THE USE OF SEMI-SUBMERGED SHIPS TO SUPPORT NEW TECHNOLOGY AT SEA

T. G. Lang, Semi-Submerged Ship Corporation*
C. B. Bishop, Stable Ship Development Company
W. J. Sturgeon, Marine Design Consultant

*417 Loma Larga Drive
Solana Beach, California 92075

Abstract

The purpose of this paper is to describe how a new type of Semi-Submerged Ship, called S^3, can be used to enhance the effectiveness of new technological developments at sea. History has shown that new discoveries in nearly any field lead to the need for new support systems. Similarly, in work at sea, new technological advances in geophysical equipment, oil drilling equipment, mining, fishing, transportation, oceanographic instrumentation, diving, submersibles, underwater work systems, etc. lead to the increased need for more stable ships with greater deck areas, all-weather operations, greater speed, and reduced overall costs. The inherent characteristics of the S^3 can help provide these needed features.

The S^3 is a proven technology, as demonstrated by the four years of highly successful range-support operations in the rough Hawaiian waters by the 217-ton SSP KAIMALINO. Thus, the time has arrived for making use of this new S^3 ship concept to support operations which employ new technology at sea more effectively and efficiently.

Introduction

In the past thirty years, great technological advances have been made in man's ability to do work at sea. Although many of these came from research and development programs conducted or sponsored by the U.S. Navy, many also came as a result of economic incentives, principally in the offshore oil industry. Several examples of new marine technology applications are: data acquisition, storage and analysis equipment in ocean science; advanced navigation and communications methods; and varieties of new devices and vehicles for undersea operations. The construction of drilling and production platforms, and the widespread use of helicopters at sea, have led to the need for new technology in the safe transfer of men and materials, and for rapid response to platform disasters. These new applications of technology, which have been economically motivated, usually reflect a common concern -- to do the job as quickly as possible and for the lowest cost. While this often results in quick improvements over previous methods, it also often falls short of the gains possible from more systematic progress in solving problems. Systematic progress would include not only the improvement of a particular equipment, but also the performance of the operating personnel and the capabilities of the ship that carries them.

This situation is common at sea, where many new technological advances find their performance handicapped by the limitations of the conventionally designed ship platforms on which they must work. This paper will discuss some of these applications as viewed in a more complete system context, that is, by attempting to match the capabilities of the new functional equipment to the operating ship at sea.

For the purpose of background, the next section describes a new semi-submerged ship concept, called S^3, which can be used to enhance the capabilities of advanced equipment at sea[1].

S^3 Background

S^3 Description

Basically an S^3 consists of two parallel, torpedo-like hulls located under the water surface, attached to two or more streamlined struts which pierce the surface and support an above-water platform. Stabilizing fins are attached near the after end of each hull, and an optional pair of smaller fins are attached near the forward end[2]. An S^3 can be designed in any size range to meet nearly any operational requirement, including large deck loads. Unless the requirements lead to a weight-limited ship, an S^3 will tend to be smaller and less costly than a conventional ship.

The only unusual aspect of an S^3 hull is its shape; consequently, it can be built with presently-available components and technology. Figure 1 is an underside view of a typical S^3 showing the submerged hulls, struts, fins, propellers, and cross-structure (ref. 1).

Although simple in concept, an S^3 has so many design variables that considerable experience is

[1]The S^3 is a type of ship called the SWATH (Small Waterplane Area Twin Hull) in U.S. Navy Terminology.

[2]Dr. T. G. Lang holds several U.S. patents on the S^3 concept and owns the commercial rights; the U.S. Government has license-free use of them.

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required, when designing it for a specific purpose, in order to fully use its many features (ref. 2). For example, it can have one or more struts per side, and the bow fins are optional; also, many variables exist in the fin, rudder, and strut shapes, sizes, and locations; other variables include the bow shape, water clearance, and vessel metacentric height and center of gravity.

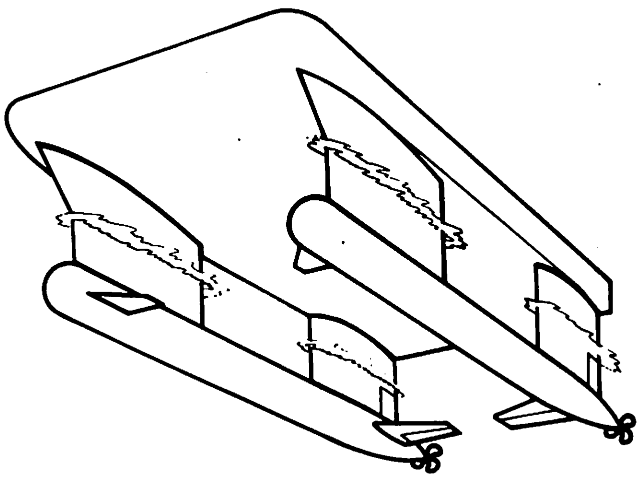

Figure 1. Underside View of A Typical S^3 Vessel

SSP KAIMALINO

The first, and only, open-ocean operational version of an S^3 in the world is the SSP KAIMALINO (ref. 3), the 217-ton range support craft shown in figure 2. It was invented by Dr. Thomas G. Lang who initiated the SSP program in May 1970, and led the hydrodynamic design work.

