UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

BASIC MINIMUM SCIENTIFIC SUPPORT CAPABILITIES FOR UNOLS VESSELS: SUPPLY, OPERATION AND MAINTENANCE

Report of Workshop at

Texas A&M University February 26-28, 1979

Sponsored By UNOLS

Contents

July

Office Memorandum • WOODS HOLE OCEANOGRAPHIC INSTITUTION

TO : Fred Sayles

DATE: 27 March 1979

FROM : Don Moller

SUBJECT: Comments on Workshop Report

Since you have been given the dubious honor of critizing the wire rope section of the UNOLS Workshop Report, I will dump my comments on you.

I feel the workshop dropped the ball by not determining the basic requirements for wire rope and winch systems. What is needed is a set of operating requirements from the scientific users of these systems, stating their anticipated needs for the next 10 years in terms of:

a.) Instrument weight
b.) Instrument bulk or size
c.) Payout and rehaul speeds
d.) Operating depths
e.) Data transmission (conductors)
f.) Anticipated annual use
g.) Likely areas of operation and sea states

Using these values, which should be considered as scientific demands, the present systems can be evaluated for ability to perform. Based on this evaluation necessary improvements or upgrading can be determined, outlined and proposed.

I will take the items as summarized in the report, one by one, and comment on them. There is no fault to be found in the essence of the recommendations if one takes the idealistic approach. I question the practical implementations and effectiveness of some of the suggestions.

1.) WIRE WINDING AND TENSIONING MACHINES - A great idea and a virtual necessity if the wires can not be streamed at sea before their first use. One should be available on the East Coast and one on the West Coast for general use. No one operator should have his own. I doubt the existance of any one machine capable of putting a load of up to 10,000# on ½" or 5/8" wire and capable of handling 3/16" to 3/4" wire, but this may not be a problem. Sending a machine to sea is attractive but cruises where it would be used will be of extended duration and with multiple disciplines on board. Can you afford the storage space for it and the spare reels of wire on cruises where space is at a premium already? I doubt its practicality. I think it will be more efficient to have a simple wire winding device aboard to change wires and then stream the wire before use. Sending a tensioning machine to sea will take it out of circulation for long and unacceptible periods of time.

2.) TENSION LIMITING DEVICES - Nice but difficult to assure correct use. Set a limit on tension and the only way of reacting to overloads is to payout more wire faster. Also, if a scientist has the success of an experiment or a cruise hanging on the end of an overloaded (in terms of tension limit) wire you know damn well that the limits will be overrode to get the instrument back, thereby negating the purpose of the device. It is much better to use foresight and planning to prevent the problem from occurring.

3.) ACCUMULATORS - I agree with their usefulness in reducing the dynamic effects of starting and stopping the winch and for reducing or otherwise smoothing out acceleration due to ship motion. A properly designed and installed accumultor may be able to reduce the vertical excursions of the wire on a moving platform. Multicheave accumulation will reduce the useful life of wire by introducing more bending stress points.

4.) LEVEL WINDING - Agree in principal with statements. Perfect levelwinding at all times depends on a match of wire size, drum flange width and throw of diamond thread, as well as proper tensioning. Assure this match for each size wire on each winch and there will be good level winding. Tolerances are very small so components must be well designed, manufactured, installed, maintained <u>AND</u> replaced when worn.

5.) MAINTENANCE SCHEDULES - A guideline, made available to the fleet, for the care and feeding of wire and winches would be useful. What would be the consequences of not following the guidelines? Off with their funding!! Proper maintenance is an absolute necessity on every winch. The question is: What is proper?

6.) RANGE OF WIRE SIZES - I disagree with the concept of making each winch capable of accommodating more than one size wire. It will be necessary to maintain multiple drums and timing gears for level-winding for each winch in order to assure the matches mentioned in Section 4. It is better to set a standard size based on needs for trawl, hydro and conducting wires. All requirements for sizes other than the standard should be handled as special cases and the individual project should provide either a special winch or provide the components for modifying the winches. As fleetwide needs change, the winches should be upgraded to a new wire size.

The above refers to existing winches. I have no doubt that a new winch system could be designed which permits multiple wire sizes to be accommodated. I would suggest that it may be time to consider a new generation of oceanographic winches capable of meeting our expanding needs.

7.) WINCH/WIRE MONITORS - I agree with the recommendations. I would encourage the use of tension recorders for all winches. They would be used to monitor the stressing of the wire for determining its life history and assist in decision making for wire replacement.

8.) SPARE WIRES - Spare reels of wire should be carried on all vessels capable of carrying them. Science programs depend too much on the integrity of the wires to neglect having spares on board.

9.) SLIP RING DEVICES - I agree with concept.

10.) LUBRICATION - Wires must be lubricated and light oils should be used. The question remains on how often wires must be lubricated.

11.) DOCUMENTATION - A necessity fully implemented at WHOI and being drummed into the Captains and Bosn's.

12.) LOADING CALCULATIONS - The determination of the effects of ship motion on the wire for a given sea state is an important factor in protecting the wire from damage, not to mention loss of equipment. The significance of the velocities and accelerations associated with ship motion, although recognzed, is not fully appreciated as a major contributor to wire abuse. Operating limits for a given wire, ship, sea state, instrument and operating depth must (and on WHOI ships will be) be imposed. I agree with the recommendations of the report. I feel a computer program is unwieldy and is overkill for all but special applications. A tabular or graphic form of sea state operating limits, easily referenced and convenient to use, should be made available for each ship.

13.) VARIETY OF WIRE ROPE SIZES - The recommendation to restrict the fleet to specific size wires is beneficial only if it means manufacturers can make larger runs of the wires peculiar to oceanographers and stockpile them, thereby reducing long delivery time. Also, it aids in standardizing end fittings, clamps and messengers throughout the fleet. Otherwise, institutions should be compelled to provide wires of recommended strength, length, number of conductors, power and resistance ratings. Let the various institutions have the freedom of choice of wire. Standardization and uniformity tends to preclude innovativeness and improvement which in the case of wire rope there is plenty of room for.

14.) BLOCKS AND SHEAVES - I agree that blocks and sheaves must be of the correct size for each size wire. The use of improper sizes is stupid and damn near criminal. But this doesn't mean that UNOLS can police their use. Let UNOLS simply provide the guidelines by publishing recommended sheave sizes for oceanographic cables. The statement, "sheaves 40 times the diameter of the smallest wire," is wrong. It should read, "40 times the overall wire diameter" or "400 times the individual wire size."

15.) STUDY OF E-M CABLES - Such a study is warrented. I think we can push the state of the art to the limit and should take advantage of any new development. The areas in need of improvement are: Weight vs. strength, torque balancing, crush resistance and electrical properties of conductors. Walden is conducting such a study now.

16.) RECOMMENDATIONS FOR E-M CABLE - I agree with the recommendations. I would add that a replacement schedule for each wire in use be established based on its actual use, its exposure to the elements and maintenance. Don't wait to replace them until they look bad. I believe the rate of deterioration of wires is very low for the first year of use and then accelerates very rapidly. Proper lubrication will undoubtedly reduce this rate of deterioration but a bright, shiny wire will weaken with use just as a rusty one. Oceanographic cables are the most critical element in the oceanographer's catalog of tools, second only to the ship itself. The only sure way to protect his instruments is to replace all wire on a regular and orderly basis.

Alarm systems are overkill.
counterbalanced blocks.

LAB FACILITIES

a) ELECTRICAL ~~aire~~ listed KW sufficient

b) XDUCERS - air locker and at least 2 science wells.

c) AIR COND - all lab spaces A/C

d) WET LAB - not a van - space can be used otherwise

e) UNCONTAM - SW - what pipe
FW - OK

f) 8) GAS BOTTLE - nothing special - general provision take care of

g) 9) ACID STOW - not special on boat. (not permanent)

h) 10) TIE DOWN - great.

i) 11) FREEZER - definitely not permanent.

j) 12) BOS'N STORES - should provide most of Sci. needs.

13) VANS - OK but play down

14) SQUAWK BOX - excellent.

