

UNOLS Input to Navy and JJMA Regarding X-Craft Hull Variant December 1, 2004

Index:

I. X-Craft Project Background	pg 1
II. Action Item	pg 1
III. Additional Navy SMRs for Ocean Class Vessels	pg 2
IV. UNOLS Comments and Questions Regarding the X-Craft	pg 3
V. Specific Suggestions for reconfiguring the X-Craft as an Oceanographic Research Ship	pg 6
Appendix A: Multibeam Issues and Comments for Consideration	pg 10
Appendix B: Beamy-Monohull Variant	pg 12
Appendix C: X-Craft Displacement Considerations	pg 15

I. X-Craft Project Background - ONR has asked JJMA to develop three X-Craft notional designs of which UNOLS will chose one. Three different designs have been suggested:

1. ~14 knot-ship with big hangar
2. ~14 knot-ship with half a hangar and more fixed space for labs and bunks, etc.
3. ~14 knot-ship with small hangar

Each of these notional X-Craft designs will consider:

1. Cranes and winch arrangements/configurations.
2. Is the upper deck useful?
3. In-port independence for handling vans and other large equipment.
4. Fixed lab and berthing space versus modular (van) based space.
5. Design effort completed as part of the ONR Ocean Class Phase II study.
6. Ocean Class SMRs.

The features identified by the Navy that are attractive in the X-Craft include:

- Modularity is important (vans) – This is not a new capability, but the X-Craft design would allow it to be taken to another level.
- Size of the vessel is generally important.
- The ability to transport equipment to and from the ship by air is important
- Access to the sea with AUV's and other autonomous gear is very important. The ability to support operations of a fleet of underwater autonomous vehicles is required.
- Support for un-manned air vehicles (UAVs) is important.
- High speed is a low priority for research operation. Additionally, the cost would be prohibitive.

II. Action Item – During the November 16-17 X-Craft meetings, ONR requested that UNOLS provide X-Craft suggestions, comments, and questions to JJMA by December 1, 2004. Using the input provided by UNOLS, JJMA is to generate ideas on how an X-Craft could be used for oceanographic research. In turn, JJMA will develop notional X-Craft designs that can meet the SMRs and operate as an oceanographic research ship.

III. Additional Navy Science Mission Requirements (SMRs) for Ocean Class Vessels –The UNOLS Ocean Class SMRs

<http://www.unols.org/committees/fic/smr/ocean/ocsmr_version1.html> have provided the basis for evaluating hull variants to date. These SMRs were created by the community and were publicly available for broad community input. The SMRs are robust and versatile. ONR has identified additional SMRs that are not addressed by the current UNOLS Ocean Class SMRs. The Navy SMRs are provided below:

Additional Navy SMRs for OCEAN Class AGOR:

Autonomous Underwater Vehicle (AUV) Capability:

The OCEAN Class AGOR should include the capability to stage, launch, recover, service, and store multiple large AUVs, including powered vehicles up to 30 feet in length and unpowered gliders up to 30 feet or more in wing span. Some AUV systems may be transported and stored in vans. The launch and recovery system should incorporate features to increase sea state performance and to improve personnel safety by reducing the need for direct human intervention. To this end, innovative technologies such as subsurface vehicle docking stations and motion-compensated lifting devices should be considered. The vehicle staging, servicing, and storage area should be protected from the weather and may be combined with the modular van stowage area. The AUV capabilities should not adversely impact the other general-purpose scientific capabilities of the ship.

Aviation Capabilities:

Helicopters - The OCEAN Class AGOR should include commercial aviation facilities for helicopters. The ability to land a commercial helicopter is desirable, but should not be a driver of ship size. Hover capability should be provided for emergency medical evacuation and loading/offloading of equipment and supplies.

Unmanned Aerial Vehicles (UAVs) - The OCEAN Class AGOR should include the capability to stage, launch, recover, service, and store UAVs. The UAV launch/recovery area may be combined with the helicopter landing/hover area through the use of readily-removable UAV capture/recovery devices.

Modular Van Stowage:

The OCEAN Class AGOR should include the capability to accommodate portable laboratory vans in numbers greater than currently carried on Global and Ocean class AGORs. The van stowage area should be fully-enclosed, protected from the weather, and accessible from the interior of the ship. Onboard cranes, trolleys, and conveyor systems should be provided to enable rapid and safe loading and unloading of vans in remote port locations with normal ship manning levels and without shoreside support. Van stowage locations should be provided with tie downs and service connections to support the variety of expected van types. Consideration should be given to enabling the van stowage area to serve as laboratory or hangar space when vans are not aboard.