The SSP KAIMALINO was constructed in the U.S. Coast Guard Shipyard at Curtis Bay, MD, and was launched 7 March 1973. It was transported to the Naval Ocean Systems Center, Hawaii Laboratory, on Oahu, in February 1975, where it is currently based. It logged 160 operational days last year, and is considered to be very successful by all who have been aboard her, including high-level personnel from the U.S. Navy, U.S. Coast Guard, State of Hawaii, private industry, various foreign countries, and various news media.

Motion Characteristics

The 88-foot SSP has operated under prevailing conditions from near calm to beyond sea state 6 at speeds from 0 to 25 knots. Her motion is small relative to a conventional monohull either when at rest or underway. Ref. 4 reports comparative motion measurements when underway at 18 knots in 4 to 6 ft. waves of: (a) the SSP and (b) the 100-ft., 100-ton monohull HAWAII; the respective peak-to-peak roll, pitch, and heave (acceleration) motions in head seas were 1.6°/11.9°, 1.5°/3.4°, and .12g/.5g; in beam seas, the respective values were 1.5°/18.0°, 1.6°/4.2°, and .11g/.40g; and in following seas, the respective values were 1.9°/12.2°, 1.4°/3.2°, and .05g/.30g. Also, the SSP has made smooth transits in swells of 15 ft. without any impacts; however, in short, steep 12-ft. waves, occasional bow impacts have occurred. No evidence of structural damage has occurred, even after encountering a storm where the waves were 25 to 30 feet high.

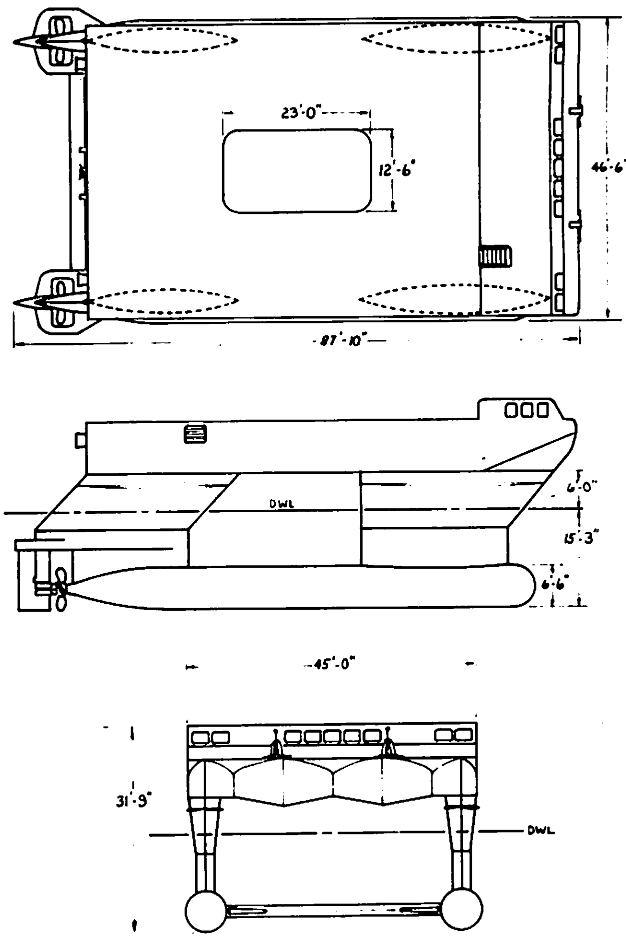

Figure 2. 217-ton SSP KAIMALINO Range Support Craft

Handling and Recovery

Several examples are presented in ref. 4 where the SSP was vastly superior to a conventional monohull in the handling and recovery of both undersea and surface objects. In 1976, the SSP successfully operated the 15-ton Remote Undersea Work System (RUWS) vehicle down to the bottom in 2,500 feet of water without having to use the associated complex and costly motion compensation system. The SSP was able to station keep and support the tethered RUWS vehicle with remarkable ease for the entire 21-hour operation during which the wave height reached 10 to 12 feet with winds of 20 knots. This same operation had previously been unsuccessfully attempted twice by using a 4,000 ton monohull ship with a bow thruster; these attempts were aborted because of excessive motion.

