OPERATIONAL EVALUATION OF THE BELL-HALTER 110 FOOT SURFACE EFFECT SHIP BY THE UNITED STATES COAST GUARD

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ABSTRACT

The United States Coast Guard operated the United States Navy owned 110 foot surface effect ship from June to December 1981 in a variety of Coast Guard missions. The operations were conducted in the Gulf of Mexico.

The Bell Halter built craft was operated as a patrol boat with standard Coast Guard patrol boat personnel. Operations included drug interdiction, fisheries law enforcement, search and rescue, environmental protection and servicing aids to navigation. Short periods of instrumented technical trial were also conducted.

The craft proved equal, and in many cases, more capable than comparable Coast Guard cutters in performing these missions. Certain problems and limitations were uncovered that are peculiar to this concept and this particular craft. However, the overall vessel concept proved valuable and potentially useful in pursuit of Coast Guard missions.

INTRODUCTION

The United States Coast Guard (USCG), is an agency of the Department of Transportation, and as such is responsible for enforcing government policies and providing humanitarian services on the contiguous zone waters of the United States. Although independent of the US Navy, which is under the Department of Defense, the two agencies often work in close cooperation.

The United States Coast Guard uses marine vehicles, ships and boats, to conduct some of its many missions. Mission areas of responsibility are similar to many coast guard agencies of other governments. Although varied, the missions can be briefly summarized. One function is the enforcement of laws and treaties. The Coast Guard's role here is as the federal government's marine police force. This includes enforcing fishing rules and regulations, enforcing drug smuggling laws and the prevention of illegal alien immigration. The humanitarian aspect of the service includes searching for an rescuing people lost at sea from small boats, yachts, merchant ships, and aircraft. Towing disabled craft, and providing fire fighting and dewatering assistance to ships in need also fall within this category. Additionally, the Coast Guard places and repairs some 44,000 navigational buoys and other aids to navigation. Collaterally, the Coast Guard endeavours to protect natural resources. This includes monitoring, containing, and assisting in cleaning up oil and hazardous substance spills. In time of war, the U. S. Coast Guard becomes an arm of the U. S. Navy and carries out military operations.

It is against this background of Coast Guard multiple mission requirements that potential replacement vessels are tested. Vessels are sought which are capable of executing these multimission aspects. To that end, the Bell Halter Surface Effect Ship (SES) was evaluated.

VESSEL DESCRIPTION

The vessel ultimately used in the operational evaluation was constructed in 1978 by Bell Halter of New Orleans, Lousiana, on speculation as a demonstrator craft. Their purpose was to prove the concept that a surface effect ship could be built and operated effectively in the competitive arena of offshore oil field operations in the Gulf of Mexico.

The craft was operated in a series of demonstrations to the offshore petroleum industry, ferry boat operators, military organizations and representatives of foreign countries until the fall of 1980. The 110 foot (33.5 m) surface effect ship, alternatively called a rigid side wall hovercraft, was constructed of welded marine aluminium. It uses conventional diesel machinery and submerged marine propellers and rudders for high reliability and low fuel consumption. The vessel has a catamaran style hull form, with flexible skirts at the bow and stern to contain the air cushion (Fig. 1).

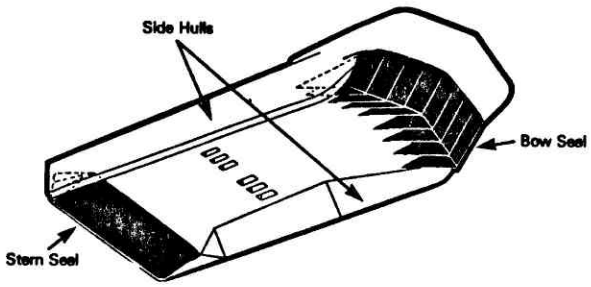


Fig. 1 Bell Halter SES Hull Form

The hull form is such that when off cushion, the waterline is well below the between hull cross structure. Air is supplied to the cushion at three points along the hull from diesel driven lift fans supplying pressure at about 1.0 psi (702 kg/m^2). The bow seal system consists of eight finger-type segments. The stern seal is an arrangement of three horizontal tubular bags extending athwartships across the stern opening between the side hulls. Both sets of seals are supplied from UK by Avon.

INITIAL EVALUATION AND SUBSEQUENT MODIFICATIONS

In March 1980, a one month technical evaluation was conducted off Norforlk, Virginia, by the US Navy under the sponsorship of the US Coast Guard and the US Urban Mass Transportation Administration. This test investigated technical performance of the craft and made direct comparisons to a Coast Guard 82 foot (25 m) patrol boat. It concluded "the Bell Halter 110 foot SES is an effective and able marine vehicle that warrants consideration for varied furture military and civilian applications"[1].

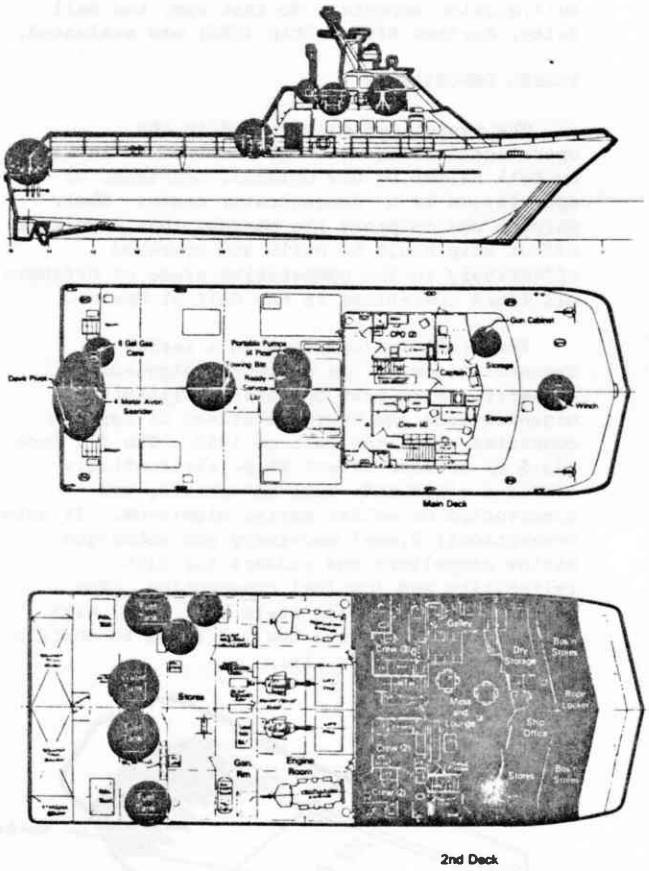


Fig. 2 USCGC DORADO Arrangements (Modifications shown highlighted)

In October, 1980, the US Navy Surface Effect Ship Project Office, with financial participation from the US Coast Guard Office of Research and Development, purchased the demonstrator vessel from Bell Halter. Modifications were necessary to convert the craft from a crew boat to a patrol boat. These modifications were part of the procurement. The modifications included crew accommodations, toilet facilities, increased fuel water and food storage, and installation of military and Coast Guard mission hardware.

The vessel was formally turned over the US Coast Guard from the US Navy on June 12, 1981, and placed in commission on June 18, 1981, as the US Coast Guard Cutter DORADO (WSES-1). The crew personnel for CGC DORADO was taken directly from the USCGC POINT SPENCER, an 82 foot (25 m) patrol boat based in New Orleans, with the additional assignment of two US Navy personnel to the crew for the duration of the Coast Guard trails. A US Navy senior petty officer was assigned as chief engineer, and the first assistance engineer was also a Navy petty officer. The crew personnel varied somewhat during the six months, depending on what missions were planned. Special ratings were assigned when required to supplement operations of limited duration.

