SESSION IV

CHAIRMAN'S COMMENTS - R.D. Hunt

This concluding session of the Symposium will consider the overwater uses of the ACV, as seen through North American eyes.

Firstly, a paper on a specifically U.S. development, the Surface Effect Ship. For some years the U.S. Navy has been studying the use of hydrofoils and hovering craft for large, fast naval vessels, and Admiral Elmo R. Zumwalt's phrase - "The 100 Knot Navy" has become well known. Two 100 ton Surface Effect Ships, more clearly described as sidewall hovercraft, have been operating for some time. Mr. Stoiko will review this program, leading up to the current competition for the 2000 ton prototype.

The role of the ACV as a ship-to-shore lighter, to reduce the requirement for wharf installations at a port, will be discussed in the context of the Bell Aerospace Canada Voyageur.

Finally, the towing of ACV lighters over sea or river ice and water will be discussed in the light of considerable experinece in the far north, and on the Yukon.

THE U.S. NAVY'S LARGE SURFACE EFFECT SHIP

Commander Jerome J. Fee, U.S.N.
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The term "Surface Effect Ship" (SES), originally grouping all waterborne air cushion vehicles, is used today to refer to a particular variation, the captured air bubble concept. A SES differs from fully skirted hovercraft in that the supporting cushion of air is contained by two rigid sidewalls partially immersed in the water and two flexible seals (bow and stern) in contact with the water, thus minimizing air leakage and reducing lift power requirements. Rigid sidewalls permit use of either waterscrew or waterjet propulsors, which are more efficient than airscrews for the speed regime considered. These sidewalls also provide stability at high speed. The sidehulls react the sideforces necessary for turns with the magnitude of forces controlled by waterjet vectoring.

There is no intrinsic limitation to the growth (displacement) potential of future SES, but evolution past 3000-4000 tons is highly dependent on advances in technology of a few critical subsystems. Specifically, there is a need for:

- high power, low-weight powerplants with low specific fuel consumption,
- lightweight reduction gears capable of transmitting over 50,000 horsepower,
- high performance right-angle transmissions for certain propulsion systems and engine-transmission arrangements,
- supercavitating propellers capable of absorbing over 50,000 horsepower,
- clutches for transmissions in lift and/or propulsion systems permitting various combinations of engines, lift fans and propulsors,
- multi-thousand ton lightweight hull construction techniques,
- sidewalls suitable for multiple propulsor installations.

Surface effect ship development under sponsorship of the U.S. Navy was started in the late 1950's and progressed steadily through the 1960's and 1970's.

Development has been solidly grounded in both analytical and experimental progress. During development of every critical subsystem, theoretical and analytical projections were verified by experimental data. Concepts and configurations have been extensively investigated through use of towing tank models and manned experimental craft.

The XR-1 (Figure 1), launched in May 1963, was the first of a series of manned testcraft. It has been a workhorse over the last decade in successfully demonstrating numerous advances in SES technology and has been modified repeatedly to incorporate many test configurations.

Testing was successfully completed on the XR-1, -1B and -1C configurations and the data employed to support the design of larger SES. In 1975 the XR-1C was further modified, and, as the XR-1D (Figure 2) incorporated many features representative of current SES technology, including variable-geometry lift fans, planing seals, heave attenuation valves, and variable-geometry water jet inlets. The XR-1D is now at the Surface Effect Ship Test Facility, Naval Air Station, Patuxent River, Maryland.

The XR-3 (Figure 3) was launched in 1967. Although much smaller than XR-1 (2.5 vs. 20 tons), XR-3 took advantage of a growing and more sophisticated technology which resulted in improved sidewall shapes and more advanced seals. Tests yielded high lift-drag ratios and proved that SES drag scaling techniques were correct. XR-3 is in operation at the U.S. Naval Postgraduate School, Monterey, California, employed for thesis research and to provide students with an insight into the technology and promise of SES.

Encouraged by early results of the XR series of testcraft and other scale-models, the Navy decided that before proceeding to transoceanic-size craft, larger manned testcraft would be required to further demonstrate operational characteristics of the SES. Early in 1969, following several concept studies and a design competition, the Navy awarded contracts to Aerojet-General and Bell Aerospace for design and construction of 100-ton SES testcraft which could attain speeds in excess of 80 knots. Designs of the Aerojet-General SES-100A (Figure 4) and Bell Aerospace SES-100B (Figure 5) were purposely different with respect to hull configuration, lift, propulsion, and control systems so that a broad base of subsystem and component evaluations could be obtained.

The Navy's test and evaluation programs began in 1972 when both 100-ton testcraft became operational. Significant test results provided confirmation of predicted performance envelopes with respect to speed, ride quality, maneuverability, and structural loads. Subsystem testing of seals, lift fans, waterjet and propeller propulsion, and heave attenuation systems also provided important data, now utilized in the design of larger SES. SES-100B, based at Panama City, attained 89.5 knots (103 mph). SES-100A demonstrated the performance of both pod and flush waterjet inlets in Chesapeake Bay. In April 1976 a Standard I Missile was successfully launched from the 100B travelling above 60 knots.

The Navy launched the XR-5 (Figure 6) in September 1973. It has a gross weight of 3.3 tons, overall hull length of 45 feet, and a cushion length/beam ratio of 6.5. In the subhump operational mode for which it was designed, XR-5 attained speeds up to 25 knots in calm water and was tested in waves up to 2-1/2 feet high. These data can be extrapolated to indicate accurately the performance of an 8000-ton SES to 60-70 knots, as well as show operational data for sea state 6. The XR-5 basic test program was completed successfully in 1974 at the SES Test Facility.

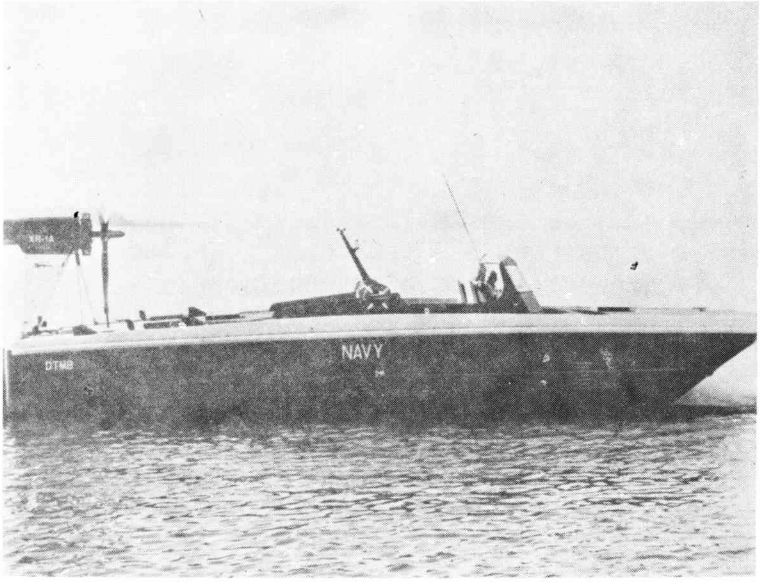

FIGURE 1 - The XR-1 with its T-53 airplane engine and propeller.

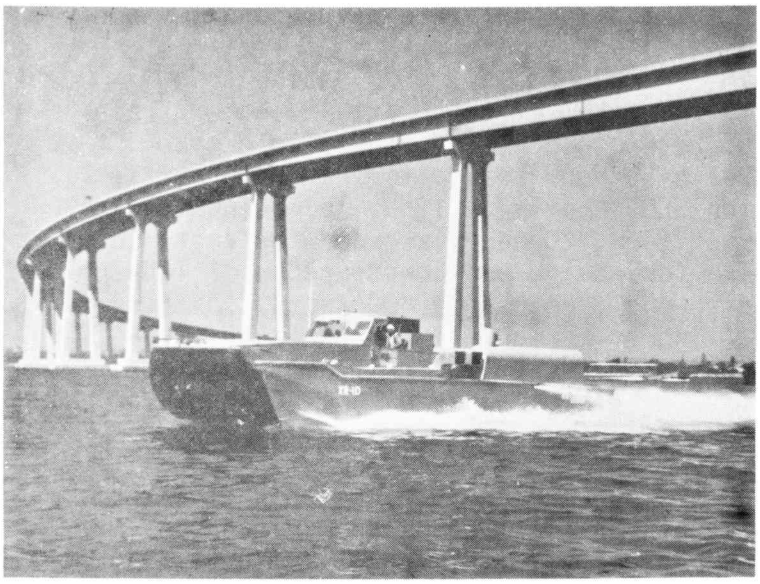

FIGURE 2 - After many modifications and refinements, the XR-1D continues to provide valuable data.

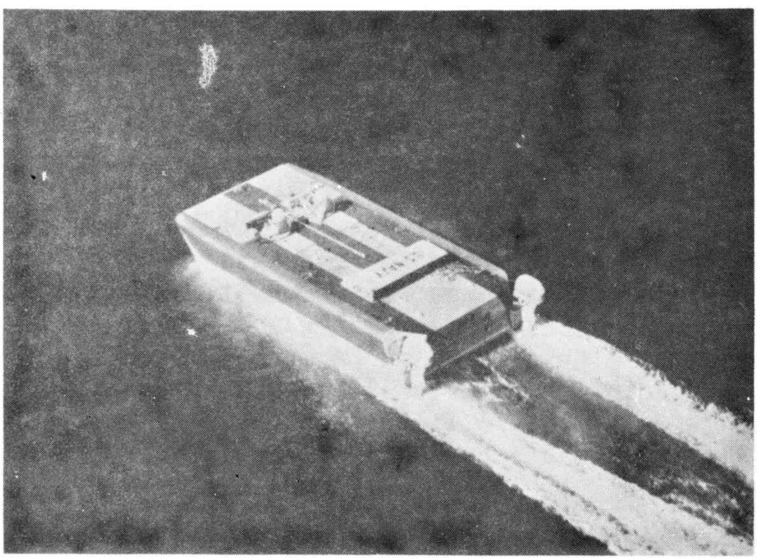

FIGURE 3 - The smallest SES, the XR-3 is assigned to the Navy Post Graduate School, Monterey, Calif.

FIGURE 4 - The beautifully streamlined SES-100A symbolizes the 21st Century Navy.

FIGURE 5 - The propeller-driven SES-100B exceeded 100 miles per hour with Secretary of the Navy Middendorf aboard.

