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Abstract

This document presents a study of an upgraded variant of the PHM 3 Series combatant hydrofoil ship. This design, designated the Model 928-83, offers increased range, both foilborne and hullborne, an integrated multimission, increased capability, weapon suite and cost effective ship systems modifications.

Key Words

Model 92883 Point Design
PHM 3 Series
Integration Study
60-Hz Electrical System
Propeller Outdrives
Hydraulic Turbine Start

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1.0 INTRODUCTION

1.1 Purpose

This document outlines a design embodying improvements in range, endurance and combat system capabilities that could be offered to the USN as a timely and cost effective solution to new and developing military threats in the Caribbean Basin. The effectiveness of the PHM squadron now stationed in that theater and the potential requirement for additional high speed, all weather combatants, encouraged Boeing Marine Systems (BMS) to establish a point design, based on the PHM 3 Series hydrofoil ship, designated the Boeing Model 928-83.

1.2 Background

In the years since the PHM 3 series ships became operational they have been criticized for having limited range and endurance, lack of combat system capability, and insufficient communications capacity. On the other hand, the employment of the ships has been considerably different than that for which they were originally intended. Realizing that the ship was designed to have a single mission capability and a defined range and endurance, the task was to expand the ship's capabilities within its growth limits. As currently configured, the PHM 3 series hydrofoil has platform and systems restrictions which limit its growth. In order to allow future growth, these restrictions had to be addressed and either eliminated or accommodated. These restrictions are:

1. limited foilborne propulsion power,
2. high forward foil loading,
3. limited fuel capacity,
4. limiting ship static stability and
5. limited combat system capability.

The Model 928-83 point design study addressed cost and manufacturing complexity reduction in addition to addressing the above mentioned growth and limitation problems.

Cost saving suggestions were solicited from Manufacturing and Engineering personnel throughout BMS as a parallel activity to the Model 928-83 point design project. The suggestions were collected, collated and presented to the design team to be included, as applicable, to the design. Time restrictions disallowed the incorporation of all of the suggestions. Not all of the studied changes proved to be cost effective, only the "apparently" more effective changes were studied and incorporated into the design.

The knowledge of the previously noted limitations of the PHM 3 series was combined with the candidate system changes to initiate the Model 92883 point design. In general terms, the design was to address the following items:

1. The capability of the foilborne propulsion system to accommodate a higher displacement ship.

2. Methods to change the internal and external configuration in order to adjust weights allowing the reduction of forward foil loading, moving the Longitudinal Center of Gravity (LCG), and lowering the ship's Vertical Center of Gravity (VCG) to improve static stability.

3. Within the constraints of the existing hull form and centers of gravity locations, additional fuel tank volume was to be created. This had to be approached with caution since rerouting of existing systems in the lower hull had to be considered.

4. A multipurpose combat system, addressing Anti-Submarine Warfare (ASW), Anti-Surface Warfare (ASUW), and Anti-Air Warfare (AAW) defense was desired. Realizing the weight, power, space and center of gravity limitations, a light weight, low volume combat system was to be developed and included in the design.

5. Cost reductions suggestions were to be analyzed and those which were effective were to be included.

The Model 928-83 design was therefore the result of the desire to increase the performance and mission capability of a PHM sized ship while simultaneously reducing its complexity and cost. All of the preliminary design methods, tools, and experience developed under the Independent Research and Development (IR&D) projects BMS 506, PHM Product Development; BMS 507, Mission Systems; and BMS project design organization were utilized to create the design.

2.0 SUMMARY AND CONCLUSIONS

2.1 Summary

The Model 928-83 design effort resulted in a feasible and more effective alternative ship, demonstrating that a point design based on a known ship could be accomplished in a limited period of time.

The Model 92883 point design is depicted in an isometric view in figure 2.0-l and in plan and profile in figure 2.0-2. Figure 2.0-3 shows the internal arrangements of the proposed main and platform deck plans. Figure 2.0-4 compares general characteristics of the Model 928-83 with PHM 3. Figure 2.04 presents Model 92883 general characteristics and principal system data. Figure 2.0-6 presents performance characteristics. Ship changes incorporated within the design are presented in table 2.0-l; their effects are presented in table 2.0-2. The actual design process and the resulting system and ship configuration are covered in detail in sections 3.0 and 5.0.

The Model 928-83 Combat System was conceived to meet a specific threat in a specific theater of operations. This approach does not negate applicability to other threats or theaters of the world but it does make possible a more objective design development. The PHM 3 series combat system was used as a basis for the process. There was one fundamental phiilosophy that made a lightweight multipurpose combat system possible, that was the willingness to exchange any equipment for an alternative or to reduce a payload component to accommodate needed additional equipments. Under this license the 76-mm OTO Melara and four Harpoon missiles were removed. The resulting weight and space differences made possible an AAW self defensive capability as well as an ASW capability. The necessary integration was then provided while remaining within the basic PHM 3 series payload.

Changes of the foilborne propulsion plant resulted in minimal technical risk to accommodate the higher horsepower rating. The LM 2500 gas turbine has demonstrated performance above this rating and the foillborne turbine gearbox and the foilborne propulsor have been tested to this rating.

A significant increase in hullborne range was attained by three primary changes; propeller outdrives replacing the hullborne waterjet propulsors, a diesel replacing the gas turbine as the prime mover on the ship's service power units, and increased fuel tank capacity. Foilborne range was also increased by the enlarged fuel capacity of the Model 928-83.

The external configuration changes were principally; enlargement of the deckhouse and pilothouse, replacement of the existing mast with a tripod-truss structure and removal of the aft cupola installation. A benefical weight reduction and increase in static stability was achieved using the truss structure for the mast. Internal configuration changes were more extensive; increases in internal volume in the deckhouse and improved accessibility for all manned spaces. The reduced magazine volume and relocation of the engineers operating station were key alterations enhancing the habitability and functionality of all spaces at the platform deck level. Extension of the deckhouse allowed the addition of the sonar room and increased space available for the combat information center, electronics equipment rooms and the CO stateroom.

Additional fuel tank volume was achieved with minimal impact to the configuration or structure by relocating the outboard fuel tank longitudinal bulkhead. Improvements in fuel replenishment rates, fuel cleanliness tolerance, and fuel service system component cost reduction were also seen.

Auxiliary system alterations resulted in a functionally similiar configuration to the PHM 3 series, however a significantly more efficient systems design was achieved. The Model 928-83 auxiliary systems improvements were attained utilizing an integrated systems design approach. Changes, intrinsic to this design and to reduction of system cost and complexity included:

1. A 60-Hz electrical power distribution and generation system replacing the existing 400-Hz system.
2. Off-the-shelf component substitution and system alterations in-kind.
3. Diesel ship service power units with auxiliary power take-offs.
4. Separation of the high and low pressure seawater supply systems.
5. Dual, high and low, pressure hydraulic supply circuits.

This approach resulted in a reduction of electrical system peak operating loads. The quantity of electrical motors was reduced substaintially by systematic substitution of hydraulic motors for standby duty cycles. The change from 400-Hz to a 60-Hz electrical distribution system enabled the cost effective utilization of off-the-shelf components. The hydraulic system dual pressure capability eliminated the hydraulic intensifier circuit and substantially simplified the foilborne turbine starting system, utilizing a proven LM 2500 hydraulic starter system. Separation of the low and high pressure seawater system considerably simplified the seawater supply system and its components.

2.2 Conclusions

The Model 928-83 is a feasible design which has sufficient improvements in capability to warrant future consideration as an addition to the U.S. Navy fleet.

All of the intended items for study were successfully addressed and satisfied:

1. The foilborne propulsion system is capable of accommodating a higher displacement ship.

2. The ship configuration was successfully changed in such a manner that the VCG was lowered and the LCG was moved aft increasing the ship's stability and keeping the forward foil loading within hydrodynamic bounds.

3. Fuel tankage was increased by 27 percent. This, plus system's changes, causes an increase in hullborne range of 147 percent and a 33 percent foilborne range increase over the PHM SSS requirements.

4. It was shown that a highly effective lightweight, multipurpose combat suite could be accommodated in the design.

5. Although limited in number and scope, cost reduction suggestions proved to be effective. The reduction in system complexity will have a positive effect on maintenance and spare part costs. Studies of cost reduction initiatives should be continued.

Designing a ship to eliminate a variety of limitations can be readily accomplished if the design team has the knowledge of how to address the limitations. This knowledge can only come from continual study of the existing configuration and its sensitivities to change.

Care must be exercised in the redesign of an existing ship to assure that system interrelationship is adequately studied. It must be noted that the Model 928-83 does not offer a list of choices of systems to be changed but rather a complete ship's configuration. Al though some of the changes incorporated within the design could be retrofit into the PHM 1 class ships detailed study of that incorporation would be required.