15) SAFETY GEAR - overside breathing is never working
survival suits excellent.

16) SHELVES & DRAWERS - as appropriate

COMMENTS

NAV. & COMM.

1) Recommendation -

a) SATNAV on larger vessels only.

b) DIGITAL OUTPUT on all is good idea particularly with GPS system.

c) SPEED - present log systems are not reliable and tend not to work well on small ships such as R/Vs

d) MANUAL DATA INPUT - tends to be arbitrary and ill used.

e) MET. DATA - who would use it! Perhaps capability available for special cruises

f) TOO MUCH DATA - what the hell do you do with it all.

g) GPS - agree with recommendation.

h) LORAN C - particularly on small vessels - sets with LAT/LONG OUTPUT and remote display at helms are very practical.

i) COMMUNICATIONS - VHF - by laws
SSB - excellent.
SATCOMM - do we really need it. Perhaps for special projects and long cruises only.

(ATS ?)

j) SONOBUOY ANTENNAS - not permanent on all!

k) CABLE RUNS - OK

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INTRODUCTION

This report is the result of a study that includes a workshop held at Texas A&M University on February 26-28 and a detailed review of the preliminary report of the workshop by each UNOLS' institution and by interested individuals in the oceanographic community. The comments of the institutions and individuals were considered and the present edited report was written on June 7 and 8, 1979 at Woods Hole Oceanographic Institution.

This study was initiated because of a growing concern in the oceanograhic research community about general inadequacies in the area of shipboard instrumentation and oceanographic equipment. Complaints range from insufficient funds in the program to the inaccessibility and poor condition of existing equipment. Further problems of a different nature have been identified, such as the widely differing capabilities of research vessels even within the same size class, especially with regard to winches, cranes and wire. The procurement, inventory, maintenance, and management procedures vary widely at research institutions represented by UNOLS.

Accordingly, the UNOLS' Advisory Council undertook to study these equipment-related problems. A workshop was sponsored by UNOLS with the cooperation of the Ocean Science Board (OSB) and Research Vessel Operators Council (RVOC). Co-chairmen of the workshop were: Dr. Richard T. Barber, (UNOLS); Dr. Derek W. Spencer, (OSB); and Mr. Robert. D. Gerard, (RVOC). Dr. George H. Keller, Chairman of the

UNOLS Advisory Council participated with the co-chairmen in the writing and editing of the report.

The objective of the workshop was to define the basic minimum ship and instrumentation capability, operation and maintenance that a scientist may expect to find aboard a UNOLS' vessel. This report is an attempt at that definition.

We recognize that the demands of many research programs will require capabilities well beyond the basic minimum set recommended here; we urge vessel operators to accommodate these demands. Major costs associated with such accommodation should be met by the research program.

The recommendations of this report are meant to apply to all UNOLS' vessels over 150'. All these ships routinely work offshore, in deep water and in areas remote from the U. S. A few of the UNOLS' vessels that are less than 150' also work offshore, in deep water and remote from the U. S. but a majority of the less than 150' vessels do not. If an institution believes its less than 150' vessel operates routinely in a mode similar to the larger vessels then that institution is urged to indicate its intention to implement the recommendations of the report. For example, it seems likely that it will be appropriate for new coastal zone vessels to comply with most of these recommendations.

DECK OPERATIONS

Recommendations

1. Wire winding machines should be used by all vessel operators.
2. Accumulators appropriate for the winch and wire system should be installed.
3. Current winch level winding systems should be upgraded to ensure proper winding of wire ropes and cables.
4. Fleet-wide maintenance schedules should be established to ensure proper care and reliability of winches, cranes and other scientific deck machinery.
5. Winch/wire monitors are required to permit documentation of wire rope and cable use and history and to assess new methods of extending wire life. This documentation should be readily available to all scientist users.
6. Interchangeable winch drums are recommended to avoid wire winding exchanges at sea and expand capabilities of vessels.
7. A low viscosity lubricant should be used on all deep sea wires. The exception to this would be special purpose applications, e.g. organic chemical sampling.
8. Calculations for each vessel that will predict wire loading vs. sea state should be available in convenient graphic or tabular form.

9. The wide variety of wire ropes and cables should be reduced to the following set (inches):

Trawl wire -- 1/2 5/8

Hydro wire -- 3/16 7/32

Electro-Mechanical (E-M) cable -- 7/32

10. Blocks and sheaves should exactly match the wire sizes in use in order to reduce wire degradation.

11. The field of E-M cables should be surveyed to determine the true state of the art.

12. At this time, the double-armored, torque-balanced electro-mechanical cable currently available should be used on all UNOLS' vessels.

Winches

Versatility in winch systems is highly desirable. We recommend that winches be designed so that they may accommodate a range of wire sizes and still spool and level wind properly. This means that winches should be so constructed that sets of gears, sprockets, level wind, grooving, etc. may be interchanged easily. Trawl winches in current use should be capable of handling 1/2" and 5/8" diameter wire rope. The ability to accommodate 0.7" diameter E-M cable (with slip ring assembly) is an important new requirement and should be incorporated in all new trawl winches and, where possible, in existing trawl winches. Hydrographic winches should accept 3/16" and 7/32" wire rope and 7/32" E-M cable. The need for a new category of winch, intermediate between the conventional trawl and hydro winch size is recognized. This winch should have the capability of handling 10,000 meters of 5/16" diameter E-M cable. A limited number of these winches should be made available to the oceanographic fleet for special projects.

Along with such changes it may be necessary to adjust the maximum hauling power of the winch such that the maximum load it could pull will be safely below the field value for each wire used. Flexibility in the winch system will permit the vessel to be more responsive to specific user needs, and will provide the vessel operator more latitude in the acquisition of wire (which may be in short supply). We also recommend that the blue water vessels have a trawl winch capacity of at least 12,000 m of wire and a hydro winch capacity of 10,000 m of wire. Existing winches should be modified to include the above capabilities.

Successful scientific operations at sea are largely the result of a combination of proper winch operation and maintenance procedures.

Wire Winding Machine

It is recommended that each shore outfitting facility have access to a portable machine to wind wire from ship's winches and/or storage reels onto winch drums. A plan for regional sharing of a limited number of machines should be developed. For example, the needs of the oceanographic community (within the contiguous 48 states) might be met by assigning one machine each to the northeast, southeast, gulf, southwest and northwest regions.

The purpose of the wire winding machine would be:

1. To inspect the wire rope for wear, breakage of strands evidence of kinking, dimensional tolerance.
2. To provide access for lubrication, particularly the little used inner layers.
3. To provide convenient means for reversing cables end for end for added wire life.
4. To provide adequate back-tension for spooling new wire onto winch drums.

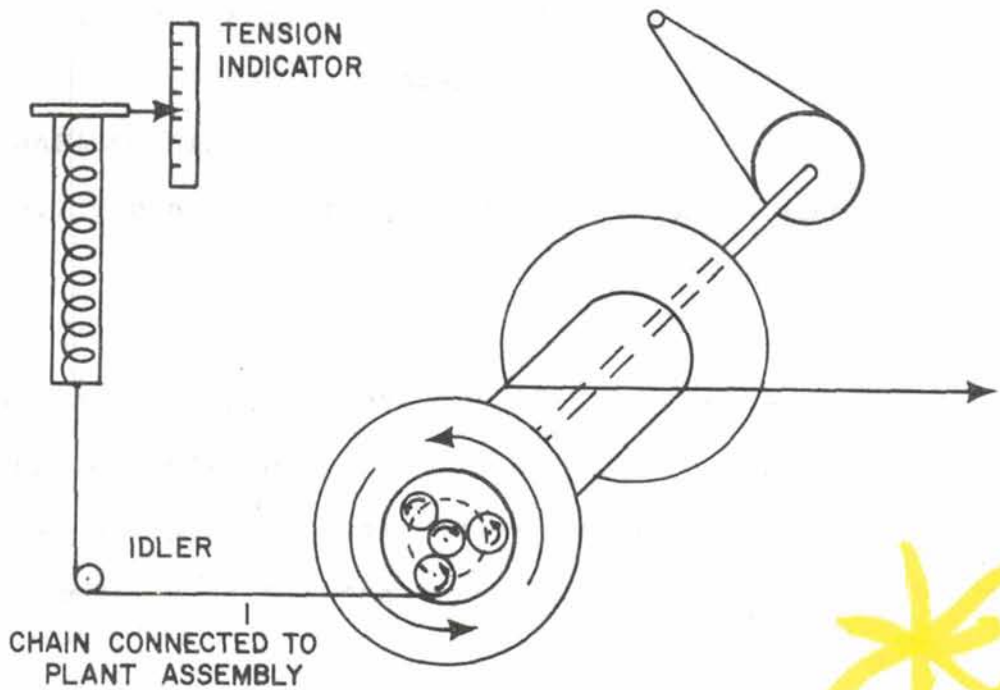
The wire winding machine should preferably be self-contained as to power supply (except for electrical input if an electrical prime mover is used), and be capable of both slow inspection speeds and moderate running speeds for loading of winches after the inspection and/or processing runs are made.

