Appendix XI

Glosten Swath Report

Summary of conceptual design
Design plans
Summary of motions and operability

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195-7940

School of Oceanography
Box 357940

January 21, 1998

Dr. Kenneth Johnson
Moss Landing Marine Laboratory
PO Box 450
Moss Landing, CA 95039

Dear Ken,

I have enclosed two documents which you should feel free to share with the UNOLS Council. The first is a letter summarizing the findings of the conceptual design study Glosten conducted for us along with the relevant drawings. (We also have the details of their analysis, but it is not light reading and I have not included it.) The second document is a discussion of the seakeeping and operability of a SWATH vessel of the size we examined. If you have questions after reading the material, give me a call.

Sincerely,

Russell E. McDuff
Associate Professor
Associate Director

RMcD/ag

Telephone: 206-543-3056(a.m.), 206-685-1947 (p.m.); Fax: 206-543-6073
Internet: mcduff@ocean.washington.edu
URL http://www2.ocean.washington.edu/rmcd.html

11/26/97 WED 17:48 FAX 2066829117 THE GLOSTEN ASSOCIATES

GLOSTEN

The Glosten Associates, Incorporated

26 November 1997
File No. 97163

Post-it* Fax Note 7671	Date 26 NOV	# of pages ▸ 7
To UW	From BILL HURLEY	
Co./Dept. ROBERT HINTON	Co. GLOSTEN	
Phone #	Phone #	
Fax # 543-6073	Fax #	

Mr. Robert Hinton
Manager of Marine Operations
School of Oceanography WB-10
University of Washington
Seattle, Washington 98195

Subject: Feasibility of SWATH research vessel

Reference: 1. NAVSEA CBD announcement of 23 October 1997 regarding a SWATH oceanographic research vessel

Dear Robert:

As you have requested we have conducted a brief conceptual design study to determine the feasibility of designing and building a SWATH research vessel at a U.S. shipyard to meet the following requirements:

- Cost ≤ $35 M (actual construction cost)
- Range ≥ 6,000 n.m. at 12.5 knot cruising speed
- Scientific Mission Payload ≥ 100 L.T.
- Crew ≤ 15 persons
- Scientific Party ≥ 26 persons
- Classification: ABS (assumed)
- Certification: U.S. Coast Guard, SOLAS and MARPOL
- Seakeeping capability: unlimited ocean service

Our efforts focused on the feasibility of meeting the stated requirements, and to do so, we developed a very rough concept design based on a combination of parametric methods and first-principles analysis. Our engineering focused on:

- weight and buoyancy calculations
- resistance, powering and fuel consumption calculations
- seakeeping to the level of estimating natural periods for pitch and roll, and comparing to desired values
- use of data on other SWATH vessels to both provide input to our evaluation and provide a realism check of our results

We have determined that your requirements can be mutually satisfied. We estimate that all of your technical requirements can be satisfied with a corresponding rough-estimate cost of about $30M.

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Mr. Robert Hinton
26 November 1997
Page 2

Because more data is available regarding aluminum SWATH designs in or near the size under consideration, we are more confident at this time, that these requirements can be mutually satisfied by an all aluminum SWATH. However, preliminary indications are that these requirements can also be mutually satisfied by a SWATH with steel hull and aluminum superstructure. It is probable that the steel/aluminum SWATH solution would be slightly larger for the same construction cost, scientific mission payload capacity and range, than the corresponding all aluminum SWATH.

The approximate principal characteristics of an all aluminum SWATH design satisfying the requirements outlined above are as follows:

L	Length	172	feet
B	Maximum beam	76	feet
d	Draft	17	feet
Δ	Displacement	1,225	LTSW
BHP	Installed main propulsion power	2,040	H.P.

The length of a steel/aluminum SWATH might be approximately 20% greater and the draft might be 10% greater than those set forth above for an all aluminum SWATH (assuming that the beam is constrained to not to exceed 76 feet).

We have enclosed a concept sketch of the all aluminum design showing that your requirements regarding space arrangements can be met. These requirements include staterooms for the complement of crew and scientists, a minimum of 3,000 sq. ft. of laboratory space, a moonpool, and space along one side of the main deck for a 90 foot geological core.

Rather than forward you a collection of notes and calculations, we look forward to meeting with you here on Monday at 10 am to review our work. Perhaps we can get comments from you at that time and work Monday afternoon in preparation for your meeting on Tuesday.

Yours very truly,

THE GLOSTEN ASSOCIATES, INC.

