

UNIDENTIFIED MALE SPEAKER: But you're still up to two metric tons there with that package.

MR. GROENEWEGER: Yes. Well, we go to 40 percent of the breaking strain.

UNIDENTIFIED MALE SPEAKER: (Indiscernible) two and a half. Yes.

MR. GROENEWEGER: We rarely go above that.

UNIDENTIFIED MALE SPEAKER: I mean, I think it's regularly run in the UNOLS fleet -- we're running at sometimes 50, 60, even as high as 70 percent of break.

UNIDENTIFIED MALE SPEAKER: It's yielding (ph). I mean, the wires are yielding, obviously.

UNIDENTIFIED MALE SPEAKER: We do have a wave motion compensation -- wave compensator in the system, and that's always a trade-off. If you have a wave compensator, you have many more flections which wear out your cable.

UNIDENTIFIED MALE SPEAKER: Right. Right.

UNIDENTIFIED MALE SPEAKER: But on the other hand, you avoid the snapping -- high forces in the cable. With this system, we -- in rough seas, we see at the max number about one ton load variance due to ship's motion. So that gives you an idea of the drag of the system.

UNIDENTIFIED MALE SPEAKER: So can I just ask, on the American ships, what sort of winches are you using? Just drum winches?

UNIDENTIFIED MALE SPEAKER: Yes.

UNIDENTIFIED MALE SPEAKER: Mostly drum winches.

MR. SUTHERLAND:  Yeah.  For the CTDs it's -- I don't know anybody that's using anything other than a single drum winch.

UNIDENTIFIED MALE SPEAKER:  We have a track (ph) also.

MR. SUTHERLAND:  On the CTDs?

UNIDENTIFIED MALE SPEAKER:  Yep.

MR. SUTHERLAND:  That size?

UNIDENTIFIED MALE SPEAKER:  We run a track --
(Multiple simultaneous speakers; indiscernible.)

UNIDENTIFIED MALE SPEAKER:  -- traction range on a CTD?

MR. FINDLEY:  We have one of each -- or a couple -- well, we have a couple -- lots of drum winches and one track unit.

MR. WOODROFFE:  We use a traction winch in the U.K. -- on the (unintelligible).

MR. SUTHERLAND:  On the CTD sites.  Yeah.

Scott.

UNIDENTIFIED MALE SPEAKER:  Woody, I was just going to ask about heave compensation.  Is that a dead technology or what?  We use it on our polar stern (ph) a couple years ago.  They had a real nice heave compensation, and it made so much difference.  The wire was a .49 inch diameter, a little bit bigger than .322.  We were doing routinely 4-, 5-, 6,000 meter casts.  It made so much difference.  We didn't have to reterminate (ph) the entire cruise.  It saved our terminations.  It saved so much wear and tear on the wire.  But I don't see any of these ships with heave compensation units --

MR. SUTHERLAND:  It's sort of come and gone.  You know, there's passive systems and active systems, and --

Do you have any experience or comments on heave compensators and --

UNIDENTIFIED MALE SPEAKER:  Well, if you're asking me, you cannot dither a single-drum winch, much less a traction winch, with -- and do it with the winch beneath an active piston-type heave compensator as a separate piece of machinery.  People who build those would be delighted to hear -- come up --

MR. FINDLEY:  I mean, --

UNIDENTIFIED MALE SPEAKER:  -- and talk to you.

MR. FINDLEY:  They're made.  I mean, they use them for launching -- I've seen some things where they use them for launching lifeboats and stuff, and really nasty -- or escape vessels and platforms.  They're around.

MR. SUTHERLAND:  So there's a new category for your Dick West hat.

MR. FINDLEY:  Compensation?

MR. SUTHERLAND:  Yes.

MR. WOODROFFE:  The point I was hoping to make earlier when we were talking about your complicated cable with the fiber was, there must be some economic point that you reach where, depending on the number of ordinary -- what I call ordinary CTD work -- the amount of ordinary CTD work you do compared to the stuff where you've got video cameras and things. There must be some point where it's not that economical to have this super-duper cable for that job, because knowing the amount of wear and tear and damage it's possible to do to a CTD cable on a daily basis. If you're just doing a lot of cruises with a lot of just fairly simple CTDs, you don't want to have to be using this Rolls Royce cable, and then chopping it, and throwing bits away, and re-terminating it all the time.

