THE PROMISE OF
ADVANCED NAVAL VEHICLES
FOR NATO

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I. INTRODUCTION

The NATO organization advises and coordinates member nations in their continuing efforts to strengthen a collective NATO defense. Under the NATO Naval Armaments Group (NNAG) all areas of Naval technology and operations are considered, The Special Working Group Six (SWG/6) was established in recognition of the potential of Advanced Vehicles (ANVs) for future NATO missions. Currently eleven of the sixteen NATO nations are members of SWG/6. Nine of these nations have been active in the development of SWATH, SES, Hydrofoils or ACVs. Following a major reorganization in 1980, the group produced two major products; the cooperative deployment and testing of the US SES 200 by six SWG/6 nations - and the development and assessment of seven ANV point designs for the ASW mission. In September of 1987, SWG/6 initiated a four-year program assessing the potential of ANVs for the NATO Patrol and MCM missions. Throughout this nine-year period, the group has worked together very effectively to transfer technology between nations and to reinforce national ANV programs.

This paper summarizes the genesis of SWG/6, defines its charter, describes its activities and products and provides some conjectures regarding its future activities. The collective technology base is described in Section III in terms of recent and current national programs of the SWG/6 nations. US Naval planners are well advised to take notice of these very extensive ANV activities of our NATO allies. Section IV summarizes the ASW design and assessment studies and Section V describes the strategy and status of the current Patrol/MCM program. Section VI concludes the paper with some thoughts on the "way ahead" for SWG/6.

II. THE HISTORY AND NATURE OF SWG/6

A. NNAG Groups

Figure II-1 illustrates the NNAG organization. It is composed currently of 6 Information-Exchange Groups IEGs and 10 Project Groups PGs reporting directly to the NNAG. SWG/6 and SWG/11 also report to the NNAG. The subgroups SGs and SWG/4 report to their parent IEGs. The IEGs are essentially technically oriented groups engaged in exchange of information and technology and the initiation of cooperative efforts in their charter areas. The SGs conduct more detailed studies in areas related to their parent groups. The SWGs deal with particularly complex issues, spanning the areas of several IEGs. Life spans of SWGs are determined by the requirements of the problem. SWG/6 is more operationally orientated than most of the other groups. At the completion of each SWG/6 program of work, a report is made to the NNAG along with proposals for the next program. The NNAG, at these reporting points, reviews the status and continued existence of the group, as well as the proposed program. The current Patrol/MCM program is scheduled to be completed in December of 1991. SWG/6 works most closely with IEG-6 (ship design) and has also established interfaces with IEG/3 (MCM) and SG-5 (seakeeping).

B. History of SWG/6

SWG/6 has existed, in various forms, since the late 1960s. The pre-1970 Exploratory-Group 2 (EXG/2) evolved into Project Group 6 (PG/6) NATO Hydrofoil Fast-Patrol-Craft. After a Memo of Understanding (MOU) was signed in 1977, the NATO PHM Steering Committee and Project Office were established. In 1973, SWG/6, concerned with Extended Roles for Hydrofoils in Naval Warfare, was born. SWG/6 completed a requirements document for an Open-Ocean Hydrofoil (approx. 700 tons) and was placed in a dormant status in 1978.

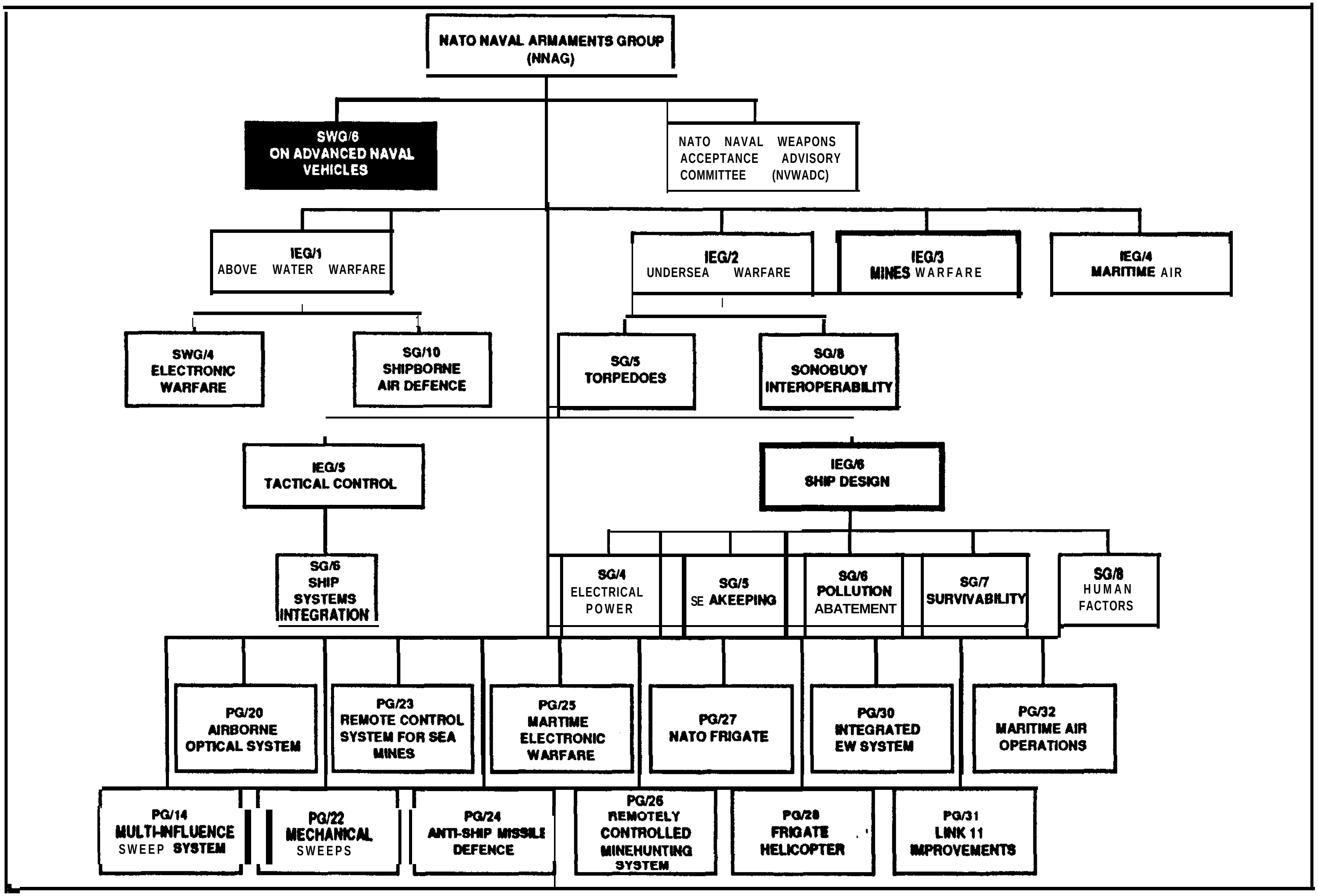


Figure II-l, NNAG Organization

Re-established, in its present form in 1980, the group was charged with examining means to exploit ANV technology in all NATO mission areas and with recommending specific areas of collaboration in the development and testing of ANVs and their subsystems. By 1983, the group had grown to seven nations (Canada, France, Germany, Italy, Spain, the UK and the US). Norway joined in 1987 and the Netherlands in 1988. Greece and Turkey joined in 1989.

The four-year ASW-study program was reported to the NNAG in December of 1987, at which time the Patrol/MCM program was initiated. The SES 200 deployment and test program, under a six-nation MOU (which included CA, FR, GE, SP, UK and US), was completed in 1986 and reported to the NNAG in 1987.

C. Modus Operandi

SWG/6 meets for 3 to 4 days, every six months (May and November). Meetings are normally at NATO headquarters in Brussels, but meetings have been hosted by Spain, France and the US, allowing on-site review of ongoing national programs and operational ANVs.

Following the normal NATO procedure, meetings are conducted in either French or English, with simultaneous translation. Agreements are made by consensus, not majority rule, strictly observing national sovereignty. SWG/6-study efforts are funded entirely by participating nations. NATO-infrastructure support is limited to the facilities and staffing of the Brussels meetings.

Documentation of the efforts to date has been comprehensive. The design and assessment reports are classified, and the SES 200 test results are restricted to participants in the trials program except when released by mutual consent. An agreement was reached allowing release of the ASW studies to concerned supporting contractors of each nation, subject only to the NATO classification restrictions.

Delegations vary in size from one to twelve members, depending on involvement of various military and civilian government engineers and supporting contractors.

The SWG/6 Chairman is elected by the national delegates. Since 1980, the Chairman has been from the US. Until 1988, the US Chairman was from OPNAV (OP321). The current Chairman is CAPT Arthur B. Shepard, Chief, Cutter Division, USCG. With current focus on Patrol and MCM missions, participation by the US Coast Guard has increased dramatically.

III. CURRENT ANV ACTIVITIES OF SWG/6 NATIONS

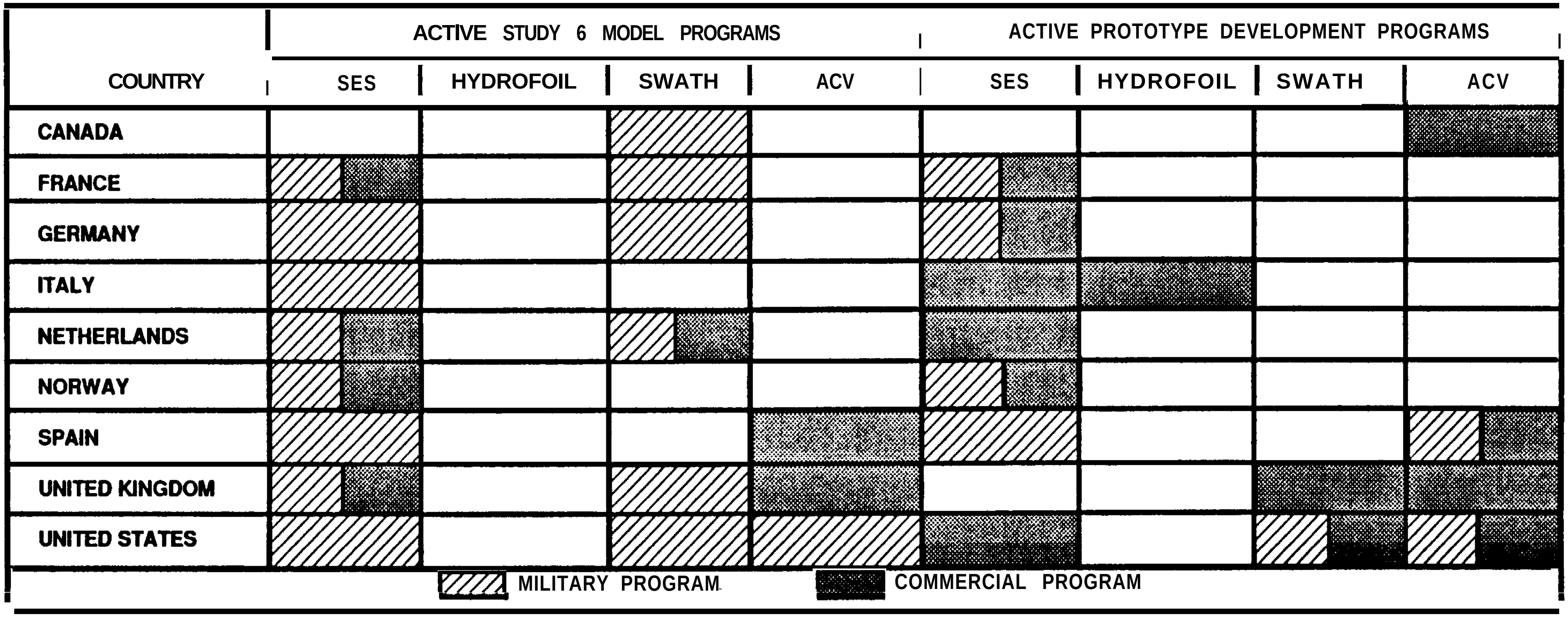
Nine of the eleven SWG/6 nations have been active, currently and historically, in the development and operation of ANVs.

Figure III-1 and Figure III-Z illustrate these activities with emphasis on current status. SES, Hydrofoils, SWATHs and Air Cushion Vehicles (ACVs) are addressed. There is also interest in, and recurring discussion of, fast catamarans in the SWG/6 meetings, with particular reference to developments in the Scandinavian countries. The group, however, has not classified the fast cats as ANVs.

A. Patterns

None of the nations, with the exception of Italy (and the Rodriguez Shipyard) is pursuing the development, or construction, of new hydrofoils. Several nations are operating commercial Rodriguez hydrofoils or Boeing Jetfoils, and Italy and the US are operating military-hydrofoil squadrons. Although two hydrofoil designs were included in the SWG/6 ASW studies, there is a current perception that, in spite of the superlative speed/seakeeping capabilities, the cost, technical risk and payload limitations of the platform preclude serious consideration of the development of new submerged-foil craft for. military missions. Surface piercing foils are affordable but speed and seakeeping are less attractive.

Of the four platforms, the capability and military/ commercial potential of ACVs is, perhaps, best understood. Only the ACV is capable of operations over land and ice, and its effectiveness in certain ferry operations is firmly established. The ACV is particularly attractive for MCM operations. As shown in the figures, Canada, Spain, the UK and the US are developing and building commercial and/or military ACVs.



COUNTRY	ACTIVE STUDY 6 MODEL PROGRAMS				ACTIVE PROTOTYPE DEVELOPMENT PROGRAMS			
	SES	HYDROFOIL	SWATH	ACV	SES	HYDROFOIL	SWATH	ACV
CANADA			▨					▩
FRANCE	▨ ▩		▨		▨ ▩			
GERMANY	▨		▨		▨ ▩			
ITALY	▨				▩	▩		
NETHERLANDS	▨ ▩		▨ ▩		▩			
NORWAY	▨ ▩				▨ ▩			
SPAIN	▨			▩	▨			▨ ▩
UNITED KINGDOM	▨ ▩		▨	▩			▩	▩
UNITED STATES	▨		▨	▨	▩		▨ ▩	▨ ▩

▨ MILITARY PROGRAM ▩ COMMERCIAL PROGRAM

Figure III-l, ANV Progress within NATO (Part 1)

COUNTRY	ACTIVE SHIP ACQUISITION PROGRAMS				IN-SERVICE ANVs			
	SES	HYDROFOIL	SWATH	ACV	SES	HYDROFOIL	SWATH	ACV
CANADA				▓				▨▓
FRANCE					▨			▓
GERMANY					▨▓			
ITALY	▓	▓			▓	▨▓		
NETHERLANDS								
NORWAY	▨▓				▓			
SPAIN						▓		
UNITED KINGDOM	▓			▓		▓	▓	▓
UNITED STATES	▓		▨	▨▓	▨▓	▨	▨▓	▨▓

▨ MILITARY PROGRAM ▓ COMMERCIAL PROGRAM

Figure 111-2, ANV Progress within NATO (Part 2)

With the exception of Italy, Norway and Spain, all of the SWG/6 nations have active SWATH-study or model-test programs. Spain is also renewing an earlier interest in SWATH. Only the US and the UK (SWG/6) are actually building and operating SWATHs. SWATH design/technology is reasonably mature and the potential of the concept for patrol and auxiliary missions, where seakeeping is a driving requirement, is well understood. Canada, the UK and the US are exploring the potential of SWATH for combatant missions, primarily ASW.

All of the nations, with the exception of Canada, have active study or development programs for SES. Four of the nations are building and operating SESs. Although the SWG/6 ASW-SES designs ranged from 1300 to 1900 tons, the nations have considered this too large a step from the largest SES currently in service (the 200-ton US SES 200) and are focusing on the smaller patrol and MCM SESs of the current SWG/6 program. There is extensive activity worldwide in the development and operation of SES fast ferries to about 700 tons.

B. Canada

Historically, Canada has actively pursued the development of hydrofoils. Figure III-3 is the 200-ton BRAS **D'OR,** commissioned in 1968. The Canadian Coast Guard is currently operating several BHC built ACVs including a recently delivered AP1:88. Smaller commercial ACVs are also manufactured in Canada.

At this time, Canada has no ANV hardware program but is studying SWATH for several missions including search and rescue and ASW. Canada and the Netherlands are continuing a long standing bilateral SWATH study project, which has included model tests and software development. Canadian exchange officers have participated in the development of US SWATH-design tools resulting in a significant technology transfer from the US.

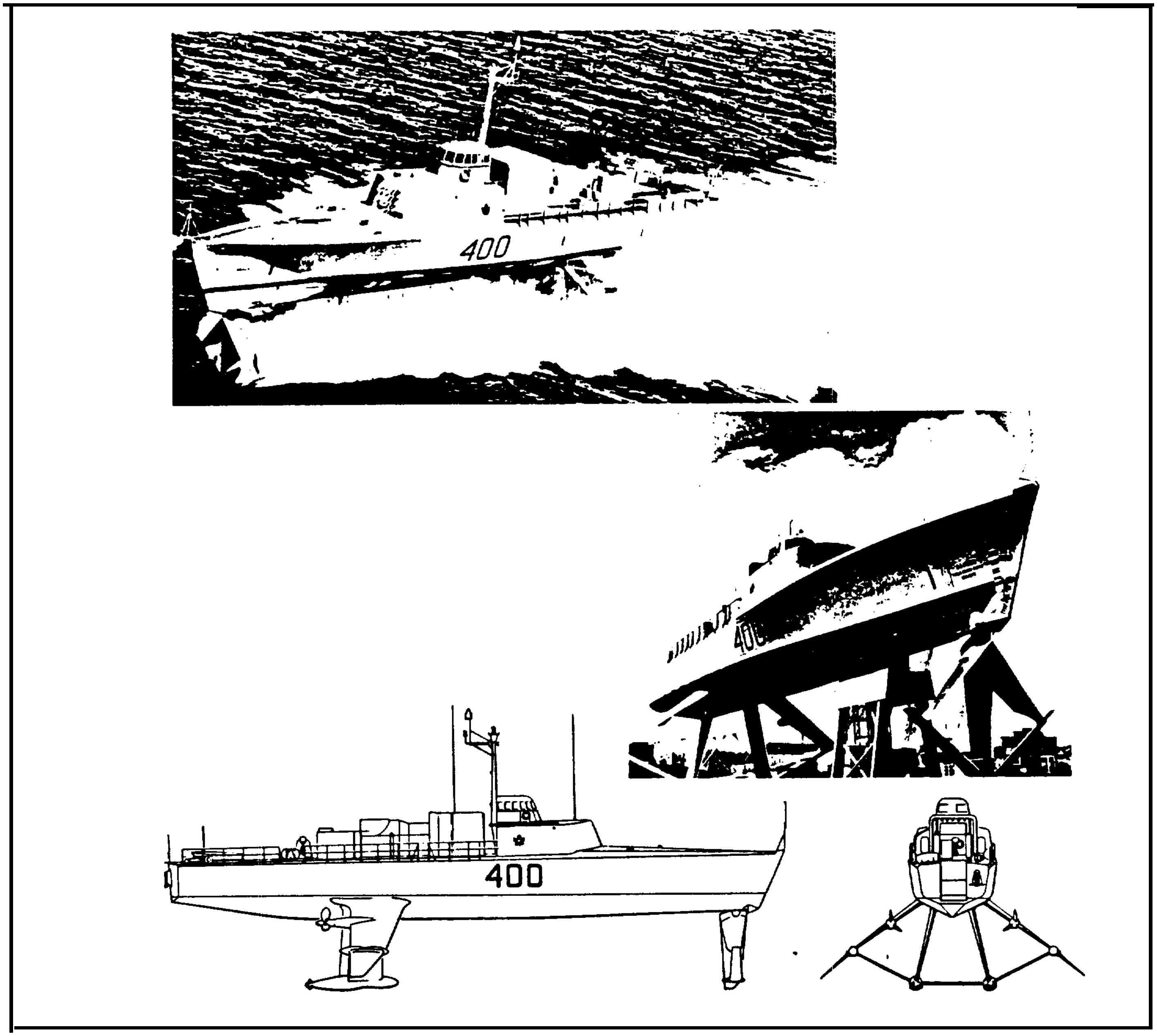


Figure 111-3, BRAS D'OR

Canada developed both hydrofoil and SWATH solutions for the SWG/6 ASW studies and, in 1988, completed studies of SWATH platforms for the MCM mission.

C. France

Historically, French firms have, along with the UK, led in the development of ACV ferries. Figure III-4 is the Sedam N500, which operated on the cross-channel route from 1978 to 1983. There are no current ACV development efforts in France. France has also studied the potential of hydrofoils for naval missions.

Recent studies, including model tests, have explored the potential of the **"Argo"** tri-hull configuration, similar in principle to SWATH.

France has firmly established an SES development program leading, in the late 1990s, to a 1250-ton Corvette, the EOLES (Figure 111-5). An EOLES variant design was developed for the SWG/6 ASW studies. During 1987 the 5-ton test craft MOLENES (Figure 111-6) was evaluated. The next step is the 250-ton AGNES 200, currently under construction at the CMN shipyard in Cherbourg. The AGNES200 (Figure 111-7) will begin testing in the Spring of 1990. Exchange of test results with the re-engined US SES200 has been proposed.

D. Germany

Blohm and Voss is currently testing their 160-ton prototype SES "Corsair" (Figure 111-8). This craft, of GRP sandwich construction with surface-piercing tunnel propellers, will be marketed for both military and commercial service.

Germany has completed a Preliminary Design for a SWATH Research Ship of around 3500 tons.

Germany and the US collaborated on the development of the US/G SES Corvette for the SWG/6 ASW studies.