In special cases winding machines might be taken to sea for short periods to serve as special purpose winches.

Accumulators

The large transient forces and displacements present at the head block of lowered instrument systems require a compliant element to absorb these forces. Heave, pitch and roll cause large motions with resulting large acceleration and velocity forces at this point which is displaced from the center of roll and pitch thus amplifying the resulting forces.

R. B. Walden, at Woods Hole Oceanographic Institution, is currently studying the effects of ship's motion on the loading stress of wire rope/cables; preliminary results indicate that normal heave and roll can impose forces on a CTD cable equivalent to +0.5G.



Sketch of L-DGO Planetary Drive—Accumulatory System

Frequent causes of failure of both mechanical and electro-mechanical cables have been attributed to the impact forces produced, particularly after the release of tension on a downroll followed by snap-loading. An accumulator can absorb these loads by responding to the change in tension in the wire with the vessel motion. The unit can be designed to absorb the resulting forces by specifying the total wire accumulation length required and the maximum tension.

As a retrofit, support should be given to those operators who wish to provide a 3-block spring accumulator (similar to R/V EASTWARD). In cases where a new winch is being designed, consideration should be given to the planetary drive accumulator system used by L-DGO (see illustration above), University of Texas, URI, and on the coring winch aboard R/V ISLAS ORCADAS. The use of air-oil accumulators in certain hydraulic winch drives may provide the same desirable features.

Slip Ring

All new winches should have provisions for conducting cable shaft take-outs and slip rings. Existing winches should be similarly modified if feasible. It should be the responsibility of the vessel operator to provide a satisfactory means for slip ring use on all shipboard winches.

Level Wind

A grooved drum, properly designed for a particular wire size in use, is recommended for all shipboard winches. In cases where the wire rope or cable has a reasonably round crossection and the fleet angle is sufficiently small, a non-powered level winding system similar to the Lebus system is recommended.

A. Trawl Winches

Since most trawl winches use a three-strand wire rope construction, which does not lend itself to the non-powered spooling system, power-driven level winds are recommended. A level wind should be designed to accommodate the recommended sizes of wire (see section on wire rope) by using changeable gears or sprockets to obtain correct ratios. They should also be designed to provide the correct carriage travel and the proper dwell time for the rope at each end of the drum during spooling. Size of shaft and thread will depend upon width of drum and distance to first fairlead or sheave to determine side loads. Variable ratio drivers are not recommended due to slippage and difficulty of obtaining the exact ratios required for spooling.

Level winds and existing equipment can in many instances be modified or updated to improve the spooling of wire ropes. Such modifications should be supported as a means of extending the operating life of costly wire ropes and cables.

B. Hydro Winches

Power-driven level winds are also recommended for hydro winches. As electrical conductor cables are normally round and uniform in size, good spooling can be expected and should be obtained. Level winds should be designed to accommodate cable sizes of 3/16" and 7/32" by using quick-change sprockets or gears. The greatest advantage to be gained from improved level winding applies to E-M cable for the following reasons:

1. E-M cables have a considerably shorter useful life than comparable wire ropes under existing conditions.
2. The most common cause reported for retiring E-M cables

is conductor loss.

3. E-M cables are roughly twice the cost of comparable diameter wire ropes

Winch Monitors

A need exists for adequate monitoring and recording of basic information relating to winch operations. The minimum system should include measurement and recording of line tension, line speed and direction, line length and time. These data are required for the following reasons:

1. To document scientific operations.
2. To observe and prevent excessive conditions which would degrade scientific observations or damage wire or equipment.
3. Provide wire-use record for use in estimating need to retire wire.
4. Provide data for design, assessment and improvement of systems or instruments, e.g. winch accumulators.

To accommodate the recommendations for use of a variety of wire sizes (see later section) the monitoring system should be adjustable to reflect accurately the parameters of the wire in use.

It appears that the technology required to accomplish this task is already available and should be considered where existing winch systems are either upgraded or retrofitted.

In addition to the primary electronic monitor a secondary mechanical back-up system is also recommended.

One additional area where monitoring systems are required is in the use of either TV cameras or electronic sensors to determine the direction and physical operation of the winch in situations where the winch is located away from direct observation.

It is further recommended that a procedure be implemented to test and calibrate these monitors at regular intervals.

Interchangeable Winch Drums

The use of winch drums which can be readily exchanged at sea or foreign port is recommended. In this way a failed wire rope or cable can be quickly replaced with minimum loss of costly ship's time. Similarly a single winch could serve different programs requiring different wire rope or cable sizes or types. An additional advantage is that when purchasing a new wire rope or cable an empty drum can be sent to a manufacturer to have the wire wound on at a specified tension so that it is ready to use immediately when installed.

Blocks and Sheaves

We strongly endorse the requirement that the blocks and sheaves used by UNOLS' vessels be matched to the specific wire size in use aboard the vessel.

To avoid the unnecessary damage currently being done to wire ropes due to inadequate sheave diameter and groove diameter it is essential that we begin matching the handling equipment to the wires in use. The formulas and rules necessary to determine proper sizes and ratios are in all standard references. It is incumbent upon UNOLS to develop the necessary procedures to ensure that the rules are followed in all cases.

B.S.

Careful consideration of sheave size is imperative; a conservative approach would be to use sheaves 400 times the outer wire diameter, or 44 times the cable diameter.

Maintenance and Inspection

Maintenance and inspection of winch systems should be made a standard procedure aboard UNOLS' vessels. Two types of inspection are recommended as follows.

Primarily, the complete winch system should be inspected regularly at brief intervals, e.g. end of the cruise but at no longer than three-month intervals. During this inspection all aspects of the winch and its associated machinery should be carefully reviewed and corrective measures taken where necessary.

In order for this inspection to be effective, it is further recommended that an appropriate check list be established, which, depending on the specific winch, would encompass the complete system and serve as a means of apprising the future user as to the documented condition of the winch.

The second phase of the maintenance and inspection program would deal with a less comprehensive inspection occurring after a long period of non-use.

Such an inspection would ensure that the system was operable, lubricated, and ready for use and would help to eliminate unnecesary delays or failures.

It is our feeling that these measures regularly followed throughout the fleet would go a long way toward providing reliable winch systems.

Future Winch Concerns

The U. S. does not have at present a vessel capable of deploying large double-warp trawls in the deep sea. In 1975 the need for such a trawling capability on a UNOLS' vessel was clearly identified by a group of nekton specialists brought together by NSF and ONR to make recommendations about problems of assessing nekton populations. The results of that workshop* clearly outline vessel and winch criteria necessary for large double-warp deep sea trawling. These criteria may be met by new vessel construction, modification of an existing vessel, or cooperative arrangement with other countries (which already have double-warp deep sea trawling capabilities).

*See Report "Workshop On Problems of Assessing Populations of Nekton", 25-27 February, 1975, Santa Barbara, CA, 30 pp. W. G. Pearcy, Editor.