MR. FINDLEY: I guess the part I left off is that you would have two versions of the cable, one with the fibers in the tube and one without, so that it would be pretty much interchangeable on the winches.

MR. SUTHERLAND: Okay. I think we need to move on. Yesterday, we had a session on bottom sampling devices and deck operations and safety. One of the issues, again, as cable limitations is the 9/16ths wire that we use as a standard on the UNOLS vessels. Doing piston cores -- is Pete Calk here still? In doing piston cores, at all times, we're reaching the breaking strength, leaving the cores on the bottom, dragging the cable, and bringing it back. Same thing with dredges if we hang up.

The scientists are clammoring for even longer and larger diameter piston core systems. So it looks like we're going to have to go to something else to accommodate those packages. The scientists are saying, well, you know, there's kevlar cable out there. Why don't you just use that? One of the issues is cost, but the other is just the upkeep and maintenance of the kevlar and what it really can do. There was a comment yesterday about the kevlar -- from experience, the breaking strength of it reduces drastically over the first 12 months or so, and then you reach sort of a stable level. So what you have to do is over-compensate on your purchase when you use it, and keep using it until you reach where it can -- you know, so that it breaks beyond your working needs.

I think I'd like to hear from any of our international community that's using the synthetic fiber cables, and what experience they have in its upkeep and maintenance and its breaking strength history.

UNIDENTIFIED MALE SPEAKER: Well, I can guess what people said yesterday -- I'm sure Colin managed to say something else -- that used the 27 millimeter Kuzan-Faray (ph) cable. The problem with it is that, as a construction, you have an outer sleeve, and then you have the inner fibers. There is slippage -- and there can be slippage between in the inner and the outer. The greater problem is when you have reverse bends, as we've found on sheaths (ph), and then you get -- you can get bunching of the actual cable. And you'll get movement between the outer and the inner. And eventually -- I think this has happened to RVS, as well -- you actually get the outer splitting. That then gives the problem whereby you get salts in the water causing the fibers to be cut, weakening the cable. We have had -- we have lost packages on the ocean floor.

Now, Kuzan-Faray -- and I think RVS -- I haven't spoke to them -- said that they can re-sheath the cable. What it actually means is taking 8,000 meters of cable, putting a knife along it, and stripping the whole of the outer and putting a new one on. The cost of doing that is almost the same as making a new cable. They've also, because the actual concentricity of the cable is not very uniform, there is also a risk that when you actually slice it, you may actually cut the fibers, as well.

I think as a facility these are very good, and when we have used it, it's been an excellent cable. But it is not a robust cable in the same way -- the Dutch may have other experience -- as using a piece of steel. You have to be just a lot much more careful with. We learned by experience that when we first use it, we didn't actually leave it in the water staff (ph) with the recommendation which was developed since we've used it is that you -- in fact, when you first deploy it, you actually deploy the whole length in the water without any weight on the bottom, or nominal weight just to get it all down. You then do two or three deployments with increasing weights. That enables the cable to actually stabilize. But we didn't do that, and that also accelerated the problems.

But I have to say, it's on our ship, and we use it when there is a need for it. It's okay.

UNIDENTIFIED MALE SPEAKER: Could I ask, does your one-inch jacketed kevlar stay round?

UNIDENTIFIED MALE SPEAKER: No. That is the problem. It does squash.

UNIDENTIFIED MALE SPEAKER: It ovals, doesn't it?

UNIDENTIFIED MALE SPEAKER: It ovals and concentricities is not very good.

UNIDENTIFIED MALE SPEAKER: And the lebus pitch (ph) becomes a challenge.

UNIDENTIFIED MALE SPEAKER: Colin (indiscernible) from RVS again. We've experienced the same problem. Basically, when you're winding the cable onto a drum, it doesn't squash, it flows. It actually flows. It totally changes its profile, and it can be a very difficult wire to spool. We use a traction winch similar to bass (ph), so we store on the low tension (ph) somewhere in the region of a ten onto the drum, and the cables are all chop (ph). It's (indiscernible) but it's very difficult to get it to actually behave itself. It's an interesting cable to work with. It's interesting (indiscernible).