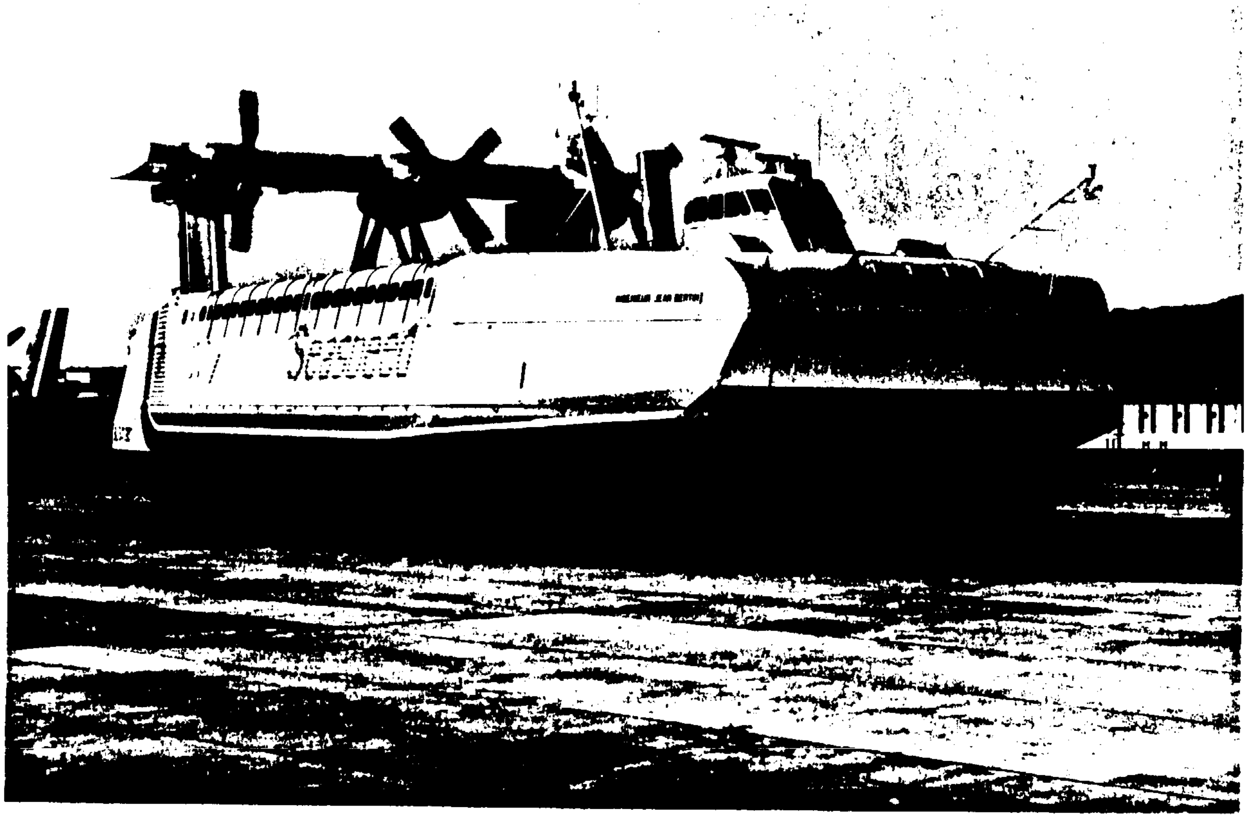


Figure III-4, SEDAM N500

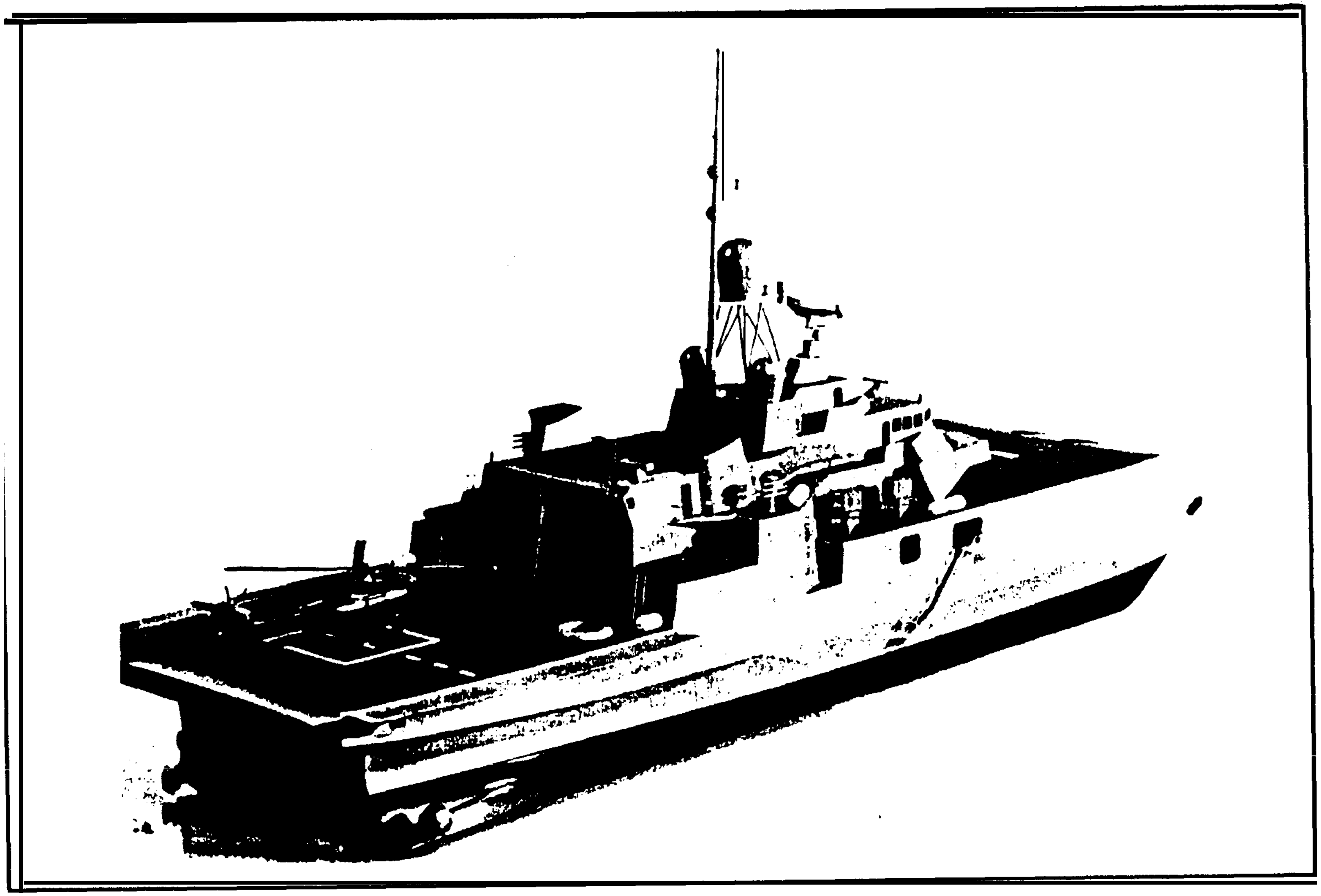


Figure III-5, EOLES

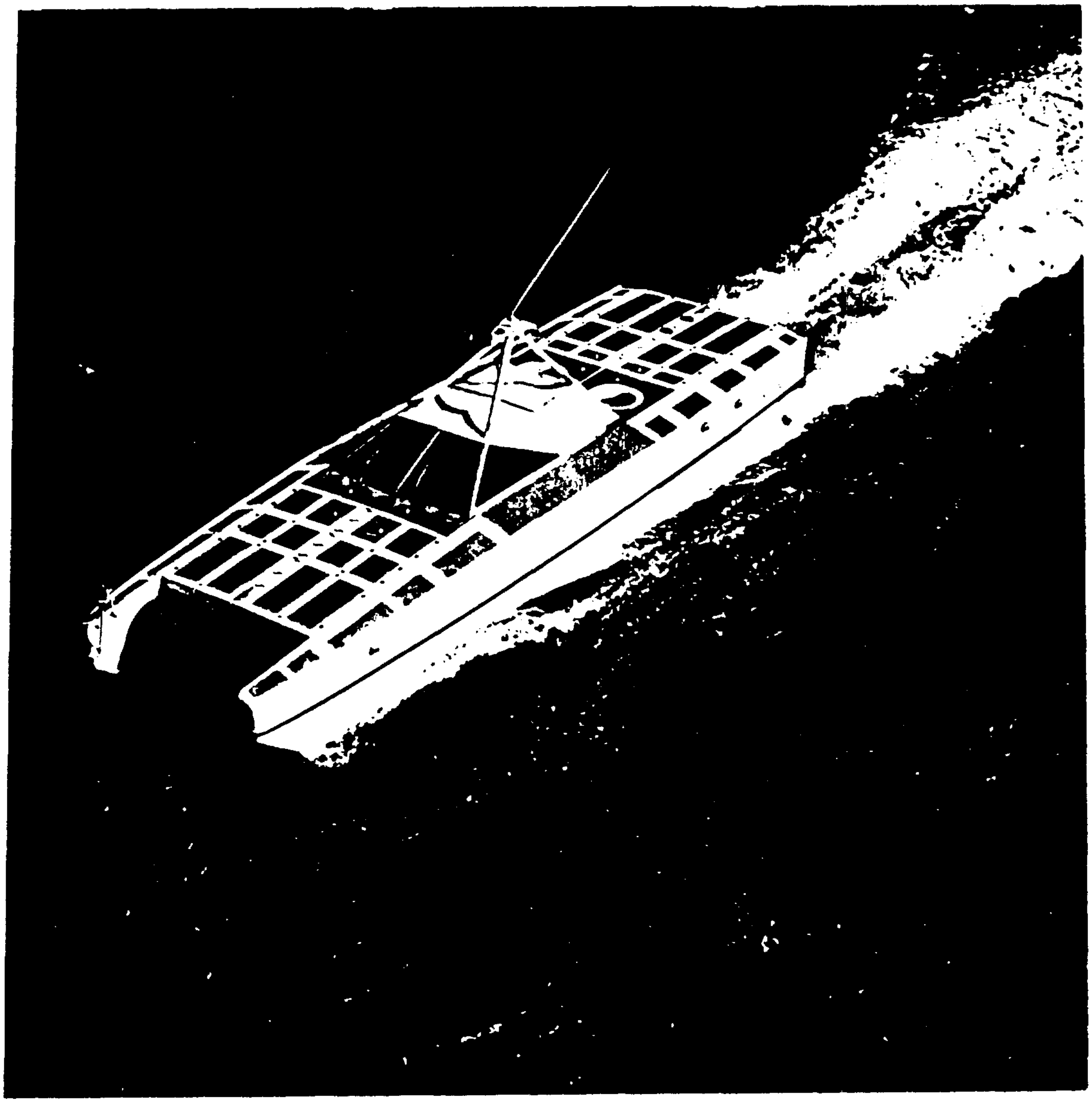


Figure 111-6, MOLENES

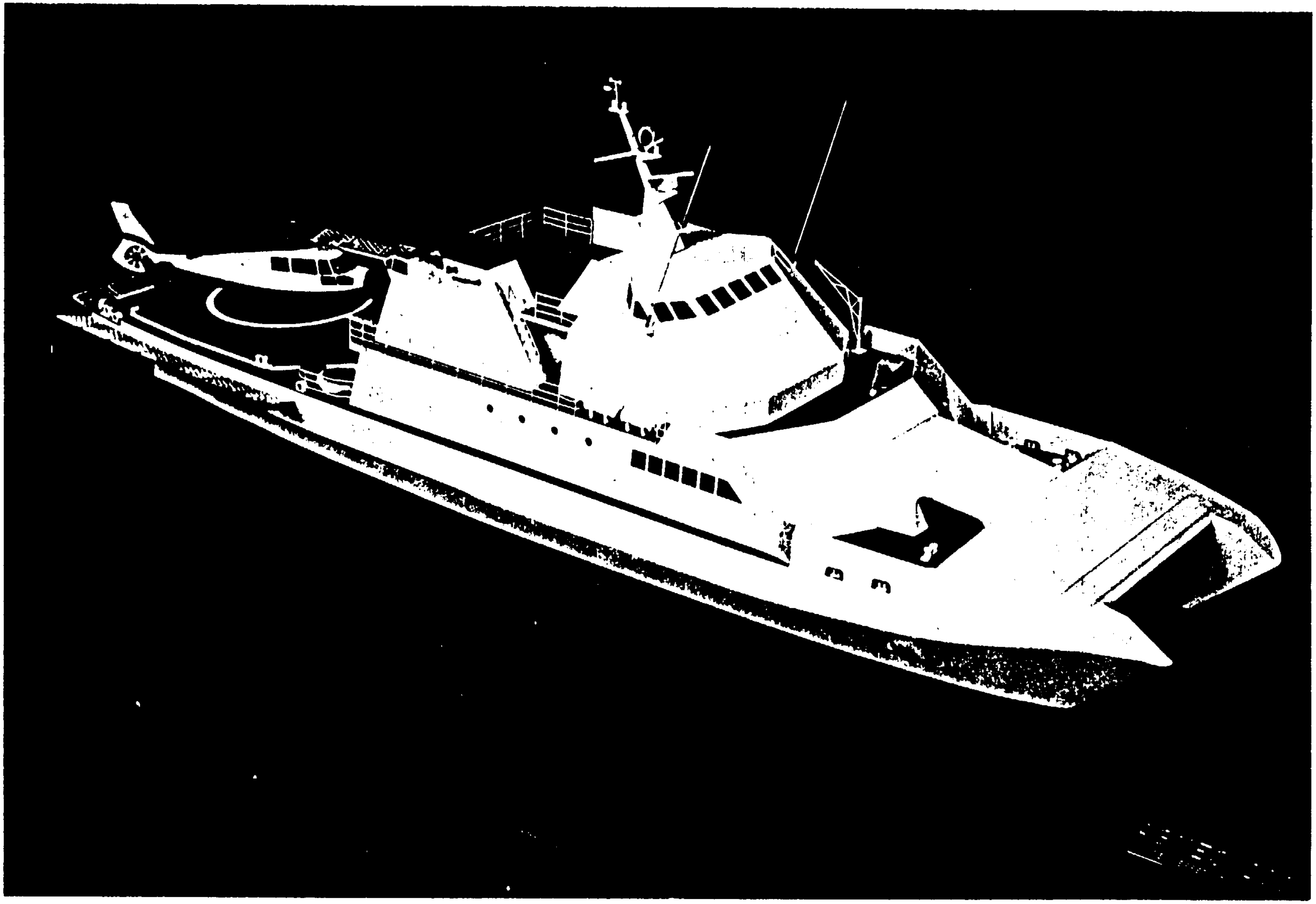


Figure III-7, AGNES 200

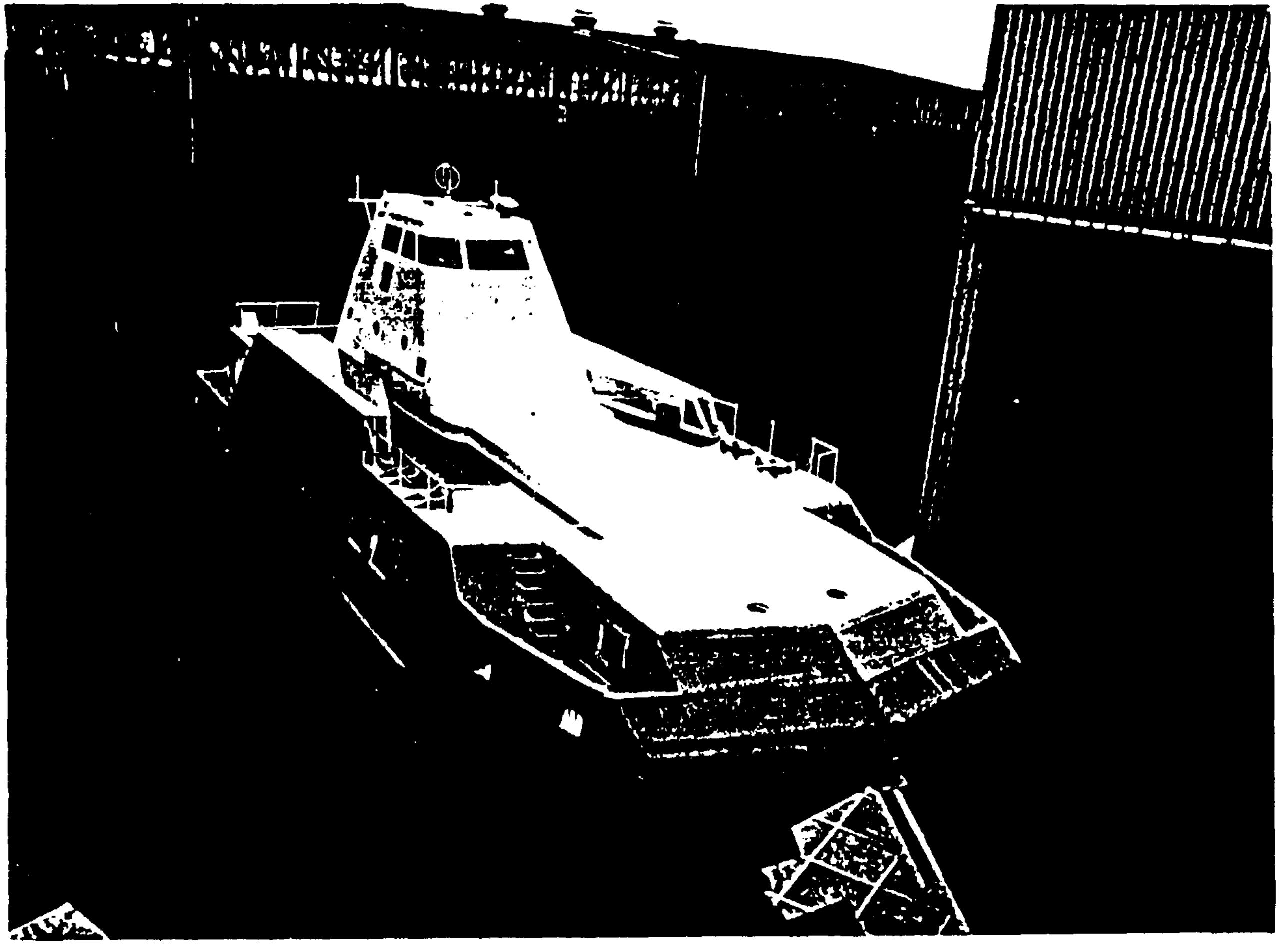


Figure III-8, Blohm und Voss SES

In April 1987, MTG in Hamburg, under **a German** MOD **contract,** completed the Contract Design for a 740-ton SES fast test craft (Figure 111-9). This steel, waterjet, gas-turbine design was developed with US support, and David Taylor Research Center is currently testing the SES 700 model under a Foreign Military Sales Agreement. Acquisition funding for the SES 700 is programmed for 1993.

E. Italy

Since 1956, the firm of Rodriguez Cantiere Navale in Messina has delivered over 150 commercial hydrofoils ranging in displacement from 30 to 120 tons (RHS-200 - Figure III-l0). Italy is currently operating **a** squadron of six 70-ton NIBBIO-class hydrofoil attack craft (Figure 111-11). These six craft were delivered between 1981 and 1983 and were based on the Sparviero prototype, which was derived, by Alinavi, from the Boeing Tucumcari (PGH-2).

An Italian firm has evaluated a 2.5 ton SES manned model and has designed a 26-meter SES fast ferry and a 400 ton passenger/car ferry. Another firm is designing a 700 ton SES passenger/car ferry.

The Italian Ministry of Defense(MOD) is currently conducting studies of SES potential for the patrol/attack mission. Italy is developing the Design Requirement for the Enforcement of Laws and Treaties (ELT) mission in the current SWG/6 Patrol/MCM studies.

F. Netherlands

The Netherlands has been active in SWATH studies and development for many years. Figure III-12 is the 1400 ton DUPLUS (now US "TWIN DRILL") built in 1969. Bilateral SWATH studies continue with Canada.

Figure III-9, SES 700

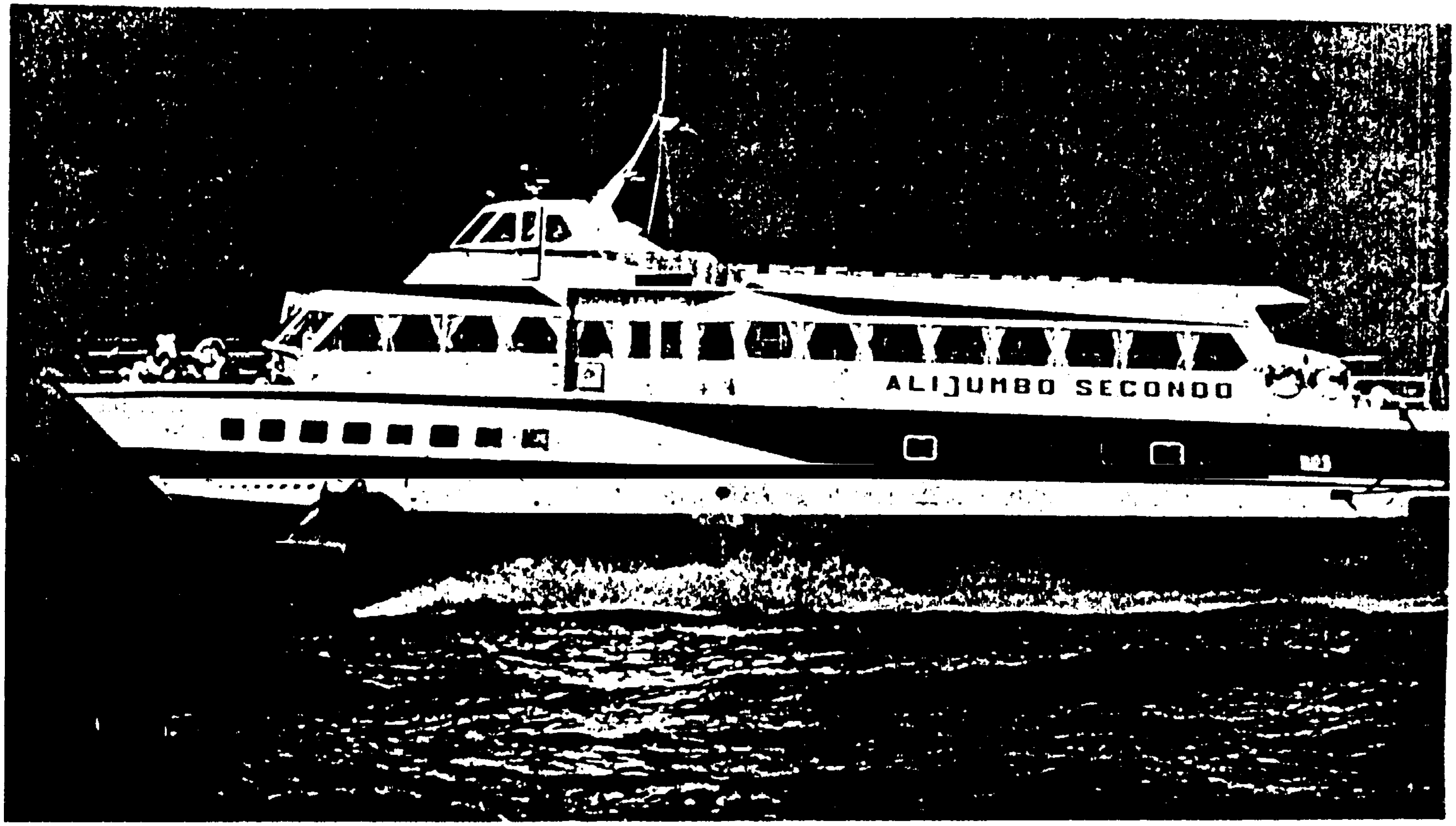


Figure III-10, RHS200

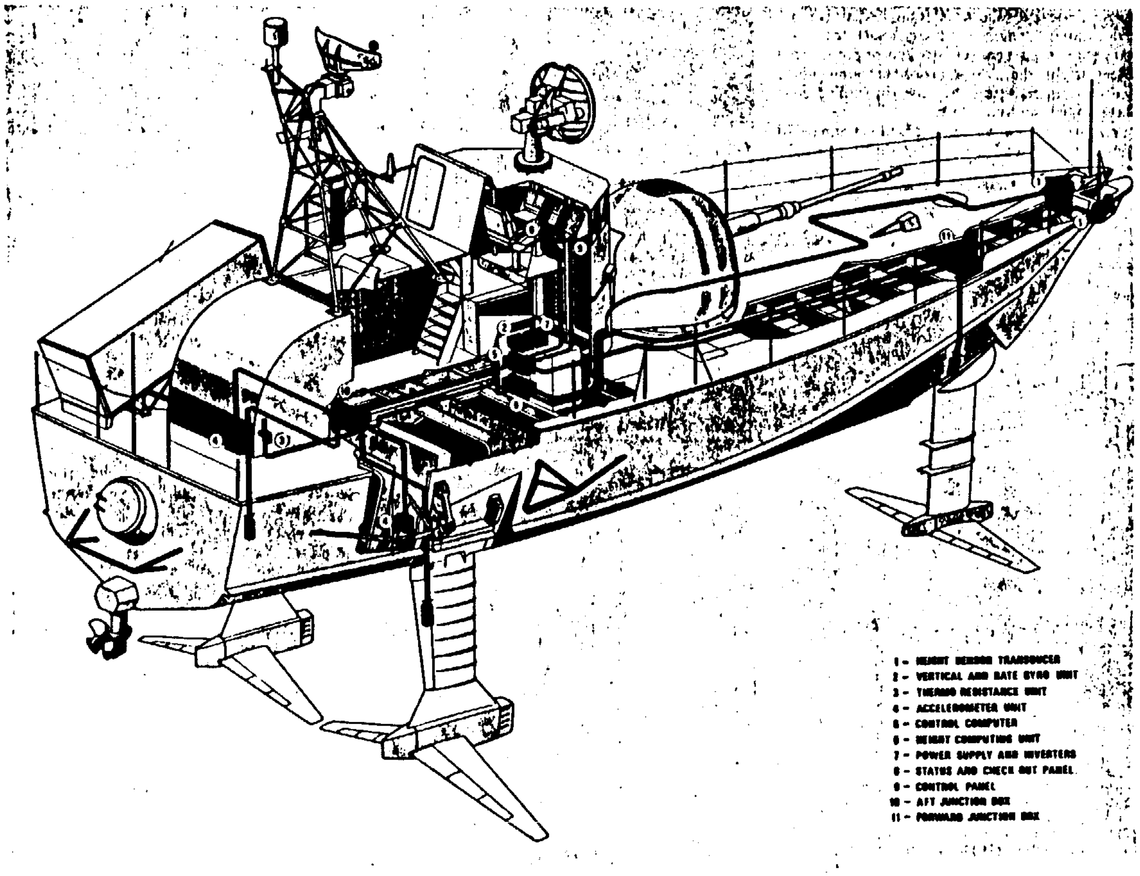


Figure III-11, NIBBIO

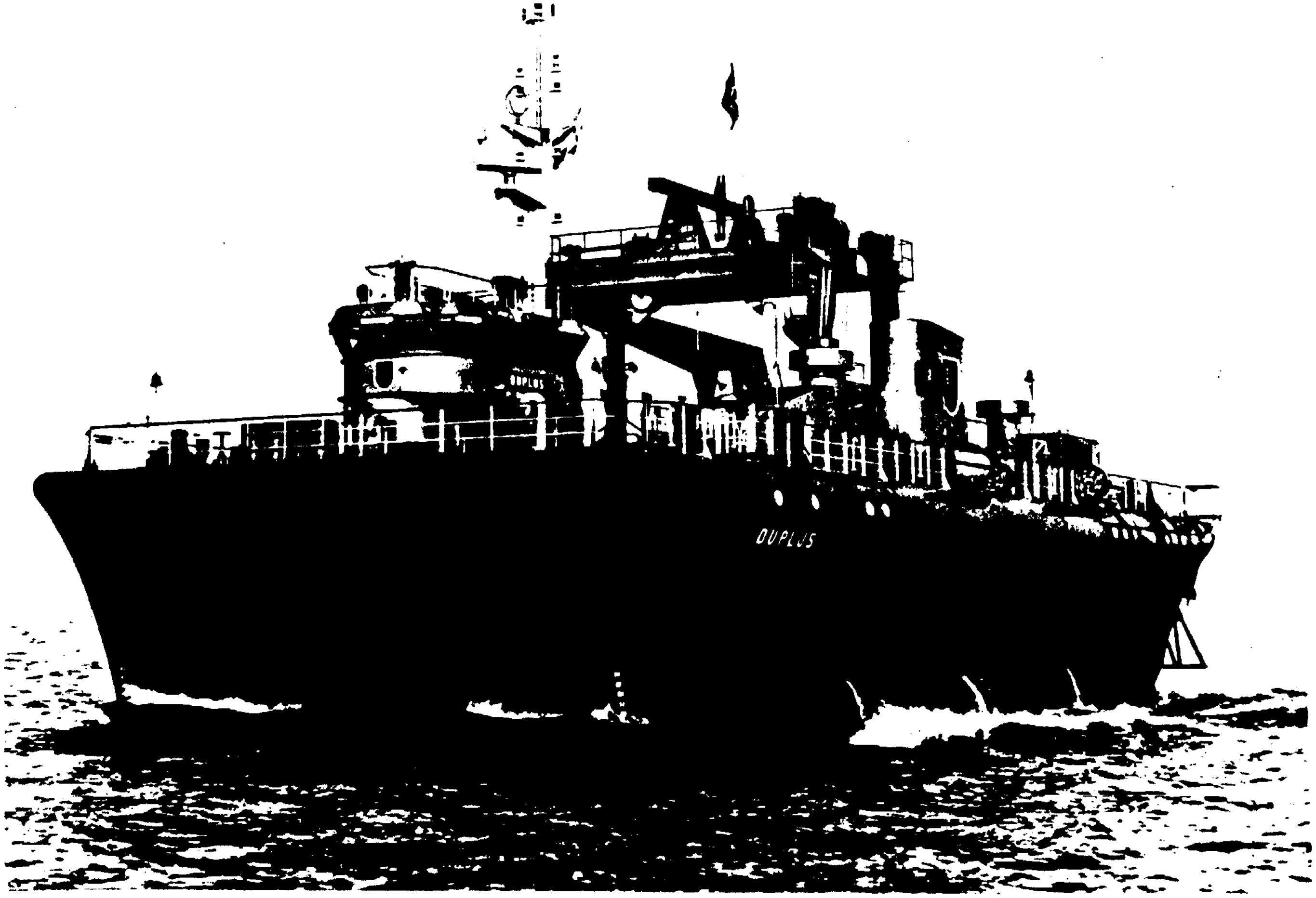


Figure III-12, DUPLUS

Currently two firms, LeComte and Royal Schelde/Weismuller, are marketing designs for SES fast ferries, with military variants.

G. Norway

The firms of Cirrus (design) and Br.AA (construction) have, under contract or have delivered, 9 SES including two 120 ton "NORCAT" type (Figure 111-13) and five 150-ton "VIRGIN BUTTERFLY" type fast ferries. All are GRP with diesel engines and KaMeWa waterjets. Passenger/car ferries of 200 and 500 tons, capable of 40 to 50 knots are also under study. The Norwegian MOD is studying SESs for future fast-attack craft.

Following an intensive evaluation of alternative platforms, the SES was selected by the MOD for construction of ten MCM vessels. Proposals for detail design and construction are being evaluated. Construction is GRP-PVC sandwich.

H. Spain

The 36-ton amphibious assault ACV, VCA-36 is successfully completing evaluation with good prospects for a production buy.

SWATH studies have been conducted and interest in this platform continues.

An SES program has been established and a design for a 350-ton, 50-meter patrol craft has been developed (Figure 111-14) by a CHACONSA/BAZAN team. A 14-ton manned model proof-of-concept (Figure 111-15) is currently completing evaluation.

Spain is developing the Design Requirements for the Fast-Attack Craft (FAC) design for the current SWG/6 Patrol/MCM studies.

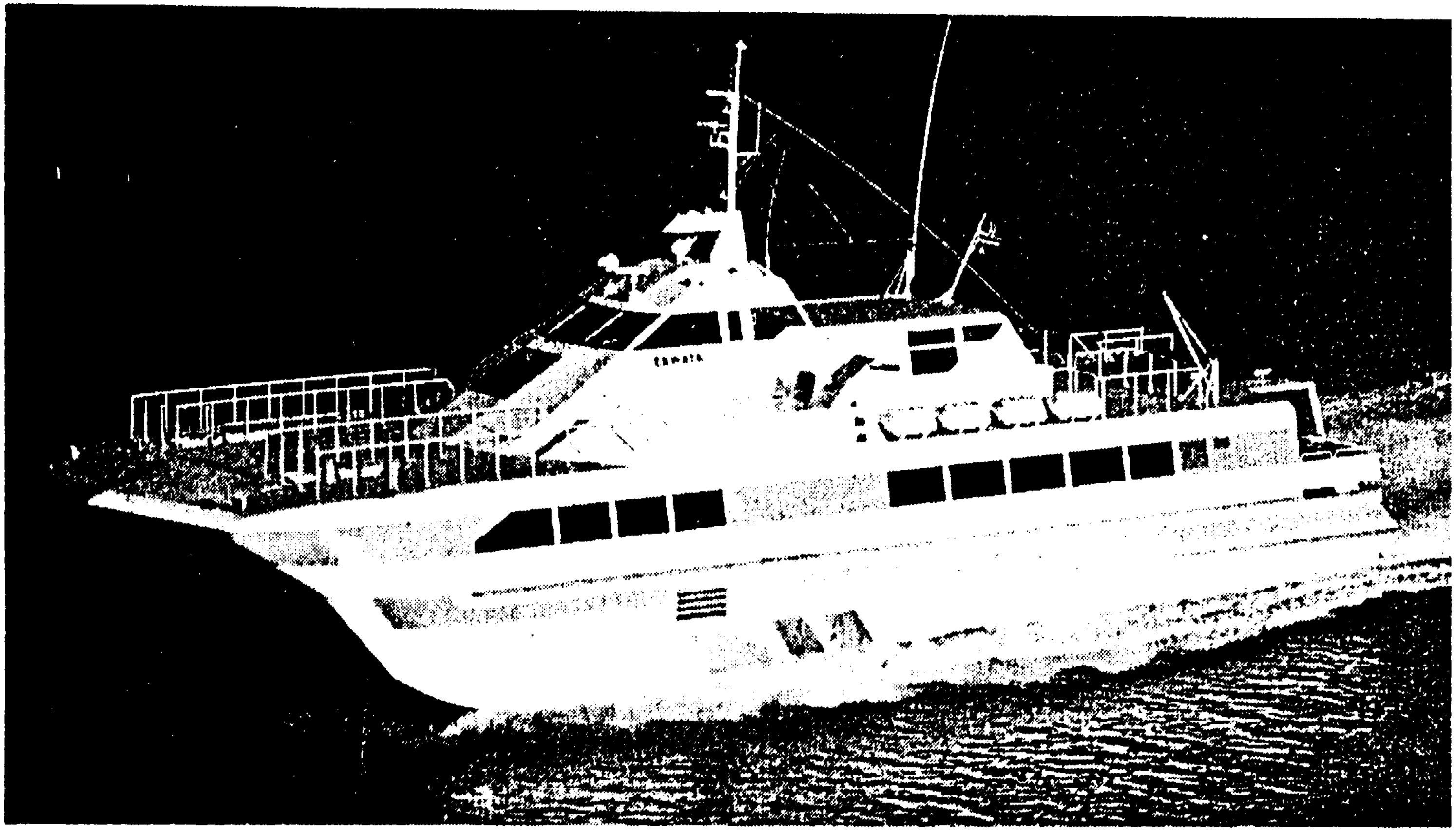


Figure III-13, NORCAT

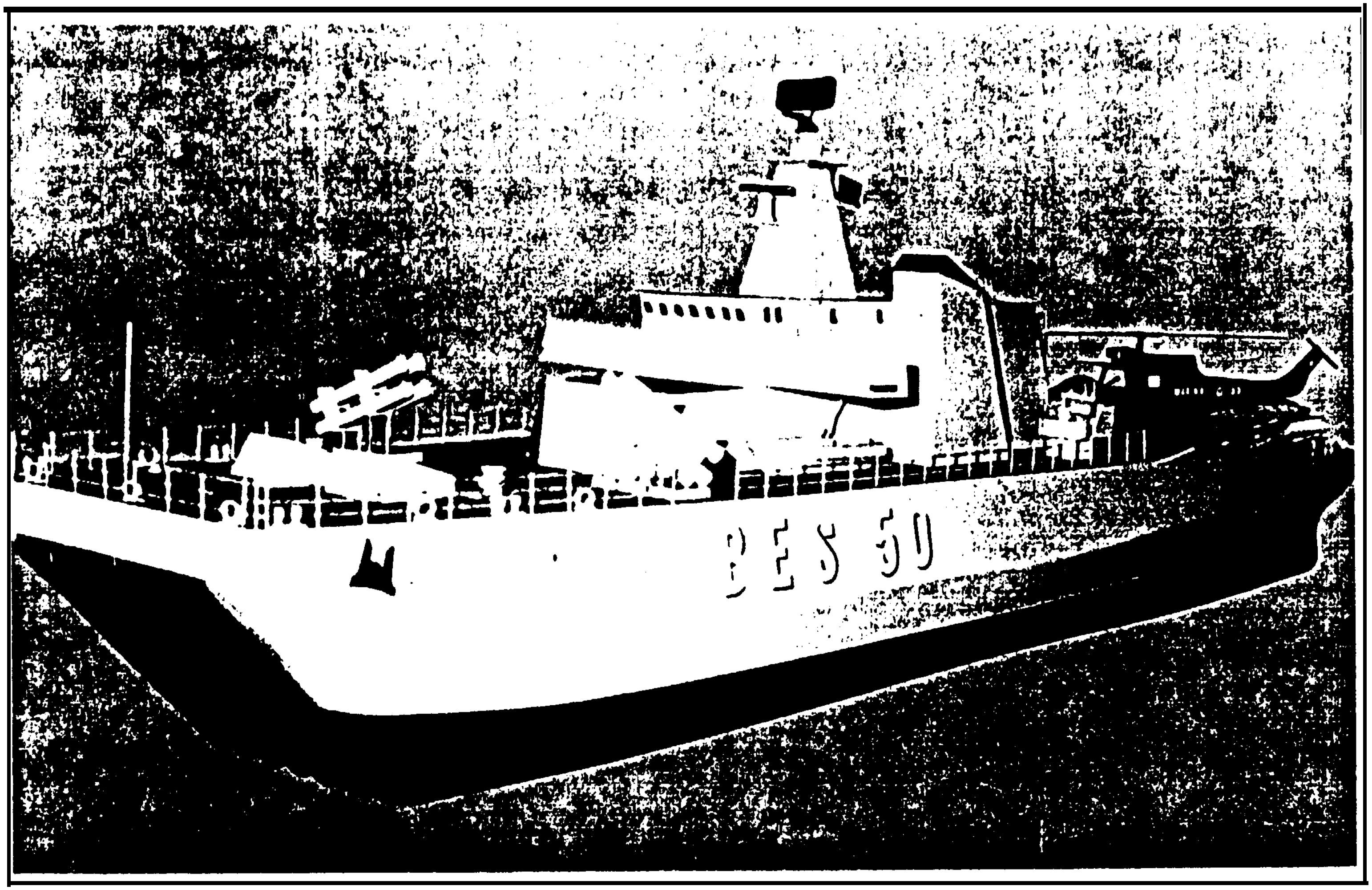


Figure III-14, BES-50

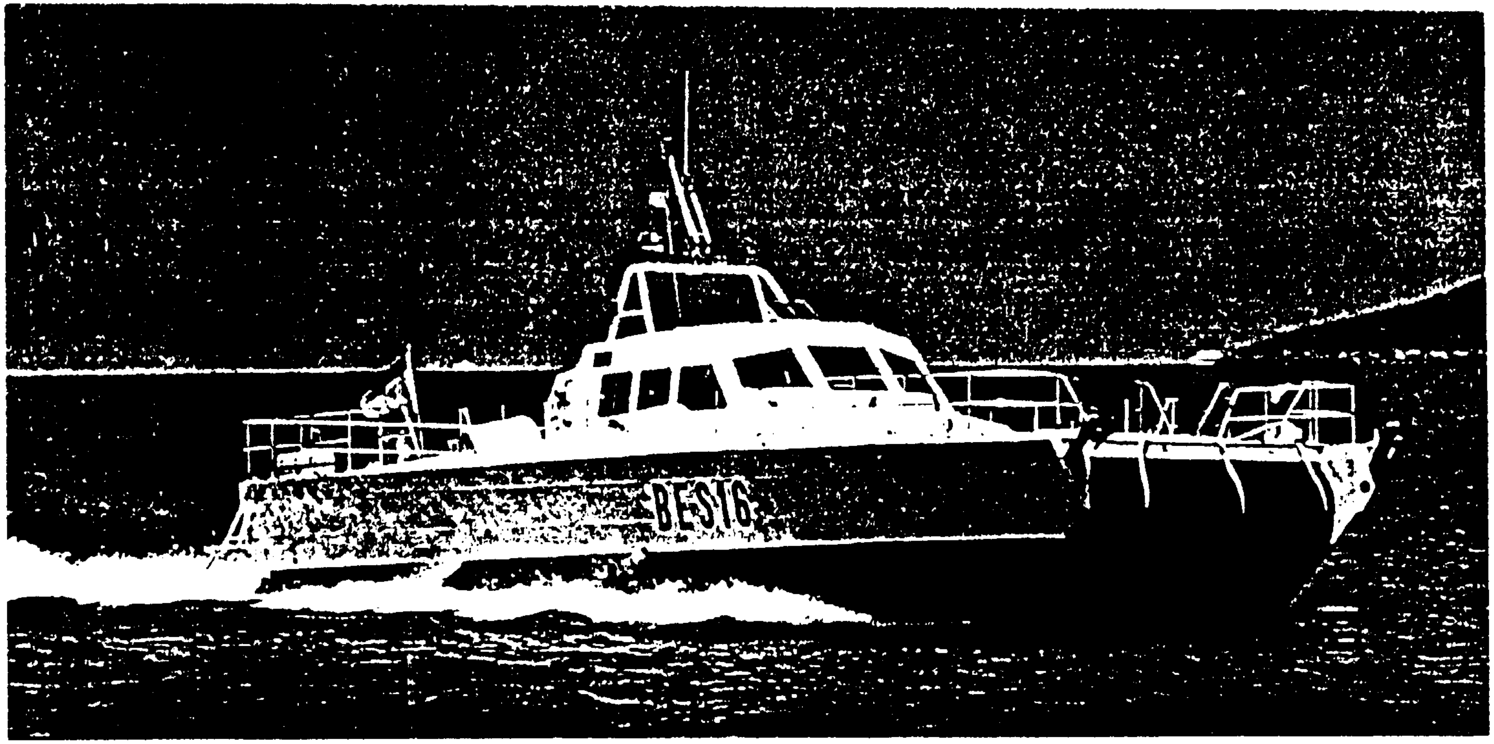


Figure III-15, BES-16

I. United Kingdom

The ACV concept originated in the United Kingdom in the 1950s with the first commercial ferry operation inaugurated in 1962. The subsequent development of the SRN series (Figure III-16), the BH-7 and, most recently, the AP1:88 (Figure 111-17) has been well documented. Various military roles have been evaluated by the Royal Navy, with particular emphasis on the MCM mission.

The UK's military hydrofoil experience has included the patrol evaluation of the Boeing jetfoil HMS SPEEDY for offshore patrol.

The UK launched the first commercial-SES ferry service in 1962, and by 1985 Hovermarine had delivered over 1.00 GRP SES (HM-218/221/527, Figure 111-18) with speeds of about 35 knots and displacements to 105 tons. Recent design studies include larger variants accommodating 400 passengers.