Ship Speed:

A maximum speed of up to 20 to 24 knots in calm water should be considered but should not have significant adverse impacts on construction cost or competitive day rate.

IV. UNOLS Comments and Questions Regarding the X-Craft - Below is a set of UNOLS comments and questions regarding the X-Craft. It is a compilation of the issues raised prior to the X-Craft visit (RVOC and UNOLS questions), during the November X-Craft meeting discussions, and in post-meeting e-mail exchanges.

1. Current X-Craft vs. Phase II X-Craft - How does the X-Craft as it currently exists compare to the X-Craft design that was looked at in the Phase II study?
2. Ships Work Breakdown Structure - Can a table of SMR particulars be prepared that compares the X-Craft with the Phase II X-Craft? Can a breakdown be done that compares various ship's component systems as suggested by Suchy i.e. Ships Work Breakdown Structure (SWBS – the method of breaking a ship down to each system, sub system, and component such as propulsion system, electrical system, sensors, navigation gear, etc., auxiliaries)?
3. X-Craft that Meets SMRs - What would it take to convert the current X-Craft into a ship that meets the UNOLS SMRs as they now exist
<http://www.unols.org/committees/fic/smr/ocean/ocsmr_version1.html> and also including the Navy SMRs (Section III). In this part of the study it would be useful to refer directly to the SWBS components to see how each of them would need to be changed.
4. Navy SMRs - The additional Navy Ocean Class SMRs (Section III) will require that the monohull and SWATH hull variants be re-examined to determine how they match up to the new requirements. UNOLS requests that any areas requiring potential tradeoff decisions as a result of the added Navy SMRs be identified.
5. Survivability: A definition of X-Craft survivability at high sea states is needed. What is the maximum sea state that the X-Craft can survive in? [Explanation of survivability - If there is a maximum sea state, it is a potential showstopper for the X-Craft. Existing ships can go to arbitrary places in the ocean (subject to ice limits). They would in fact maneuver to avoid storms insofar as possible, but if push comes to shove they deal with the weather and ride it out. If the X-Craft has some upper limit at which it cannot be at sea, or some finite limit on how far it can be from shelter/port, then it would not be a suitable platform for research operations.]
6. Sea Keeping – The sea keeping characteristics defined by the Ocean Class SMRs are important. The Ocean Class should be more sea capable than the current Intermediate Vessels and have the ability to operate at higher sea states.

- a. If the opportunity becomes available and timely, UNOLS requests the opportunity to ride the X-Craft to evaluate seakeeping characteristics.
 - b. Damping systems can be complex and expensive. Are these realistic alternatives?
 - c. The user community for the R/V *WALTON SMITH* should be approached to evaluate pros and cons of the catamaran hull form for science ops in higher sea states. The captain and crew should be interviewed to see how they have overcome the unique vessel motions associated with catamarans.
7. Station Keeping: Hull forms designed for speed normally don't perform well on station, which is a significant part of an R/V's mission requirement. Model analysis of X-Craft station keeping should be conducted. What modifications will be necessary to achieve the dynamic positioning requirements?
 8. Life Expectancy: A 30-year ship is required as a minimum. Aluminum hull life expectancy should be evaluated.
 9. Tie-down Inserts – Evaluate whether the combination of an aluminum hull and steel tie-down inserts, especially on weather decks, will work as regards corrosion. Will aluminum sockets have the requisite strength for deck tie-downs? The steel/aluminum combination has to be viable for the life of the ship, if the hull is aluminum.
 10. Multibeam: Can the X-Craft Catamaran hull accept a 1-degree multibeam system? Is a gondola configuration feasible? See *Appendix A* for a discussion on multibeam issues.
 11. Bubble sweep down effects – Bubble sweep down problems are a potential problem on all three hull variants. This will greatly impact transducers performance and is of great concern to research.

Models that analyze bubble sweep down effects on the X-Craft and other hull variants should be considered. Selected propulsion systems, as well as, hull form configurations can impact bubble sweep-down effects. It is possible that the gondola approach would resolve the bubble and flow noise issues for all the sonars. However, a gondola will probably add approximately a meter to the draft.

12. Habitability – UNOLS requests single staterooms for crew and assigned (resident) technicians. Accommodation requirements should be consistent with those stated in the UNOLS Ocean Class SMRs.
13. Maintenance Cost for Aluminum Hull – There is concern that an aluminum hull ship requires more expensive, and specialized, shipyard work to perform standard maintenance. Recommend a comparative analysis of maintenance costs between an aluminum hull vessel with steel hull vessel (perhaps POINT SUR and WESTERN FLYER).
14. Worldwide Service Sites – Recommend that the availability of worldwide repair/service sites for aluminum hulls be identified.