Wire Rope

Prior to the workshop all of the operators were requested to fill out and return a questionnaire on wire rope/cable history and characteristics. Eight institutions responded and certain of the data are summarized below. From the data given it would appear that consolidation of wire/cable classes to one E-M cable size and 4 wire rope sizes would serve most existing needs.

TABLE OF WIRE SIZES VS. USE

This table reflects the current wire size and use employed on UNOLS' vessels in the 80' - 200+' class.

Trawl Wire

Dia., (inches)	3/8	1/2	9/16	5/8
No. Vessels	4	15	4	2*

*Indicates the capability of two institutions to use more than one wire size on the same winch.

Hydro Wire

Dia., (inches)	3/32	5/32	3/16	7/32	.225	1/4	3/8
No. Vessels	1	1	14	1	1	4	1

Electro-Mechanical Cable

Dia., (inches)	1/8	5/32	3/16	7/32	.220	.225	.250	.300	.322
No. Vessels	1	1	5	4	1	1	1	1	1

Recommendations for more closely standardizing wire ropes and electro-mechanical cables among UNOLS' vessels are as follows (inches):

Trawl wire - 1/2, 5/8

Hydro wire - 3/16, 7/32 1/4

E-M cable - 7/32 .303

It should be noted that the above recommendations represent the minimum number of sizes believed necessary to conduct standard operations. Non-standard operations requiring special wire/cable sizes are also recognized: For example, the 5/16" diameter E-M cable for GEOSECS-type CTD Operations. probably too small

Other data show that E-M cable is retired mainly due to conductor loss (50 to 100% of retirements at 4 out of 6 institutions).

Regarding the use of lubrication/preservative, about 70% of the institutions employ some type of oil but the effect on wire life is unclear due to poor documentation of wire use and reasons for retirement.

Torque Balance

Need: Torque balance of a tension member, either electro-mechanical or strictly mechanical (wire rope) is considered synonymous with the tendency to rotate as tension is increased. As the tension member rotates torsional energy is stored and the rate of dissipation of this torsional energy must be controlled to prevent damage to the tension member. Rapid dissipation such as that occurring when an instrument is allowed to hit the sea bottom or the instrument package is overrun (payout speed exceeding the terminal velocity of the instrument package) generally results in cable kinks. These kinks damage the strength member construction and any electrical conductors.

In some missions the orientation of the instrument is important and a cable having a 30° per foot rotation at 40% of its breaking strength has little application in such service.

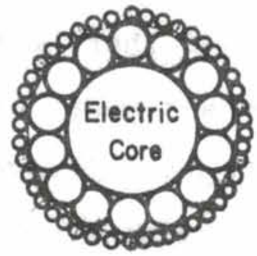
Torque balance or a zero rotation as a tension characteristic is very important in oceanographic instrumentation work.

Short Term Considerations: The oceanographic community is familiar with the 3x19 strand wire rope which has a near zero rotation vs. tension characteristic. Very successful service has been reported by the oceanographic community. At present, the kinking problem has been solved for wire rope; there now remains the problem of level winding referred to in an earlier section (p. 6 et seq.).

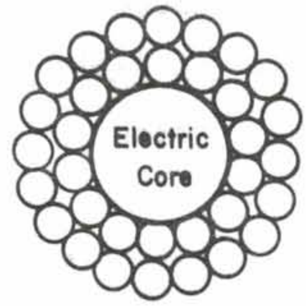
For electro-mechanical cable a solution is available through a number of special constructions, all of which have "trade-off". These generally are:

Braided: When braided wires are crushed high compression stresses are set up at braid crossovers resulting in shorter life characteristics due to flexure and tensile fatigue. Also, corrosion damage is very severe in the event of puncturing the protective covering jacket, usually a thermoplastic.

Specialized double layer armor: This construction embodies a number of small diameter wires in the outer armor as follows:

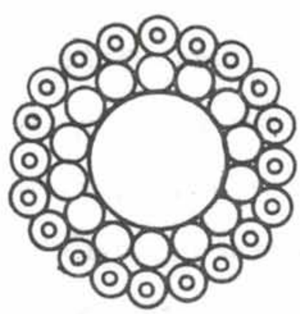


TORQUE BALANCED
DOUBLE ARMOR

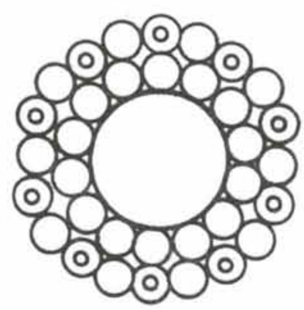


CONVENTIONAL
DOUBLE ARMOR

The ratio of lay lengths of the outer-to-inner armor layers (lay ratio) is also increased to balance the torque of the two layers. The small diameter wires in the outer armor are less geometrically stable than those of a conventional double armor and are more subject to physical damage from snagging, crushing, etc. Further, this construction has a low flexure fatigue life.



ALL OUTER ARMOR
WIRES JACKETED



ALTERNATE OUTER ARMOR
WIRES JACKETED

Various E-M cable constructions using jacketed wires have been designed to improve torque balance. The shortcomings of these constructions are:

a. Manufacturing: The jacketed wires do not pre-form (assume the proper helical shape) well and therefore become loosened sooner in service. This increases wear, shortens flexure fatigue life and increases susceptability to snagging.

b. Cold flow or wear of the jacketing on wires in service promotes the development of a loose armor condition. This results in a significant increase in the tension/elongation characteristic and decreased overall useful life.

Other torque balanced constructions are as follows:

a. Three layer armor: To avoid very small diameter armor wires this construction results in increased diameter and weight over that of a double armor on the same electrical core.

b. Electrical conductors in wire ropes: A very special rope manufacturing requirement which can accommodate few conductors (six have been installed).

The recommendation of this particular group, at present, is twofold. First, that the double-armored, torque-balanced electro-mechanical cable currently available be used on all UNOLS' vessels. Secondly, that the cable industry and commercial users be surveyed by a sub-group of UNOLS to determine possible alternatives to cable currently in use and to assess the state-of-the-art.

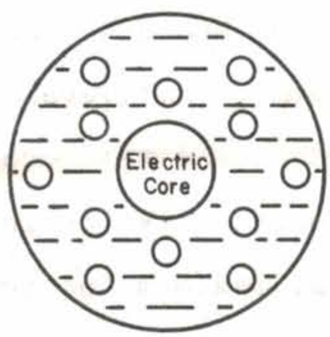
Long Term Considerations:

Wire rope: To improve the corrosion resistance and spooling characteristics (roundness) some wire rope may be jacketed.

Electro-mechanical cable: Two developments are finding increased use.

Kevlar: The use of the high strength Aramid fibers is increasing and initial problems with self-abrasion are being alleviated somewhat. These cables are usually made to order and the cost is higher than for a steel strength member cable of the same strength.

Double-Caged Armor: This construction involves essentially a conventional double layer armor cable wherein every other wire is omitted in both armor layers. The spaces are then filled with the jacketing material. The crossection therefore appears as illustrated below.



Manufacturing techniques are being developed by several manufacturers so that the present higher cost is expected to decrease.

Long-Term Recommendations for E-M Cable: Major improvements are anticipated with the long-term development of special E-M cables, handling equipment and predictive modeling for oceanographic operations. Cables and equipment currently in use are commonly adaptations from other industries, principally the oil industry. These components do not have the dynamic or corrosion performance requirements in their designs required by the oceanographic community.

Therefore, a principle recommendation is to initiate a technology-based program to identify the general oceanographic cable requirements and develop and test cables to meet these requirements.

Further Recommendations and Discussion on Cables

Mechanical performance instrumentation should be provided on all winching operations of E-M cable. These include accurate measurement of length and dynamic tension displayed at the control site. Alarm instrumentation should be provided if possible to avoid two-blocking instrumentation on retrieval.

An operation, performance and maintenance record should be kept on each cable during its useful like to include for instance the number and length of casts, maximum tension, mishaps, damage, etc. Measurements of conductor loop resistance and insulation resistance to ground, should be recorded periodically during the life of the cable. Reflectometer measurements should also be performed on coaxial cable.

