NAVAL SHIP DESIGN WORKSHOP
AT MIT

ADVANCED NAVAL SURFACE VEHICLES
THREE CASE STUDIES: PXH, JEFF, SWATH

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by

James L. Schuler

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JAMES L. SCHULER
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Yesterday you concentrated on a single case study for a whole day. Today, I'd like to cover three case studies in a morning. I'll treat the PHM as a past case leading to this afternoon's discussion in greater detail. I'll treat the JEFF craft as a present case because it is just now emerging as a production design program. I'll treat the SWATH as a future case because the advanced development program is just beginning.

My father always says, "consider the source," so I'd like to start out by telling you who I am and then you'll know where I'm coming from and can properly filter what I have to say.

I started my engineering career at the Seattle University in 1943, then joined the Navy and went to the University of Washington in Seattle. I was later transferred to the Webb Institute of Naval Architecture and Marine Engineering. I got out of the Navy in 1946 and received my B.S. degree in Naval Architecture in 1947. I then spent a year designing fishing boats at the Tacoma Boatbuilding Company followed by a short period of work at The Boeing Company.

I got married and moved to New York in 1949. I took a job as an insurance underwriter while attending the Fordham University School of Education for about a year. In 1950, I came to work in the Preliminary Design Branch of the Bureau of Ships. I worked on the NAUTILUS and FORRESTAL classes while I attended the George Washington University law school at night and received my Juris Doctor degree in 1954. Then I spent about 5 years in the Value Engineering Program of the Bureau of Ships trying to reduce the cost of ships. In 1961, the Bureau was reorganized and I moved into the R&D business. I managed Research and Development programs in hydromechanics, logistics, hydrofoils, hovercraft, fire fighting, life saving, etcetera. I even had one program called "Miscellaneous Other."

For the past 20 years, I've been trying to find and develop ways to make naval ships better and cheaper. I've probably made most of the possible mistakes. My intention today is to pass on to you the distilled essence of my painfully accumulated prejudices. You can then decide whether to repeat past mistakes or go forward and make new ones on your own.

OUTLINE OF PRESENTATION

- TOPIC AND SPEAKER
- OUTLINE
- VISUAL DEFINITIONS
- SWATH FEATURES AND CHARACTERISTICS
- SPEED REGIMES

- HYDROFOIL TECHNILOGIC DIAGRAM
- ACV TECHNILOGIC DIAGRAM
- SWATH TECHNILOGIC DIAGRAM

- REPEAT OUTLINE
- TECHNOLOGY TRANSFER
- TECHNIQUES FOR TECHNOLOGY TRANSFER

- EARLY PHM MILESTONES
- EARLY AALC SCHEDULE
- CURRENT SWATH SCHEDULE

- TECHNICAL ISSUES
- LESSONS LEARNED
- ORGANIZATIONAL CHART

This outline is really a list of the titles of the viewgraphs which I intend to discuss today. It's divided into five groups. The first group is really background which will include some definitions of Advanced Naval Surface vehicles. I'll define speed regimes because ship speed is such a basic parameter and ship power tends to be a major cost factor in all kinds of ships. You may wonder why the next item is called "Technology Transfer." That is because I visualize the design process as a fundamental example of this broader subject.

In my experience with the Research and Development business, I've come to think of the design process as an exercise in Technology Transfer. If technology is know-how, then the transfer of technology is education. And this is exactly what the designer does. He searches and researches the available information and then arranges it in the form of a design - usually expressed as drawings and specifications - as a guide to the shipbuilder.

Viewed in this light, research and design are processes by which the designer gains, selects, and expresses the technology to apply to the particular ship. This whole process implies that someone knows something about a problem which would be of value if transferred to someone else to help solve some other problem.

One obvious way to transfer technology is to move the person who knows from job to job so that his knowledge is transferred. Another way to transfer technology is to engage in a formal or informal program of instruction. Both techniques work and each has been successful under favorable circumstances.

I will then move on to discuss some of the issues as the designer manages and monitors the flow from 6.1 (Research) through 6.2 (Exploratory Development), 6.3 (Advanced Development) and 6.4 (Engineering Development) into the Ship Construction Program.

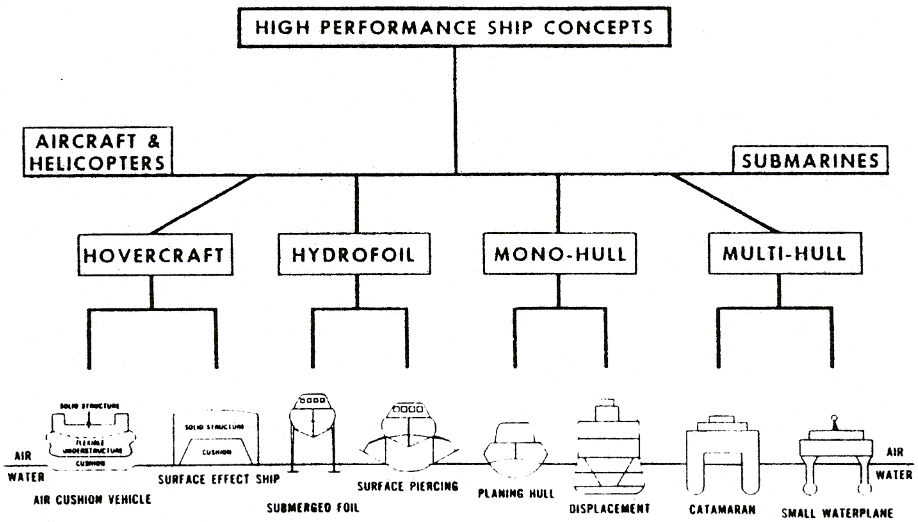
If these terms are unfamiliar to you, I'll explain them now.

It is my opinion that this is the true role of the designer - to transfer technology from the general national and international pool to the specific ship being designed.

The next group of viewgraphs really shows activities and events in three cases. These will be used to discuss the dynamics of each case with particular emphasis on who was doing what to whom and when and who was in charge. Past milestones in the PHM program will be discussed first. Then early milestones in the JEFF craft development will be noted. Finally, the current SWATH program schedule will be discussed.

The last three viewgraphs are really a summary of the basic ship design issues, lessons learned, and how they relate to the theoretical and actual organizational context in which Naval ships are designed. You are encouraged to interrupt with questions or comments at any time. That won't get my mind off the track - it has been derailed for a long time already. I also have a few hand-outs and a few film clips which I'll show on request.

VISUAL DEFINITIONS



I call this a visual definition chart. It shows four generic types of ships which operate at the air-water interface. Aircraft and helicopters are designed to operate in one medium, while submarines are designed to operate in the other. But the most difficult problem is to operate economically and efficiently at the interface.

Hovercraft are shown divided into two classes. The amphibious hovercraft is totally supported on a captured bubble of air. It operates over land, water, marshes, swamps, and tundra. It requires air propulsion and air controls to preserve its amphibious capability. The solid top structure is fitted with a flexible understructure or "skirt" to provide obstacle clearance and mitigate the impact of waves. In contrast, surface effect ships have solid sidewalls which penetrate the surface of the water. They have flexible end seals at the bow and stern. Water screw propulsion or waterjet propulsion is used to increase efficiency - compared to air screws - while the sidewalls reduce the loss of cushion air.

Hydrofoils are similarly divided into two major types. The basic idea is to lift the hull clear of the water by generating lift on the foils operating near or at the surface. The surface-piercing systems respond to waves by increase or decrease in lift generated by the variation in submerged area. They require control surfaces in the form of rudders, flaps, or changes in angle of attack to maneuver. The fully-submerged, automatically-controlled foil system used in U. S. Navy hydrofoils are fundamentally different. The total lifting surface is submerged below the interface. A height sensor and autopilot are used to generate control signals and to command flaps or incidence control systems which guide the craft. For this reason, they have "controlled sensitivity to the surface of the sea" with excellent ride quality and remarkable maneuverability.

The commonly used monohull ships depend on their displacement to provide buoyancy. Planing hulls tend to depend on lift from dynamic forces generated by their forward motion. Combinations are obviously possible.

The multi-hull ships are shown as having two hulls although obviously more could be used. The catamaran is similar to a conventional monohull ship divided into two separated demi-hulls to provide increased roll stability by having a large moment of inertia for the waterplane area. The small water - plane area twin hull, or SWATH concept is different. Buoyancy is provided by submarine-like lower hulls. The topside cross structure is supported on struts which penetrate the surface. These struts have the small waterplane area which gives the concept its name.

The U.S. Navy is, of course, interested in all these types of ships and I don't intend to get into the subject of their relative merits at this time. Such a discussion is highly dependent on what you want to do with the ship.

SPEED REGIMES

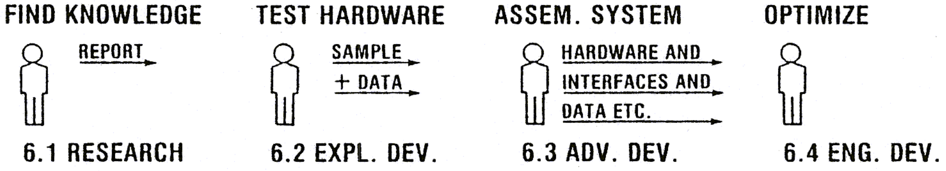
0 TO 20 KNOTS	LOW SPEED
20 TO 40 KNOTS	MODERATE SPEED
40 TO 60 KNOTS	HIGH SPEED
60 TO 80 KNOTS	VERY HIGH SPEED
ABOVE 80 KNOTS	ULTRA SPEED

These definitions are presented because they will make it easier to discuss the relationships among speed, size, and types of ships. Ship speed is a major factor in design because the speed requires power and the propulsion system is a major cost item as well as a major factor in arranging and balancing the design. It should also be noted that naval ships are characteristically operated at several speeds. They spend a lot of time at a low speed and should be economical to operate at a variety of speeds. Commercial ships, on the other hand, tend to operate at a single predetermined design speed most of their lifetime.