15. Engine Access – Ease of access to engine room machinery for repair and maintenance is desired. The location of the engine rooms in the X-Craft pontoons may make access difficult. Is it possible to make the ship more maintenance friendly?
16. Life Cycle Costs - What are the life cycle costs for modified X-Craft?
17. AUV Operations - What is required to do AUV launch and recovery in SS3 or higher on the X-Craft or the other two hull types (Monohull and SWATH)?
18. High Latitude Operations - The Ocean Class SMRs call for some ice strengthening. Operations in high latitudes also have potential for ice loading conditions. This area should be explored more thoroughly in regard to the X-Craft.
19. Noise issues: X-Craft internal and radiated noise characteristics should be evaluated to determine if they meet established standards and SMR specifications. Both are of importance. Internal noise levels can impact habitability. Habitability for long and complex research cruises is important both to insure the highest quality science and as a facilitator in retention of crew and technical support staff. Noise levels in occupied spaces should be essentially consistent with the AGOR specs (which the contractor did not meet) or more recent/stringent OSHA, etc. guidelines. Radiated noise impacts should be evaluated for sonar system performance. Another concern is that forward propulsion systems (thrusters, Z-drive, etc) must be compatible (in its stowed/off position) with low flow noise and will not preclude high quality sonar data.
20. Aircraft Support Needs – Request that the Navy define the level of aircraft support that is needed to support their research missions and evaluate how it could be accommodated on each hull variant. Aviation needs from the low end up should be explored - what could be accomplished with hover-only capability or with light commercial helo landing capability or with modest UAVs that don't require any runway? Space needs are of concern.
21. Experimental Hull Form:
 - a. Is a finite element analysis available for the X-Craft?
 - b. Have insurance costs been addressed for an experimental craft? A significant insurance differential or even insurance industry uncertainty is of concern.
22. Weight Sensitivity: It is assumed that the hull form is somewhere between a mono-hull and a SWATH with regard to weight sensitivity.
 - c. Because of mobilization needs in foreign ports, the vessel will need to carry several cruises worth of gear. Will this be possible?
 - d. How location sensitive is this hull form compared to a SWATH?
23. Endurance: What is actual endurance for an X-Craft with a conventional power plant?
24. Vessel Profile: The proposed X-Craft looks like military vessel with a rather “hostile” profile. Given the foreign waters this vessel would have to operate in, the look should be “softened” so it appears more like a benign research vessel.

25. General-Purpose Oceanography Support - How will the X-Craft be used to support traditional oceanographic day-to-day operations? For example, how would one do a piston core, a CTD cast, launch/recover and tow a towed vehicle, launch/recover an AUV or ROV, tow a MOCNESS net, do a multi-core, perform a trace-metal bottle cast, deploy and recover a mooring, and so on? Clearly articulated plans for carrying out these science operations should be in place as early as possible so that they can be considered during the hull decision process. Information on procedures for long coring operations is of great interest. Any issues regarding the high freeboard associated with the X-Craft should be addressed.
26. Economic needs/use analysis - How much will it cost to maintain and operate the X-Craft versus traditional hull form?
27. Beamy-Monohull Concept – Request that JJMA evaluate the concept of a beamy monohull and its ability to meet the Ocean Class SMRs as well as the desired X-Craft features recently identified by ONR. See *Appendix B* for comments from Bob Knox regarding the potential attributes of this hull form.

V. Specific Suggestions for reconfiguring the X-Craft as an Oceanographic Research Ship:
(Frame numbers based on [General Arrangement Dwg # NG422-650-01-1](#)
<http://www.nicholsboats.com/current_projects.htm>)

1. Bridge should extend all the way across and be extended back to Frame 46 (on baseline) to allow for science space, communication office, and aft steering station on starboard side.
2. Locate another steering station at starboard aft upper deck (now flight deck) to enable operator to see stern ops.

As another alternative, the height of the hangar deck is such that the aft-facing control station could be under slung beneath the flight deck without much impact to the fore and aft movement of equipment on the hangar deck below. That would allow provision of an internal route to the aft station booth. Additionally, this aft station could have windows looking aft, toward the stern a-frame and deck, and forward into the hangar deck, allowing observation of submersible and equipment preparations and movement of components by means of the overhead crane system. Such an under slung arrangement for the after control cab would also preserve the maximum amount of usable flat space on the aviation deck above.