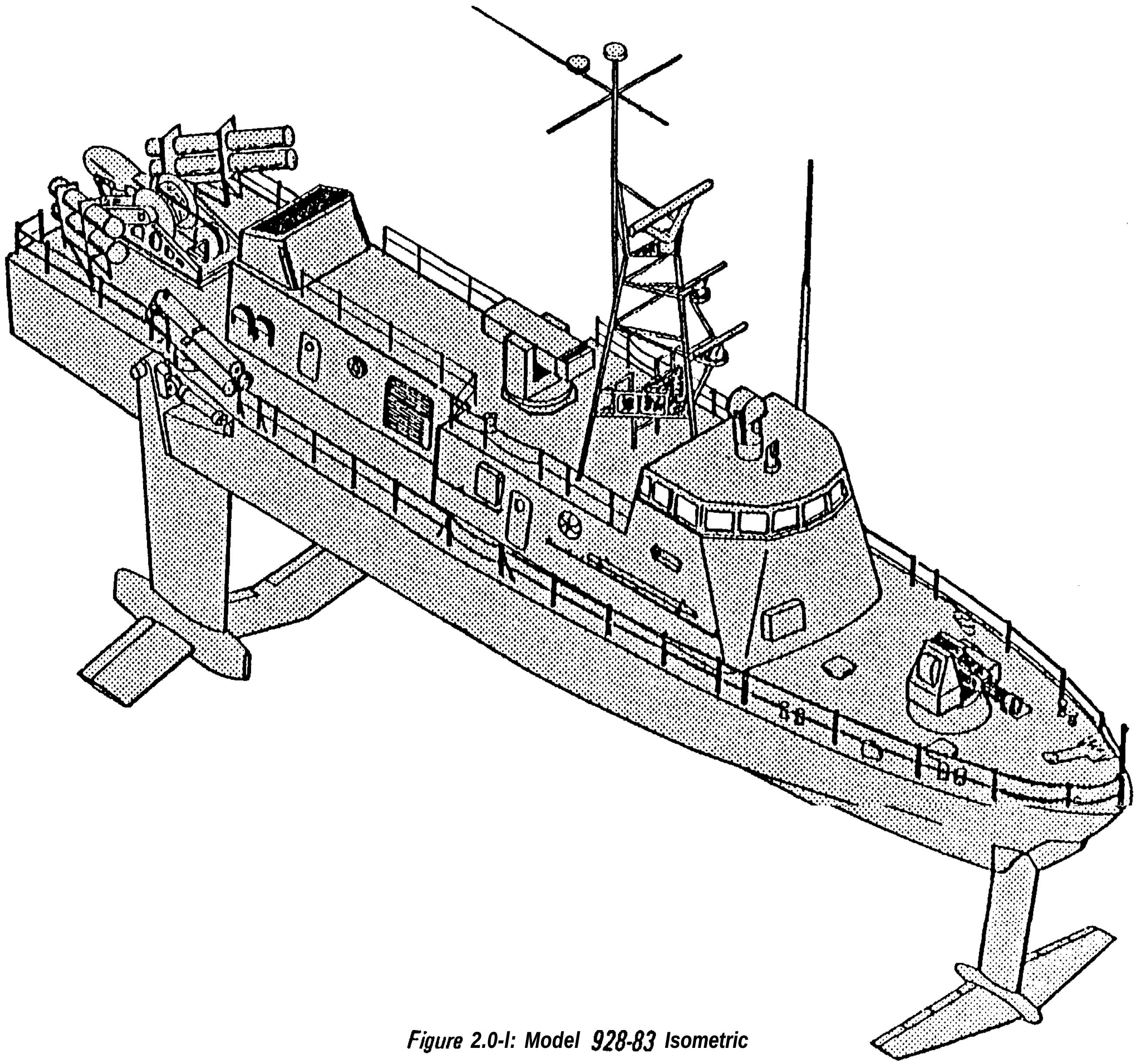

Figure 2.0-I: Model 928-83 Isometric

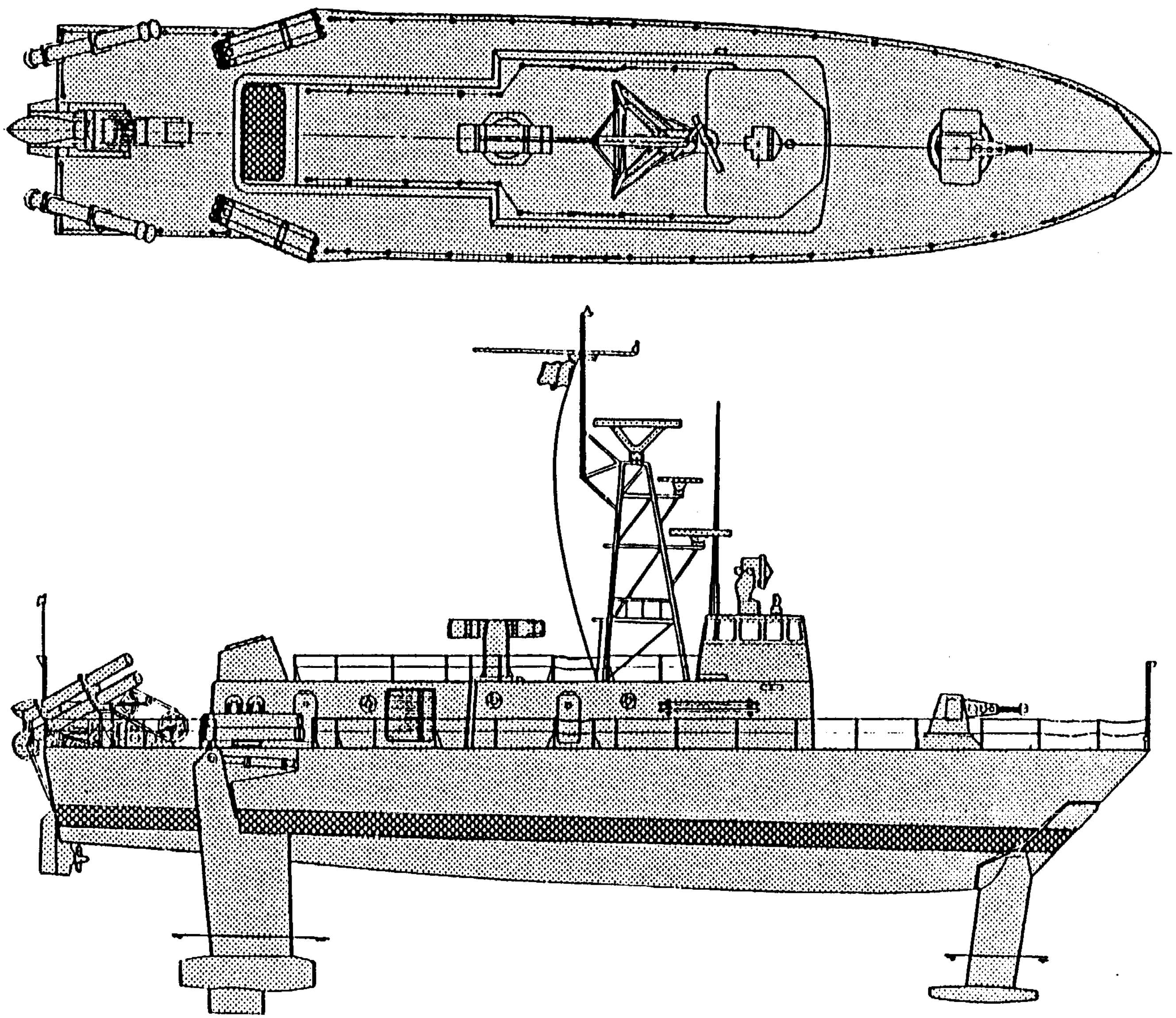

Figure 2.0-2: Model 928-83 Outboard Profile

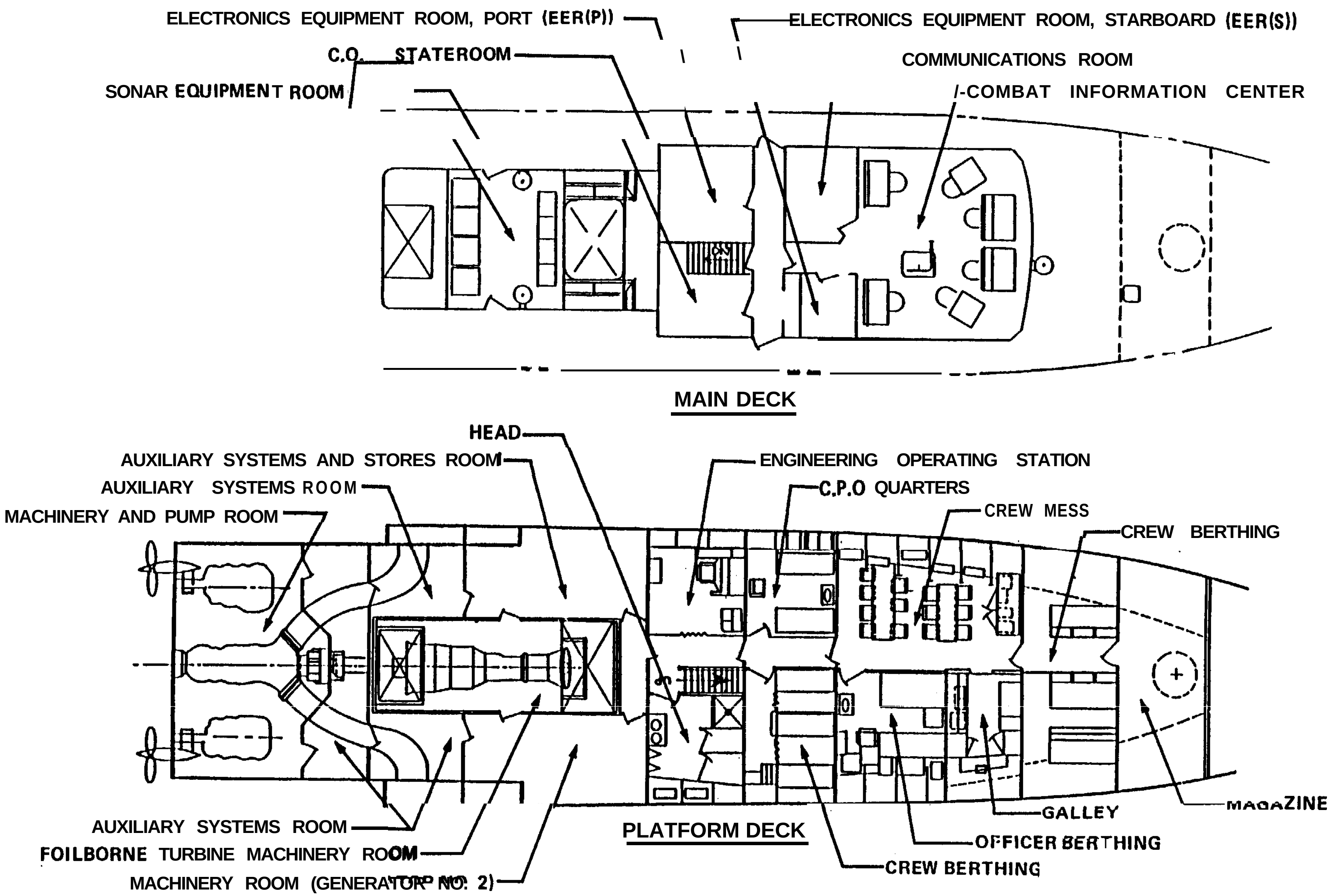

Figure 2.0-3: Model 928-83 Internal Arrangements

ITEM	PHM 3	Model 928-83
Length overall, foils down, m	40.5	40.5
Length overall, foils up, m	44.7	44.7
Beam, m	8.6	8.6
Overall aft foil span, m	14.5	14.5
Foil-tip protection beyond maximum bean-r, m	2.95	2.95
Draft, foils down, m	7.1	7.1
Draft, foils up, n-r	1.9	2.4*
Height of bridge, foilborne, (hullborne), m	11.1 (6.8)	10.8 (6.5)
Height of Fire Control Radar, foilborne, (hullborne)	15.2 (10.9)	—
Height of Air Search Radar foilborne, (hullborne), m	—	18.3 (14.0)
Height of Surface Search Radar foilborne, (hullborne), m	—	15.8 (11.5)
Height of Tracking Radar, foilborne, (hullborne), m	—	12.9 (8.6)
Height of Optronic Head, foilborne, (hullborne), m	—	12.0 (7.7)
Full load displacement, metric tons	241.3	263.6

*Ou tdrives extended.

Figure 2.0-4: General Characteristics Comparisons

Hydrostatic Particulars	Full Load Displacement 263.6 metric toils Length overall, foils down 40.5 meters Draft, foils up 2.1 meters 2.4 meters*
Foilborne Propulsion	1-General Electric LM2500 gas turbine engine 1- Aerojet General Company waterjet propulsor
Hullborne Propulsion	2-800 horsepower light diesel marine engines 2- propeller driven outdrives
Electrical	2-345 horsepower light diesel marine engines, each driving a 450 volt ac, 250 kVa (200kw), 60 hz 3 phase generator
Fuel	Diesel Fuel Marine or JP-5
Accommodations	Berths for 5 officers, 4 chief petty officers, and 18 enlisted men
Provisions	10 days

*Outdrives extended.

Figure 2.0-5: Model 928-83 General Characteristics and Principal Systems

Loads	Fuel	63.3 metric tons
	Military Payload	30.6 metric tons
	Total mission load	100.2 metric tons
Design Speed	Hullborne	13.6 knots
	Foilborne	(same as PHM 3)
Range at Design Speed	Hullborne	2.47 times PHM 3 H/B SSS at 13.6 knots
	Foilborne	1.33 times PHM 3 F/B SSS

Figure 2.0-6: Model 928-83 Performance Characteristics

Table 2.0-1: Model 928-83 Changes

System	PHM 3 Series	Model 928-83	Remarks
Hullborne Propulsion	Diesel Driven Waterjets	Diesel Driven Outdrives	Improve range and speed with same horsepower
Foilborne Propulsion	LM 2500 and Waterjet	Increased Ratings 19,000 mhp	Turbine and pump relocation, higher horsepower within existing capability
Accommodations	24 Max. 1 CO 4 OFF 4 CPO 15 Enlisted	27 1 CO 4 OFF 4 CPO 18 Enlisted	Required to man increased weapons system on three section watch bell
Electrical	400-Hz	60-Hz	Major cost reduction, affects all systems. Change in prime-mover from gas turbine to diesel increases range
Hydraulic	3000 PSI 8 Pumps	3000/4800 PSI 2-3000 PSI Pumps 2-3000/4800 PSI Dual Pumps	No booster required for strut retraction. Hydraulic turbine start reduces size of SSPU prime mover required. System complexity reduced by 50%.
Foilborne Turbine Start	Pneumatic	4800 PSI Hydraulic	More efficient than air start, less weight. Combined with hydraulic system. Allowed considerable SSPU prime mover horsepower reduction.
Fuel Capacity	47.2 Metric Tons	63.3 Metric Tons	More fuel tankage required affects structure and other systems routing.
Fuel System	4 AC Pumps 2 DC Pumps and 1 Hyd. Pump	1 AC Pump 1 DC Pump and 1 Hyd. Pump	Allows "UNCLEAN" fuel acceptance using centrifugal separator. Piping complexity reduced.
Environmental System	Foreign Built 400 Hz system	U.S. Built 60-Hz system	Reduced system cost retaining same capability. More reliable, repairable equipment.
Mast	Pole	Truss	Required to accommodate radar changes. Reduced weight.

Table 2.0-1: Model 928-83 Changes (concluded)

System.	PHM 3 Series	Model 928-83	Remarks
Sea Water	4-200 PSI Pumps serve both cooling and firefighting	2-40 PSI Pumps 2-200 PSI Pumps	Reduces electrical power load simplifies system - separate cooling/firemain piping
Fresh Water	1,134 Kg Distiller	136 Kg Reverse Osmosis Water Maker	More reliable, less expensive, less weight, lower power requirement.
Sewage System	Macerator and Cooker	Holding Tanks	Reduced system complexity and cost.
Waste Water System	Holding Tanks	Overboard flow	No environmental impact.

Table 2.0-2: Model 928-83 Effects

Item	Effects
Foilborne Engine, Gearbox and pump horsepower capability	Requires 19,000 metric horsepower. Within gearbox tested range. Engine completely satisfactory.
Stability Margin	Increased stability. Lowered ship VCG from 3.27 to 3.10 (6.69 in. change) foils up and 2.46 to 2.38 (3.15 in. change) foils down.
Foil Loading	Forward system increased from 1401.6 to 1445.3 PSF. Aft system increased from 1111.9 to 1251.1 PSF. All within hydrodynamic limits. Has effect on foil system fatigue life.
Fuel Load	Increased fuel from 47.2 to 63.3 metric tons. Fatigue evaluation based of a 60 percent fuel load. Forward and aft foil fatigue life reduced. Foilborne range increased to 1.33 X PHM SSS at design speed (including diesel SSPU effect)
Increased Displacement	Reduces calm water takeoff margin from 33 to 19.4 percent. Reduces foil system fatigue life.
Diesel SSPU (Reduces electric load)	Fuel consumption at maximum power reduced from 137.5 kg/hr at 11 knots. Increased hullborne range by 20.8 percent disregarding outdrives resistance effects.
Propeller Outdrives	Fuel consumption increased from 235 kg/hr at 11 knots to 280 kg/hr at 13.6 knots at maximum speed hullborne. Hullborne range increased (including diesel SSPU effect) to 2.47 X PHM SSS at 13.6 knots.

3.0 SHIP CHANGE DESCRIPTION

3.1 Ship Configuration

A comprehensive approach to point design mission requirements, habitability, and new propulsion and electric plant configurations was combined with knowledge gained from PHM 3 series construction and operational experience to synthesize a multimission point design.

The predominent structural changes incorporated in the Model 928-83 point design are: extension of the deckhouse, removal of the main deck cupola installation, relocation of the foilborne propulsion system turbine and water-jet pump, alteration of PHM 3 series pump machinery room aft bulkhead and alteration of the fuel tank longitudinal boundaries.

The deckhouse extension accommodates the new ASW sonar room and encapsulates the foilborne turbine exhaust. This space provides sufficient volume for all of the Raytheon 1167 sonar system electronics. The turlbine exhaust educator and inlet plenum are moved one meter aft in conjunction with the turbine installation relocation. This change created a one meter void, the additional volume is used by a new fifth fuel day tank. The auxiliary machinery rooms ventilation supply and diesel intakes previously located at the aft weather deck cupola are relocated to the deckhouse aft weather bulkhead.

Benefical increases in noise attenuation of the turbine inlet plenum are achieved by the addition of the void forward of the plenum at the main deck level. Internal arrangements on the maindeck forward are improved by increased floor space for those compartments. The combat information center (CIC) port bulkhead is moved aft, providing a symmetric arrangement and improved accessibility to the pilot house via a direct corridor to the deckhouse passageway. The athwartships oriented passageway improves external access and safety incorporating an aft sloping companionway to the platform deck. The electronics equipment room (EER) is split into separate compartments, while the communications room and the commanding officer's (CO) stateroom maintain separate access to the passageway.

The Model 928-83 radar array configuration requires a structurally rigid and efficient structure to insure geometric integrity. The tripod truss mast arrangement provides a weight effective design 400 kilograms less than the PHM 3 series stayed pole mast. The new forward mast location provides the maximum distance from the turbine exhaust for placement of the rolling air frame missile (RAM) launcher. The pilothouse enlargement and lhridge modifications enhance visibility, particularly in turns. The greater pilothouse internal volume will accommodate a potential fourth fire control optical system command station.

A new magazine arrangement accompanied the Sea Vulcan 30 gun mount reducing both volume and sprinkler system requirements. This arrangement permits the former magazine volume to be utilizied as crew's quarters for nine personnel at the platform deck level. The engineer's operating station (EOS) on the port side is relocated forward of the auxiliary machinery room forward bulkhead. This improved EOS habitability and provides a huffer for the new chief petty officers (CPO) berthing space forward of the EOS. Foilhorne turbine noise attenuation and habitability on the starboard side is improved due to the buffer provided by the head. An additional noise attention barrier is provided by the corridor aft of the machinery room bulkhead and forward of the turbine plenum.

The machinery rooms arrangement plan incorporates significant alterations which include: auxiliary system component changes, the diesel ship's service power unit (SSPU) replacement of the gas turbine SSPU, relocation of the foilborne turbine, and the hullborne propeller outdrive installation. The Machinery Room (Generator No. 2) starboard includes a battery pack, diesel SSPU, and associated waterlift exhaust installation. One of the electric system switchboards is placed in the Auxiliary Systems and Store Room, while the second switchboard is in the Machinery and Pump Room. The fuel system centrifugal separator and a hydraulic system reservoir are located in auxiliary room to starboard of the Foilborne Turbine Machinery Room. The reverse systems osmosis system and two air condition units are in the auxiliary system room to port of the Foiilhorne Turbine Machinery Poom.

The substantial increase in fuel capacity is obtained by alteration of fuel tanks 2, 3 and 4. The increased tank capacity is achieved with limited structural alteration, relocation of the outboard longitudinal tank boundary to buttock line 2200 is the principal structural change. This simplified approach limited structural impacts and provided sufficient void area for the ship services piping runs forward and aft.

3.2 Mission Systems

The Model 928-83 was developed as a multimission platfonm to counter a Caribbean threat. The basic ship size was predicated on a PHM 3 series hull with the only changes being those necessary to reduce cost, increase performance or allow for weapon system update, figure 3.2-l.

3.2.1 The Caribbean Threat

The development of a platform combat systems suite in this case was based on possible adversaries in the Caribbean. The most probable adversary is certainly Cuba or, at least, a country with a warfare capability like that of Cuba. The surface threat is a summation of those elements in the Cuban Order of Battle that could be brought to bear offensively against naval forces. The current (1984) Cuban surface threat is presented in table 3.2-l. Also presented is the main battery associated with each of the elements.

3.2.2 Command and Control

The Combat Information Center (CIC) of a 1990s vessel will not be adequately served by a few independent radar repeaters. Similarly, an integrated system that requires excessive operator intervention will fail to meet the needs of the CIC. Integration of combat information will have to be automatic to be effective. Combat information will also need to be as near to real time as possible so that command decisions are timely. Ships that cannot automatically exchange tactical information will be a liability to the warfare commander rather than an asset. These are the ground rules by which the command and control system was conceived.