The UK MOD has conducted extensive SWATH studies and model tests over the past three years. Auxiliary and combatant missions have been considered. Yarrow has constructed a small experimental SWATH and a 20-ton commercial fishing SWATH has been built. Fairey Marine is completing a 180-ton, 30-aknot, SWATH passenger ferry to operate from Madeira to a neighboring island.

The UK is currently collaborating with the US on the feasibility-level design and assessment of a single-mission ASW SWATH.

The UK developed a GRP SES Corvette for the SWG/6 ASW studies and is currently the lead on the MCM studies in the ongoing program.

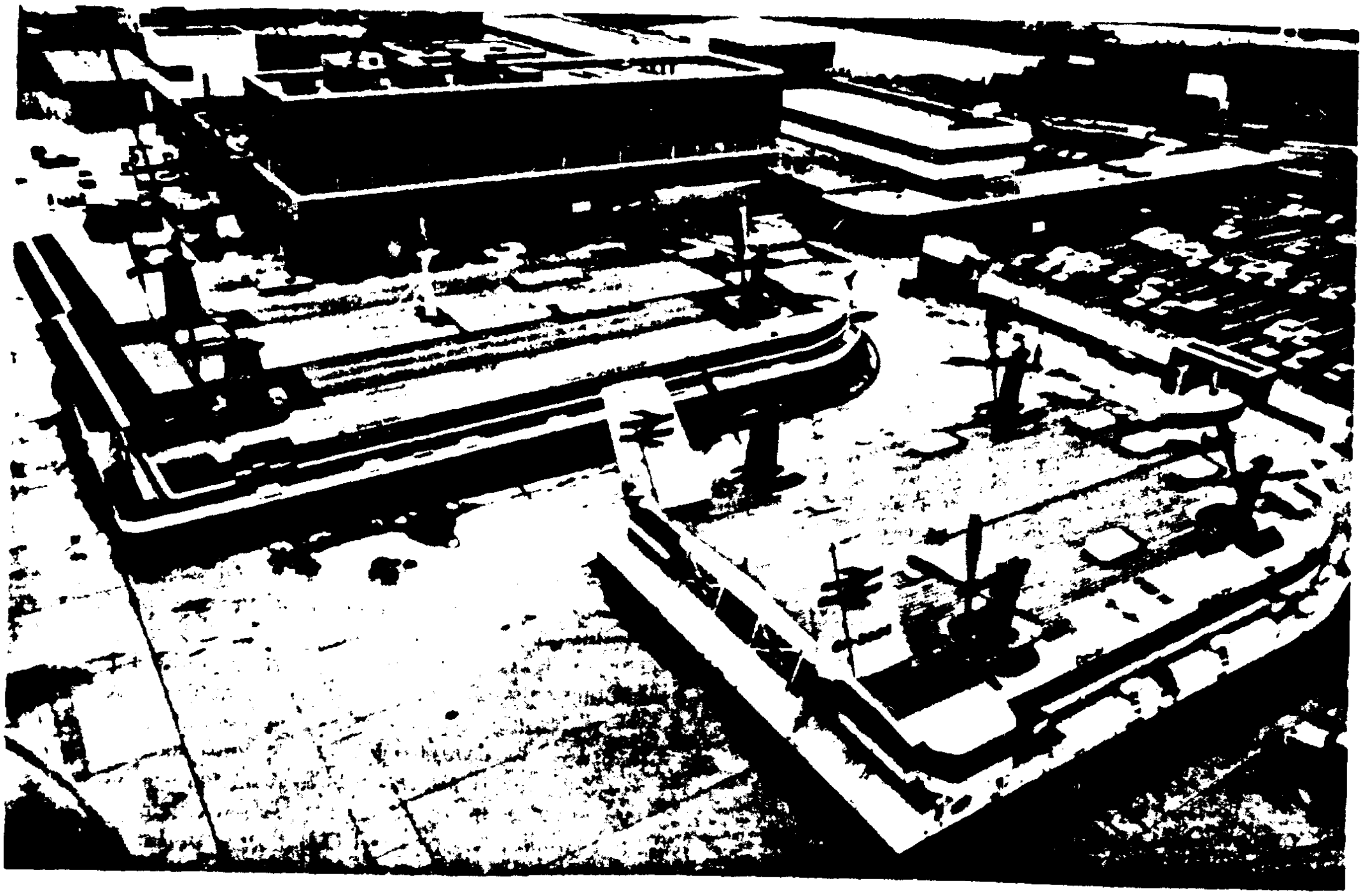


Figure 111-16, SRN-4, Mk 1 & 3

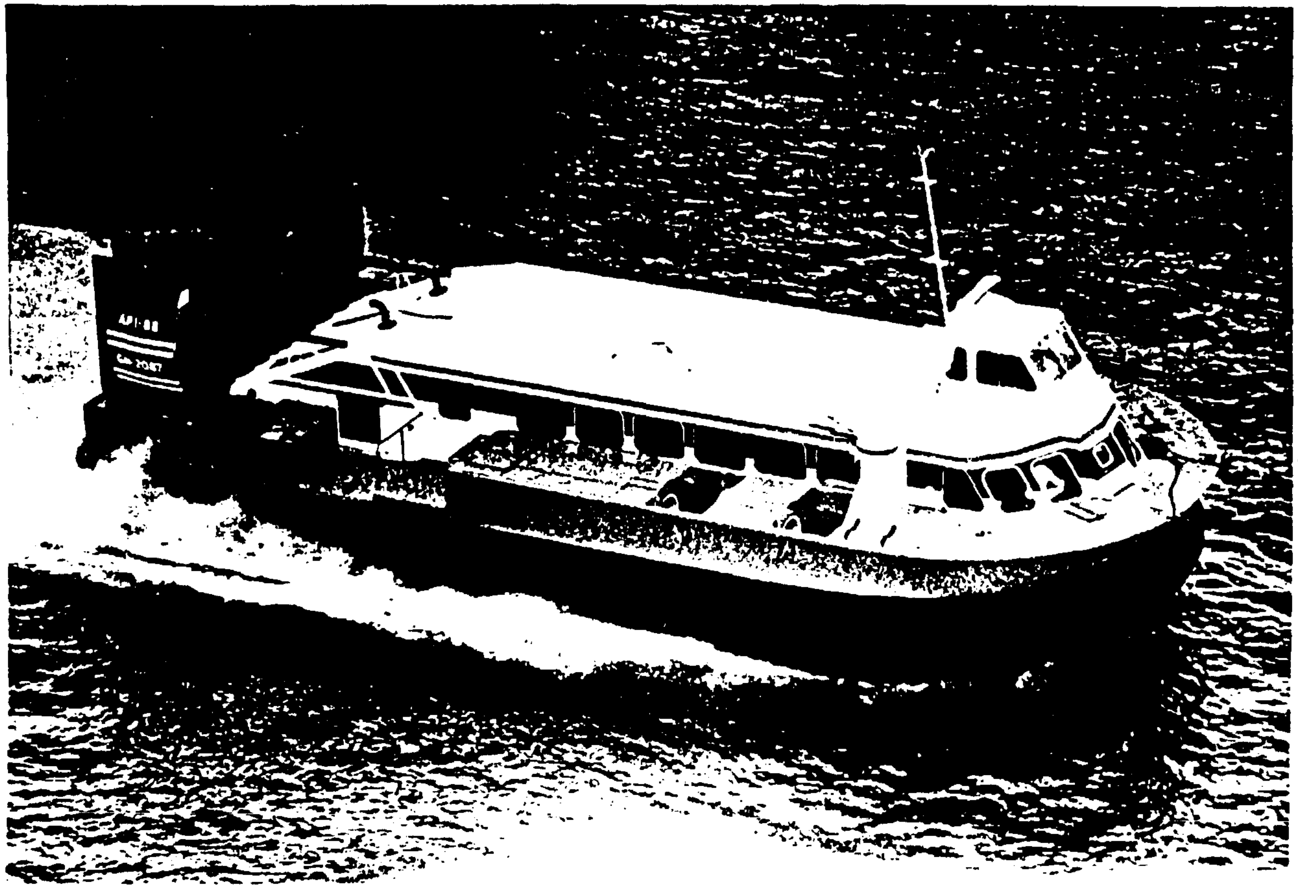


Figure III-17, AP1:88

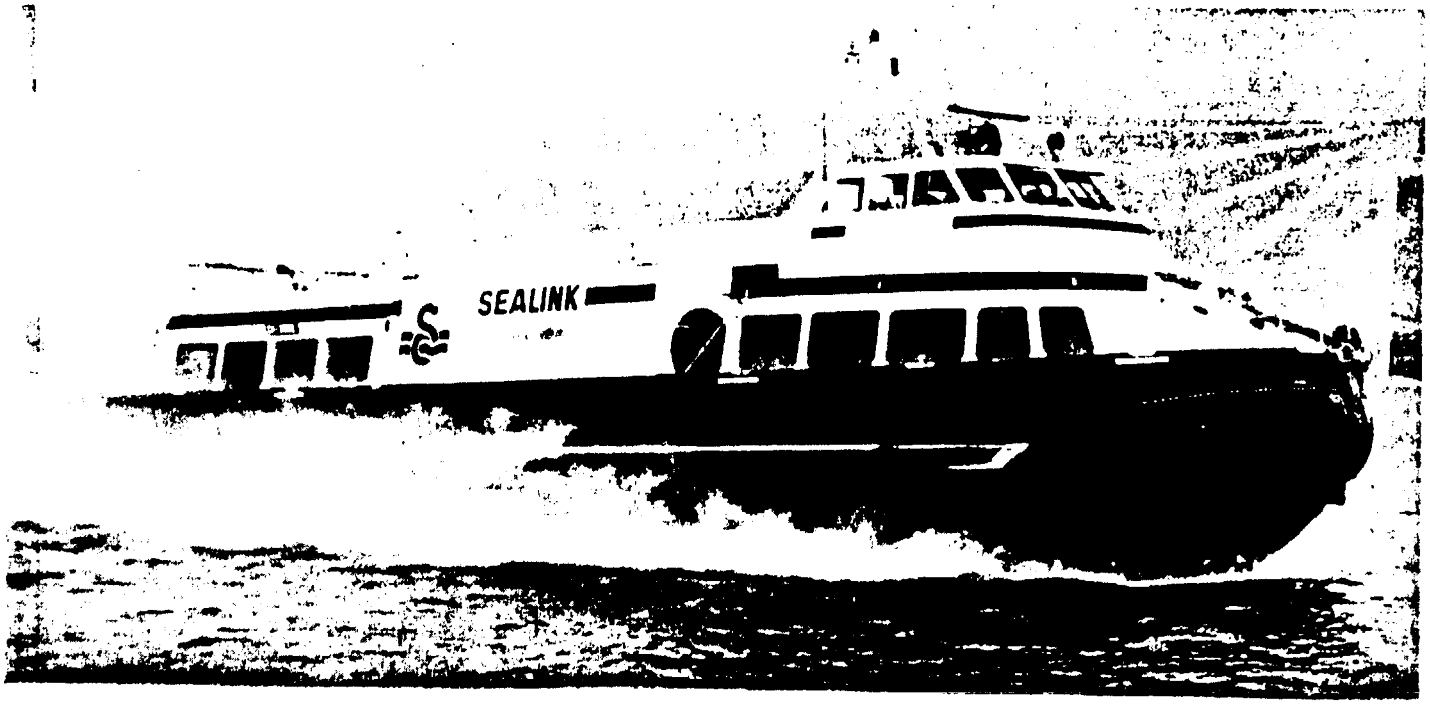


Figure III-18, HM 527

J. United States

The US has an extensive background in analysis, R&D, model testing and prototype development for all four ANV types which has been amply documented, notably in the February 1985 ASNE JOURNAL special edition on modern ships and craft which addresses , activities of all nations.

Currently, there is no hydrofoil analysis or development activity in the U.S., but the PHM squadron (Figure 111-19) is operating very effectively out of Key West and follow-ons to these craft are periodically considered.

The acquisition program (Figure III-20) for the LCAC continues and studies have been made of MCM and arctic variants of these craft. Studies of new design arctic ACVs have also been accomplished.

The U.S. Army is also gaining valuable experience with their fleet of 26 LACV-30 ACVs and is planning to issue RFPs to industry in early 1990 for the construction of a heavy-lift ACV designated LAMP-H.

The 219-ton SWATH KAIMALINO is still in operation and the first of four 3400-ton SWATH TAGOS-19 class ships (Figure 111-21) will begin trials in 1989. The contract design for the 5365-ton TAGOS-23 is complete. Studies of combatant SWATH applications continue, including the joint US/UK single-mission ASW SWATH study.

The SES 200 (Figure 111-22) ride-control system has been updated and is being evaluated. In 1990 the SES 200 will be re-engined and fitted with KaMeWa waterjets resulting in a 45-knot capability.

SES design studies continue, most recently including a

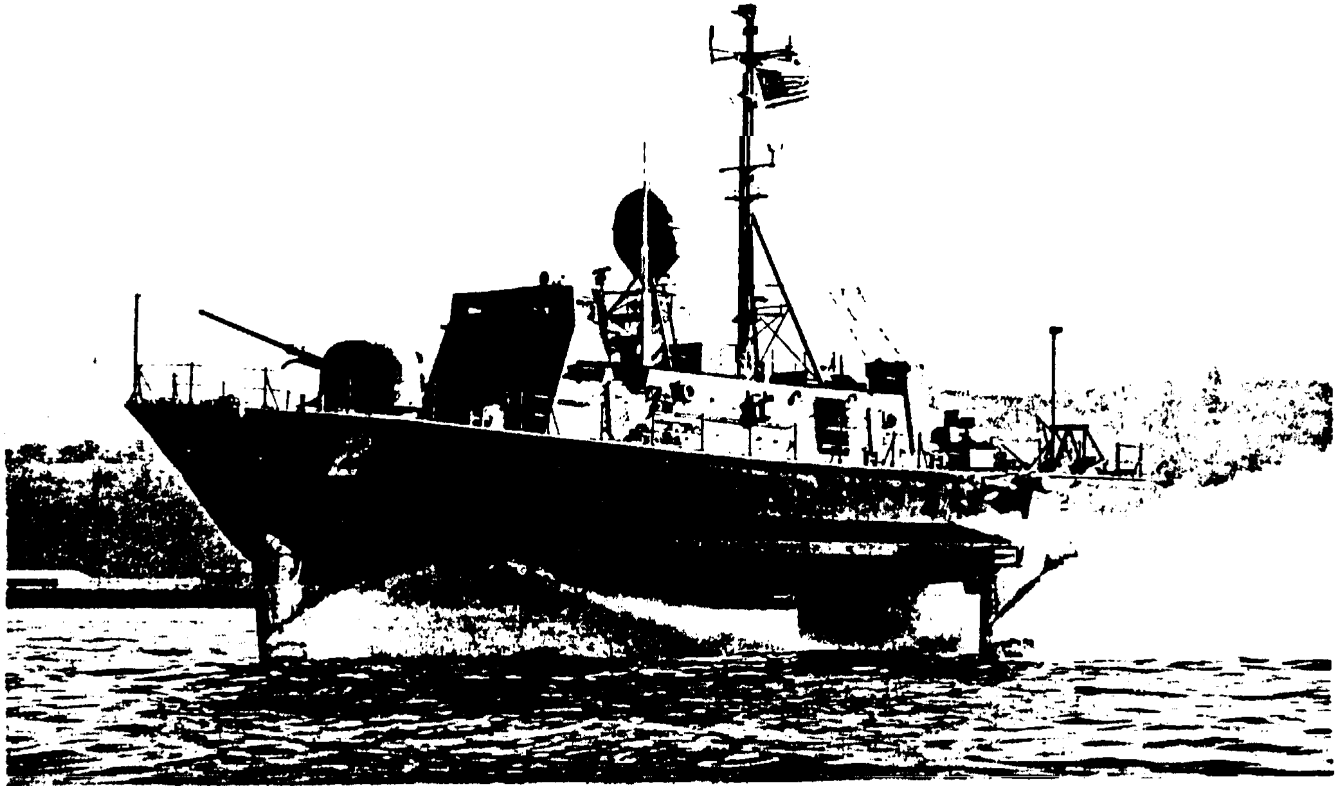


Figure III-19, PHM - 2

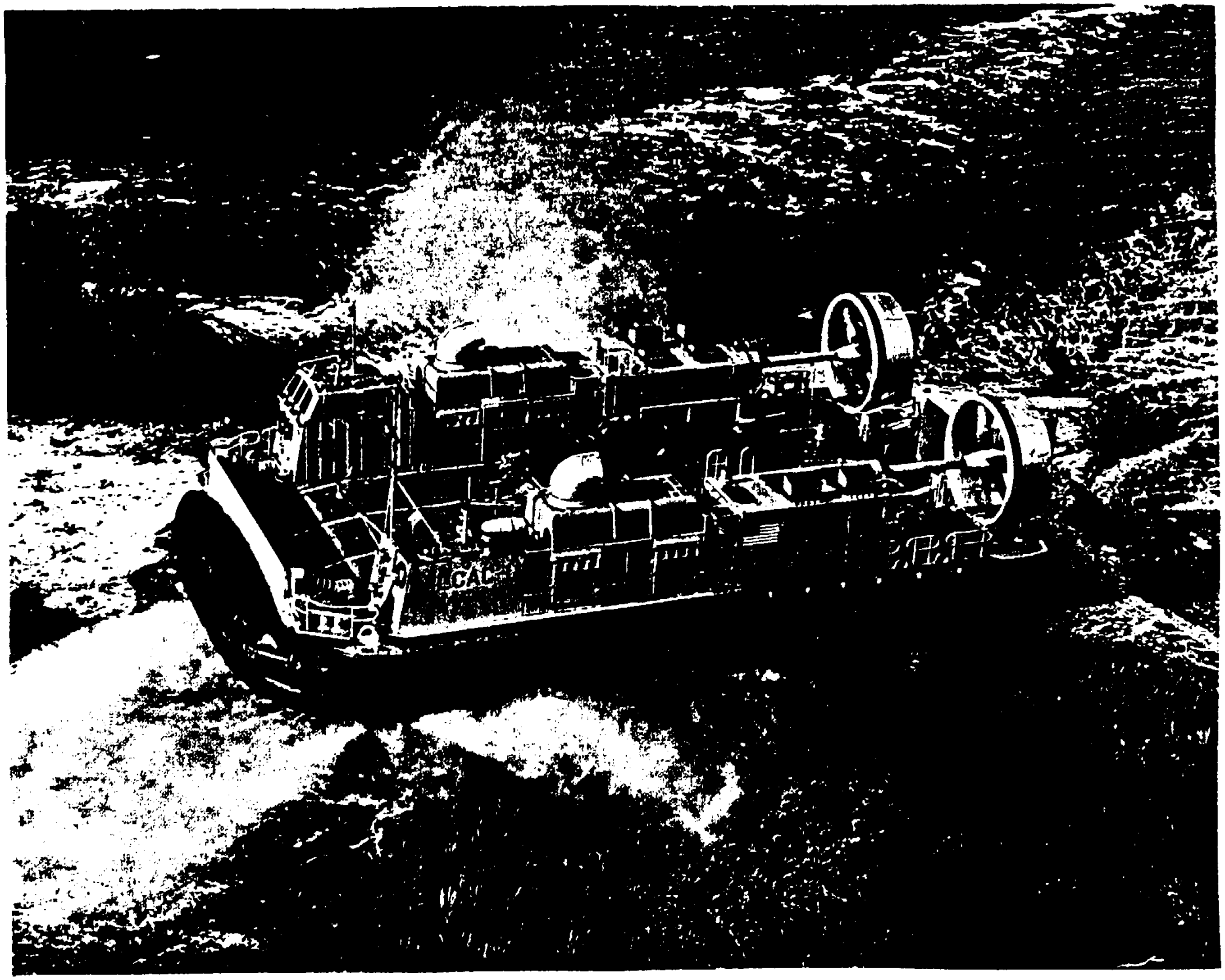


Figure III-20, LCAC

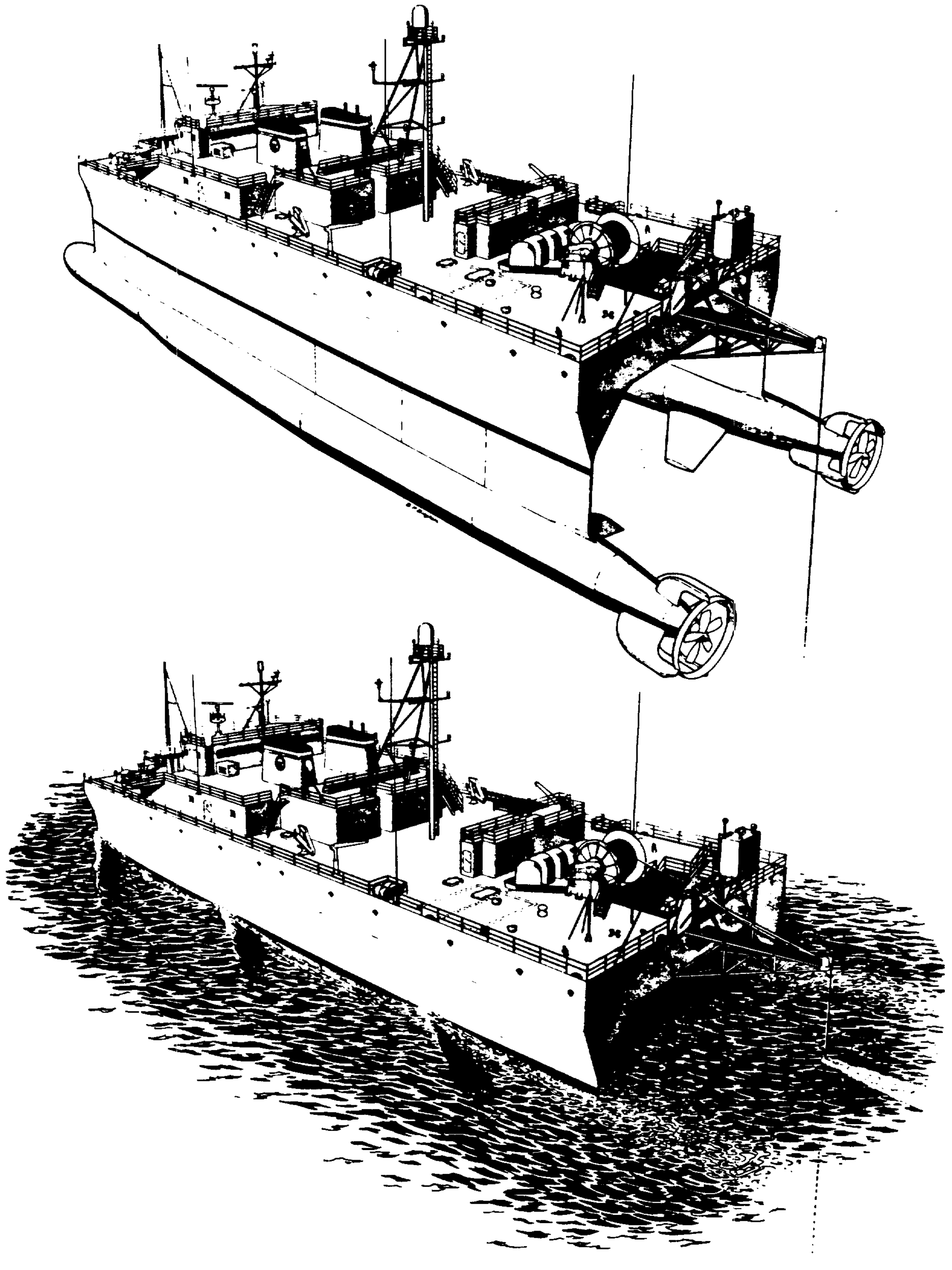


Figure 111-21, T-AGOS-19

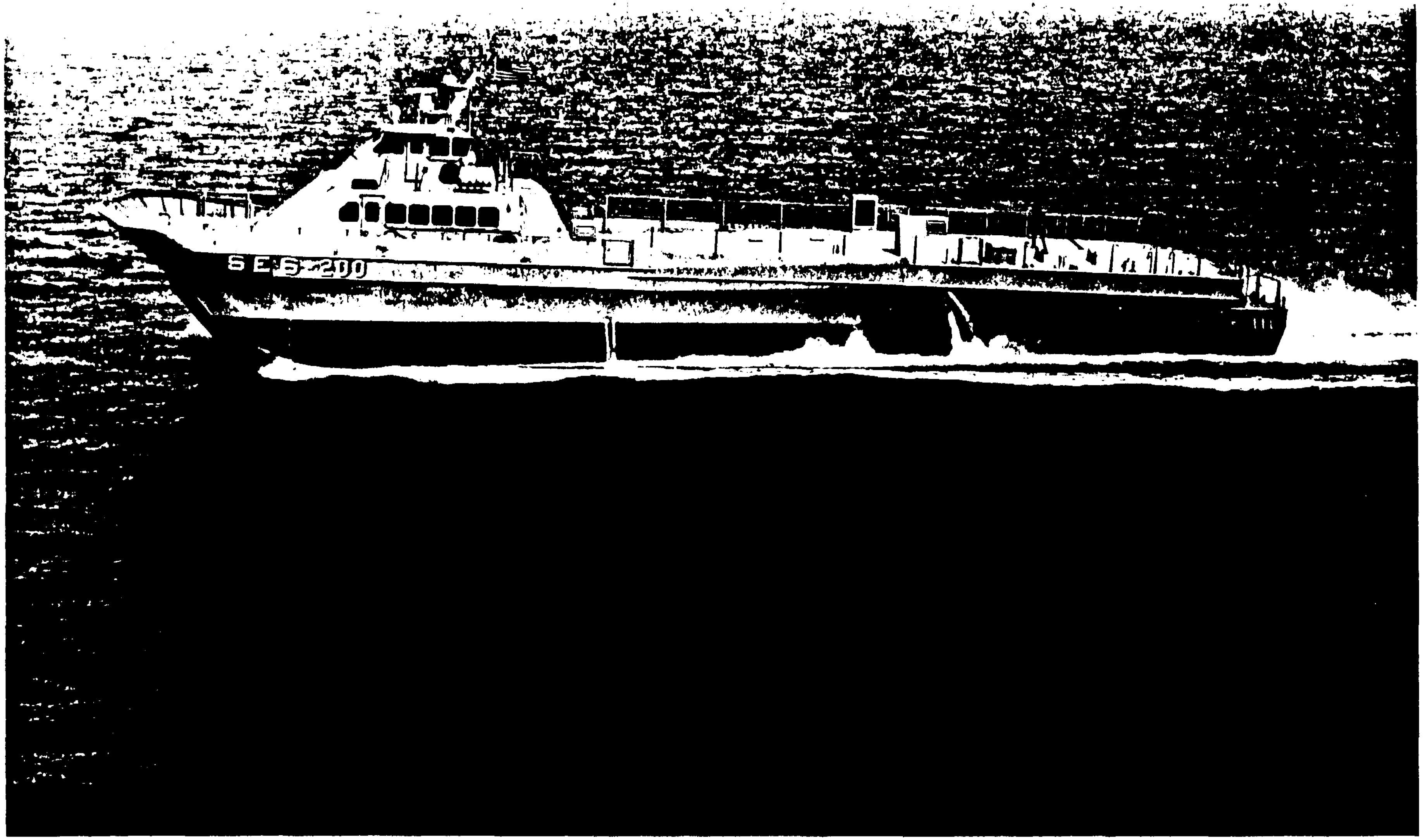


Figure 111-22, SES 200

20,000-ton SES sealift ship. A Hydrofoil design and a US/G SES design were developed for the SWG/6 ASW studies. The US has completed Design Requirements for the SWG/6 Harbor Coastal-Patrol Craft design and feasibility studies are underway.

IV. THE ASW STUDIES

A. Objectives

NATO needs surface ships capable of operating year round in support of the ASW mission without restriction from weather conditions. The attributes of a number of advanced naval vehicle (ANV) types indicate that their application to this mission may be highly beneficial in the areas of speed, seakeeping, flexibility of arrangements, and operability when compared to conventional monohulls. Furthermore, costs at a total force level, as opposed to an individual ship level, could be equal or less than for conventional hull forms.

In 1984 SWG/6 initiated a program to evaluate the use of ANVs in supporting the overall NATO ASW mission. A series of pre-feasibility point designs were developed for am ASW corvette using hydrofoil, SES, and SWATH configurations. The potential and desirability of these designs were then assessed against the conventional ASW monohull in the following areas:

- o Military value for the ASW mission.
- o Development, acquisition, and operating costs.
- o Technical feasibility and technical development needs assuming an initial operational capability (IOC) after the year 2000.

The assessment effort concentrated on technical feasibility rather than mission feasibility although the value of high speed and improved seakeeping to specific mission elements was investigated.

B. Approach

The overall effort began with the development of a series of Outline NATO Staff Targets **(ONST's),** one for each type of hull form being considered, i.e., hydrofoil, SES, and SWATH. Although each ONST addressed a common threat, a similar mission, and comparable environmental conditions, the differing attributes of each hull form required that the ONST's exploit their unique characteristics. The ONSTs were prepared by Canada (SWATH), France (SES), and the United States (Hydrofoil) and could be considered analogous to a set of top-level requirements oriented towards a particular hull form.

The ONSTs were followed by the development of a common Study Guidance **Document** to help maximize commonality in design criteria, approaches, etc; however, because each country developing a design was free to use its own criteria, design approaches, shipbuilding technology, etc., the major benefit of the Study Guidance Document was to define terms and the required content of the design reports.

During 1985 the following five pre-feasibility point designs for an ASW corvette/frigate were initiated:

1. SES - UK
2. SES - France
3. SES - U.S. with input from the Federal Republic of Germany
4. SWATH - Canada with input from the U.S.
5. Hydrofoil - U.S.

The assessment was subsequently expanded to include another SES from Spain and a low-cost hydrofoil from Canada.

The approach to the assessment is illustrated in Figure IV - 1. This assessment was oriented towards evaluating each point design against the requirements in the ONST's, comparing each design to the conventional approach, and evaluating technical risk. This assessment was not intended to be a competition among the point designs: however, it did point out the various national approaches taken including differences in ship design and construction practices.

With respect to the effectiveness assessment, operational capabilities in a number of mission areas were evaluated

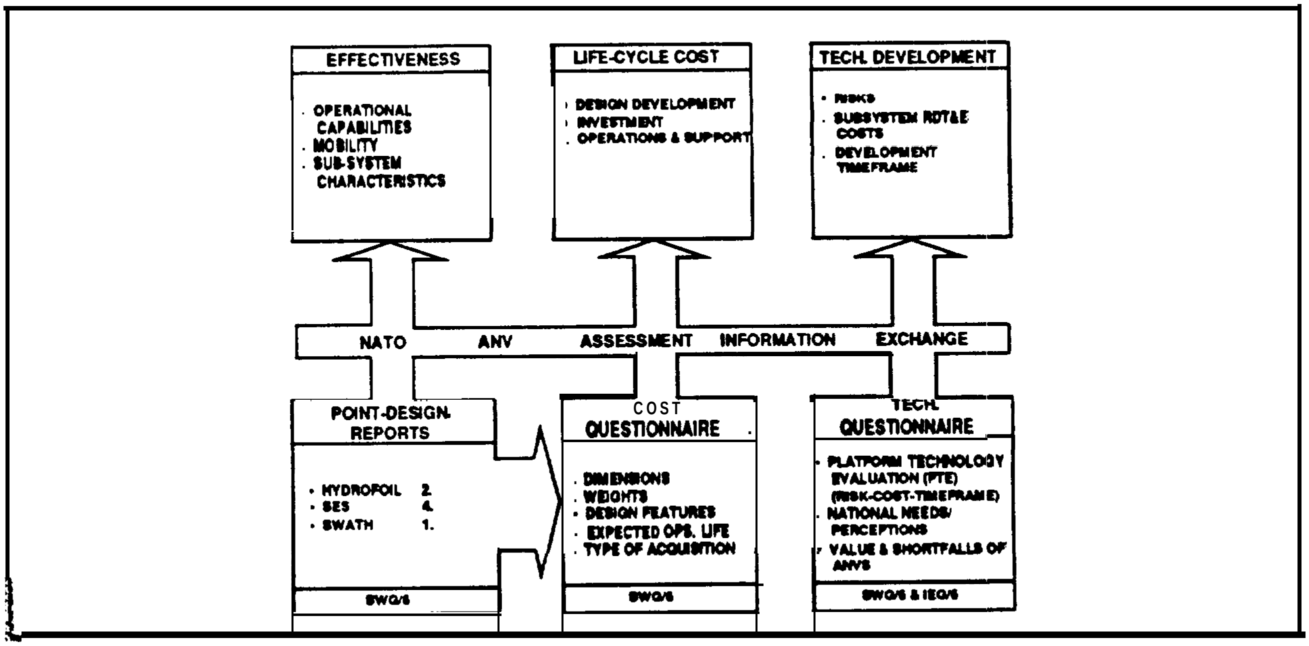


Figure IV-1, , Approach to Point Design Assessment qualitatively using the quantitative results from the mobility assessment, which looked at speed, seakeeping, maneuverability, endurance, etc. The assessment of subsystem characteristics, i.e., the basic hull, mechanical, and electrical elements of the designs, was also used to support the evaluation of operational capabilities as well as validating reported design characteristics using trend data to establish comparisons with prior ships or ship design studies. The subsystem assessment also helped define the technologies used in the ANV point designs, particularly those that deviated from current practice. This subsequently served as input to the Platform Technology Evaluation (PTE) portion of the technical development portion of the overall assessment.