Periodic lubrication of the cable is recommended.

A principle failure mode of E-M cable is related to torque and thus kinking during load relaxation. Therefore, operating procedures should be followed which maintain tension all the time. These procedures should be based on predictive analysis applicable to the ship, winch wire system, and lowered device. Fairleads and head blocks should be arranged to follow the lead angle of the cable to minimized torque induced by the cable riding up the side of sheave.

The use of counter-balanced blocks should be carefully considered together with keepers to ensure that cables remain in sheaves' grooves should they become slack.

Manufacturers' recommendations should be followed in selecting minimum sheave diameter and sheave groove size.

Institutional cable retirement criteria are poorly defined at present. Visual observations along with performance and damage record are still the only guide available.

Wire rope fails from various factors such as bending fatigue, axial loading fatigue, corrosion fatigue, wear, and above all, mechanical damage.

The strength of the wire rope when new should be known and a certified test report of breaking strength from the manufacturer should be ordered when the rope is purchased.

Tests should be made in a dynamic test machine having both ends fixed and also with one end fixed and the other free to rotate.

After the rope has been put to use it should be inspected visually as it is reeled in. A written record of broken wires by location in the reel should be maintained.

Fatigue damage cannot be seen until wire breaks appear. It may be estimated from data recorded in a log of the number of trips the wire rope/cable made and the peak loads experienced. The number and degree of bends, and the ratio of wire diameter to sheave diameter should also be recorded. Calculations can then be made to determine fatigue damage after a given period of usage.

Corrosion affects fatigue life by lowering the fatigue endurance limit of steel. It also leads to pitting which decreases breaking strength.

During inspection the wire rope should be checked for size. Three strand rope must be checked with a three-point micrometer. Even a slight reduction from normal diameter (5%) under no load is a reason for retirement, at least until a break test can be performed.

Kinks significantly reduce rope strength and should be cut out and the ends spliced or the rope replaced.

Lubricant applied to wire rope should be of such a consistency as not to impede rope inspection by concealing defects.

It is estimated proper lubrication can double the life of wire rope. A suitable lubricant should contain rust inhibiting properties to control corrosion.

Lubrication

Lubrication of wire ropes and cables reduces internal frictional wear and inhibits corrosion. Establishing regular procedures and schedules for lubricating wires and cables on research ships is the simplest means to extend their useful life. We strongly recommend regular lubrication be carried out. Where the lubricant could contaminate scientific samples a leader of inert material should be used. In other cases the use of a complete reel of stainless steel wire rope is the best solution. Lubricant can be applied in a variety of ways on shipboard: spraying, brushing, and dripping procedures have been followed by various operators. The same lubricant-preservative which is applied at sea should also be specified for application during manufacture of wire rope or cable to ensure chemical compatibility as well as corrosion protection during the period of storage prior to use.

Predictive Models

Insufficient consideration of the dynamic motions of the headblock for instrument lowering systems has led to catastrophic wire failures. Normally the headblock is placed well outboard and above the center of roll and may be 60 feet or more aft of the center of pitch. The resulting motion from combined heave, pitch and roll may be large. For instance, the peak velocity at the headblock on the R/V KNORR due to a 15° roll in a 7-second sea has been calculated to be 7 ft./sec. or 125 meters/minute. If the package's terminal velocity at the end of the wire is not greater than this it is obvious that slack in the cable above the package will occur. Under such circumstances kinking and snap loading may take place which may severely damage the wire.

Predictive models should be developed and available to the principal investigator to permit him to make on the spot decisions regarding the speed of lowering of his instrument package or even whether it should be deployed at all. Input to such a model would be factors such as wave height and period, estimated resulting ship motions, and characteristics, both mechanical and hydrodynamic, of the wire and instrument package. The model should be configured so that required information could be fed to an onboard computer to produce the data on which to base a decision, or it could be derived easily from a nomograph or tables.

too bulky for all but special application

Cranes

Crane characteristics that are important in oceanographic shipboard cranes are:

1. Ease of maintenance
2. Protective coatings, i.e. marinized
3. Separate hydraulic power system
4. Safety interlocks
5. Slewing control (against ship's roll)
6. Crane safety standards (at sea)
7. Capacity and working radius
8. Effects on ship stability
9. Certification

No recommendations are made for the type of crane (articulated, telescoping boom, kingpost & boom) to be installed on research vessels because such decisions depend on use and size of the vessel. With respect to crane installations, either retrofit or new construction, a careful review should be made of intended service, ship compatibility and location before settling on a specific crane. Increased contact should be developed with industry representatives to make them aware of research needs and to obtain their recommendations regarding the adaptability of their standard products.

On-board cranes should be designed to be used at sea and not only as devices to load cargo and scientific equipment at dockside. This will require engineering development to increase strength and safety factors for the higher angular, non-stable, loading conditions experienced at sea. This is especially true with slewing controls. Overall considerations must include possible effects on a ship's stability over a variety of conditions. Because of the possibility of power failure at sea, emphasis on safety interlocks is necessary. While there is no strong recommendation for crane portability, it is a desirable characteristic in smaller cranes. When portable, they can be placed in various shipboard locations or on other ships within the same institution or elsewhere.

There is a strong potential for more scientific use of cranes at sea as part of a deep sea winch/wire system. With the ability to rotate the crane to follow the wire, the inflexibility of the standard A-frame is eliminated. In some instances this is desirable. Both a crane and A-frame are desirable on UNOLS' vessels. Sole reliance on either system is not recommended. Versatility and ability to adjust to the use of either system might mean the difference between success or failure of a particular operation.

We recommend that an RVOC committee should:

a. Make a review of crane manufacturers to determine which, if any, have ABS or Coast Guard certification.

b. Make contact with manufacturers relative to their interest in research cranes.

c. Poll UNOLS' members for information relative to minimum and maximum working radii and related weight loading.

d. Develop a set of guidance specifications to be used in procurement of research vessel cranes that can be used at sea.

e. Distribute the information developed to all UNOLS' members.

INSTRUMENTATION

Recommendations

1. A person(s) should be designated as Equipment Officer(s) at each institution or for each vessel to oversee maintenance, calibration and management of shipboard scientific equipment.
2. Each ship should have the following:
   a. Ship parameter network
   b. Precision echo sounder, 12 kHz
   c. 3.5 kHz transducer
   d. Location(s) suitable for placement of science antennas, i.e. radio direction finder, sonobuoy antenna
3. Each institution should identify and advertise the equipment they wish to designate as shared-use equipment.
4. Maintenance, management and calibration of the designated shared-use equipment should be the responsibility of the Equipment Officer and this effort should be an integral part of the ship operating costs.

Instrumentation

The minimum instrument capability that should be on the UNOLS' vessel is described in this section. The equipment and instruments required to provide this capability must be maintained and in some cases calibrated. To ensure that this is done on a routine basis and that these items are available and functional for the scientists as they come aboard a ship, it is recommended that an Equipment

Officer be designated at each institution or for each vessel as appropriate to the institution. This individual is to have the responsibility to either oversee or to actually carry out the maintenance and calibration of these various items as is appropriate to the operational plan of the institution. The Equipment Officer will see that appropriate logs are kept on mechanical equipment and that this information is available to each principal investigator coming aboard a vessel. This individual should have authority and responsibility parallel to that of the engineering and deck officers to ensure that the science support capabilities of the ship receive the attention that is required. The Equipment Officer may or may not accompany the scientific party to sea, depending on the institution's mode of operation and the needs of the scientists.

The following items, 1 through 4, are the recommended instrument capability for each UNOLS' vessel.

1. Ship Parameter Network. The set of observations that should be available includes the following:

- o *time - year, month, day, hour, minute, second
- o *position - latitude and longitude
- o * ship's speed and heading
- o *winch activity data - wire out, speed, tension

*Priority should be given to these items since they are basic to all ship users' needs.

all should be available if wanted

- o water depth
- o wind speed and direction - relative to ship
- o sea surface temperature
- o air temperature and wet-bulb temperature
- o barometric pressure

There are two modes in which all standard parameters should be available: as visual digital information and as electronic digital information. Signals for analog recording should be available for the following parameters: winch activity, wind speed, sea surface temperature.