The SSP has also operated several times off Kauai at the BARSTUR Range in support of operations which included hardware implantation and recovery, surface recovery, and acoustic range surveys. Package sizes ranged up to 4,000 pounds, and operations took place in the prevailing waves which ranged up to 12 to 15 feet high with winds gusting to 40 knots.

Maneuverability and Towing Capability

The SSP has excellent maneuverability and course keeping characteristics; it has stayed on track for 200 miles in 12 to 15 ft. waves in gusty winds. When compared to the 230-ton ex-subchaser ISLAND TRANSPORT in towing an SMS sonar, ref. 4 reports that the SSP tow resulted in reductions of towed body motion in pitch of 10% to 60%, in roll of 50% to 70%, and in towline tension of 50% to 75%. Also, it was found that the SSP could be used in the higher sea states where operations with the monohull had to be curtailed.

Drag

The drag and power of an S^3 ship in large waves will generally be less than that of an equivalent monohull. In calm water, the drag of an S^3 may be either less or more than that of a monohull, depending upon the speed and the type of monohull being compared.

Published test data[3] from a number of displacement and planing monohull models were analyzed for drag against an equivalent S^3 vessel. The models represented various types of passenger ships, tugs, trawlers, PT boats, utility boats, river boats, planing craft, etc. The results showed that the calm water drag of a well-designed S^3 would be less, in general, than that of a monohull in the Froude number region where monohulls have very large wave-making drag. (This region corresponds to a length Froude number range of around 0.40 to 1.10.)

This region is an important operating region; for example, it encompasses speeds of from 21 to 58 knots for a 3,000-ton ship, or speeds of 14 to 39 knots for a 300-ton vessel. In rough water, this S^3 region would expand significantly due to the much greater increase in drag for monohulls than for S^3 vessels.

Payload and Cost

The payload of an S^3 will tend to be less than that of a monohull of the same displacement unless the monohull is volume-limited rather than weight-limited, in which case an S^3 should provide a greater payload. An S^3 will also be smaller and less costly than a monohull in those cases where a monohull is made large specifically to handle the waves better or to attain higher speed. In many cases, however, a ship is weight-limited, so an S^3 would tend to have a greater structural weight than a monohull, and therefore a smaller payload for a given displacement. Different techniques, however, can be used to minimize S^3 hydrodynamic loads and structural weight. In general, the structural weight of an S^3 will be similar to a conventional catamaran, although it should not be classed as a catamaran and does not have as large motions as a catamaran. Since acquisition cost is largely a function of structural weight, power, and the mission, the initial cost of an S^3 may either be more or less than an equivalent monohull; however, its characteristic advantages should make its life cycle cost considerably lower for many kinds of applications.

Draft and Beam

Since S^3 vessels have a greater beam and draft than a monohull, one must be careful to insure that they meet the draft and beam criteria for a given design situation. In general, there should be no problem, especially for the smaller S^3 vessels. If necessary, draft can be reduced by: (a) topping off the fuel tanks in deeper water, (b) flooding down to the operating level in deeper water, or (c) utilizing expandable flotation devices to raise the hulls. The beam can be reduced, if necessary, by enlarging the strut waterplane area, but this may increase drag.

S^3 Development Activity

The success of the SSP has stimulated interest in the U.S. Navy, U.S. Coast Guard, and various industrial companies of the U.S. and overseas. A Japanese company has developed a 20-ton experimental S^3 similar to the design of the SSP, and is actively marketing toward larger versions. Several companies in Europe are interested in applying the concept, especially in the North Sea area, for the offshore oil industry. In the U.S., the Semi-Submerged Ship Corporation was established specifically to conduct design work on S^3 ships, and the Stable Ship Development Company was established to conduct the marketing aspects of this new design for industry.

New Technology Applications

Seismic Exploration

In considering applications of new technology at sea, seismic exploration is a good place to start. This involves a geophysical measuring technique originally devised for petroleum prospecting on land which made its way to sea about 30 years ago, thanks to the development of arrays of hydrophones which could be deployed long distances

[3] SNAME resistance and propulsion data sheets #1 to 175.

behind a towing ship. The technology of this method of exploration has advanced over the years in every aspect save one -- the seagoing platform. High power, controlled sound sources; higher sensitivity hydrophones; sophisticated beam-forming; and better hydrodynamically-designed towed arrays are now available. The recent advances in navigational accuracy and in data acquisition, analysis and communication have made great improvements in survey results possible. However, these advanced components of the total system are still carried to sea by modified offshore oil supply boats which are slow, have large motions, and have severe limitations to their operations in rough sea conditions. As an illustration, a recent advertisement for one of the newest of these ships, which has complete data processing onboard, states, "This may be the only computer center where one of the job hazards is seasickness."