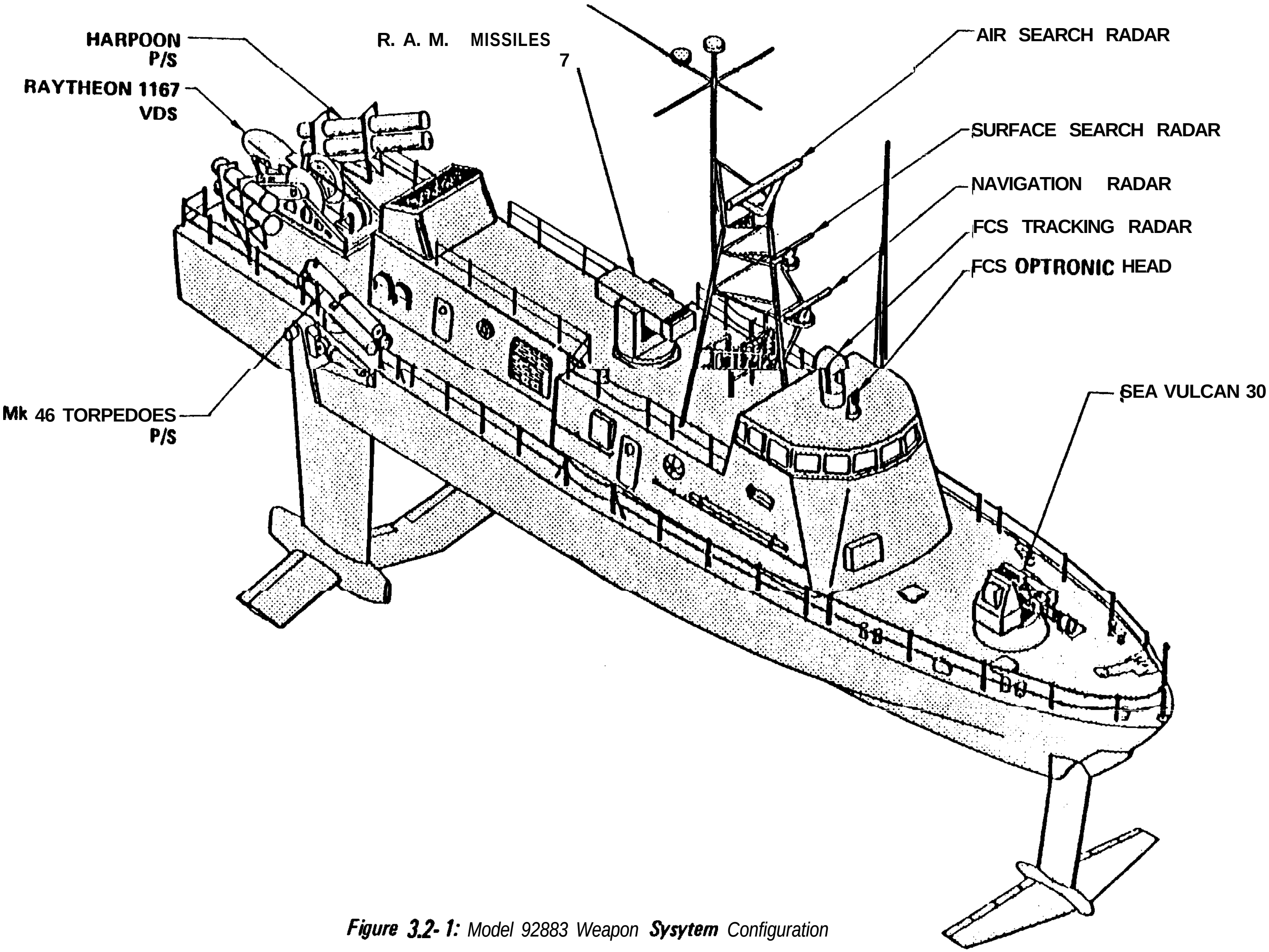

Figure 3.2- 1: Model 92883 Weapon Sysytem Configuration

Table 3.2-l: Cuban Order of Battle (Present)

SHIPS

QTY	SHIP CLASS	TYPE	MAIN WEAPON
2	KONI	FF	76mm
2	SONYA	MSH	30mm
4	KRONSHTADT	PC	85mm, 37mm
9	SO 1	PC	25mm
10	TURYA	PCH	57mm, TORPEDO
20	QSA 1,11	PF	STYX
12	KOMAR	PF	STYX
9	YEVGENYA	MSI	14.5mm
6	P6	PF	TORPEDO
20	ZHUK	PC	14.5mm
12	P4	PF	TORPEDO
1	K8	MS	14.5mm
3	FOXTROT	SS	TORPEDO

AIRCRAFT

QTY	AIRCRAFT CLASS	TYPE	MAIN WEAPON
75	FRESCO	MIG-17	ROCKETS
15	FLOGGER-E	MIG-23MS	RCCKETS
15	FLOGGER-F	MIG-23BM	ROCKETS
40	FARMER	MIG-19	ROCKETS
50	FISHBED-C	MIG-21F	ROCKETS
30	FISHBED-J	MIG-21F	ROCKETS

The heart of the command and control system on a small ship is the fire control system. The system selected for this point design was the Honeywell H-930 Modular Combat System (KS). As the term modular implies, it is an expandable system based on a distributed computing architecture. Now in its fourth version, the H-930 concept represents more than just a fire control system. Indeed, it is as much like a Naval Tactical Data System (NTDS) as it is a fire control. Available combat capabilities include target detection, acquisition, tracking, threat evaluation, weapon assignment, kill assessment and weapon control for Anti-Air Warfare (AAW), Anti-Surface Warfare (ASUW), Anti-Submarine Warfare (ASW), Naval Gunfire Support (NGFS), and Electronic Warfare (EW) missions.

To better facilitate exchange of information between units of a task group, the system is compatible with a real time, two way, radio data link such as TADIL A (Link 11). The group commander is, therefore, provided up-to-date, near real time tactical information outside the reach of his flagship sensors. The link also allows more precise targeting of Over-The-Horizon (OTH) weapons through passive tracking techniques.

3.2.3 Navigation

Like the command and control system of the 1990s, the navigation system that operates in conjunction with it will be somewhat different than today. The navigation equipment suite is envisioned as an integral part of the command and control system. It will provide continuous inputs of latitude, longitude, speed, set, drift, water depth and wind information. Inertial navigation will provide the core element of the system. It will be updated by "NAVSTAR" Global Positioning. System (GPS) as well as Omega and the various visual position fixing procedures now available. In combination with ancillary components such as the electromagnetic speed log and the acoustic depth sounder the navigation system will provide a real time display of the ship's position automatically overlayed on and scaled to any appropriate chart.

3.2.4 Interior Communications

Communication throughout the ship is provided via intercom, sound powered telephone circuits and announcing/alarm systems. Circuits are designated in accordance with standard U.S. Navy circuit symbols.

3.2.5 Exterior Communications

Space and weight have been set aside for radio equipment to provide voice, Teletype, and data communication circuits. These circuits are capable of operation either in covered or uncovered modes. Satellite communications equipments are fitted as well. For line-of-site signaling; directional light, yardarm blinker and signal flags are also provided.

3.2.6 Surveillance

Surveillance of the nearby environment is made possible by separate air and surface search radars. Each are also equipped with AIMS Mk XII, Identification Friend or Foe (IFF) interface. In addition, a navigation radar provides more precise information about the nearby environment. The optronic sight associated with the fire control system is also an important part of the surveillance system. It makes possible passive tracking of either visual or infrared (IR) targets.

3.2.7 Countermeasures and Decoys

The PHM 3 Series ship carries Rapid Blooming Offboard Chaff (RBOC) as an exclusive countermeasure. The Model 928-83 is to be outfitted with an ESM/ECM system operating over the frequency range of 2 to 18-GHZ. Chaff is also available in the form of two new ADLS launcher units and system, which has infrared decoys as well. Since the Model 928-83 retains the maneuverability of the PHM 3, this enhanced countermeasures suite will make it an extremely elusive target. Analysis suggests that the Model 928-83 will be able to evade all but the most sophisticated of today's anti-ship missiles.

3.2.8 Fire Control

The Modular Combat System (MCS) is made up of Weapon Control Consoles (WCC) each with an embedded Distributed Computing Unit (DCU). The number and type of WCCs will vary with the combat system equipment configuration installed. In this case, a console is provided for ASW, AAW, ASUW, EW, Tracking radar control and optronic director control functions. One command and control console is also provided. Additional DCUs are fitted for computing speed and redundancy purposes.

The MCS accepts information from the various ship surveillance sensors via installed DCUs and interface converters where appropriate. The information is processed and made available on a data bus for use by other system components. Redundancy of data buses as well as automatic switching are Vital elements in the system as is redundant software and a Built-In-Test (BIT) capability.

3.2.9 Armament

The Model 928-83, as'proposed, has a true multi-mission weapon suite onboard. The guiding premise in its development was to provide AAW and ASW systems to a PHM or PHM size variant without giving up ASUW capability. Equipment tradeoffs were only permitted where capabilities dictated by the threat were not compromised.

The various elements of the design threat, table 3.2-1, were considered for the most appropriate weapon pairing. Harpoon targets were assigned first. Cl early, the Harpoon targets are the KONI, KRONSHTADT, OSAI, OSAII and KOMAR classes. These all have main battery components large enough to inflict unacceptable damage, perhaps even sink U.S. components, costing far more than the Harpoon missile. The TURYA class doesn't seem to fit into this category. Configured primarily for ASW, the TURYA with its torpedoes and 57-mm gun mount is the one enigmatic portion of the threat. If a Harpoon is not used on the TURYA, the only other U.S. Naval weapons that outrange the 57-mm are the 5"/54 caliber and the 76-mm gun mounts. Of these, only the 76-mm is compatible with a hydrofoil of this size. The remaining surface threat can be countered by gunfire of 30-mm.

The submarine, while commanding much concern for its stealth, is the easiest threat for which to select a weapon countermeasure. The Mk-46 torpedo is the only surface launched torpedo operational in the U.S. Navy.

The only sonar that has been operated from a hydrofoil at foilborne speeds, provides both active and passive surveillance and physically fits the Model 928-83 is the Raytheon 1167 Variable Depth Sonar (VDS). Therefore, this VDS and Mk-46 torpedoes are the only near term ASW alternatives,

The AAW defense is best accomplished by a combination of the Rolling Airframe Missile (RAM) and a 30-mm gatling gun (Sea Vulcan 30). The "fire and forget" RAM provides a lightweight system capable of either RF or IR terminal guidance to ranges beyond that of accurate gunfire. The Sea Vulcan 30, with a rate of fire of 4200 rounds/minute, provides the most effective short range protection.

The TURYA problem is all that remains. The RAM missile has a maximum range greater than that of the 57-mm gun. It is capable of countering low flying aircraft. The TURYA Gun Fire Control radar is within the RAM seeker bandwidth. While RAM is not designed as a surface-to-surface weapon, it appears to have utility in that role; Harpoon is certainly capable of countering TURYA. Rather than outfit the vessel with a heavier gun just to counter the TURYA, it is more appropriate to use RAM and Harpoon for the purpose.

3.2.10 Manning

The Model 928-83 will have a total crew of 27 personnel. Accommodations are available for one commanding officer, four other commissioned officers, four chief petty officers and eighteen enlisted personnel. Table 3.2-2 depicts a proposed Watch, Quarter and Station Bill for Condition III and General Quarters.

Table 3.2-2: Condition III Crewing

RANK 1 RATING	GENERAL QUARTERS	CONDITION III
LCDR	CO	CO
LT	TAO	TAO (P)
LTJG	Weapons Control	TAO (S)
LTJG	EOOW	EOOW (P)
ENS	OOD	OOD (P)
QMC	Navigator	Navigator
OS1	Air Search	CIC (P)
OS2	Surface Search	CIC (S)
EW2	ESM Operator	EW (P)
EW3	ECM Operator	EW (S)
FTM1	Weapon Coordinator	Helm (P)
GMG1	Gun/Launcher Capt	Helm (S)
STGC	Sonar Control	Sonar Control (P)
STG1	Sonar Operator	Sonar Control (S)
STG2	Hoist Operator	Sonar Operator (P)
STG3	Hoist Operator	Sonar Operator (S)
RM2	Communicator	Communicator (P)
RM3	Communicator	Communicator (S)
MS2	Repair Party	Mess Specialist
MS3	Repair Party	Mess Specialist
GSMC	Repair Party (Leader)	EOOW (S)
GSM3	Repair Party	Propuslion Operator (P)
GSE2	Propulsion Operator	Propulsion Operator (S)
ET2	Repair Party	On call
BM2	Helm	Lookout (P)
BM3	Lookout	Lookout (S)

3.3 Ship System Details

Details of the ship and its systems are presented in the following sections. A brief description of the variances to the existing PHM 3 series systems, reference 9, and definition of the changes effect on complexity and cost are presented.

3.3.1 Structural Revisions

Cost effective structural design simplifications were pursued with moderate revisions to the PHM 3 series hull and deckhouse. The deckhouse structural alterations include internal joinery relocations and the addition of weather boundaries for the new sonar room described in section 3.1. The mast structure is configured as a tripod-truss construction increasing rigidity and reducing assembly weight by 400 kilograms.

The increase in fuel load from 47.2 to 63.3 metric tons is achieved with minimum structural alterations to the hull by adding new tank boundaries at buttock line 2200 on tanks 2, 3 amd 4. The tank volume aft is increased by adding a fifth tank forward and below the turbine inlet creating a separate day tank. The prime impact of the longitudinal bulkhead relocation is modification of routing and interferences of ship equipment and services that occupied void volumes deleted from the PHM 3 series.

The two hullborne diesel and outdrive installations necessitated the relocation of the platform deck Machinery and Pump Room forward (frame 33) bulkhead, figure 2.0-3. The entire bulkhead is moved one meter forward and is offset to accommodate the foilborne propulsor bifurcated water duct. The outboard portion of the watertight bulkhead is one meter aft of the portion of the bulkhead centerline. The bulkhead segments are joined by an angled segment oriented perpendicular to the intersection with the duct.

3.3.2 Propulsion System

The Model 928-83 point design propulsion system refinements and performance improvements are consistent with the design goals of cost effective, minimum impact design changes.

The foilborne propulsion system is rated at 19,000 metric horsepower, both the General Electric LM2500-30 gas turbine and the Aerojet propulsor will accept this rating. Foilborne gearbox operation at 19,000 metric horsepower is within the tested power ranges of the PHM 3 series design. The foilborne propulsor gearbox retains the PHM 3 series hydraulic power take-offs for foilborne hydraulic power generation. The proposed hydraulic foilborne turbine starti'ng system will considerably simplify the turbine starting system installation, eliminating the pneumatic turbine starter, air start load compressor, and associated piping.

The placement of the foilborne turbine, gearbox and waterjet propulsor on PHM 3 is such that a one meter gap exists between the nozzle of the pump and the transom. Elimination of this gap allowed the addition of one meter more fuel and caused an aft movement of the LCG by adding that fuel and moving the foil-borne propulsion system. This also causes the movement of the aft exterior bulkhead of the deckhouse.

The hullborne propulsion system incorporates two fuel efficient 800 metric horsepower high speed diesels coupled to propeller outdrives. The resulting moderate increase of propulsion system weight is offset by fuel savings after 14 hours of hullborne operation at11 knots.

3.3.3 Electrical System:

The Model 928-83 electrical system, figure 3.3-1, is significantly refined and simplified from the PHM 3 series electric power generation and distribution system. Cost effective improvements were achieved with minimum technical risk.

The alteration of the electric power distribution system is based on a change from primary 400-Hz to 60-Hz power generation. This fundamental design change allows substitution of qualified off-the-shelf marine electrical components. The electrical subsystem design alterations reduce redundant installations while retaining subsystem function. Standby electric users were systematically replaced with hydraulic units further increasing electric power generation load margins.

Fuel efficient, turbocharged diesel SSPUs reduced electric power generation fuel consumption by 72.9 percent, from 137.5 kg/hr to 37.31 kg/hr. The net SSPU weight increase was offset by fuel savings after 22 hours of hullborne operation while the cost savings implicit to the diesel SSPU installation were derived from the following improvements:

1. Acquisition cost and schedule savings
2. Simplified SSPU installation and support system eliminating bleed and combustion air system, demister and deicing system, surge air piping
3. Reliability, maintainability and uniformity with existing U.S. Navy inventory and maintenance practices
4. Reduction of local and EOS station controls and instrumentation
5. Reduction of ventilation and hotel load

Additional system simplification and cost savings were realized due to the hydraulic foilborne turbine starting system, detailed in section 3.3.11.

Considerable cost savings and power distribution system simplifications were attained by the previously noted systematic replacement of electric motors with hydraulic motors. The Model 928-83 Loads Analysis, table 3.3-1, defines the resulting load reduction which increases the electric load power generation growth margin to 15 percent. The remaining 400-Hz users from the PHM 3 series are primarily government furnished electronics with distribution panels at the CIC and EER supplied by two 30-KVA frequency converters. These alterations and refinements of the Model 928-83 electrical system are interdependent with simultaneous auxiliary system improvements.