UNIDENTIFIED MALE SPEAKER: Another thing is termination. We have to develop the techniques (indiscernible) certainly Kusan-Faray, if you go to the factory, and we've sent out boatswains over there to have a (indiscernible). They show -- you just weave it in and it's (indiscernible) and it fits together quite well. It's not as easy as actually putting a shackle or something around the cables or terminate it with a piece of steel. It does take a lot more technique and is a lot more difficult to terminate. It does work, and it actually solves the problem. It's just it's not -- I think the main point, again, it crosses -- it's not as robust as a steel wire, but its works.

UNIDENTIFIED MALE SPEAKER: But you said the end termination. It's also possible to do that by nicopress (ph) sleeves. You can do it that way, and then it's very simple. It takes about ten minutes, and you have a new end termination. You have the equipment to take it with you, but then you can very easily make an end termination on it. What we do, we find out you can make a hundred percent end termination. We look for it and we have said, okay, we want to use the cable for one third of the breaking strength. And we did some tests, and we make now an end termination that it's slip out by one third of the breaking strength. That works for our -- what I said yesterday. That worked for ten years very well. I think the problem you can find out another way, and then it's not --

(Multiple simultaneous speakers; indiscernible.)

UNIDENTIFIED MALE SPEAKER: I know the splice of Kuzan-Faray. You have to be a real expert to make it, and it takes you about one day to make it. Now on this way it takes you about ten minutes is all -- let me say a half hour --

UNIDENTIFIED MALE SPEAKER: I have to say, as a matter of interest from a scientific point of view, we're getting less and less use of cores. We're going much more to drilling in the U.K. (indiscernible). It's almost as though coring is losing its attractiveness. That is why we haven't actually used the cable as much over the last three or four years as we have when we first got it.

DR. SHOR: Sandy SHOR again from NSF. I'll say that we've gone through that valley and we're climbing the other side now. We've been through a rather long period of low acquisition of large cores on the ships. But we're now in a boom cycle in which we're seeing a minimum of two or three long cruises asking for 30-meter cores, and we're buying time on the Marian Dufrein (ph). That's a growth cycle in what we call the MESH -- the Marine Earth Sciences History.

UNIDENTIFIED MALE SPEAKER: Just to follow on what the gentleman from (indiscernible) from RVS. We use this subarmey (ph) cable for giant piston coring. And it does work. It's been on the ship for several years. And it does work, and it does provide the goods. The experience and the knowledge and the longevity of the operation of this type of cable is not with us yet. I mean, in Europe, you've got the French (indiscernible), you've got the British Antarctic survey in the U.K., and you've got the Research Vessel Services at the Southampton Oceanographic Center. I think experience is quietly being built there with the operation of these cables, but it's very early days. The more pressure that could be put on manufacturers and development organizations to look at these new materials, the better it's going to be for us in the long-run. Because, I mean, I feel instictively that higher loads are going to be called for for oceanographic operations wire work over the next -- over the coming years. Steel is going to be, unless something very interesting occurs that I'm unaware of, they're going to be left begging. There's going to be a gap. And we're seeing this gap actually starting to open up now between what we can get away with in steel, closing down the safe working loads, and starting to work in areas that are quite spooky, actually. I mean, told -- what? -- 70 percent? That's wicked.

MR. SUTHERLAND: Would you recommend --
(Multiple simultaneous speakers; indiscernible.)

UNIDENTIFIED MALE SPEAKER: Taking into account that the offshore industry has a safety factor load of four.

UNIDENTIFIED MALE SPEAKER: Of course.

UNIDENTIFIED MALE SPEAKER: And 25 percent of your (indiscernible) you're allowed to use.

UNIDENTIFIED MALE SPEAKER: That was the reason for -- another reason for the manufacturer backing the 10,000 breaking cable down to 2500. That's the -- I had a couple other quick points.

MR. SUTHERLAND: Well, just a minute. So would you recommend that it's time for some of the scientists or technical groups to get together in some sort of consortium to start to address the manufacturers and saying, this is what we --

UNIDENTIFIED MALE SPEAKER: It's high time. It's actually really important. I mean, the thing is, as engineers and ship operators, we have a responsibility to see this problem coming in advance. It's all (unintelligible) as we actually do now. We have a situation with deep sea (indiscernible) in the WOCE program saying, well, we can't really do that CTD to that depth because it exceeds the safe (indiscernible) lower cable. So the PI says, well, what are you going to do, then? You say, well, if you'll just go away and don't (unintelligible) we'll give you your CTD. And that's actually what was actually happening until new safe working load parameters were discussed and actually okayed and put onto our vessels.