The total systems for seismic exploration at sea would be greatly improved by the capabilities of an S^3 vessel, which can be designed to travel between operating areas at speeds of 15-20 knots and be able to maintain accurate survey lines at 5 knots, all through seas of 15 to 20 feet and winds of 20 to 30 knots.

A 175-foot, S^3 seismic survey vessel is depicted in figure 3. This 900-ton platform would have a range of 5000 n. miles at 16 knots, even in adverse weather, and is well under the 300-ton GRT limit. This design would be diesel-electric powered, and would accommodate a 26-man complement of crew and scientific personnel.

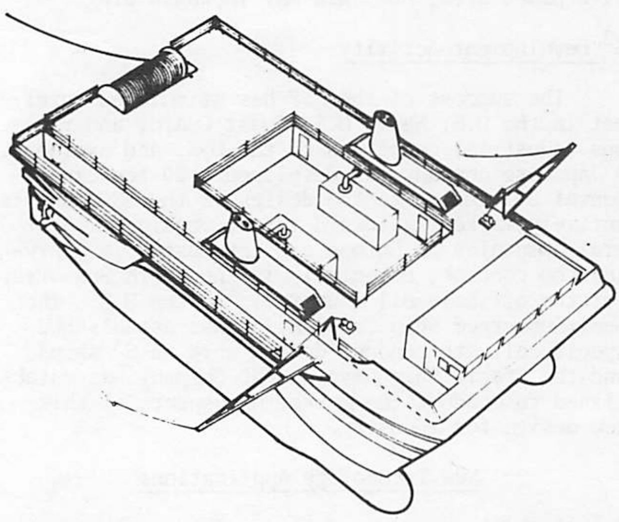

Figure 3. 900-ton S^3 Seismic Survey Vessel

S^3 Helicopter Operations

A different type of advanced technology has become very useful at sea in the form of the helicopter, which can transfer priority personnel and equipment at high speeds between land, ships, and offshore platforms. Helicopters can operate very effectively over 200 mile ranges.

S^3 ships are, in many ways, far superior to conventional hull-form vessels for supporting aircraft. While opening up the weather window for extended flight operations in higher sea states, the expansive, highly stable S^3 deck offers greatly increased margins of safety for both aircraft and personnel.

Over 80 landings and takeoffs were conducted by the U.S. Navy and Coast Guard on the SSP KAIMALINO (fig. 4). The tests were conducted in a variety of sea and wind conditions, including sea state 4, and most involved the use of a 12,800 pound Navy LAMPS helicopter. A typical motion record (ref. 4) taken from instrumentation aboard the SSP with automatic motion control showed that in 8-foot waves and a 26-knot wind, the SSP motions in pitch, roll, and heave were less than ± 0.4°, ± 0.7°, and ± 1.0 ft. respectively. Helicopter pilots reported that they were able to easily and safely land on the 217-ton SSP under conditions that would preclude normal landings on the Navy's 4,200-ton FF-1052 class ships.

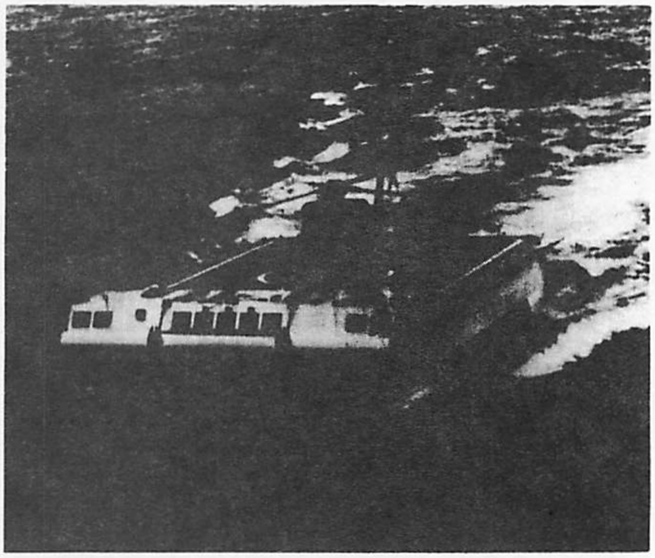

Figure 4. Navy Helicopter Landing on SSP KAIMALINO

Various commercial and government uses of S^3-based helicopters could include air/sea rescue, area surveillance, and deep-ocean survey operations. A typical application of an S^3 vessel design would be a relatively small heliport platform stationed in support of offshore oil operations in the North Sea environment. This vessel would serve as an intermediate refueling and servicing station for personnel and high priority cargo helicopters operating along an extended range route. This vessel could also be outfitted for standby/rescue and disaster control missions, and would serve as an emergency landing platform.