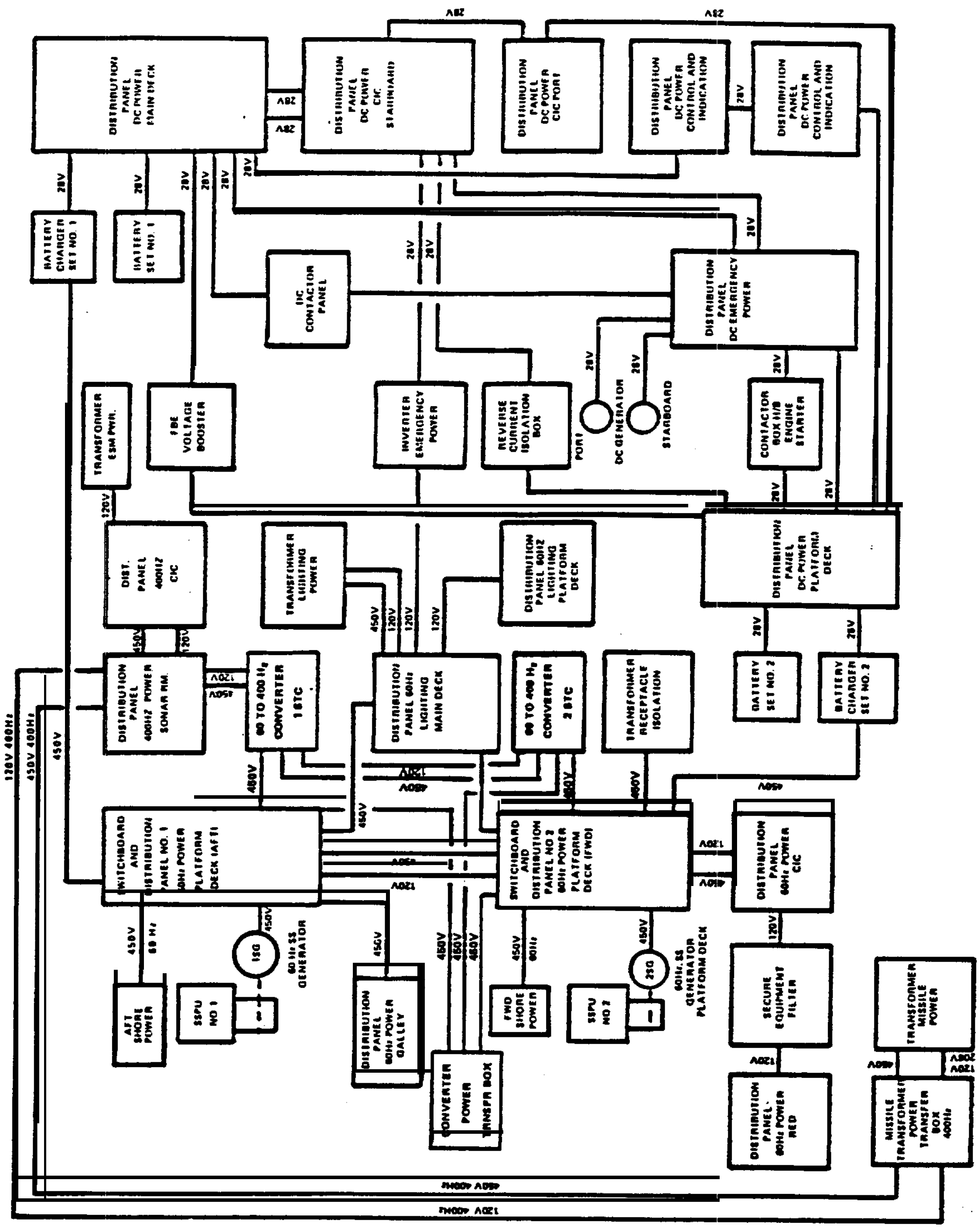

Figure 3.3- 1: Electrical System Diagram

Table 3.3-1: Summary of Model 928-83 Electric Load Changes

Load Category	Electric Load Operating Conditions						
	CONN KW	SHORE KW	ANCHOR KW	CRUISE HB KW	CRUISE FB KW	BATTLE HB KW	BATTLE FB KW
Propulsion, Steering	-18.6	+ 0.9	- 1.2	+13.7	+ 3.1	+13.7	+4.1
Auxiliary Machinery	-161.	-29.5	-42.8	-40.2	-12.1	-35.1	-11.5
Deck Machinery							
Shops							
IC, CM & Electronics							
Ordinance Systems	+13.7					+19.4	+19.4
Hotel							
A/C & Ventilation	-17.5	- 8.2	- 9.4	- 5.2	- 5.2	- 9.5	- 9.6
Conversion Losses		- 2.5	- 2.6	- 2.6	- 2.7	- 3.9	- 4.0
Heating	- 5.8			- 3.2	- 3.2	+ 0.2	+ 0.2
Cable Losses		- 1.3	- 1.8	- 1.1	- 0.5	- 0.7	- 0.1
Test Equipment							
Net Load Changes:	-189.	-40.6	-57.8	-38.6	-20.6	-15.9	- 1.5
Total Electric Loads: Model 928-83	547	58	74	124	108	169	149

HB = Hullborne Operation FB = Foilborne Operation Blank Space = No Change

3.3.4 Environmental Control Svstem

The Model 928-83 point design Environmental Control System is both an improvementand refinement of the PHM 3 series system. This configuration employes a simplified system design that incorporates cost-effective, low maintenance, standard marine 60-Hz components.

The ventilation system blowers and distribution ducting are modified by consolidation and simplification of the auxiliary machinery room vent systems to accommodate the diesel propulsion plant and the diesel SSPUs. New distribution ducting is configured for the alterations of the CIC, EER, communications room and pilothouse. Standard marine 60-Hz multizone and outside air conditioning units replace custom manufactured 400-Hz units.

The aft deck cupola installation has been eliminated, the former cupola inlet ducting is located at the aft weather bulkhead of the extended deckhouse with louvers facing aft. Vent system modifications incorporate 60-Hz off-the-shelf fan motors, single room thermal units and related electric components. These changes reduce both the total number of units required and environmental system cost with no net increase in vent system weight. A subsequent vent system enhancement is the reduction of airborne vent system noise as a result of the lower rpm 60-Hz electric motors.

The chilled water system improvements reduce both acquisition cost and logistics. Two low maintenance, variable capacity, semi-hermetically sealed compressors replace the four PHM 3 series fixed capacity, hermetically sealed units. A coinciding fabrication cost reduction is the replacement of the chilled water fiberglass piping, valves and fittings with copper-brass components.

3.3.5 Seawater System

The separation of the Model 928-83 high and low pressure seawater systems, figure 3.3-2, achieves considerable system simplification,, reduces the quantity of components, and decreases maintenance requirements. The systematic replacement of continuous duty 400-Hz seawater pump motors with 60-Hz off-the-shelf electric motors reduces both system cost and maintenance,, Standby duty cycle

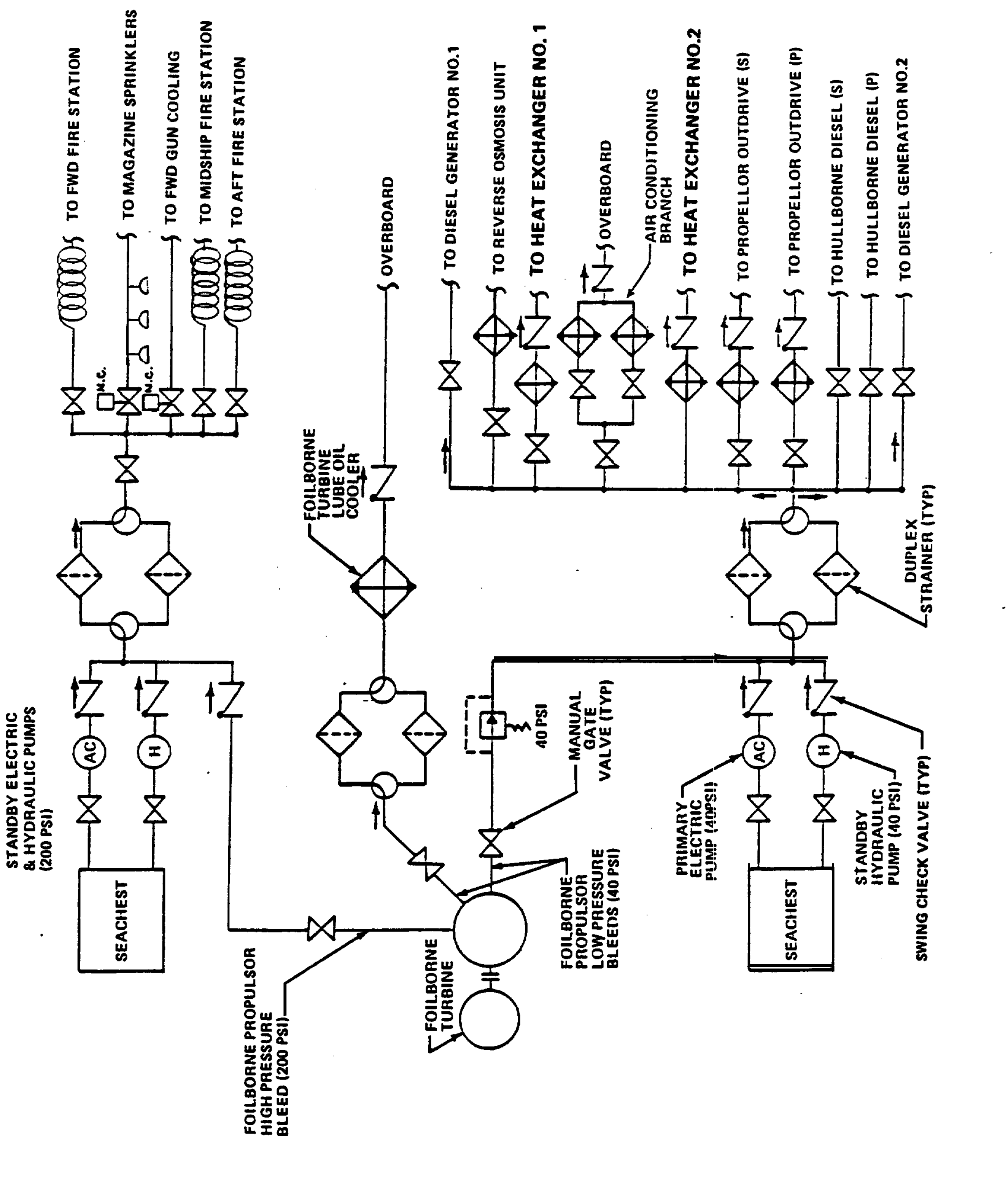

Figure 3.3-Z: Seawater System Diagram

seawater pump electric motors are systematically replaced with hydraulic motors. Substituting hydraulic motors reduces both the quantity of electric motors and peak electric power generation loads.

Cost effective features of the Model 928-83 point design 40-psi low pressure seawater system includes elimination of the following items; two sea chests, orificing, two electrical pumps, and sewage evaporator rinse. The PHM 3 series fiberglass piping is replaced with copper-nickel piping and fittings reducing fabrication costs. The Model 928-83 low pressure seawater system seachest flowrate is reduced from 210-gpm to 165-gpm as a result of high and low pressure system separation.

The high pressure seawater fire extinguishing system redesign eliminates the high maintenance and acquisition cost components of the single seawater supply system of the PHM 3 series. The separation of high and low pressure seawater systems in conjunction with the 60-Hz electrical service allows substitution of off-the-shelf pumps and components. Reduction of electric plant load is attained by replacing standby electric pump motors with hydraulically driven motors.

The second stage of the foilborne propul'sor is utilized for high pressure, 200-psi, seawater bleed. The foilborne propulsor first stage low pressure, 40-psi, seawater bleed supplies the low pressure seawater services. The new magazine arrangement reduces sprinkler flowrate from 365-gpm to 180-gpm which, in turn, reduces piping diameters and total system capacity. The Sea Vulcan 30 gun substitution reduces gun cooling requirements from 25-gpm to 10-gpm. The Model 928-83 point design will replace the PHM 3 series high pressure piping with copper nickel piping, reducing pipe system fabrication costs.

3.3.6 Waste Water Svstem

The Model 928-83 waste water system alterations and refinements accommodate revisions of manned space arrangements and the fuel tank configuration. Significant acquisition and life cycle cost reductions are attainable by utilizing overboard flow/holding tanks and 60-Hz standard marine equipment. The use of these standard marine components provides commonality to typical Navy installations.

3.3.7 Sewage System

Considerable reduction in sewage system acquisition cost, weight, complexity, and maintenance is achieved by design of a flow through commercial marine sewage system. The replacement of the macerator-evaporator configuration of the PHM 3 series design with holding tanks yields a net connected electric load reduction of 9.0-KW. Two automatic, electric toilets replace the PHM 3 series units. they are connected in series with 1 1/2 inch diameter hose and piping and require 24-volt DC power.

3.3.8 Fresh Water System

An improvement was realized by replacement of the PHM 3 series distilling installation with a 1200 gallon-per-day reverse osmosis distilling plant. This distilling plant reduces installation volume weight 680 kilograms, and electric load 10 kilowatts. Plant maintenance is reduced to intervals of 6 months versus 24 hours for the PHM 3 series plant. The reverse osmosis technology has been proven on board systems in service on U.S. Navy vessels.

3.3.9 Fuel System

Substantial improvement of the fuel system capacity, complexity and replenishment capabilities were attained. Fuel supply and distribution system complexity is reduced as well as the quantity of fuel system components, figure 3.3-3. Fuel tank boundaries were altered, as described in section 3.3.1, increasing fuel tank capacity for tanks 2, 3, 4. Moving the foilborne turbine and associated structure aft one meter, as described in section 3.3.2 created a fifth (day) tank. These extensions of the tank boundaries results in a 34 percent increase in tank capacity, 47.2 metric tons to 63.3 metric tons, distributed between the tanks.

The Model 928-83 underway replenishment rate is increased from 1000 to 1450 liters per minute. Adequate venting is provided allowing the maximum Navy specified flowrate of 25 feet per second without over-pressurization of tank walls. A centrifical fuel separator is added to accommodate alternate fuel sources presently unavailable to the PHM 3 series. This separator will clean contaminated fuel allowing the Model 928-83 point design a greater choice of fleet or other fuel sources.

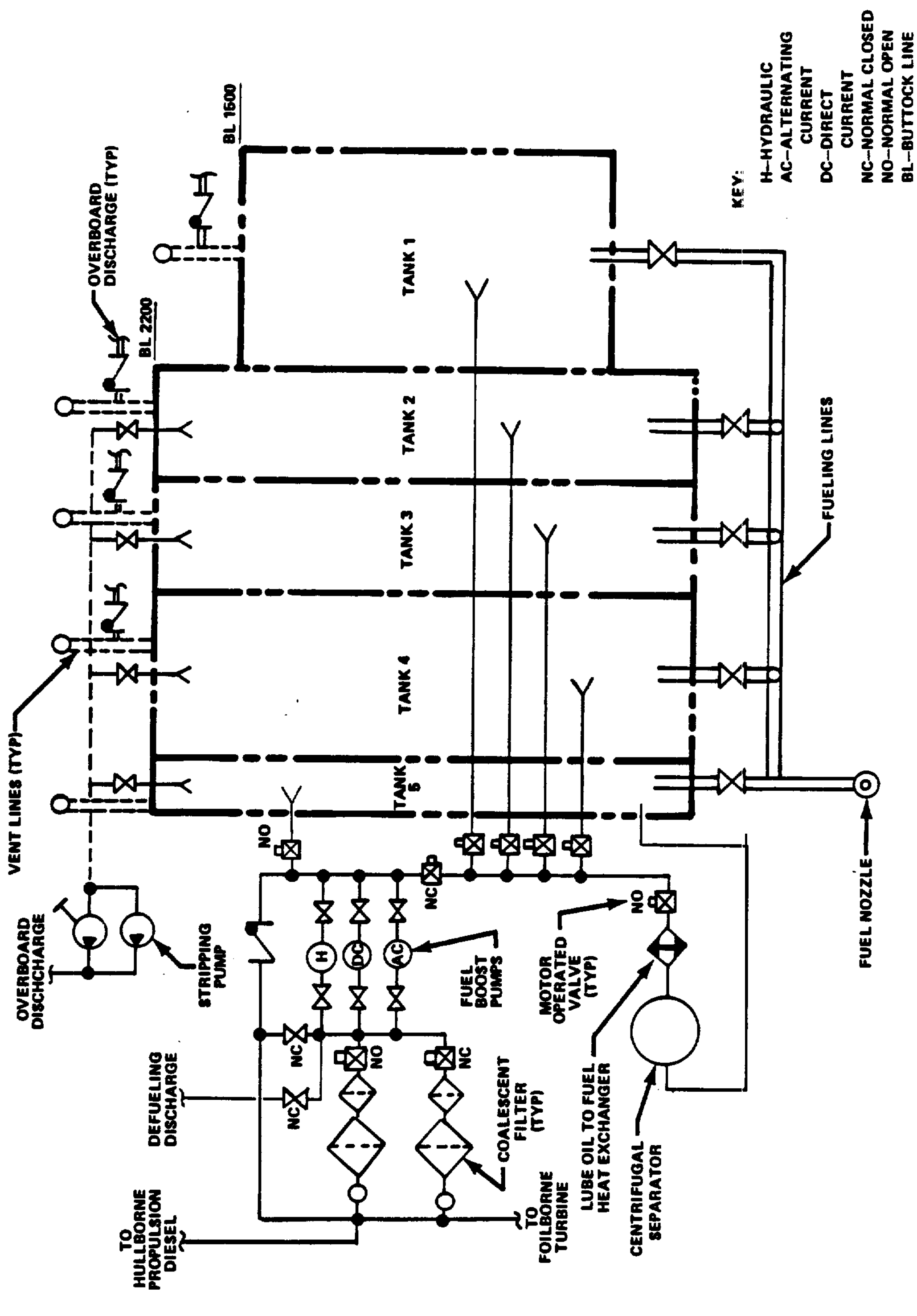

Figure 3.3-3: Fuel Service System Diagram

3.3.10 Hydraulic System

The Model 928-83 hydraulic system reflects design simplifications that incorporate state-of-the-art technology to insure system integrity of this critical auxiliary system. The hydraulic system uses two -redundant hydraulic power generation subsystems similiar to the proven Boeing JETFOIL configuration. System isolation is enhanced with state-of-the-art flowrate sensing hydraulic fusing technology, figure 3.3-4. System integrity improvements are derived from advanced F-18 aircraft hydraulic reservoir monitoring systems and monitoring logic. The monitoring systems were modified for the bimodal reservoir level cycles associated with foil retraction and deployment.