This aspect is very relevant because the Hydrofoil PHM and the Air Cushion JEFF Craft are High Speed Vehicles while the SWATH Ship is essentially a low speed or moderate speed concept like the monohull displacement ship.

TECHNOLOGY TRANSFER

TECHNOLOGY IS KNOW HOW—THE KEY IS TO KNOW WHO KNOWS



MANAGEMENT ACTION

A. DOWNSTREAM PEOPLE REVIEW PRODUCTS AND PLANS OF UPSTREAM PEOPLE
B. AVOID DOING SOMEBODY ELSE'S JOB
C. SET CRITERIA ON WHAT AND WHEN — NOT ON HOW
D. PROVIDE RESOURCES OR DON'T EXPECT RESULTS
E. KEY FACTORS
  6.1 IS THE SCIENTIST COMPETENT ?
  6.2 IS THE SAMPLE TEST RELEVANT?
  6.3 WOULD YOU BUY IT IF IT WORKED?
  6.4 WHAT IS THE COST/BENEFIT RELATIONSHIP?

This little diagram illustrates the four key phases of the R&D cycle which are Basic Research, Exploratory Development, Advanced Development and Engineering Development. The ship designer plays a key role in each phase. We are most familiar with his, or her, role in 6.4 where the system, that is, the ship, is being optimized for its mission and tasks. However, the role which he plays in the other phases is most critical. The ship designer who stands in the middle must somehow review the products and plans of the upstream people to be sure that the research, exploratory development and advanced development are relevant. Of course, he must avoid doing the research job unless he is performing research work as part of his own professional training.

When he's acting as a ship designer, his emphasis must be on defining criteria to determine what research and development should be done and not how it is done. An easily overlooked factor is that if the designer is to be the beneficiary of research then he must play some part in obtaining, justifying, and providing the resources. The Golden Rule says that "He Who Has The Gold Rules." If the designer is not providing resources for development, then he cannot expect to influence or control the results being produced.

The basic factors which are used in selecting research to be done are different in different stages in the process. For example, the factor which is most critical in 6.1 is the competence of the individual principal investigator. The key issue in exploratory development is whether the hardware being explored is relevant. In 6.3, the total system must be assessed terms of cost and benefits. This is similar to engineering development where the ship is optimized for its military role.

I think it's clear that the ship designer has an important role in each stage, even though his role varies from participant to leader as the process moves forward. It is only by this kind of participation that the ship designer can act with confidence and competence. The conditions for this are:

First, the ship design manager must be technically competent and knowledgeable of the design technology and alternative design concepts.

Second, the designer needs a supporting organization capable of managing the design process through which he can manage the design process.

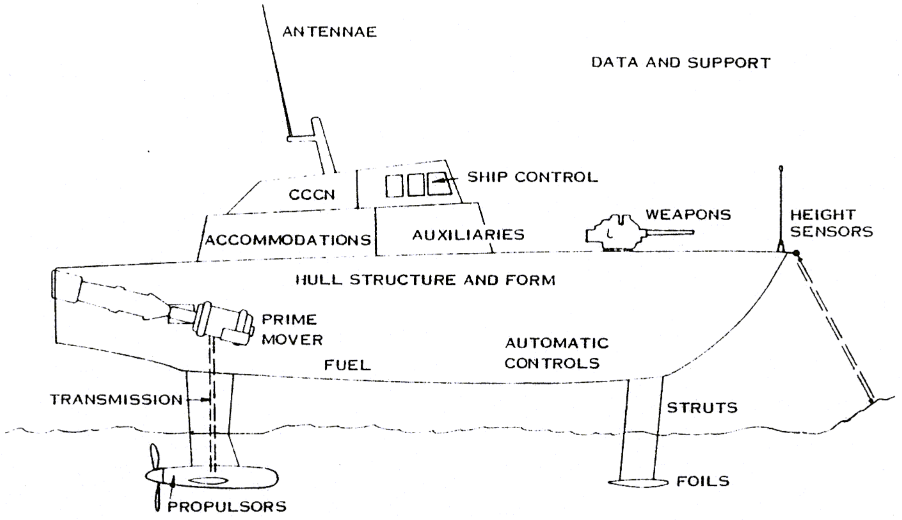
Third, the designer must have technical control of the design.

Fourth, he must control the people and the dollars to develop the design, i.e., the resources.

In this way, effective technology transfer - the ship design process - depends on the basic technological knowledge in the mind of the designer coupled with a management system capable of implementing the designer's decisions.

With this introduction, I will now move on to a discussion of three cases where ship designs are turning technology into military capability for the U.S. Navy. The first example is a hydrofoil.

ADVANCED HYDROFOIL SYSTEMS
FUNCTIONAL DESCRIPTION

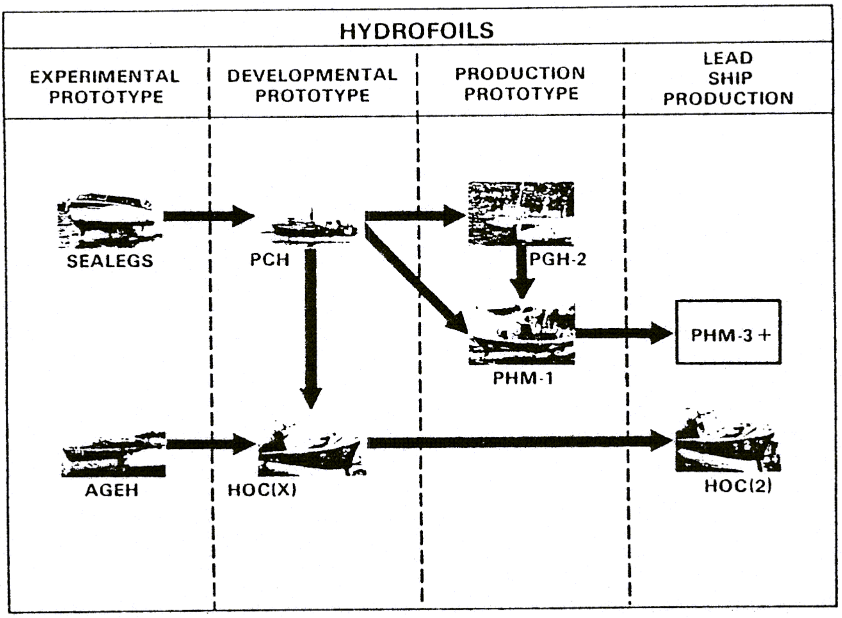


This diagram shows the major subsystems in a typical hydrofoil ship. Note that the hull, propulsion, electrical, communications, and armament subsystems are the same as you would expect to find on any naval surface combatant ship.

The struts and foils are obviously different. These are not fragile appendages. They are very strong members capable of lifting the total weight of the ship and controlling its motions in calm or rough waters. The height sensor searches the oncoming sea and signals the autopilot. The autopilot is a computer, which already knows the dynamic characteristics of the craft and how it is moving. The operator's command signals are fed into the autopilot and it commands changes in flaps, foils, and rudders to achieve the desired course with minimal disruption of the performance of the platform and payload.

Naval hydrofoils are operated in either a hullborne mode or a foilborne mode. They have two separate propulsion systems. Because they are dynamically supported while foilborne, they present a formidable engineering design problem and require a lot of special knowledge to work properly.

HYDROFOIL TECHNILOGIC DIAGRAM



I invented this diagram to show the relationship among the technologies represented by several ships. Note that an experimental ship is the kind of craft built with exploratory development funds. The SEALEGS was a Chris-Craft converted to a hydrofoil by Gibbs & Cox using an MIT autopilot to demonstrate that fully-submerged, automatically-controlled hydrofoils could operate foilborne on a steady course or turning in rough water and smooth water.

The AGEH-1 (PLAINVIEW) was the largest hydrofoil ship in the world. It was designed in 1960 to demonstrate 90 knot operations in the open ocean. The PCH-1 (HIGH POINT) was built in 1962 as an operational ship, but turned out to be better suited for the role of a developmental prototype. HIGH POINT has been and is being used to test new subsystems and components in a real foilborne environment. Propulsion, foils, struts, materials, coatings, autopilots, weapons, and sensors have all been tested and retested on this craft.

The PGH-1 and PGH-2 were supposed to be the lead craft in a major buy of hydrofoil gunboats in 1965. Actually, this technology was the basis for larger PHM-1 (PEGASUS) which is the production prototype of a class of hydrofoil ships now under construction.

The Hydrofoil Ocean Combatant (HOC) is a conceptual design of a 1058-ton ship. This concept is being used to help guide us into research and development areas which will be necessary for the possible next generation of hydrofoil ships.

The Hydrofoil Ocean Combatant is a concept derived from both the PCH technology and AGEH experience. It will also benefit by feedback from the PHM class and may be a developmental prototype. The important thing to remember is that the PHM design is based on technology primarily demonstrated on the PCH HIGH POINT as well as the PGH-1 FLAGSTAFF and PGH-2 TUCUMCARI.