3. Reduce size of A/C bay to accommodate six vans. Possibly three each side or all six on one side.

4. Keep elevator but move back to frame 36-40. Keep overhead crane, which allows moving the vans.
5. Incorporate berthing spaces, labs and rearrange galley eating area (enlarge) to accommodate more people at one sitting and eliminate the need for two eating areas by utilizing space back to frame 42. All crew cabins should be single staterooms. Accommodation needs should be consistent with Ocean Class SMRs.
6. Open up deck from frame 20 to stern. Remove elevator and install a large 'A' frame like CALEY with a pendant and lift winch (similar to both *Seward Johnson's* and *Atlantis* configuration). This will allow for AUV, HOV, ROV and UUV ops.
7. Install a tracking mechanism to move vehicles into the A/C work area.
8. UAV and HELO ops can still be accommodated on the upper deck with the exception that only one HELO could land due to the reduced area. [Note – refer to issues raised in item IV.18]
9. Consider a moon pool for CTD and Instrument launching (consider lessons learned from KILO MOANA, WALTON SMITH and WESTERN FLYER).
10. Consider a notch in the starboard side for over the side ops with an A-frame.
11. Keep all science winches inside and fairlead to frames.
12. Propulsion systems should be able to support Dynamic Positioning (DP). Consider Gill type thrusters for the bow. Will not increase draft. Retractable pods will also work well but create more turbulence. Conventional propulsion might be considered but would necessitate stern thrusters VS Z-Drives or AZIPODS, which would not.

The selection of propulsion system--deserves a careful economic and life-cycle costs study. Conventional shafts will necessitate stern (tunnel?) thrusters. But these are simple and low-tech: given our experience with Z-Drives' ongoing maintenance costs, this may be the most cost effective way to provide DP capability.

13. In keeping with the Littoral Concept keep draft to a minimum <12'
14. Consider other systems instead of a 1-Degree multibeam to avoid adding a gondola to one hull or both. The trade-offs must be carefully evaluated. [See *Appendix A* regarding multibeam issues.]
15. Incorporate a 1 meter square moon pool in one or both hulls for a retractable underwater communications / tracking array for vehicle or other locating. Deployed and used only at no or low speed up to 5-6 knots. As an alternative, consider a retractable sword such as used on the FRV.

16. Displacement Considerations – Potential weight reduction scenarios are provided below. A full description provided by Rich Findley is included as *Appendix C*. Most of the displacement and weight reductions require tradeoff decisions that will need to be carefully evaluated and considered:

- Hull Structure - The largest section of the weight (550 tons) in the stacked bar graph on V3 is the hull structure. This is the same weight for the first variant (V1) from the right the Navy X Craft under construction. From discussion we had with builder and designer I thought they expressed that the scantlings would be reduced for a vessel that was operating at 12-18 knots instead of 45-50 knots. It would also appear that the weight of the upper deck could also be reduced as it is currently designed to handle the very high landing loads of heavily loaded helicopters. Further reductions would be made by removing the ramp and the after section of the hangar. The yard also indicated that an additional weight savings of 10 tons (as well as reduced maintenance costs) could be realized by not painting the hull above the waterline.
- Fuel - The next most significant weight is fuel (450 tons). This can be reduced by reducing all of the other weights and optimizing propulsion systems, a lighter ship will be more easily driven requiring smaller and lighter engines.
- Mission Payload - The next most significant category is the Mission Payload (200 tons). This is a SMR requirement, a 10% reduction to 180 tons would probably not restrict the ship's ability to meet its scientific missions and save 20 tons.
- Propulsion and Electrical (125 tons) - Consider using Compact Azipods which are available in ranges from 400 kW to 5 MW (536 - 6,700 HP) Azipods are AC motors directly coupled to the propeller in underwater pods that can rotate 360 degrees. (Think of an electric trolling motor on steroids) Because the motor is submerged it is buoyed up by the amount of water it displaces, meaning the hull does not have to displace as much as it would for an electric motor mounted inside the hull. Additionally because there aren't any gearboxes power losses, Azipods tend to be more efficient than Z drives, resulting in smaller generators and lower fuel requirements. Reports indicate Azipods can achieve a 10% fuel savings; this savings could possibly reduce the fuel weight by 45 tons. [Note: The ARRV design had considered Azipod propulsion, but later rejected them because of potential noise issues. If Azipods are to be considered further, potential noise issues should be thoroughly addressed.]
- Handling Systems (125 tons) - Typically, fleet wide we have not pressed the winch manufacturers to build lightweight handling systems. Our emphasis has been on big iron solutions, while this approach has worked well in general it is not the only solution. Reliable winches can be constructed that are lighter than presently in use. A frames and cranes can be built strong and lighter. Extend the modularity to the handling systems; don't carry around a trawl winch, a winch for .680 wire, two smaller conductor winches and a hydro winch if they aren't required. However, the

costs and logistics associated with shipping wire/winch should be carefully evaluated if an extended modularity capability is considered.