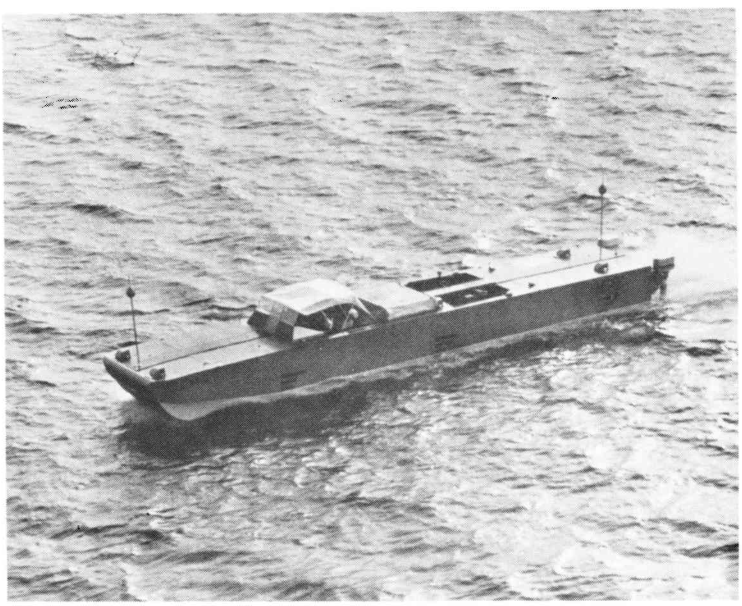

FIGURE 6 - Characteristics of high length/beam ratio SES were determined from tests of the XR-5.

Concurrent with manned testcraft development, more than forty-eight major studies were conducted to investigate missions, weapons, tactics, and operations of surface effect ships.

The SES development program is aimed at expanding the technology to ships of oceangoing size. Operation of the 100A, 100B and smaller testcraft demonstrated the validity of the SES concept and provided verification of the design data base needed for proceeding to large ships. During July 1974, contracts, amounting to about $72 million, were awarded to Bell Aerospace Company and Rohr Industries to develop SES-critical subsystems and conduct parallel ship design efforts. Data generated from these contracts minimize the risk in design and construction of a large open-ocean SES prototype.

Late in 1974, the Navy decided on development of a one ship prototype rather than a previously outlined two ship program. This decision was based on the confidence that a one ship program could satisfactorily demonstrate open ocean capability and military utility while substantially conserving R&D funds. In early February 1975 DDR&E again reduced program funding, thereby necessitating program schedule stretchout and some reduction of technology effort.

Advance Development Phase Contracts, awarded in July 1974 to two contractors (Bell Aerospace Company and Rohr Industries), called for risk reduction programs in critical SES-unique areas and for parallel ship design efforts. The design philosophy was to achieve a proper balance of features to provide minimum risk to cost and schedule and yet meet or exceed all minimum levels of Navy requirements for speed and range.

Although safety and survivability were not to be compromised for performance, attainment of high speed and range were considered to be the most important performance characteristics to be demonstrated. Careful balances in the design rationale were made at the system level to ensure that thrust, drag, stability, and control, and ride qualities were consistent with these goals. Tradeoff studies between range and speed were made for each specific requirement. This ensured that the optimum balance in meeting the requirements were achieved.

The SES program received essential and vital impetus in May 1976 when Deputy Secretary of Defense, William P. Clements, Jr. sent a memorandum to the Secretary of the Navy, J. William Middendorf which stated, "I have determined that we should proceed to design, construct and test a prototype SES of approximately 3000 tons design gross weight. This is to serve as a combined technology prototype and operational practicality prototype for a possible frigate-size operational SES."

During the summer and autumn of 1976, the proposals for contract design, detail design and construction were evaluated. The Source Selection Authority chose Rohr Marine, Inc., as the winner and a contract was awarded 9th December 1976.

The Large Surface Effect Ship (LSES), (Figure 7) will be a test ship designed for high speed operation in an open ocean environment. It has an extended range capability and will carry a substantial payload.

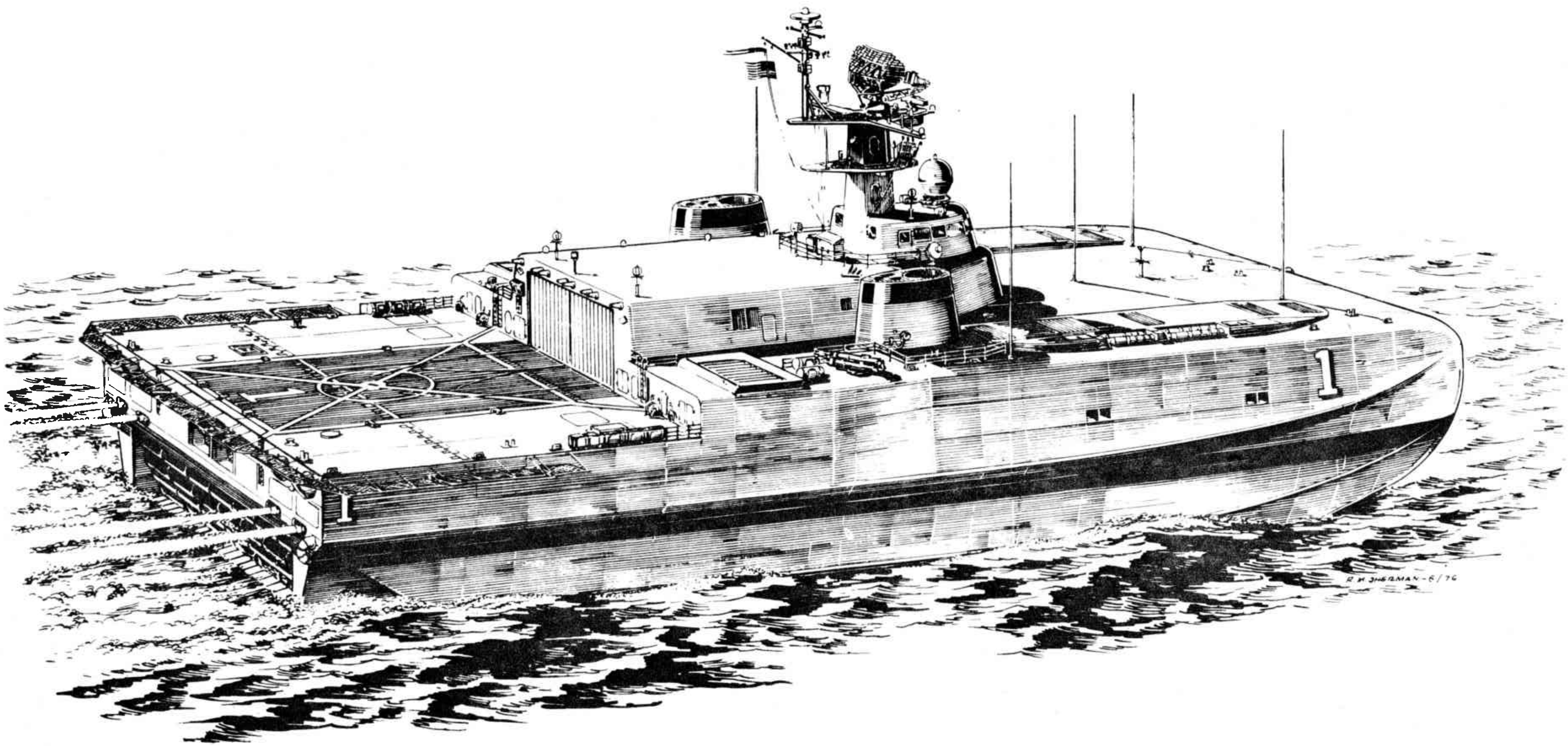

FIGURE 7 - The U.S. Navy's Large Surface Effect Ship

The LSES program objectives are to:-

1. Demonstrate SES performance, characteristics and technology in open-ocean environment,
2. Test engineering features and systems of large SES,
3. Demonstrate weapon system compatibility with SES platform,
4. Demonstrate SES military utility.

Design and construction is expected to be completed during 1982-83. At-sea tests will last about two years and focus upon the ship's ability to perform in an operational environment, depending upon Navy systems and practices - far more severe than the specialized support provided by dedicated facilities to a research ship.

The LSES is characterized by the rigid main hull (centerbody), full length rigid sidewalls, and durable bow and stern seals. Like other SES, it achieves high speeds on-cushion. In addition, it can "hover" at stand-still or at very low speed. Off-cushion, it operates as a displacement ship. This ship maneuvers well in either mode, including, turning, accelerating, decelerating and backing.

Principal dimensions are presented in Table I. The dimensions of 266 feet length overall and 108 feet maximum beam satisfy volumetric and performance requirements. The maximum beam permits transit of the Panama Canal. Effective cushion dimensions are 221 feet length and 85 feet beam. A cushion height of 18 feet was selected to ease ship motions and structural loads in Sea State 6, and enhance roll stability. The square bow and full length sidehulls provide resistance to rapid bow-down motions.

3KSES HULL RELATED CHARACTERISTICS*

Full Load Displacement, (FLD)	3000 tons
Length Overall	266' 3"
Beam Overall	108' 0"
Draft: On Cushion, with fin	14' 0"
Off Cushion	30' 8"
Main Deck Height (on cushion)	40' 8"
Wet Deck Height (on cushion)	18' 0"
Effective Length-to-Beam Ratio	2.60
Cushion Pressure (FLD)	275 lbs/ft^2
Propulsion Engines (4)	FT-9A-2
Lift Engines (2)	LM-2500

*Characteristics may change during initial design period.

TABLE 1

The ship will fulfill all speed requirements including the very stringent minimum of 30 knots at full load displacement (FLD) in Sea State 6.

The preliminary design offers the potential to trade fuel weight for structural weight, either to increase the margin of safety due to impact loads or trade structural weight for ease of productivity.

The performance predictions (mostly classified) are conservative in that they do not yet include the reduced drag characteristics of the full keel length "fences" (skegs). The addition of fences was such a recent modification that the performance program has not yet been modified to reflect the change, although the advantages of full length fences have been adequately demonstrated by the XR-1D and SES-100A.

The following descriptions of major systems are abstracted from unclassified sections of technical reports prepared by the Rohr Marine Corp. There are, of course, other systems and subsystems, but only those unique to SES are discussed.

HULL STRUCTURE

The hull structure of aluminum alloy 5456, (Figure 8) included the shell and supporting structure, structural bulkheads, decks and platforms, superstructure, foundations, and masts. The hull is designed so that it will not fail in the combination of extreme sea/wind conditions and the worst case of ship loading.

The structure is designed to resist damage from direct wave impact and slamming, ship motions, aerodynamic loading, impact with floating objects, and cavitation erosion so that operation of mission essential systems is not degraded under severe weather and sea conditions. The structure is designed to withstand the following emergency conditions:

a. Loads caused by sudden loss of bow seal integrity.

b. Propulsion subsystem failure.

c. Lift subsystem failure in straight-ahead travel or turn.

d. Emergency stops.

In addition, it can withstand all conditions of miscellaneous loadings, as occur when under tow, drydocking, ship handling alongside a pier, wind loading up to 100 knots from any direction while moored, helicopter operations, and reactions from weapon system operation.