EARLY PHM MILESTONES

1960	START HYDROFOIL ACCELERATED RESEARCH PROGRAM
1960	BUILD 120 TON PCH-1 (HIGH POINT) ANTI-SUB PATROL CRAFT
1962	BUILD 320 TON AGEH (PLAINVIEW) RESEARCH SHIP
1965	DESIGN AND BUILD PGH-1 AND PGH-2 GUNBOATS
1968	PCH-TWO STUDY (BASED ON HIGH POINT EXPERIENCE)
1969	PHM DESIGN BY NAVSEC (MISSILE ARMED 150 TON HYDROFOIL) EVOLVED INTO PXH CONCEPT—FIVE ALTERNATIVE PAYLOADS
1970	TDP FOR ENGINEERING DEVELOPMENT OF PXH PREPARED NAVSEC DESIGN—TWO DAY CONFERENCE AT CARDEROCK
NOV 1970	U.S. NAVY INFORMS NATO OF INTENT TO BUY EIGHT PHM
MAR 1971	PMS-391 ASSIGNED TO MANAGE PHM PROGRAM
NOV 1972	MEMORANDUM OF UNDERSTANDING SIGNED (U.S.,FRG, ITALY)
APR 1973	PMS-303 ESTABLISHED TO MANAGE ACQUISITION OF NATO PHM

This tabulation provides a chronological listing of some of the major events in the U. S. Navy Hydrofoil Research and Development program leading up to the establishment of the NATO PHM program. The first seven events are a series of steps that provided the technological foundation. The latter four events cover the period when the technology moved from a generalized basis to a specific project.

In 1960, the Navy took three actions based on successful demonstration of SEALEGS by Gibbs & Cox using the autopilot developed by MIT, which I mentioned before. Funds in the amount of $11.5 million were allocated to start a hydrofoil accelerated research program. The Navy procured the 120-ton PCH, which was designed by BUSHIPS and built by The Boeing Company. Funding to procure the 320-ton Experimental Hydrofoil PLAINVIEW (AGEH-1) was included in the fiscal year 1962 shipbuilding budget. The R&D program also included funding for construction of a high-speed test craft, FRESH-1.

HIGH POINT was built and delivered to the Navy in October 1963. It had a multitude of technical problems. Rather than assign it to the operating forces, it was assigned to the newly established Hydrofoil Special Trials Unit.

The AGEH-1 is the largest hydrofoil in the world, designed by Grumman and built by Lockheed Shipbuilding Company. It was also delivered to the Hydrofoil Special Trials Unit. This unit is operated as a field activity of the David W. Taylor Naval Ship Research and Development Center.

In 1965, the Navy procured the two gunboats, the PGH-1 and PGH-2. These gunboats have been extensively reported on. Comparing these two gunboats shows that the issues of canard versus airplane foil configuration and waterjet versus propellers for propulsion were still being debated.

Then, in May of 1968, at a meeting among Owen Oakley, Bill Ellsworth, and Jim Schuler, we discussed whether there was sufficient data flowing back from all these activities to warrant a new look at the problem. The PCH-2 study was started. This was a design study to answer the question, "what would we do if we had a chance to redesign the PCH?" There were two reasons for this study. One reason was to measure how much better the PCH-2 would be compared to the PCH-1, which we already had. The other reason was to assess how well the data from the tests of PCH, AGEH, FRESH, PGH-1 and PGH-2 were flowing back to the ship design community. This design study would also provide some insights into what further test data would be most useful and how these data should be presented.

It quickly became apparent that the strut-mounted sonar on the PCH-1 and its limited topside submarine warfare armaments were inadequate. It was decided to put a nominal guided missile system on the PCH-2 and its designation was changed to PMH. This quickly evolved into the PXH concept which employed a common platform - hull, propulsion, struts, foils, controls, and accommodations - with five interchangeable combat systems. The "G" carried a Gun. The "A" configuration mounted an ASW suite. The "M" configuration carried guided missiles. The "E" version was configured for electronic warfare and the "S" configuration was equipped for special warfare missions.

The PXH concept was carefully documented and an Engineering Development Plan was prepared. There was, as yet, no stated requirement. This planning exercise provided a firm basis for providing technical inputs to the ongoing operational studies such as the NATO Fast Patrol Boat. The PXH concept was presented during a two day conference at Carderock in late 1970.

The NATO Hydrofoil Guided Missile (PHM) had its beginnings in mid-1969 when CINCSOUTH presented to NATO a requirement for a large number of fast patrol boats to counter the OSA/KOMAR threat in the Mediterranean Sea. Later that year, a subgroup of a NATO information exchange group with eleven nations involved, met to discuss the requirement. These discussions resulted in a threat definition that included major combatants as well as fast patrol craft over the entire Allied Command Europe area. Further deliberations were deemed necessary.

During 1970, NATO Exploratory Group Two was established to deliberate the concept of a NATO Common Fast Patrol Craft. This group completed its deliberations in September of 1970 and concluded that a submerged foil hydrofoil craft - basically, the 140-ton size proposed by the United States Navy - was the craft most suitable for meeting the NATO mission requirement. The NATO Naval Armaments Group received this report the following month, accepted the recommendations contained therein, and approved the establishment of NATO Project Group Six to conduct the planning stages of the program and the initial determination of the PHM characteristics.

Under the sponsorship and chairmanship of the United States, Project Group Six held its first meeting in November of 1970, and reached general agreement on the management approach to be pursued. It was established that early phases of the program would consist of several open-ended meetings with participation by all interested countries. Through June 1971, a series of four such meetings were held with representatives from ten nations. During this period, the United States presented a draft outline of a Memorandum of Understanding and conducted further hydrofoil baseline design studies and cost estimates. These design data provided for the operational performance agreed upon by Exploratory Group Two and incorporated previously expressed national requirements.

In addition, as a program sponsor, the United States committed itself to building two PHM lead ships, with or without successful negotiation and formulation of a cost-sharing program. To accomplish this, the United States placed funding for a two-ship program in the fiscal year 1973 budget and programmed a limited amount of early design and long lead procurement funding for fiscal year 1972. At the conclusion of the June 1971 meeting, it was mutually agreed that active participants at subsequent meetings would be limited to nations willing to declare formally their intention to proceed in the cooperative hydrofoil project and, subject to conclusion of an earlier Memorandum of Understanding, to formally enter upon a program as an engaged nation. Letters of intent were signed by the governments of Italy, the Federal Republic of Germany, the United Kingdom, and Canada.

In October of 1971, the United States announced its intention of awarding the lead ship design and construction contract to The Boeing Company, builder of the HIGH POINT and TUCUMCARI. The initial effort under the contract would be to prepare detailed feasibility design studies. The objective of these studies was to obtain clear agreement on a specific common ship design which would satisfy all of the engaged nations' requirements. Further, in order to satisfy the schedule without having yet obtained a satisfactory MOU, the United States indicated that it would proceed at its own expense with the NATO design, share the results of these studies with all nations - with a cost to be reimbursed only when the engaged nations later signed up - and to conduct all aspects of the design development, contract defintion, and management in cooperation with the engaged nations.

In November of 1971, the United States awarded a letter contract to The Boeing Company, thus initiating the first phase of a multiphase design and construction program. Throughout 1972, efforts were devoted to completion of the feasibility design and completion of a draft MOU suitable for ratification. All other nations at that time either dropped out or moved to an observer status. This agreement to proceed with a joint warship project for the NATO countries was the first of its kind in the 23-year history of the alliance.

NOTE THE KEY OMISSION

From March of 1971 through April of 1973, the technical input of the U.S. Navy was assigned as a part-time ancillary duty to PMS 391. Inputs from NAVSEC and NAVSEA were presented to an international group. The Project Manager and his technical staff were caught in the middle between the contractor and the sponsor. They were preparing the Circular of Requirements to impose on the contractor. The contractor was dealing simultaneously with each of three navies - the Federal Republic of Germany, Italy and the United States without competition. The Italians really needed a small ship - say 50 to 75 tons with short endurance. The PXH was a moderate size ship of 140 to 170 tons. The Federal Republic of Germany wanted a larger ship to operate in the Baltic and North Seas. Obviously, the larger ship would have more capability and thus be "better." So the contractor's interest was to sell a Cadillac rather than a Volkswagen. Without active technical input from the U.S. Navy, the ship grew to accommodate the Italian Gun and the German Command/Control concept. It became apparent that the engines were too small and the larger, proven LM-2500 was selected to replace the four TF-40s that had been considered in the PXH studies. Then, with an overpowered ship, there was nothing to stop its growth. The PHM, which started out to be two times TUCUMCARI, that is, 2 x 60 tons, or a PCH-2 at 120 tons - was now a 240-ton craft. The ship was designed. The technology was transferred. But it wasn't until the Project Office was established in PMS 303 that the design got back in control. The technology was transferred via the contractor rather than via the U.S. Navy. The consequences of this break in continuity will be discussed this afternoon.

TECHNIQUES FOR TECHNOLOGY TRANSFER

ACQUISITION MANAGER PROVIDED WITH TECHNICAL DATA AND BACKGROUND INFORMATION

- STAFF INCLUDED PERSONNEL PREVIOUSLY INVOLVED IN PCH, AGEH, & PGH

BOEING SELECTED AS SOLE SOURCE CONTRACTOR BASED ON EXPERIENCE

- CONSTRUCTION OF PCH
- CONSTRUCTION OF PGH-2
- SUPPORT OF TESTS AND TRIALS BY HYDROFOIL SPECIAL TRIALS UNIT

ACQUISITION MANAGER USED IN-HOUSE KNOW-HOW

- NAVSEC REVIEW OF CONTRACTOR PLANNING
- NAVAL LABS STUDY AND ADVISE ON SPECIAL TECHNICAL ISSUES (DTNSRDC, NELC, NRL, ETC.)