Bruce L. Hutchison

BRUCE L. HUTCHISON, P.E.
Vice President, Ocean Engineering & Analysis

Enclosures: 1. Glosten Dwg. No. 97153-1, UW SWATH Space Allocation Sketch

cc: via facsimile

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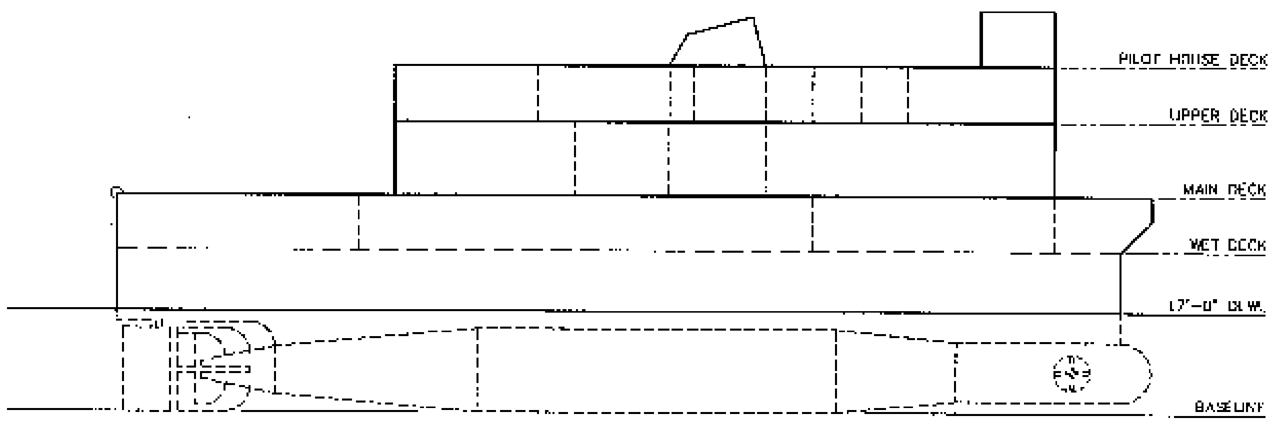

OUTBOARD PROFILE

PRINCIPAL CHARACTERISTICS

LENGTH, MAIN DECK	172'-0"
BEAM, MAXIMUM	76'-0"
DRAFT	17'-0"
DISPLACEMENT	1,225 LTSW
INSTALLED MAIN PROPULSION POWER	2,700 H.P.
LAB/STAGING	4,270 SQ. FT.
STATEROOMS	28

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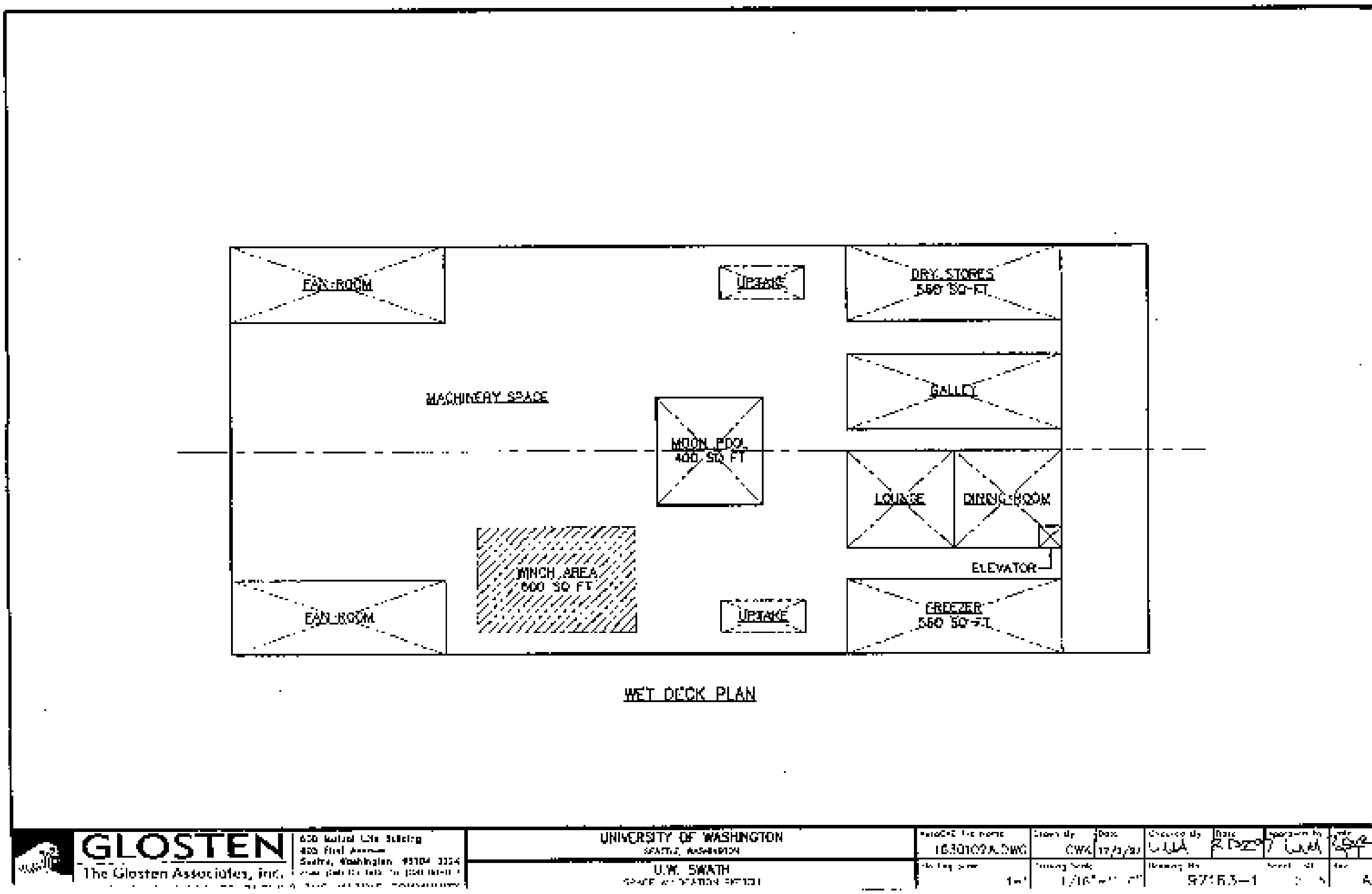
U.W. SWATH