Model 928-83 hydraulic power generation is derived from power take-offs from both the ship's power service units (SSPU) and the foilborne turbine gearbox. Each SSPU incorporates a 1800-rpm power take-off providing 3000-psi and-4800 psi hydraulic power using two 0- to 55-gpm, pressure compensated, pumps. The foilborne gearbox has two hydraulic pump power take-offs with ratings of 3000-psi pressure, 0- to 33-gpm flowrate.

The hydraulic system services perform a diverse range of duties and were systematically integrated into other auxiliary systems whenever standby and intermittent duty cycles are defined. The high pressure circuit eliminates the PHM 3 Series hydraulic intensifier installation, direct actuation of the aft foil retraction actuators is provided. The standby fire pump, fuel pump and seawater pump are hydraulically powered as well as the hydraulic anchor winch motor and sonar hoist motor. The PHM 3 series emergency hydraulic hand pump is upgraded utilizing a hullborne diesel power take-off belt drive assembly. The pump drive provides emergency hydraulic hullborne steering and propeller outdrive retraction.

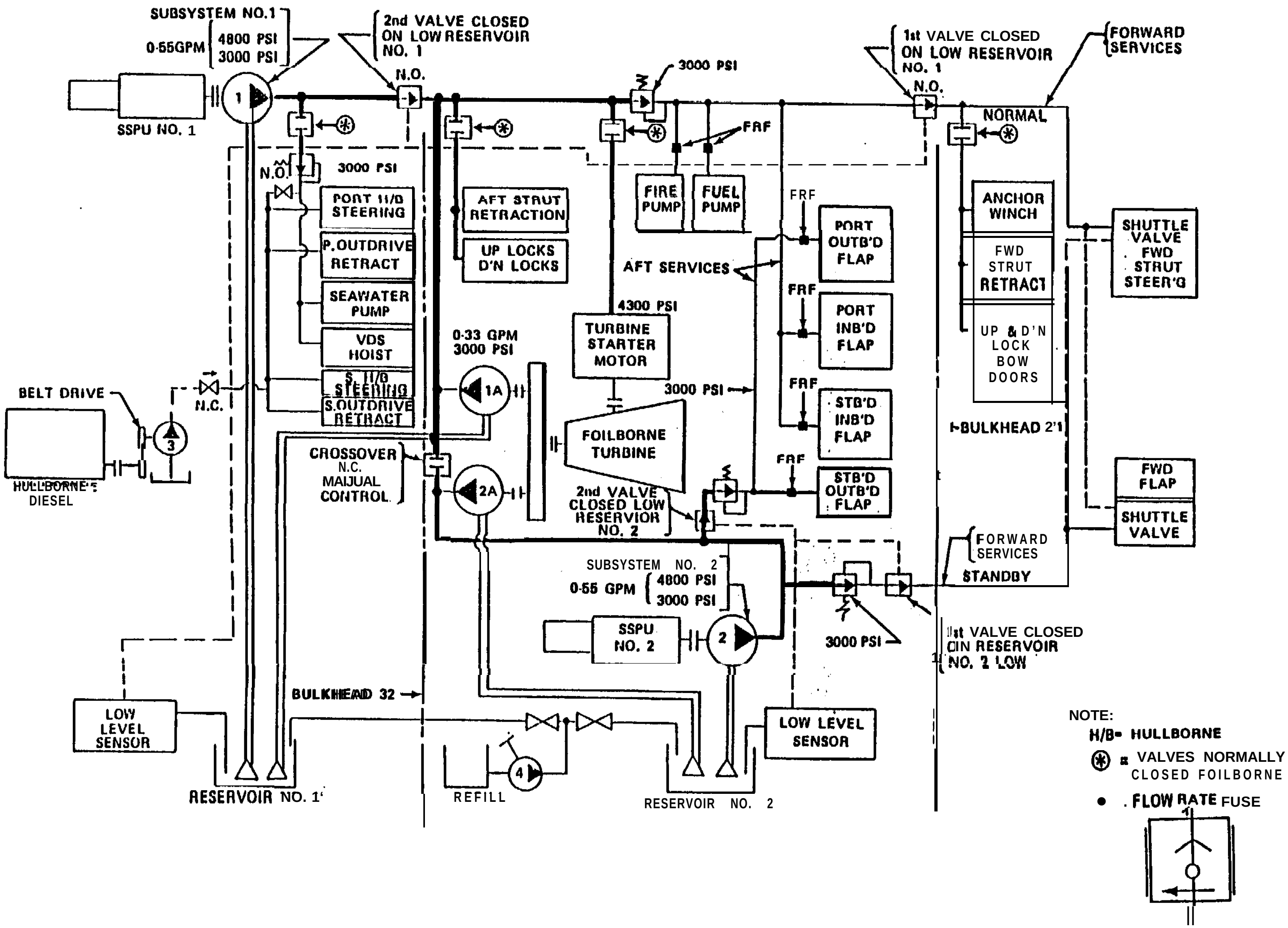

Figure 3.3-4: Hydraulic Service System Diagram

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The Model 928-83 hydraulic system employs fail-safe logic that maintains two levels of system integrity. Table 3.3-2 defines significant fail-safe features of the hydraulic system which are paramount to hydrofoil operation and survivability. In addition the fail-safe logic is illustrated on the Model 928-83 hydraulic system block diagram, figure 3.3-4.

Table 3.3-2: Model 928-83 hydraulic System Fail-Safe Logic

System	Function	Fail-Safe Operability (Function Operational After Fault)
Steering	Outdrive	Failure of 2 hydraulic subsystems and/or 1 outdrive actuator.
	Strut	Failure of 1 hydraulic subsystem
Roll Control	Outboard	Failure of subsystem 1, maintain one-half of roll authority
	Inboard	Failure of sybsystem 2, maintain one-half of roll authority
Pitch Control	Forward Flap	Failure of one subsystem
Auxiliary Systems	Turbine Start	Failure of one subsystem, use manual
	Retraction	Crossover valve to maintain functions
	FW, SW, FO	Crossover valve to maintain functions
	Pumps	Crossover valve to maintain functions
	Winches	Crossover valve to maintain functions

3.3.11 Hydraulic Turbine Start

Replacement of the SSPU air starting system by a hydraulic turbine start system provides a low failure rate system which substantially reduces system complexity and acquisition cost. The system utilizes a General Electric qualified system in service with marine installations for the General Electric LM-2500, LM-1500 turbines and the Pratt and Whitney FT-4 turbines, reference 10. A 9 cubic inch per revolution (CIR), 55-gpm, 4800-psi dual pressure compensated pump is mounted on each diesel SSPU. Each pump provides 150 hydraulic horsepower output to the hydraulic power generation subsystem circuits. A variable displacement, 6.0 cubic inch per revolution, hydraulic starter motor with integral overrunning clutch is mounted on the foilborne turbine accessory gearbox. The hydraulic starter motor generates 340 ft. lbs. of torque to accelerate the foilborne turbine through light-off. The hydraulic starter motor provides torque limiting with destroking and starter overspeed cut-out.

A key attribute of the turbine hydraulic start system is the immediate restart capability versus the air bottle charging cycle of the PHM 3 series. Minor modifications to the foilborne turbine accessory gearbox mounting pad are required to implement this installation.

3.3.12 Control and Lift System

The propeller outdrive alteration of the hullborne propulsor improves ship maneuverability and enhances reverse thrust significantly. The improved maneuverability allowed elimination of the bow thruster system. The Model 928-83 point design increased displacement is accommodated by the PHM 3 series canard hydrofoil system. The foil loading remains within hydrodynamic limits, foil loads increase from 1,402 to 1,445 lbs per sq foot on the forward foil and from 1,112 to 1,251 lbs per square foot on the aft foil. These wing loadings resulted from a major effort to keep thr forward foil within hydrodynamic limits by relocating systems, equipment and loads items as far aft as possible to balance the fore and aft wing loadings. The foil system fatigue life is altered with forward foil life reduced to 90 percent of the PHM 3 series and aft foil life to 75 percent of the PHM 3 series life. The actual fatigue life at the most critical foil system component is 11,100 hours.

3.4 Model 928-83 Design Integration

The Model 928-83 point design methodology incorporates an integrated, comprehensive approach to optimize cost effectiveness and system simplification. This is an integrated design point which is contingent on the entire change. The following features are closely integrated:

- 60-Hz primary electrical power system
- Diesel ship's service power units (SSPU) with hydraulic power take-offs
- Dual pressure hydraulic system power for intermittent, standby loads
- Seawater system with separation of fire main and low pressure
- "Off-the-shelf" component integration
- Fuel tank arrangement and capacity increases

The hydraulic service system incorporation is contingent on 60-Hz electrical service, diesel SSPU and propulsion installation power take-offs. The hydraulic turbine starting system requires the incorporation of the high pressure circuit of the hydraulic system. The fuel service system is based on 60-Hz electrical service and hydraulic system design. The fuel tank enlargement is contingent on the foilborne engine relocation which resulted in the day tank arrangement. The fuel tank alterations modify seawater piping configuration outboard of the tank boundaries. The waste water and fresh water systems are similarily affected by the fuel tank outboard longitudinal bulkhead relocation and are contigent on 60-Hz electric service as well. Environmental control system alterations are contingent on 60-Hz electric service, new machinery room equipment and the arrangement plan changes. The seawater system installation is dependent on both the 60-Hz electrical service and the hydraulic system services. The modifications of the fire extinguishing system depend on the point design compartment arrangement and the electric and hydraulic services that provide power to the firepumps.

4.0 HYDROSTATICS

This section contains all information pertinent to the hydrostatic properties of the ship. A description of the increase in fuel tankage is included here, even though it could be contained in the systems section, 3.3.9. The derivation of the ship weights and centers is outlined, and a summary of the loading conditions provided. Finally, an evaluation of the ship's hydrostatic properties is documented in the form of an intact and damaged static stability analysis.

4.1 Fuel Tankage

One of the major goals of the Model 928-83 Point Design was an increase in range of the ship. It has also become apparent from other design efforts that if the foilborne range is lengthened, the hullborne range will also be increased. The converse of this is not always true. Several things can contribute favorably to foilborne range; decrease in ship weight, better turbine specific fuel consumption, reduced SSPU fuel flow, reduced drag, increase in tankage. Because this is a modification and not a new design, many of the above are not available. It then was necessary to examine various schemes to store more fuel aboard. There were two criteria imposed throughout the whole study, reduce the VCG of the ship, and move the LCG aft. There are also volume and space limitations to be considered.

The final configuration chosen consists of widening tanks 2, 3, and 4 from the 1.500 meter to 2.200 meter buttock line. The foilborne turbine and propulsor were moved aft one meter allowing another meter of fuel tank length. This tank and the existing tank 4 were repartitioned as a day tank to separate the clean filtered fuel from the dirty fuel. The total tankage now provides volume for 63,323 kilograms of Diesel Fuel Marine(DFM).

4.2 Loading Conditions

The present PHM 3 weight data, 1200 input items, was available on a BMS computer system. This data was downloaded to the IBM PC-XT used for BMS 506. The inputs only required minor modification and were then acceptable for input to WBSWT, the PC based weights management computer program, reference 2. The weights file was then revised as changes from PHM to Model 928-83 were accomplished. This allowed constant tracking of displacement, LCG and VCG. Because of the onset of the SWBS, reference 3, for weights documentation after the start of PHM, there is some disparity between the item numbers for SWBS and the way PHM was first reported. The Model 928-83 is displayed in the present SWBS format.

Output from WBSWT for minimum operating and full load conditions are presented as tables 4.2-l and 4.2-2. A complete WBSWT computer printout of all weight groups and light ship load condition is contained in the appendix. Finally, a comparison of PHM 3 in SWBS format and Model 928-83 major weights groups is presented in table 4.2-3.

4.3 Static Stability

One of the presently limiting areas on the PHM 3 series ships is static stability. PHM is presently in Stability Status 2: "Neither an increase in weight nor a rise of the ship's center can be accepted.", reference 4. This is because the ship's VCG with the NAVSEA margin included is at the limiting VCG from the static stability analysis, reference 5. As the ship grew in the design and construction phase, the NAVSEA margin was revised to keep the Full Load VCG at the limit, 3.27 meters above the baseline. If the NAVSEA margin is removed, there is plenty of VCG margin available for growth.

Since there has been difficulty in negotiating this issue, it was necessary to examine the effects of growth to the Model 928-83 from the present PHM 3 displacement. A static stability analysis was conducted on the worst cases for intact and damaged stability. These are all at minimum operating displacement, foils retracted. Intact stability continues to be the most critical. Using the present criteria, there is no margin at this case.