ONGOING R&D PROGRAM USED TO BACKUP AND PROVIDE ALTERNATIVES

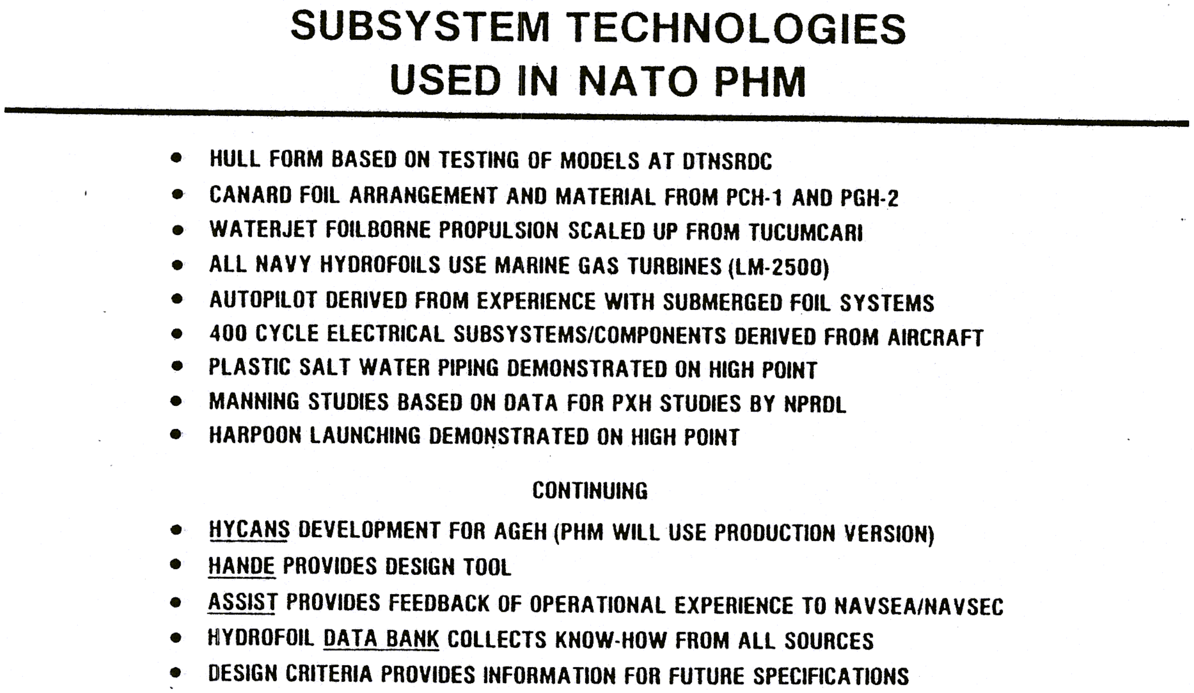
- DESIGN OF HY-130 STRUT/FOILS
- DEVELOPMENT OF HYDROFOIL COLLISION AVOIDANCE & NAVIGATION (HYCANS)
- FIRING OF HARPOON MISSILE FROM PCH TO PROVE LAUNCHER
- FIRING OF 152mm GUN FROM PGH-1 TO MEASURE DECK LOADS
- FATIGUE LOADS AND CRACK GROWTH DATA FROM PCH EXPERIENCE

This diagram displays some of the techniques which have been used to transfer technology in the case of the NATO PHM. One technique was to provide the Project Office, once it was established, with data developed by the research and development community. Support from the engineering community and the fact that several key personnel in the Project Office had experience with prior hydrofoils provided a channel for historical experience to be focused on the PHM project goals. But who was the transferee?

The second route was technology transfer via the contractor. The Boeing Company had built the FRESH-1, PCH-1, and PGH-2. Boeing had provided support to the Hydrofoil Special Trials Unit in tests and trials of U.S. Navy hydrofoils. The project manager also had direct access to the engineers at NAVSEC and the scientists at the Naval Laboratories to provide advice and recommendations on specific technical issues as they arose. The ongoing Research and Development program was focused to provide back-up and alternatives. For example, the PHM-1 used 17-4 Ph stainless steel struts and foils while the R&D program sponsored the design of an alternative set of struts and foils using HY-130 steel. Technical data and operational simulations were provided as well as the development of a Hydrofoil Collision Avoidance and Navigation System (HYCANS).

The net result of these and other activities is the NATO PHM. The PEGASUS has been delivered to the Fleet. Five additional ships of this class are being constructed. This afternoon, Tony Johnson will pick up the story and discuss how the project fared under the intensive management of PMS 303. But remember that the technology had already been transferred, that The Boeing Company's technology was being applied and that these ships were subject to very small variations.

This is the first case. It illustrates how the technology is transferred with a minimum of technical control from the NAVSEA/NAVSEC community. It is interesting, since this is a past case, to note where the technology came from as it moved into the first PHM.



SUBSYSTEM TECHNOLOGIES USED IN NATO PHM

- HULL FORM BASED ON TESTING OF MODELS AT DTNSRDC
- CANARD FOIL ARRANGEMENT AND MATERIAL FROM PCH-1 AND PGH-2
- WATERJET FOILBORNE PROPULSION SCALED UP FROM TUCUMCARI
- ALL NAVY HYDROFOILS USE MARINE GAS TURBINES (LM-2500)
- AUTOPILOT DERIVED FROM EXPERIENCE WITH SUBMERGED FOIL SYSTEMS
- 400 CYCLE ELECTRICAL SUBSYSTEMS/COMPONENTS DERIVED FROM AIRCRAFT
- PLASTIC SALT WATER PIPING DEMONSTRATED ON HIGH POINT
- MANNING STUDIES BASED ON DATA FOR PXH STUDIES BY NPRDL
- HARPOON LAUNCHING DEMONSTRATED ON HIGH POINT

CONTINUING

- HYCANS DEVELOPMENT FOR AGEH (PHM WILL USE PRODUCTION VERSION)
- HANDE PROVIDES DESIGN TOOL
- ASSIST PROVIDES FEEDBACK OF OPERATIONAL EXPERIENCE TO NAVSEA/NAVSEC
- HYDROFOIL DATA BANK COLLECTS KNOW-HOW FROM ALL SOURCES
- DESIGN CRITERIA PROVIDES INFORMATION FOR FUTURE SPECIFICATIONS

This viewgraph tabulates nine subsystems and technological concepts in the NATO PHM and identifies where these technologies came from. It also identifies five areas of continuing technology development which will have broader applicability.

The PHM hull form evolved from seaplane technology. It evolved through earlier hydrofoils to provide a sharp bow for cresting waves and a broad stern to assist in take-off. The actual form was tested on models in the laboratory and modified to suit the specific arrangements and structure of PHM.

The canard foil arrangement had evolved from airplane work as incorporated in the PCH and PGH-2. Having the major part of the lift aft of midships balanced the location of the center of lift with the center of gravity. The twin struts aft tend to have better dynamic stability in turns than the more conventional airplane foil configuration.

Waterjet technology is based on liquid rocket experience.

A waterjet foilborne propulsion system appeared in the PGH-2, the TUCUMCARI.

They used marine gas turbines. That technology comes from the aircraft industry. The autopilot was derived from computer technology as modified by experience with flying previous hydrofoil systems. The 400-cycle electrical subsystems and components were derived from aircraft components to be operated in a marine environment.

Plastic saltwater piping had been demonstrated on the HIGH POINT technology came from modern materials developed for the space program.

The manning studies and the manning approach to the NATO PHM were based on the data in the PXH studies which were derived from concepts used in manning aircraft, primarily.

The Harpoon launching was demonstrated on the HIGH POINT before it was incorporated in the NATO PHM, and obviously the Harpoon system was derived from rockets and missile technology.

Not only did the technology which is embodied in the NATO PHM come to it from many sources through many different routes, but it is a continuing effort to employ advanced technology in this hydrofoil and future hydrofoils. The HYCANS which is now being developed to be installed in the PHM, is a collision avoidance and navigation system derived from experience with high-speed aircraft. The HANDE is a hydrofoil design tool which is based on modern computer technology and is used in analyzing the impact of changes in the design.

ASSIST is a system for feedback of operational experience to the technical community based on the operational experience of the PHM and other hydrofoils. ASSIST is based on modern computer technology.

There's a hydrofoil data bank which collects know-how and inputs from many sources, including not only the hydrofoil community, but the conventional ship community, the aerospace community, aircraft and other technologies which may have applications to hydrofoils. And these data are expressed in design criteria which provide information for future specifications.

The purpose of running through that list, and it's very abbreviated, is to indicate the large number of sources for the technology, and therefore the complex problems that face the designer as he brings these technologies to bear on any ship that has to be designed. The hydrofoil is a very good example of that.

The key conclusion is that the technology in the PEGASUS came from many sources, through several routes and the Navy was not really in control because of the political situation of the contractor after the SHAPM decision to go sole-source for design.

From the ship design point of view, all of the technical data on hydrofoils are being accumulated in the hydrofoil data bank at DTNSRDC. The HANDE Program is available to conduct design trade-off studies. The ASSIST program is collecting data on the real experience in the operation, maintenance, and repair of Navy hydrofoils. These data are even coded to indicate how reliable they are.

This all started in the early 1960s when I became responsible for hydrofoil Research and Development. I went to the Ship Design Division and asked for help because I had a large number of projects and no assistants (just like I do now). I got a cool reception, so I went to Carderock.

The Assistant Secretary of the Navy had ordered a complete review of the hydrofoil technology due to the problems encountered on the HIGH POINT. The Carderock laboratory loaned me Bill Ellsworth. He directed the review and reformed the R&D Program to solve the problems identified on the PCH-1. Bill ran the program as my assistant in NAVSEA for about a year and a half, and in the process assigned a lot of the responsibility to Carderock.