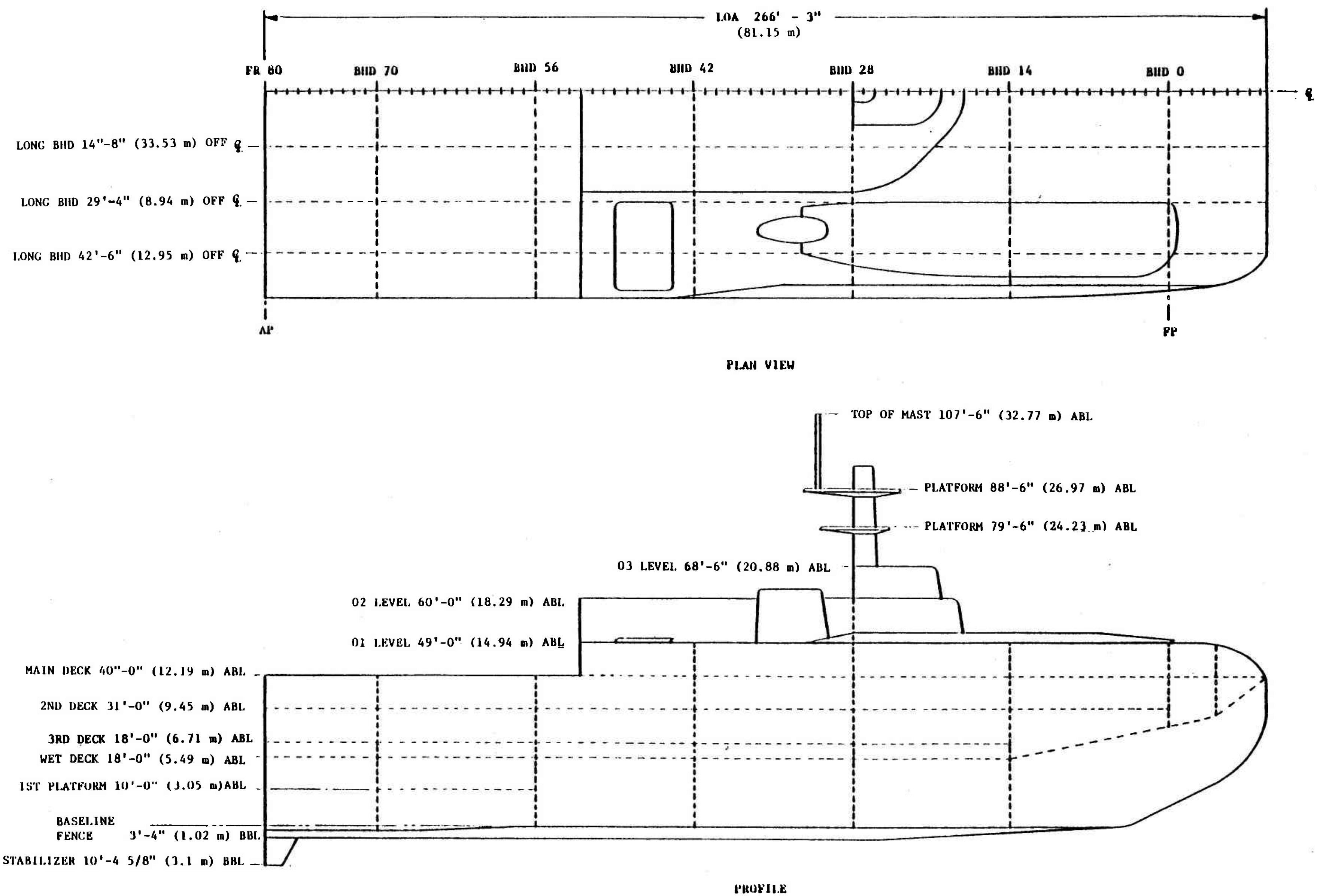

FIGURE 8 - Basic structure, hull and superstructure

PROPULSION

The propulsion plant (Figure 9) comprises four units, each consisting of a two-stage pump and nozzle, reduction gearing, and FT-9 gas turbine engine. Two units are located in each side at the stern of the ship.

Each sidewall contains a single semi-flush waterjet inlet (Figure 10). The inlet water duct bifurcates to direct the flow of water to each pump. Inlet area is controlled by a variable ramp-roof positioning mechanism. Full length sidehull fences, previously mentioned, extend 40 inches below the keels to alleviate the ingestion of cushion air into the waterjet inlets.

Each pump discharges through a steering nozzle designed to provide thrust vector control for on-cushion and off-cushion operations. Turning is accomplished by vectoring the steering nozzles and use of thrust differential. Outboard propulsors are provided with thrust reversers for maneuvering, stopping and backing.

LIFT SYSTEM

The lift system consists of - lift fans, gear boxes, engines and ducting; ride control equipment and bow and stern seals.

Lift air is provided by identical sets of starboard and port equipment, (Figure 11) each consisting of a gas turbine engine, reduction gear, three lift fan assemblies, lift fan discharge ducting, ride control valves and ducting, support systems and controls and machinery lubrication system.

The centrifugal lift fans are double suction, with airfoil-shaped blades and a single volute discharge housing. Mechanisms permit remote-controlled decoupling of any fan while operating. Each fan assembly discharges into a separate and independent air distribution duct. The forward fan assembly supplies air to the bow seal, the centre assembly to the cushion, and the aft assembly to the stern seal. The fan assemblies draw supply air through intake openings in the weather deck. Each constant speed fan assembly has a variable geometry inlet mechanism which permits rapid regulation of air flow.

A LM2500 gas turbine engine powers each set of lift system machinery. Combustion air is provided through a common intake shared with the propulsion gas turbine engines. Exhaust gas from the lift engine is utilized for anti-icing or preheating combustion air for the electric generating, propulsion, and lift turbines before exiting through stacks. Lift system gearboxes utilize double helical herringbone reduction gears.