DIMENSIONS		
Length	110 ft.	33.5m
Beam	39 ft.	11.9m
Height (off cushion)	22.6 ft.	6.9m
(on cushion)	28 ft.	8.5m
Draught (off cushion - maximum)	8.2 ft.	2.5m
(on cushion)	4.6 ft.	1.4m
WEIGHTS		
Maximum displacement	150 LT	152.4t
Design displacement	125 LT	127t
CG Operated displacement	147 LT	149.4t
Fuel	6582 gal.	249161
Water	1089 gal.	41221
Lubricating Oil	174 gal.	6591
Crew	14	
MACHINERY		
Propulsion - Two 16v-149TI Detroit Diesel Marine Engine - Two 40x50.86 Gawn Burrill Subcavitating fixed pitch propellers		
Lift System - Two 8v-92TI Detroit Diesel Marine Engines - Two Double Sublet 42 inch diameter centrifugal fans		
Generators - One 3-71 General Motors Diesel Generator (55KW) - One KATO KAMAC 14 generator (40KW) driven from lift engine		
PERFORMANCE		
Maximum Cruise Speed	SS0	SS3
On Cushion	30 kts.	25 kts.
Off Cushion - fans on	19 kts.	15 kts.
Off Cushion - fans off	6 kts.*	6 kts.*
Range at maximum speed - Sea State 3 - 1000 n.m.		

(*Speed limit to prevent damage to stern seal when water is not blown out by lift fan).

Table I: CGC DORADO Characteristics

The characteristics of the craft, configured and outfitted as USCGC DORADO (WSES-1) are shown in Table 1. The speed performance at different displacements and sea states, as predicted by Bell Halter, is shown in Figure 3. The actual conditions experienced by CGC DORADO during the six months of operation are also shown.

On June 20, 1981, the USCGC DORADO (WSES-1) began the six month evaluation. During the evaluation, she participated in numerous missions demonstrating the usefulness of this

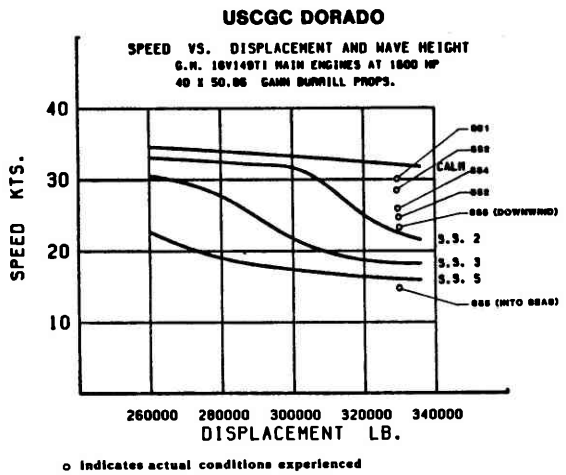


Fig. 3 Performance-Predicted and Experienced

craft concept for Coast Guard duties in the Gulf of Mexico. On December 15, 1981, the USCGC DORADO was decommissioned, and the vessel was returned to US Navy custody. The craft is presently in New Orleans undergoing major structural modifications by insertion of a 50 foot extension.

OPERATIONAL EXPERIENCE

The USCGC DORADO was in commission service for 181 days. The craft was underway 84 days; in a ready-for-sea standby status 47 days; and in a maintenance status 50 days during the trial period.

Maintenance requirements generally were similar or slightly less trouble than other Coast Guard cutters. The unpainted interior of the aluminum hull proved quite easy to maintain.

MAJOR MAINTENANCE

On September 10, 1981, the DORADO experienced an engineroom fire. There were no serious injuries, but the incident necessitated a return to New Orleans for two weeks to repair the fire damage. The fire was caused by a cracked lubricating oil line on the reduction gear which failed through fatigue due to vibrations. The installed fixed flooding carbon dioxide fire extinguishing system in the engineroom successfully extinguished the fire.

The only other major repair effort was the replacement of all eight bow seal fingers. On August 28, it was discovered that two of the bow finger seals had ripped causing the cushion pressure to be vented through the bow. This necessitated a return to port for repairs. The seals had been creased along the vertical center axis for shipment prior to initial delivery. It was along this crease that the two of the eight seals had failed, ripping nearly the entire length. This seal failure was sufficient to vent the cushion preventing normal operation. The seals had between 350 and 400 hours of operation on them when failure occurred. As a preventative measure, all eight seals were replaced, since all had been received at the same time.

Replacement of the bow seal was surprisingly quick and easy. Four personnel from the ship's crew replaced all eight seals in two days (24 hours effort) while DORADO remained in the water at pier side. The last seal took only one hour to remove and replace. The replacement cost for new bow finger seals was quoted as $5300 each. The expected life of the seals is estimated to be between 1500 and 2000 hours of operation. This figure is based on US Navy operating experience with test air cushion vehicles (JEFF A and B) and surface effect ships (100A and 100B).

SPECIFIC TESTING

The US Coast Guard Research and Development Center conducted two fourteen day periods of extensive testing during the operational evaluation. Using special instrumentation and prepared test plans, R&D Center engineers conducted tests of the vessel's characteristics including speed and powering, fuel consumption, maneuverability, as well as motions, noise and vibration measurements. Fuel consumption as determined in these trials is shown in figure 4.

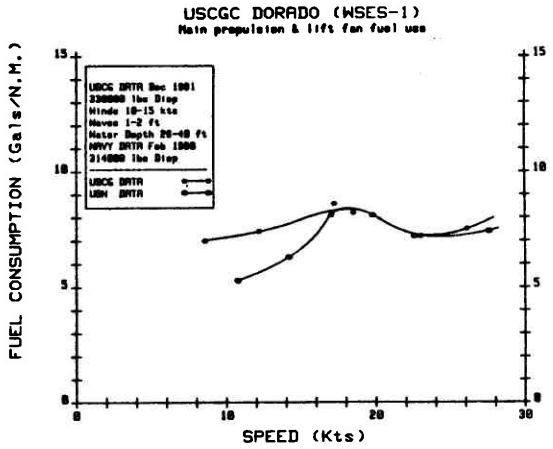


Fig. 4 Fuel Consumption per Naut. Mile

Physical vessel characteristics were also calculated. The volume and deck areas as determined are shown in table 2.

Questionaires to crew personnel were prepared and compiled by R&D Center personnel. These were a combined subjective comparison of the crews' experience aboard DORADO relative to other units on which they had served. Topics ranged from ease of conducting operational evolutions to habitability and creature comfort comparisons.

USCGC DORADO (WSES-1)

Total enclosed volume of hull		31500 cu ft
Total enclosed volume of deckhouse		8400 cu ft
External deck area	Aft platform	270 sq ft
	Main deck	2490 sq ft
	01	400 sq ft
	02	120 sq ft
Internal deck area	01	100 sq ft
	Main	1160 sq ft
	1	3350 sq ft

Special use suitability	Max Area/Vol	Min Area/Vol
a. Liquids	13800 cu. ft	5500 cu. ft
b. Accommodations, etc.	1770 sq. ft	800 sq. ft
c. Machinery Spaces	1990 sq. ft	870 sq. ft
d. OPS and Communications	1500 sq. ft	700 sq. ft
e. Pilot House	700 sq. ft	700 sq. ft
f. Provisions and Cargo	2060 sq. ft	360 sq. ft
g. Stacks and Uptakes	140 sq. ft	140 sq. ft
h. Boat, Helo and AtoM	1500 sq. ft	0 sq. ft
i. Ground Tackle	100 sq. ft	0 sq. ft

Table II: Deck Area and Internal Volume

OPERATIONAL EXPERIENCE

During the evaluation, CGC DORADO was assigned to various commands along the Gulf of Mexico, and employed in different missions. In June and early July the craft was operated out of Galveston, Texas in fisheries law enforcement duties. This included boarding vessels for inspection of catch and cargo as well as identification of vessels.