One of the key problems was the trouble we were having with the PCH. It was not operationally acceptable. And the Navy was trying to figure out what to do with it. It had been designed as an antisubmarine warfare craft, but was not reliable enough to pass to any operational force. Specifically, it had been planned for assignment to the mine warfare forces. The mine forces had no use for it. So the problem was, "What do you do with it?" So we said, "All right, what we'll do is we'll invent something called the 'Hydrofoil Special Trials Unit (HYSTU),' to investigate its advantages and disadvantages and cure its problems."

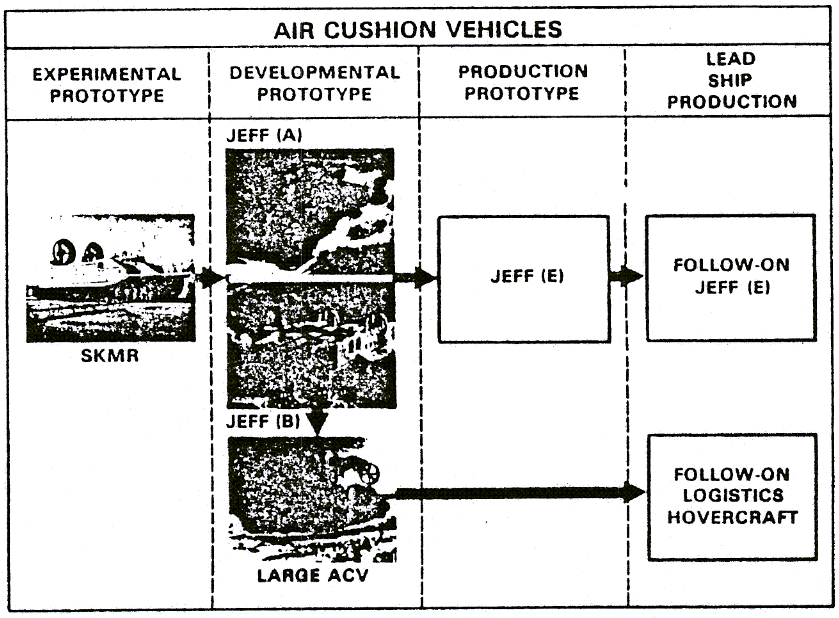
HYSTU was specifically located at a BUSHIPS activity, as a tenant, in order to continue to have BUSHIPS technical support for it. But that was located at the naval shipyard. That was chosen as opposed to say, pier 91 on the Seattle side, or Norfolk which would be an operating kind of base, not a technical base.

This was a new mode of operations. The HIGH POINT was placed "in service, special." It was operated by a military crew and was organizationally attached to the laboratory but physically located at a naval shipyard to receive industrial support. Boeing, located in nearby Seattle, provided technical support. This combination of technical, operational, and industrial support was provided in a laboratory environment with emphasis on solving technical problems and learning how to use hydrofoils effectively.

When the AGEH-1, PLAINVIEW, was delivered to the Navy, it was also assigned to HYSTU. The two unfortunate consequences of this set of facts were that they minimized the involvement of the in-house Navy design community and the geography tended to strongly favor a single contractor.

The second case will illustrate how we succeeded in tapping the creative inputs of not one, but two, contractors and are moving technology from the laboratory to the Fleet in a more controlled fashion.

ACV TECHNILOGIC DIAGRAM



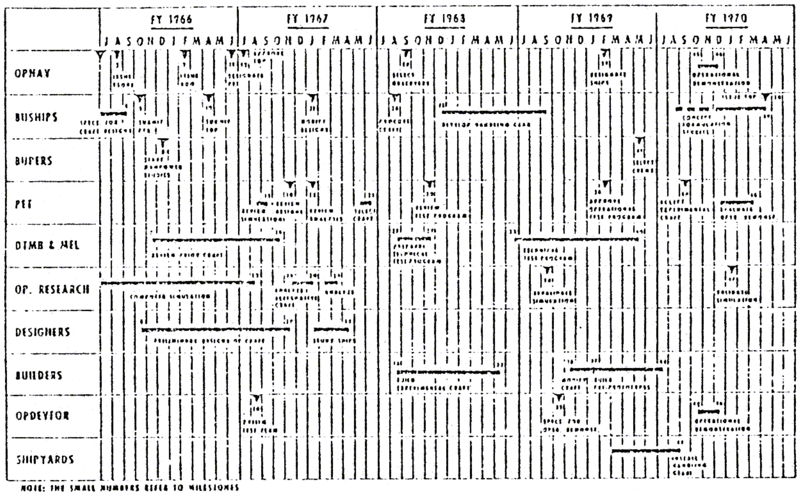
This is a similar technilogic diagram for air cushion vehicles. The SKMR-1 was designed by the Bureau of Ships and built by the Bell Aerospace Company. It was a small experimental craft that provided the basis for developing the JEFF(A) and JEFF(B) in the AALC program. These developmental prototypes are full-scale models of the production craft now being defined in the LCAC program. For our purposes, at this time, it is sufficient to notice that the two JEFF craft are functionally equivalent, that is, they do the same job, but they are technically different in every major subsystem - structure, propulsion, control, lift, etc.

The JEFF craft are true amphibious hovercraft about 50 feet wide and 100 feet long, 23 feet tall and having a design all-up-weight of about 160 tons. The early history of the program is documented in the April 1973 issue of the Naval Engineers Journal.

This technology which is being developed and demonstrated in the JEFF craft has three ways to go. It can be applied directly to the LCAC Production Program. It can also be used to demonstrate other mission applications for hovercraft in this size. Furthermore, it provides a basis for future, larger, more capable hovercraft and hoverships.

Note that this approach puts the Navy between the contractors as an arbiter in control of the technology flow rather than as a ratifier of the technology proposed by a single contractor.

EARLY AALC SCHEDULE



This viewgraph represents the program schedule as it appeared in 1966. You can tell it's old, because the players are identified by their old names, like BUSHIPS, DTMB, and MEL. Incidentally, the PET, which was supposed to be a Program Evaluation Team, was never established and its functions were performed by the program manager. The designers were a group of thirteen companies who submitted designs of 57 different types and sizes of craft. These craft designs were reviewed, modified, and analyzed. One large craft design, two medium-sized designs, and two alternative small craft designs were selected. See Milestone 25. It was then decided to procure the medium-sized JEFF craft. The milestone scheduled for August 1967 actually occurred in March of 1971 when contracts were signed for the construction of JEFF(A) and (B).

The JEFF(A) is an Aerojet General design and the JEFF(B) was designed by Bell Aerosystems Company. These are two design solutions to the same problem. The naval technical community (the NAVSEA, NAVSEC and naval laboratories) conducted regular in-depth technical reviews of the designs as they evolved. We approved all major subcontracts but we relied heavily on the contractors' innovation and motivation. The contractors were looking forward to the future quantity buy of Air Cushion Landing Craft. We were pressing into new technology and the question was, "Could the craft be designed and built to operate as planned?"

The schedule delay and the cost escalation - which I won't delve into deeply - were my fault because I failed to secure enough funding early enough to meet this very optimistic schedule. We have taken delivery of both the (A) boat and the (B) boat. The operational demonstration scheduled for October of 1969 will not take place until at least October of 1979.

You may ask, "why bring up this obviously painful example?" I have two reasons. One is to illustrate the long period of time - nearly 15 years - that it takes to bring really new technology into the Fleet. It can't be done in a 3-year tour of duty even though someone may think so. Secondly, this program has developed a new concept in technology transfer and thereby defined a new role for the designer.

When we hired Jeff Benson to run the AALC program, he did many remarkable things. One of the most remarkable was the invention of technology batons. His idea was to create a set of documents which could bring together all that had been learned from JEFF(A) and (B) as well as related technologies so that the designers of the production craft would be able to really absorb the lessons learned. There are 24 such documents.

The situation is similar to hydrofoils, i.e., the technology is being developed by contractors and naval laboratories. In the hydrofoil case, we are creating a 14-volume set of "General Specifications." In the hovercraft case, we are using technology batons. The JEFF Craft situation is unique in other ways. One is that we are using two contractors and the other is that the technical manager is reporting to a project manager. Jeff Benson has both the research and the acquisition responsibility. The key to technology transfer in this case is the management plan created by Ken Spaulding and the use of the technology batons.

TECHNOLOGY BATONS

CRAFT SUBSYSTEMS

A1.1	**STRUCTURAL LOADS**
A1.2	**STRUCTURAL DESIGN**
A2.1	**POWER PLANTS**
A2.2	**INLET AIR FILTRATION**
A2.3	**PROPULSORS**
A2.4	**POWER TRANSMISSION**
A3	**ELECTRICAL**
A5.1	**HYDRAULICS (AUXILIARIES)**
A5.2	**FIRE PROTECTION**
A6.1	**LIFT AIR SUPPLY**
A6.2	**SKIRT SYSTEM**
A7	**VULNERABILITY**
A9.1	**CARGO HANDLING**
A9.2	**CRAFT HANDLING**

CRAFT CHARACTERISTICS

B1.1	**POWER, RESISTANCE RANGE & ENDURANCE**
B1.2	**MANEUVERING & CONTROL**
B1.3	**SEAKEEPING**
B1.5	**OVERLAND DYNAMICS**
B2.1	**CUSHIONBORNE STABILITY**
B2.2	**HULLBORNE STABILITY**
B3.1	**CRAFTBORNE VIBRATION**
B3.2	**AIRBORNE ACOUSTICS**
B5	**RELIABILITY, MAINTAINABILITY & AVAILIBILITY**
B6	**SUPPORTABILITY**

These are the titles of the 24 technology batons being created under the AALC program. In each case, they are documents which explain what was done and why it was done on the (A) boat and the (B) boat. These documents also include some discussion of how the specific technology should be applied to the production configuration. They include references and will also include tests results - particularly failure reports - as they become available. These technology batons are similar to the design data sheets which we used in the Bureau of Ships. They are a textual mechanism for transferring the technology from the designers of the JEFF(A) in Aerojet and JEFF(B) in Bell and their subcontractors to the designers of the production configuration.