The FFG 7 class of frigates was used as the primary conventional monohull reference for the SES and hydrofoil corvettes. The NFR 90 design and DD 963 class were used for the SWATH since their size was more in keeping with that point design. A series of other non-US warships were included in the comparison to serve as baselines reflecting non-U.S. design and construction practices. The use of these ships as references does not imply that the ANV designs are being judged against monohull criteria. The intent was to use them to illustrate and highlight technology and performance differences between the conventional approach and that of the ANVs.

Acquisition Cost and Life-Cycle Cost (LCC) were examined for each point design to determine the cost to design, procure, and operate the ship and its support facilities over a specified lifetime period. For each of the cost elements emphasis was placed on achieving consistency in the cost estimates across all the designs being considered. To achieve this consistency the same basic Life-Cycle Cost (LCC) structure and cost-estimating relationships (CER's) were used to ensure that cost differences between designs were due solely to differences in the platforms' characteristics. The estimated costs were computed from CERs which have been derived from historical data modified where necessary to reflect technological differences.

It was recognized that the absolute value of life-cycle cost will vary from nation to nation due to differences in design, specifications, procurement methods, and operational and support philosophies.

The technical development assessment focused on risk using a previously developed procedure to evaluate the development status of those technologies which were to be incorporated in the design and were not yet state-of-the-art or approved for full production. This approach is called the Platform Technology Evaluation (PTE) and was used to evaluate specific proposed subsystems on the basis of being required by the point design to meet mission or performance goals, current development status and development schedule relative to proposed funding.

The forms used in the PTE process were completed by each of the participating nations for their designs and by the SWG/6 Chairman's Assessment Team for all of the designs. Additionally some of the nations provided input on other nations' designs.

C. Point Designs

C.l. General

This portion of the paper provides a brief description of the various ASW-corvette point designs developed as part of the SWG/6 ASW study. Performance data, specifically that having to do with endurance, speed and combat-system capabilities have been deleted for security reasons. In addition, certain technical details were withheld because of the proprietary nature of the information.

As discussed in Section IV A, seven major designs were developed and are presented in the following sections. These are as follows:

1. United Kingdom (UK) SES
2. French (FR) SES
3. U.S./Federal Republic of Germany (US/G) SES
4. Spanish (SP) SES
5. U.S. Hydrofoil
6. Canadian (CA) Hydrofoil
7. Canadian (CA) SWATH

Note that these designs were developed to varying levels of detail. This was a function of available funding to each design team, the existence of ongoing development programs, schedule, and national practices: however, all were assessed using the same minimum required level of information.

C.2 UK SES

The UK SES was designed as an open ocean ASW platform for use against high-speed quiet SSNs. It has ocean limited capabilities in the areas of anti-surface vessel warfare (SUW) and anti-aircraft defense.

The principal characteristics of the UK SES may be found in Table IV-l.

Length, Overall	92.9 M
Beam, Maximum	29.0 M
Draft, On-Cushion (Aft)	1.5 M
Draft, Off-Cushion (Mean)	4.6 M
Displacement, Full Load	1601 MT
Displacement, Light Ship	1041 MT
Propulsion Power Installed	36000 KW
Lift Power Installed	10800 Kw
Electric Generating Capacity	1200 Kw
Complement	113
Maximum Continuous Speed	40+ Knots

Table IV-l. UK SES Principal Characteristics

Figure IV-2 shows the overall configuration of the UK SES point design.

This design has a fiber-reinforced plastic (FRP) structure for both the hull and superstructure. The hullform is based on the Vosper Hovermarine Deep-Cushion Craft concept and is designed to have good speed and seakeeping characteristics in high sea states.

The propulsion plant consists of a twin-shaft CODOG propulsion plant with two Rolls Royce Spey SMlC gas turbines for on-cushion propulsion and two MTV 20V 1163 TB83 diesels for lift fan power on-cushion and propulsion power when hullborne. Two waterjet propulsors are installed for use both on and off-cushion. The electric plant is comprised of four 300 KW diesel generators.

The combat system is made up of the following major elements:

- Passive towed array sonar
- Active conformal sonar
- Standard air/surface search radar
- Surface to surface missiles
- AAW point defense missiles
- One medium ASW helicopter
- Air and ship launched torpedoes.

C.3 FR SES

The FR SES is designed with a primary emphasis on ASW, although it has good self-defense capabilities in anti-air and surface warfare. Principal characteristics are contained in Table IV-2 and an overall configuration is depicted in Figure IV-3.

Length, Overall	89 M
Beam, Maximum	21.10 M
Draft, On-Cushion (Aft)	1.58 M
Draft, Off-Cushion (Mean)	4.00 M
Displacement, Full Load	1400 MT
Displacement, Light Ship	911 MT

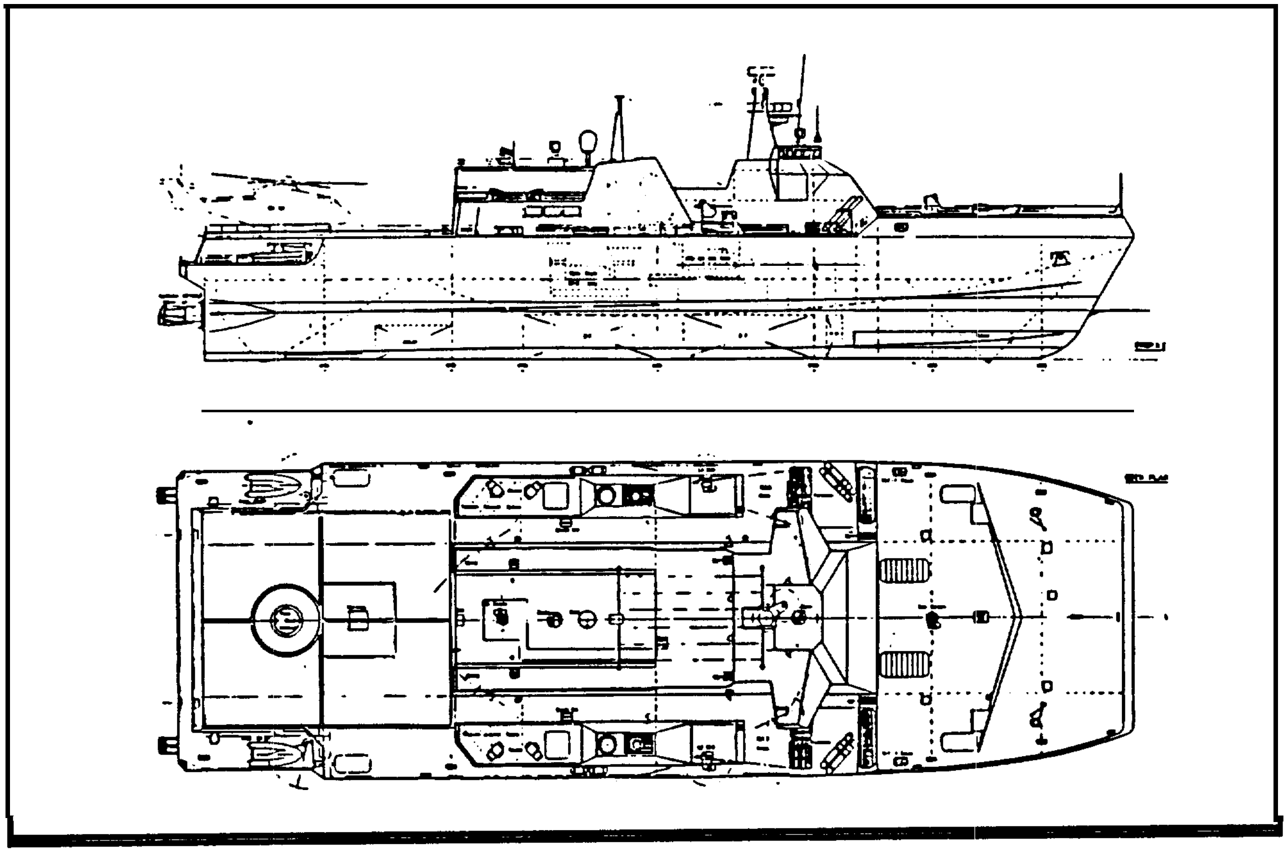


Figure IV-2, , Overall Configuration, UK SES

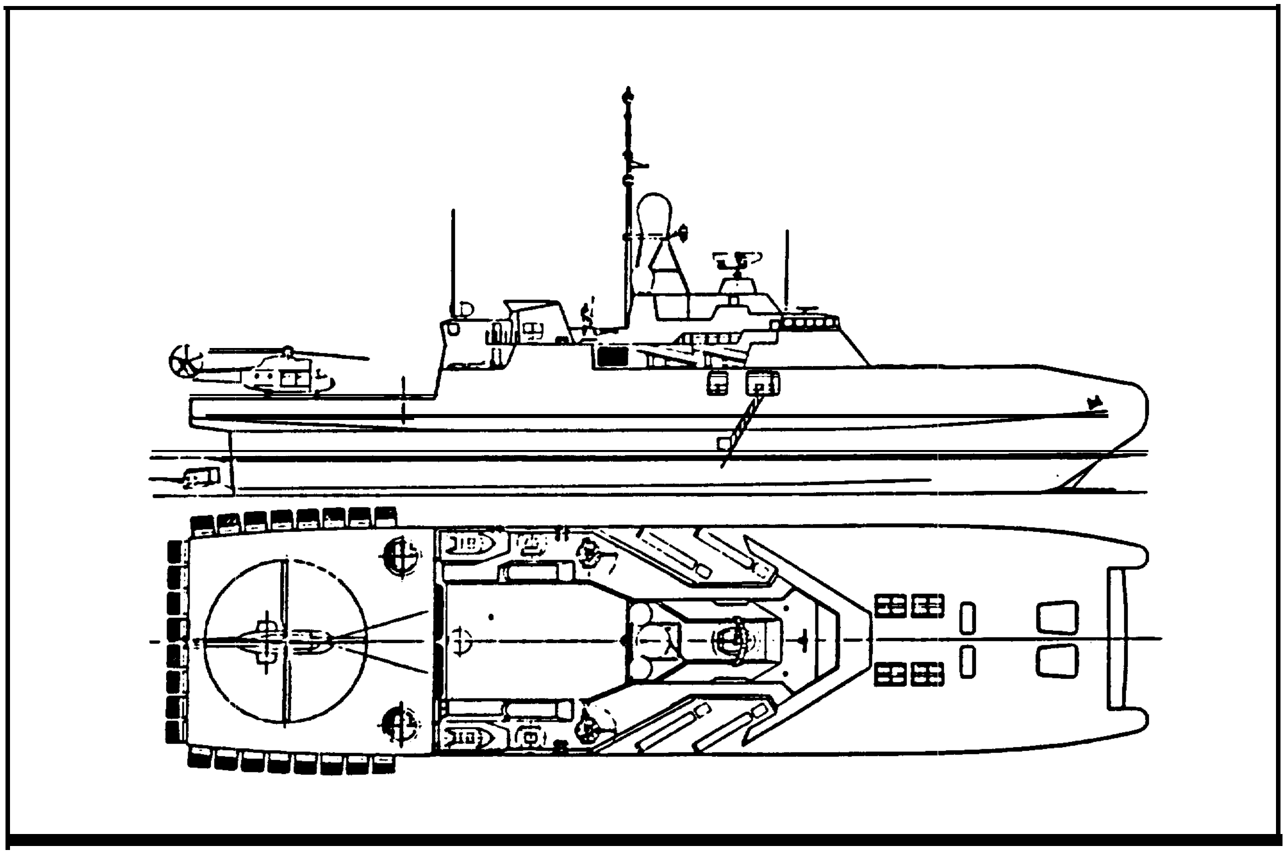


Figure IV-3, , Overall Configuration, FR SES

Propulsion Power Installed	44200 Kw
Lift Power Installed	8800 Kw
Electric Generating Capacity	1280 KW
Complement	94
Maximum Continuous Speed	40+ Knots

Table IV-2, FR SES Principal Characteristics

The FR SES hull and superstructure are of aluminum alloy, although studies are underway to investigate FRP construction. The length to beam ratio is greater than that for the UK SES and is midway between the UK and US designs.

A CODOG propulsion plant is also used in the FR SES with two LM-2500 gas turbines providing propulsion power on-cushion and two 4400 KW diesels, such as the SACM 195 V20 H, providing power either to the lift fans on-cushion or the propulsors when hullborne. Two KaMeWa waterjet propulsors are used in all operating modes. The electric generating plant consists of two diesel generators and two gas turbine generators.

The combat system is comprised of the following:

- A passive, towed linear array
- Active sonars
- Air/surface search radar
- Surface to surface missiles
- Missile-launched torpedoes
- Two AAW point defense missile systems.
- Two ASW helicopters with air-launched torpedoes.

C.4 US/G SES

The US/G SES Corvette is a surface escort vessel dedicated to a single-role ASW mission, namely the anti-submarine defense of surface groups composed of naval and merchant shipping. The principal characteristics of the US/G SES are shown in Table IV-3 and a configuration sketch in Figure IV-4.

Length, Overall	104 M
Beam, Maximum	19.5 M
Keel to Wetdeck Clearance	6.7 M
Draft, On-Cushion (Aft)	1.2 M
Draft, Off-Cushion (Mean)	4.3 M
Displacement, Full Load	1937 MT

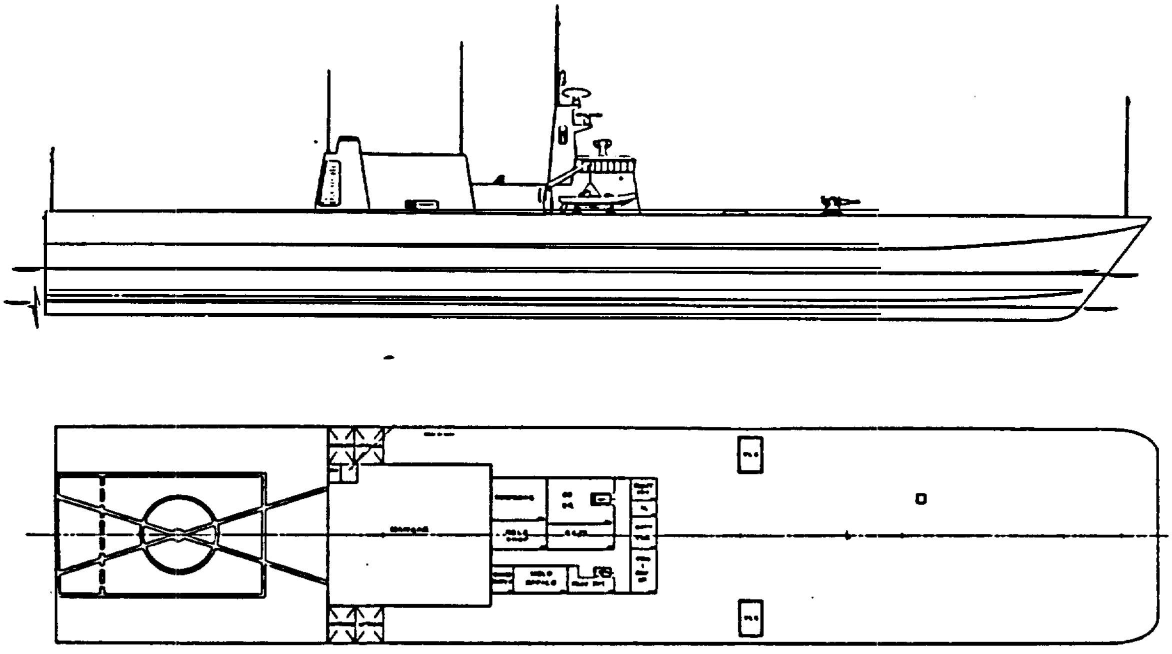


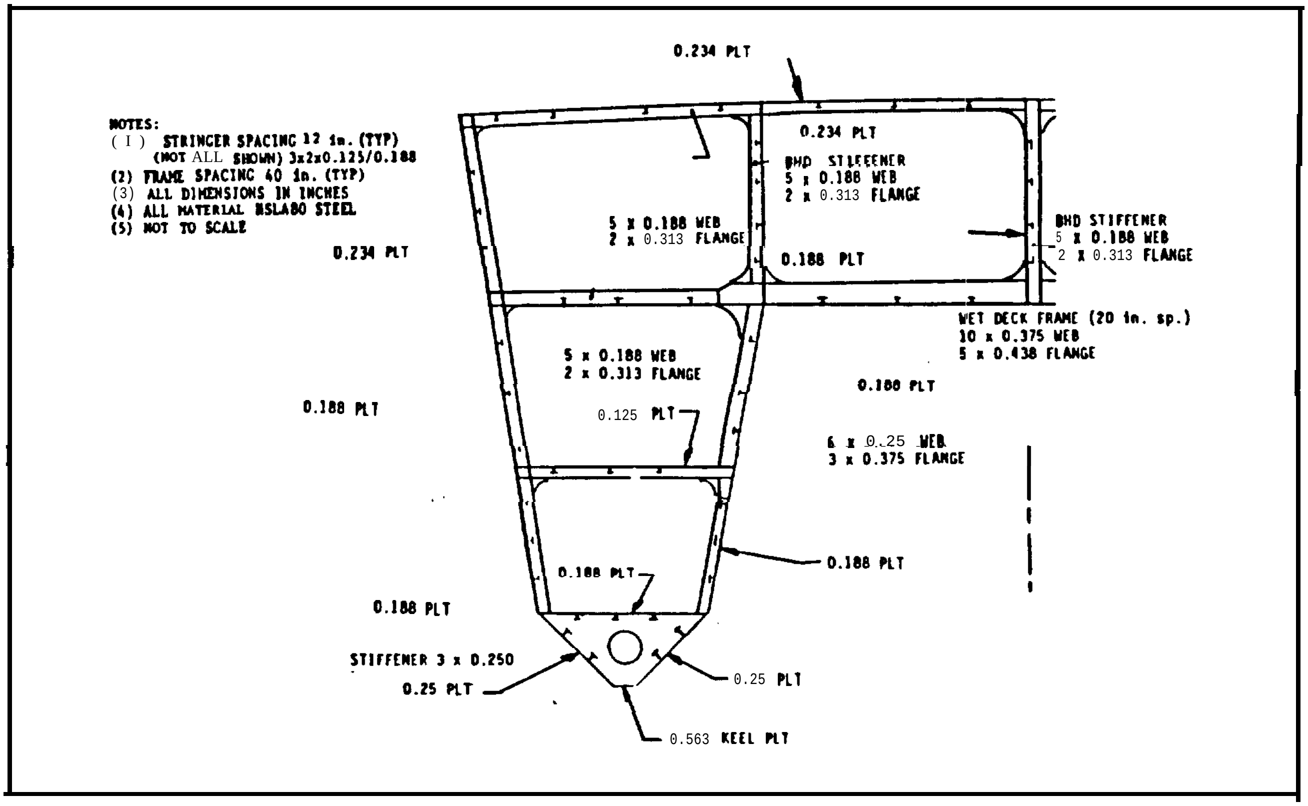
Figure IV-4, , Overall Configuration, US SES

Displacement, Light Ship	1514 MT
Propulsion Power Installed	40280 KW
Lift Power Installed	6710 KW
Electric Generating Capacity	1500 Kw
Complement	99
Maximum Continuous Speed	40+ Knots

Table IV-3, US/G SES Principal Characteristics

The US/G SES has a high length-to-beam ratio primarily to reduce resistance at endurance speeds and to enhance seakeeping. The hull structure is of high strength low alloy steel (HSLA 80), and the deckhouse is of aluminum alloy. A simplified midship section is shown in Figure IV-5. Although this choice of materials results in a performance penalty due to the increase in structure weight, as compared to the more conventional choice of aluminum alloy for an SES, it represents an effort to seek a less expensive and more robust material more suited to conventional large shipbuilding practice. The propulsion plant design is of CODOG configuration similar to that found on the UK and FR designs. Two LM-2500's provide cushion-borne propulsion power and three SACM 195 V16 RVR diesels supply power to the lift fans. In the hull-borne mode only two of these diesels are required for propulsion. For this design the LM-2500's are rated at 27000 SHP, a figure that is currently not approved by the U.S. Navy. The propulsors consist of twin semi-submerged, supercavitating, controllable-reversible pitch propellers chosen over waterjets because of their performance over the wide operating speed range of the US/G SES. It was felt that the propulsive efficiency gains offset the risks associated with the concept. The electric generating plant consists of three 500 KW diesel generators. Locations of the major machinery plant components are shown in Figure IV-6.

Much of the internal non-watertight subdivision uses very lightweight unpainted Nomex honeycomb panels. This type of structure has been used extensively in the commercial sector but is not common on U.S. Navy ships.



'Figure IV-5, , US/G SES Midship Section

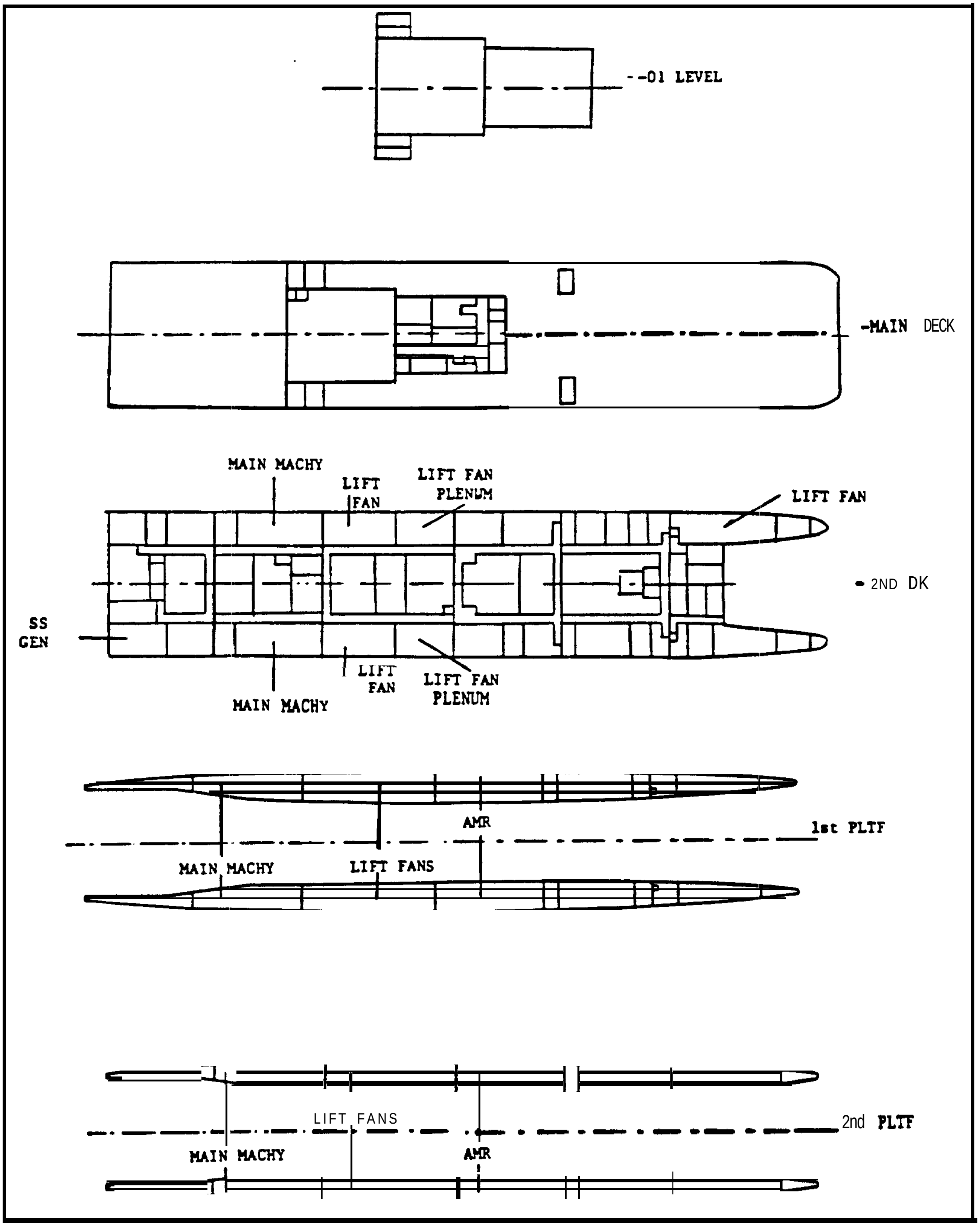


Figure IV-6, , US/G SES Machinery Arrangement

The US/G combat system consists of the following major elements:

- Notional towed array sonar
- Notional VDS
- Air/surface search radar
- Link 11 Data Link
- Two 8-cell VLS capable of launching ASW stand-off, anti-ship, or medium range AAW (Standardl) missiles.
- 30 mm CIWS (Goalkeeper)
- Two Javelin point defense triple launchers
- Two MK 32 triple torpedo tubes
- Two LAMPS MK III helicopters

C.5 SP SES

The SP SES was designed for ASW escort and submarine hunting and possesses self-defense capabilities against air and surface threats. Its principal characteristics are summarized in Table IV-4, and an overall configuration is shown in Figure IV-7.

Length, Overall	95 M
Beam, Maximum	20.40 M
Draft, On-Cushion (Aft)	1.25 M
Draft, Off-Cushion (Mean)	4.38 M
Displacement, Full Load	1742 MT
Displacement, Light Ship	1328 MT
Propulsion Power Installed	42000 KW
Lift Power Installed	12410 KW
Electric Generating Capacity	N/A
Complement	95
Maximum Continuous Speed	40+ Knots

Table IV-4, SP SES Principal Characteristics

The hull has a lower length-to-beam ratio than the US/G SES but still greater than the French design. The hull is constructed of high strength steel (HTS and HY-80), and the superstructure is GRP.

A CODOG propulsion system comprised of two LM-2500 gas turbines, two MTU 16 cylinder diesels, and two MTU 20 cylinder diesels is installed. The arrangement is similar to that of the

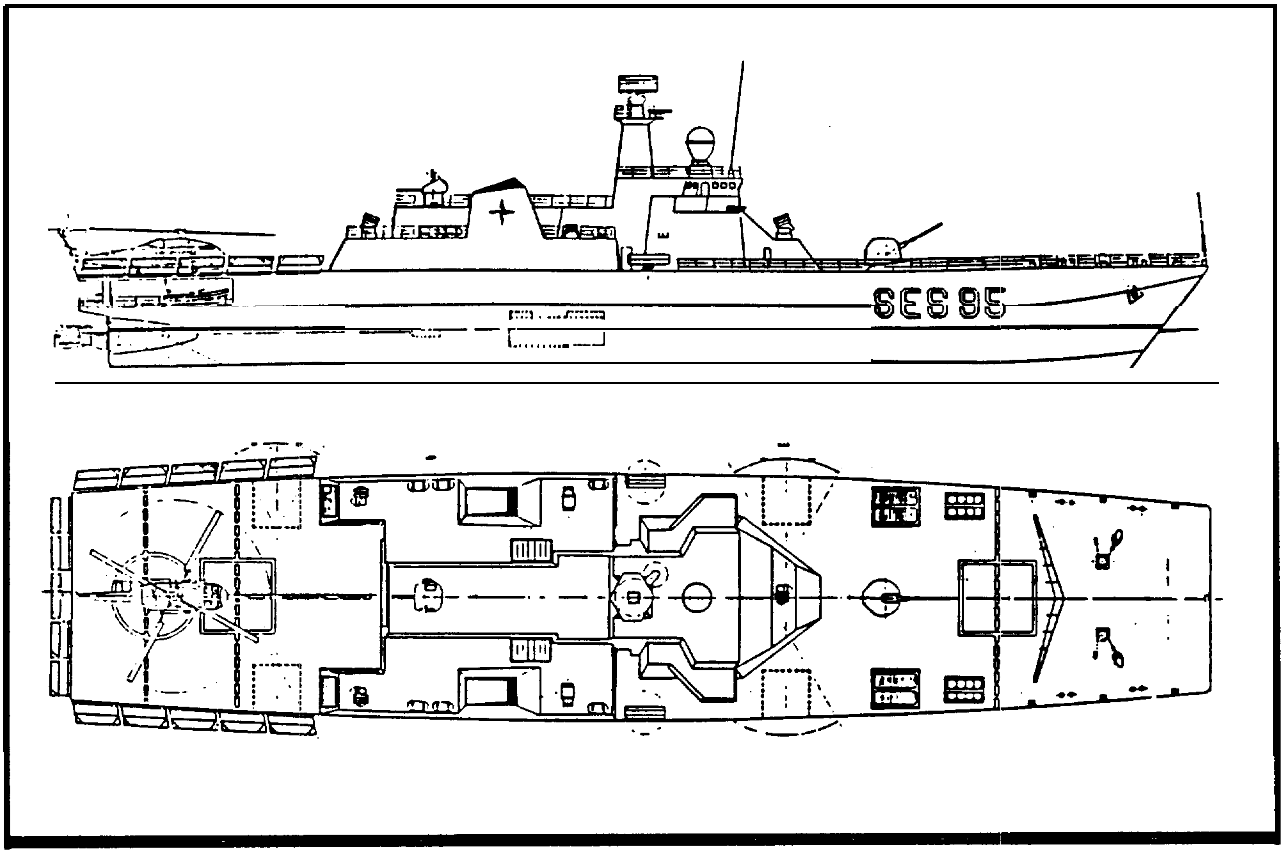


Figure IV-7, , Overall Configuration, SP SES other SES designs, except the smaller diesels are dedicated to the forward lift fans while the larger ones alternate between lift and propulsion. KaMeWa waterjets are used as propulsors.

The SP SES Combat system is similar to that on the US/G SES and consists of the following:

- Towed array sonar (HITAS)
- VDS (HYTOW)
- Air/surface search radar
- MEROKA close-in weapons system
- Oto Melara 76mm gun
- Three Javelin point defense tripod launchers
- Two 8-cell VLS for ASW stand-off, AAW (Standard), or anti-ship missiles
- One LAMPS MK III helicopter

C.6. US Hydrofoil

Basic missions of the US Hydrofoil Point Design are escort operations, open-ocean sea-control operations, surveillance and reconnaissance, barrier or containment operations,, mine warfare (optional), and other less demanding tasks such as, protection of maritime resources, or search and rescue. The principal emphasis is on Anti-Submarine Warfare (ASW) and Surface Warfare (SUW) with Anti-Air Warfare (AAW) limited to a self-defense capability only. This ship is not required to, and is therefore, not designed to carry a helicopter.

Table IV-5 summarizes the principal characteristics of the US hydrofoil. Figure IV-8 depicts its overall configuration which could be classified as an extreme canard.