96/97151A.DWG	CMK	12/2/97
1=1	1/16"=1'-0"	97153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UPTAKE
DRY STORES
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MACHINERY SPACE
GALLEY
MOON POOL
400 SQ FT
LOUNGE
DINING ROOM
ELEVATOR
WINCH AREA
600 SQ FT
FAN ROOM
UPTAKE
FREEZER
550 SQ FT
WET DECK PLAN
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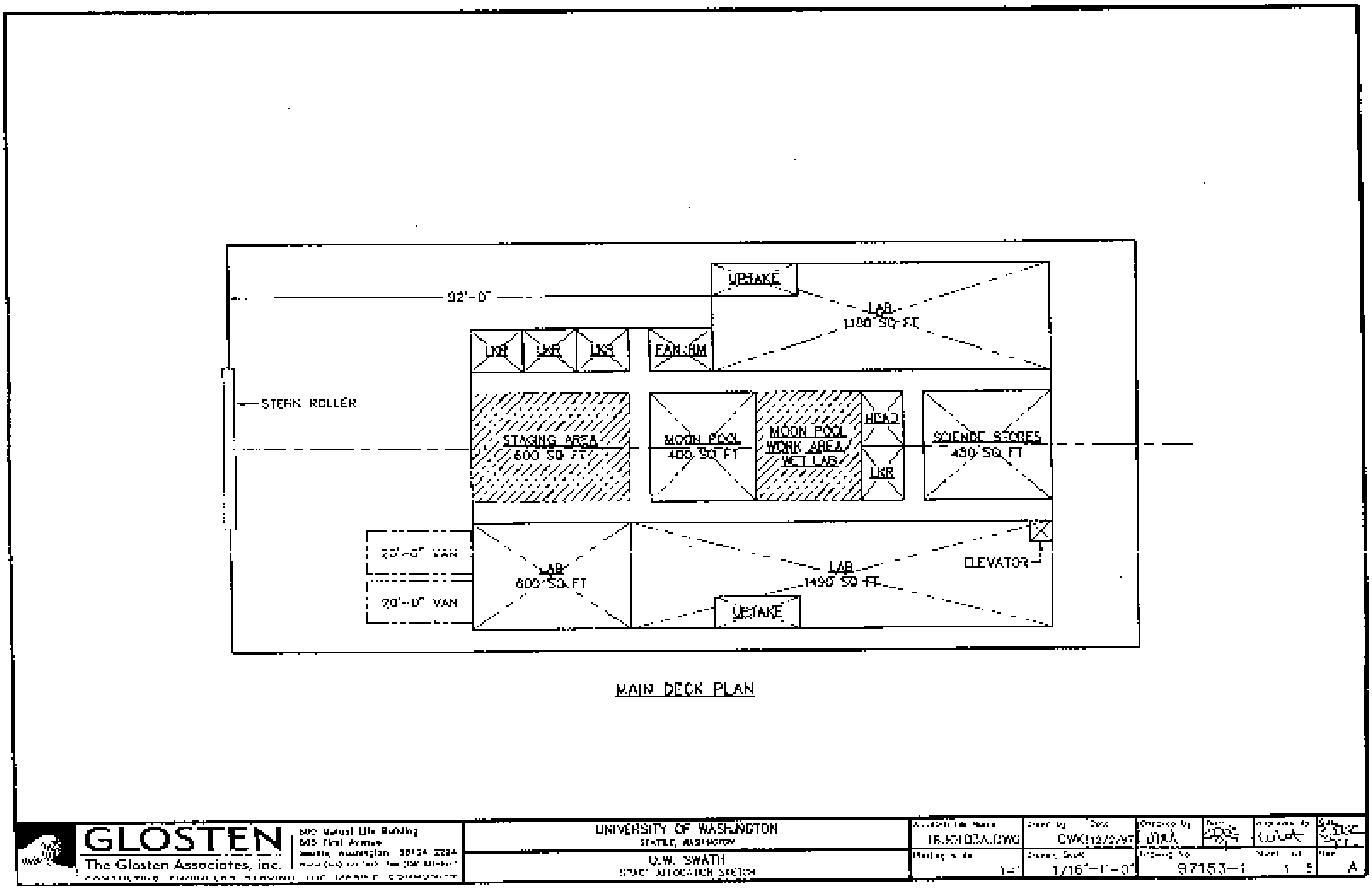
UPTAKE
LAB
1300 SQ FT
92'-0"
LKR
LKR
LKR
FAN RM
STERN ROLLER
STAGING AREA
600 SQ FT
MOON POOL
400 SQ FT
MOON POOL
WORK AREA
WET LAB
HEAD
LKR
SCIENCE STORES
480 SQ FT
20'-0" VAN
20'-0" VAN
LAB
600 SQ FT
LAB
1490 SQ FT
ELEVATOR
UPTAKE
MAIN DECK PLAN
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SEATTLE, WASHINGTON