In mid-July, the craft was based at Corpus Christi, Texas, and employed in search and rescue duties and law enforcement patrols. The particular emphasis was on prevention of drug smuggling.

In August CGC DORADO conducted missions servicing aids-to-navigation while based out of New Orleans. This included minor repairs to buoys as well as fixed aids-to-navigation and transporting equipment. Late in August, the vessel was one of many employed in a pollution control drill in and around the Louisiana Offshore Oil Port.

Much of the operational evaluation was spent on multi-unit law enforcement patrols in the southern portion of the Gulf of Mexico. These patrols involved coordinated operations with other Coast Guard units working to prevent the smuggling of drugs. These operations were from 7 to 10 days in duration usually requiring continuous operation at sea. Resupply, including fuel, was from larger Coast Guard units. The seaworthiness characteristics of DORADO provided very habitable conditions for the crew. They were well rested and remained alert. This is in sharp contrast to the case on normal patrol boat sized craft, where the crew is usually exhausted from merely operating the craft in rough seas. During one extended patrol of this type, the seas were running up to 16 feet, and the DORADO, by drifting, was able to experience less than 18 degree rolls.

During the operational evaluation, methods of operation were developed to maximize the DORADO's unique capabilities, while bypassing its negative features. Due to the broad beam and wide set screws, maneuverability was very good. Such a good degree of control was afforded by this, and the one set of ship controls looking aft, that the crew often boarded vessels directly from DORADO without resorting to the small boat carried aboard. During the evaluation, the small boat was relocated from the stern step aft to the port side of the main deck. This proved more desirable because of the spray thrown on the step during normal operation.

In order to conserve fuel, the vessel would frequently sprint to a picket position then shut down and drift. While maintaining a radar guard, DORADO could take advantage of the improved seakeeping to rest the crew and still be ready to respond to an interception when required.

During the six month period, CGC DORADO provided to be a vehicle capable of performing Coast Guard duties in law enforcement, including fisheries patrol as well as coastal smuggling prevention and as a choke point patrol vessel. As a search and rescue craft, it responded to calls for assistance, conducted searches, salvage and firefighting duties as well as performed towing of disabled craft. Multi-ship and aircraft operations, medical evacuations, and cargo carrying capability were also satisfactorily performed.

The large deck aft and relatively high speed and resistance to roll made vertical lift operations with helicopters particularly easy. While not suitably sized nor strengthened to land or refuel a helicopter, the aforementioned characteristics afforded helicopter pilots significantly more control and margin for error than conventional slower speed vessels. On one occasion a medical patient was evacuated from a conventional Coast Guard cutter and transported quickly to within range of land based helicopters. The personnel transfer was accomplished successfully and resulted in the patient reaching medical facilities 6 to 8 hours sooner than would have been possible with conventional vessels.

Speed was one of the obvious advantages of CGC DORADO. The craft was able to transit in excess of 30 knots in low sea states in spite of the operating displacement of 147 long tons (149 metric tonnes) which was well in excess of the designed displacement of 125 long tons (127 metric tonnes). This advantage continued even with speeds of 28 knots in seas up to eight feet. During one patrol CGC DORADO encountered 12 to 14 foot (3.6 to 4.3 m) seas, and swells to 18 feet (5.5 m). The crew was able to make good 16 knots into the seas, and 25 knots when running with the seas. This range of relatively constant high speeds with increasing sea states was found to be a particularly desirable feature. Once DORADO, responding to a call for assistance, beat a helicopter to the scene of a burning yacht. Slow speed operations, however,

use considerable fuel, hence normal operations were usually conducted at or near full speed. Fig. 5 shows fuel consumption plotted against speed. The transit speed of around 30 knots had positive effect on crew morale as well. When on patrol in the Yucatan region, CGC DORADO could be ordered home, and within 19 hours grant liberty. Conventional cutters would take two days or more to cover the same distances.

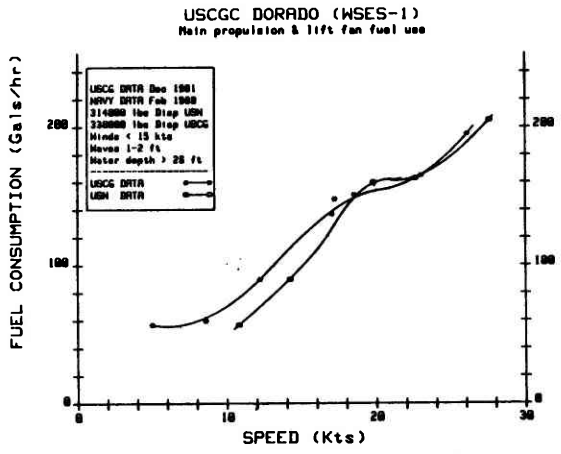


Fig. 5 Fuel Consumption

The high level vibrations and rapid speed of advance made conventional navigation methods near obsolete however. Automatic position plotters, using Loran-C, were utilized, and stabilized binoculars for bridge lookouts were a necessity.

The level of vibration made simple tasks such as writing difficult, and as such log entries were hard to maintain. The speed by which contacts were identified, coupled with the motions, made preparation of sighting reporting forms difficult.

Ship speed was found to be very sensitive to trim adjustment. At or near full load displacement, CGC DORADO was very sensitive to the position of its longitudinal centre of gravity. The crew had to become much more aware of trim than on a conventional ship, because improper trim would often prevent achievement of hump speed. Operations were then limited to between 18 to 22 knots until trim conditions were corrected.

The seaworthiness and habitability of CGC DORADO proved to be two particularly desirable features. With the broad beam, crew living conditions aboard compared more to shore side barracks than they did to shipboard conditions. Ship motions, particularly heaving and lurching, were rough during full speed operations and often prevented normal activities. However, due to the seaworthiness of the hull, either a course alteration, or a complete stop, would moderate motions to such a significant degree that activities approaching inport routine could be conducted. One method of operation that developed was to stop and drift once the operating area had been reached. This technique provided an extremely well rested and alert crew for when action was required, as well as a method to conserve fuel. This is in contrast to conventional vessels which would, of necessity, be steaming at slow speeds in their patrol areas.

Operationally, the DORADO presented a small radar and visual target when viewed from a bow aspect. This was useful when coupled with the high speed of the vessel while the craft was being used in law enforcement missions.

The widely separated propellers provided DORADO with excellent maneuverability at pier side and when alongside other vessels at sea. The maneuverability, coupled with the variable deck height, due to lift engine throttle settings, was used to advantage by DORADO's crew during boardings and inspection of other vessels. DORADO would manever alongside, then adjust cushion height, to match deck levels, allowing the boarding crew to step directly from one ship to the other.

The broad beam, and shallow step aft also allowed easy boat launching and over the side operations. The crew reported a significantly improved sense of safety during these operations when compared to conventional patrol vessels. Items were easily launched and recovered off the stern platform. Small Coast Guard boats moored across the stern on occasion.