In a few years time, I mean, we're going to be left with -- it's going to be interesting. You could have scientific organizations asking us why didn't we see this problem coming. I mean, it takes a long time to develop this type of technology. It's quite a complex technology. It takes a long time to develop it. Actually, it's not the time that's the problem; it's the (unintelligible).

I mean, you can't expect a specialist cable manufacturer to invest potentially millions of pounds, millions of dollars, in a new product that he or she does not know where the market really is. I mean, we're at the sharp end. We've got to drive this. That's what I feel. There's a lot of research ships working deep-sea oceanography around the world. There's a lot of money involved in it.

MR. FINDLEY: There's a slight problem with that that we're still in the lower percentage -- I mean, it's the oil industry that drives these cables. Basically, we're all living off of hand-me-down well logging (ph) cables or some slight modification of that. When you talk -- and until the oil industry says, we need something new, we're going to continue to be on -- because they'll just say, well, it's too much trouble. We just won't bother making anything different. You guys figure out your -- I mean, it's not like we have -- we're buying 50 percent of their wire, or 40 percent; we're down in the five or ten percents things -- we're in the noise.

Even if we -- and it's probably going to be very necessary for both the European and the U.S. contingents to get together and put pressure on them. But we still are not -- even at that level, we're still in the noise of the manufacturefer.

UNIDENTIFIED MALE SPEAKER: But until we embark on this exercise, we don't know how much clout we might have as a unified organization. We might be surprised. We might be positively surprised.

MR. FINDLEY: It'd be nice to be surprised, but I --

UNIDENTIFIED MALE SPEAKER: Given the money some of these organizations are charging for cable, such as Super Alamed (ph) -- I mean, we're talking big bucks. What are we talking, 200,000 pounds for this cable?

UNIDENTIFIED MALE SPEAKER: It's gone down. You can probably get some for $50,000 now.

UNIDENTIFIED MALE SPEAKER: Dirt cheap.

UNIDENTIFIED MALE SPEAKER: Only a couple.

UNIDENTIFIED MALE SPEAKER: I think you have to make another calculation also. When you use the kiffer (ph) cable and we did the calculation, and I said always -- we had some experience in the Caribbean. We take 20 book scores, and colleagues of us takes also 20 book scores in a difficult situation. They had two good book scores from 20, and we had 18 good book scores from 20. If you add -- also look to that calculation. Because ship's time is also very expensive.

UNIDENTIFIED MALE SPEAKER: As in broken cables are very expensive.

UNIDENTIFIED MALE SPEAKER: To operating with a keffer cable. (Unintelligible) easier than with a steel cable.
(Multiple simultaneous speakers; indiscernible.)

MR. FINDLEY: But there's one more weak link in this whole thing. Now you've got to replace the gallows, and the A-frame, and all the blocks. Then you have to look at the stability of the ship. I mean, you can pull like hell and roll the ship over. These are all issues you have to look at. It's not "a" cable. You have to go from end to end on this problem.

UNIDENTIFIED MALE SPEAKER: It's only going to be the big cables or big operations with these ridicilously sized piston draws. Horrible things to work with. It's only those that are going to threaten the stability of the vessels. You can increase a CTD package --
(Multiple simultaneous speakers; indiscernible.)

MR. FINDLEY: I wasn't considering the CTD package going to threaten it, but certainly the --

UNIDENTIFIED MALE SPEAKER: You couldn't use a wire, but you could use a ship.
(Laughter.)

DR. SHOR: Woody, could I ask that Rich get some names -- take names and get some information on who is using fiber optics -- not fiber optics, I'm sorry -- synthetic cables in Europe and get some -- serve as a point of contact for some exchange of information. We can find somebody more appropriate later, but he's already got the (laughter; indiscernible).

MR. FINDLEY: A job I didn't want. Yeah.

MR. SUTHERLAND: I was going to mention that soon after this meeting we'll put together a participants' list with all the e-mail addresses, et cetera, et cetera. And what we may want to do on the international level is create some mail lists to discuss some issues. So I'll take the lead on that. But they wanted to bring up that Rich Findley has been designated as the U.S. representative for new cable development -- the head of that committee. So you might want to start talking to him. And I do think it's high time that we address industry.