Length, Overall	66 M
Beam, Maximum	23.3 M
Keel Clearance	3.66 M
Draft, Foilborne	3.60 M
Draft, Hullborne (Foils down)	8.63 M
Draft, Hullborne (Foils up)	2.62 M
Displacement, Full Load	773 MT
Displacement, Light Ship	577 MT

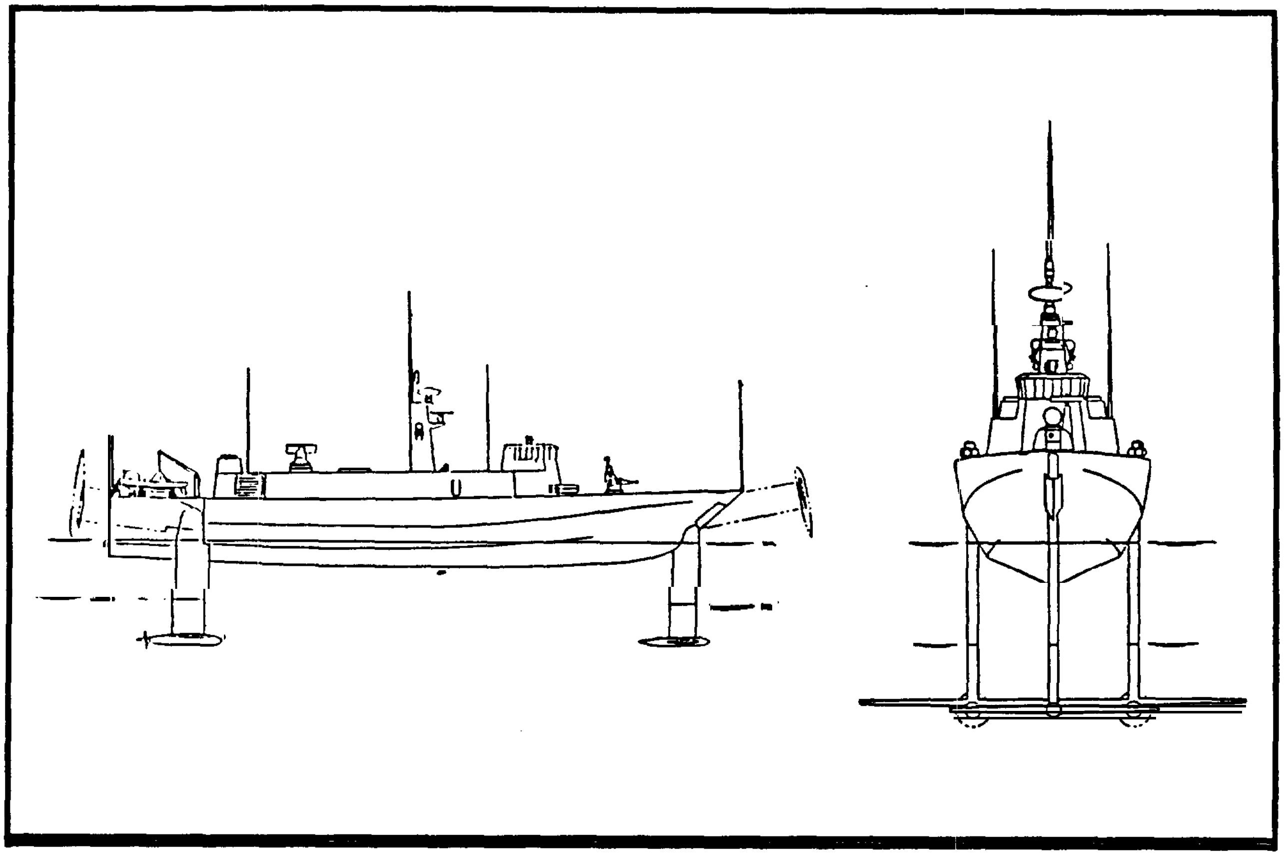


Figure IV-8, , Overall Configuration, US Hydrofoil

Propulsion Power Installed (GT/Diesels)	22380/3133 KW
Electric Generating Capacity	1035 Kw
Complement	54
Maximum Continuous Speed	40+ Knots

Table IV-5, US Hydrofoil Principal Characteristics

The primary structure is aluminum alloy and a midships section sketch is included as Figure IV-9. The struts and foils are fabricated from high strength steel (HY-130) although it is realized that material and configuration optimizations must be undertaken.

Foilborne and hullborne propulsion are provided by a CODOG arrangement of two separate sets of engines driving through a common, mechanical transmission. These engines, two Rolls Royce Spey (SM 3A) gas turbine and two MTU diesels, drive two controllable and reversible pitch transcavitating propellers mounted at the aft end of two nacelles located at the main (aft) foil/strut intersection. Power is transmitted to these propellers by a mechanical "Z" drive transmission that is housed inside the aft struts. The ship is also equipped with auxiliary hydraulic motors for emergency and shallow-water propulsion. Foilborne steering is accomplished by the forward strut. Hullborne steering is accomplished by the forward strut and by differential thrust of the two propellers. Basic power to the electrical system is supplied by three, diesel-driven generators. The generators are sized so that any two can handle the ship's predicted battle condition loads. The machinery arrangement is shown in Figure IV-10.

The ship's Automatic Control System (ACS) provides continuous dynamic control of the ship during takeoff, landing and all foilborne operations. In addition to providing ship roll stability, the ACS controls the height of the hull above the water surface, initiates and holds coordinated turns, and attenuates ship motions caused by wave action. The combination

NOTES ;
(1) STRINGER SPACING 50 CM
(2) FRAME SPACING 200 CM
(3) ALL DIMENSIONS IN CENTIMETERS
(4) ALL MATERIAL ALUMINUM
(ALLOY 545611116)
(5) NOT TO SCALE

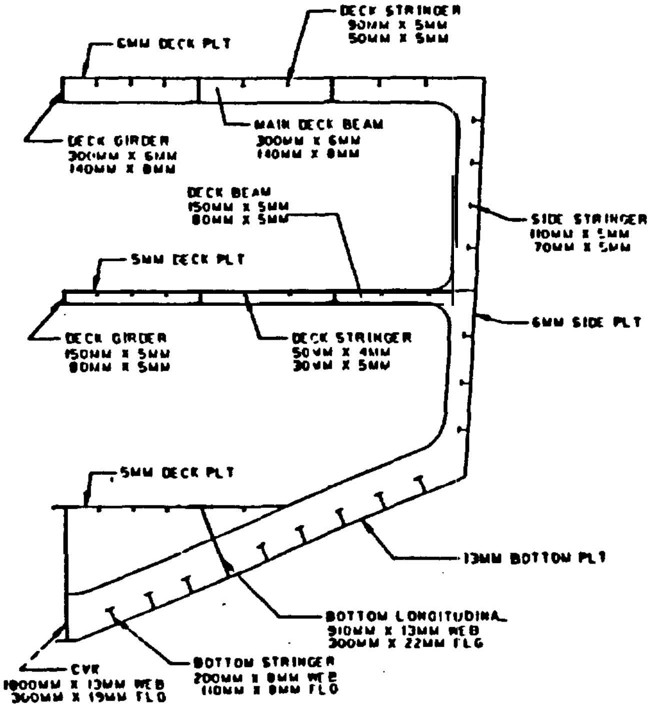


Figure IV-9, , US Hydrofoil Midship Section

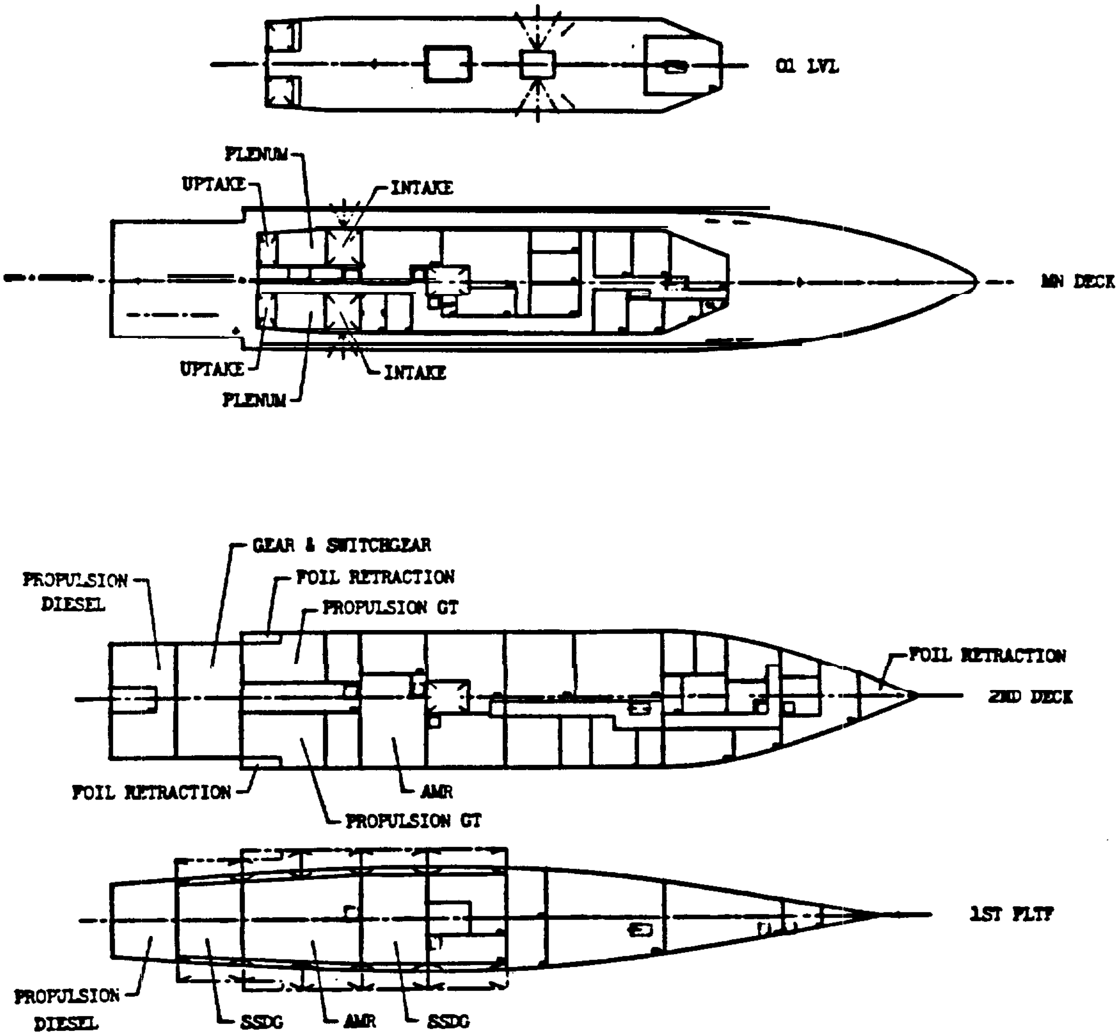


Figure IV-10, US Hydrofoil Machinery Arrangement of the ACS and fully-submerged foils permits the ship to operate in seas up through Sea State 6. This system is similar to ACS presently in use on the PHM. The addition of a forward-looking radar will provide smoother ride conditions than achieved by previous hydrofoils.

The ship's electric plant consists of three 345 KW diesel generators.

A notional combat system consisting of the following components is proposed:

- High-speed towed array sonar or (HITAS)
- High-speed VDS (HYTOW)
- 21 cell Rolling Airframe Missile (RAM) launcher
- Two 3-cell Javelin launchers mounted on the side of a 30mm close-in weapons system (Goalkeeper)
- Lightweight 8-cell VLS for ASW or anti-ship missiles
- Two triple Mk 32 torpedo tubes.

C7. CA Hvdrofoil

Canada was not originally responsible for a hydrofoil design; however, it offered a previously developed design. Although it did not satisfy the complete SWG/6 ONST, it represented a favorable compromise between performance and cost. Principal characteristics are summarized in Table IV-6 and a configuration is shown in Figure IV-11.

Length, Overall	64 M
Beam, Maximum	19.84 M
Keel Clearance	2.6 M
Draft, Hullborne	8.14 M
Draft, Foilborne	3.60 M
Displacement, Full Load	458 MT
Displacement, Light Ship	286 MT
Propulsion Power, Installed (GT/Diesel)	14000/2000 KW
Electric! Generating Capacity	700 Kw
Complement	40
Maximum Continuous Speed	40+ Knots

Table IV-6, Principal Characteristics, CA Hydrofoil

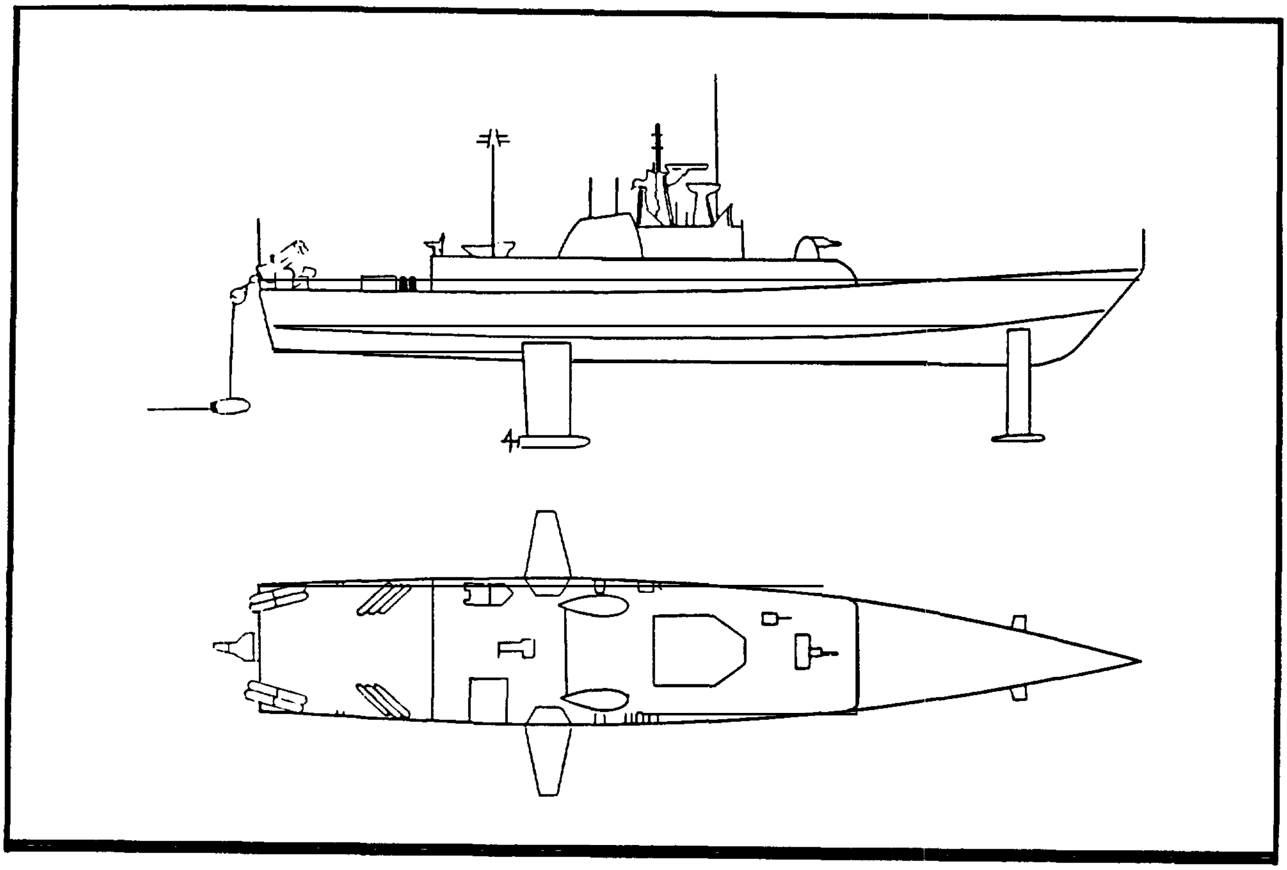


Figure IV-11 Overall Configuration, CA Hydrofoil

The objective of the Canadians was to offer an ocean-going hydrofoil which was smaller, more austere and which would cost less than one third of the cost of a "standard frigate". A fixed, fully-submerged, canard-foil configuration was selected, which in addition to saving weight, produced both a seakeeping advantage and a lower stress for the steerable bow foil, which is normally a serious design problem for large hydrofoils equipped with retractable foils.

The structure of the CA hydrofoil is envisioned to be aluminum alloy. The propulsion plant consists of two Detroit Diesel-Allison 570 KB gas turbines for foilborne operation, and two MTU-12V 493 diesels for hullborne power. Two CRP screws are used as propulsors in both modes of operation.

Although the mission-related payload of the low-cost option is 87% of the payload of the US Hydrofoil, it is equipped with a similar combat capability.

C.8 CA SWATH Point Desisn

The CA SWATH was designed to meet the requirement for an inner screen general purpose combatant. Although this mission differs from that of the other point designs it better exploits the advantages of the SWATH over a monohull. Principal characteristics of the design are contained in Table IV-7, and the general configuration is shown in Figure IV-12.

Length, overall	115.8 M
Beam, Maximum	30.5 M
Draft	9.2 M
Displacement, Full Load	9548 MT
Displacement, Light Ship	7391 MT
Propulsion Power Installed	40000 Kw
Auxiliary Power Installed	9600 KW
Complement	279
Maximum Continuous Speed	25+ Knots

Table IV-7 CA SWATH Principal Characteristics

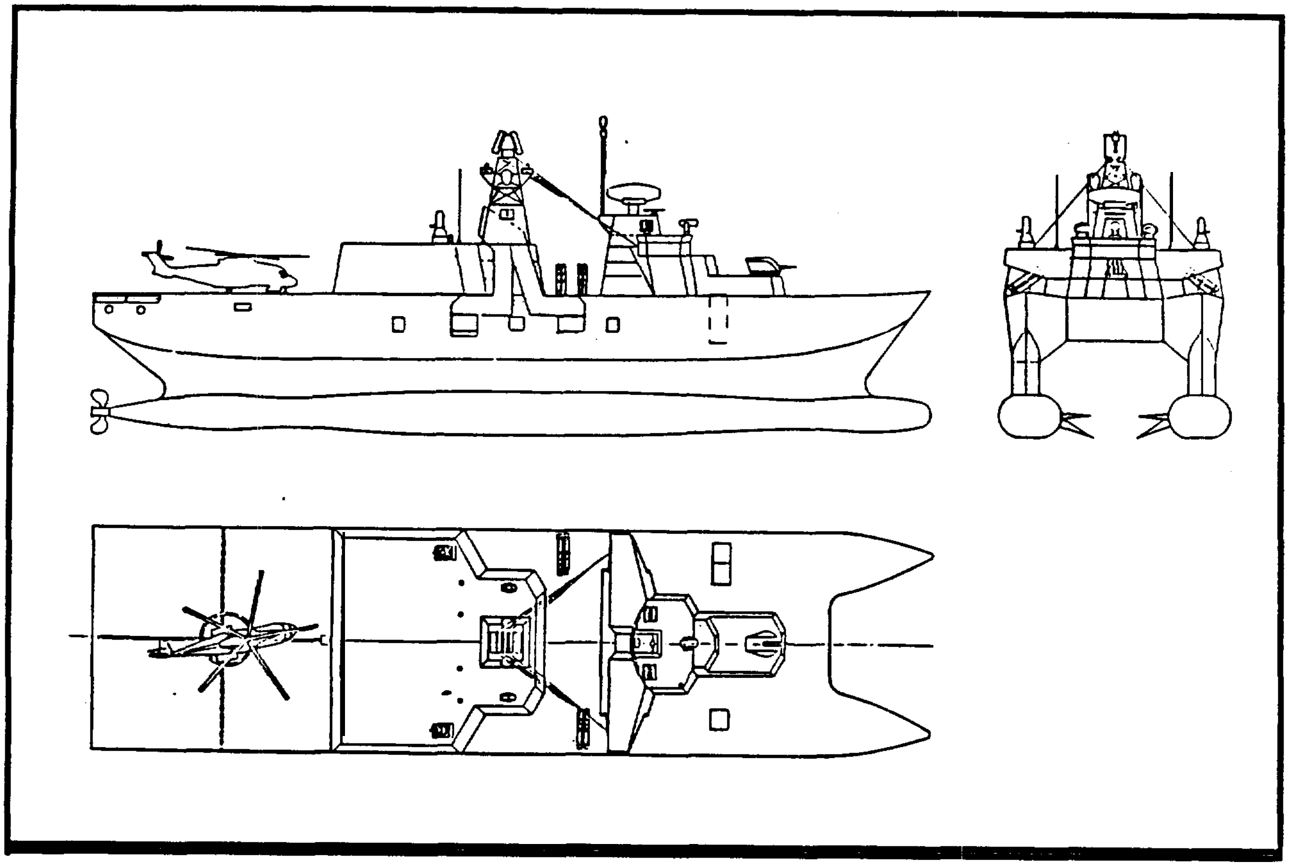


Figure IV-12 Overall Configuration, CA SWATH

The lower hulls are contoured and are oblong in cross-section and were designed to trade-off some cruise speed efficiency for extra speed at maximum power. The eccentricity of the hulls in cross-section contributes to a smaller draft than circular hulls would provide and has the added advantage of increasing heave, pitch and roll damping. The lower hull centerlines are inset approximately 1.4 m from the strut centerlines in order to reduce the overall beam without affecting the transverse stability. A two deck (plus inner bottom) box was selected. The box does not extend the full length of the ship to reduce excess internal arrangeable volume and to reduce the frequency and severity of box slamming. The wet deck is tapered upward at the bow and stern to further reduce slamming. The primary structural material is steel.

The design features short, single struts and a combined stabilizer/rudder ("stabiludderl") concept.

The propulsion system is an integrated electric drive with the ship's service power derived from the main propulsion bus. The motive power is produced by two 20-MW Rolls Royce Spey gas turbines (intercooled and regenerated) and three 3.2~MW Pielstick diesels each driving liquid-cooled stator synchronous generators. Two cross-connected propulsion switchboards supply power to the two 22-MW liquid-cooled induction motors which directly drive the slow turning propellers. Ship-service electrical power is derived from the propulsion switchboards (6300 volts) and converted to 440 volts by solid-state power converters.

This combat system of the CA SWATH is comprised of the following:

- Towed array sonar
- VDS
- Conformal hull-mounted sonar
- Air and surface search radars
- VLS for point defense AAW missiles
- Torpedo tubes

- Vertically launched ASROC
- Two Phalanx CIWS
- One Bofors 57 mm gun
- Four large ASW helicopters
- Ten RPVs

D. Assessment

D.l General

As discussed in Section IV-B, the assessment of the suitability and desirability of the ANV point designs for the NATO ASW mission focused on effectiveness, life-cycle costs, and the state-of-technology development of the various systems required, i.e., risk. This portion of the paper deals with the latter area primarily through an evaluation of certain technical characteristics of the designs.

Again, the reader should be cautioned that the assessment was not intended to be a contest among the various point designs; instead, it was structured to evaluate the ANVs against the conventional approach to the mission. No criticism of any design was intended, although differences in design approaches, criteria, and shipbuilding practices were highlighted.

D.2 General Comoarison of the Desisns

SESs. The main differences between the SES designs include:

- The wide range of full-load displacements.
  - UK - 1601 MT
  - FR - 1400 MT
  - US/G-1936.5 MT
  - SP - 1742 MT
- The extreme spread of selected length to beam ratios ranging from 3.2 for the UK ship to 5.3 for the US/G ship.
- The choice of propulsors:
  - UK, France, and Spain - Waterjets
  - US/G - Surface Piercing Marine Screws

- The number and type of lift fans, the air distribution systems, the design of end seals and the methods used for ride control.

The assessment has shown that the high length/beam ratio of the US/G design offers advantages as far as forward speed in calm water is concerned: however, the greatest stability is offered by the UK short L/B design. The ships with lower length/beam have less margin against capsizing in synchronous beam seas and when turning at high speed. The choice of steel as a structural material results in a weight penalty and highlights the U.S. concerns regarding fire and fatigue with aluminum alloys. Composites emerge as a possible optimum structural material, although manufacturing techniques for this size of structure need to be developed, particularly in the U.S.

Hvdrofoils. The main difference between the hydrofoil designs include:

- Foil Configuration:
  - us - Retractable
  - CA - Non-Retractable

- Displacement
  - us - 773.3 MT
  - CA - 458 MT

The Canadian @'intermediate" hydrofoil concept incorporates ideas to reduce the risk and cost of hydrofoil ships, and has some features that may be of interest to the smaller NATO nations. It is viewed, not as proposing a competing design, but as introducing some topics worth investigating in the further development of any multi-national hydrofoil program from an extensive series of hydrofoil parametric studies evolving from lessons learned from the HMCS BRAS D'OR.

For Canadian requirements, the compromise between performance and costs led to an "intermediate" hydrofoil -

intermediate in the sense that the concept lies between aeronautically-based USN designs, such as the PHM, and the simpler commercial European designs.

Fundamental to the low-cost, low-risk concept is:

- Reduced power per ton, with reduced speeds foilborne,
- A non-retracting, flap-controlled, fully-submerged foil system,
- An canard configuration, with only 10 to 15% of the weight on the bow foil,
- Conventional propellers, and no separate hullborne propulsion system,
- An emphasis on long range and good seakeeping qualities necessary for the multi-purpose operational concept envisaged for this ship.

SWATH. The SWATH was determined to be technically feasible, and although the design did not achieve the specified speed, the design philosophy for this ship permitted trading-off top speed in favor of improving other performance characteristics and reducing cost.

The SWATH Point Design is much larger than expected, partially as a result of the following:

- The aircraft complement (4 large ASW helicopters);
- SWATHs are less structurally and volumetrically efficient than monohulls
- SWATHs are sensitive to weight changes compared to other displacement hulls; hence must carry future growth margin from commissioning to restrict draft changes.

A significantly smaller, less expensive variant is achievable only at the expense of reduced payload, performance or margins.

The ship is well-suited to operating helicopters because it is a very stable platform with a large deck. Damage below the waterline, however, will cause pronounced trim and heel, severely affecting the ship's ability to continue operating until counterflooded.

D.3 Arrangements

SESs. The arrangement of SES platforms can be divided into three major areas: box or cross-structure, sidehulls, and superstructure. The arrangement within each of these areas is dependent upon the L/B ratio of the platform, hydrodynamically constrained sidehulls and the basic design philosophy.

The rectangular platform of the cross structure simplifies its arrangement as does the generally greater subdivision length found on SESs of this size. The lower length to beam ratios, i.e., greater beams, often require a different approach to passageway layout than on comparable monohulls, which may result in a greater access volume. A complication in arranging the cross structure can arise from the longitudinal wing bulkheads that follow the inner shell of the sidehulls. These bulkheads are generally required for structural continuity, and on smaller SESs with relatively narrow sidehulls, they can limit the functions that can be placed in the outboard areas of the cross structure. This is similar to the situation encountered on SWATH ships.

Another difference with monohulls and similarity to SWATHs is the sizing of combat systems having depths greater than approximately two deck heights. This forces their location to areas over the sidehulls where the requisite depth exists: however, it can create conflicts with machinery arrangements.

SES sidehulls are dedicated to a great extent to propulsion and lift systems, although the latter can also occupy significant space in the cross-structure. The outboard location of the prime movers facilitates uptake and intake runs and permits relatively simple systems. The actual arrangement of the machinery within the sidehulls is often complicated by the relatively limited beam of the sidehulls, again particularly on smaller platforms or on those designs featuring lenticular hulls and alignment requirements for the propulsion-lift power train. The latter is a function of shaft lines and the large amount of installed power required for high speed and lift fan operation. It is far from a fatal flaw; instead, it is merely a design consideration unique to SES that is analogous to that encountered in laying out shaft lines in a monohull.

A situation often encountered with SESs is that their designs may be far from volume limited. This is a function of hydrodynamic and performance considerations driving hull geometry and dimensions and has been experienced in the high L/B US SES and other similar designs. This can permit a reduction in deckhouse size and weight on such designs which is advantageous from a stability point of view particularly with the narrow beam of the US/G design.

Hydrofoil. Hydrofoil arrangements are driven primarily by foil configuration, machinery arrangements, and by their small size relative to their payload. On a canard-foil configured hydrofoil it is advantageous to locate the center of gravity as far aft as possible in order to maximize the load on the more efficient, and more easily supported, aft foils. For this reason, and the requirement to have the propulsion shafting or ducting running down the aft struts, the machinery is generally located as fa:r aft as possible. Combat systems, with below deck space requirements, and other critical spaces, often fill the remaining prime areas within the hull. The superstructures therefore tend to be relatively large to accommodate the remaining required volume.

The machinery spaces on the U.S. Hydrofoil occupy most of the aft half of the hull along with the aft part of the deckhouse.

The CA Hydrofoil follows a different trend in its arrangement. The somewhat more forward location of the aft foil and the lack of foil retraction systems allows for consolidating and locating machinery systems closer to the longitudinal center of gravity. With this configuration, some accommodations can be located aft of the machinery box. Another impact of a fixed-foil system on arrangements is the ability to reserve a higher percentage of its full-load displacement for fuel and payloads as compared to a hydrofoil with retractable foils.

SWATH. SWATH arrangements are typically centered around the box with only tankage, propulsion motors, buoyancy foam, miscellaneous machinery and storage spaces located in the struts and lower hulls. This is, of course, a result of the geometry of the unique shapes of the spaces located in the struts and lower hulls, and the access problems associated with locating frequently used spaces in these areas.

The machinery arrangements can feature transversely mounted prime movers because of the excellent seakeeping qualities of SWATHs. This facilitates the arrangement of transverse subdivisions, a closer spacing of which compared to monohulls, is often required for stability performance. The propulsion motors are located in the lower hulls, as far aft as possible to allow short shafting runs. Electric propulsion also allows shorter intake/uptake runs due to the prime movers' location in the box as opposed to the lower hulls.

D.4. Propulsion Systems

The basic configurations of the propulsion systems for six of the point designs are shown in Figure IV-13. The major difference between these plants and those of conventional monohulls is their relative complexity, particularly in the case of the SESs. This is primarily a function of the need for SESs to operate in two environments, i.e., on and off cushion, which requires a lift system and a wide range of power over the entire speed range. Hydrofoils have similar characteristics with respect to the speed range and power requirements, thus making a CODOG plant attractive even with its attendant complexities.

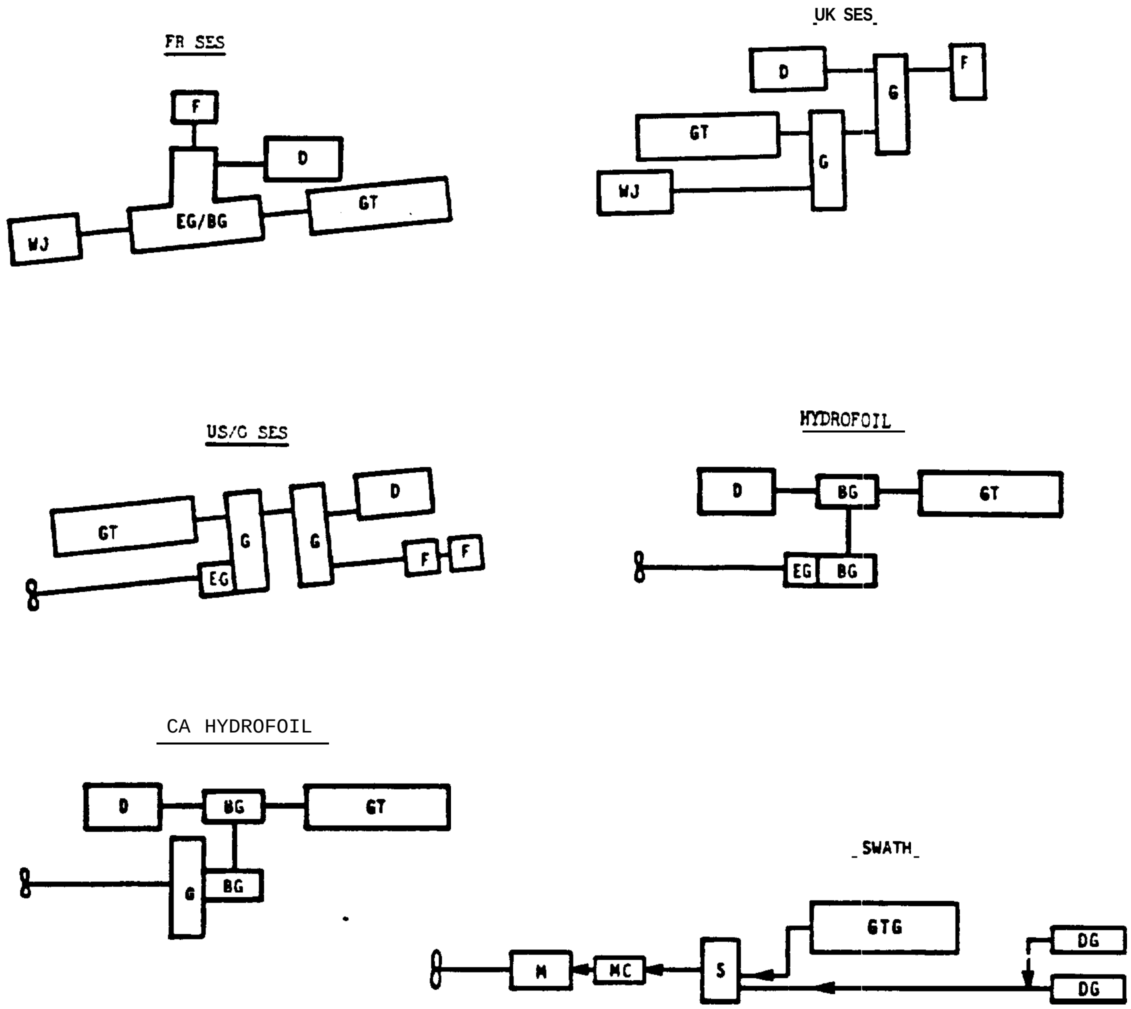
All the SES designs use CODOG mechanical drives. An alternative arrangement that has been used on some U.S. SES design concepts is an electric transmission between the lift fan prime movers when on-cushion and the lift fans or the propulsors when off-cushion. This has facilitated machinery arrangements, particularly in smaller SES designs.