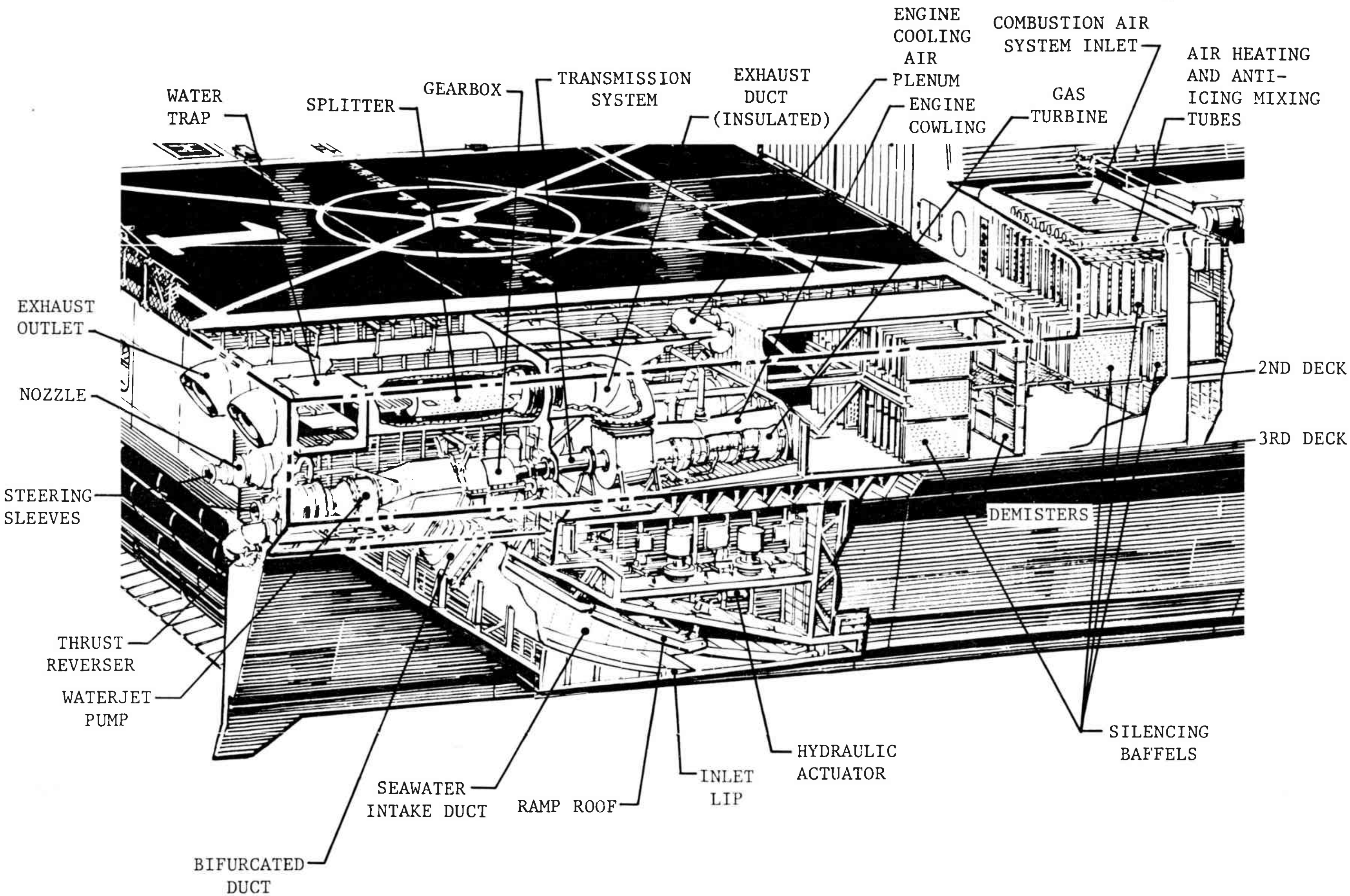

FIGURE 9 - General arrangement of starboard propulsion plant

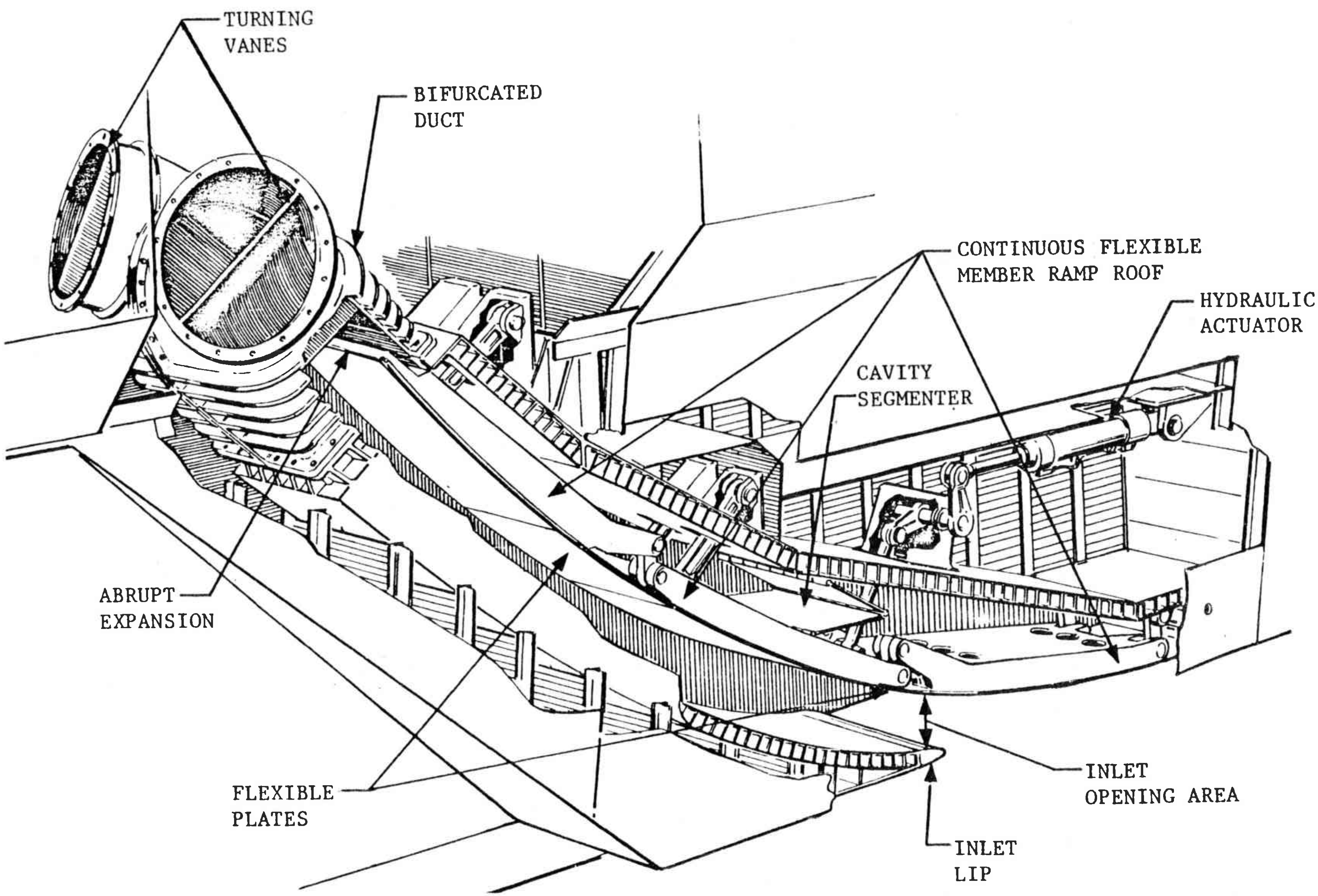

FIGURE 10 - Waterjet inlet duct and adjustable ramp roof

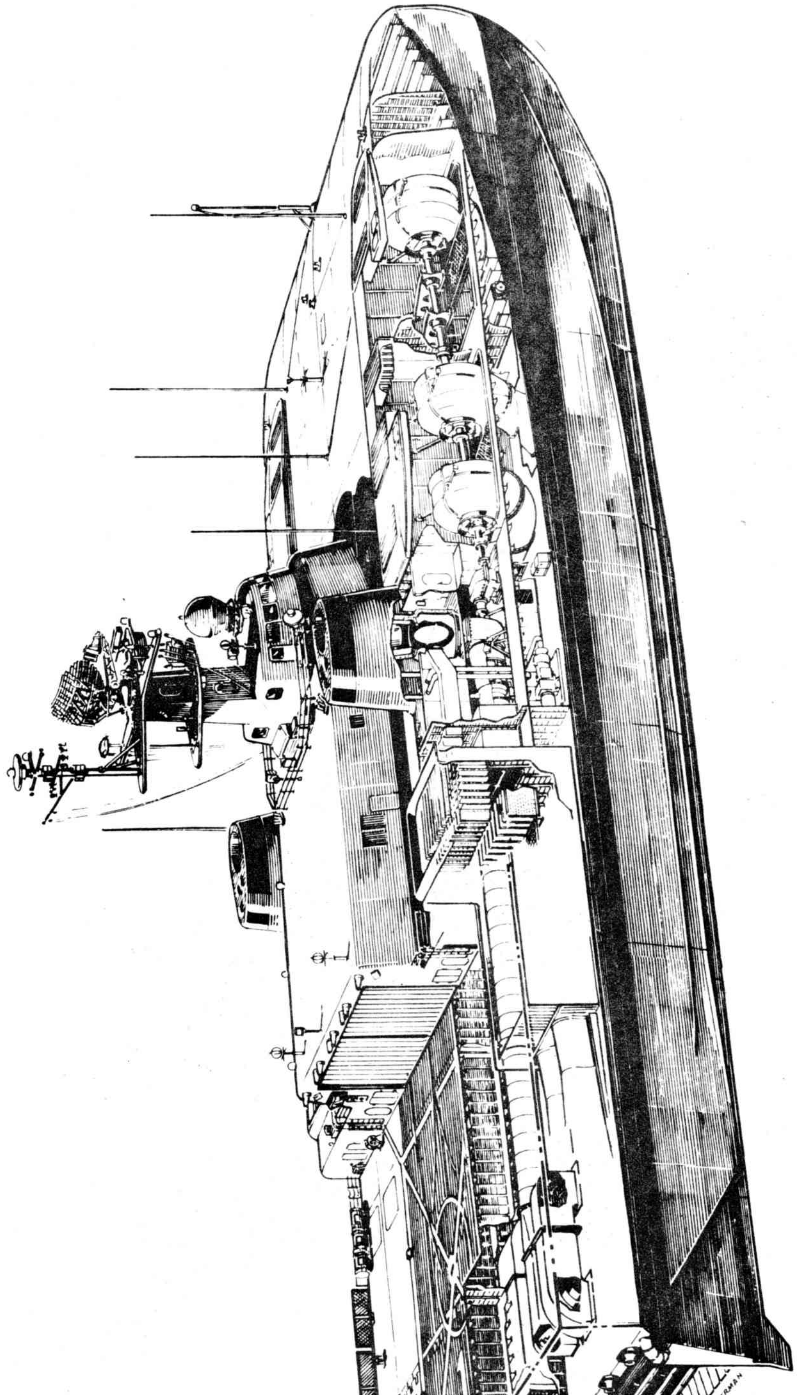

FIGURE 11 - Lift system arrangement, entirely enclosed within the centrebody

RIDE CONTROL SYSTEM

The cushion vent vales of the ride control system, (Figure 12), combined with the variable geometry lift fans (Figure 13) form a total system which alleviates ship vertical motion more effectively than by vent valves alone. The system was evaluated comprehensively during the XR-1D program, substantiating the remarkable results predicted by analyses and model tests.

The variable geometry feature of the lift fan consists of a translating sleeve in each axial inlet. The hydraulically operated sleeve is capable of a full stroke frequency of 2 Hz which provides a means for ship vertical motion control at the airflow source more efficient than a system which only vents cushion air.

SEALS

The 3KSES uses advanced planing bow and stern seals. The seals feature:

a. Design simplicity exemplified by two dimensional structures enclosed between full length sidehulls,

b. Commonality of elements which improve availability and reduce spares provisioning considerations,

c. Durability for extended useful life and increased reliability,

d. Superior performance under the most adverse conditions in a seaway.

The seal configurations are a significant departure from conventional, three dimensional, bag and finger design. Tests have shown that elastomer coated fabric finger materials have inordinately high water-line wear rates. The bag and finger concept also tends to have marginal performance characteristics in high sea state environments. The planing seal, on the other hand, with its glass reinforced plastic (GRP) planing surface materials, has shown extremely low water-line wear rate characteristics after actual test exposure to high speed water impact for many hours. In addition, the planing seal promises to have excellent overall performance characteristics in high sea states. This has been demonstrated repeatedly in many tests with tow tank models and in large scale with a design variation of the 3KSES seal on the XR-1D manned testcraft (Figure 14).

The planing seals of the 3KSES are fully retractable both at the bow and stern. This capability allows them to be deployed sequentially in order to reduce ship drag at critical primary and secondary hump transitions. Independent stern seal position scheduling permits control of immersion of the waterjet inlets for all ship speed regimes. Fully retracted, off cushion, a full range of 3KSES manuevering capabilities, either ahead or astern can be achieved.