The crew learned to operate the craft quickly. The only controls beyond those found on a normal vessel were the lift engine controls. The large beam and draught, when off cushion, were factors the operators had to keep in mind when operating in restricted waters however.

The DORADO proved capable of operating in a causalty mode with either one main engine, or one lift engine secured. With one lift engine secured, the craft was able to make 25 knots. With one propulsion engine secured however, only 12 knots were achieveable, dispite two lift engine operating. This was due to inadequate thrust to push the craft over hump. Adjusting the heel to raise the idle screw somewhat out of the water helped increase speed. A similar adjustment was necessary to maintain level operations when, with all engines functioning, a heavy beam wind was blowing.

ENGINEERING PROBLEM

Noise and vibration were two negative factors determined during the trial. The main engines were hard mounted to the aluminium hull structure, and as a result, transmitted engine noise throughout. The craft, being a prototype, has some insufficient propeller tip clearance induced vibrations. The propellers were turned down from 42 inch (1.06 m) to 40 inch (1.02 m) diameter before delivery in a partially successful attempt to alleviate this source of

vibration. The inherent pneumatic spring effect of the air cushion also contributed to the unusual motions. While the motions often seemed extreme to visitors, the fact remains the crew lived and functioned very well for the six month evaluation period.

The vibrations did contribute to numerous piping failures and hull cracks. These failures illustrate the need for care in designing aluminium craft. Flexible connections and more numerous pipe system supports would have reduced the occurrence of these failures. Strengthening of hull plating in discovered weak areas, as well as more use of continuous, rather than skip welding techniques would lessen the occurrence of hull cracks.

The aluminium construction allowed for unpainted interior spaces, and hence reduced maintenance despite the increased area to be cleaned. The low melting point of aluminium requires adequate fire protection. The installed carbon dioxide fire extinguishing system and remote ventilation fan shut off switches proved vital during the evaluation of DORADO.

Engineering experience aboard CGC DORADO has shown the craft is within the scope of normal maintenance expertise found on other Coast Guard cutters. The diesel propulsion and conventional ship characteristics offered no problem for crew operations. The main diesel engines are common to those used on 95-foot Coast Guard patrol boats. The use of large injectors in the main engines, to provide necessary power for getting over hump, proved to be a problem at low speed. Excessive fuel caused considerable smoke and carbon formation. The exhaust smoke, and resultant necessary cleaning, was one of the reasons for painting the hull black.

When on cushion the craft has limited maneuverability when backing down. This is due to the loss of engine cooling water suction. Designed for forward motion, the sea suction inlets do not provide sufficient flow when the craft is moving backward on cushion. When hullborne, cooling flow is adequate. The only feature unique to the DORADO are the bow and stern seals. There were no repairs made to the seal system, except direct replacement, so an assessment of the crew's capability to make repairs cannot be made.

The extensive use of aluminium pipe and the use of dissimilar metals in piping systems, such as brass valves, are a potential problem. The generous use of protective zincs is necessary for long term operation of craft similar to DORADO. Similarly, vibration mounts, flexible bulkhead penetrations, and more supports for pipes should be installed to reduce one of the major maintenance problems encountered on DORADO.

CONCLUSIONS

The six month operational evaluation of the USCGC DORADO proved that the SES concept can be valuably employed as a Coast Guard resource. The craft proved equal or more capable in conducting most of its missions than comparable Coast Guard cutters. While problems and limitations with the concept and this particular vessel exist, solutions are not beyond the reach of technology. On balance, the concept is valuable and useful in pursuit of many Coast Guard missions.

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OPERATIONAL DEPLOYMENT OF THE AIR CUSHION VEHICLE

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INTRODUCTION

Once a requirement for the use and application of an air cushion vehicle has been identified, and a program of objectives established, it is necessary to develop fielding and support plans that will ensure the achievement of those objectives. Development of the fielding and support plans requires extensive analysis of the program objectives to define the tasks and functions that will require action and implementation to ensure a successful program. To do these things well requires careful planning. Whilst many of these tasks and functions will require accepted methods to effect, many will be peculiar to the application of the ACV and therefore require a more specialized approach. Almost certainly, all will be influenced by the site and location of operations.

There are, of course, significant differences in the type of fielding and support plans required to inititate and sustain single vehicle operations that are to be undertaken in remote areas, than for those which employ multi vehicle applications operating from a fixed base. The introduction into service of the LACV-30 for example is a massive undertaking, requiring a totally integrated logistics support plan of which the fielding and support plans are but a small part. To describe the assembly and implementation of this plan would make fascinating reading, but it is quite beyond the scope of this paper at the present time. The basic ingredients of the fielding and support plans are, however, the same in many respects and it is therefore appropriate to illustrate their assembly and implementation with respect to a small commerical venture.

Analysis of the program objectives form the foundation for the assembly of the fielding and support plans. The type of vehicle or vehicles to be used will determine the requirements for the base of operations, the type and quality of ground support equipment and the requirement for spare parts and special tools. The type of payloads to be carried, either passenger or cargo or both also influence these requirements, particularily with respect to the provisioning of mechanical handling equipment. The frequency and duration of operations determines the need for maintenance equipment and spare parts. Mission profiles and route stage lengths determine fuel requirements and so on. Each task is accomplished by a function which in turn is influenced by the preceeding task. Failure to identify any one, or to adequately provision for those identified, will almost certainly have a detrimental impact upon the achievement of the program objectives.

The basic program requirements indicate the area of operations and the mission profiles that the ACV will be required to undertake. From these requirements, the sequence of events that will inititate the program are established. It is the intent of this paper to describe these events, and to illustrate not only the task involvement in establishing a program of ACV operations, but the reasons why they should be approached in a particular way.

LOCATION AND SITE OF OPERATIONS

There are many factors which influence the location for the site of ACV operations. By nature of it's amphibious capabilities, undoubtedly the operations base will be located on land with easy access to open water. Before selecting a suitable site, it is first necessary to conduct a thorough survey of the proposed area of operations. This survey not only provides the necessary information through which the technical phases of the program can be planned, but also establishes the contracts which are so necessary in assuring that the operations personnel will have the help and support needed to perform their work.

PRELIMINARY SITE SURVEY

Prior to undertaking a physical site survey, it is highly desirable to

obtain all available data on the proposed area of operations. Answers must be obtained to questions such as: What are the range of environmental conditions under which operations will be performed? Are there any physical obstacles that will hinder starting the operation? Most of this information may be obtained by studying topographical maps and marine charts of the area. These will show the evalations and contours of the land and local water conditions, thus giving good indications of potential problems that may have to be overcome.

The topographical maps show terrain contours and are of value in finding overland routes to potential destinations. Invariably, ACV operations are carried out over water, if these are navigable by displacement vessels, marine charts are available which will indicate not only water depths, but also obstructions that must be avoided. Knowledge of water depths and the location of sand bars are vital pieces of information, particularily if the area of operations extends into rivers and delta areas. The reasons are explained later in the text, but early access to this kind of information assists greatly in route planning.

Information on climatic conditions and/or anticipated sea states, if applicable, should be obtained, since again these will assist in advance planning of vehicle routings. Information on the local area should be obtained with respect to centers of population and the local services available. Granted this information, once assembled cannot take the place of a physical survey, but done with care it can provide a preview of the conditions under which the program will be conducted. More important it will indicate the areas where information is missing, thus generate questions to be answered at the time of the physical survey.