Coastal Zone Oceanic Research

The increasing importance of coastal zone waters surrounding the United States has led to greater activity in shallow water oceanographic measuring and monitoring. Historically, U.S. ships for deep ocean research work have tended to be of moderate size (1000 to 2000 tons), long endurance (7-10,000 miles) and fitted for multiple purposes. Coastal zone operations are more likely to benefit from ships which are small enough to be economically manned, yet fast enough to be able to minimize transit times and maximize time on station, and with the stability characteristics both underway and at rest that are needed for useful scientific work at sea.

The Navy's SSP KAIMALINO, has shown us (ref. 4) that a small S^3 ship is highly capable of meeting these same requirements in the rough Hawaiian waters, where she has operated since February 1975. Many of these operations have required her to make a rapid transit across the 90 miles of the Kauai channel to the BARSTUR range west of the island of Kauai, where she deployed divers and undersea devices in sea conditions that kept equivalent monohull craft in port.

Figure 5 illustrates a 400-ton modularly-outfitted oceanic research vessel designed for coastal zone operations. Instrumentation and laboratory vans (8'x8'x20) would be accommodated within the superstructure, leaving the top deck clear for helicopter operations. Berthing and messing accommodations for 26 crew and scientific personnel are provided. This design would allow a rapid turnaround capability for a wide range of oceanic research applications, including coastal hydrography, meteorology, oceanographic surveys, fishery studies and marine biology.

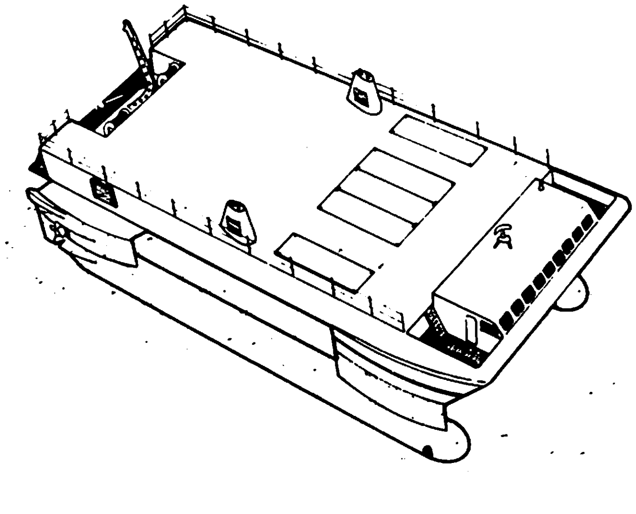

Figure 5. 400-ton S^3 Coastal Zone Oceanic Research Vessel

Deep-Sea Oceanographic Research

Operation of many scientific instruments for the acquisition of oceanographic data and samples is sea-state limited. In marine geology, the ship must stop to put over heavy apparatus for taking core samples of bottom sediments and for dragging rock samples off the bottom. These operations are rarely feasible on even the larger research vessels when winds are above 30 knots, and above 15 knots for the smaller ships. As the seas build up, the hazards to material and personnel during the transfer from water to deck increase. Seismic multichannel refraction measurements require the ship to slowly tow extremely long (3000 meter) streamers containing sensitive hydrophones in a straight line while transmitting high energy sound pulses from devices towed close to the ship. Lack of stability in the the towing characteristics of these constant depth, sophisticated electrical and electronic devices degrades the quality of the data received when winds are above 20 knots for most seismic exploration ships. Another example of new technology is the ocean bottom seismograph which is planted on the sea floor to record seismic disturbances over a period of time, and then brought to the surface by its own buoyancy after releasing its anchor on acoustic command. Recovering the floating device is a straightforward operation in calm seas, but above sea state four with six foot waves, the seismograph and its valuable data are in danger of being damaged or lost during the recovery operation.

Among the most significant contributions of electronic technology to the improvement of operations at sea has been the employment of satellites for navigation and communication. With SATNAV equipment, the modern navigator is no longer dependent on weather-limited celestial measurements, and has much greater accuracy available to him several times a day. The new NAVSTAR systems will be able to provide practically continuous positional information with accuracy measured in tens of meters. Communications via satellite today make possible the clear, noise free transmission of information between oceans. Reliable reception of these valuable signals from satellites however, requires motion stability in the receiving antenna. As seas get larger and masts gyrate, the beam patterns of the antennas are no longer optimized for reliable reception of these signals from space. Gyro-stabilized antenna platforms can be used, but at considerable expense and they have their own reliability problems.