MODEL 928-83 DETAILS 09-24-85

WBS DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
• LIGHTSHIP, FOILS DOWN	187.106	187106.0	2.727	510199.3	20.975	3924S37.0	0.010	1782.8
A00 LOADS	31.931	31930.9	2.177	69504.6	22.90s	721150.3	0.095	3035.2
A10 SHIPS FORCE, AMPHIB. FORCE, TROOPS A	3.304	3383.7	3.275	11080.3	13.129	44424.1	0.550	1860.6
A11 SHIPS OFFICERS	0.907	907.2	3.760	3411.1	14.170	12855.0	1.600	1451.5
AI2 SHIPS NONCOMMISIONED OFFICERS	0.999	598.7	2.930	1794.2	16.660	9974.3	-2.610	-1S62.6
AI3 SHIPS ENLISTED MEN	I.878	1877.8	3. is0	591s. 1	11.500	21594.7	1.050	1971.7
A20 MISSION RELATED EXPENDABLES AND SYST	6.086	6086.5	5.814	35385.0	29.915	182074.2	-0.047	-284.8
A21 SHIP AMMUNITION (FOR USE BY SHIP ON	5.990	5989.9	5.789	34675.5	30.192	100840.2	-0.017	-101.4
A29 SPECIAL MISSION RELATED EXPENDABLES	0.097	96.5	7.350	709.5	12.700	1225.9	-1.900	-183.4
A30 STORES	0.624	623.6	3.050	1901.9	10.000	6235.7	2.000	1247.1
A31 PROVISIONS AND PERSONNEL STORES	0.624	623.6	3.050	1901.9	10.000	6235.7	2.000	1247.1
A40 FUELS AND LUBRICANTS	21.170	21170.5	0.954	20204.1	22.630	479083.0	0.010	212.3
A41 DIESEL FUEL	21.108	21107.7	0.949	20040.8	22.604	477100.3	0.000	0.0
A46 LUBRICATING OIL	0.063	62.8	2.600	163.3	31.444	1974.7	3.300	212.3
AS0 LIQUIDS AND GASES (NON FUEL TYPE)	0.667	666.7	1.400	933.3	14.000	9333.4	0.000	0.0
AS2 FRESH WATER	0.667	666.7	1.400	933.3	14.000	9333.4	0.000	0.0
*A+ MINIMUM OPERATING COND., FOILS DOWN	219.037	219036.9	2.647	579703.9	21.210	4645687.0	0.022	4818.0
A MINIMUM OPERATING COND., FOILS UP	219.037	219036.9	3.517	770306.9	21.647	4741544.0	0.022	4819.0

Table 4.2-I: Model 928-83 Minimum Operating Condition

MODEL 928-83 DETAILS 09-24-85

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
* *	LIGHTSHIP, FOILS DOWN	187.106	187106.0	2.727	510199.3	20.975	3924537.0	0.010	1782.8
F00	LOADS	76.498	76498.0	1.518	116135.6	18.109	1385320.0	0.075	5751.2
F10	SHIPS FORCE, AMPHIB. FORCE, TROOPS A	3.384	3383.7	3.275	11080.3	13.129	44424.1	0.550	1860.6
F11	SHIPS OFFICERS	0.907	907.2	3.760	3411.1	14.170	12855.0	1.600	1451.5
F12	SHIPS NONCOMMISIONED OFFICERS	0.599	598.7	2.930	1754.2	16.660	9974.3	-2.610	-1562.6
F13	SHIPS ENLISTED HEN	1.878	1877.8	3.150	5915.1	11.500	21594.7	1.050	1971.7
F20	MISSION RELATED EXPENDABLES AND SYST	6.732	6732.2	5.642	37983.8	27.442	104746.0	-0.072	-487.6
F21	SHIP AMMUNITION (FOR USE BY SHIP ON	6.636	6635.7	5.617	37274.3	27.657	183520.1	-0.046	-304.2
F29	SPECIAL MISSION RELATED EXPENDABLES	0.097	96.5	7.350	709.5	12.700	1225.9	-1.900	-183.4
F30	STORES	1.871	1870.7	3.050	5705.6	10.000	18707.0	2.000	3741.4
F31	PROVISIONS AND PERSONNEL STORES	1.871	1870.7	3.050	5705.6	10.000	18707.0	2.000	3741.4
F40	FUELS AND LUBRICANTS	63.511	63511.4	0.944	59965.8	17.689	1123442.0	0.010	636.8
F41	DIESEL FUEL	63.323	63323.0	0.939	59476.0	17.648	1117518.0	0.000	0.0
F46	LUBRICATING OIL	0.188	180.4	2.600	489.8	31.444	5924.1	3.380	636. B
F50	LIQUIDS AND EASES (NON FUEL TYPE)	1.000	1000.0	1.400	1400.0	14.000	14000.0	0.000	0.0
F52	FRESH WATER	1.000	1000.0	1.400	1400.0	14.000	14000.0	0.000	0.0
F	FULL LOAD CONDITION, FOILS DOWN	263.604	263604.0	2.376	626334.9	20.143	5309056.0	0.029	7534.0
F	FULL LOAD CONDITION, FOILS UP	263.604	263604.0	3.099	817017.9	20.507	5405713.0	0.029	7334.0

Table 4.2-2: Model 928-83 Full Load Condition

SWBS	DESCRIPTION	MODEL 928-83	PHM2 (SWBS)
		WEIGHT (METRIC TONS)	
100	HULL STRUCTURE, GENERAL	46.334	46.779
200	PROPULSION PLANT, GENERAL	25.434	26.104
300	ELECTRIC PLANT, GENERAL	11.768	8.619
400	COMMAND AND SURVEILLANCE (EMPTY WT)	3.757	2.900
500	AUXILIARY SYSTEMS, GENERAL	50.157	52.790
600	OUTFIT AND FURNISHINGS, GENERAL	18.216	15.827
M00	MARGINS	7.769	4.836
• [illegible]	EMPTY WEIGHT	163.435	153.339
400	COMMAND AND SURVEILLANCE (PAYLOAD)	12.858	8.001
700	ARMAHENT, GENERAL	10.812	9.542
F20	MISSION RELATED EXPENDABLES AND SYST	6.732	14.153
F46	LUBRICATING OIL	0.188	0.188
• **	TOTAL PAYLOAD	30.591	31.885
F10	SHIPS FORCE, AMPHIB. FORCE, TROOPS A	3.384	2.635
F30	STORES	1.871	0.728
F41	DIESEL FUEL	63.323	47.200
F50	LIQUIDS AND GASES (NON FUEL TYPE)	1.000	1.000
. ***	TOTAL USEFUL LOAD	100.169	83.448

Table 4.2-3 PHM 3 and Model 928-83 Weight Summary

It was also discovered that the damaged cases had been done incorrectly, due to a confusion of filling tanks with fuel and then damaging them. These now show significant margin for the worst cases.

Since one of the goals was to meet all the present PHM 3 Series SSS requirements, it was decided to seek alternative means of providing margin to the VCG limit. Clearly, there is no other alternative short of revising the hull form except lowering the ship's actual VCG. This was accomplished #rough detailed attention to arrangements as discussed elsewhere in this document. As far as hull form revision stands, for every inch desired in VCG height, an inch of additional maximum beam is needed at the waterline to provide VCG margin.

It should also be noted that at delivery there was approximately 5 metric tons of weight margin available for growth to the PHM Full Load displacement. However the changes made during Fitting Out Availability (FOA) and Post Shakedown Availability (PSA) have nearly used up that margin and the VCG grew during that time. That was before the Stability Status 2 notification. For the Model 928-83 two margins were established. Based on NAVSEA advice, a 1 percent margin was placed on all lightship weight items repeated from the original PHM 3 Series production. All other weight items new to this design had a 17 percent margin placed upon them. This results in a total margin of 7.8 metric tons.

5.0 SHIP PERFORMANCE

5.1 Hullborne

Hullborne performance was first derived from a HANDE calculation of drag, reference 6. This drag correlates well with drags calculated from sea trials, references 7 and 8. Thrust calculations were made with a personal computer program. The optimum propeller for the preliminary design was a Troost series B5-60 with a pitch/diameter ratio of 0.9 and a diameter of 1.60 meters (5.25 feet). Assuming the present 800 horsepower rating of the light marine diesels providing hullborne power, the maximum continuous speed would be 13.6 knots, and maximum intermittent speed of 13.9 knots. A specific fuel consumption of 0.17 kilograms per hour (0.38 lbs/hr) was assumed. The hullborne range at maximum speed would then be 2.47 times the PHM 3 SSS hullborne requirement, reference 1. A hullborne range/speed plot is shown as figure 5.1-1. Also shown is hullborne range for VDS towing. The maximum continuous speed while towing drops to 13.3 knots, and the range is then 2.44 times the PHM 3 SSS hullborne requirement.

5.2 Takeoff

Because of the increase in full load displacement, it was deemed necessary to increase the maximum power of the present propulsion system of LM 2500 gas turbine, gearbox, and waterjet pump. The LM 2500 is presently being utilized for operation at horsepowers greater than 25,000 and is therefore not limiting. Previous studies indicate power increases could be accommodated by the propulsion pump with minor changes. The foilborne gearbox is the weakest item, and an increase only to the tested 19,000 HP is presently envisioned. Based on this power, HANDE (reference 6) predicts a calm water takeoff thrust margin of 19.4 percent. This is generally considered acceptable in providing adequate thrust for takeoffs in head seas in design sea states. Thrust margin as a function of ship displacement is shown as figure 5.2-l for both a 17,000 and 19,000 horsepower limited ship.

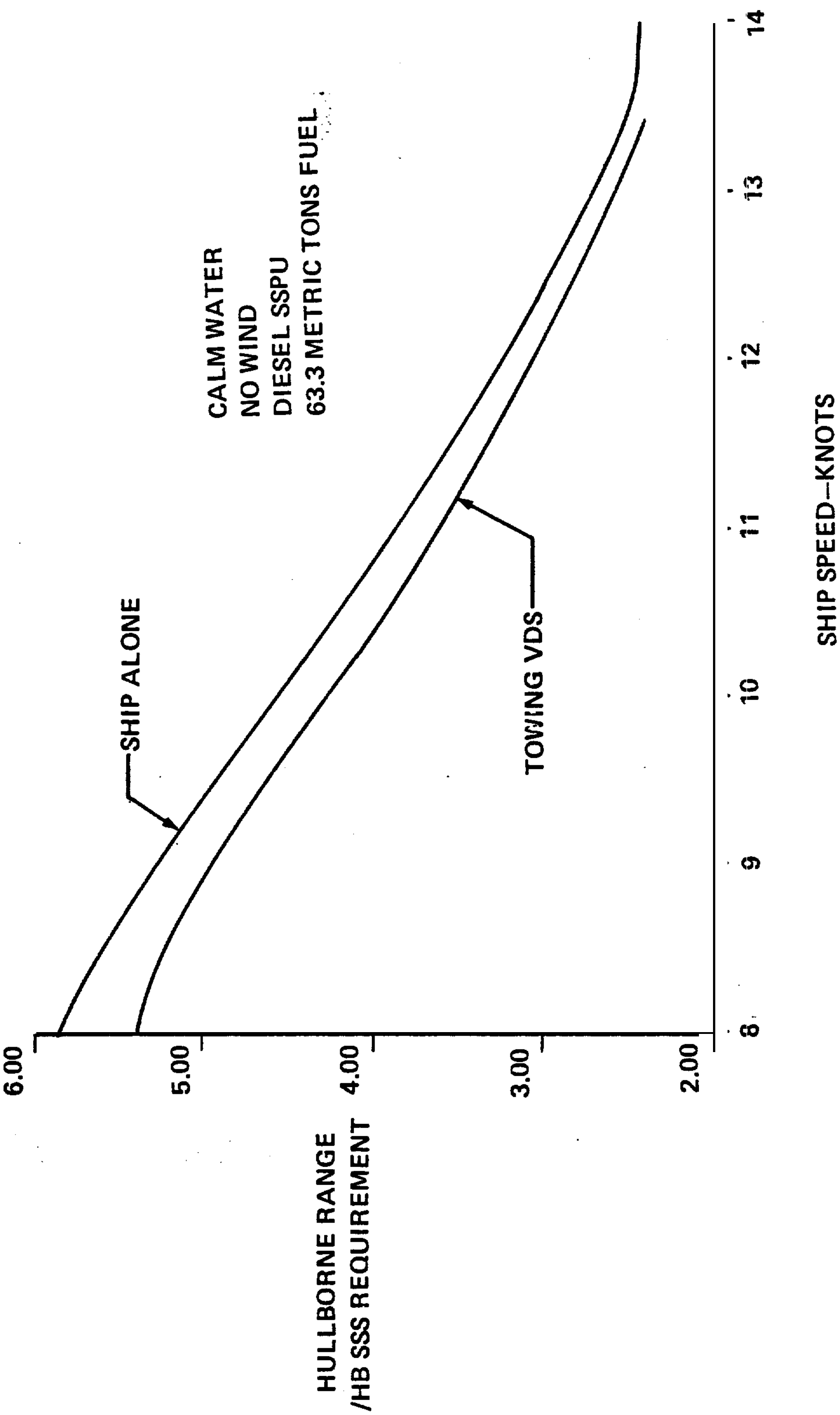

Figure 5.1-1: Model 928-83 Hullborne Range

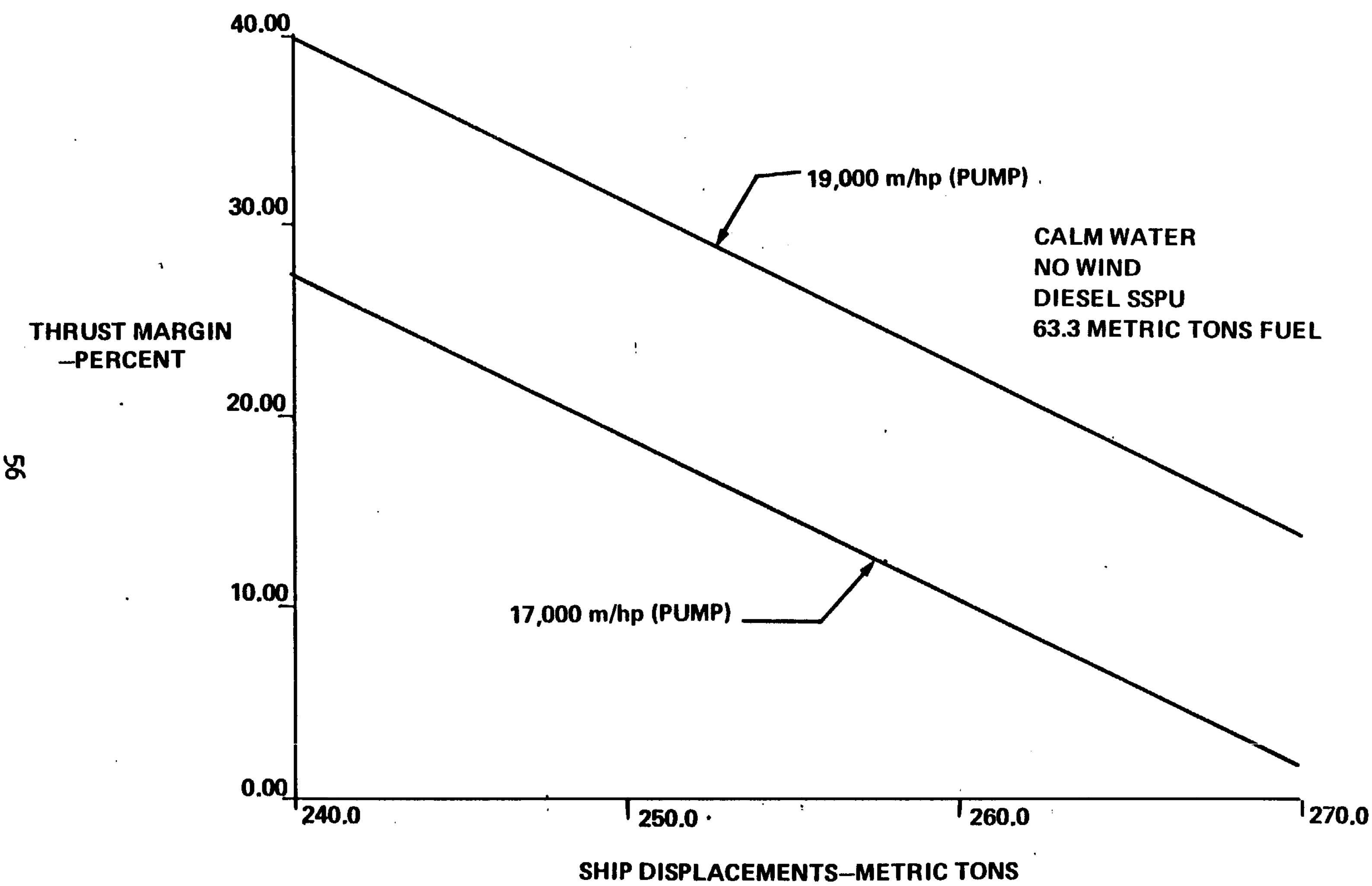

Figure 5.2-1: Model 928-83 Takeoff Margin

5.3 Foilborne

Data generated by HANDE was corrected with data from references 7 and 8 to produce predictions for foilborne performance, figure 5.3-l. The maximum speed at full load displacement would then be PHM 3 design speed plus 5.0 knots. Specific fuel consumption data available in the LM 2500 was used to calculate foilborne range. Range at design speed would then be 1.33 times the PHM 3 SSS foilborne requirement.