SITE LIAISON

Where the operational deployment of a small ACV unit is being established to support or extend the existing transportation systems of an already established site of operations used as a base to conduct major exploration or large scale civil engineering activities, it is most important that the first priority be to contact the person or persons in charge of the program or project. At this meeting, the method and support requirements of ACV operations are explained and potential problems discussed. This is done on a general basis essentially to introduce the ACV and to establish a base of cooperation. In the case of ACV operations, independent or remotely situated from the primary program, it is most advisable to contact the senior elected public official and to discuss the program objectives with him. This simple act of protocol is often overlooked yet it is the first step to cementing cordial relations with the local populace, a factor which is most important if good cooperation is to be forthcoming once operations get underway.

When the ACV operations are to be integrated into an existing transporation system or support a primary program which has a formal organization, it is important to obtain copies of the program organizational chart. Detailed organizational charts are valuable for planning, since they indicate local or customer services which might be able to supply field support. They also define areas of responsibility and serve as a guide for contacting key personnel. There is nothing more frustrating than to need support from a local service group and not know who to contact. This can be avoided with an up to date service group organization chart. The area and people who will interface with the ACV operation can then be quickly identified and the information used to contact the right person when help or support is needed.

PHYSICAL ENVIRONMENT

There is no substitute for being at the site of operations to determine it's physical environment. Books and information sheets may tell you that the annual rainfall is large, but no where will it tell you about the knee deep mud that may be encountered. Areas of high rainfall and high temperatures are continuously wet and humid, subject to floods and the associated reptiles and man eating insects that may plague the site of operations. Equally, cold winter temperatures and snow fall amounts can seriously impact operations if not adequately provisioned for. Wind velocities, ice thickness, the occurence of fog and periods of low visibility, the frequency of thaw periods and floods are all characteristics that should be known. If operations are to be conducted in tidal waters it is important to know the effect these have locally. At low tide, for example, is the beach area covered with jaggered rocks or easily negotiated over mud, sand or shingle beaches, is the slope of the exposed ground at low tide of a gradient within the operational capability of the ACV's that are to be used.

Naturally the site survey team cannot observe the physical environment through all seasons, but discussing the environment and climatic conditions with local residents can produce a wealth of

information that will be of invaluable assistance in planning the support and equipment needs of the proposed program.

SITE FACILITIES

The kind of environment in which the operations crew has to work makes a great deal of difference to the efficiency of operations. Morale is a vital factor in achieving operational success. Men working with inadequate tools and equipment out of stifling vans in the desert, leaky huts in a jungle or tents in a winter environment are capable of turning in a creditable performance for relatively short periods of time. When such conditions continue, however, the crew will become increasingly concerned for their own welfare and spend much time tending to their personal comforts, griping and complaining with the result that their work output will decline alarmingly. It is simply not realistic to have damp, wet, freezing or unbearably hot working conditions for the operations crew and expect maximum effort at all times. It is therefore a very simple fact that to obtain the maximum efficiency of operation, that personnel should be provided with comfortable working conditions.

If buildings are available for use at the proposed site of operations, they should be checked for suitability of use during the preliminary site survey. Answers to the most basic questions, frequently forgotten, will assist enormously in planning the actual operations. Does the roof leak? Are the doors wide enough, well there is nothing funny about the spare engine falling through a weak floor or rain dripping all over the radio communications equipment. A simple survey to check these things can list the deficiencies so that corrective action can be taken which will save hours of anguish and lost productivity later on.

The availability and type of power should be checked, for example, is it AC or DC, is it 110V single phase, or 220 volts three phase, 50 or 60 cycle, commerical power or produced by separate motor generator sets? Are there adequate outlets and lights? What type of heating is employed, is there an adequate water supply? It is easy to overlook these details as they do not seem very important, but once the preliminary site survey has been made and detail plans are being assembled for the operation, answers to these questions will be required.

Others aspects of the survey would be to ascertain the availability of local fuel supplies, area transportation systems, railroads and airports to facilitate logistics support. These are just some of the general items to be considered.

Living accommodations for the operations crew must be explored. If the operations are to be carried out as part of a major contract, it is not unusual to find living accommodations supplied, inclusive of meals and services. Should it be necessary to utilize local accommodations, hotels, boarding houses, etc., it is important to ensure that meals and services are available outside normal hours of work in the event split work shifts are to be employed.

The information gathered in the preliminary survey should be studied carefully to ensure that it does not negate any aspects of the overall fielding plans already being assembled. Any number of conditions or situations may impact the fielding plans with the possible need to provide additional equipment or accommodations. It is easier to plan for all eventualities with a wealth of factual information at hand, than to make judgements made on assumptions. These are invariably wrong and only induce costly delays when operations begin.

Once the preliminary site survey has been completed, identification of the tasks and functions necessary to establish the base of operations can be made and detailed plans for the implementation of operations can be undertaken. The information gathered should be compiled into suitable documents which then become the basic planning tool for the entire program.

OPERATIONS BASE FACILITIES AND EQUIPMENT REQUIREMENT

The base from which the ACV is to operate and the supporting facilities do not have to be elaborate, but they must be adequate. A ramp or parking apron on dry land upon which to place the craft for security and maintenance is of course the essential feature of the base. It is highly desirable that a defined arrival and departure ramp be provided. This must be free from obstructions and constructed in such a manner that it's approach is normal to the water. The ramp should lead to the apron which provides a flat area a minimum of approximately two craft lengths sqaure, per craft. The surface should be constructed of relatively hard materials, and possess adequate drainage. It is not absolutely necessary to have a concrete surface or be an area covered with tarmac, although either of these would be a desirable feature. It is, however, highly desirable that the apron not be on area of sand or fine gravel, since both of these

substances are easily dissipated by cushion air. Should cargo handling facilities be required, these should be of the mobile variety, capable of bringing the cargo to the craft. Should there be a requirement for a vehicular loading ramp, this may be either a portable or permanent structure. If a permanent structure, it should be constructed in such a manner that the craft may approach it unhindered by obstructions. A clear turning area to facilitate departure from either side of the ramp is essential.

Water wash facilities and electrical power should be provided at the apron. By preference these should be located at the apron extremities and be flush mounted at ground level. Failing this, a suitable hydrant equipped with hoses placed well back from the apron is acceptable. Similarily an electrical junction box should also be provided. A grounding point or points are essential so that the craft may be earthed securely during maintenance and fueling activities. An emergency station containing fire fighting equipment in the form of portable extinguishers should be provided. A pick-up truck dedicated to craft support should be available. This should be equipped with ground power units, lubricants, engine wash equipment and the special tools and equipment peculiar to the craft.

A maintenance shop and parts storage building is essential. Separate storage facilities should be provided for lubricants and flammable materials. Office and off duty crew accommodations are also a necessary feature of the base. These facilities would also serve as the home of the base communications system. Fuel stowage facilities should be both sized and located to match the operational requirements of the program. In many instances it will be possible to arrange for a local fuel supply organization to supply directly to the craft on an as needed basis, but failing this, a fuel tank of sufficient size to permit three days of craft operation without the need for replenishment is most desirable. It is most important to ensure that the fuel to delivery system be compatible with the craft system. The type of fuel delivery system offered by the supplier should be identified during the site survey to establish if there is a need to supply special adaptors. Mission profiles may require the craft to range far from the main base. In this event it may be necessary to provide refueling facilitated at the route extremities. Shore based bladder tanks are ideal for this purpose with the craft being equipped with it's own refueling pump and filtration system.