The propulsion schemes for both hydrofoils use supercavitating propellers which were chosen because of their expected efficiency over the wide operating speed range of these point designs. The U.S. hydrofoil also includes a hull-borne propulsion system consisting of two out drives powered hydraulically from the diesels.

The Canadian SWATH follows typical SWATH practice with an electric drive system.

D.5. Electric Plant

The electric generating and distribution systems on the various designs follow the relatively conventional practices of the various nations. Differences in national practice including margin policies were the major drivers in the variations in electric plant capacity within a given hullform.



BG. BEVEL GEAR
D: DIESEL
DG: DIESEL GENERATOR SET
EG: EPICYCLIC GEAR BOX
F: LIFT FAN
G: GEAR BOX

GT : GAS TURBINE
GTG : GAS TURBINE GENERATOR SET
M : DIRECT DRIVE MOTOR
MC : MOTOR/FREQUENCY CONTROLLER
S: PROPULSION SWITCHBOARD
WJ: WATER JET

Figure **IV-13** Propulsion System Schematics use of lightweight systems similar to that on the SES designs.

Outfit and furnishing densities for the SESs and hydrofoils are generally 25 to 75% those of the monohull analogues. This is a function of the smaller size of these ships, varying national standards, and maximum use of lightweight materials, primarily composites.

D.7 Costs

Costs for all point designs were estimated by NAVSEA. In addition, each nation developed costs for their own designs and France and the UK provided costs for the other nations' SES designs. Since these estimates were based on each nation's shipbuilding methods and infrastructure the values were difficult to rigorously correlate; however, the cost estimates done by the US and the cost estimates for the US SES designs were higher than those estimates by the other nations. Generally, the US Hydrofoil was the most expensive on the basis of cost per lightship ton and the CA SWATH the lowest with the SES designs falling between the extremes. All designs were more expensive per ton than the monohulls on an individual ship basis; however, the ANVs were shown to offer cost advantages when looking at the total force required. Actual cost numbers cannot be presented because of proprietary considerations.

E. Conclusions

A summary of the conclusions derived from the ASW study is as follows:

- ANV platforms can offer significant speed and seakeeping advantages over conventional monohulls.
- Higher acquisition and operating costs of ANVs relative to conventional ships can be offset by operational advantages resulting in reduced overall mission or force costs.
- All three platform concepts are technically feasible.

SWBS Group	UKSES		FR SES		US/G SES		SPSES		FFG-7		DD 963		U.S. Hydrofoil		CA Hydrofoil		SWATH	
	w-r	%	WT	%	WT	%	WT	%	WT	%	WT	%	WT	%	WT	%	WT	%
100 Structure	366	19.7	339	42.5	744	55.0	575	57.2	1462	47.(	3124	52.6	152	26.5	84	29.7	3984	80.6
200 Propulsion	301	t2.4	176	22.1	242	16.0	217	16.4	267	9.(	774	13.0	69	13.3	38	13.4	610	9.3
300 Electric Plant	48	5.1	50	62	50	3.7	52	4.4	216	7.1	289	4.6	35	6.6	14	5.0	325	4.6
400 Communications/Control	48	5.1	56	7.0	68	5.0	46	3.6	145	4.7	361	6.1	25	4.6	28	9.9	203	3.1
500 Auxiliary Systems	80	8.7	83	11.6	116	8.8	83	7.0	544	17.5	746	12.6	156	30.6	73	25.8	613	12.4
600 Outfit/Furnishings	69	7.5	62	7.7	102	7.6	72	6.1	342	11.1	486	8.2	54	10.4	36	12.7	556	6.5
700 Armament	11	12	33	4.0	26	2.0	35	3.0	101	3.2	1%	2.6	22	4.3	10	3.5	76	12
Margin*	116	2.5	101	12.5	168	12.5	148	12.5	103	2.5	85		65	12.5	28	9.9†	1523	3.2‡
Light Ship	)41		111		513		128		1212		023		572		311		8093	
Loads**	560	4.0	188	34.9	423	21.8	114	3.8	655	21.0	2007	25.0	197	25.3	147	32.1	1455	152
Full Load	501		199		934		'42		4067		1030		779		158		9548	

* % of LS W/O Margins

** % is Expressed as Part of FL

† CA Hydrofoil designed to 9.9% margin rather than the required 12.5% margin

‡ 12.5% design~~ed~~ build margin + 10% service life applied to full load which must be carried by SWATH at beginning of service life

Table IV-8, Point Design Weight Summary

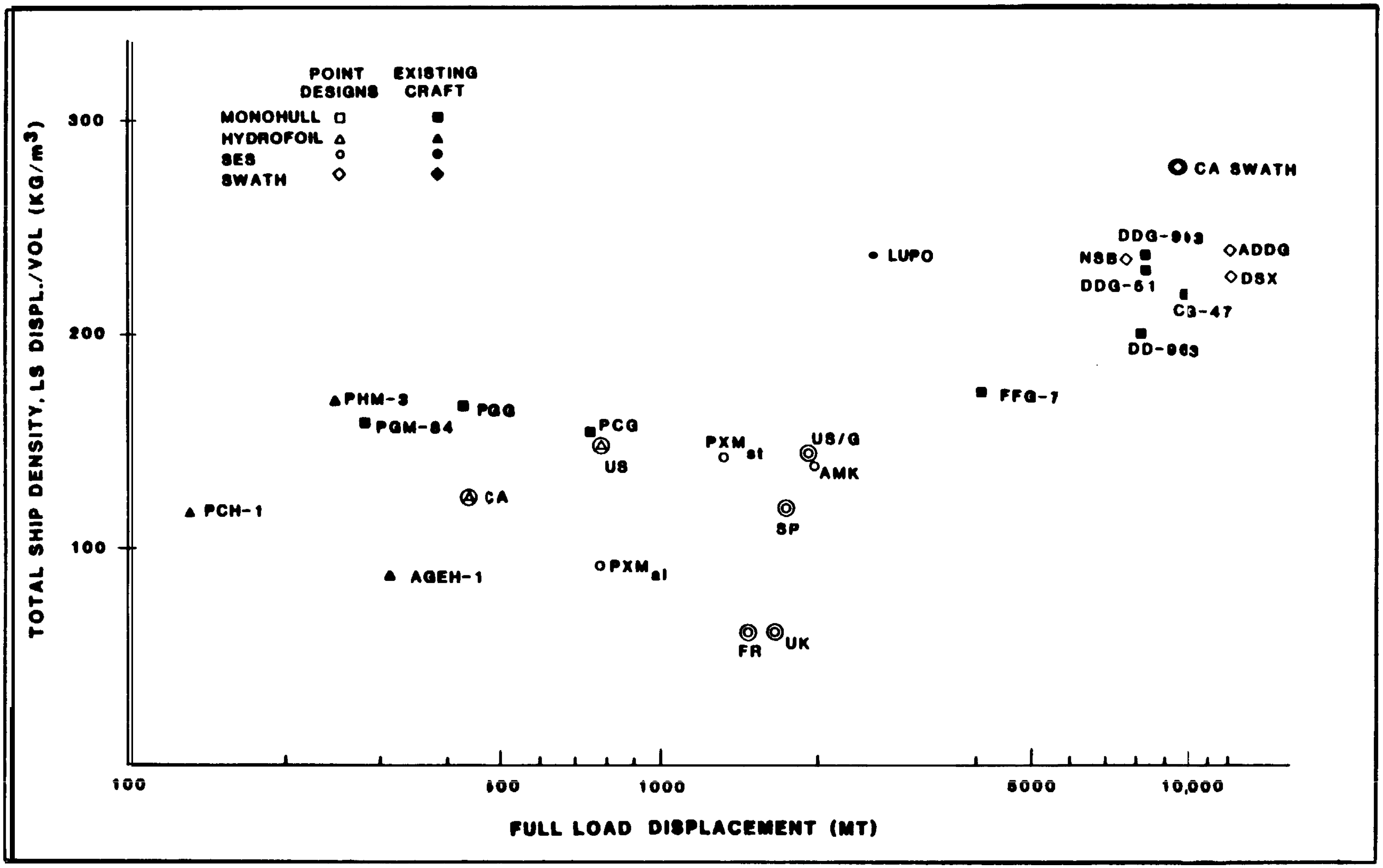


Figure IV-14 Total Ship Density

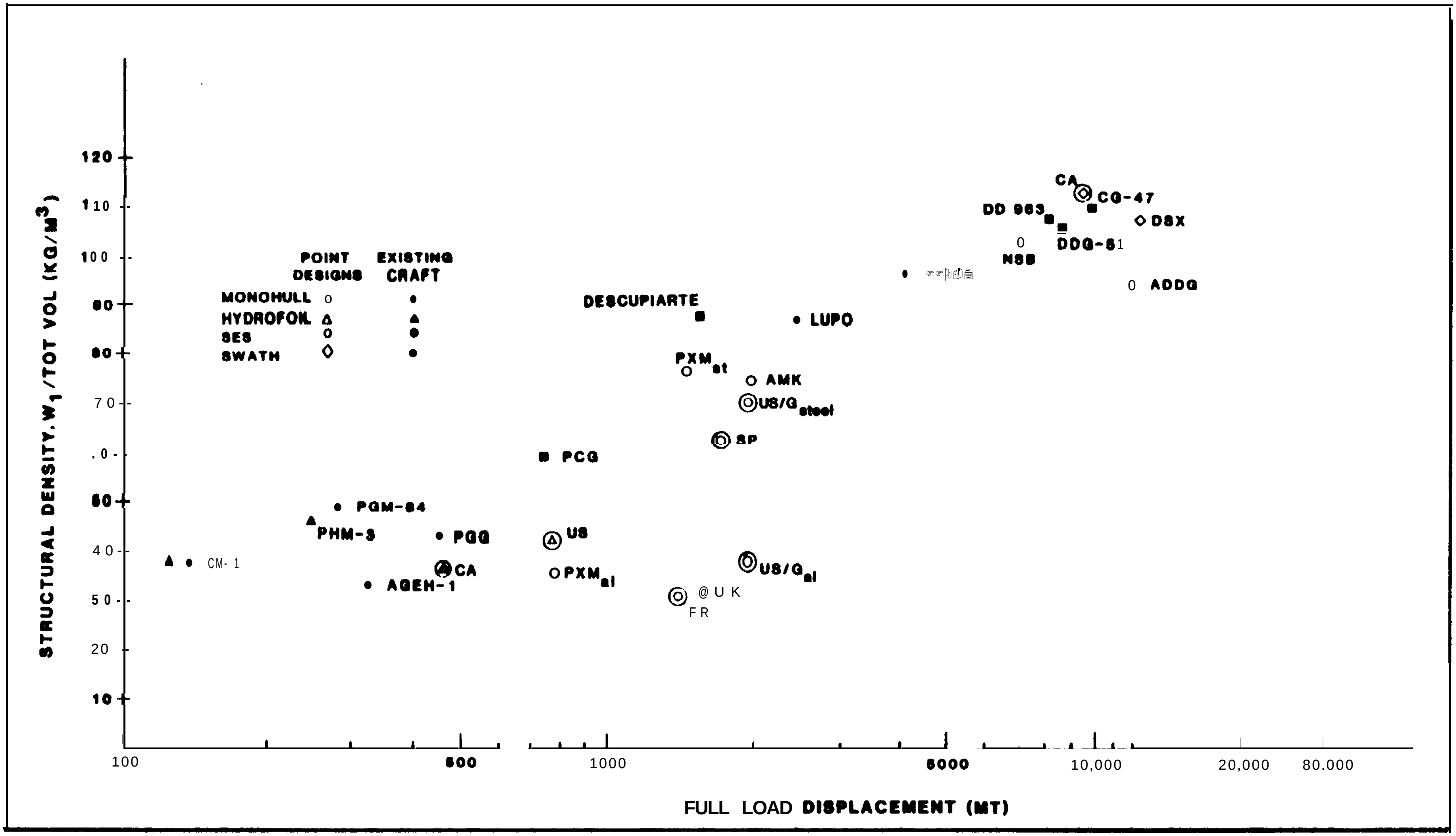


Figure IV-15 Structural Density

that the point designs generally fall within a reasonable band with the French and UK SES's at the lower bound because of their structural materials (aluminum and FRP, respectively) and national design practices, and the Canadian SWATH at the upper end as would be expected for a ship of that size and configuration. The low densities of the French and UK SES's reflect an aggressive approach towards reducing structural weight that represents a risk area if construction of a similar design were to be done in the U.S.

Propulsion plant densities (total propulsion plant weight including lift fans on the SES's divided by the total installed horsepower) as shown in Figure IV-16, follow expected trends with hydrofoils being the lightest and the SES's falling between them and the group containing the SWATH and conventional monohulls. The ANV's, with the exception of the SWATH, tend to use higher speed propulsors, lightweight diesels, and higher K-factors in their gearing, all of which combine to reduce propulsion plant weight but add risk.

Figure IV-17 shows total electric plant weight (generation and distribution) plotted against total installed generating capacity. The densities fall into a fairly narrow band, reflecting the generally conventional nature of the electric plant. Some weight reduction initiatives have been taken including the use of aluminum switchgear and variations on generator sub-bases and acoustic enclosures.

The final density plot is for auxiliary machinery and is presented in Figure IV-18. The hydrofoils come in high because of the inclusion of their foil systems. The SES's bound the low end of the field, primarily as a result of the use of lightweight systems and their higher percentage of unmanned volumes low in the ship reducing the need for HVAC and other distributive systems in those areas. The hydrofoil densities would be reduced significantly if the foil weights were subtracted, indicating a

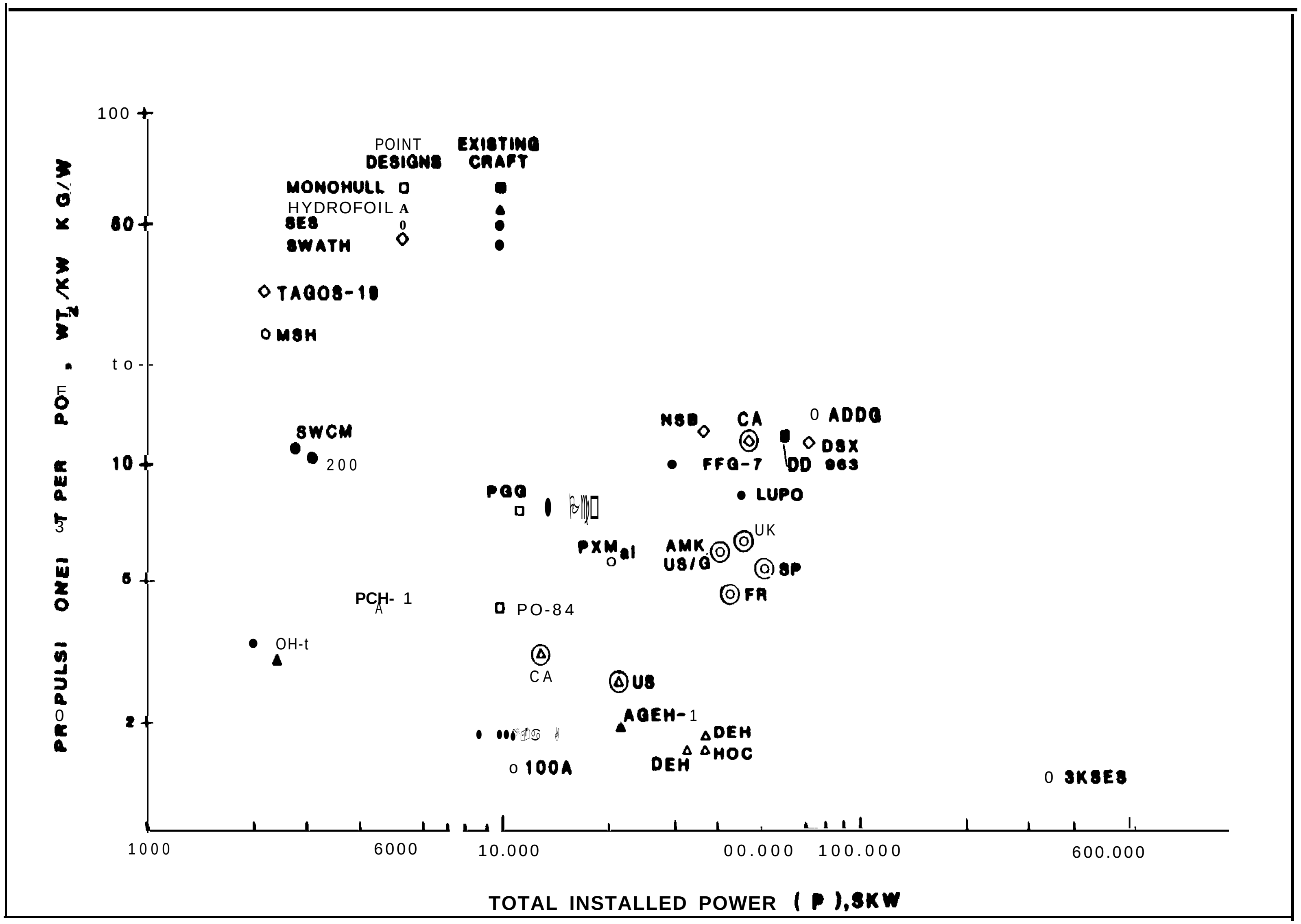


Figure IV-16 Propulsion System Weight per Installed Horsepower

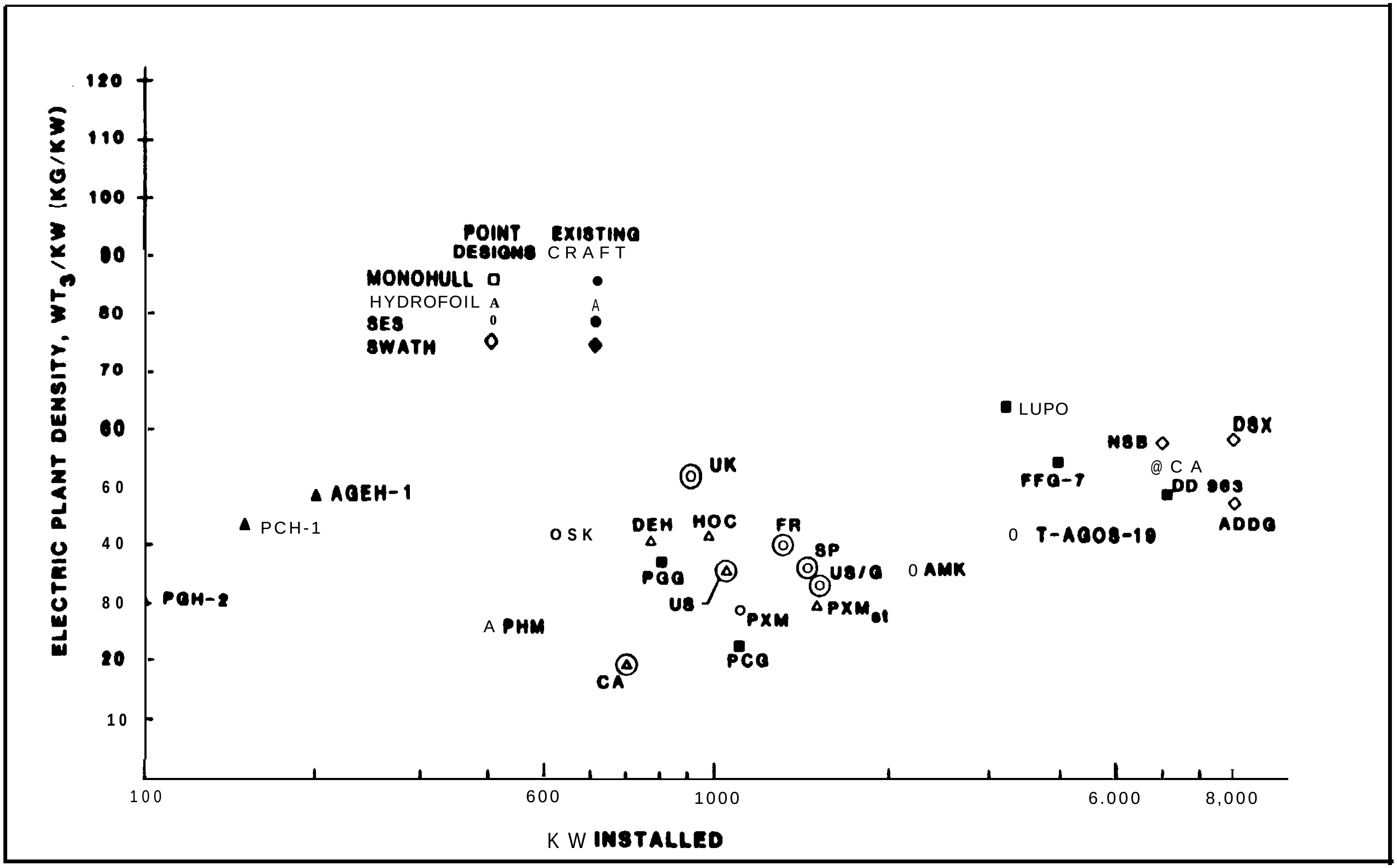


Figure IV-17, Electric Plant Weight per KW

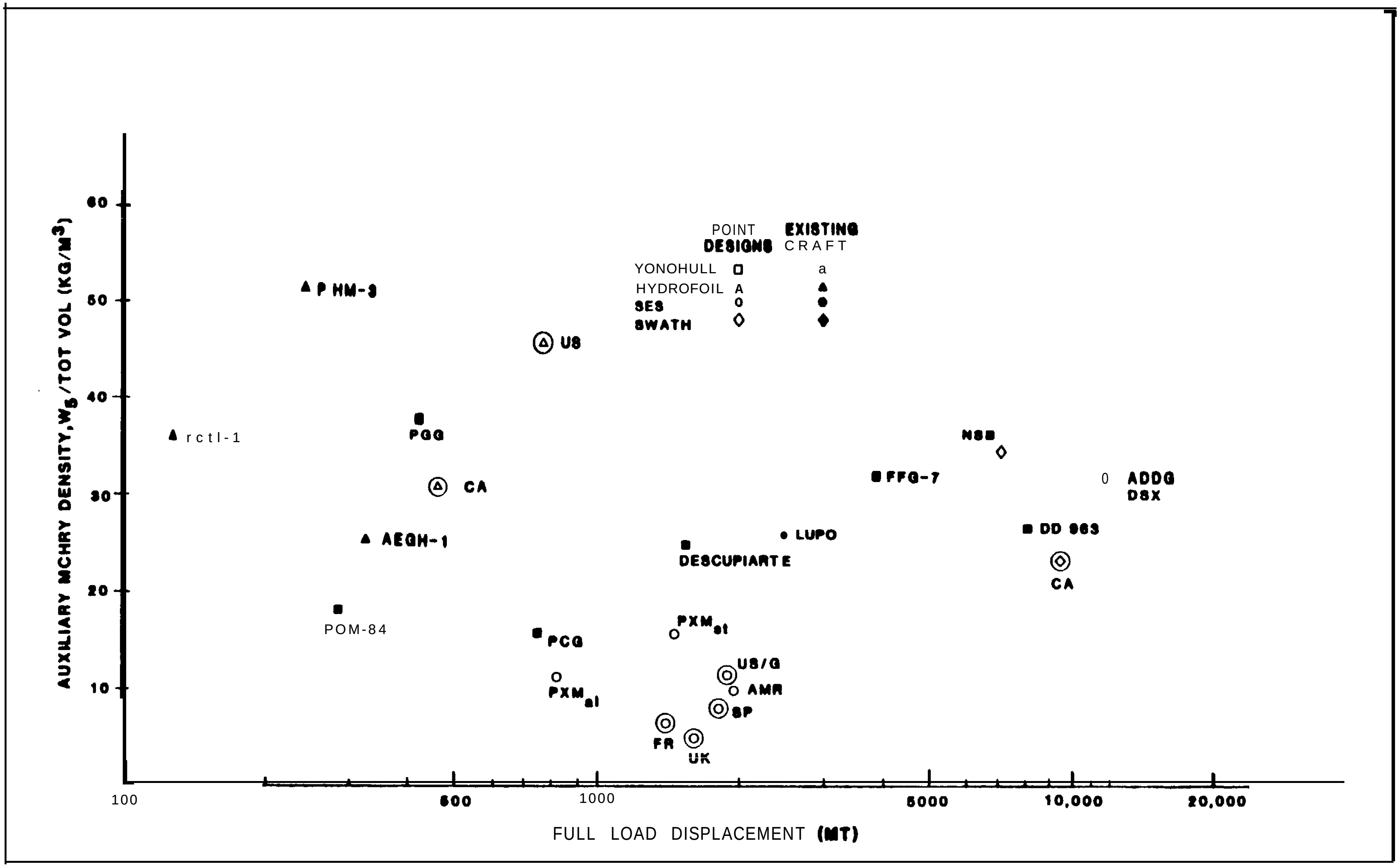


Figure IV-18, Auxiliary Systems Density

use of lightweight systems similar to that on the SES designs.

Outfit and furnishing densities for the SESs and hydrofoils are generally 25 to 75% those of the monohull analogues. This is a function of the smaller size of these ships, varying national standards, and maximum use of lightweight materials, primarily composites.

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Costs for all point designs were estimated by NAVSEA. In addition, each nation developed costs for their own designs and France and the UK provided costs for the other nations' SES designs. Since these estimates were based on each nation's shipbuilding methods and infrastructure the values were difficult to rigorously correlate; however, the cost estimates done by the US and the cost estimates for the US SES designs were higher than those estimates by the other nations. Generally, the US Hydrofoil was the most expensive on the basis of cost per lightship ton and the CA SWATH the lowest with the SES designs falling between the extremes. All designs were more expensive per ton than the monohulls on an individual ship basis; however, the ANVs were shown to offer cost advantages when looking at the total force required. Actual cost numbers cannot be presented because of proprietary considerations.

E. Conclusions

A summary of the conclusions derived from the ASW study is as follows:

- ANV platforms can offer significant speed and seakeeping advantages over conventional monohulls.
- Higher acquisition and operating costs of ANVs relative to conventional ships can be offset by operational advantages resulting in reduced overall mission or force costs.
- All three platform concepts are technically feasible.

- Development requirements are associated with each concept.
- Intermediate sized ships may be required as an interim step to these designs.

V. CURRENT PATROL AND MCM STUDIES

A. Lessons Learned from the ASW Studies

Four years of design and assessment activity for the ASW mission were completed with the delivery of the final report to the NNAG in December 1987. A new four-year program of work, addressing the **potential** of ANVs for the NATO Mine Countermeasures (MCM) and Patrol Craft (PC) missions, was then agreed by nations at the May 1988 meeting. This **new program of** work was approved by the NNAG at their June 1988 meeting. In September, nations presented a description of their perceived requirements for each mission in order that "envelopes" of mission requirements could be defined - within which parametric cost/performance trade-off analyses could be developed. The U.S. provided a "strawman"plan of action for this new program of work.

The "lessons learned" from the ASW studies were discussed at the May 1988 meeting and the following items were considered in planning the new program:

- Parametric cost/performance studies must be performed initially (within the nations' envelope of requirements) in order that the design requirements selected for prefeasibility studies would truly represent affordable solutions.
- Operational scenarios must be identified - including support logistics and manning criteria.
- Equivalent conventional solutions for comparison must be identified or designed.
- Critical technology risk and performance prediction **areas should be** recognized early on and **addressed** throughout the studies.

- Requirements. Mission Proposals for Comparative Analyses (MPCAs) should not be overly detailed and should address the mission; and not be tailored to the particular ANV platform.

It was also agreed that, in parallel with (or supportive of) the MCM/PC studies, SWG/6 should continue to provide a forum for continuing ANV technology transfer with respect to each nation's ANV activities and with specific focus on efforts to reduce the risk of critical technologies.

B. Approach

The schedule for the current program of work is shown in Figure V-l.

Identical parallel efforts are in progress for MCM and three PC variants: Fast Attack (FA), Enforcement of Laws and Treaties (ELT) and Harbor/Coastal Patrol (HCPC) Craft.

The major milestones for this effort are shown in the schedule of Figure V-I

C. Parametric Studies

The main purpose of the parametric studies was to provide an **"up front"** understanding of the sensitivity between cost and performance so as to provide a guide in the selection of **"affordable"** requirements. Parametric studies were conducted for both the MCM and PC missions. Types of craft explored for the MCM mission included ACVs, SES, Planing Catamarans; and SWATH. For the PC mission only SES and monhulls have so far been examined.

The approach used was similar for all missions and platform types. By way of example, the following summarizes the scope and results obtained for SES in the MCM role.

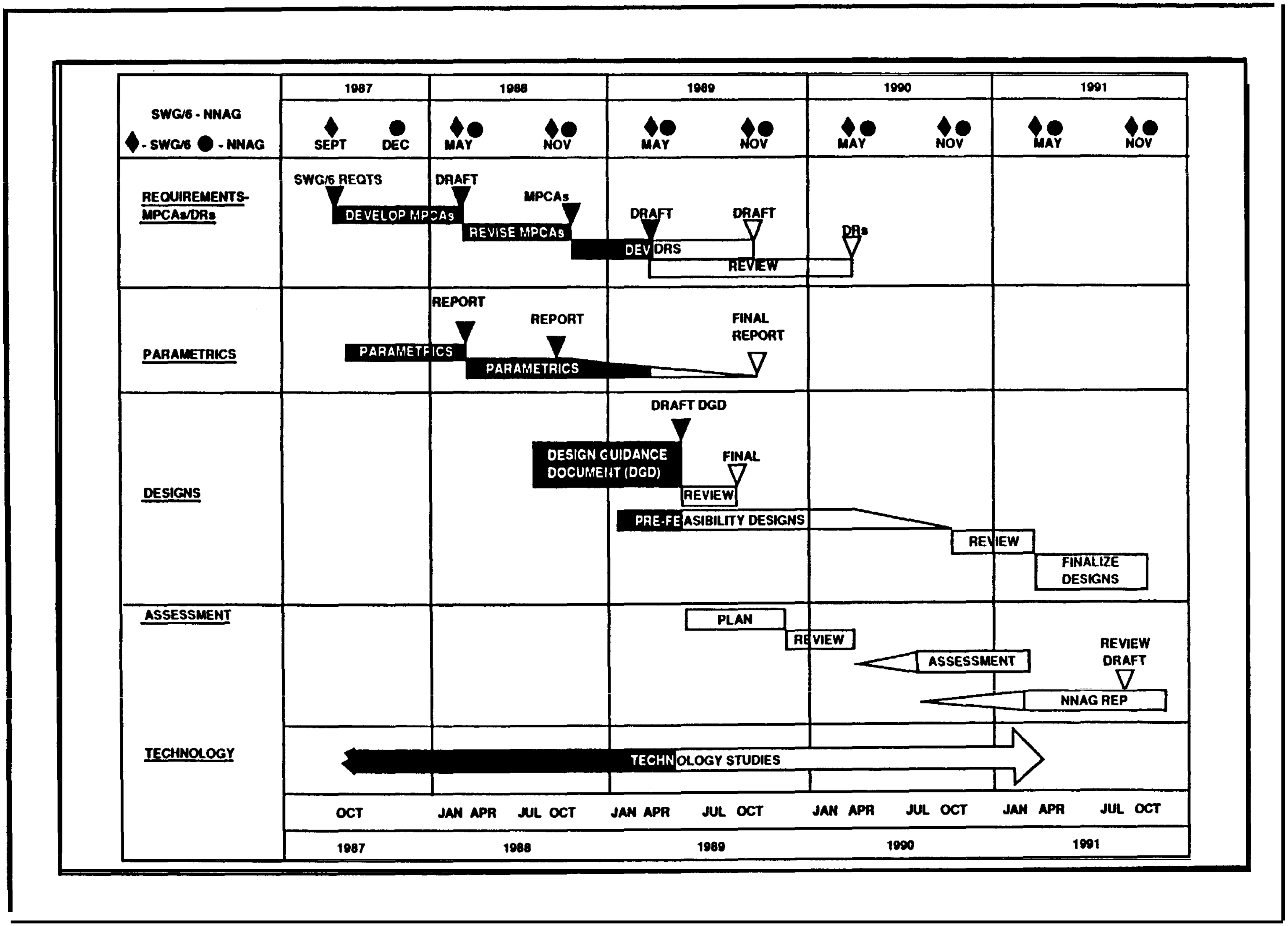


Figure V-1. Schedule

Figure V-2 identifies the range of requirements derived from the draft MPCA. The values enclosed within the boxed-in area of the figure are values for which complete permutations were examined. The values which are highlighted represent a smaller set to explore the effect of changing on-station endurance when towing MCM gear (at line 4 in the figure) and also to explore a higher value for round-trip range (at line 6). Lines 9 and 10, at the bottom, show the range of craft sizes explored. In all, a total of 828 balanced SES designs were developed using a "whole-ship" conceptual-design synthesis model.