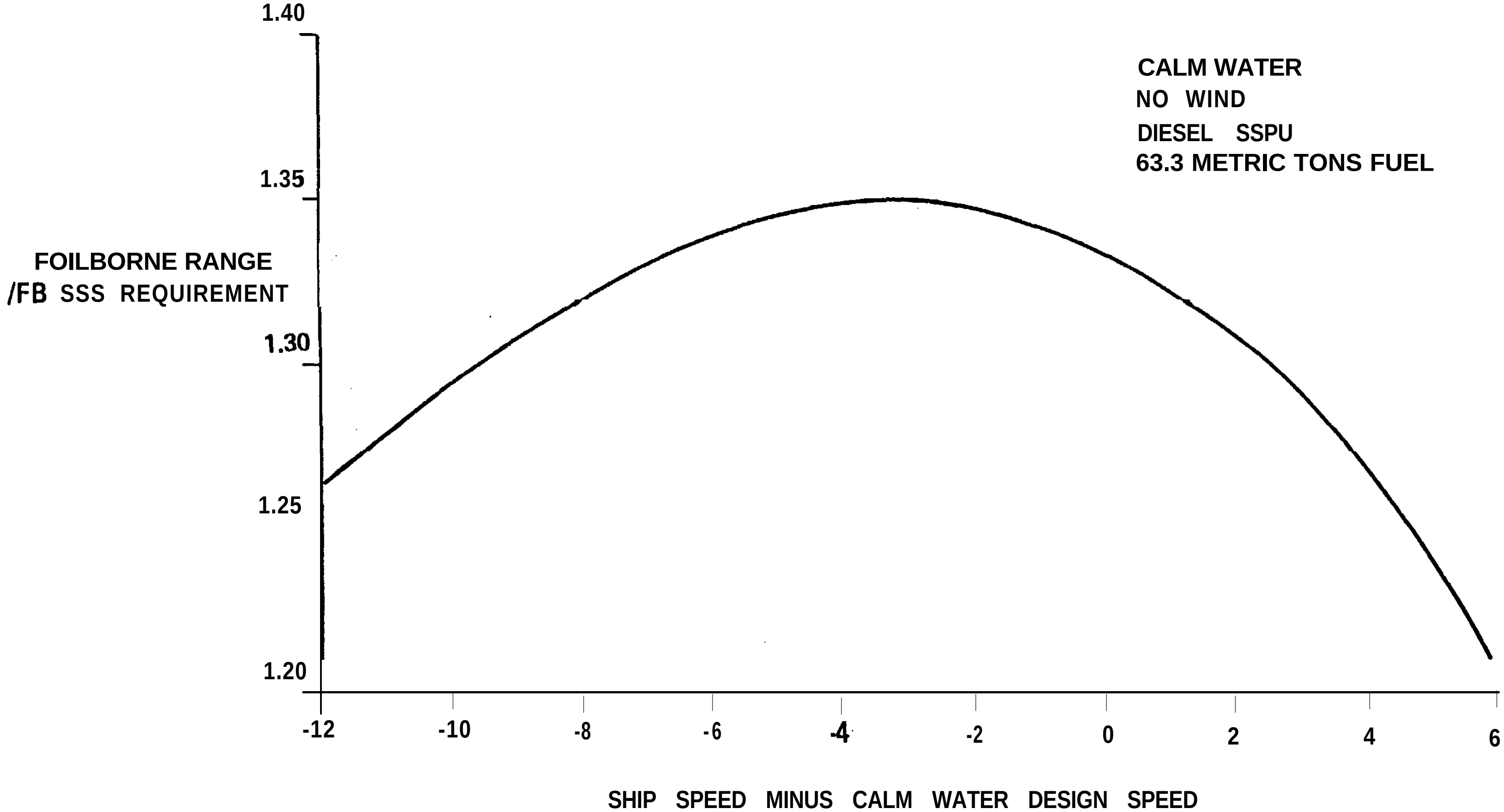

Figure 5.3-l : Model 92883 Foilborne Range

REFERE ICES

1. "Ship System Specification for Building Patrol Combatant Missile (Hydrofoil) PHM 1 Class (PHM 3 Series), "S9PHM-00-SPN-010/PHM-1CL, 30 November 1977, Unclassified, Addendum, S9PHM-00-SPN-020/(C) PHM-1 CL, 30 November 1977, Confidential -3.

2. "WBSWT - A Preliminary Design Tool for Weights Documentation", D321-11021-1, Revision A., by L. F. Ahearn Jr., dated 13 August 1984

3. "Ship Work Breakdown Structure", Naval Sea Systems Command document S9040-AA-IDX-010/SWBS, 1 Apri 1 1981 Repri nt

4. "Surface Naval Ships - Weight and Moment Compensation and Limiting Drafts", NAVSEAINST 9096.3A 55W4/RSL Ser 01, by M. V. Ricketts, dated 23 May 1983

5. "PHM 3 Series Hydrostatic Properties and Limiting Drafts", D312-80324-1, Revision C, by L. F. Ahearn Jr., dated 27 April 1981

6. "Hydrofoil Analysis and Design Program (HANDE) Users Manual - Volume I", D321-51312-1, Revision D. by M. D. Devine, dated 19 September 1980

7. 'Performance of USS Gemini (PHM 6) as Demonstrated in Sea Trials", D312-80248-6 by A. E. Noreen et al, dated 30 July 1982

8. "PHM 3 Series Average Ship Performance", D312-80248-7 by A. E. Noreen, dated 30 August 1982

9. "A Hydrofoil Missile Combatant for Naval Forces", D312-80950-1, by BMS Research and Development Organization, dated 25 August 1981

10. "LM 2500 Marine Gas Turbine Installation Design Manual", MID-IDM-2500-2, by Marine and Industrial Engine Department, General Electric Company, revised April 1984

GLOSSARY

AMR	Auxiliary Machinery Room
BMS	Boeing Marine Systems
CIC	Combat Information Center
CIR	Cubic Inch per Revolution
CO	Commanding Officer
CPO	Chief Petty Officer
DFM	Diesel Fuel Marine
EER	Electronics Equipment Room
EOS	Engineer's Operating Station
gpm	Gallons per Minute
GPS	Global Positioning System
Hz	Hertz
IFF	Identification Friend or Foe
IR&D	Independent Research and Development
KVA	Kilovolt Amps
KW	Kilowatts
LCG	Longitudinal Center of Gravity
PHM	Patrol Combatant Missile (Hydrofoil)
psi	Pounds per square inch
SSPU	Ship's Service Power Unit
SSS	Ship's Systems Specifications
SWBS	Ship Work Breakdown System
TTY	Teletype
VCG	Vertical Center of Gravity
WBSWT	Work Breakdown Structure Weight Program

APPENDIX A

WBSWT Computer Print-out

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
100	HULL STRUCTURE, GENERAL	4b. 334	4b333.7	3.243	130263.5	1s. 334	858766.1	-0.009	-413.2
110	SHELL AND SUPPORTING STRUCTURE	16. 852	16851.6	1.854	31237.4	19.047	320980. S	-0.004	-67.3
111	SHELL PLATING, SURF.SHIP AND SUBMARI	8.645	0644.7	1.818	13719.4	18.781	162337.9	-0.009	-74.3
113	STANCHIONS	0.130	149.6	3.000	448.9	19.300	2888.2	-0.100	-13.0
116	LONGIT. FRAMING, SURF-SHIP AND SUBMA	2.029	2029.4	1.614	3276.1	21.240	43120.2	0.003	9.2
117	TRANSV. FRAMING, SURF-SHIP AND SUBMA	6.028	6027.9	1.956	11792.8	18.682	112614.4	0.002	12.9
120	HULL STRUCTURAL BULKHEADS	4.620	4620.4	2.608	12049.3	19.819	91373.0	-0.008	-3b. 4
121	LONGITUDINAL STRUCTURAL BULKHEADS	0.346	346.0	2.800	968.7	23.000	7937.1	0.000	0.0
122	TRANSVERSE STRUCTURAL BULKHEADS	4.274	4274.4	2.392	11080.6	19.362	83613.9	-0.009	-36.4
130	HULL DECKS	6.723	6725.3	4.296	28890.6	18.033	121421.8	0.034	226.2
131	MAIN DECK	6.723	6723.3	4.296	28890.6	18.055	121421.8	0.034	226.2
140	HULL PLATFORMS AND FLATS	2.443	2443.0	1.833	4478.3	13.077	36833.8	-0.023	-33.9
141	1ST PLATFORM	2.443	2443.0	1.833	4478.3	13.077	36833.8	-0.023	-33.9
130	DECKHOUSE STRUCTURE	3.104	3103.6	6.294	32121.1	lb.203	02703.9	0.029	130.1
151	DECKHOUSE STRUCTURE TO FIRST LEVEL	3.039	3038.3	5.799	17620.2	16.916	31400.7	0.029	89.3
132	1ST DECKHOUSE LEVEL	2.063	2065.1	7.022	14300.9	15.139	31303.2	0.029	60.7
160	SPECIAL STRUCTURES	2.944	2944.2	3.706	10910.5	15.274	44970.8	-0.062	-183.8
163	SEA CHESTS	0.049	48.8	0.459	22.4	29.009	1415.4	0.000	0.0
167	HULL STRUCTURAL CLOSURES	2.043	2043.4	4.234	8652.b	20.303	41894.8	-0.103	-209.9
169	SPECIAL PURPOSE CLOSURES AND STRUCTU	0.832	832.0	2.624	2233.3	1.949	1660.7	0.031	26.1
170	MASTS, KINGPOSTS, AND SERVICE PLATFO	0.499	498.9	11.303	5639.9	13.984	7974.4	0.000	0.0
171	MASTS, TOWERS, TETRAPODS	0.499	498.9	11.303	3639.9	13.984	7974.4	0.000	0.0
180	FOUNDATIONS	7.147	7146.7	3.489	24936.6	21.311	132303. b	-0.063	-440.2
182	PROPULSION PLANT FOUNDATIONS	0.761	761.3	1.623	1237.2	32.310	24597.1	0.110	83.6
183	ELECTRIC PLANT FOUNDATIONS	0.518	518.2	3.429	1776.7	24.790	12843.3	-1.173	-600.0
184	COMMAND AND SURVEILLANCE FOUNDATIONS	1.356	1353.6	3.331	7497.1	23.239	31329.4	-0.121	-164.2
185	AUXILIARY SYSTEMS FOUNDATIONS	3.764	3764.3	3.120	11746.3	18.662	70230.4	-0.016	-61.1
186	OUTFIT AND FURNISHINGS FOUNDATIONS	0.613	614.8	3.408	2095.7	13.779	9701.8	0.303	309.3
187	ARMAMENT FOUNDATIONS	0.133	132.3	4.404	383.7	23.313	3381.3	-0.060	-7.9

MODEL 928-83 DETAILS 09-24-85

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
200	PROPULSION PLANT, GENERAL	25.434	25434.5	2.159	54909.5	31.051	789773.3	-0.051	-1296.3
230	PROPULSION UNITS	10.356	10355.9	2.215	22939.8	30.573	316608.0	-0.002	-18.4
233	PROPULSION INTERNAL COMBUSTION ENGIN	5.230	5230.0	2.001	10466.0	33.990	177766.0	-0.010	-54.0
234	PROPULSION GA5 TURBINES	5.126	5125.9	2.433	12473.8	27.086	138842.0	0.007	35.6
240	TRANSMISSION AND PROPULSOR SYSTEMS	10.543	10543.1	1.594	16803.4	32.909	346965.1	0.002	25.9
241	PROPULSION REDUCTION GEARS	2.367	2366.7	2.132	S045.9	30.068	71160.5	-0.001	-2.5
243	PROPULSION SHAFTING	0.017	17.0	2.620	44.5	29.230	496.9	0.000	0.0
245	PROPULSORS	3.000	3000.0	0.800	2400.0	35.900	107700.0	0.000	0.0
247	WATER JET PROPULSORS	5.159	5159.4	1.805	9313.0	32.486	167607.6	0.006	28.4
250	PROPULSION SUPPORT SYS. (EXCEPT FUEL	3.273	3273.4	3.872	12676.0	27.106	88728.3	-0.094	-309.1
251	COMBUSTION AIR SYSTEM	1.250	1249.6	4.362	5451.2	25.173	31496.8	0.000	0.0
252	PROPULSION CONTROL SYSTEM	0.598	598.3	2.715	1624.5	26.128	15633.3	0.000	0.0
256	CIRCULATING AND COOLING SEA WATER SY	0.554	553.7	1.955	1082.3	29.643	16413.5	-0.558	-309.1
259	UPTAKES (INNER CASING)	0.872	871.7	5.183	4S18.0	28.936	25224.8	0.000	0.0
260	PROPULSION SUPPORT SYSTEMS (FUEL AND	0.643	642.5	1.709	1097.8	30.046	19305.2	-0.178	-114.4
262	MAIN PROPULSION LUBE OIL SYSTEM	0.610	610.0	1.659	1011.9	29.916	18247.3	-0.369	-225.1
264	LUBE OIL FILL, TRANSFER, AND PURIFIC	0.033	32.5	2.640	85.9	32.500	1057.9	3.400	110.7
290	SPECIAL PURPOSE SYSTEMS	0.620	619.5	2.248	1392.5	29.323	18166.8	-1.421	-880.1
298	PROPULSION PLANT OPERATING FLUIDS	0.547	547.3	2.188	1197.4	29.960	16396.6	-1.133	-620.0
299	PROPULSION PLANT REPAIR PARTS AND SP	0.072	72.3	2.700	195.1	24.500	1770.1	-3.600	-260.1

MODEL 928-83 DETAILS 09-24-85

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
300	ELECTRIC PLANT, GENERAL	11.768	11768.0	3.258	38340.1	25.311	297865.2	0.224	2636.3
310	ELECTRIC POWER GENERATION	7.064	7064.5	2.771	19572.4	27.843	196696.3	0.685	4836. a
311	SHIP SERVICE POWER GENERATION	4.699	4699.0	2.850	13392.6	28.496	133903.0	1.499	7044.0
313	BATTERIES AND SERVICE FACILITIES	0.798	758.0	2.559	1939.9	29.862	22635.7	1.966	1414.2
314	POWER CONVERSION EQUIPMENT	1.607	1607.5	2.638	4240.0	24.980	401SS.6	-2.253	-3621.4
320	POWER DISTRIBUTION SYSTEMS	3.367	3367.3	3.792	12768.2	22.301	75768.8	-0.778	-2619.2
321	SHIP SERVICE POWER CABLE	2.109	2109.2	4.015	a46a.9	20.39s	43016.9	0.048	101.7
322	EMERGENCY POWER CABLE SYSTEM	0.134	133.9	5.230	700.0	24.710	3307.7	0.206	27.6
324	SWITCHGEAR AND PANELS	1.124	1124.3	3.201	3599.3	26.190	29444.2	-2.445	-2748. s
330	LIGHTING SYSTEM	1.099	1099.2	4.743	5213.4	17.465	19198.5	0.108	118.6
331	LIGHTING DISTRIBUTION	0.162	161.9	4.108	665.1	18.442	2986.2	0.484	78.4
332	LIGHTING FIXTURES	0.937	937.3	4.852	4548.2	17.297	16212.3	0.043	40.2
340	POWER GENERATION SUPPORT SYSTEMS	0.200	200.0	2.950	590.0	29.250	sa50.0	1.500	306.0
342	DIESEL SUPPORT SYSTEMS	0.200	200.0	2.950	590.0	29.250	5850.0	1.500	300.0
390	SPECIAL PURPOSE SYSTEMS	0.037	37.0	5.300	196.1	9.500	351.5	0.000	0.0
399	ELECTRIC PLANT REPAIR PARTS AND SPEC	0.037	37.0	5.300	196.1	9.500	351.5	0.000	0.0