The needed stability is inherent in an S^3 ship, designed to provide the optimum mobile working platform at sea. Figure 6 depicts a large, 3000-ton oceanic research vessel for world wide operations, having a clear topside deck area of about 19,000 ft^2 and capable of supporting and operating two helicopters. Interior mission spaces, located in a central, two-deck bay would provide about 18,000 ft^2 of laboratory, workshop, and storage area. This design features a modular-format capability for rapid interchange of research facilities, and would be capable of supporting all types of open-ocean research activities, including submersible operations.

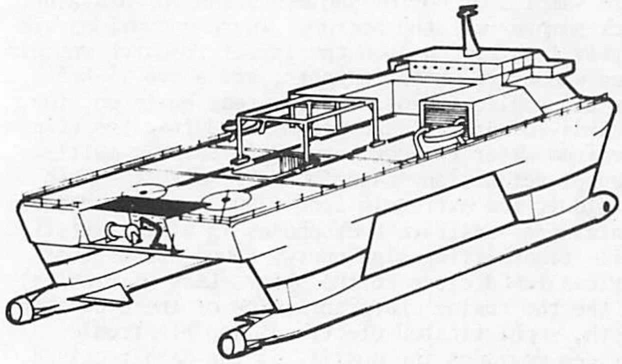

Figure 6. 3000-ton S^3 Oceanic Research Vessel

Diving and Undersea Vehicle Support

The demands for underwater work, inspection and monitoring in the offshore oil industry have led to the development of new technology for diver equipment, remotely-controlled undersea vehicles and manned submersibles. The progress in our abilities to observe, to measure, and to do useful work in deep water, which has been achieved in the past 15 years, has been extraordinary. Again, this new equipment must be installed on and operated from ships whose basic motion characteristics are incompatible with their needs. Safe transfer of diving bells, remotely-controlled vehicles, and submersibles through the air-sea interface continues to be a controlling problem when the seas build up. The need to make a quick and well-controlled transfer has forced design improvements in deck cranes and the development of specialized motion-compensation devices. These devices introduce their own problems, and do not fully solve the existing problems. The best capability to date has come from the conversion of large ships and platforms to act as diving support ships, but only at great expense.

The inherently low motion characteristics of the S^3 designs would not only provide an optimum platform for this transfer operation, but would provide the additional ability to transfer highly qualified divers and vital supplies by helicopter when they are needed quickly. Figure 7 presents an artist's rendition of a 2000-ton S^3 undersea vehicle and diving support vessel. This ship is additionally outfitted for standby/rescue and disaster control functions in support of offshore oil platforms. Similar designs would have significant application in the newly emerging deep-sea mining and offshore power industries, serving in logistic support roles as well as for diving support.

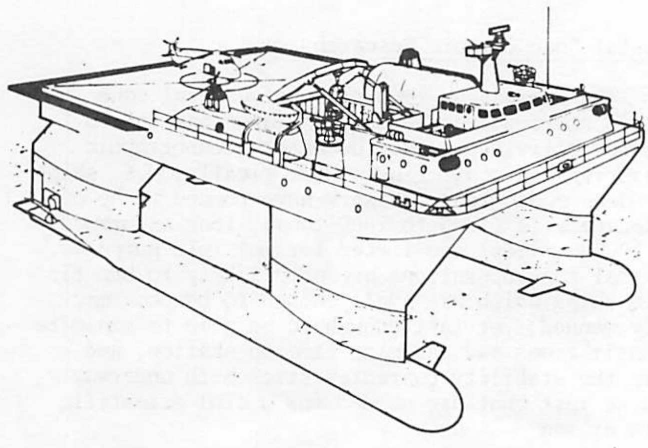

Figure 7. 2000-ton S^3 Undersea Vehicle and Diver Support Vessel

Offshore Oil Industry Support Vessels

The offshore oil industry represents a huge increase in the number of people involved in seagoing operations, and in the rapid development of new technology. The cost of these operations is so great that a high premium is placed on avoiding any down time. Deliveries of personnel and vital spare parts and supplies to offshore oil platforms are made by small, fast crewboats, larger supply-type vessels, and by helicopters when the weather permits. This highly important and often hazardous function could be improved considerably by the use of a delivery vehicle whose motions relative to the platform are much less than for conventionally designed ships. The S^3 not only makes the rapid transit of people from shore to the platforms possible, but also permits much safer transfer of people to the platforms in rough weather.