Appendix A

Multibeam Issues and Comments for Consideration

Comment (Dan Schwartz): AGOR-23 has an effective 1-degree by 1-degree multibeam, but it is a relatively high frequency (30KHz) set not intended for 'full ocean depth' mapping. Are deep diving AUVs with installed swath mapping systems the solution to high resolution data gathering in the future, thereby obviating the need for the higher resolution hull mounted system?

Dale Chayes Reply (excerpts):

Yes. For clarification, the EM300 on the Thompson is considered a "medium" frequency sonar. The operating frequency (30 kHz) results in efficient survey at depths (defined by the depth at which the swath width drops to twice the water depth) not much greater than a few thousand meters.

High resolution multibeam systems operate in the 100 to 500 kilohertz range but are only "reach" through a few tens to a couple of hundred meters of seawater and produce swath widths in the range of 50-500 meters.

We can expect improvements in these kinds of performances over the next 10 years as better signal processing becomes available (mature and stable algorithm implementations and affordable hardware) but:

- 1) Its not likely to make a factor of two improvement in performance
- 2) The improvements are very likely to scale across all frequencies

AUVs - Are deep diving AUVs with installed swath mapping systems the solution to high resolution data gathering in the future, thereby obviating the need for the higher resolution hull mounted system?

Not likely in many cases. They are the functional equivalent of bottom photos and require context to make sense.

The plausible high resolution swath mappers available on plausible AUVs of the next 10 years will be in the 100 to 300 kilohertz range and operate at altitudes above the bottom of 10s to a couple of hundred meters. At these frequencies the physics of sound in the ocean will allow very high resolution (10-100 cm) over swath widths on the order of a few hundred meters. At realistic AUV speeds of a couple of knots, you get a few 10 to 20 square kilometers per day (max.) Full ocean hull mounted systems produce 5,000 to 10,000 square kilometers per day (depending on water depth.)

In order to use AUV-based swath mapping tools effectively (even in swarms) you need to carefully target them at the right pieces of seafloor. The wide swath (10-20km) hull (or gondola) mounted 10-15 kHz multibeam is the tool of choice for reconnaissance that enables a single ship to find the right targets and launch the AUV(s)

To make a simplified analogy: do you use a flashlight or a searchlight? It depends on the problem you are trying to solve, but in many cases you find the lifeboat with the searchlight and help the folks up the ladder with a flashlight.

Gondola for support of 1-degree multibeam - It appears that an ~8m gondola would likely have to "hang" between (and below) both hulls or possibly be displaced to one side. What would be the impact of stability and handling?

Question for UNOLS is, what is the priority of the 1-degree multibeam system? - That is unclear at present. The Ewing-replacement will carry a one-degree multibeam. It's likely that the community opinion (in the future) will depend to some extent on how well that system works.

Independent of that specific installation works, it would be somewhat less than forward thinking to envision this platform that will (at least at times) be the host to swarms of AUVs intended for high resolution survey and mapping to have a less-than-optimum reconnaissance tool to insure that the high resolution, near bottom surveys are done in the "right place" or at least a broader context is available.

We also need to think about how we reconcile the Ocean-class, deep-sea mission with the Navy's littoral mission with regard to equipment (including multibeams.) If the mission is only littoral, higher frequency sonar with narrower (1/2 degree) beam width is more appropriate but would still be a relatively wide array. For the deep-sea mission, it's hard to (realistically) get much higher than 15 or 20 kilohertz and the resulting larger aperture.

Appendix B

Beamy-Monohull Variant

Comments from Bob Knox (message 1):

In reflecting on our X-Craft visit on Wednesday and our various discussions during that time, I'd like to (re)call attention to an existing monohull concept that seems to me to provide, in some degree, one of the features of a modified X-Craft that our discussions indicated as a key distinguishing feature of this form, i.e.:

- The large enclosed space ("the box"), available for modular mission elements (vans) or other variable uses.

At the same time, this monohull approach suggests surprisingly good results on one of the key aspects wherein we encountered some doubts about the existing X-Craft design, i.e.:

- Good seakeeping.