Jeff Benson, the current program manager for the AALC program, is also acting as the assistant project manager for the production craft. He had these technology batons prepared by the most knowledgeable people in each of the 24 areas. They are a must reading for anyone who aspires to design a production air cushion landing craft for the U.S. Navy.

I've brought along a sample. This demonstrates a new and creative technique for technology transfer. The JEFF craft are designed to carry a payload of 60 tons in the form of either a tank or truck trailers. They are designed to move at 50 knots in Sea State 2. They run their payload from ship-to-shore and discharge it on the beach. Then, they return to the ship for reload.

They are constrained to a width of less than 50 feet and a length of less than 100 feet. On cushion, they are 23 feet high and fit in the well of well-deck ships. This combination of physical and performance constraints places the JEFF craft at the limit of the technology. It would be true to say that they are of the "state-of-the-art." For this reason, the concept of technology batons is a powerful and vital instrument for preserving and transferring this technology as it evolves.

Now let's move on to the future case. The Small Water Plane Area Twin Hull (SWATH) Ship is a new concept. It has some unusual feaures. The lower hulls look like submarines but SWATH is really a blend of conventional monohull surface ship technology and offshore drilling rig technology. This is occuring at a time when the whole technology of motions (seakeeping and seakindliness) is better known. This is partly due to better facilities such as the Maneuvering and Seakeeping Facility at Carderock and because the exceptional ride quality of hydrofoils has started many people in the Navy to thinking that ships don't have to be large to ride well in a seaway. Just notice the recent emphasis on fin roll stabilizers on both naval and passenger ships.

The U.S. Navy SWATH program is only 10 years old. I've included it as my third case study because I hope to get some feedback from this conference which will be useful as we move forward in the planning and execution of the program to develop the next SWATH.

One of the basic problems, as you will see, is that the vast majority of people in NAVSEC have been trained over the last few years to be operating in a <u>responsive as opposed to an initiative leadership mode</u>. They have been so busy responding to so many people and doing what somebody tells them, whether it's the SHAPM or somebody else, they have not had the time nor have they devoted the resources to provide the leadership which will allow them to be in a position to take the lead in the design of some of these advanced craft. I'm less familiar with whether that's happening on conventional ships, but I suspect a similar situation. You have to make a conscious command management decision that a certain fraction of your personnel resources is not going to be responsive. They are going to be <u>leaders</u> and not followers. <u>We have to start acting like leaders</u>.

Leadership is not something you can pick up in your post graduate source, you've got to start off leading the technology. Then the transfer problem can be solved.

SWATH FEATURES AND CHARACTERISTICS

HULL CONFIGURATION RESULTS IN:

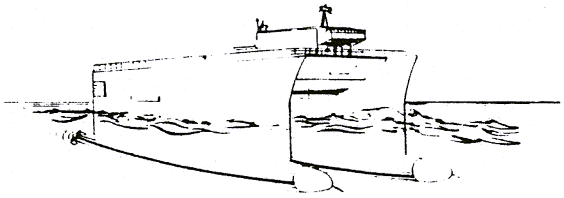
- COST COMPARABLE TO MONOHULLS
- SEPARATED LOWER HULLS
- GOOD COURSE KEEPING ON ONE PROPELLER
- GOOD LOW SPEED MANEUVERABILITY
- LARGE OPEN DECK AREA
- RESERVE BUOYANCY OF CROSS STRUCTURE
- GREATER WETTED SURFACE, HIGHER CALM WATER POWER REQUIREMENTS

LARGE FREEBOARD RESULTS IN:

- DRY DECKS

SMALL WATER PLANE AREA RESULTS IN:

- IMPROVED SEAKEEPING
- HIGHER SUSTAINED SPEED IN WAVES
- SENSITIVITY TO UNANTICIPATED WEIGHT GROWTH AND LOSS OF BUOYANCY



DEEP DRAFT RESULTS IN:

- IMPROVED PROPELLER EFFICIENCY
- IMPROVED SONAR PERFORMANCE
- NAVIGATIONAL LIMITATIONS

I've included this diagram because I suspect that this group may be less familiar with the SWATH concept than with the others I have mentioned. The sketch in the center shows the characteristic twin hulls well below the water surface. It shows the topside cross-structure and one long strut per side. Some current SWATH configurations use two struts per side, which increases the number of design variables. These are not exotic ships. They use structures, materials, and components like conventional monohulls even though their hydrodynamic form is unusual. They have advantages and limitations, some of which are listed here.

The small water plane area reduces ship motions. This results in better seakeeping and permits operation at higher sustained speed in a seaway.

The SWATH is more sensitive to unanticipated weight growth. It also tends to have larger changes in draft and trim when loads are shifted. SWATH is more sentitive than a monohull to the loss of buoyancy which could occur as a result of damage to the lower hulls.

Compared to a monohull, the SWATH has a deeper draft. This places the propellers deep in the water where they operate in a good hydrodynamic environment, thereby improving propeller efficiency. The twin lower hulls provide an excellent location for sonar. This location will tend to prevent sonar emergency even in extreme sea states.

The deeper draft may be a navigational limitation for large SWATH ships. However, the problem is not serious because the SWATH concept is expected to be applied to ships of less than 20,000 tons displacement. The draft of a 20,000-ton SWATH would be about 36 to 44 feet at normal operating conditions. Ballasting can be used to increase or decrease the draft in special circumstances if required.

The SWATH ship has an unusual hull configuration. However, the ship construction cost per ton should be comparable to conventional monohull costs assuming comparable design standards. The separated lower hulls lead to widely-separated twin screws and rudders which provide good low speed maneuverability. The separated rudders and struts ensure good course keeping, even on one propeller.

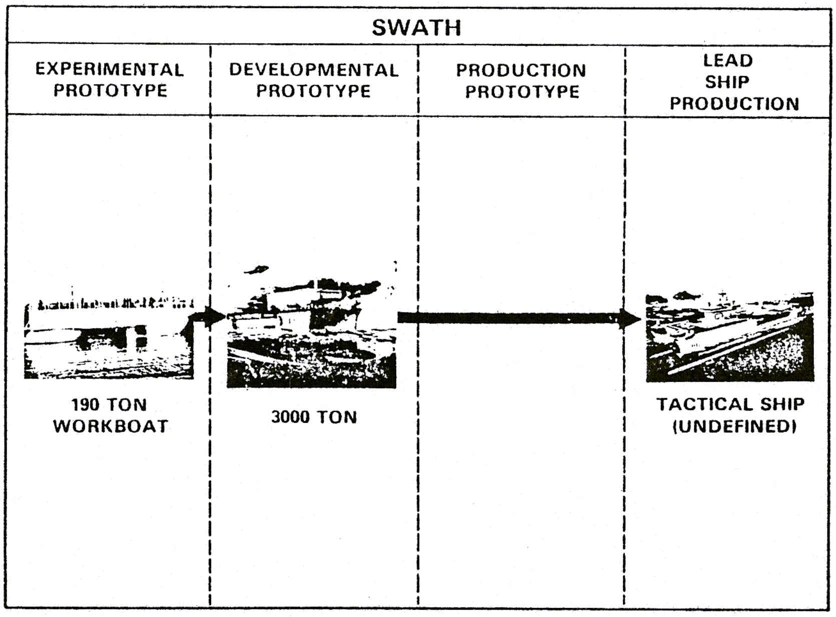
The large open deck area and the rectangular cross structure are well-suited for both aircraft operations and support. The reserve buoyancy provided by the cross structure combined with distributed subsystems and redundancy of vital propulsion components in the twin hulls will increase survivability of the SWATH.

The greater wetted surface area of the SWATH hull form tends to require more propulsion power in calm water than a monohull because of the greater frictional resistance. However, sustained speed in rough water is higher.

The large freeboard and wide open deck area combined with good ride quality and dry decks show the natural compatibility of the SWATH concept with aircraft operations.

Recognition of these features has led the Navy to explore many possible applications of the SWATH concept.

SWATH TECHNILOGIC DIAGRAM



This is the technilogic diagram for the Small Water Plane Area Twin Hull ship. Note that the only real hardware shown is the 190-ton workboat, SSP KAIMALINO. I didn't show the many models such as the 18-ton model by Mitsui Engineering, who are now building a 500-ton SWATH passenger ferry in Japan.

You can see that our full-scale experience with SWATH is very limited. However, we can draw on current technology for the lower hulls. We can also draw on the technology of offshore drilling platforms as well as what we know about Air Craft Carrier Bent Frame Structures to help fill the gaps.