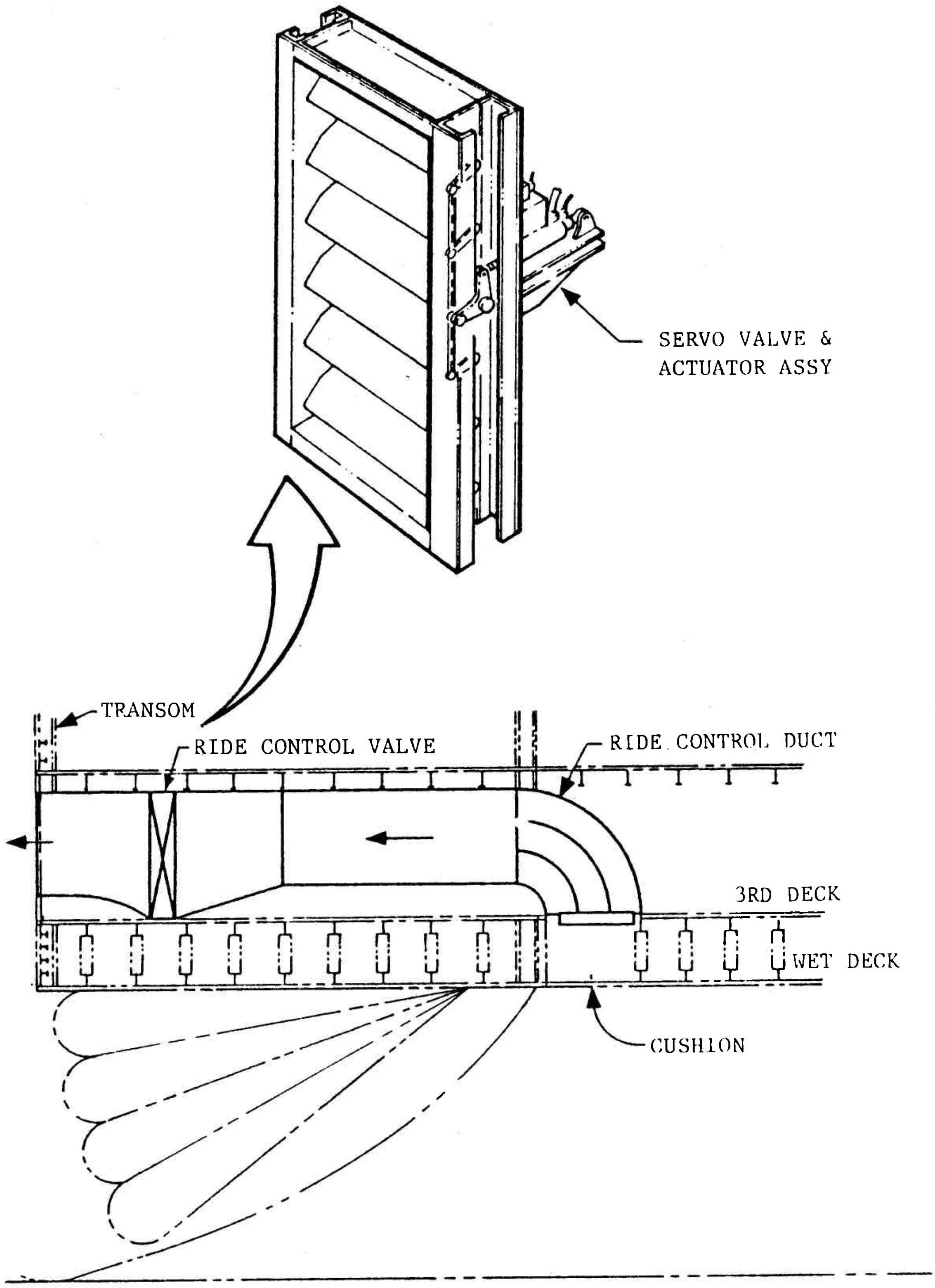

FIGURE 12 - Ride control system vent valve module

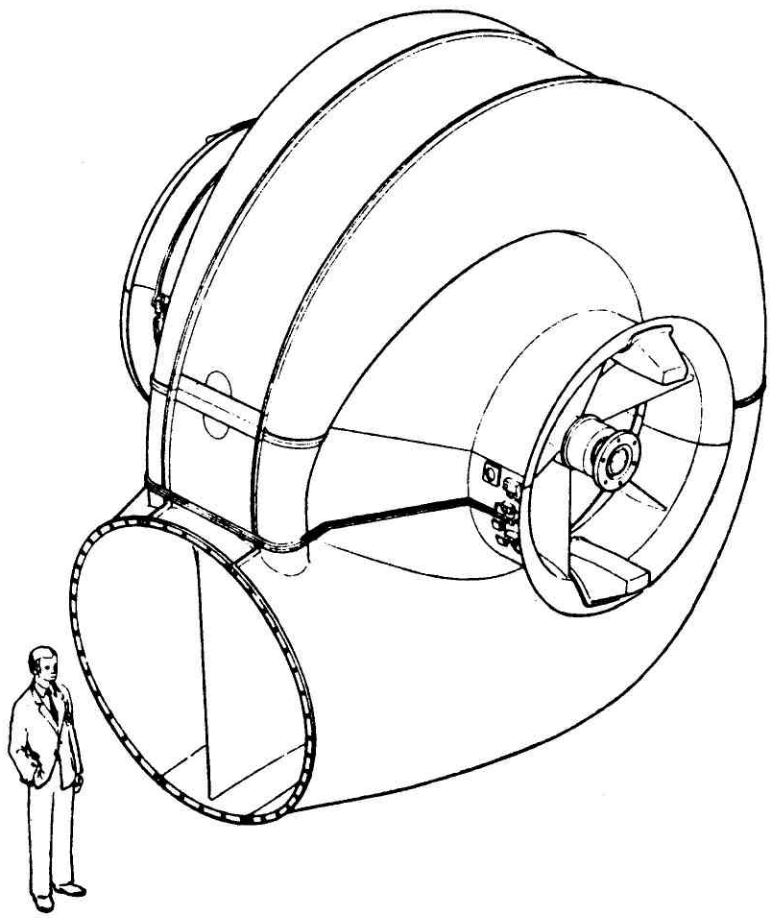

FIGURE 13 - 3KSES lift fan

Finally, the advanced planing seals perform the normal vital function of containing the air in the cushion providing stabilizing pitch restoring forces without disturbing ride quality.

SUMMARY

Since the ultimate objective of the SES program is to introduce this technology on a broader scale in the future, the development program plan also includes planning and conceptual design studies for a class of SES escort ships of approximately 3000-ton size as well as subsequent design and construction of larger vessels. Plans for both the SES escort and the larger ships will be technology-paced and synchronized with development and test of the prototype.

As the Navy moves out of subsystems development and into design and construction of the 3000-ton Surface Effect Ship, we move into an exciting new era. To those who have been assigned responsibility to guide this ambitious project, the challenge will be great. We are confident that this program will substantially advance marine technology and greatly expand our Navy's capabilities and effectiveness.

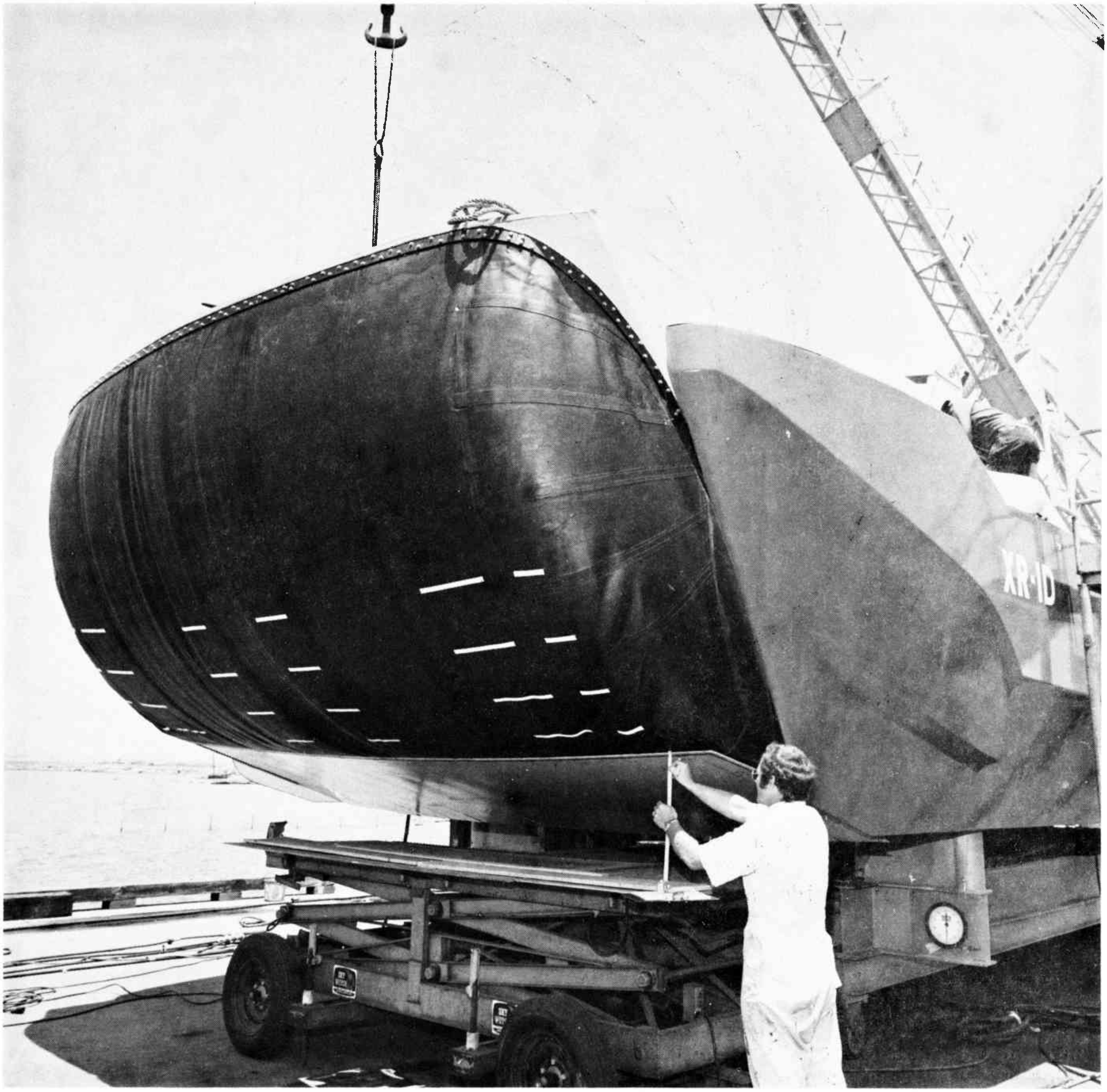

FIGURE 14 - XR1-D planing bow seal

SHIP TO SHORE LIGHTERING WITH THE VOYAGEUR

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INTRODUCTION

One of the more interested facets of the Bell Aerospace Canada Textron Voyageur air cushion vehicle's applications has been that of a ship to shore lighter.

Conceived as a heavy haul freighter, Voyageur lends itself to a multitude of applications, ranging from a passenger carrying element in an urban mass transit system to an ice breaker. The vehicle's versatility is without question, but in the area of ship to shore lighterage the Voyageur is at its best.

A lighter is defined as a large open barge used chiefly in loading or unloading larger ships whenever shallow water prevents these coming in to the shore. Voyageur's no draft/amphibious nature, large flat deck with control cabin and machinery located discretely away from the cargo loading area, make it an ideal vehicle to fulfill this role. Its high speed is a feature which permits a degree of productivity unequalled with present day lighterage equipment.

In the course of Voyageur history, the vehicle has been involved in a number of lighterage operations. It is the intent of this paper to discuss these operations and to look at future applications of the vehicle in the concept of a total Air Cushion Vehicle Lighterage System.

OSDOC II

At the completion of its overwater trials program in the summer of 1972, Voyageur's first operational program called for its participation in the U.S. Army's Off Shore Discharge of Container Ships (OSDOC II) trials to be held at Fort Story, Virginia. The objective of the trials was to evaluate selected items of currently available lighterage in the role of lightering containerized equipment from ship to shore. Specifically, the objectives of Voyageur's participation were as follows:

1. To evaluate the effectiveness of air cushion vehicles in future U.S. Army lighterage roles.
2. To obtain realistic A.C.V. data inputs to the continuing U.S. Army Trans Hydro Study.

3. To identify those areas of craft configuration, support equipment, and A.C.V. operating techniques where change could result in Voyageur more effectively performing Trans Hydro missions.

4. To assess the transportability and maintainability of Voyageur and simulate, where practicable, remote field assembly conditions.

Considering the limited scope of the trials, and accepting the prototype nature of Voyageur 001, a considerable amount of relative data was accumulated.