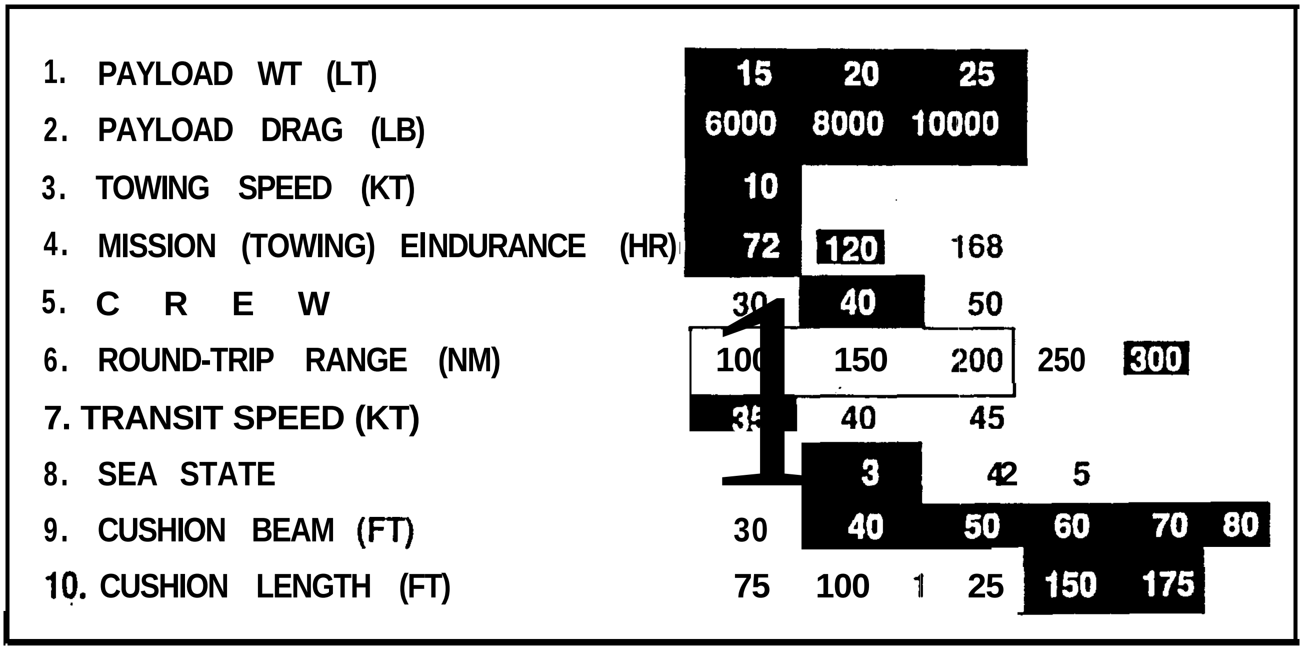
Seakeeping criteria were considered to be one of the most important constraints on the selection of minimum acceptable platform size and for the parametric study the following criteria were adopted:

- Vertical Acceleration in Head Seas:

  $\leq$ 0.15 g RMS at CG
  $\leq$ 0.275 g RMS at Forward Perpendicular

- Freeboard Limit (Hullborne for SES)

  Open Ocean Curve from Figure V-3



1. PAYLOAD WT (LT)	15	20	25			
2. PAYLOAD DRAG (LB)	6000	8000	10000			
3. TOWING SPEED (KT)	10					
4. MISSION (TOWING) EINDURANCE (HR)	72	120	168			
5. CREW	30	40	50			
6. ROUND-TRIP RANGE (NM)	100	150	200	250	300	
7. TRANSIT SPEED (KT)	35	40	45			
8. SEA STATE		3	42	5		
9. CUSHION BEAM (FT)	30	40	50	60	70	80
10. CUSHION LENGTH (FT)	75	100	1 25	150	175	

Figure V-2. Range of Operational Requirements

Other seakeeping criteria were considered beyond the scope of the study. However, the use of the criteria used in the study should ensure sufficient confidence in the feasibility of results. For the subsequent prefeasibility-level designs, a more comprehensive set of criteria is being used.

The vertical acceleration limits were assumed to apply for situations in which the SES Ride-Control System (RCS) was inactive. However, the prediction of SES response to the various sea states assumed a coisine-squared spreading function to account for multi-directional seas.

The freeboard limit used is based on the curves derived from Figure V-3. The figure was developed for small monohulls and shows the ratio of freeboard (at the forward perpendicular) to the length on the waterline plotted as a function of waterline length.

The top curve labeled "suitable for open ocean" was adopted and was applied to govern the minimum acceptable freeboard for SES operating hullborne.

Figure V-4 is an example of one of the working plots showing relative cost versus platform dimensions. Plots like these were used to determine the minimum cost solution for each set of requirements. Figure V-4 presents quite a busy chart but shows how cost varies with changing length and beam for craft all designed to meet just one set of requirements.

Overlaid on the chart, as broken lines, are two sets of curves of varying RMS vertical acceleration. There is one set for CG acceleration and another set for bow acceleration, all for operation at 35 knots while heading into a sea-state 3.

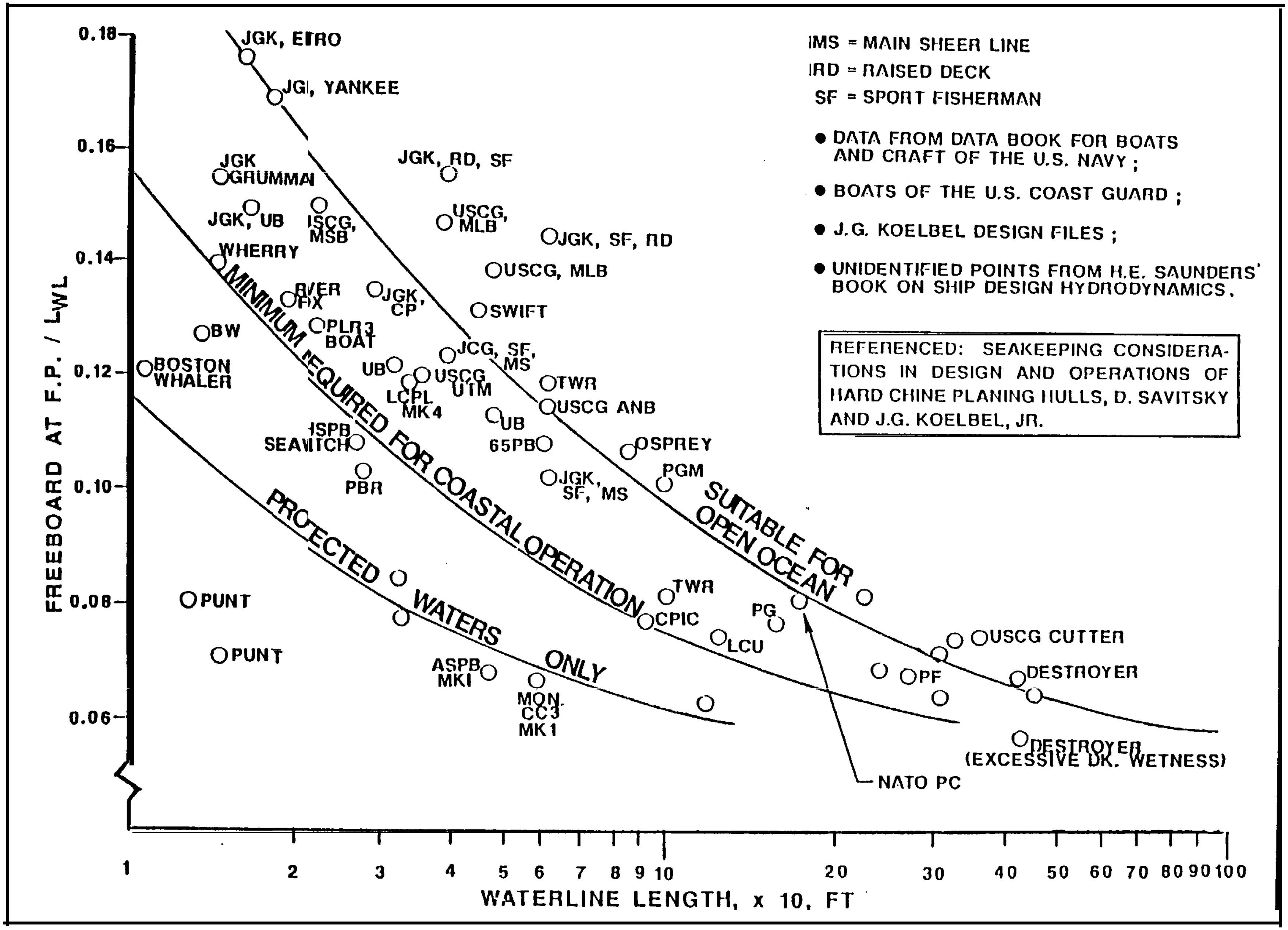
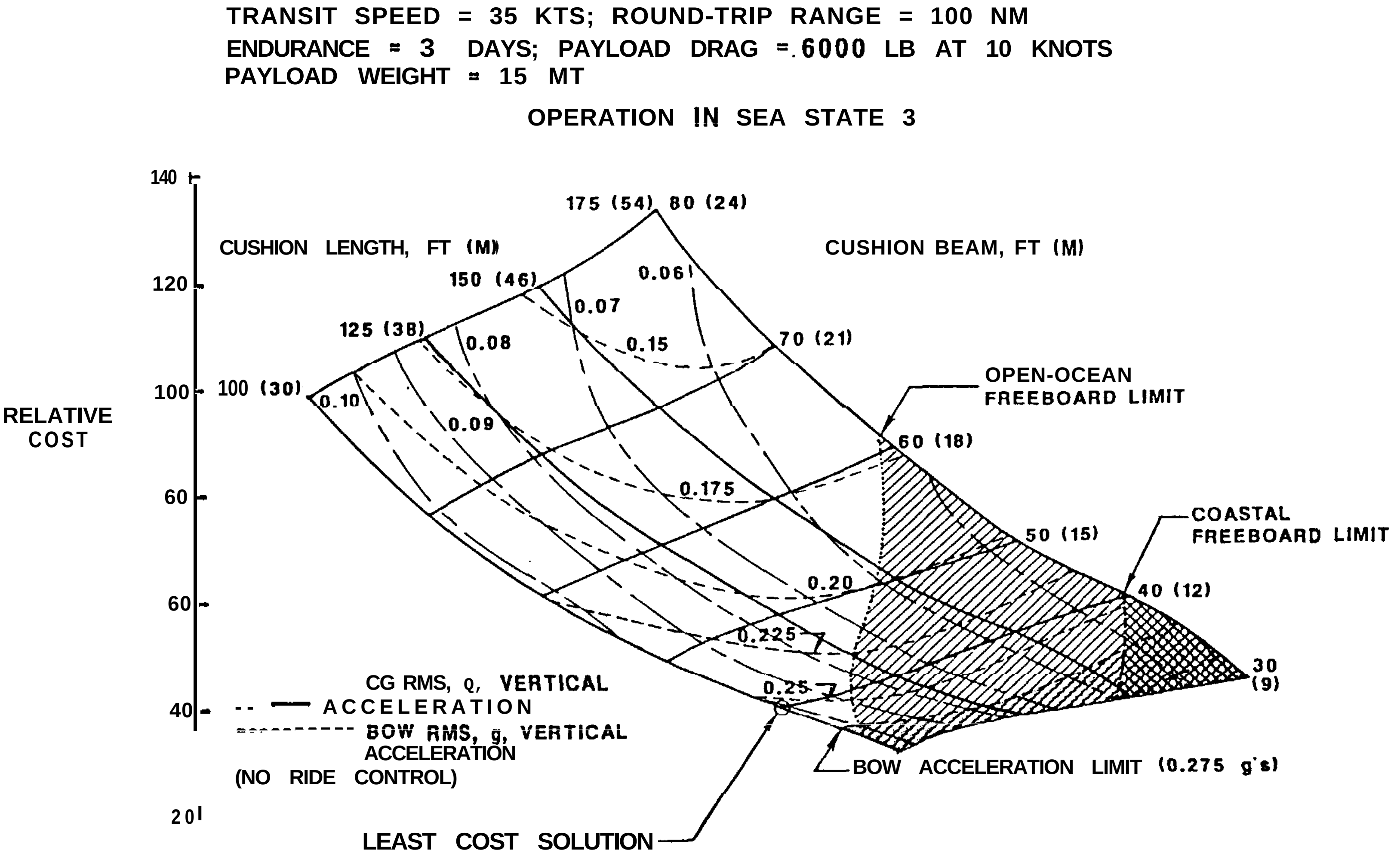


Figure V-3. Guidelines for the Selection of Freeboard



NOTE: ALL POINTS MEET THE 0.15 g RMS ACCELERATION LIMIT AT THE LCG

Figure V-4. Typical Plot of Cost Versus Length and Beam (Sea-State 3)

Craft which exceed the bow acceleration limit are below the lowest shaded area of the plot. None of the craft, however, exceeded the CG acceleration limit. Also shown are the freeboard limits which restrict our choice of platforms to those which are to the left of the shaded areas on the right-hand side of the figure.

The least-cost solution which satisfies these specific requirements is a craft having cushion dimensions of 30 meters by 12 meters, as shown on Figure V-4.

Figure V-5 shows all the least-cost solutions for the requirements stated on the figure. The solution taken from Figure V-4 is shown at the bottom. Similar figures were developed to describe the relationship between cost and all of the requirements shown in Figure V-2.

The results shown in Figure V-4 and V-5 were for operation in sea-state 3. Thus, all craft were designed with power to achieve 35 knots while heading into a sea-state 3 with acceptable ride quality without active ride control.

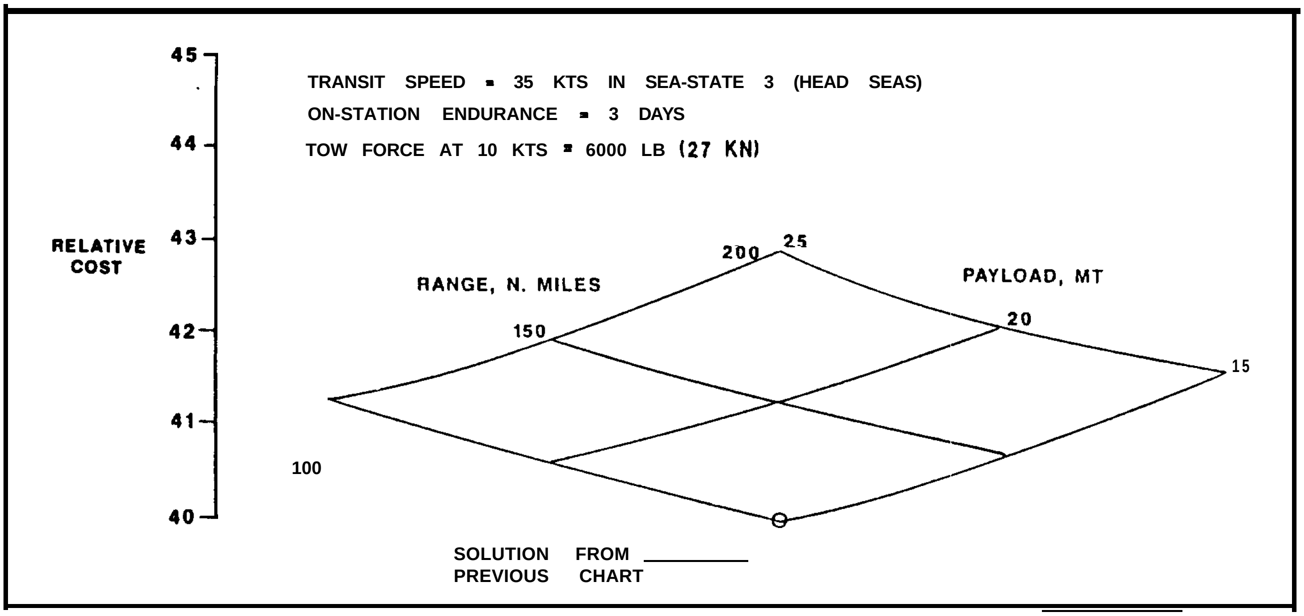


Figure V-5. Cost Versus Range and Payload (Sea-State 3)

However, for nations interested in a higher sea-state capability we investigated the effect on seakeeping of operating these same craft in sea-state 4 at a lower speed of 25 knots. This is a speed that all the craft could achieve without increase in total power. In this case, as shown in Figure V-6, much larger craft are required to meet the requirements. Here the vertical acceleration at the bow is the controlling factor and we cannot select craft dimensions from within the shaded area of this figure.

The least-cost boat for sea-state 4 that meets the stated requirements listed at the top of this figure is, therefore, a boat with cushion dimensions of 50 by 18 meters as compared to 30 by 12 meters for sea-state 3. The corresponding cost has doubled as a result of designing for sea-state 4 as compared to sea-state 3.

Since these craft are to operate for a much longer period of time at low speed while towing we also looked at the 10 knot case in sea-state 4. As one would expect, or at least hope, Figure V-7 shows the 10 knot case in sea-state 4 to be far less restrictive than the 25 knot case in sea-state 4.

Figure V-8 shows a plot of all the least-cost solutions for sea-state 4.

Figure V-9 is a repeat of the previous figure but to a different scale to show the impact of increasing the on-station endurance from 3 days to 5 days. This again, is for operation in sea-state 4. The platform cost increase is seen to be approximately 12% when designing for 5 days as opposed to 3 days.

Figure V-9 also features the effect of extending the roundtrip transit distance to a range of 300 nautical miles. The figure shows that the cost increment in selecting 300 nautical miles, as opposed to 100 nautical miles, is only 1.6%.

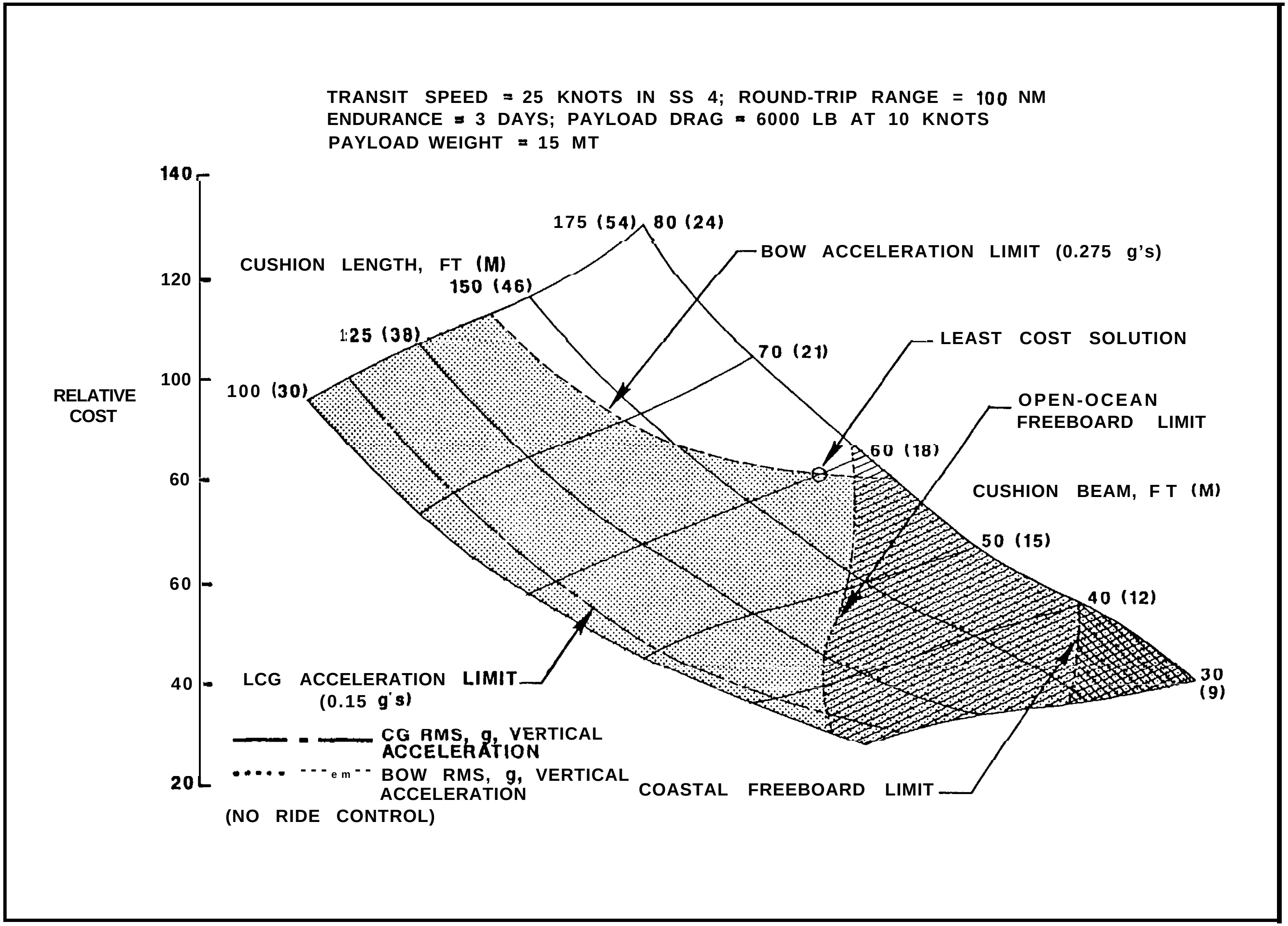


Figure V-6. Cost Versus Length and Beam (Sea-State 4)

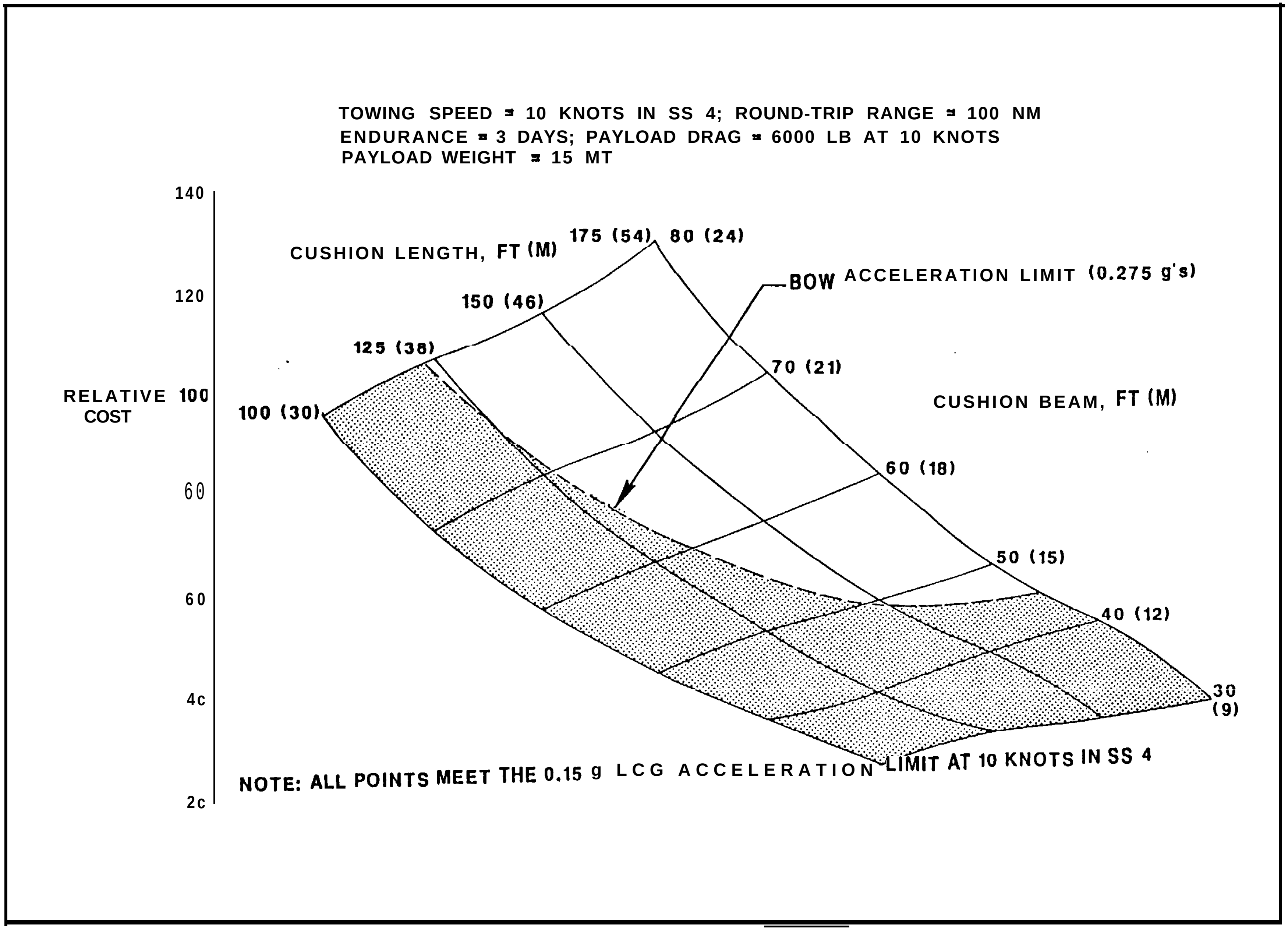


Figure V-7. Cost Versus Length and Beam at Low Speed in Sea-State 4

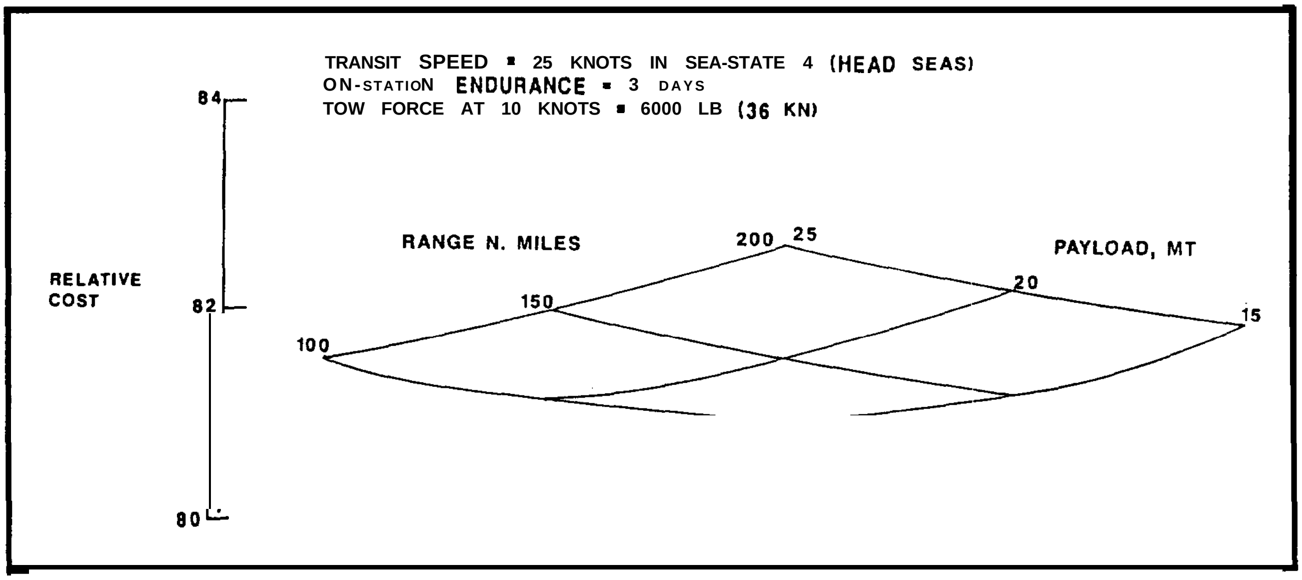


Figure V-8. cost Versus Range and Payload (Sea-State 4)

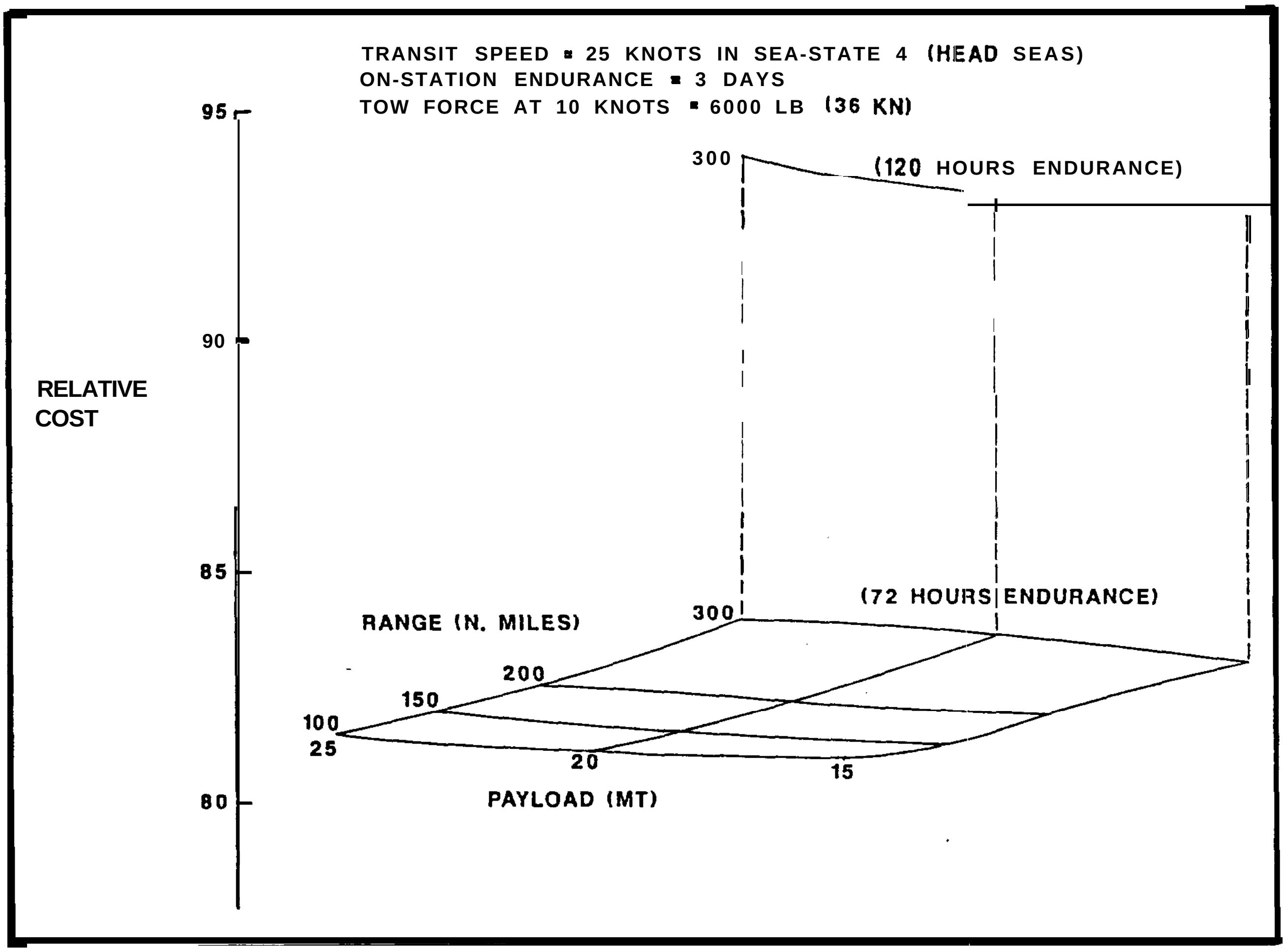


Figure V-9. Cost Vs Range, Payload & Endurance in Sea-State 4

Tables V-l and V-2 provide a summary of results obtained for sea-states 3 and 4, respectively. Table V-l shows, for craft designed for habitability in sea-state 3 at 35 knots, the effect of varying payload, payload drag and round-trip range.

No single one of these variations has dramatically altered the design. The payload is relatively small in comparison to the total displacement of the craft and a total payload variation of 10 mt is therefore not especially significant. Since the propulsion power requirements have been dictated by the 35 knot cruise speed and not the 10 knot towing mission, the impact of changes in the payload drag is largely reflected in the required fuel load that occurs as the engines operate at different points along the engine performance curves in order to accommodate the changing tow loads. The round-trip range also has its greatest impact upon the fuel load. However, limited investigations of the effect of varying mission endurance indicate that this will have a far more dramatic effect on design than payload weight, payload drag or round-trip range.