The input data for some parameters is obtained by simple visual observation with conventional ship facilities, e.g. the bridge watch reads the chronometer and performs sling psychrometer observation for wet and dry-bulb temperature which is then manually inputed to the network. For other parameters the inputs come directly from sensors.

Analog records provide a dimension of history allowing the science party to read the present value of the parameter and to observe trends and changes in the property. The signals for analog recording of the stated parameters should be available in the science laboratory and on the bridge or in the chart room. The signals should be of one type so that a common recorder model can be used.

A system is suggested which allows the input of navigation information into a data logging circuit (Fig. p. 30). The navigation information provided to this circuit should include fixes (latitude, longitude), DR's (latitude, longitude) and time from the satellite navigation units. Similar navigation data (latitude, longitude) along with lines of position (LOP's) from the LORAN-C units should enter this loop. Ship's speed and heading and a time base must also be entered into the loop. The time base (day number, hour, minute, seconds) is necessary for the proper phasing of operations. Provisions should be made for the manual input into the circuit of other data either by bridge or scientific personnel. Other routine measurements such as meteorological observations and sea surface temperature and salinity could be entered into the current loop. These data should be recorded digitally in a routine fashion with a minimum period between observations of 10 seconds.

A digital interface allows direct access via standard electronic means to the information. Each output is represented by digital numbers proportional to the value of the parameter being measured. All parameters are presented in a common industry standard digital format at a central location in the science laboratory.

Included in the digital format of each sensor is specific information about the sensor, its calibration history and its accuracy. In all cases, readily available sensors are used with state-of-the-art accuracy and resolution. It is essential that all parameters on UNOLS' ships use one common format. As to the specific system that should be used, it is recommended that the UNOLS Techonology Committee undertake a study to come up with a suggested system.

2. 12 kHz Precision Echo Sounder. The basic bathymetric system aboard a research vessel should include a precision depth recorder and 12 kHz transceiver system. In addition to supplying a record of bathymetry, the system will provide the capability of recording acoustic signals from over-the-side instrumentation (e.g. pingers, acoustic releases, and navigational transponders). It is highly recommended that the recorder and transceiver electronics be redundant systems and that the transducer be redundant or replaceable at sea to ensure reliability. A portable echo sounder fish should be available through the shared-use source in those cases where underway echo sounding with built-in transducers is poor.

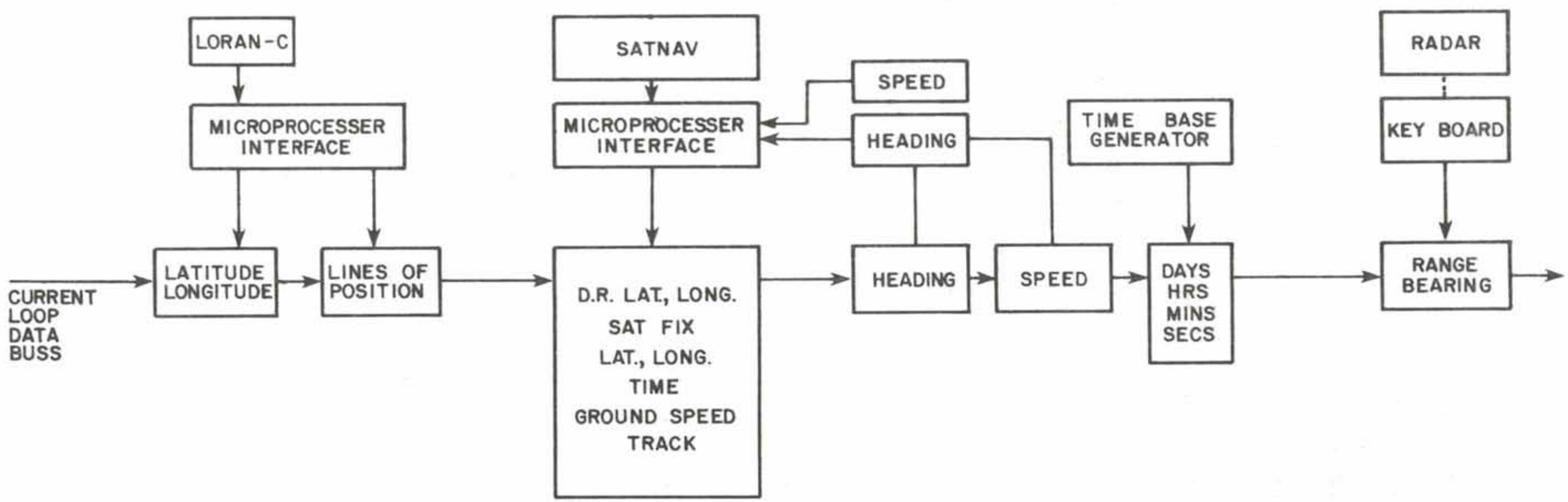
3. 3.5 kHz Transducers

4. Suitable location(s) for the placement of science antennas, i.e. radio direction finder, sonobuoy antenna

Shared-Use Equipment

Some equipment is currently in common usage within widely differing disciplines. The complexity of the equipment, its use rate, and its cost do not justify their presence aboard a research vessel at all times. Furthermore, this equipment requires special care, and it is wiser to remove it from the ship when it is not being used so that it can be maintained and stored in a controlled environment. We recognize two categories of shared-use equipment.

RECOMMENDED MINIMUM INTEGRATED NAVIGATION SYSTEM



One class of equipment can be supplied from an equipment pool for use by others at sea assuming they are trained in its use, the other class of equipment must be used as a system that includes an operator and/or maintenance personnel. Obviously, the shared-use of equipment of the latter category presents a more complex management picture since personnel costs have to either be paid by the investigator or charged against a particular research grant as ship time is done now.

The list of shared-use equipment that can be provided without personnel is:

1. Water samplers, including rosette samplers
2. Reversing thermometers
3. Freezer storage, 20 cu. ft.; reefer space, 80 cu. ft.
4. Dredges
5. Simple bottom cameras
6. Coring equipment
7. XBT System (launcher, cable, and recorder)
8. Bottom-pinger
9. Copying machine
10. Salinometers
11. Oxygen titration equipment
12. Fluorometers
13. Spectrophotometers
14. Scintillation counters
15. Microscopes
16. Water stills and deionizers

Shared-use equipment that can only be used as a system involving both people and hardware are:

1. Computers
2. Transponders and acoustic command units
3. CTDs
4. Autoanalyzers

While efficient use of shared equipment can improve research effectiveness and reduce expenses, the quality of the system will depend on careful development of a management program to ensure adequate availability, maintenance, replacement, documentation and calibration of the equipment.

The formation of computer, CTD, or autoanlyzer shared-use pools at all UNOLS' institutions is neither wise nor possible. The development of institutional equipment centers should and will depend on initiative of the institutions and their varied strengths and interests.

We recommend that institutions carefully inventory their equipment and decide what equipment they wish to designate as shared-use equipment. The availability of the designated equipment at various institutions would be made known to users of that institution's ships by a flyer or manual. (This procedure is presently followed by most UNOLS' institutions.) We do not recommend what the shared-use equipment should consist of; that will always depend on the size and interests of the institution. We do recommend that the maintenance and care of this equipment should be an integral part of ship operating costs. The Equipment Officer described early in this section would head this effort.

Equipment Officer

In addition to coordinating the shipboard equipment and support logistics, the Equipment Officer has the responsibility to ensure that the equipment is functional and available to the principal investigator. His responsibilities include the following areas:

a. Cranes and deck handling equipment

b. Winches

c. Conductor cable and wire

d. Laboratory equipment & space

e. Shipboard electronics for:

Navigation

Echo sounding

Speed log

Time

Wind speed-direction

Remote read-out terminals

Communications

NAVIGATION AND COMMUNICATIONS

Recommendations

1. UNOLS' vessels should be equipped with SATNAV, LORAN-C, doppler speed log and gyrocompass. Interfaces should be developed and supplied to all UNOLS' vessels to allow digital output from the navigation instruments to be entered into the ship parameter network described in the Instrumentation Section of this report.