The design in question is the beamy monohull, first explored in 1985 by Glosten on behalf of SIO as one entry in the new-design portfolio of "Medium Endurance Ships" developed under the auspices of the old UNOLS Fleet Replacement Committee. Fred Spiess spearheaded the SIO end of this. The Glosten draft report is their file #8534. A later, updated report with more detail was done for FIC in 1989; Glosten # 8808. I have one copy of each; I believe Mike has further copies of at least one of these.

The essential point is that, contrary to intuition, for ships of about this size range (approx 220 ft) there are some seakeeping advantages to building a relatively beamy monohull. The reason is that although the widening makes the ship's natural roll period shorter (i.e., how fast would the ship rock you tipped it abruptly in still water), the natural period is not the whole story. At sea, the ship motions are forced by the waves. In significant seas most of these wave periods are longer than the natural roll period, and the result is that the hull motions are rather more benign than one might infer by considering the natural roll period - the forced roll response is supercritical in this sense. From this kernel of physics flows the substance of the report as regards seakeeping for this hull form, and the (fairly favorable) comparisons with more conventional designs. It's important to note that size matters here; the result flows from the comparison between a scale imposed by the ocean (dominant wave periods as a function of sea state) and a scale intrinsic to the ship (beam and hence natural roll period).

Part two is that if a beamy hull is built, then - like the X-Craft - one has the extensive real estate upon which to construct something like "the box." The Glosten scheme incorporates a sheltered space for a number of vans - not as many as the X-Craft, to be sure, but a significant number. So some of the attributes of "the box" are realized. The Glosten concept has the ship handling its own van loading. (The Glosten design also incorporates built-in berthing and labs in the usual fashion in addition to the shelter-deck van volume, though the question of single-person crew accommodations would have to be revisited.)

In passing I'd note that because of the beamy form, the main deck freeboard is fairly low (3-4 ft). This is a positive advantage to some users and just a source of wet feet to others. There is also

working deck space at the O1 level, with 15-16 ft. freeboard, so the potential exists to give different users the freeboard they prefer for over-side work. The Glosten concept includes a well, which could become a means of dealing with ROVs, AUVs, etc., and/or a stern platform/ramp arrangement that could be used to this purpose; this is also sketched.

At this stage I would just suggest that if, as we discussed in Lynnwood, we are about to start conceiving of substantial modifications of the existing X-Craft design to render it or something like its hull form closer to meeting the SMRs and thus a candidate in the eventual hull selection, we might also want to consider a parallel morphing of the monohull concept to achieve some of the same ends and candidacy. Of course the monohull approach does not morph readily into a twin-hull one; indeed, that's a matter of definition at some level. But I think the 1989 monohull approach may warrant a fresh look, perhaps subjecting it to some of the same seakeeping computations that have already been run on the other concepts, so as to do apples vs. apples (the seakeeping calculations in the Glosten report are presented differently and presumably stem from different/older software than the JJMA ones).

Clearly it's up to ONR as to whether to ask JJMA to exert effort in this direction. I just thought I would raise the issue. Several of the folks involved in this matter perhaps do not recall or had no contact with the 1985-89 Glosten beamy monohull concept. It's an interesting read; hit up Mike for one of his spare copies if you care to.

Dan Rolland reply:

I am familiar with the Glosten study on beamy monohulls and have a copy. As I'm sure most are aware, wider beam can offer improved seakeeping and arrangeability, but at a cost of higher resistance and fuel consumption. Our feasibility study monohull settled on a beam that seemed to be a good compromise. At $L/B = 4.5$, it's actually a bit lower than our current globals.

As we revisit our monohull concept design, I agree that it would be worthwhile to consider the advantages and disadvantages of lowering the L/B ratio still further.

Bob Knox comments following Tim Askew suggested modifications to the X-Craft:

Useful comments, all. One interesting point - Tim notes the desirability of modifying the large enclosed "box" to include labs and quarters, reducing its van capacity to, say, 6. I'm reminded once again of the Glosten beamy monohull design of 1985-89. In the 1989 version, an example (table 4.12) of a heavy van load is given. Ten vans. Three of these would fit in the shelter-deck area - the analog of the X-Craft box. Others would be on weather decks but in useful and tenable locations, except for two on the foredeck - and as we know there are many instances in which a foredeck site for a van would be quite OK - sample storage, dredged rocks, etc. don't require sheltered real estate. So again, though the beamy monohull does not offer exactly the same interior volume characteristics as X-Craft, it does offer a surprising amount on this score.