Access to crane services are a most essential feature of the craft operations base. The size of crane would depend upon the type of vehicle being used, but in any event, it should be of sufficient capacity to lift the craft fully assembled. A source of compressed air of sufficient capacity to supply air tools is also necessary. If the compressor is rented or leased, care should be taken to ensure line sizes and hose couplings are compatible with the shop equipment being used. Again, a point to check on the initial site survey. For remote site operation, portable equipment to supply 110VAC and 28VDC electrical power, compressed air, pumps for water supply and engine wash rigs should be available. By preference, these should be independently powered to preclude any one piece of equipment being dependent upon the next.

ROUTE SURVEY

The ACV being fully amphibious is not restricted to travelling navigable waterways, however, it is necessary to examine very closely proposed routings in some detail and to assess them in conjunction with the proposed mission tasks.

OVERLAND OPERATIONS

Overland operations require a more detailed route analysis than do those that are to be conducted overwater. The slope of the terrain and natural obstructions can frequently pose a problem for the ACV to negotiate. Experience in the past has shown that it is necessary to conduct a physical survey of the proposed routings. These are best preformed by the use of helicopters which permit landings to more closely examine potential obstacles to the path of the craft. Due regard for the slope of the terrain must be taken into account, since the ACV has a propensity to always seek low land. Once an overland route has been established it should be defined with clearly identifiable range markers. A chart of each route should be devised which records variations in the topography illustrating marsh lands, scrub, tundra, rocky areas, etc. Each of these variations in the landscape require different operating techniques to negotiate. Under no circumstances should extended overland missions be undertaken without first of all a thorough survey of the route to be taken and secondly without the craft being fully outfitted with winching equipment. The very fact that an ACV is being used in all probability, means that the ground is inaccessible to other forms of transportation with the net result that if a craft becomes stuck, it will be at it's own mercy and the resourcefulness of it's operating crew to effect it's recovery.

Overland operations can be successfully carried out by the ACV, but they do require careful route selection.

OVERWATER OPERATIONS

Overwater operations of the ACV place the craft in it's ideal environment, however, there are a number of considerations that must be examined in establishing safe overwater routes. Deep open waters do not present a problem other than at the interface with the shore line. This must be surveyed to explore a suitable beaching area that is not adversely influenced by tidal changes, surf zones or natural obstructions. Routings which parallel shore lines requires close scrutiny to avoid running over fish traps, oyster beds, pilings and other marine objects. When operating in defined navigation channels, it is most important to comply with the rules of the road. Whilst the ACV is more versatile in it's use of the waterways, this is not recognized by the tug boat captain who in unfamiliar with the ACV. He anticipates other vessel's movements as he does his own and makes judgements on course corrections based upon accepted principals. It can be safely assumed that an ACV flashing across his bow will be responded to by more than a blast on his whistle.

Establishing routes in confined waters such as rivers and estuaries requires careful planning also. Knowledge of water depths is an important factor. Frequently the ACV will be expected to operate at maximum gross weight. If the water depth is at the critical point for the craft when it is operating at low speeds, it may not be possible to exceed the hump drag speed with the result that excessive amounts of fuel will be consumed and block times will be extended. In shallow rivers and delta areas in particular, knowledge of sand bar locations can assist in getting the craft back above hump speed. It is important to realize in route planning, than an ACV, when transitioning from water to land must do so normal to the beach slope. Speed is an important factor in coming ashore, therefore a beaching site should be selected with sufficient open water normal to the shore line to permit the craft to attain an approach speed consistant with the requirement to negotiate the beach gradient.

A survey of routes that use small rivers require special attention. Water levels can and often do vary enormously over the seasons. Surveys conducted during the spring can be quite deceiving. Fast flowing rivers with wide tracts of open water may be reduced to a trickle of water mingling it's way through massive rocks in the summer and thus become totally unsuitable for ACV operations. In rivers normally navigable by the ACV, heavy rains can change the nature of the river within a matter of hours. Care should always be exercised when operating the ACV in small rivers, since submerged tree stumps can play absolute havoc with a skirt system.

A fully descriptive chart and guide should be prepared for each proposed route. For remote area operations, the chart should be marked by a grid reference so that in the event of trouble, the location of the craft can be accurately determined.

ICE OPERATIONS

Winter is of course synonymous with ice and snow. Operating the ACV over ice required a cautious approach. Rafted ice in rivers and along the shore lines of open water can present a serious hazzard to the vehicle's skirt system. Negotiating ice ridges must be done with great care since drifted snow frequently disguises the true profiles of the ridge hiding the often razor sharp protrusions. Ice formations change frequently and impact routings of the daily missions. Open sheet ice permits the attainment of high speeds, but care should be exercised when operating over this type of environment, since areas of open water are not easily distinguished and plough in situations can develop instantaniously, with disastrous results. Stopping distances are also increased enormously. In remote areas ice covered rivers are frequently used as highways, and care should be taken to avoid damage to the ice surface. Rememerbing of course, that the ACV is a most efficient ice breaker.

CARGO HANDLING EQUIPMENT

The ACV, of course, must be furnished with the necessary equipment to permit it to perform the mission requirements. Should the vehicle be engaged in cargo and freight hauling operations, then loading equipment of the appropriate type should be provided. Analysis of the types of cargo to be hauled will define the type of equipment required. This equipment, however, must be compatible with the craft cargo hold down equipment. Hold down straps, chains and binders are commonly used to secure cargo and should be provided in adequate quantities. Heavy pieces of equipment may require deck dunnage. Break bulk cargo will require containers. If the craft is required to self unload at the point of destination, it may be required to carry mechanical handling equipment. The

LACV-30 for example, is equipped to carry a swing crane capable of lifting 20 tons, provision is made for the installation of a small davit crane also. Voyageur 002 has provision for a HIAB swing crane. It should be realized however, that carrying cargo handling equipment detracts from the vehicle's useful payload, therefore in planning the craft operations, it is most advisable to secure mechanical handling equipment at the point of destination, or at least if repeat missions are planned and the equipment is not available, deliver it on the first mission and retrieve it on the last. If bulk liquids are to be carried, a pumping delivery system will be necessary, preferrably with an independent power source and a selection of hose and couplings for adapting to a variety of receiving points. Careful planning to provide the craft with the means to accomplish the job will increase it's versatility and improve productivity.

SPARE PARTS PROVISIONING

Careful analysis of spare parts requirements is a vital function in planning the operational deployment of the ACV. The vehicle manufacturer will undoubtedly have a comprehensive list of recommended spare parts which in most cases can be tailored directly to the operational needs of the program. This list will not, however, include standard hardware that has a tendency to become lost during routine maintenance. Expendable materials always have a tendency to be underestimated. Cleaning rags, locking wire, split pins, sand paper, greases, paint and cleaning solvents all fall into this category. As an example of even this seemingly insignificant provisioning plan, an analysis of the LACV-30 support requirements in this regard, defines over one hundred eighty expendable items, a not unconsequential figure. Failure to plan for even the smallest event can be just as injurous to the program as a whole as the failure to provide fuel to the craft at the right time and the right place. Often forgotten in the spares provisioning plan are the spare parts necessary to maintain the ground support equipment. Equipment just as important to the program as the craft itself.

CRAFT EQUIPMENT

Outfitting the ACV with the necessary equipment to ensure it's safe and efficient operation is most important. In the selection of deck equipment for example, the choice of anchor will be influenced by the water bottom conditions in the area of operations. The choice of navigation and communications systems will be dictated by the need for it to be compatible with the system used in the local area. The requirement for winches, ropes, lines, life rafts and emergency life support systems for remote area operations must all be considered. Lights and shapes, first aid equipment, pyrotechnics, fire extinguishers all form part of craft equipment. Many of the items will be part of the vehicle's standard furnishings, but each must be examined for it's suitability for used in the area of planned operations. For missions of extended duration, provisioning for crew comfort is most important. Again careful analysis of the program objectives and mission profiles are necessary to ensure the craft is adequately equipped to perform the role for which it is intended.