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1/16"=1'-0"
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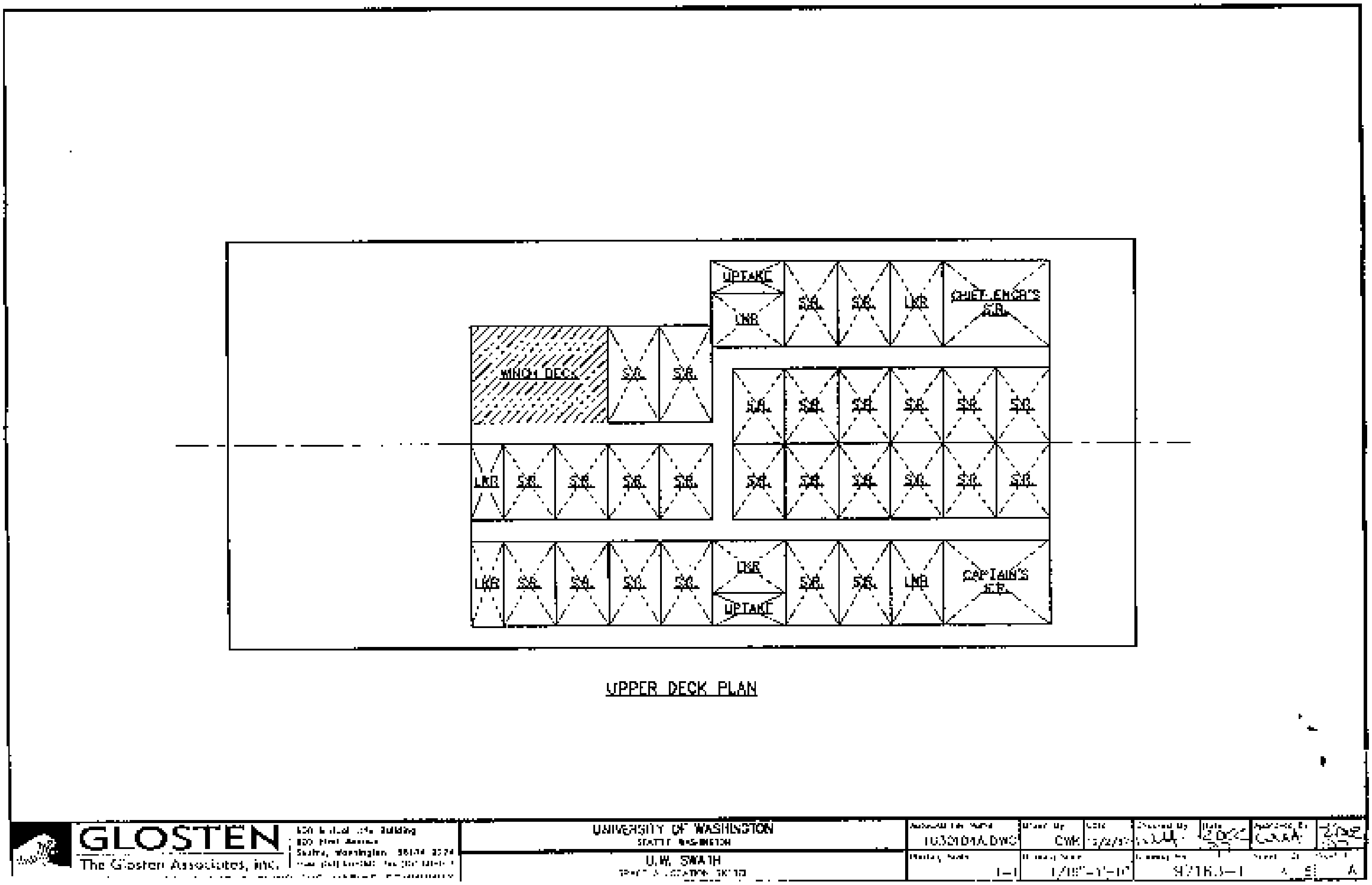
UPTAKE
LKR
S.R.
CHIEF ENGR'S S.R.
WINCH DECK
CAPTAIN'S S.R.
UPPER DECK PLAN
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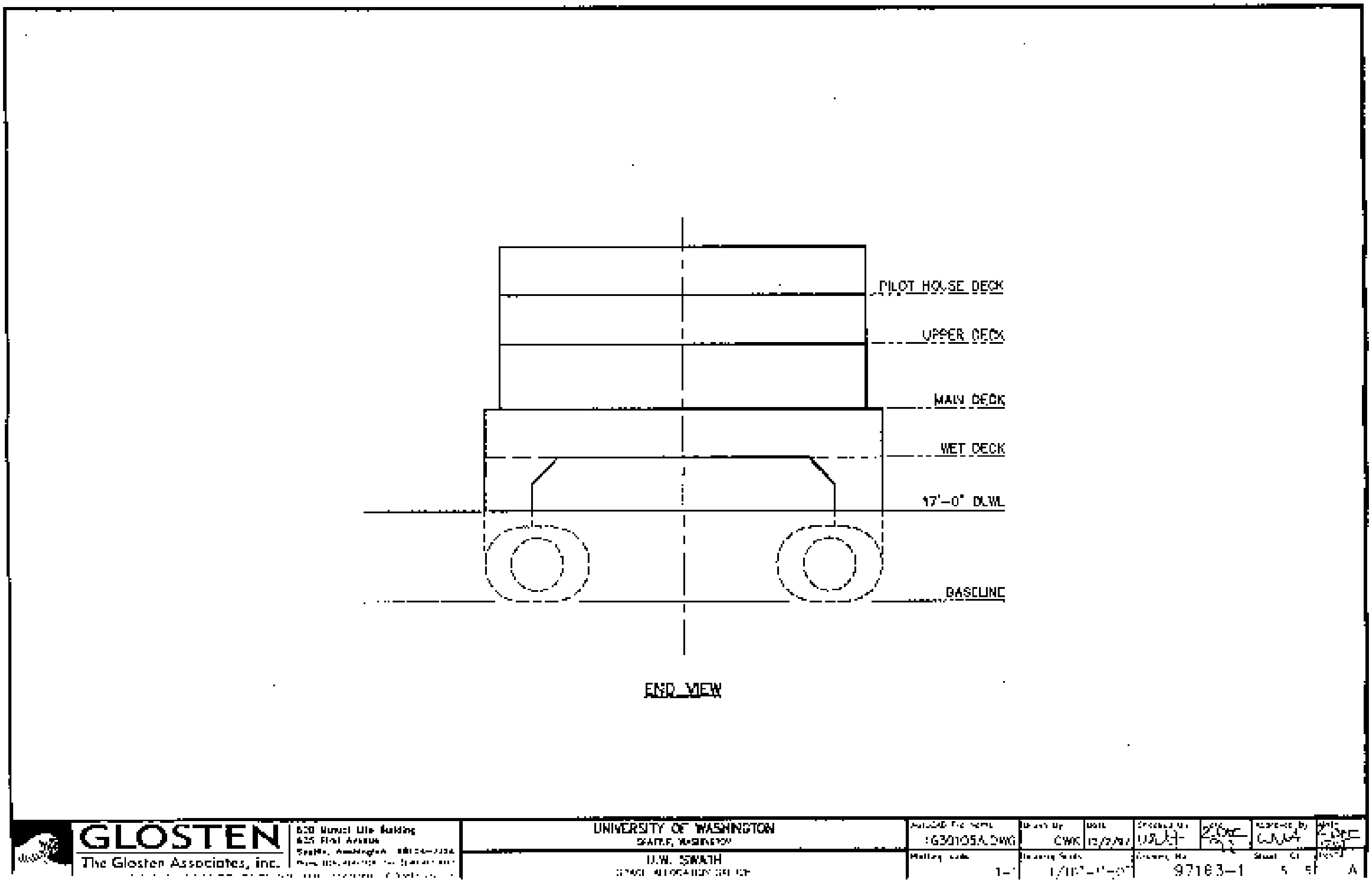
U.W. SWATH