2. On UNOLS' vessels, existing MX-706 or MX-702 satellite navigation receivers should be replaced as they fail with the Magnavox MX-1112 receiver.

3. Minimum communications equipment for UNOLS' vessels operating in distant waters should consist of:

a. high frequency (single-side band) radio

b. very high frequency radio

c. satellite communications (SATCOM), ATS I and ATS III.

Navigation

Accurate navigational information is essential to all activities at sea. On research vessels one can identify two distinct ways in which this information is put to work. The first (and continuing) requirement is that of the ship's officers for position, speed and heading for safe passage and for meeting the objectives of the scientific mission. The second requirement is for an accurate chronological log of the ship's movements for later, detailed analysis by the scientific party. While we can expect standard logs to be maintained by the ship's officers, the increasing sophistication of many investigations points to an increasing necessity for the frequent, automatic recording of such information. With the advent, in recent years, of microprocessors and inexpensive recording systems the task of realizing such a capability is vastly simplified. Such an automatic logging system becomes even more urgent as we undertake increasingly complex programs in smaller vessels with concomitant limitations in the size of the scientific party.

In the past 10-15 years we have witnessed extraordinary developments in electronic navigation, specifically TRANSIT and LORAN-C. The coming decade will be even more dramatic with the advent of the new Global Positioning System (GPS). When it becomes available, extremely accurate positioning information will be continuously available on a global basis and will open up new research possibilities. In the meantime there will be a transition period, 5-10 years say, before GPS will provide worldwide coverage. Thus there is a strong and continuing need for TRANSIT and LORAN-C. We recommend therefore that UNOLS' vessels be equipped with receivers to exploit the full potential of these systems. As discussed in the Instrumentation Section we recommend the development of electronic interfacing of these receivers to a common ship parameter network. Through this step we believe that navigational data logging requirements of most scientific missions can be achieved in a very cost-effective manner if this interfacing is accomplished.

We have reviewed OMEGA and its importance to the UNOLS' fleet and have concluded that its usage is too infrequent to require its inclusion as a standard navigation system even though we recognize that there are large areas of the world's oceans where it is potentially of very great value.

Present Minimum Requirements

The present minimum navigation requirements for the UNOLS' fleet are fulfilled by satellite navigation and LORAN-C units. The satellite navigation requirements are commonly being satisfied by the Magnavox MX-706 and 702 instruments, whereas the LORAN-C needs are fulfilled by a number of various instruments. A requirement exists for all SATNAV units to have an automatic input of ship's speed (from a speedlog) and heading (from a gyrocompass) available to the unit for accurate satellite fixes and for the DR-type fixes. It is left to the individual users to determine whether the speed and heading information should go directly into the navigation unit or whether this data should go into a computer used to determine position (such as with the MX-702). As described above, the output of the SATNAV receiver should enter the data loop along with ship's speed and heading.

Similarly, the LORAN-C units should have the capability of producing an output of calculated latitude and longitude and LOP's, which can be entered directly into the data loop. While it will be assumed that all LORAN-C's will be capable of providing the LOP's directly, it will be a user decision as to where and how the latitude and longitude are determined. Several possibilities exist for these determinations. Some units, such as the NORTHSTAR 6000, use an internal microprocessor; an external computer or microprocessor could be used on others, which determine position for LOP. An interface has been developed within the oceanographic community to serve this purpose. The dual outputs of latitude-longitude and LOP's from the LORAN-C permit investigators to use the LOPs to improve their positioning accuracy, if they desire to do so.

The SATNAV and LORAN-C units complement each other and can serve as backups in some operating areas. The SATNAV positioning is of sufficient accuracy for most oceanographic needs but is limited in its abilitiy to provide information on demand, since it requires a satellite to pass over in order to determine a position. The time intervals between satellite overpasses is variable and ranges from several minutes to several hours. Between these overpasses, the SATNAV system dead reckons from data based on ship's speed and heading. (Ship's speed and heading are also very important for an accurate fix.) SATNAV has the advantage of world-wide coverage. On the other hand, while LORAN-C provides limited global coverage, it provides continuous positioning of sufficient accuracy for common oceangraphic needs.

Future Recommendations in Navigation Systems

1. Phasing In the Global Positioning System (GPS)

We envision that the present TRANSIT satellite system will remain in use up to the year 1990. At that time the GPS should be fully operational and supporting a constellation of 24 satellites. However, the phasing-in period for GPS with regards to the oceanographic community will begin around 1985 and continue until all vessels are equipped with the new GPS receiver. It is recommended that the GPS should then become the primary method of navigation for the UNOLS' fleet. For minimum ship requirements, the single channel receiver will be capable of tracking three or four satellites sequentially and provide continuous navigation capabilities globally. The performance of these receivers will yield accuracies within the range of approximately 75 meters. The use of GPS will preclude the need for other types of navigation aids such as LORAN-C or TRANSIT since it will meet the accuracy criteria of present systems and provide global coverage.

2. <u>Replacing the Present Satellite Navigator</u>

Replacement of the present satellite navigation receivers (MX-706 and MX-702) with the Magnavox MX-1112 is recommended as they fail. We urge these replacements for several reasons:

a. The present units are experiencing an increasing number of failures due to their age and it is expected that this trend will continue and increase within the next seven years--the operational period of the TRANSIT system.

b. To eliminate a costly repair depot maintained by ONR at a cost of $4000 per set per year for 15 sets. These repair depot funds could then be applied to the purchase of new equipment.

c. To simplify the complexity of satellite receivers presently being used in an effort to increase reliability.

During the transition from TRANSIT to GPS, the same MX-1112 receiver main frame can be used with internal card replacements to track the GPS satellites. This should substantially reduce the cost of the new GPS receiver to the UNOLS' fleet.

Communications

Objectives

Our objective is firstly to define a minimum set of communications facilities which should be required at present aboard all UNOLS' vessels. In defining these facilities we have taken into account two factors which are of primary importance to our work: 1) scientific use and value of various communication modes; and 2) reliability of emergency communications when questions involving the health and safety of the ship's complement are involved.

Secondly, we make some recommendations for future work which take into account changes we expect to see in the area of shipboard communications within the next decade.

Currently Existing Communication Modes

A brief summary of presently existing modes of communications is given below, together with some advantages and disadvantages of each mode.

1. High frequency (single-side band) (required on all inspected vessels)

Advantages:

a. HF/SSB facilities are widely available, both on oceanographic ships as well as on other vessels.

b. 24-hour communication is possible.

c. The HF mode is used for transmission of weather facsimile (FAX).

d. This mode can be used as a data transmission link.

Disadvantages:

a. HF propagation conditions can be erratic, particularly for long distance communication. One consequence is that emergency communication can be difficult to achieve using this mode.

b. The effectiveness of this mode depends strongly on the level of local interference, or the extent to which frequency channels can be guarded.

c. When commercial stations are used the cost is high.

2. Continuous Wave (CW)

Advantage:

a. This mode is much more effective than HF/SSB under adverse propagation conditions.

Disadvantage:

a. Requires the presence of a trained radio operator.

3. Very High Frequency (VHF)

Advantage:

a. Communication is reliable under most propagation conditions.

Disadvantage:

a. Normal range of effective communication is restricted to 20-30 mi.

4. Satellite communications (SATCOM); ATS I and ATS III

Advantages:

a. Frequencies are guarded.

b. A communication net with a central control operator is available.

c. Communication links do not usually depend strongly on propagation conditions.

d. Facilities required can be built at relatively low cost.

e. Use is at no cost.

<u>Statement of Present Minimum Requirements and Short-Term Communications</u>

It is clear that no one mode listed above can be singled out as fulfilling all of our requirements. Therefore, we have established that the minimum set of communications facilities must include HF/SSB, VHF and SATCOM in UNOLS' vessels operating in distant waters. (CW has not been included because this mode is dependent on individual ship-licensing requirements and personnel.)