OSDOC II was a large scale test consisting of the discharge from container ships of MILVANS, TRICONS, container inserts, pallets and selected outsize cargo. Included in the surface lighterage operations were U.S. Army LCM-8's and U.S. Army and U.S. Navy LCV's. Air operations were conducted using U.S. Army CH54 and U.S. Marine Corps CH53 helicopters. Beach transfer equipment included a 250 ton crane, flatbacks and tractors, bulldozers, rough terrain cranes, and forklifts.

OPERATIONAL EXPERIENCE AT OSDOC II

Voyageur entered the OSDOC trials as a basic vehicle. Cargo tie down equipment consisted of conventional chain and binders. No equipment was provided that was specifically designed for handling cargo containers. With the exception of the deck dunnage, no special deck fittings were installed on the craft.

In some thirty (30) hours of operation, the craft conducted the majority of its lighterage missions in sea state 2 with wind of 20-25 knots. At no time did these environmental conditions have an adverse effect on the vehicle's ability to complete its objectives. The vehicle was able to cross the surf zone in either direction and frequently negotiated three to four foot spilling/plunging surf. Maximum payload carried was 19 tons (two 20 ft. containers). Block speeds averaged 30 m.p.h. between ship and shore. During beach transitions, the maximum grade negotiated was 6% from a 5 m.p.h. forward entry speed with a 12 ton payload.

Transversing the beach to the sand dunes presented no difficulties. Transit of the craft to the cargo distribution area necessitated the craft negotiating a series of sand dunes and with the aid of minimal bulldozing to level the crown of the dunes, the craft was able to negotiate them with ease. Once in the cargo yard, the craft was able to maneuver quite readily and, in fact, positioned itself between containers and reversed clear once loading activities were completed. Standard mechanical handling equipment was used throughout the trials and proved to be compatible with the need to load and unload the craft.

Docking of the Voyageur against the ship was relatively easy and much less of a hazardous operation than had at first been thought. The technique used was to maneuver the craft on cushion to within 50 feet of the ship, at which time lift power was reduced and the craft maneuvered in the displacement mode until a painter line could be received from the ship. With the strain of the sea painter on the outboard bow, the opening of the inboard puff port, and occasional applications of differential thrust, the stern of the Voyageur remained well clear of the ship. In the majority of cases, Voyageur operated from the windward side of the ship in more severe weather than that occuring on the sheltered leeward side. Fendering was effected when necessary with applications of differential cushion on the side of the craft adjacent to the ship.

Loading Voyageur proved to be simple and fast. On land and at sea, a four-man deck crew was able to rapidly position containers within acceptable craft centre of gravity limits. The 54 cargo tie downs located on the main deck of the craft offered an adequate grid and at no time when a container or containers were loaded were tie down fittings not readily accessible. The cargo tie down chains and binders were not the easiest units to handle, but were adequate for the job. The average loading time per container was four minutes.

Durability of the deck dunnage was amply demonstrated when, on one occasion, the crane mounted container suspension rack malfunctioned, dropping a loaded container onto the deck of the craft from a height of four feet and no damage to the craft was experienced.

CONCLUSIONS OF THE OSDOC II EXERCISE

The trials practically demonstrated that the A.C.V. could operate in a lighterage role. Cycle times were much lower than with alternate surface systems and would increase with longer offshore distances. The ability of the Voyageur to transit the shoreline and penetrate inland to the cargo distribution point offered a decided advantage over conventional lighterage systems. The vehicle's compatibility with existing mechanical handling equipment used in the cargo clearing yard also added an advantage over the need to use more specialized and complex equipment at the beach.

RESULTS OF OSDOC II

As a direct result of OSDOC II, the U.S. Army procured two LACV-30's, Voyageur's "big sister", for further evaluation in their Trans Hydro studies. It is not proposed to discuss the experience obtained with these vehicles in this paper, other than to mention that with an increased payload over the conventional Voyageur, they are configured specifically for the lightering role and are offering a good account of themselves. I feel sure we shall be listening to an account of them in a future paper.

QUEBEC LOWER NORTH SHORE DEMONSTRATION PROGRAM

In contrast to the virtually ideal climatic conditions of the Virginian coastline in the late summer, Voyageur's next lighterage application was on the Quebec Lower North Shore of the St. Lawrence River during the most bitter and severe months of the Canadian winter.

The Quebec Lower North Shore is that region of the province extending some 410 miles from Sept Iles to Blanc Sablon, (see Figure 1). This region possesses many small towns and communities whose only access to the outside world is by sea or air. In the winter months, ice build-up on the Gulf shore and poor weather often isolates the communities for prolonged periods of time. In recent years, increased cargo demand in the re-supply of these communities has exceeded the capacity of the freight delivery system, a situation that is further aggravated when the re-supply ships are prevented from making deliveries of essential goods and supplies due to the ice conditions.

Although the Provincial and Federal Governments have made efforts to improve the cargo delivery system in this region, the limitations of transportation technology and economic constraints limited the options available for improvements in service. In late 1973, Bell Aerospace Canada Textron undertook an operations analysis of the transportation needs of the area and together, Agence Maritime (the company responsible for freight deliveries), the Province of Quebec, and the Federal Ministry of Transport, initiated the Voyageur Air Cushion Vehicle Lower North Shore Demonstration Program - a program designed to prove the feasibility of an air cushion vehicle to augment the existing marine cargo delivery system.

In the early part of the program, a Voyageur was deployed at Hâvre St. Pierre and was used to deliver cargo on a point-to-point basis. As the winter closed in and the ice barrier from the small towns and communities developed and moved further into the gulf, ships were no longer able to effect their re-supply mission.

Voyageur, with its ability to traverse any relatively flat surface, was teamed with the re-supply ships and undertook the role of a lighter, meeting the ship at the edge of the ice. Cargo destined for a specific community was loaded onto the craft and transported directly into the heart of the settlement. Expansion of this method of delivery developed into a "leap frog" system, where Voyageur, because of its high speed capability could load cargo, effect delivery, and move on to the next rendezvous point in the same time as the much bigger and slower vessel made transit between the two points.

Strangely enough, the presence of the ice many times simplified the lightering operation since if the ship was made fast in the ice, Voyageur could simply come alongside the vessel and shut down during loading operations. On the occasions when this was possible, it often made a welcome meal or coffee break for the Voyageur's crew. (For I'm sure as any of the Voyageur's crew members will tell you, even a poor cuisine on board ship is better fare than that served on a Voyageur!)

The increase in productivity afforded by this type of ship/ACV relationship is readily apparent. The ability to deliver cargo on schedule in anything other than the most adverse weather conditions becomes a reality and in the case of the residents of the Quebec Lower North Shore, the long and arduous winter of 1974-75 was made a little more tolerable.

THE COMPLETE A.C.V. LIGHTERAGE SYSTEM

We have looked, briefly, at two aspects of Voyageur's versatile role in the scheme of existing transportation systems. We have seen that it can readily adapt itself to perform productive work in extremes of environments, so let's now look ahead at future applications of the vehicle and apply its full potential to a complete A.C.V. Lightering System.

In countries where economic growth is severely hampered by inadequate port facilities, it is of paramount importance that relief from such a situation be effected immediately, if that country is to exploit its economic potential. Building of new port facilities requires massive capital investment and even though this be available, the lengthly construction period necessary to create new facilities would preclude an early solution to the problem. However, if we were to introduce an amphibious lighterage system into or adjacent to the congested ports, an immediate solution is possible.

Such a system, utilizing Voyageur AL-30's, (see Figure 2), offers an enormous advantage over conventional lighterage and cargo distribution systems. The vehicle's high speed and amphibious capability not only offers high productivity for unloading ships but is able to operate independently of dock facilities, thus transporting cargo directly into the transportation infrastructure of the country. Studies show that a fleet of A.C.V. lighters would not only assist in, and hasten, port decongestion but would form a cargo handling system that is fully integrated, flexible, and possesses an inherent growth potential.

Let us consider the introduction of an A.C.V. Lighterage System deploying ten Voyageur AL-30 vehicles in a typical port congestion situation.

A unit of ten AL-30's initially handling only containers can immediately and dramatically increase the daily tonnage off-loaded and cleared for final distribution and thereby initiate an activity which will decrease the overpowering amount of cargo presently creating "port problems". The effect of these vehicles operating as an integrated system would have a related effect in releasing ship berths in the congested port and thus contribute to the increased efficiency of the port itself.

Based on information regarding loading, off loading, and transit conditions, in several ports studied, a unit of ten AL-30's operating in a twelve hour period could off-load and deliver from 300 to 500 twenty foot containers, depending on the distance from ship to depot. The conclusion is that ten AL-30's would off-load one ship per day in a twelve hour period of operation. This, in effect, would release one berth per day in the port for use by other ships with general break/bulk and perishable cargo.

Further, the system provides an important added economic advantage in that the AL-30 could return three or four empty containers from the depot to the ship with each trip, thereby completing the container cycle.

The AL-30 can accept up to four standard containers on its deck providing the combined weight does not exceed the craft payload.

Voyageur has demonstrated it can complete docking and tie up in two minutes, and load a container in four minutes. Block speeds of 30 miles are taken as average across each staging leg.

Assuming a 12 hour operating day with 80% vehicle availability, it is estimated that each AL-30 will have an operating period of 288 hours per month. At a productivity of 3.66 containers per hour, an effective container movement of 1,056 units per month could be achieved. Although it is not possible to know how many undelivered containers would be involved in any specific port, using the parameters outlined above, the first year of operation alone could result in the off-loading of 115 ships (with 450 containers per ship). In the second year, assuming new arrivals at ten to twenty ships per month, depending upon the number of containers per ship, the ten AL-30's could off-load 126,720 containers at a 3.5 miles lighterage distance. (See Fig. 3).

Calculations show that the Voyageur AL-30's direct operating costs would allow containers to be delivered a distance of 3.5 miles for less than $100 per unit.

TERMINAL FACILITIES

The Voyageur AL-30 provides a direct connection between ship and ultimate cargo destination. However, the organization of the cargo distribution at the base or terminal would be an integral part of the complete A.C.V. Lightering System and must be configured to compliment the Voyageur's productivity.

The containers being lightered ashore must be efficiently handled and dispatched to the consignee, otherwise the system would fail to function. To effect this aspect of the operation, co-operation of Customs and other government agencies concerned would have to be obtained so that the examination and clearance of cargo would be compatible with the pace of delivery offered by the AL-30's.

As previously mentioned, up to 500 containers per day can be off-loaded and brought to the depot in a single day. To move this volume of freight, an efficient rail or trucking system becomes another prime requirement of the overall system, since it would require some 250 truck departures per day to keep pace with the A.C.V.'s, assuming each truck has the capacity for two containers.