PILOT HOUSE DECK
UPPER DECK
MAIN DECK
WET DECK
17'-0" DLWL
BASELINE
END VIEW
GLOSTEN
The Glosten Associates, Inc.
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U.W. SWATH
CWK
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COMMENTARY ON SWATH MOTIONS AND OPERABILITY

The Glosten Associates have been asked to evaluate the feasibility of designing and building a SWATH research vessel, suitable for unrestricted ocean service, for no more than $35 M, capable of carrying at least 100 L.T. of scientific payload and with a nominal range of 6,000 n.m. at 12.5 knots. This feasibility study is the subject of a separate letter report to the University of Washington. The determination of feasibility was based primarily on design data for all aluminum SWATHs (since data for all aluminum SWATHs was most available in this size range), though it is our judgment that a steel hulled SWATH with aluminum superstructure, with slightly larger principal dimensions, would also constitute a feasible, and perhaps preferable, design solution. The principal dimensions of the all aluminum SWATH considered in the feasibility study are:

L	Length	172	feet
B_{WL}	Waterline Beam	76	feet
B_{MAX}	Maximum Beam	76	feet
Draft	Design Draft	17	feet
Δ	Design Displacement	1,225	LTSW

The length of a steel/aluminum SWATH might be approximately 20% greater and the draft might be 10% greater than those set forth above for an all aluminum SWATH.

The Glosten Associates have been asked to comment on the seakeeping and operability of such a SWATH when compared to the *R/V Thomas Thompson* (265 feet LOA, 3,500 LTSW displacement). An authoritative commentary should be based on seakeeping and operability analyses of both vessels using analytical or model testing methods, and evaluated in the same climatology. Such activities are beyond the scope of the current effort. The commentary which follows is based on generalizations that are readily available in the technical literature.

Comparative Seakeeping Performance

The following commentary is excerpted directly from Section 6.2.4 of reference 1:

> *A relatively large amount of data has been collected on the motions of SWATH ships, considering the limited number of these ships in service. Data are available for KAIMALINO, CREED, HALCYON, and KAIYO. These ships represent a wide variety of SWATH hull form variations over a range of ships sizes from 60 tons to 3,400 tons. Results of these trials are summarized as follows:*
>
> > *The motions of the 200 ton, 90 foot KAIMALINO were found to be comparable to measured motions of a 3,000 ton, 378 foot USCG high endurance cutter in side-by-side trials in moderate seas. Similar results were found for KAIMALINO*

in side-by-side trials with a 1,000 ton, 180 foot USCG oceangoing buoy tender, a lower speed monohull.

- *Motions of CREED (70 tons, 65 feet) were found to be generally superior to those of the Canadian fisheries patrol vessel GOOSE BAY (110 tons, 66 feet) in seas between sea state 2-4. Exceptional seakeeping was observed during additional tests conducted on CREED throughout the 0-20 knot speed range in sea state 5.*

Measurements on the 60 ton, 65 foot HALCYON showed significant roll and pitch amplitudes to be less than 1.5 degrees at 17.5 knots in sea state 4. Accompanying vertical accelerations were less than 0.15 g's on the bridge and in the living spaces.

Measured data on KAIYO showed the 3,400 ton ship pitched less than 4 degrees and rolled less than 6 degrees in seas up to sea state 7. Vertical accelerations were less than 0.15 g's during these measurements.