The design also offers a well (fig. 3.4), a schematic submersible handling method (fig. 4.1), a stern loading access (fig. 3.5), etc. My point is that a goodly part of the attractive features of the

X-Craft can be had in a reasonable monohull design, and one that already has had a good deal of homework on seakeeping and other critical requirements. Thus we should be VERY careful about any possible X-Craft showstoppers like the "survivability limit" that we talked about in Lynnwood - I repeat, "possible," not settled yet. I'm not ruling anything out at this point, just echoing something that RADM Cohen said at the UNOLS meetings about the monohull being the least-risk approach. Quite a bit of the capability we desire is apparently - and perhaps surprisingly - achievable in a monohull, certainly with no more conceptual redesign effort than we (i.e.. Dan Rolland) apparently are now contemplating re X-Craft, and if that comes with less risk attached it would seem to warrant consideration.

Appendix C
X-Craft Displacement Considerations
(Message from Rich Findley with replies from Dan Rolland Inserted in *Italics*)

I am excited to be working with this group on selecting the hull for the Ocean Class. Since the University of Miami is the only institution operating a catamaran in the UNOLS fleet I hope I can provide some experience from the lessons learned in the design and construction of the R/V WALTON SMITH that can be of use in making a final decision on the hull type.

In general the X Craft has much to offer in terms of deck space and interior volume. The modular mission configuration capability provides a ship that can be specifically tailored to the current mission(s) instead of one size fits all approach we have grown used to.

In my understanding of multi-hulls, the key to success is narrow easily driven small water plane hulls, this requires a lightweight vessel. It then follows the key to a successful multi-hull is controlling weight at every opportunity.

Rolland Comment: I agree that saving weight is a good idea - on every ship, but especially weight sensitive ones. However, lightweight equipment and design often comes at increased cost. For a 50-knot ship, weight control is absolutely critical because a slight growth in displacement can have a very significant impact on speed and fuel consumption. For a slower speed ship designed for 12 to 14 knots, the benefit from saving weight won't be as significant, so I'm not sure how cost effective it would be.

When I examine the “Weight Breakdown for X Craft Variants” on page 22 of the 7 July Web meeting (attached) it becomes obvious that what is needed is something in between the third variant (V3) from the right (which won't float) and the sixth variant (V6) from the right (which is going to be too big, too heavy, too expensive and morphs into a SWATH). Essentially V3 is estimated to displace around 1,850 tons, being overweight by about 400 tons.

Rolland Comment: I think 400 tons could be saved, but not without significant reductions in the SMRs. Variants #4 and #5 attempt to do that by reducing payload, range, winches, and scientists.

The largest section of the weight (550 tons) in the stacked bar graph on V3 is the hull structure. This is the same weight for the first variant (V1) from the right the Navy X Craft under construction. >From discussion we had with builder and designer I thought they expressed that the scantlings would be reduced for a vessel that was operating at 12-18 knots instead of 45-50 knots. It would also appear that the weight of the upper deck could also be reduced as it is currently designed to handle the very high landing loads of heavily loaded helicopters. Further reductions would be made by removing the ramp and the after section of the hangar as suggested by Tim Askew. The yard also indicated that an additional weight savings of 10 tons (as well as reduced maintenance costs) could be realized by not painting the hull above the waterline.

Rolland Comment: Yes it is true that the sizes of some structural members and shell plating can be decreased if we slow the design speed from 50 knots to 12 knots. However, I think the savings would be primarily in the forward areas where speed induced slamming occurs. Also, keep in mind

that the current X-Craft structure is designed for sea state 6. A lot of structure would probably have to be beefed up to survive in sea state 8 or 9, as we normally require for unrestricted ocean service. In addition, if we cut out the after part of the hangar to provide open working deck, we'll need to compensate by beefing up the wet deck cross structure. Twin hull ship structure is very critical in the transverse direction. That may negate the overall weight savings. As far as the flight deck goes, that could possibly be lightened. However, that will depend on what use is made of that upper deck area. ONR would like to retain some helicopter capability and there may be a desire to store vans and equipment up there.

Also, there are no noise or vibration control treatments anywhere on X-Craft. These will add some weight.

The next most significant weight is fuel (450 tons). This can be reduced by reducing all of the other weights and optimizing propulsion systems, a lighter ship will be more easily driven requiring smaller and lighter engines.

Rolland Comment: True, but again, the benefit of reduced weight may be small at endurance speed (10 or 11 knots).

The next most significant category is the Mission Payload (200 tons). This is a SMR requirement, a 10% reduction to 180 tons would probably not restrict the ship's ability to meet its scientific missions and save 20 tons.