The probability that the system could create a land congestion of containers is a strong possibility; however, land congestion eliminates demurrage charges with a substantial benefit not only to the port authority but to the ultimate consumer. Land congestion would also be preferable to warehouse stowage, since handling costs are high and time loss in the distribution of the cargo is considerable.

As can be readily seen, the efficient handling of the cargo beyond the actual lighterage from the ship to shore is an important aspect in the scheme of a complete lighterage system if maximum benefit is to be derived from the system as a whole.

DEPOT OPERATION AND MAINTENANCE FACILITY

Figure 4 depicts an ideal depot, operation and maintenance facility for the A.C.V. Lighterage System.

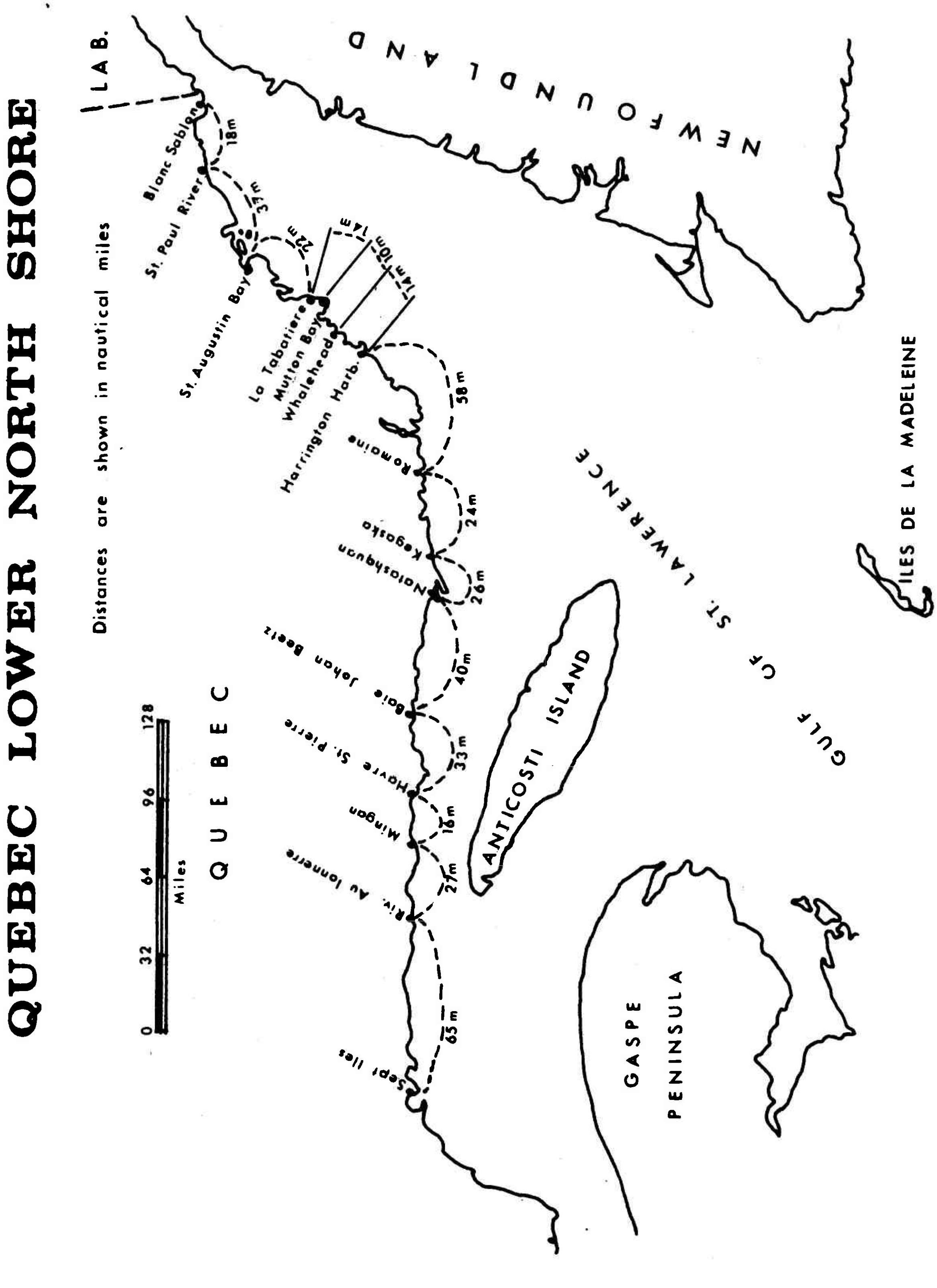
The operation and maintenance facility will provide all necessary cargo handling, maintenance and overhaul facilities for an entire A.C.V. Lighterage System.

The cargo area would be planned for safe and easy ingress and egress of the A.C.V.'s, as well as for efficient and speedy off-loading operations. Paved surfaces are proposed to eliminate bad dust conditions, as well as for the ease of movement for transfer of equipment. Space is proposed for approximately 3,600 containers.

Adjacent to the cargo area is the A.C.V. maintenance facility, which could provide adequate parking for the A.C.V. fleet. Service and repair buildings are proposed for heavy maintenance, while ingress and egress ramps are proposed to avoid the possibility of accidents and to provide for faster, smoother operation.

CONCLUSION

The introduction of an Air Cushion Vehicle Lighterage System offers a new and exciting dimension in the application of the Air Cushion Vehicle. The system, as conceived by Bell Aerospace Canada Textron, is unique and offers the possibility of a fully integrated transportation system that could prove to be a catalyst to stimulate the development and adoption of new methods of cargo handling and delivery.


QUEBEC LOWER NORTH SHORE
Distances are shown in nautical miles
0 32 64 96 128
Miles
QUEBEC
LAB.
NEWFOUNDLAND
GULF OF ST. LAWRENCE
ILES DE LA MADELEINE
ANTICOSTI ISLAND
GASPE PENINSULA
Blanc Sablon
St. Paul River
St. Augustin Bay
La Tabatiere
Mutton Bay
Whalehead
Harrington Harb.
Romaine
Kegaska
Natashquan
Baie Johan Beetz
Havre St. Pierre
Mingan
Riv. Au Tonnerre
Sept Iles
18m
37m
22m
14m
10m
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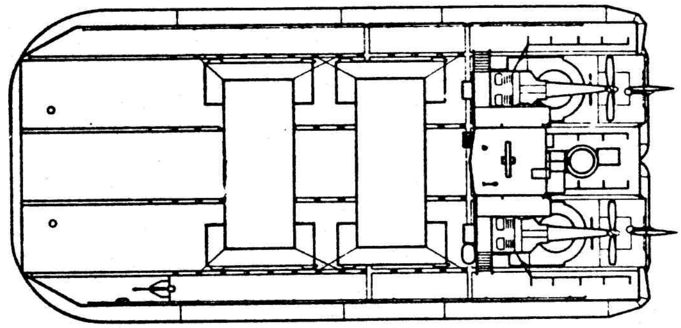
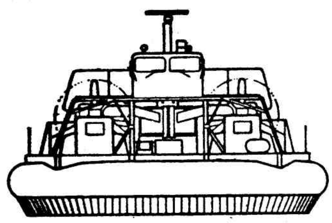
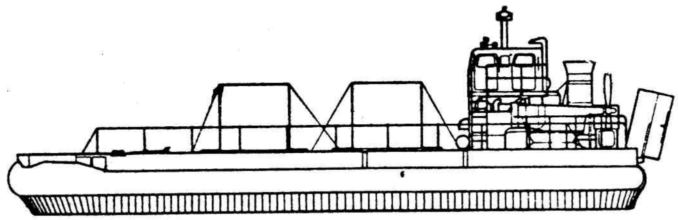
58m
24m
26m
40m
33m
16m
27m
65m

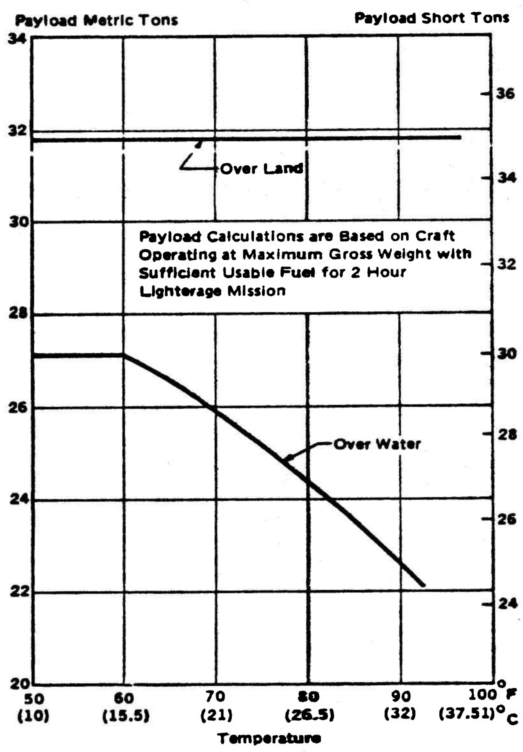
FIGURE 1

The Voyageur AL-30 Leading Particulars









Payload versus Temperature

Principal Dimensions	
Overall length (without optional swing crane)	76 ft 3 in.
Overall beam (skirts inflated)	36 ft 8 in.
Overall height on landing pads	21 ft 6 in.
Overall height from skirt hemlines (hovering)	24 ft 8 in.
Cargo deck length	51 ft 6 in.
Cargo deck width	32 ft 6 in.
Cargo deck height	3 ft 11.5 in.
Cushion height	4 ft 0 in.
Cishion area	2103 sq ft
Cushion pressure at max, gross weight	54.7 psf
Reserve buoyancy	155%
Performance (Estimated)	
Maximum calm water speeds at 109,751 lb gross weight (49,783 kg) with zero wind	Normal rating 42 mph Maximum rating 54 mph
Endurance with full main fuel tanks doing lighterage missions	15.5 hr (See Appendix I)
Power and Transmissions	
Engines	Two Pratt & Whitney Twin Pac ST6T-76 Gas Turbines
Maximum Rating (standard day) (Each)	1800 SHP
Normal Rating (standard day) (Each)	1400 SHP
Propellers	Two Hamilton Standard 3-blade variable pitch
Lift Fan	Two 7 ft centrifugal, 12-bladed fixed pitch
Fuel	
Fuel Types	Standard Turbine Fuel either Jet A-1, JP4, JP5; or light diesel fuel oil
Main Fuel Usable Capacity	2,272 U.S. gallons (15,450 lb) (7,000 kg)
Fuel Ballast/Emergency Fuel Capacity	1,520 U.S. gallons (10,350 lb) (4,695 kg)
Estimated Fuel Consumption during lighterage missions	147 U.S. gallons/hour (1,000 lb/hr) (454 kg/hr)
Electrical	
Starter Generators per Twin Pac Powerplant	Two (4 total) Gearbox driven brushless 28 VDC, 200 amps (each)
Batteries	Two Nickel-Cadmium 28 VDC, 40 amp hr (each)