Motions were measured during side-by-side trials on CREED and the Canadian fisheries protection vessel LOUISBOURG. Similar heave acceleration and pitch levels were measured on the 70 ton, 65 foot SWATH and the 250 ton, 125 foot monohull. Roll and lateral acceleration were generally much higher on the monohull. The superior motions of SWATH ships have been demonstrated in similar trials with KAIMALINO and two USCG CUTTERS (as described above).

The reduced motions possible using SWATH hulls improve ride quality and enhance operational capabilities in rough weather. The commercial utility of these attributes has been documented for operations of SEAGULL II. This 350 ton, 27.5 knot ferry maintained an average operational rate of over 98 percent while carrying 160,000 passengers over a 10 month period. About half of these passengers were transported in sea conditions greater than sea state 3. While the incidence of seasickness increases as rougher seas were encountered, only 6 percent of the passengers aboard in sea state 6 were affected. Overall, seasickness affected relatively few of the passengers, averaging about one-half of one percent of all passengers carried. Performance characteristics such as these confirm the reputation of SWATH ships as ships that provide reliable, comfortable service in rough seas.

The following commentary is excerpted directly from reference 2:

An example of a design-related effort was reported in reference 3. The operational requirements stated that an acceptable hull must safely transit at 12 knots at all headings through Sea State 4, transit at 6 to 10 knots at best heading through Sea State 6. The transiting criteria in the following table were used in conjunction with the winter SOWM database for the general North Atlantic. Calculations are for short-crested seas and roll responses are considered.

Limiting Seakeeping Motion Criteria for Transiting

Roll	8.0 degrees
Pitch	3.0 degrees
Vertical Acceleration	0.4 g's
Slams per Hour	20
Deck Wetness Events per Hour	30

In this investigation, two configurations of about 1675 tons were included. These designs were developed by the Naval Sea Systems Command. The two baseline configurations differed in length: the first, denoted as AGOR1, had a strut length of 170 feet and a lower hull length of 230 feet, while the second, denoted as AGOR2, had corresponding lengths of 146 feet and 173 feet.

An initial investigation of the AGOR1 showed that it did not have acceptable operability at 6, 9, or 12 knots. In the original design the LCF was forward of the LCB by about 1.5 percent of the lower hull length. When the strut was shifted so that LCB and LCF were coincident, operability improved considerably. The designers felt that shifting the location of the strut would not impact the design. The final version of this design meets the specified operational requirements.

An investigation of the AGOR2 showed that it did not meet the operational requirement at 12 knots. Simple variations in the strut did not result in acceptable performance. Consequently, an active control system was designed. This configuration has a relatively low value of GM_L and the performance needed improvement between following and beam seas where encounter periods are low, so that it was likely that activating the stabilizers could improve performance. This approach allows for reduction in roll as well as vertical plane motions. The desired improvements were achieved and the predictions indicate that performance is not limited below a high Sea State 4 so that the hull form meets the stated operational requirements.

Although both hull forms meet the operational requirements, AGOR1 has higher operability than AGOR2. Comparison of the predicted percentage time operable as a function of significant wave height shows that the AGOR1 has better predicted operability than the AGOR2 for the operations and speeds specified in the operational requirements. The AGOR2 also has the disadvantage of requiring machinery to drive the active control system. At the same time, the two hull forms differ considerably in overall length and strut length which impacts various design considerations.

SWATHs in this size range offer larger deck areas and can have higher operability than monohulls designed for the same mission, particularly at lower speeds. The 1675 ton design investigation demonstrates that hull form modifications can help assure good operability. However, it is difficult to design a SWATH in this size range with high predicted operability, particularly if operability in the winter is of primary importance. This is due, in part, to size; a reasonably well designed larger ship will naturally be able to operate well in the lower sea states. The challenge *then is to design a hull form which will operate well in the higher sea states. A smaller ship must be designed first to be seaworthy in the lower sea states. This is challenging because high Sea States 4 and 5, corresponding to significant wave heights of 8.2 feet and 13.1 feet, have a wide range of highly probable modal periods. In the winter, these modal periods have nearly equal probabilities of occurrence. Therefore, the advantage which the SWATH geometry offers the designer – of shifting responses away from likely spectra – is of less consequence in this size range than it is for larger displacement designs.*

Based on full-scale seakeeping trials, as described in reference 4, the Navy's 164 foot, 560 ton A-frame SWATH known as *SEA SHADOW* meets the Navy's operability criteria (same as given in table above) through Sea State 4 and even meets all of the operability criteria through Sea State 5 except in following waves where pitch exceeds the mobility criteria (the design requirement was only for survivability in Sea State 5). Ride quality in terms of standards for human exposure to whole body vibrations is also good.