The minimum requirements for these modes are as follows:

HF

1. HF/SSB facilities should be available on all UNOLS' vessels.
2. Facilities for the reception of weather facsimile should be available.

In addition, we strongly recommend that an effort be made to reduce the problem of interference on HF/SSB voice channels commonly used by oceanographic vessels. The possibility of allocating new frequencies should be explored.

VHF

VHF communications should be present on all UNOLS' vessels, and VHF facilities should be easily accessible to both ships' officers and scientists (in some cases this requires that more than one VHF transceiver be available).

SATCOM

We recommend that the use of ATS I and ATS III be expanded so as to be generally available to the UNOLS' fleet. The following minimum capabilities are required:

1. Transmission of voice and telecopy
2. ASCII - PCM data link
3. Antenna tracking capability

This system will provide the capability for reliable voice and telecopy communications for several hours each day between UNOLS' vessels and base stations, as well as the capability to carry low-speed data transmissions (and teletype communications) for about 18 hours per day.

A basic terminal for voice and ASCII - PCM transmissions costs about $6000 and consists of the following elements: antenna, rotator, VHF transceiver, PCM decoder, teletype, power amplifier, pre-amplifier, and trackboard.

A short-term recommendation regarding satellite communication is that improvements are needed in the dual yagi shipboard satellite antenna systems that are currently in use.

Future Recommendations

The future status (beyond about 5 years) of the ATS satellites is in doubt. The ATS satellites are well suited to our needs because of the low cost of implementation, the background of work which has already been carried out and the level of technology required to use VHF links effectively, but efforts should be made to explore the feasibility of future satellite communication systems. MARISAT is an example of a system that should be considered although at present this appears to be a costly and less flexible alternative.

In addition, UNOLS should take an active role in discussions with NASA concerning the possible future use (and even deployment) of ATS-type satellites.

SHIP LABORATORY SPACE AND FACILITIES

Scientists boarding the vessels considered in this report should expect to find a minimum set of facilities and laboratory space. The supply and maintenance of these facilities and space should be the responsibility of the operator of the vessel and the costs included as part of the vessel operating costs. The minimum set of laboratory space and facilities considered necessary for the conduct of oceanographic research at sea are given in the following recommendations.

Recommendations

1. Electric Power. Primary voltages of 480V and 120V, three-phase, 60-cycle are expected to be available and distributed on all vessels. 240V and 280V power is a variation of 480 and 120 volts and therefore an acceptable, but not a preferable, alternative. All vessels greater than 150' are expected to provide at least 30 kw of power for laboratory and portable van use of which 15 kw regulated and 15 kw unregulated 120 volt power should be distributed through 20 amp convenience outlet circuits. Voltage regulation should be within 5% on the regulated circuits which should be clearly marked to prevent the inadvertent connection of machinery that would destroy the regulation (e.g. freezers and refrigerators).

The term "regulated power" is intended to cover voltage variations, harmonics, spikes, etc. and not frequency regulation. Normal frequency regulation through the diesel generators and auxiliary loads should be within $\pm$ 2%. More stringent requirements should be the responsibility of the individual scientist. All ships should have devices (or separate generators) to prevent major electrical fluctuations when heavy equipment comes on line.

2. Transducers. All vessels without a multiple transducer system should have the capability of replacing transducers without dry docking.

3. Air Conditioned and Heated Laboratory Space. All enclosed laboratory space should be air conditioned and heated. The temperature should be controllable to within $\pm 5^{\circ}C$, in the range 15° to $25^{\circ}C$, and the systems should be capable of dissipating 15 kw of power. The minimum amount of air conditioned and heated laboratory space should be 300 sq. ft. This minimum may be provided by portable vans.

4. Wet Laboratory Space. Wet laboratory space should be provided by all UNOLS' vesels. This space should be easily accessible to the working deck; it should contain deck drains to handle 20 gallons a minute, a sink and source of hot and cold fresh water and salt water. The wet lab may be a ship's lab or a portable van. The minimum space provided should be 200 sq. ft.

5. Salt Water. Salt water taken into the ship near the bow and pumped to the laboratory and working deck, using PVC pipe, should be provided by all vessels. The minimum rate of supply should be 5 gallons per minute and the pump should be plumbed so that it can be replaced. Placement of the intake and the pump size should be arranged to minimize bubble generation. Through-the-hull access for special clean salt water systems should be provided on all vessels

but the plumbing and pumping of these systems should be the responsibility of the scientist user. Provision should be made for the mounting of a temperature sensor at the intake.

6. Freshwater. All vessels should supply hot and cold fresh water at sinks with the minimum available supply being at rates of 250 gallons per day for all vessels.

7. Gas Storage. Secure storage facilities for standard gas bottles should be provided by all vessels. This storage should be both in the laboratory, for immediate use and outside the laboratory for reserve bottles. The storage should be arranged so that a single bottle is individually accessible without removing other bottles. The proposed minimum storage facilities are 5 in lab, 12 outside. This storage should be provided by portable racks capable of being located in several areas and removable when not required.

8. Acid and Solvent Storage. Storage facilities, approved by the Coast Guard, should be provided by all vessels. The minimum storage capacity proposed is 20 gallons.

9. Tie Downs. Tie downs on 2' centers should be provided in all laboratory and storage space that has been assigned for general use. Tie downs on the bulkheads and overhead can be Unistrut (or equivalent) and threaded deck sockets should be provided. The minimum bolt size should be 3/8".

10. Freezer and Cold Storage. Freezer and cold storage space should be provided by all vessels. The minimum requirement should be met by chests and portable units available on a shared-use basis. This item is discussed further under the shared-use equipment section of this report.

11. Special Tools. Access to special purpose tools should be provided. Items normally carried in the ship's bosun's locker should be available in small quantities for emergency scientific purposes.

12. Portable Van Support. Where space is available for portable vans, water, drain, power and intercommunication connections should be provided. The power connections should supply both regulated and non-regulated 110v power.

13. Communications, Internal. All work stations including vans should be provided with intercommunication devices.

14. Safety Equipment. The minimum safety equipment to be provided by all UNOLS' vessels should include hard hats, breathing apparatus and working life vests. For operations in cold waters ($<10^{\circ}C$) survival suits should also be provided.

15. Drawer and Shelf Space. All UNOLS vessels should supply modular drawer, counter and shelf space in the laboratories. This space should be appropriate to the scientific operations.

16. Cableways. Accessible cableways should be provided between all scientific laboratory space, portable van locations, the bridge and locations of sensing instruments.

Oceanographic Equipment Workshop
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ARNOLD E. BAINBRIDGE

During the morning of February 27, 1979, while attending the UNOLS Workshop on Ship Facilities and Instrumentation, Arnold Bainbridge died. With his passing the oceanographic community has lost a valued colleague whose selfless efforts and leadership have provided many with the means to view the ocean in exciting new ways. His skill and dedication contributed greatly to a legacy of data on the composition of the ocean that is unparalled in its quality and global extent. Most importantly, he showed that, in the quest for more ocean data, modern technology, applied with insight and care, can enable us to achieve quantity without sacrificing quality.

Arnold Bainbridge was born in Invercargill, New Zealand on December 16, 1930. He was awarded a B.Sc degree in physics from the University of New Zealand in 1951. After working with the Department of Scientific and Industrial Research, New Zealand, he came to the United States in 1960 to join the Department of Chemistry at UCSD. From 1962 to 1966 he worked with the National Center for Atmospheric Research in Boulder, Colorado, and then returned to UCSD, to the Scripps Institution of Oceanography, where he remained until his death. In 1970 Arnold Bainbridge undertook the position as Project Director of the GEOSECS Operations Group and in 1975 his duties in the management of scientific operations at sea were extended when he became head of the Data Collection and Processing Group at SIO.

Arnold Bainbridge leaves a wife, Janet and three teenage daughters, Pamela, Susan and Jennifer.