The general observations made of craft designed for sea-state 3 seakeeping requirements at 35 knots also pertain to craft designed for sea-state 4 seakeeping requirements at 25 knots. It was necessary, however, to resort to larger craft to accommodate the sea-state 4 requirements than was the case for sea-state 3. The displacement and cost have roughly doubled from one design to the other. The impact of the changes in payload weight, payload drag and round-trip range have, therefore, in relative terms, become even less marked.

Similar results to those presented here for SES are now available for ACVs and Planing Catamarans designed for the MCM mission. Parametric results for SWATH designs are being prepared by the UK.

Table V-l

Design Variations to Satisfy Sea-State 3 Seakeeping Requirements at 35 Knots

L_C = 100 FT (30 M); B_C = 40 FT (12 M)
CRUISE SPEED = 35 KNOTS IN SEA STATE 3
TOWING SPEED = 10 KNOTS IN SEA STATE 3
DESIGN COMPLEMENT = 40

PAYLOAD WT (MT)	25	15	20	BL	BL	BL	BL
PAYLOAD DRAG (LB)	8000	BL	BL	6000	10000	BL	BL
MISSION (TOWING) ENDURANCE (HRS)	72	BL	BL	BL	BL	BL	BL
ROUND-TRIP RANGE (NM)	200	BL	BL	BL	BL	100	150
DISPLACEMENT (MT)	375.3	353.6	364.7	365.1	385.8	360.5	367.3
POWER • THRUST (KW)	10373	9378	9873	9892	10877	10179	10026
• LIFT (KW)	1634	1567	1597	1599	1663	1588	1611
FUEL LOAD (MT)	119.9	113.5	116.7	111.9	128.0	111.1	113.4
RELATIVE COST	38.3	37.0	37.7	37.7	39.0	37.0	37.9

↑ BASELINE **EXAMPLE (BL) - SS** 3

Table V-2

Design Variations to Satisfy Sea-State 4 Seakeeping Requirements at 25 Knots

L_C = 165 FT (49 M); B_C = 60 FT (18 M)
CRUISE SPEED = 35 KNOTS IN SEA STATE 3
TOWING SPEED = 10 KNOTS IN SEA STATE 3
DESIGN COMPLEMENT = 40

PAYLOAD WT (MT)	25	15	20	BL	BL	BL	BL	BL
PAYLOAD DRAG (LB)	8000	BL	BL	6000	10000	BL	BL	BL
MISSION (TOWING) ENDURANCE (HRS)	72	BL	BL	BL	BL	BL	BL	BL
ROUND-TRIP RANGE (NM)	200	BL	BL	BL	BL	100	150	300
DISPLACEMENT (MT)	736.4	720.4	728.3	728.3	743.7	719.0	727.8	755.6
POWER - THRUST (KW)	14974	14402	14672	14673	14959	15153	15143	14997
- LIFT (KW)	3330	3260	3306	3300	3355	3275	3304	3387
FUEL LOAD (MT)	159.4	156.6	157.9	152.9	164.1	147.7	153.9	171.8
RELATIVE COST	82.6	81.9	82.1	82.1	83.2	81.5	81.9	84.1

BASELINE EXAMPLE (BL) - SS 4

Results for the patrol-craft mission have been developed for the SES while comparable monhull parametrics are in preparation. The range of craft examined by the parametric study of SES patrol craft is illustrated in Figure V-10.

All of these results produced to date by the parametric studies have been used to guide nations in the selection of useful and affordable requirements.

D. Design Guidance

D.l Background

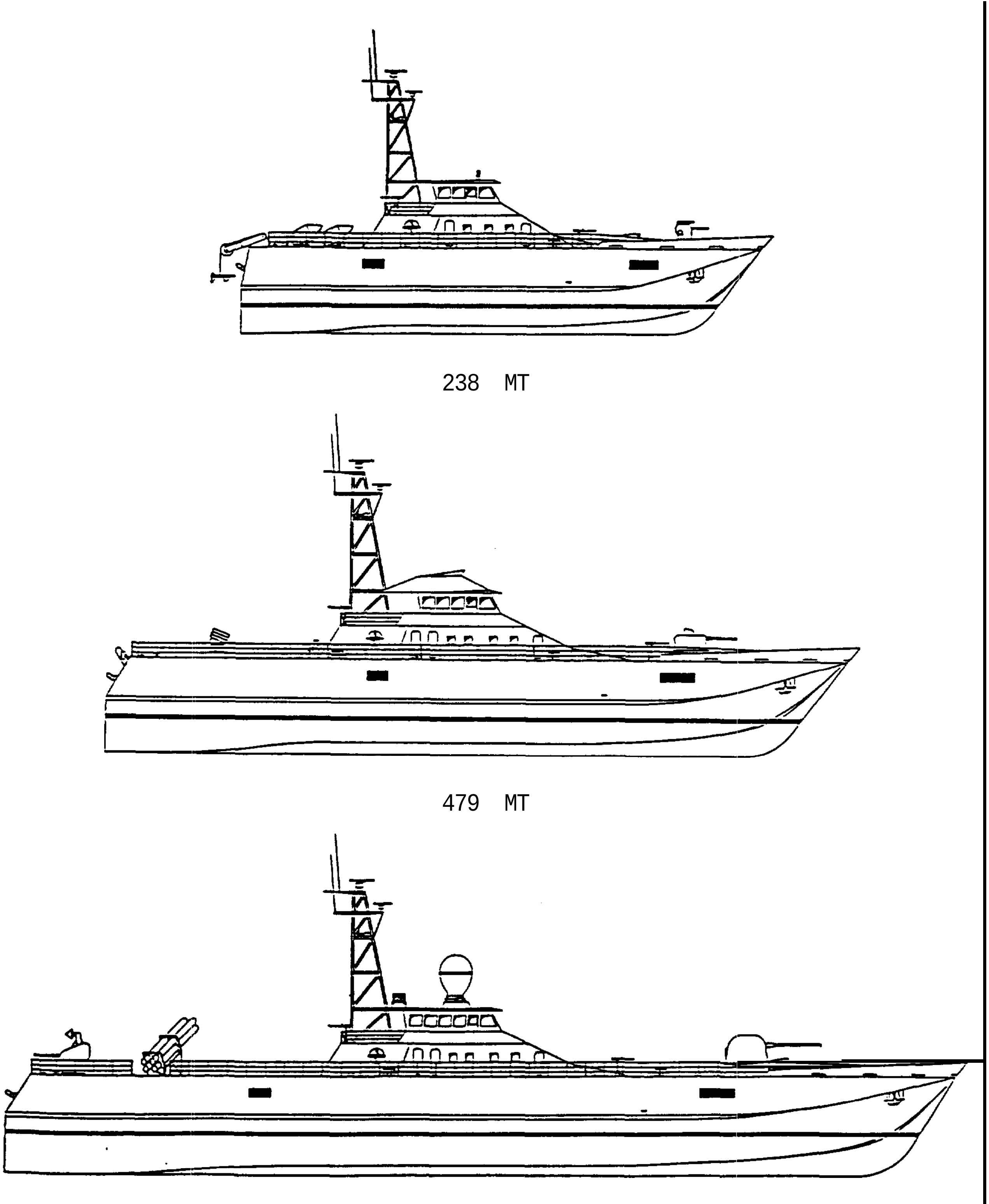
The study of ASW escort vessels conducted by SWG/6 between 1983 and 1987 relied upon a common "Study Guidance Document" which helped the designers to develop point designs to a common set of standards and to provide information requested for a subsequent technical assessment. This document was specific to ASW ships and was limited to the three types of ANVs studied for that mission. For the new study engaged by the SWG/6 in 1987 it was necessary to update this document.

This new document has been prepared as one in a logical chain of requirements documents which are being developed for the current SWG/6 studies. The documents being produced, in the order of their development, are as follows:

a. Mission Proposal for Comparative Analysis (MPCA) (equivalent to a Mission Need Document (MND) in the NATO design procedure)

b. Design Requirements (DR) Document (equivalent to an Outline NATO Staff Target (ONST))

c. Design Guidance Document (DGD).



238 MT

479 MT

734 MT

Figure V-10. Range of SES Examined for the Patrol-Craft Mission

D.2 Purpose

The purpose of the design guidance document is to provide a common set of design standards, definitions and units and a common reporting format to facilitate a fair evaluation of specific prefeasibility-level point designs in terms of cost, effectiveness and technological risk.

The purposes of developing designs in a prefeasiblity study are:

a. To define ships that meet or approach the design and operational requirements of the mission considered

b. To evaluate the potential of ANVs for the mission considered

c. To achieve a balance between operational requirements, projected production costs, and technological risks

d. To identify major technological risks

e. To identify advantages and disadvantages in comparison with conventional ships designed for a similar mission.

D.3 Definition of a Point Design

The evaluation of any proposed major military hardware system is always a function of three closely interrelated factors, namely:

a. Military Value or Effectiveness,
b. Cost or Affordability, and
c. Technological Feasibility.

When trying to make decisions regarding the relative merits of various types of Advanced Naval Vehicles (ANVs), a decision-maker is confronted with a large number of design parameters associated with each of the factors listed above. Also, each design parameter is capable of taking on a wide range of possible values. To deal with the complexity of the problem of an incredibly large number of possible trade-offs, it is considered necessary to focus attention on a specific design (i.e., some "point" of the possible range of parametric design curves) for purposes of analysis. Use of a specific design (or "point design" in our new terminology) enables us to make a more meaningful evaluation of performance, cost and technological risk. Each point design is fashioned around a particular set of desired features, or is used to highlight certain technological or operational issues.

It is recognized that design standards and the design process itself will differ among nations. For purposes of comparison and evaluation, however, all designs should adhere to a common report format, common standards and common guidelines. In SWG/6, therefore, an ANV "point design" is a prefeasibility-level design that assumes an Initial Operational capability (IOC) date for the ship some 10 to 20 years in the future depending on the complexity of the mission and the size of the ships envisioned. Such a design represents possible alternatives for satisfying the future mission requirements. The design guidance document prescribes the format and basic content for the "point design," as well as the specific products desired of the point-design process, to provide a common basis for evaluation.

E. RequirementsDetermination

The typical schematic for a SWG/6 Program of Work shown in Figure V-11 might cause one who is unfamiliar with the ship design process to conclude that the step from the Design Requirement Document to the point design is simple and straightforward. Regrettably, this is not the case. The purpose of this section, therefore, is to discuss some of the complexities involved in this transition. In general terms, there are a number of steps involved in transforming the broad mission statements and goals of the design requirement document into a more definitive set of top-level design requirements which a design team can begin to deal with. This discussion is treated generically in recognition that unique national processes for determining these design requirements will vary. The process of defining mission requirements and "required" ship capabilities is of fundamental importance to the ultimate design process. The designer would like to specify required features or capabilities as narrowly as possible in order to "optimize" his design with respect to certain key parameters. The operator, or fleet user, on the other hand, would like to retain maximum flexibility with respect to future employment options, and thus, desires a broad definition of requirements. The operator realizes that naval warfare scenarios cannot be predicted with great precision over the projected life of a surface platform (i.e., 20 to 30 years): therefore, design requirements must remain broad and flexible. Clearly, the requirements determination process must recognize both of these viewpoints - the designer and the user.

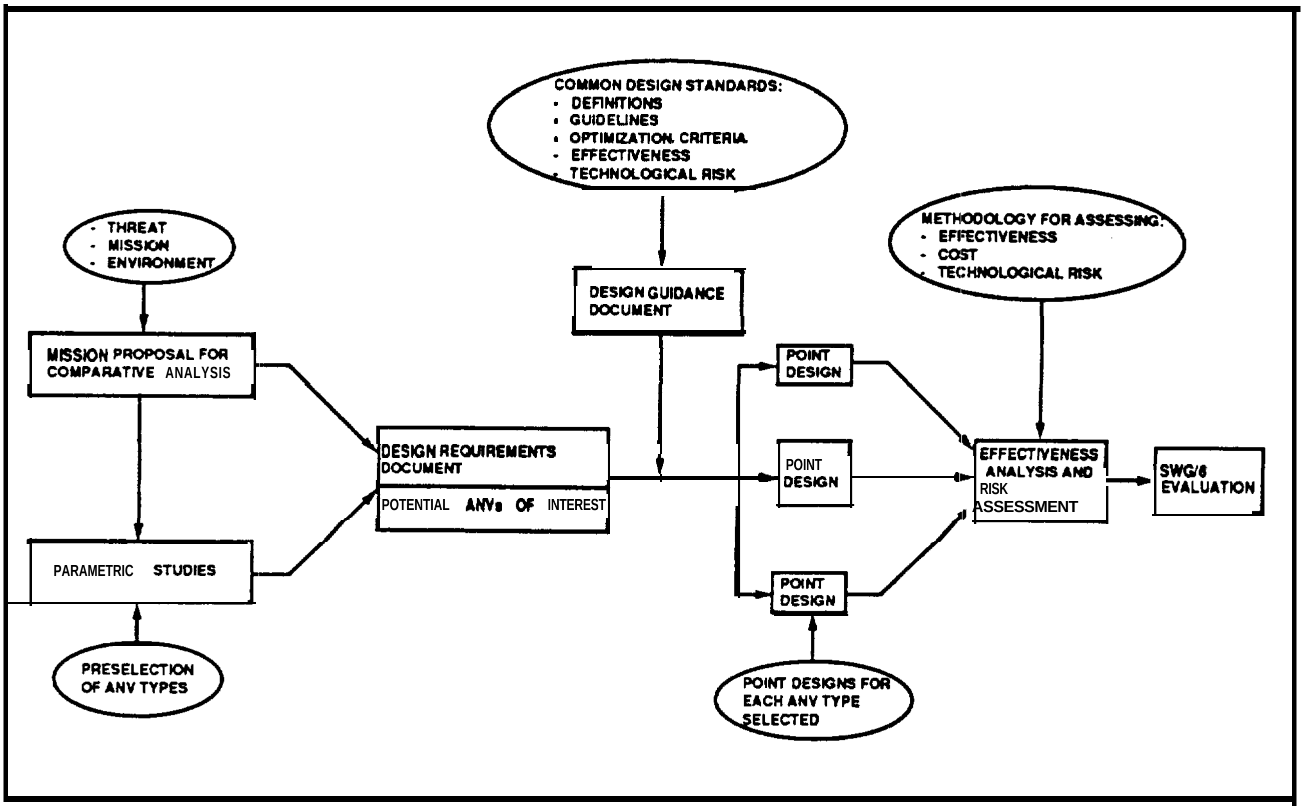


Figure V-11. Schematic of SWG/6 Program of Work

Figure V-12 shows a general process for determining the top-level requirements for a point design. In the discussion which follows, each of the essential steps (the numbered blocks in the diagram) are briefly discussed.

The first three blocks derive their basic information from the Design Requirement Document. The broad mission requirements (block 1) are based on the postulated threat and proposed concept of operations spelled out in the Design Requirement Document. Examples of broad missions, or tasks, that might appear in this step, are the following:

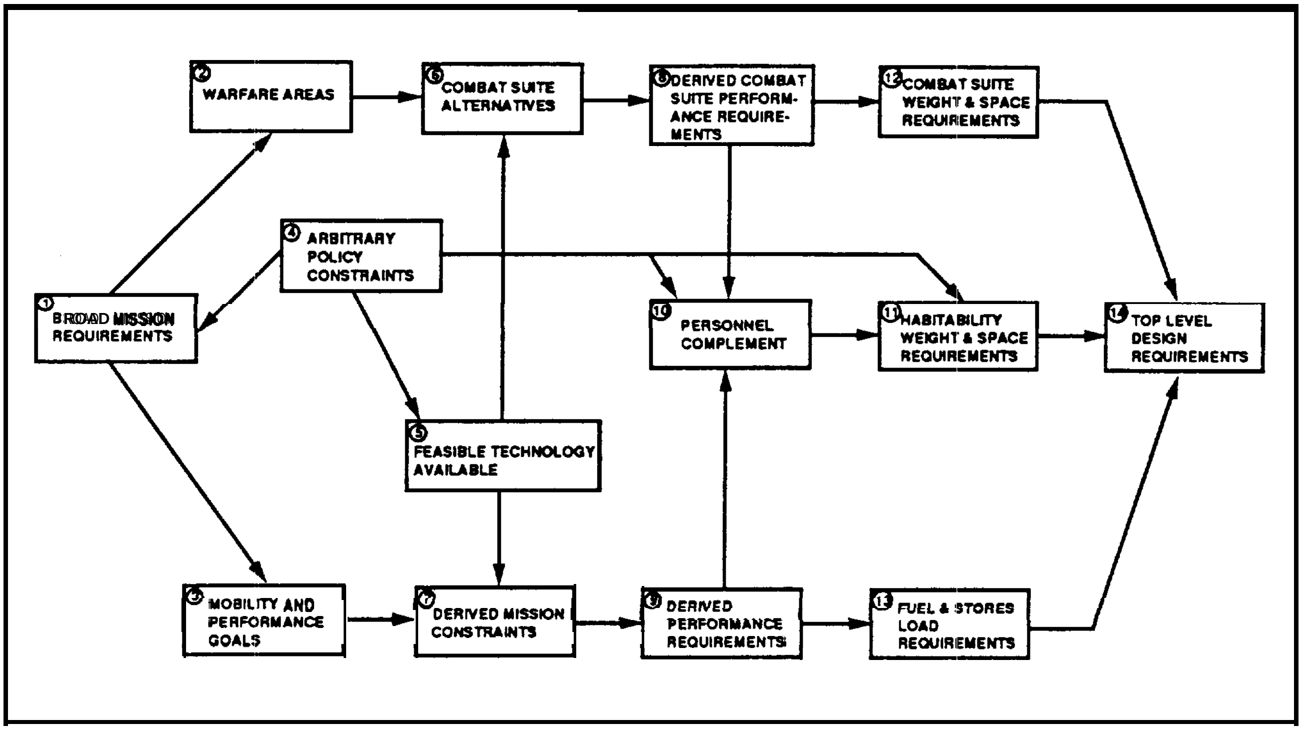


Figure V-12. Determination Process for Top-Level Design Requirements

a. Escort operations involving the protection of Allied Naval Forces and merchant shipping against enemy air, surface or subsurface attacks,

b. Open-ocean, sea-control operations involving clearing and use of ocean areas and/or the denial of their use to 'enemy air, surface or subsurface forces, and

c. Barrier or containment operations involving the denial of passage to enemy air, naval or merchant forces through a fixed zone.

The threat information contained in a Design Requirement Document is not normally definitive enough to suit the combat system design community. What is sometimes lacking is sufficient depth of detail on the assumed threat with respect to density, rates of attack, etc.

The broad mission statements may, or may not,, indicate the specific mission warfare areas involved. In either case, the Design Requirements Document addresses the essential capabilities in terms of warfare such as:

a. Anti-Submarine Warfare (ASW)
b. Anti-Air Warfare (AAW)
c. Surface Warfare (SUW)
d. Mine Warfare (MIW)
e. Others

The list of warfare areas and required capabilities defined in block 2 of Figure V-12 is a necessary starting point for the development of alternative combat suites in block 6.

Block 3 deals with the specification of mobility and performance goals spelled out in the Design Requirements

Document. Examples of the kind of mission-essential performance information, at specified wave heights, are as follows:

a. Speed,
b. Range,
c. Endurance,
d. Seakeeping,
e. Maneuverability.

It is emphasized that these items represent "goals" and not hard and fast "requirements" at this stage of the design process.

In a period of scarce national resources for all NATO members, any process such as this must consider the impact of arbitrary policy constraints. Realistically, there will always be affordability constraints and sometimes political constraints that impact our consideration of mission requirements (block 1), the potential utilization of available technology (block 5), or the number of personnel available (block 10). Block 4 represents our recognition of these arbitrary policy constraints which sometime limit our options.

A key step in the requirements processed is the determination of what technology will be feasible and available (block 5). A technology freeze date is usually assumed and in particular for subsystems, which may be candidates for consideration, are either available or not based on their assumed stage of development in the R&D process. This information becomes an important input to blocks 6 and 7.

Alternative combat suites (block 6) are developed based on the warfare areas (ASW, AAW, SUW, MIW, etc.) to be covered, and the technology assumed to be available. For the first iteration at least three fundamental levels of capability are proposed.

Each alternative combat suite will be composed of different elements to achieve the different levels of capability postulated.

Based on the elements in each of the proposed combat suite alternatives, the next step (block 8) is to derive appropriate performance requirements associated with the various elements proposed. These derived performance requirements then serve as inputs to blocks 10 and 12, as shown.

In block 7, derived mission constraints are developed based on the mobility and performance goals (block 3) and the assumed technology available (block 5). These derived mission constraints consider such things as required speed of advance for an escort mission, and maximum allowable search speed for a mine surveillance sonar.

The derived mission constraints (block 7), in turn, drive the determination of derived performance requirements in block 9. Specific examples are a speed-range profile, speed-time profile, and, for a hydrofoil in particular, a foilborne range required.

The determination of personnel complement in block 10 is based on derived requirements to man both the combat system (block 8) and the platform (and propulsion system) (block 9), plus provision for maintenance personnel, support personnel etc., based on appropriate logistics guidance and goals outlined in the Design Requirements Document. Once the personnel functional requirements have been determined, then the habitability space and weight relationships (block 11) can be determined.

Similarly, once the combat suite requirements (block 8) have been fixed, then the weight and space requirements can be determined (block 12). Also, once the platform performance requirements (block 9) have been determined, the rough fuel and stores load parameters (block 13) can be determined.

Finally, block 14 depends on inputs of space and weight relationships for the combat suite, personnel, and fuel and stores, as well as the propulsion plant for the platform itself.

The foregoing general discussion on the process for determining requirements is in no way intended to be a detailed "how to" guide for each step, but merely an outline for a logical approach to a credible set of top-level requirements for prefeasibility level design.

F. Pre-Feasibility Designs

During the period November 1988 to March 1989 the U.S. Delegation to SWG/6 developed a set of specific design requirements for a Harbor and Coastal Patrol Craft. These requirements were selected on the basis of the results produced by the parametric study and were forwarded to other member nations for their consideration. In the mean time, the U.S. embarked upon the initial development of pre-feasibility point designs of an SES and Monohull to meet these new requirements.

The requirements were specified, in some instances, in terms of goals and thresholds of requirements. For example, there was a 10 knot difference between the goal and threshold speed requirements. As a result, the SES, which could be shown to be relatively more efficient at higher speeds, was designed to satisfy the speed goal whereas the monohull was better suited to meeting the minimum threshold for speed. These initial designs were presented to SWG/6 in May 1989 to stimulate a cooperative effort between countries to develop the designs further for presentation to SWG/6 in November 1989. Although it was anticipated that some of the specific requirements might change as a result of review in May 1989 to accommodate other national interests, it was believed that some changes could be accepted without major impact at such an early stage of design.

These initial designs are illustrated in Figures V-13 and V-14.

The monohull has a full load displacement of 280 tons compared to 309 tons for the SES, which has a 10 knot higher speed in sea-state 3 and 20 knot higher speed in calm water.

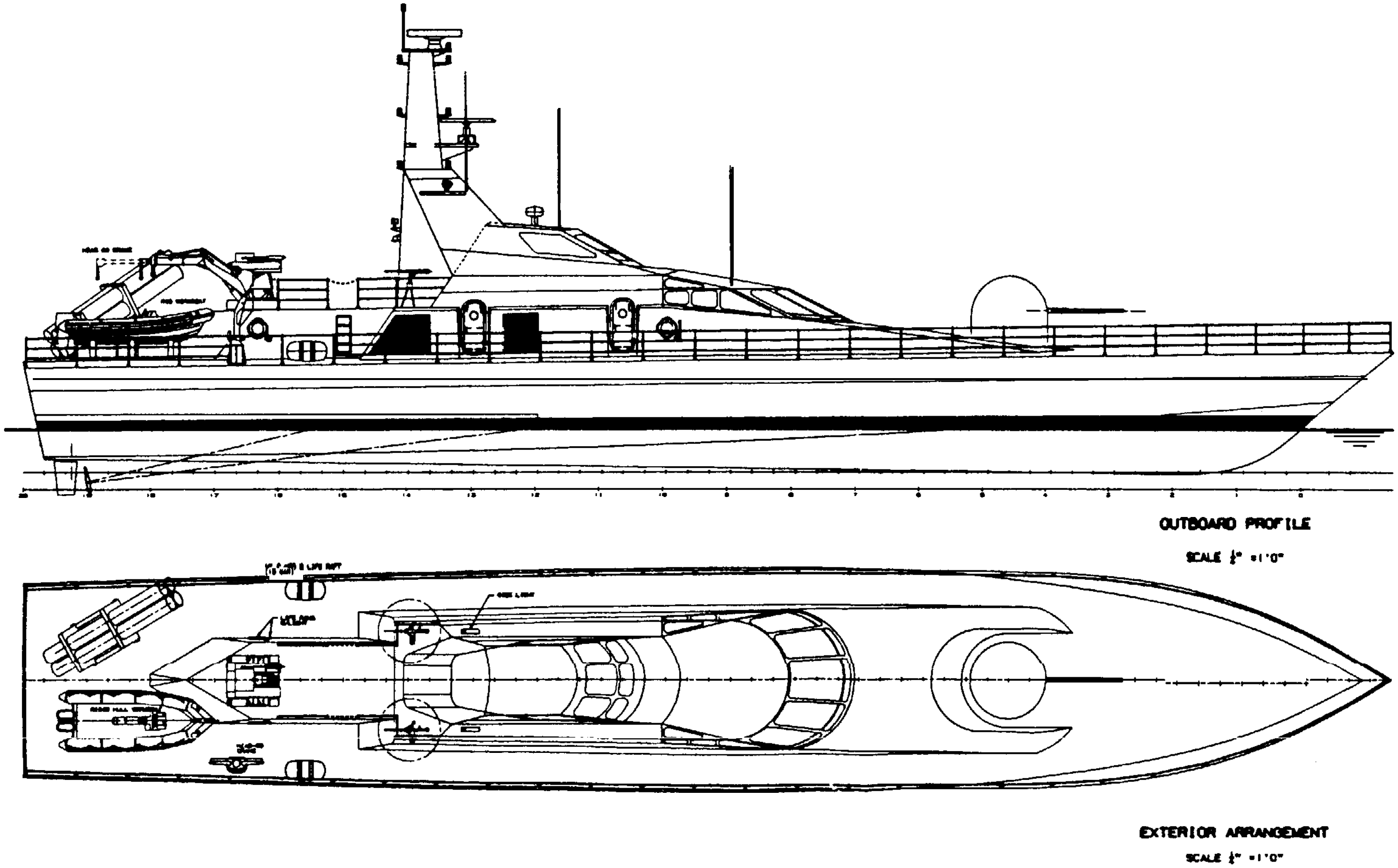
G. Monohull/SES Comparisons

In recent years there has been an increasing demand for feasibility-level comparisons of various types of high-speed hullforms with conventional monohulls.

Comparisons of ANVs and monohulls usually fall into one of two categories. The first category covers comparisons that try to show the superiority of one hullform over another. The second category covers comparisons that try to find a particular operational niche for each hullform.

Unfortunately, life is not that simple and clear cut, which is why these feasibility-level comparisons continue to recur and the question of whether, or not, the comparisons are objective continue to be raised.

It is this second area (objectivity) that led to the development of a joint parametric study for SWG/6 between the United States (US) and West Germany (GE). One problem that occurs when comparisons are made is that many people become involved because of the magnitude of the project and each has his own analytic methods, preferences and biases. As a result different standards, margins and practices are often employed so that each of the hullforms are not always designed to the same standards, resulting in the proverbial "apples and oranges"



FigureV-13. **HCPC Monohull**

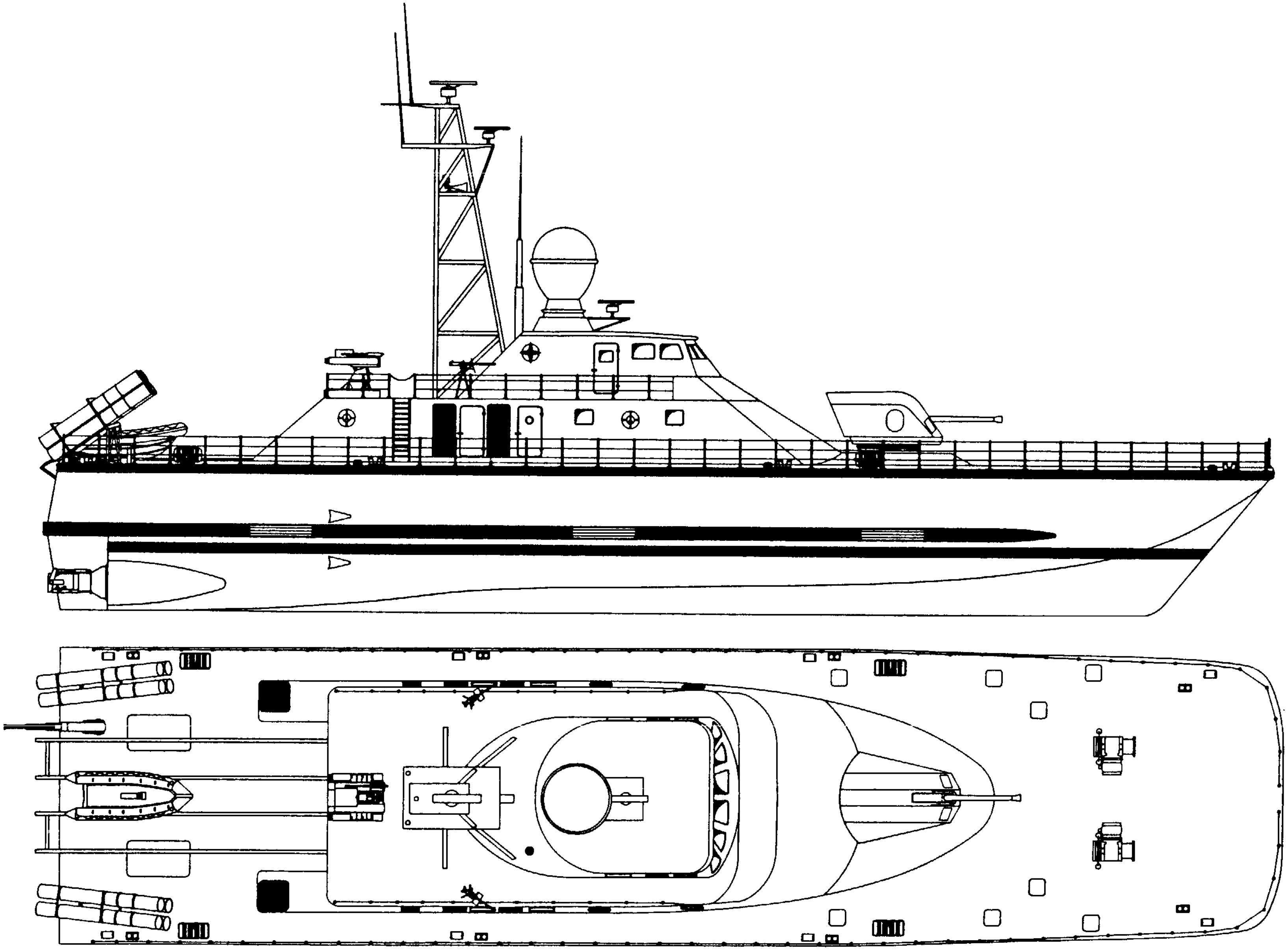


Figure V-14. HCPC SES

comparisons. Even the use of computerized design-synthesis models does not always eliminate this problem since the programs are generally written by different people, or organizations, and for different purposes.

An attempt has therefore been made by the US and GE to reduce, if not eliminate, these inconsistencies by using one set of standards for the design of SES and Monohulls. In this way, any biases or preferences that may be built into the respective programs are present in all of the programs so that when all comparisons are made they are biased in the same manner, thus negating the personal preference for one hullform over another.

This is an ongoing effort and results are to be presented to SWG/6 in November 1989.

VI. THE FUTURE OF SWG/6

As shown in Figure V-l the current Patrol/MCM studies are scheduled to be completed in December, 1990 with a report to the NNAG. By that time the group must have developed,, and presented to the NNAG, a proposal for the next program of work.

There are a number of possibilities:

- Ideally: two or more nations would form a Project Group and embark on a program to produce one of the craft designed.
- An "assessment" similar to the one developed in the studies, may be'appropriate.
- Additional patrol or MCM designs may be required if requirements have changed or expanded or if additional platforms should be explored, such as a SWATH patrol craft.
- Model tests or technology risk-reduction studies on one or more designs may be desired.
- A new NATO mission may be addressed; oceanographic/ surveillance for example.
- The group could become simply an information exchange/ technology transfer forum.

In any case, as long as ANV technology is developing and the potential of its application is unrealized in the NATO arena there will be a continuing need for the group.