SWATH DEVELOPMENT PROGRAM MILESTONES

1969 U.S. NAVY LABORATORY IED PROGRAMS INITIATED
1972 EXPLORATORY DEVELOPMENT STARTED
1972 BEGIN CONSTRUCTION OF SSP KAIMALINO
1975 SSP KAIMALINO BEGINS OPERATIONS
1977 SWATH SHIP POINT DESIGNS FOR ANVCE STUDY
1978 PARAMETRIC STUDY OF SWATH COMBATANTS FOR OASN (RES)
1978 TECHNICAL INPUT TO NATO LONG TERM SCIENTIFIC STUDY

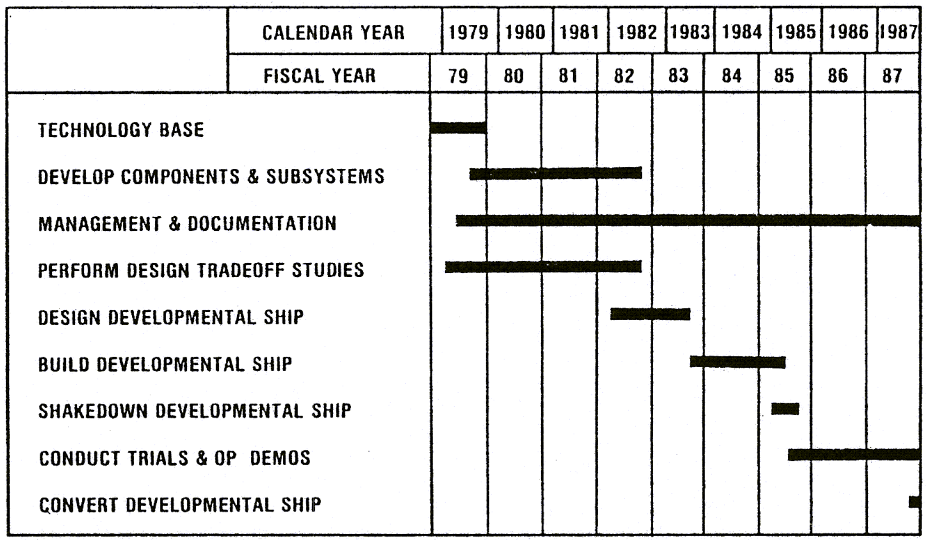
U.S. NAVY INVESTMENT TOTALS ≌ $17M

These are some early milestones in the development of the SWATH program. We've first discussed the PHM as a past program where technology has been transferred to the Fleet. We then discussed the JEFF Craft as a present program where it's in the process. The SWATH program which is only now beginning to develop the technology to be transferred is really a future program.

The milestones start in fiscal year 1969 when the first exploratory development program was initiated. Our efforts include the construction of the 190-ton workboat, which is now operating in Hawaii, SSP KAIMALINO. It's included many point designs which we've used for guidance in technology and trade-off studies to determine what features and factors are significant in the ship concept. Parametric studies have been made to see what happens when you press one variable such as speed to its limit. This activity has provided technical input to other nations, and the commercial community, in terms of what SWATH is and what can be done with the SWATH configuration.

So far, we've invested about $17 million in this relatively low technology concept and we're ready to move forward. As you can see, it's been a fairly level-funded effort, and has led us to the point now where we believe we're prepared to move into the serious development of a larger platform to demonstrate what SWATH's values are and what its limitations might be.

CURRENT SWATH SCHEDULE

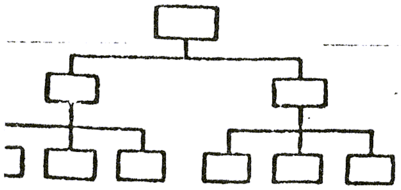


This is a schedule for a SWATH Ship development program, which the U.S. Navy is now proposing. Our approach is to use very conventional technology in all subsystems except hull form. We will design and build a multi-thousand ton platform with this unusual hull configuration. In this case, most of the technology is in hand - the hull form, speed-power relationship, and particularly the motion characteristics are the major platform characteristics requiring definition. Interfaces with the payload and proof of performance are the big issues.

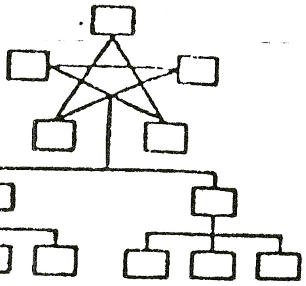
Creative design, but very little new technology, will be required to build this platform. The open questions, after the program gets underway, are, "who will build the ship?," "who will design the ship?," and "who will write the specifications?" The answers to these questions are still in the future.

I hope to be able to use the products of this seminar as inputs as we firm-up the details of the U.S. Navy SWATH Development Program. To conclude my input to your deliberations, I was asked to define some of the issues and lessons learned from these three cases.

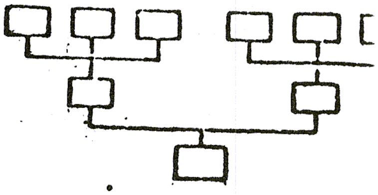
TRADITIONAL



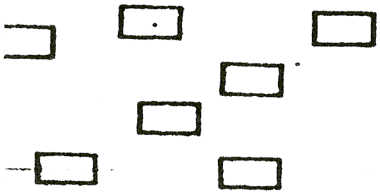
RUSSIAN



POLISH



ARAB



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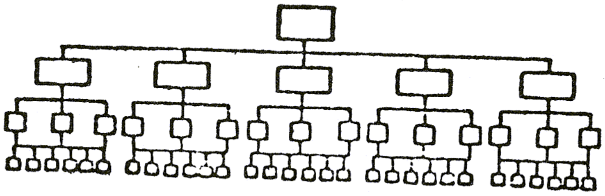
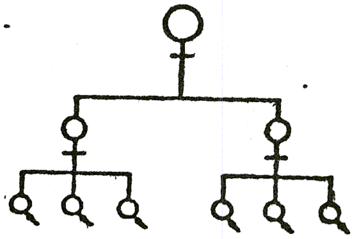
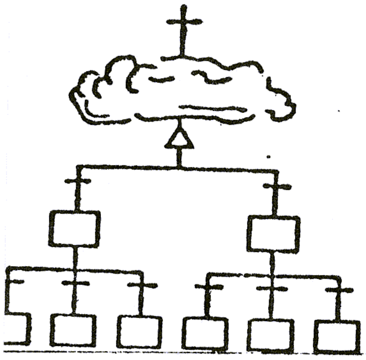


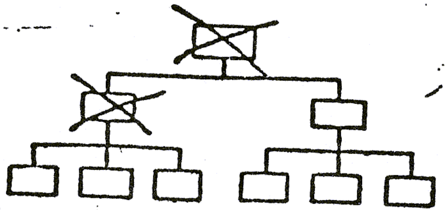
WOMEN'S LIB



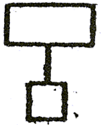
VATICAN



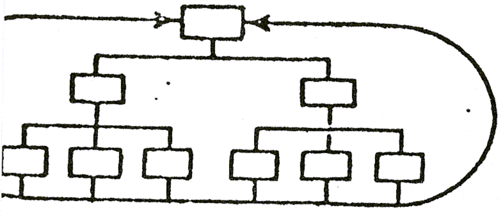
LATIN AMERICAN



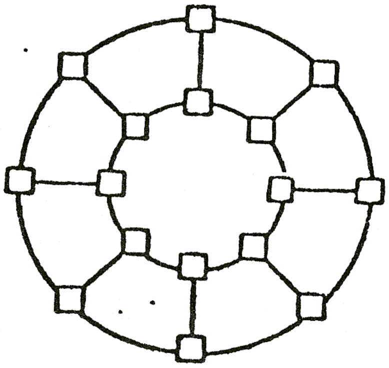
LIECHTENSTEINIAN



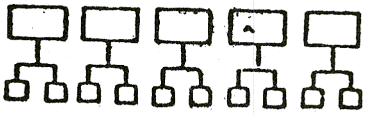
AMERICAN



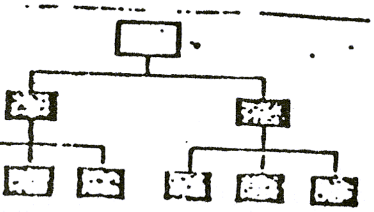
UNITED NATIONS



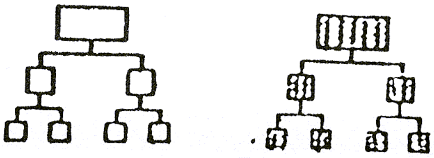
ITALIAN



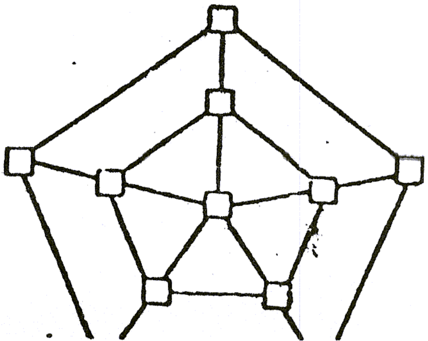
RHODESIA



PRISON



PENTAGON



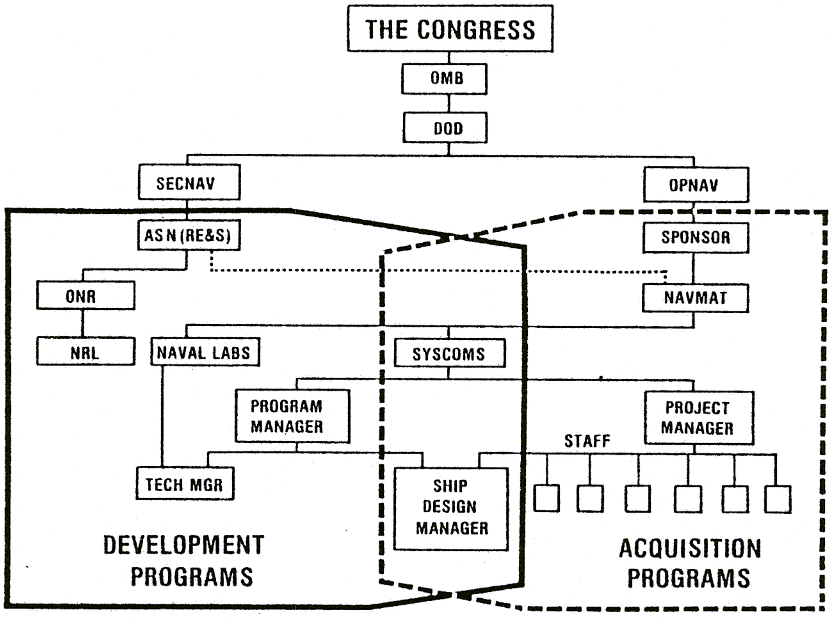
I'm a firm believer in the theory that organizations don't do anything. People do the work and good people tend to do good work. But, all of us work in an environment provided by our organizational structure, so I must start from there.