And as I was going to say, timing is everything. I mean, if we hit a point with the cable industry where the oil industry is full and they're not buying any more, then they may be more interested in talking to us then.

MR. FINDLEY: And it's also winch manufacturers. You can mention things like tapered cables to Mike Markey over there. I mean, that was the technology we used years ago when the wires couldn't carry their own weight. They got strong enough to do it. Maybe we need to look at tapered cables again.

UNIDENTIFIED MALE SPEAKER: Can I just say that --

MR. FINDLEY: There's a guy that's been around a long time going, oh, God.
(Laughter.)

UNIDENTIFIED MALE SPEAKER: Kuzan-Faray telephoned me a month before I came here because I (indiscernible) selling their cable, and they were chasing around trying to find if we wanted to buy some more. So they're actually actively thinking about what the long-term future is as to whether there is a long-term market for it.

MR. WOODROFFE: So buy now.

MR. FINDLEY: So, yeah, I'll be -- I guess I'll be at the reception, or whatever that is. If people could pass me some cards in the meantime, that'd be great.

MR. SUTHERLAND: Any other discussions on this or other topics?

Andy.

MR. MAFFEI: To go back to the CTD package thing a little bit, something that was sort of overlooked by a lot of people, and it's something that I think is important only in that I looked at a lot of people's data -- we spent the afternoon watching talks about WOCE calibrations and all these standards, and how we really want good CTD data. We're talking about people pushing fourth decimal places.

As you get these big huge packages and you start strapping on ADCPs, and this, and the cameras, and all the other -- using a polite word, "junk" -- you have to be very careful where you put these things on your package, because there's an incredible amount of microstructure flow that comes off all of this stuff. When you start talking about WOCE level CTD data, me being a SeaBird and a CTD person in general, my -- to me, the CTD is -- that's the pure data. It really does affect your measurements at WOCE levels.

I have seen a couple of data sets where -- with SeaBirds, you can run dual sensors. The customer will say, well, on the last cruise, on my dual sets of data, my temperatures agreed to -- down deep they were agreeing to something on the order of -- you know, it might -- you know, a millidegree or two millidegrees. And then this last cruise, there's like a five milli-K offset. What's wrong with my sensors? They send the sensors back, we calibrate 'em up, they're both looking fine, there's no problem. And they get the sensors back, and lo and behold on the next cruise, they're back to the normal milli-K or two offsets. And they're like, wow, you fixed our sensors. And we say, well, we didn't do anything. And we start to talk a little more. Well, what was going on with this package? And, you know, did anybody come out that did something different. Well, you know, Joe brought his ADCP out and strapped it on. Then we start to looking at where he put his ADCP, and he put the lobe of the transducer right in front of one of the temperature sensors.
(Laughter.)

You laugh, but even at a finer scale than that, it's very important that as we start to develop these huge packages -- 36 bottles and stuff -- that we're aware that the sensor placement, especially on surb (ph) some sensors, and I would imagine on even optics packages and all these other things, it's going to become very important that they see good clean water, and that we're not just measuring a bunch of wakes from all these different things that we're putting on the packages. It's important to think about that, and also for some applications, maybe big packages isn't that good after all, and so we can get away from some of this cable problem by saying, we don't really want big packages because your data's not going to be any good.

MR. SUTHERLAND: Andy brought up the subject of noise in the data. No one has mentioned at all slip rings. So I thought I'd throw that out as to what people are using, what experiences they're finding with them. I know there's the mercury slip rings. I'll just mention something that Barrie passed on to me which I hadn't discovered until he thought it up -- the mercury weighting (ph) slip rings.

Correct me if I'm wrong, but my understanding of your explanation to me was that the slip ring technology was developed for high RPM turns, and that we've now put that application on these slow-turning drums -- the winches -- and there's some sort of, not corrosion, but film that's developing from the slow use, and can introduce noise. So the remedy to that is to take your slip ring off, put it in some sort of drill or high RPM and just spin it for a little while, and then it'll wear down that film, and then you can have clean data again. Is that correct?