Figure 8 illustrates an S^3 crewboat alongside a fixed production platform and figure 9 shows an S^3 supply ship alongside a semi-submersible drilling rig.

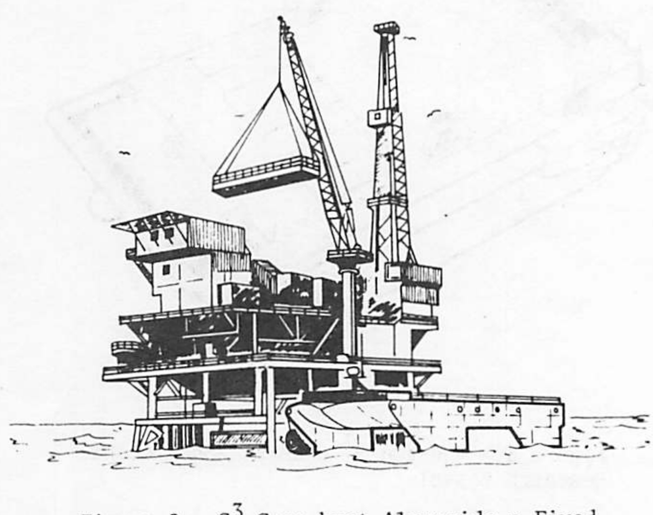

Figure 8. S^3 Crew-boat Alongside a Fixed Production Platform

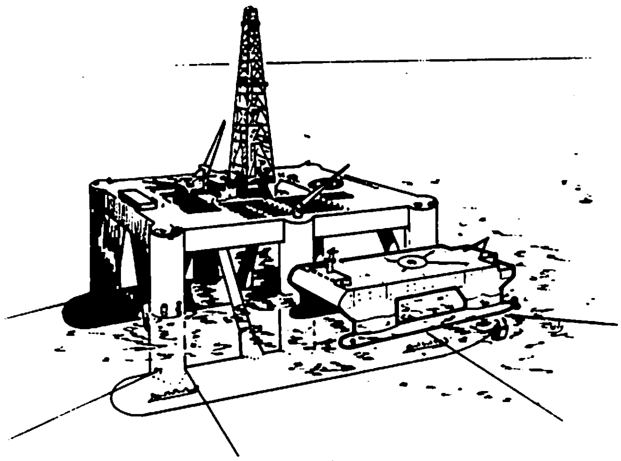

Figure 9. S^3 Supply Ship Alongside a Semi-submersible Drilling Rig

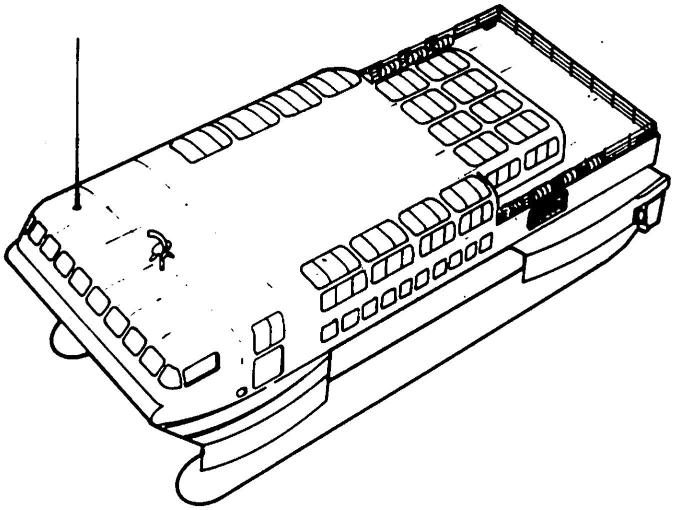

Figure 10. 300-ton S^3 Passenger Excursion Vessel

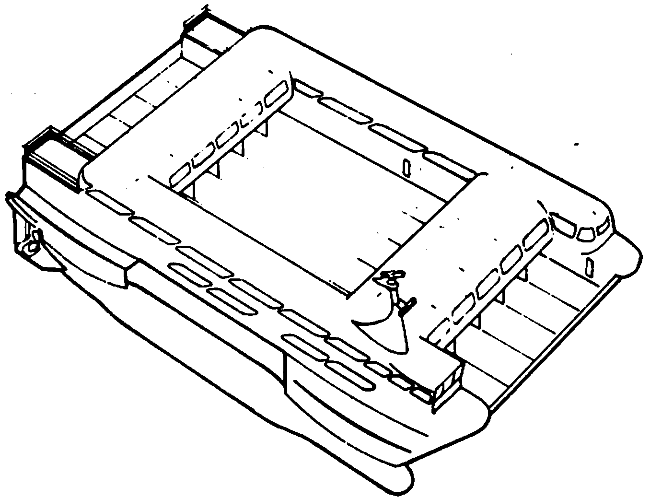

Figure 11. 500-ton S^3 Passenger/Auto Ferry

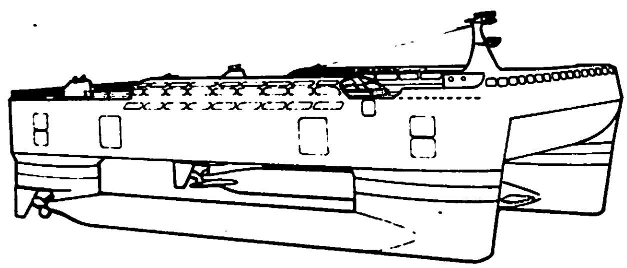

Figure 12. 3200-ton S^3 Passenger/Vehicle Ferry

Ferries, Excursion Boats, and Cruise Ships

Another example of new electronics technology which can be applied to improving operations at sea is the microcomputer and associated small-scale functional components. This makes it possible to design highly responsive automatic systems for the control of ship motions using control fins. Motion control permits higher speeds in rougher sea conditions, and not only improves the economy of transit operations but also enhances the performance of the personnel aboard ship. In addition to such working platforms as research ships, diving support ships, offshore oil supply ships, and others, the improvement of motions at high speeds should be of great benefit to the various classes of ferries and other personnel transport ships which must operate in rough seas. The flexibility, reliability and economy of these new electronic devices are valuable assets aboard conventional ships, but their usefulness is limited to roll control, since insufficient control force is available to control heave and pitch. On the other hand, the control fins of the SSP KAIMALINO have proven to be highly effective for high-speed rough-water heave, pitch and roll reduction, further reducing the already-low motions in S^3 designs. Figure 10 depicts a 300-ton passenger excursion vessel, and figure 11 illustrates a 500-ton passenger/car ferry. Figure 12 shows a 3200-ton passenger/vehicle ferry which would have a payload of 600 passengers, 100 autos, and 30 commercial vehicles.

Commercial Fishing Boats