Reference 5 reports on design studies of naval combatants for North Atlantic deployment. Three designs were developed, two monohulls and a SWATH. One monohull and the SWATH were both designed to carry the design mission payload. The second monohull was designed to equal the seakeeping performance of the SWATH. The principal dimensions of these three designs are given in the following table:

	Payload Monohull	SWATH	Seakeeping Monohull
LOA (ft)	455	380	619
LBP (ft)	420	310	554
Beam (ft)	49	90	62
Draft (ft)	19	28	18
Displacement (LTSW)	5373	7070	9116

"The seakeeping monohull was required to have equivalent seakeeping performance to the SWATH based on a set of motions limitations criteria, but was not required to have equivalent ship motions. For example, even though the roll amplitudes for the SWATH and seakeeping monohull were different for a given sea condition, the two ships were judged to have equivalent performance for roll if neither violated the roll motions criterion. In general, the magnitude of the ship motions are less for the SWATH than for the seakeeping monohull. A monohull with equivalent ship motions would be much larger than the seakeeping monohull."

The seakeeping criteria used in the design study of reference 5 may be summarized as follows:

Limiting Seakeeping Motion Criteria for Transiting

Roll	8.0 degrees
Pitch	3.0 degrees
Vertical Acceleration (bridge)	0.4 g's
Vertical Velocity for Helo Ops	6.5 fps
Bow Sonar Emergences per Hour	24
Slams per Hour	20
Deck Wetness Events per Hour	30

Summary and Conclusion

The generally supported evidence in the readily available technical literature all seems to support the idea that SWATH hull forms can offer comparable seakeeping performance and operability at smaller size than monohulls. It still follows, however, that larger SWATHS are better than smaller SWATHS.

The findings of the various design studies and full-scale, side-by-side, seakeeping experiments, suggests that a SWATH needs to be 60% to 65% of the length of a monohull to obtain comparable seakeeping performance and operability. There may also be a size below which a SWATH can no longer be considered an unrestricted ocean going vessel.

Applying the rule of thumb to the length of the *R/V Thomas Thompson*, a SWATH should be perhaps 164 to 177 feet in length to offer comparable seakeeping performance and operability.

As regards the size below which a SWATH can no longer be considered an unrestricted ocean going vessel, it is noted that SWATH hull forms down to 173 feet were considered in the Navy's AGOR 23 studies, and were regarded as suitable for unrestricted ocean going service. The question of unrestricted ocean service for a SWATH is probably only weakly associated with the length, and more strongly associated with the air gap. For a SWATH of the size under consideration an air gap of 11 or 12 feet is thought to be adequate for unrestricted ocean service.

Finally there is the question of operability for specific on-board activities, such as deployment and retrieval of scientific packages through the moonpool. There is relatively little experience with SWATH research vessels with moonpools. Based on such experience as their is, and the findings of various theoretical studies and model tests, it is anticipated that such activities should be possible, on a vessel such as that proposed, up to sea state 5 or perhaps even to high sea state 5.

Because of the superior ride quality of SWATH designs it is anticipated that it will be possible to maintain many other on-board science activities (other than deployment/retrieval) in sea conditions greater than those in which these activities must be curtailed in a monohull such as the *Thomas Thompson*.

References

1) Kennell, Colen, "SWATH Ships," SNAME Technical and Research Bulletin , No. 7-5, 1992

2) McCreight, Kathryn K., "Assessing the Seaworthiness of SWATH Ships," SNAME *Transactions*, Vol. 95, 1987, pp. 189-214

3) McCreight, Kathryn K, Hering, J.A., and Waters, R.T., "Seakeeping and Maneuvering Assessment of SWATH AGOR 23 Configurations," DTNSRDC Report SPD-1198-01, July 1986

4) Reed, Arthur M.; Dipper, Martin J. Jr.; Brady, Thomas F.; Turner, Charles R.; and Dinsenbacher, Alfred L., "Seakeeping and Structural Performance of the A-Frame SWATH Vessel SEA SHADOW," 1998 SNAME Annual Meeting, Ottawa, Ontario, Canada, October 16-18

5) Kennell, Colen G.; White, Brian L.; and Comstock, Edward N., "Innovative Naval Designs for North Atlantic Operations," SNAME Transactions, Vol. 93, 1985, pp. 261-281