MR. WALDEN: It's not actually a film. It's the mercury -- the mercury moves. It puddles, essentially. That's why they tell you to store them vertically. You're not supposed to leave them in a desk drawer horizonally. You're supposed to store them vertically just so the mercury will pool all the way around the ring. At least that's better than having a low spot and a high spot.

And it's a noticeable effect. Frequently we've been able to bring back slip rings simply by chucking them up in a lathe and letting them spin for six hours -- slow -- I mean, not that slow, not as slow as a winch, but not in danger of spinning them off.

MR. SUTHERLAND: Any other comments on slip rings?

UNIDENTIFIED MALE SPEAKER: Yeah. We're using two sets of slip rings, one at the drum end of the winch and one at the bottom end of the cable before you're connecting to your CTD package. Both --

MR. SUTHERLAND: So your package is on a swivel and turns.

UNIDENTIFIED MALE SPEAKER: Freely rotating, yeah, to protect the cable. For that, we use slip rings from a German company. They're made of a rare earth metal. I don't know what. They are capable of both handling high current, and yet ensuring very low noise. And we're very content with that and never had any problem since -- since we got away from the silver, silver graphite slip rings. I've never used mercury.

UNIDENTIFIED MALE SPEAKER: Tell 'em what you used 'em for.

MR. SUTHERLAND: And the bottom end slip ring also holds the weight.

UNIDENTIFIED MALE SPEAKER: To swivel.

UNIDENTIFIED MALE SPEAKER: Yes.

MR. SUTHERLAND: There's no other --

UNIDENTIFIED MALE SPEAKER: Not the slip ring. The cage holds the weight and the slip ring is inside, and that's pressure-balanced, oil-filled.

UNIDENTIFIED MALE SPEAKER: Conducting swivel.

UNIDENTIFIED MALE SPEAKER: It's a conducting swivel.

MR. DIEBOLD: John Diebold from Lamont. This is an area where the oil industry may be helping us, because tail buoys are now powered from the long cables that they use to -- hydrophone cables. There's a new development -- the swivels -- the slip ring swivels that they use for those. They're just hoping Sandy will buy it -- a couple for our streamer (indiscernible).

MR. FINDLEY: Somebody at the aquarium had them sitting there on that display. I don't know if you saw them.

MR. DIEBOLD: No, I didn't.

MR. FINDLEY: The one that was right.

UNIDENTIFIED MALE SPEAKER: Yes, yes.

UNIDENTIFIED MALE SPEAKER: We had them on our (indiscernible).
(Multiple simultaneous speakers; indiscernible.)

MR. WOODROFFE: I'm sorry. It wasn't about slip rings, actually. It was while we were on the subject of package size and cables and everything. I hate to harp back to this because I know we've covered it a lot. But if chemists and biologists could be persuaded to use a lot less water --
(Laughter.)

-- you could reduce -- you could cut all these problems in half overnight. We've had a CTD on our ship in the last couple years, and she's got 12 30-liter bottles. I mean, we started out using 12 1.7s when I first joined BAS. You give these people a bit more water, and they want more and more and more. And you never satisfy their demand. So I think they need to learn some new analysis techniques that just don't use as much water. I mean, I'm quite serious.

MR. SUTHERLAND: You heard Jim Swift in his presentation talking about the sample cop. We literally have sample cops on these WOCE expeditions that say, okay, you can't go before -- the freon has to go before the dissolved oxygen, which has to go before the salinities, et cetera. So you have to keep people in order and make sure that they only take as much; otherwise, we're down to fistfights out there on the sampling deck.

MR. FINDLEY: Maybe bandwidth solved some of our problems, because then we can get more in situ sensors that actually measure --

MR. SUTHERLAND: No, because they still have to ground-truth them.

DR. SHOR: Now, every now and again there's a positive -- something positive in that area. As you may recall, between Geosect (ph) and WOCE, there was a change in the radiocarbon requirement which required humongous amounts of volumes of water in the earlier years, and which they're now -- he's satisfied to work from the same Niskins because they can use accelerator techniques now. So, I mean, there have occasionally been some reductions. They don't always want more and more. But the steps are few and far between.

MR. AMOS: We go on cruises sometimes where most of the water goes on the deck. We've lifted all that water up to the surface, somebody'll take a couple of oxygens, and chlorophyll, and salinities, and the rest of it just goes on the deck.

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