The next category is Propulsion and Electrical (125 tons). Consider using Compact Azipods which are available in ranges from 400 kW to 5 MW (536 - 6,700 HP) Azipods are AC motors directly coupled to the propeller in underwater pods that can rotate 360 degrees. (Think of an electric trolling motor on steroids) Because the motor is submerged it is buoyed up by the amount of water it displaces, meaning the hull does not have to displace as much as it would for an electric motor mounted inside the hull. Additionally because there aren't any gearboxes power losses, Azipods tend to be more efficient than Z drives, resulting in smaller generators and lower fuel requirements. Reports indicate Azipods can achieve a 10% fuel savings; this savings could possibly reduce the fuel weight by 45 tons. A concern was raised about the acoustic noise created by these systems but as best as I can remember there was not any information available.

Rolland Comment: I think azipods are worth considering if the noise issues can be resolved. The ARRIV program found them to be unacceptable for meeting the ICES radiated noise limits. According to Glostén, this was based on review of proprietary noise data supplied by ABB. I also think they are more expensive than Z drives (at least that was the case during the design of KILO MOANA). They also carry some risk because they are still fairly new technology. The Royal Navy had some failed seals on one of their new survey vessels resulting in flooding of a motor. I know azipods been proven in a variety of applications, but so were Z drives before the AGOR fleet began having so much trouble with them.

Carefully analyze power requirements. The Azipods can share a common power source with the hotel load and the oceanographic equipment load such as cranes and winches. Optimize the generator configuration for fuel efficiency and weight; it would not be typical to need full main propulsion power at the same time that winches, cranes and a-frames are in use.

Rolland Comment: Agree. Common practice in AGOR design has been to develop a comprehensive electrical load analysis which covers a variety of load conditions - transit, on station, DP, winter, summer, anchor, etc.etc. The plant is sized by taking the largest load condition and adding a suitable growth margin (on non-propulsion electrical loads). Typically, during high-speed transit, none of the handling gear is operating, except perhaps a crane or winch for spooling wire. Most existing big AGORs, and likely any new ones we build, will have fully integrated electrical systems where propulsion and ship service loads are fed from a common bus. That arrangement allows for the most efficient generator lineups and loading conditions.

Additional information about Compact Azipod is available at:

<http://www.abb.com/global/seitp/seitp161.nsf/0/cbbadf75f8a42d27c2256ad90033c245?OpenDocument>

<http://www.nsrp.org/st2004/presentations/pakaste.pdf56AD90033C245>

<http://www.marinelog.com/DOCS/PRODS/MMIVprod0115a.html>

http://www.dynamic-positioning.com/dp2002/design_azipod_semisubmersible_rig.pdf

The next category is Handling Systems (125 tons). Typically, fleet wide we have not pressed the winch manufacturers to build lightweight handling systems. Our emphasis has been on big iron solutions, while this approach has worked well in general it is not the only solution. Reliable winches can be constructed that are lighter than presently in use. A frames and cranes can be built strong and lighter. Extend the modularity to the handling systems; don't carry around a trawl winch, a winch for .680 wire, two smaller conductor winches and a hydro winch if they aren't required.

Rolland Comment: Again, lighter equipment, and especially anything not-off-the-shelf, will likely cost more. But I'm in favor of saving weight anywhere we can in a cost effective manner. Winch modularity sounds like a good idea, but I wonder how practical it would be to ship these systems around and remove/install them aboard ship during 2 or 3-day port stays. KILO MOANA was originally delivered with a single stowage winch to save weight and money. Changing the wire out was a pain, so a second winch was recently added to the ship.

There is nothing in the SMRs or the typical missions scenarios that require that all of the SMRs need to be met simultaneously. What are the odds of needing the full science payload of 200 tons, the full load of 450 tons of fuel for a range of over 10,800 miles, and the full suite of handling systems at 125 tons and a full complement of scientists simultaneously? This ship is designed to be rapidly and easily configured for each mission or groups of missions use that capability to create a new paradigm for oceanography.

Rolland Comment: Good question and worth thinking about. One could envision if we have a full complement of scientists on board, that could mean a variety of simultaneous research projects, which may increase the likelihood of needing a full payload, all the handling systems, and a full load of fuel. It might not be a bad idea to consider trading off payload for fuel capacity - i.e. have

the tankage to carry 10800 NM of fuel, but during those few times when you actually have the gas tank full, you have to give up some science load.

It is obvious to me at least that there are opportunities to make significant reductions in the 1,850 ton displacement of V3 variant, it may not be possible to get to the 1,450 ton displacement of the V1 variant.

Sincerely,

Richard Findley