CONCLUSION

Successful operational deployment of the ACV depends exclusively on careful planning. In the space and time available, it is obviously not possible to discuss in detail all the tasks and functions to be actioned in assembling fielding and support plans. The brief highlights described, illustrate but a few of the many aspects to be considered. Experience has shown that there is always a tendency to overlook the small and seemingly insignificant items. Regrettably their real importance only becomes apparent when their omission is discovered at the most inopportune time at some point after the commencement of operations.

It is an acknowledged fact that we do not plan to fail, but fail to plan. The extra attention spent in planning the small details is frequently the only difference between the assembly and implementation of a successful program, and the one which continually struggles to stay alive.

COMBAT DAMAGE - A UNIQUE ELEMENT

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ABSTRACT

Design engineers confronted by stringent operational requirements must also give a high priority to the supportability aspects of combat damage. Maintenance planning emphasis is usually given to preventive maintenance and correction of malfunction failures. Damage control procedures and repairs are well established for normal ships. But air cushion vehicles (ACVs) are abnormal ships of peculiar construction, and require a different approach. The types of damage which ACVs receive in many instances will not be visible at first glance. Diagnosis of the extent of this damage will require new techniques as will the determination of spare parts inventories. The effect on the design of accommodating normal failures and combat damage to produce a more available and repairable design is discussed in conjunction with normal Logistic Support Analysis (LSA) procedures. Failure Modes and Effects Analyses (FMEA), which consider combat damage, are compared with FMEAs, which consider only malfunctions. The difficulty of assessing the debilitating effect of combat damage is addressed.

INTRODUCTION

Combat damage is a subject which operators and maintainers alike would rather not consider. For consideration of combat damage is an admission of vulnerability and that the potential for physical harm exists. But ignoring combat damage is like living with one's head buried in the sand, and may invite disaster. Advance planning with its potential in mind should eliminate primary failures or failures which could amplify damage.

For this dissertation the types and quantities of failures will be a limited representation of what might be expected.

FAILURE ANALYSIS

Failure modes and effects analysis is a process which lists the most likely failure mode for the equipment or system being analyzed. FMEA normally considers failures caused only by malfunction. Secondary failures caused by primary failures are also considered. A consumer example of this type of failure is:

- Primary failure: flat tire
- Secondary failure: bent wheel rim

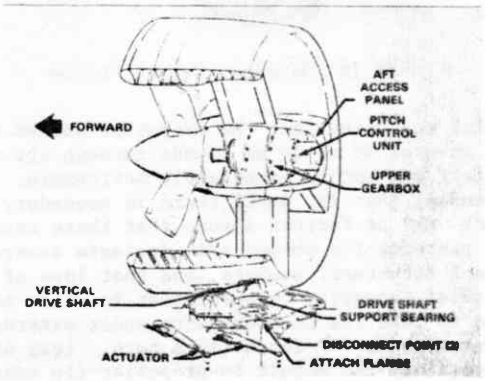
The secondary failure does not always occur but it may be caused by the circumstances which provoked the primary failure, or by the primary failure itself. In this case continuing to drive with a flat tire could easily damage the wheel rim.

LOGISTIC SUPPORT ANALYSIS

Logistic support analysis is a totally encompassing process during which all aspects of ownership of an equipment or system are examined, delineated and quantified. FMEA is a most important part of LSA. For FMEA tells us what we can expect to replace and how often we should expect to do so. But LSA also examines the effect of preventive maintenance (PM) on the failure rates. Will more or less PM affect the failure rate? If so, how much? If we eliminate the primary failure, will that eliminate the secondary failure?

ACV PROPULSORS

Propulsors for ACVs appear to be rather simple looking devices i.e., a propeller which rotates within the confines of a sheet-metal shroud. The ACV novice might guess that the worst fate that could befall a propulsor would be to have some foreign object be sucked up by the propeller and strike one of the propeller blades. Indeed, this might be true for a low performance, backyard crafted ACV. A high performance, high technology ACV is more critical.



Jeff (A) Shroud

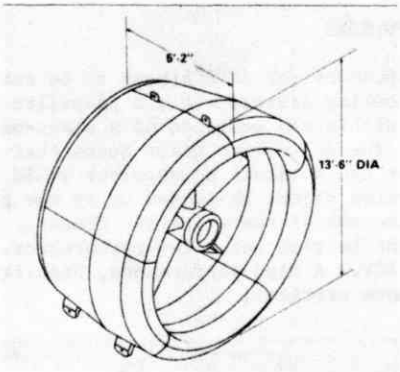
High performance usually requires a controllable pitch propeller and an airfoil shaped shroud with close tolerance between the two to minimize

losses. For cold weather operation a de-icing system may further complicate the design.

Some of the types of failures which we might expect to see are:

- Propeller
  - Foreign object damage (FOD) to blades or hub
  - Hydraulic failure loss in pitch control
  - Mechanical seizure of pitch control
- Shroud
  - Foreign object damage
  - Stress cracks
- De-icing system
  - Loss of heat source

These are the normal, everyday types of civilian or non-combat failures that can be easily diagnosed. However, there are combat damage conditions which might be almost impossible to detect but which may cause incipient primary, secondary and even tertiary failures.



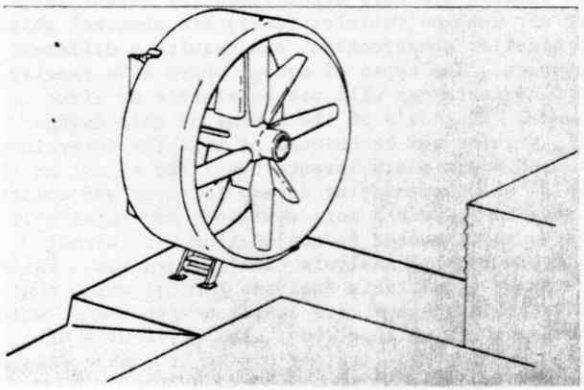
Jeff (B) Outside View of Shroud

Let us assume that the propulsor shroud has taken several 20 or 30 mm rounds through its skin. This fact may not be immediately noticeable. Not noticeable, that is, until there is secondary damage. Let us further assume that these rounds after piercing the shroud skin decimate several internal structural members, and that loss of structural integrity is sufficient to allow the shroud to lose its concentricity under external loading such as "G" forces in a turn. Loss of concentricity can result in propeller tip contact and sufficient propeller tip contact can result in permanent propeller and shroud damage.

If we have done our homework properly, we will know how much structural damage is sufficient to warrant replacement of the shroud, whether we may continue operations at reduced capability or that we can ignore the damage. The design will have some structural margin, but since it is a lightweight aircraft type design, the margin must be small.

The secret of success is the ability of the analyst or engineer to determine the extent to which the shroud may be damaged and still be safely operated. Additionally propulsor performance or condition must be translatable into tests which may be performed by the operating crew in the field or by maintenance personnel at some rear echelon.

If the shroud is so greatly damaged that propeller tip contact is obvious when the propeller is stationary, then operation is not wise. Some guidance might be provided regarding removal of the torn shroud skin, for example, to clear the obstruction. Then should structural integrity still be intact, operation in a degraded mode may commence.