FIGURE 2

AL-30 CONTAINER DELIVERY RATE

12 Hr Operating Day 80% Availability

	Distance	Total Container Delivery 1AL-30	5 AL-30's	10 AL-30's
1 Day (12 hr)	1 Mile	46	228	456
	1 Miles	41	204	408
	3.5 Miles	35	176	352
	4.5 Miles	31	155	310
1 Week (7 Days)	1 Mile	319	1,596	3,192
	2 Miles	286	1,428	2,856
	3.5 Miles	246	1,232	2,464
	4.5 Miles	218	1,092	2,184
1 Month (30 Days)	1 Mile	1,368	6,840	13,680
	2 Miles	1,224	6,12	[illegible]240
	3.5 Miles	1,056	5,280	10,560
	4.5 Miles	936	4,680	9,360

AL-30 SINGLE CRAFT CAPABILITY (12 HR OPERATING DAY)

Distance (Miles)	Number of Trips	Number of Trips as a Function of Payload: 1 cont.	2 cont's	3 cont's	Total No. of Containers Per Day
1	29	12	8	9	57
2	26	10	7	8	51
3.5	23	9	6	7	44
4.5	20	8	6	6	39

*Figures Rounded to Include Decimals not Detailed

AL-30 OPERATIONS ANALYSIS SINGLE CRAFT (12 HR OPERATING DAY)

Distance (Miles)	Transit Speed (mph)	Average Round Trip Time (Minutes)	No. of Trips Per Day
1	30	24.9	29
2	30	28.1	26
3.5	30	32.6	23
4.5	30	36.6	20

AL-30 AT 3.5 MILES

	Shipside Tie-Up and Load (Minutes)	Transit (30 Kts) (Minutes)	Depot Ingress and Unload (Minutes)	Total Round Trip Cycle Time (Minutes)
1 Container	6	6.75	8	27
2 Containers	10	6.75	10	33
3 Containers	14	6.75	12	39

AL-30 CONTAINER WEIGHT STATISTICS

Container Weight (Metric Tons)	Frequency of Occurrence	No. of Containers in AL-30 Payload
2.0 (Empty)		4
2.0 to 6.7	50%	3
6.7 to 9.1	30%	2
9.1 to 20.4	20%	1

FIGURE 3 - Voyageur AL-30 productivity analysis

Air Cushion Vehicle Lighterage System Depot/Operation and Maintenance Facility

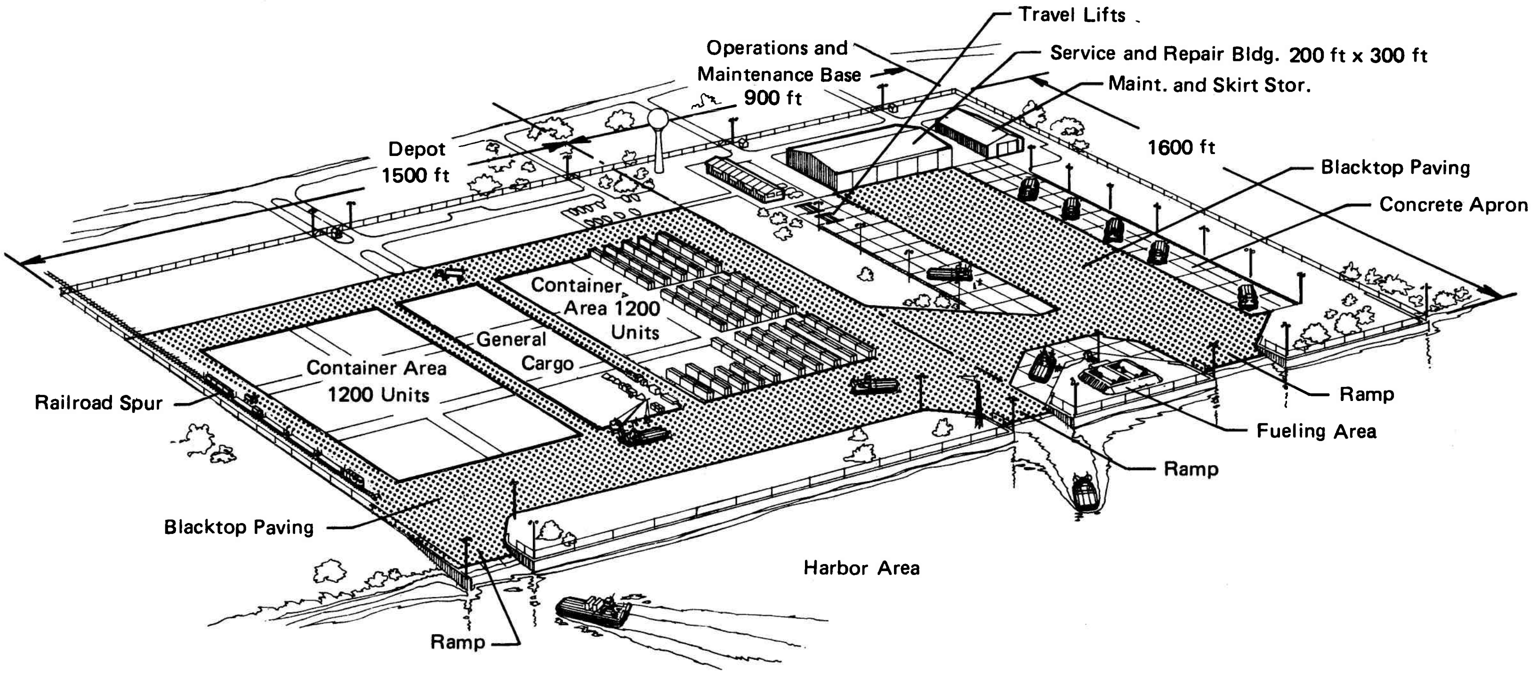


FIGURE 4

THE YUKON FERRY OPERATION

J.E. Ireland
Mackley Hover Peterborough Ltd.

The Trans Alaska Pipeline, the world's costliest construction project ever undertaken by private industry, necessitated crossing the Yukon River and the need for a year round operation to provide a support system for the Alaskan Pipeline.

One of the most important problems to be solved was the crossing of the Yukon River about 50 miles south of the Arctic Circle. The strategic crossing points were resolved by selecting a location that would allow the minimum distance from the original planned route of the pipeline, yet merge with the permanent bridge due for completion in late 1975. The south debarkation area is located on the tip of Carlos Island while the north site is located within five miles of the main artery which supplies the northern sector of the pipeline.

Due to the extreme changes in climatic conditions in the North, conventional methods such as causeways, bridges, etc., were ruled out at this time. Crossing on the frozen river would at best provide limited use and at considerable risk due to the heavy equipment to be transported and the quantity of other material so necessary in pushing forward this unbelievable project with dispatch.

Due to the nature of this project, Mackace Hoversystems, with considerable experience in Air Cushion Technology throughout the world were selected to modify their transporters to Yukon River requirements bringing forth the ACT (Air Cushion Transporter) Ferry System, the first of its kind in the world.

Timing was acute and immediate decisions were demanded. The system would have to be in operation when the "ice bridge", consisting of reinforced layers of ice capable of supporting traffic crossing the river during winter months, was no longer operable. The maximum time allowed for a completed working system was ten weeks.

Criteria based on the amount of supplies necessary to support the demanding work schedule of the project called for two ACT's capable of delivering a payload of 160 tons every 30 minutes. The design of the ACT's and peripheral equipment had to be flexible enough to operate in arctic winters and mild summers, while adjusting to the conditions brought about by the unpredictable Yukon River. The design of the skirt system was especially demanding since the ACT's would be required to hover over solid irregular ice, land, water and any combination of these. The system would also be subjected to floating ice, dislodged trees, and other types of debris during spring thaw.

Civil work started while Mackace was finalizing the design of a total 'ACT' system. To adjust to the rise and fall of the Yukon River's waterline, a portable ramp system was constructed allowing moveability, while having the strength to unload single-bearing loads in excess of 160 tons. The final link in the operation was the winch and cable system which would propel the ACT's to their destination. Two double drum winches were positioned on the north bank and a tail pulley system was set on the south bank. Cable guides were attached to the ACT's and stationary guides were mounted in front of the winches. A total of 42,800 feet of cable was strung across the Yukon River and travels in excess of 24 miles every 24 hours.

A skirt system was designed that would deflect the various types of debris encountered while sustaining the work load with minimum damage or downtime. The skirt fabric had to be specially coated to maintain flexibility during the arctic winters. In all, over four miles of this specially developed coated fabric able to operate in temperatures of minus 100°F had been prepared.

The skirt for each craft contains 160 segments. Over 13 tons of material had been used for the two skirt systems and their associate 70 inch deep spray skirts. The skirts were completed in under two months and air freighted to the site via Calgary and Fairbanks.

The order follows the launching of the world's largest hover transporter late in 1974, designed and built by Mackace for ferrying LNG plant from Abu Dhabi to Das Island.

The Yukon ACT's were assembled by linking 33 pontoons, forming a load bearing deck section, and then attaching the skirt system around the periphery. The supporting air system, driven by two centrifugal fans and two GM Detroit diesel engines which have been winterised to operate in temperatures of at least -60°F was installed with the auxiliary support equipment.

This included sump lube oil immersion heaters, jacket water immersion heaters and a heater system for the batteries. Thermostatically controlled radiator shutters are also fitted. Each engine is rated at 700 bhp @2000 rpm's. Fuel capacity is 1000 U.S. gallons of diesel fuel per engine. The engines and fans are mounted on a sub-frame as a complete unit, with the fuel tanks located separately.

Both craft, which were built on the north bank of the Yukon are Coast Guard approved and operated under U.S.C.G. regulations.

Some further interesting statistics which should be mentioned are: length, 129.5 ft.; width, 84.5 ft.; depth of hull, 4.0 ft.; minimum operating hover height, 4.5 ft.; and a deck loading area of 97.0 ft. x 52.0 ft.

During the approximately 5-1/2 months of operation, the two transporters (Yukon Princess I and II) have travelled over 7,000 miles in crossing the 5,400 ft. Yukon River. An operating efficiency of 95% had been achieved over this time period. The hover ferries have carried over half a million tons of cargo north and 200,000 tons south. Over 25,000 vehicles were carried across the river during that time. A maximum of 230 vehicles has been moved in one day. Maximum load carried on one ferry was 258 tons (Radmark Vehicle).

With the completion of the bridge in late 1975, the world's first cable-operated ACT ferry system had been utilized, thus conquering the Yûkon.

Mackley Ace Limited 160 ton payload "Yukon Princess" ferries operating on the Yukon River in Alaska