The U.S. fishing fleet that works in U.S. waters tries to maximize the catch while minimizing the cost. This usually means small ships, small crews, long hours, hard work, and uncomfortable and hazardous working conditions. Small conventional ships mean less productivity in rough sea conditions. Slow speed means less fishing when fishing seasons are time-limited. The combination of higher transit speeds, steady working platform conditions, larger deck areas and adequate payload capacity should make the S^3 a highly effective fishing boat in many U.S. fisheries. Figure 13 shows a design concept for a 200-ton combination crab or lobster, long-line, or bottom fishing vessel.

A 300-ton S^3 ship of similar design is under active consideration for use in the Hawaiian fishery (ref. 5).

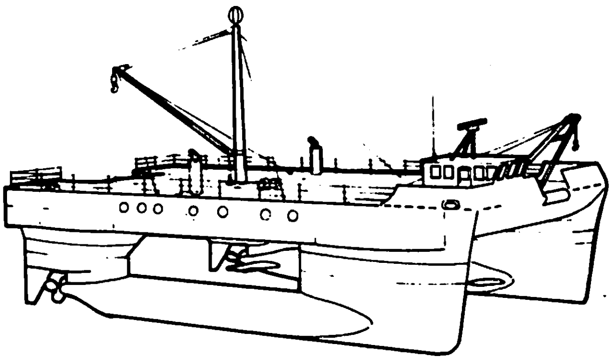

Figure 13. 200-ton S^3 Fishing Vessel

Conclusions

Great advancements have been made in developing new equipment and techniques for working at sea. These include improvements in seismic explorations, oceanographic equipment, offshore oil production, fishing techniques, ship-based helicopters, automatic motion control, satellite communications, saturation diving, submersibles, etc. The application of these new advancements remains limited in most cases by the motion characteristics and other limitations of their support ships.

The S^3 semi-submerged ship concept provides greatly reduced motion at rest and underway, larger deck areas and internal volumes, and certain other special features of its new hull shape. Consequently, realization of the full potential of new equipment and techniques at sea could be advanced considerably if they were used onboard an S^3.

In this regard, considerable interest is being shown in this new ship concept by the U.S. Navy, U.S. Coast Guard, Maritime Administration, university oceanographic laboratory systems, and several kinds of industry, both in the U.S. and abroad, and especially in the offshore oil industry. The U.S. Navy's SSP KAIMALINO, as the world's first and only open-ocean, operational S^3, has met all of its design objectives, and continues to provide outstanding performance. It should help lead the way toward larger numbers of smaller and less expensive support platforms for the new sea-going technology.

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