MODEL 928-83 DETAILS 09-24-85

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (H-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (H-KG)
400	COMMAND AND SURVEILLANCE, GENERAL	16.615	16615.4	5.765	95788.5	20.801	345615.0	-0.335	-5572.7
410	COMMAND AND CONTROL SYSTEMS	0.113	113.2	6.898	780.9	il.008	1246.2	-0.089	-10.1
411	DATA DISPLAY GROUP	0.113	113.2	6.898	780.9	11.008	1246.2	-0.089	-10.1
420	NAVIGATION SYSTEMS	2.021	2020.8	6.490	13115.3	12.512	25285.3	-0.015	-31.0
421	NON-ELECTRICAL/ELECTRONIC NAVIGATION	0.051	51.1	6.052	309.4	13.147	672.2	1.002	51.2
422	ELECTRIC NAVIGATION AIDS (INCL NAVIG	0.148	147.9	7.828	1158.2	16.952	2508.0	0.583	86.3
423	ELECTRONIC NAVIGATION SYSTEMS, RADIO	1.040	1039.7	6.779	7047.9	11.692	12156.3	-0.179	-185.7
424	ELECTRONIC NAVIGATION SYSTEMS, ACOUS	0.057	57.1	5.262	300.3	9.919	566.0	0.114	6.5
426	ELECTRICAL NAVIGATION SYSTEMS	0.725	725.0	5.931	4299.6	12.942	9382.7	0.015	10.7
430	INTERIOR COMMUNICATIONS	1.736	1736.3	5.884	10216.5	14.886	25847.2	-0.362	-627.8
431	SWITCHBOARD8 FOR I.C. SYSTEMS	0.160	160.2	5.569	892.2	12.906	2067.6	-1.910	-306.0
432	TELEPHONE SYSTEMS	0.201	201.2	5.479	1102.2	16.553	3329.9	0.090	18.2
433	ANNOUNCING SYSTEMS	1.060	1060.0	5.375	5697.1	16.333	17312.2	-0.278	-295.0
438	INTEGRATED CONTROL SYSTEMS	0.290	290.0	8.233	2387.5	10.000	2900.0	0.000	0.0
439	RECORDING AND TELEVISION SYSTEHS	0.025	25.0	5.500	137.5	9.500	237.5	-1.800	-45.0
440	EXTERIOR COMMUNICATIONS	2.290	2290.4	6.138	14058.6	16.505	37803.9	-0.783	-1792.5
441	RADIO SYSTEMS	1.459	1458.0	6.217	9069.9	16.699	24360.4	-0.937	-1366.6
443	VISUAL AND AUDIBLE SYSTEMS	0.106	105.6	8.005	845.3	13.280	1402.4	0.000	0.0
445	TTY AND FACSIHILE SYSTEMS	0.202	282.1	5.407	1525.4	14.972	4224.3	-1.455	-410.6
446	SECUR:TY EQUIPMENT SYSTEMS	0.444	443.9	5.898	2618.0	17.609	7016.8	-0.034	-15.3
450	SURVEILLANCE SYSTEMS (SURFACE)	0.694	693.5	5.614	3893.1	15.844	10988.4	-0.452	-313.5
451	SURFACE SEARCH RADAR	0.328	328.3	6.176	2027.3	13.835	4541.0	0.083	27.3
455	IDENTIFICATION SYSTEMS (IFF)	0,365	345 3	4.109	1865.P	17.650	6446.5	-0.933	-340.7
460	SURVEILLANCE SYSTEMS (UNDERWATER)	5.759	5759.4	5.053	29103.8	32.102	i 84886.0	0.059	340.7
462	PASSIVE SONAR	5.759	5759.4	5.053	29103.8	32.102	184886.0	0.059	340.7
470	COUNTERMEASURES	0.069	69.1	5.492	379.5	13.454	929.6	-0.102	-7.0
472	PASSIVE ECH	0.054	54.1	5.305	287.0	13.330	721.1	-0.158	-0.5
474	DECOYS (OTHER)	0.015	15.0	6.167	92.5	13.900	208.5	0.100	1.5
400	FIRE CONTROL SYSTEMS	3.823	3823.0	6.152	23519.0	14.835	56713.4	-0.778	-2975.0
481	GUN FIRE CONTROL SYSTEMS	2.242	2241.8	6.491	14550.6	15.710	35218.9	-1.449	-3249.4
482	MISSILE FIRE CONTROL SYSTEMS	1.581	1581.3	5.672	8968.4	13.593	21494.5	0.174	274.4
490	SPECIAL PURPOSE SYSTEMS	0.110	109.6	6.585	721.8	17.474	1915.1	-1.428	-156.5
494	METEOROLOGICAL SYSTEMS	0.045	44.6	8.202	365.8	15.810	705.1	-1.849	-82.5
496		0.045	45.0	6.710	302.0	16.000	720.0	0.000	0.0

MODEL 928-83 DETAILS 09-24-85

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	(KILO-GRAMS)	VERTICAL CENTER (METERS)	MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	MOMENT (M-KG)
499	COMMMAND AND SURV. REPAIR PARTS AND	0.020	20.0	2.700	54.0	24.500	490.0	-3.700	-74.0

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILOGRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
500	AUXILIARY SYSTEMS, GENERAL	50.157	50156.6	0.187	9371.3	20.726	1039944.0	0.063	3151.5
510	CLIMATE CONTROL	3.518	3518.0	4.537	15959.9	20.897	73516.3	-1.107	-3893.9
511	COMPARTMENT HEATING SYSTEM	0.211	211.4	3.339	705.8	18.360	3881.5	-0.006	-1.2
512	VENTILATION SYSTEM	0.300	500.0	5.040	2520.0	14.890	7445.0	-0.460	-230.0
513	MACHINERY SPACE VENTILATION SYSTEM	0.315	315.0	4.881	1537.6	29.085	9161.8	0.022	6.8
514	AIR CONDITIONING SYSTEM	2.492	2491.6	4.494	11196.4	21.283	53028.0	-1.473	-3669.5
520	SEA WATER SYSTEMS	2.529	2528.8	2.668	6746.8	24.871	62892.3	-0.072	-181.8
521	FIREMAIN AND FLUSHING (SEA WATER) SY	1.518	1517.7	2.765	4196.9	26.724	40557.8	-0.024	-36.2
522	SPRINKLER SYSTEM	0.060	60.1	4.528	272.1	10.930	656.9	-1.361	-81.8
526	SCUPPERS AND DECK DRAINS	0.020	20.0	3.960	79.2	32.000	640.0	0.000	0.0
528	PLUMBING DRAINAGE	0.623	623.4	2.577	1606.3	20.331	12673.3	0.075	46.9
529	DRAINAGE AND BALLASTING SYSTEM	0.308	307.6	1.925	592.2	27.188	8364.3	-0.360	-110.8
530	FRESH WATER SYSTEMS	0.814	814.3	2.516	2048.5	20.812	16947.3	1.907	1552.7
531	DISTILLING PLANT	0.136	136.0	2.560	348.2	27.010	3673.4	2.770	376.7
533	POTABLE WATER	0.678	678.3	2.507	1700.3	19.569	13274.0	1.734	1176.0
540	FUELS AND LUBRICANTS, HANDLING AND S	1.866	1863.7	2.246	4190.6	23.961	44703.5	1.180	2202.1
541	SHIP FUEL AND FUEL COMPENSATING SYST	1.866	1865.7	2.246	4190.6	23.961	44703.5	1.180	2202.1
550	AIR, GAS, AND MISC. FLUID SYSTEMS	3.033	3032.8	3.200	9704.3	23.304	70677.5	0.939	2848.5
551	COMPRESSED AIR SYSTEMS	0.186	186.3	2.526	470.7	26.411	4921.5	2.084	388.3
555	FIRE EXTINGUISHING SYSTEMS	1.373	1374.7	3.742	5144.6	22.777	31311.9	-0.156	-213.9
556	HYDRAULIC FLUID SYSTEM	1.452	1451.9	2.794	4057.2	23.399	33971.7	1.840	2672.0
558	SPECIAL PIPING SYSTEMS	0.020	19.9	1.600	31.9	23.700	472.3	0.100	2.0
560	SHIP CONTROL SYSTEMS	35.555	35555.3	-1.199	-42637.3	20.271	720744.9	-0.013	-460.6
561	STEERING AND DIVING CONTROL SYSTEMS	0.592	592.2	4.327	2562.5	17.375	10288.9	-0.187	-110.5
567	STRUT AND FOIL SYSTEMS	34.963	34963.1	-1.293	-45199.8	20.320	710456.0	-0.010	-350.1
570	REPLENISHMENT SYSTEMS	0.516	516.3	6.148	3174.2	14.144	7302.5	0.160	82.6
571	REPLENISHMENT-AT-SEA SYSTEMS	0.516	516.3	6.148	3174.2	14.144	7302.5	0.160	82.6
580	MECHANICAL HANDLING SYSTEMS	1.595	1594.9	4.985	7950.3	17.597	28002.0	0.654	1043.8
581	ANCHOR HANDLING AND STOWAGE SYSTEMS	0.658	658.4	5.119	3370.4	16.645	10958.4	0.804	529.6
582	MOORING AND TOWING SYSTEMS	0.532	532.3	4.742	2524.3	15.221	8102.4	-0.235	-125.0
583	BOATS,BOAT HANDLING AND STOWAGE SYST	0.404	404.2	5.086	2055.7	22.120	8941.2	1.582	639.3
590	SPECIAL PURPOSE SYSTEMS	0.731	730.5	3.058	2234.0	20.200	14757.4	-0.057	-41.8
593	ENVIRONMENTAL POLLUTION CONTROL SYST	0.202	202.0	2.221	448.6	30.404	6141.5	-1.678	-339.0
598	AUXILIARY SYSTEMS OPERATING FLUIDS	0.339	338.5	3.305	1118.7	12.163	4117.6	1.442	488.2

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	(KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
599	AUX. SYSTEMS REPAIR PARTS AND TOOLS	0.190	190.0	3.509	466.7	25.672	449s. 3	-1.00s	-191.0

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WBS	DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
600	OUTFIT AND FURNISHINGS, GENERAL	18.216	18216.0	3.876	70610.7	15.900	291087.7	0.087	1587.4
610	SHIP FITTINGS	0.707	707.1	5.497	3887.0	18.968	13411.7	0.163	115.5
611	HULL FITTINGS	0.069	69.1	4.380	302.9	33.000	2281.6	2.051	141.8
612	RAILS, STANCHIONS, AND LIFELINES	0.613	613.2	5.553	3405.4	17.736	10876.2	0.009	5.8
613	RIGGING AND CANVAS	0.02s	24.7	7.229	178.7	10.272	253.9	-1.299	-32.1
620	HULL COMPARTMENTATION	2.286	220s. 9	4.026	9204.3	19.094	43647.7	0.176	401.3
621	NON-STRUCTURAL GULKHEADS	0.746	746. S	3.880	2896.0	17.328	12934.6	0.113	04.1
622	FLOOR PLATES AND GRATINGS	0.832	831.0	2.994	2157.6	25.109	20884. S	0.041	34.2
623	LADDERS	0.113	113.5	2.635	299.1	18.930	2148.4	0.974	110.5
624	NON-STRUCTURAL CLOSURES	0.275	275.1	3.959	1089.1	14.906	4100.9	0.345	94.9
625	AIRPORTS, FIXED PORTLIGHTS. AND WIND	0.319	319.1	8.657	2762.6	11.216	3579.4	0.243	77.7
630	PRESERVATIVES AND COVERINGS	6.131	4130.6	4.198	25737.0	16.890	103546.2	-0.136	-834.6
631	PAINTING	0.793	793.3	3. ss3	2810.8	15.858	12500.2	-0.219	-173.5
633	CATHODIC PROTECTION	0.241	240.8	1.324	310.8	22.957	5527.3	1.675	403.2
634	DECK COVERING	2.124	2124. S	3.892	8267.9	16.861	35820.2	-0.226	-480.5
635	HULL INSULATION	1.985	1984.7	4.943	9810.8	16.427	32603.3	-0.100	-214.1
637	SHEATHING	0.987	987.3	4.579	4520.7	17.234	17015.3	-0.374	-369.7
640	LIVING SPACES	3.532	3531.9	3.133	11066.5	14.664	51792.1	0.606	2423.4
641	OFFICER BERTHING AND MESSING SPACES	1.218	1218.4	3.323	4049.1	14.460	17610.4	1.827	2226. S
642	NONCOMMISIONED OFFICER BERTHING AND	0.499	499.1	2.866	1430.4	16.040	8404.1	-2.532	-1263.5
643	ENLISTED PERSONNEL BERTHING AND MESS	1.373	1373.1	3.061	4202.3	13.272	18223.8	0.424	581.8
644	SANITARY SPACES AND FIXTURES	0.441	441.3	3.138	1384.7	17.099	7545.7	1.991	878.6
650	SERVICE SPACES	2.144	2144.4	2.860	6132.4	10.943	23465.8	0.473	1013.8
651	COMMISSARY SPACES	2.068	2067.6	2.830	5851.2	10.685	22090.8	0.499	1031.4'
652	MEDICAL SPACES	0.077	76.9	3.658	281.2	17.888	1375.1	-0.229	-17.6
660	WORKING SPACES	1.739	1739.1	4.603	8005.0	14.900	25913.2	-0.707	-1229.4
661	OFFICES	0.164	163.7	7.183	1175.9	12.669	2073.9	0.402	65.8
662	MACHINERY CONTROL CENTERS FURNISHING	0.040	39.8	2.570	102.3	19.620	780.9	-2.540	-101.1
663	ELECTRONICS CONTROL CENTERS FURNISH1	0.694	694.2	5.216	3621.0	12.944	8985.4	-0.627	-435.1
664	DAMAGE CONTROL STATION5	0.041	841.4	3.691	3105.8	16.725	14073.0	-0.902	-759.1
670	STOWAGE SPACES	1.677	1677.0	3.923	6578.6	17.470	29311.0	-0.180	-302.6
671	LOCKERS AND SPECIAL STOWAGE	1.677	1677.0	3.923	6578.6	17.478	29311.0	-0.180	-302.6

MODEL 928-83 DETAILS 09-24-85

WBS	DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (M-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
700	ARMAMENT, GENERAL	10.812	10012.3	5.616	60721.0	11.975	129482.2	0.105	1134.6
710	GUNS AND AMMUNITION	6.676	6676.4	5.333	35602.4	3.875	25871.0	0.274	1829.6
711	GUN5	6.676	6676.4	5.333	35602.4	3.875	25871.0	0.274	1829.6
720	MISSILES AND ROCKETS	1.897	1896.7	7.599	14414.1	24.279	46050.6	0.000	0.0
721	LAUNCHING DEVICES (MISSILES AND ROCK	1.897	1896.7	7.599	14414.1	24.279	46050.6	0.800	0.0
750	TORPEDOES	1.896	1096.0	4.760	9025.0	29.000	54984.0	0.000	0.0
751	TORPEDO TUBES	1.896	1896.0	4.760	9025.0	29.000	54904.0	0.000	0.0
760	SMALL ARMS AND PYROTECHNICS	0.265	265.2	5.275	1398.6	8.010	2124.1	-2.062	-546.8
761	SMALL ARMS AND PYROTECHNIC LAUNCHING	0.096	95.5	3.976	379.7	5.425	518.2	-2.426	-231.7
763	SMALL ARMS AND PYROTECHNIC STOWAGE	0.170	169.7	6.006	1018.9	9.466	1605.9	-1.857	-315.1
790	SPECXAL PURPOSE SYSTEMS	0.078	78.0	3.600	280.8	5.800	452.4	-1.900	-148.2
799	ARMAMENT REPAIR PARTS AND SPECIAL TO	0.078	78.0	3.600	280.8	5.800	452.4	-1.900	-148.2

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MODEL 928-83 DETAILS 09-24-85

WBS DESCRIPTION	WEIGHT (METRIC TONS)	WEIGHT (KILO-GRAMS)	VERTICAL CENTER (METERS)	VERTICAL MOMENT (M-KG)	LONGITUDINAL CENTER (METERS)	LONGITUDINAL MOMENT (H-KG)	TRANSVERSE CENTER (METERS)	TRANSVERSE MOMENT (M-KG)
* * LIGHTSHIP LESS MARGINS, FOILS DOWN	179.337	179336.5	2.677	480004.6	20.922	3752133.0	0.007	1225.6
* * LIGHTSHIP LESS MARGINS, FOILS UP	179.337	179336.5	3.740	670687.6	21.457	3847990.0	0.007	1225.6
M00 MARGINS	7.769	7769.5	3.886	30194.7	22.190	172403.4	0.072	557.3
M10 CONTRACTOR CONTROLLED MARGINS	7.769	7769.5	3.806	30194.7	22.190	172403.4	0.072	557.3
M11 DESIGN AND BUILDING MARGIN	7.769	7769.5	3.886	30194.7	22.190	172403.4	0.072	557.3
* * LIGHTSHIP, FOILS DOWN	187.106	187106.0	2.727	510199.3	20.975	3924537.0	0.010	1782.8
* * LIGHTSHIP, FOILS UP	187.106	187106.0	3.746	700882.3	21.487	4020394.0	0.010	1782.8