I spent about a year, from October 1976 to September 1977, on the Naval Sea Systems Command Study. We reviewed a wide spectrum of Organizational Concepts.

(TO BE SUPPLIED)

These are a few of the many organizational alternatives that we studied. There was a lot of sentiment in favor of the AMERICAN organization where everyone reports to the Boss. A few people favored the Pentagon-type or the United Nations-type where everybody reports to everybody and nobody is responsible. Our current organization has most of these desirable features but it is too complex to discuss fully in our lifetime. So, I have prepared a simplified verion.

SIMPLIFIED ORGANIZATION CHART



The basic idea is that we work for the Congress of the United States. They provide the Policy Guidance and the cash. Our requirements and needs are communicated up the chain of command. Our resources flow down through the Office of Management and Budget, the Department of Defense and the Secretary of the Navy or the Chief of Naval Operations. The several Assistant Secretaries of the Navy such as the ASN for Research, Engineering and Systems control resources for development. These people tend to operate through the Office of Naval Research and Laboratories such as the Naval Research Laboratory.

The Chief of Naval Operations also has sponsorship for Programs in the later stages of development as well as acquisition of hardware for Fleet use. CNO works through the Chief of Naval Material whose NAVMAT staff includes the Chief of Naval Development. NAVMAT owns the Naval Laboratories as well as the Systems Commands such as NAVSEA.

The Systems Commands are organizationally equal to the Naval Laboratories. However, we are really more equal because we have Flag Officers whereas the Laboratories have Captains. These Naval Laboratories, as well as Private Laboratories and Corporations, provide access as well as contributions to the national and international technology base.

The Naval Sea Systems Command has Program Managers and Project Managers (plus a lot of other people). There is a crucial difference between these kinds of cats. The Program Managers have general areas of responsibility. Theoretically, the sum of these areas adds up to the total area of responsibility of the Commander. However, some specific projects require "Intensive Management." These projects are assigned to Project Managers whose responsibilities are relatively narrow in scope and limited in time. For example, I am the Program Manager for Hydrofoil R&D. I am responsible for all hydrofoil work except the NATO PHM Project Office. PMS 303 has a charter to manage that project. It is an Acquisition of a Ship, therefore he is a Ship Acquisition Project Manager (SHAPM).

PMS 303 has a staff to provide intensive management of his project. He also draws on other resources within the command such as Comptroller, Contracts, and Personnel Division. I have singled out the Ship Design Manager who should be his Staff Naval Architect. The key point of this Diagram is that the Program Manager who needs Naval Architectural support also shares the Ship Design Manager even though he may have a Technology Manager or other financial, clerical or administrative support.

The point is that the Ship Design Manager is a key link for the Systems Command to bring the Research and Development to bear on the Ship Design.

SHIP DESIGN ISSUES

THE QUESTIONS	*THE ELEMENTS*
● WHAT IS THE MISSION OF THE SHIP? — THE FORCE?	MISSION PROFILE, PLAN FOR USE, 30 YEARS IS 2,628,000 HOURS
● WHAT IS THE SPEED OF THE SHIP?	PROPULSION SYSTEM, SEAKINDLINESS, MANEUVERABILITY, DESIGN SPEED, CRUISE SPEED, FLANK SPEED, SPEED PROFILE
● WHAT IS THE MANNING LEVEL OF THE SHIP?	WATCH STANDING, ONBOARD MAINTENANCE
● WHAT IS THE SIZE OF THE SHIP?	THIS IS THE ANSWER - NOT THE QUESTION
● WHAT IS THE COST?	DESIGN COST, QUANTITY, ACQUISITION COST, LIFE CYCLE COST

What are some of the design issues that the ship designer must face in order to perform his function as the technology transfer agent?

The first issue is simply, "What is the mission of the Ship?" That kind of question is liable to get an answer such as "Surface Warfare" or "Anti-Submarine Warfare." That kind of answer may satisfy some people but it can't satisfy the needs of a ship designer. Starting with the broader questions of "What is the force trying to do?," the dialogue must focus on the specific ship in context. This can be evolved into a "Mission Profile" stated in operational terms or a "Plan for Use" stated in technical terms. Ideally, this definition should address the total life cycle of the ship which could be 30 years (286,200 hours).

I call these "ship design issues" because they have a major impact on the adequacy of the design in terms of its ability to do its job. I remember when I first got into the hydrofoil development business, it was generally assumed that a hydrofoil would spend most of its time in a foilborne mode. A hullborne hydrofoil was considered to be like an airplane which had to taxi to the runway. Its normal "thing" was to fly.

Well, as a matter of fact, our estimates today are based on a year (8,760 hours) of hydrofoil operation which includes 2,500 hours (about 30%) underway of which about 750 hours is foilborne. Obviously, the ship must be designed for efficient operation while foilborne. Just as obviously, it must be efficient while hullborne and habitable all the time. These kinds of questions and answers, this dialogue, is vital for the ship designer in two ways. One way is so that the design emphasis is correctly placed and the other is to guide the technical requirements for subsystems. For example, if a part or subsystem will last a quarter of a million hours without repair, it would be nonsense to try to improve its life expectancy. On the other hand, if a foilborne system must last about 20,000 hours, this is a good criteria for selecting subsystems and components.

A second, and closely related question is, "what is the speed of the ship?" or "how much time is the ship required to operate at a certain specified speed?" This impacts on the selection and arrangement of the propulsion system. It provides a focus for studying the open ocean environment and the ship response to that environment. Seakindliness, course keeping and maneuverability are all speed-related. The Design Speed, Cruise Speed, Flank Speed and Sustained Sea Speed are some of the ways of expressing this variable in the speed profile over the life of the ship or the duration of a mission.

Manpower, manning level, accommodations, and crew cost are a set of major design issues. The PHM has a small crew because it is too costly to carry a large crew. This had led to creation of a support group and a new policy for repair and maintenance. The onboard crew requirement is based on watchstanding and onboard maintenance requirements as well as manning for battle conditions. This concept has a major impact on the ship design and illustrates both the infusion of aircraft concepts and the vital need for an ASSIST program to provide vital data for ship design and component selection.

The final set of issues relates to cost. I have depicted the ship designer as the conduit for technology transfer. He (or she) is also the translator between costs and benefits. The designer, theoretically, starts with the military benefits of the mission and then, through the design process, derives the cost. This is a complex variable including design cost, how many are being bought and when to determine acquisition cost and operating costs. It leads to life-cycle costs which include all the elements of ownership associated with having the military capability which the ship embodies. These are the design issues. What else have we learned from these three cases?

The first lesson is to recognize that Ship Design is a complex business and that the answers are very sensitive to the questions. The rule is, "If you ask the wrong questions - you will get the answer you deserve." On the other hand, if you want the right answer, you must take the time to phrase the questions correctly and listen carefully for the nuances in the answer.

The key point is that the size and cost of the ship are really answers.

What other lessons have we learned?

LESSONS LEARNED

DESIGN INITIATION QUESTIONS - ACTIONS - ISSUES

- WHO IS RESPONSIBLE FOR WHAT <u>BEFORE</u> THERE IS A PROJECT?
  - SHIP DESIGNER BEARS PERSONAL IDENTIFICATION WITH THE PROJECT
- WHERE IS THE REWARD FOR EXCELLENCE?
  WHAT IS THE PENALTY FOR FAILURE?
- INDEPENDENT ASSESSMENT OF TECHNOLOGY
  THE BALANCE OF THE DESIGN BY THE NAVAL ARCHITECT
  WHO SELECTS THE TEAM?
  WHO CONTROLS THE FUNDING?
- WHERE IS THE CREATIVITY?

What I'd like to do now is mention briefly some of the lessons that I feel we have learned from past experience of the PHM and current experience of the AALC program, and hope to apply to the future development of the SWATH ship concept. You'll notice that these lessons are stated in the form of questions. For example, who was responsible for what before there was a project? It may be, now that a project is established, the decisions which are critical to the life-cycle cost and the design configuration of the technology have already been decided. What means do we have for the ship designer to be personally identified with the project? I think of the Messerschmitt airplane, and I know who's responsible. I think of the FFG 7 and I'm not sure. Where in the system is the reward for excellence and what is the penalty for failure? It seems that we can design poor ships, and no one pays a price. It seems that if we design a good ship no one gets any credit. I think that's a serious deficiency.

I think it's necessary to have an independent assessment of the technology - every engineer knows that what he has written down on a piece of paper is merely a representation of what reality is all about. What he needs is an independent assessment. The essence of the scientific approach is to test your theories and ideas against the real world. That's what I mean by an independent assessment of the technology. We must have designers who are aware of the technology and are able to independently assess its validity as applied to the particular ship.

If the design is to be done by somebody whom I'll call a naval architect, then he does not operate alone - he operates with a team. The question is, who selects the team? Who controls the funds? But, I think the most important question that we have to ask if we intend to discuss the subject on how to improve the design of naval ships of the future is, where is the creativity?

I hope that this conference will help us to answer the management and political questions without losing this vital force.