Jeff (B) Propeller Installation

Subtle damage is the real problem. Though the shroud may appear to be undamaged at first glance, a thorough inspection may reveal several holes in the skin. The probability is high that the fragments or small caliber rounds that made these holes caused some type of internal damage. The extent of the structural damage is unknown since it is hidden by the skin. If we were at a major shore-based repair facility, we could use many different inspection methods to determine the extent of the damage and/or the resultant remaining structural integrity. In the field (defined here to include amphibious ship well decks) diagnostic methodology must be crude, relatively speaking that is. However crude the methods are, they must be sufficiently accurate to allow continued safe operation of the craft. Some examples might be:

- Limit the number of damaged structural ribs
- Limit the number of adjacent damaged structural ribs
- Limit turning the craft to a specified rate or series of rates to reduce centrifugal deflections

These types of criteria would result from the designer's desire to avoid propeller tip contact caused by a loss of concentric rigidity in the shroud.

In addition to failures induced by shroud damage, damage to the propeller itself may allow the propeller to continue to operate for a while, but fail or cause a propeller failure at some indeterminate time. Propeller blades have always been subject to FOD. However, the impact velocity associated with FOD on an ACV is considerably less than the impact velocity of an explosive warhead fragment or small arms fire. Combat damage may be expected to extract a greater toll in blade failures or propeller imbalance. Blade failures will be obvious. Propeller imbalance may be very subtle. A slight imbalance may be observable only if we have vibration monitoring capability. If we have monitoring capability we must set realistic limits on our warning device so that the mission may be completed even though the imbalance is constantly working towards component failure.

This is the point at which the talent of a really good analytical engineer enters the supportability arena. Almost any experienced analyst or engineer can predict failure modes with reasonable accuracy when supplied with thousands or millions of bits of maintenance history data. Experience tells us specifically what generic or trademark parts are the weak links. We can learn to live with these weak links by stocking spare parts for repairs and, given enough experience, we can predict a time range within which failures are likely to occur. With this information we can fill our parts bins to the proper level, and we can replace worn parts before failure.

Combat damage is an unpredictable element which defies the laws of normal maintenance engineering. We can understand that the seals in a controllable pitch propeller will eventually leak and that propeller blade failures may be caused by FOD or that erosion will force us to replace propeller blades that are no longer efficient.

But propeller shrouds, for example, which are inherently reliable under normal circumstances are targets which may often need to be replaced in combat. To minimize craft downtime while assuring continued operation which will not cause catastrophic failure is our goal.

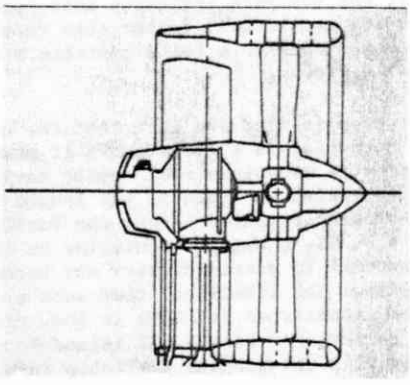
Two propulsor failure modes stand out as good illustrative examples:

- Propeller imbalance
- Loss of shroud structural integrity.

Propeller imbalance can be easily detected by the crew if the imbalance is sufficiently large or by instrumentation for lesser degrees. Imbalance detected by the crew would probably be cause for propeller shutdown unless the craft is in a life-threatening situation. Imbalance detected by instrumentation would require limits set analytically and, hopefully, experimentally.

For a commercial craft any imbalance which reached damaging limits would be cause for automatic shutdown. For a military craft this would be feasible for peacetime training operations. For wartime deployments battle override switches would be required. However when the override is being used some type of control panel warning or alert signal should warn the crew that the situation has become critical, and give an indication of the degree of the criticality.

To achieve this goal, dynamic analysis of the propeller and its effect on the shroud, shafting and gearboxes is necessary. Depending upon how much imbalance the propulsor can stand and still survive, the analysis may have to be carried to the propulsion engines and even the lift fans, since this is an integrated system.



Jeff (A) Propulsor Assembly

Loss of structural integrity of the propulsor shroud is much more difficult to detect prior to the occurrence of a major event like propeller tip contact. What may actually be happening is a gradual loss of structural strength due to fatigue within internal components. Instrumentation is possible but would probably be difficult as well as expensive for in-flight monitoring. Post-flight examination would allow maintenance personnel to determine structural integrity based upon remaining whole structural members or by using a strain gage to determine deformation relative to load.

DAMAGE CLASSIFICATIONS OR CATEGORIES

Damage could be classified or categorized one of two ways:

- that which is sudden and/or obvious
- that which is hidden and/or continuous

Sudden and/or obvious damage will probably manifest itself by a loss of system performance, while hidden and/or continuous damage may be lurking there waiting for the most inopportune time to reveal its presence. Each of these two classifications may be caused by malfunction or by combat damage. With these sub-sets in mind we must devise a way to provide sufficient spare parts aboard ship to last through at least one amphibious assault.

To do this we must use our maintenance history file to determine malfunction spare parts requirements and we must analyze the likelihood that a part will require replacement due to combat damage. The former is sometimes inexact due to the wide range of values around the mean; while the latter will be inaccurate due to our lack of knowledge relevant to what threat we will meet, in what concentration, when and where.

The result of this analysis will probably be:

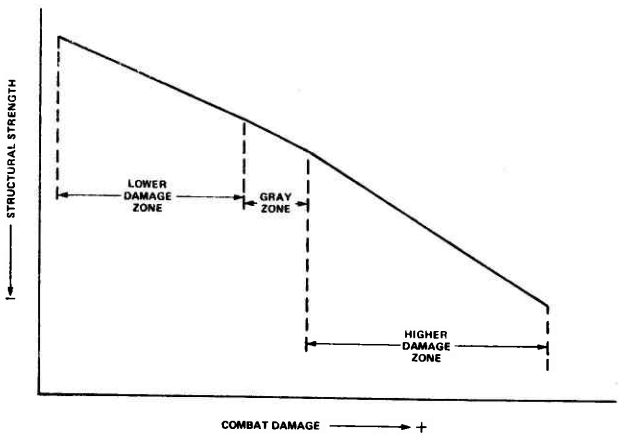
- That for parts which we may expect to replace often due to malfunction, we will probably have more than enough spares for the combat damage situation.

- For parts that we would not spare due to their long life we should carry at least one spare if our analysis indicates that combat damage may require replacement rather than repair to return our system to a fully operable status in a reasonable time.

We must keep in mind the fact that the combat damage potential is a guesstimate if made before the system is used in a real combat environment. For a protracted war such as was fought in the island-hopping assaults across the Pacific Ocean during W.W. II, a data base similar to our peacetime material (3 years) history may become meaningful. The likelihood that such a data base could be established for ACVs is low, since a repeat performance of W.W. II island-hopping is unlikely with the weapons available in the 1980s.

CONCLUSION

Combat damage which is obvious is also accessible and most likely easily assessable. Since obvious damage is visible and measurable, an assessment of where, when and how to make repairs is easily accomplished. But combat damage which is hidden and inaccessible requires innovation to determine its severity and repairability. The analyst is faced with a task of indeterminate scope since he doesn't know the boundaries of the expected damage. With this in mind he must try to confine the task within the limits of repairability. These define two significant zones of damage. The lower zone of damage does not have significant structural degradation and does not require repair at the moment. The higher zone of damage contains structural degradation which requires repairs now. But! There is a gray zone in between these two, where we may have doubts about repairing it now or taking a chance on letting it wait. And that is the subject of another dissertation.



Repair Decision Zones

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THE POTENTIAL FOR MILITARY HOVERCRAFT ON NATO'S NORTHERN FLANK

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ABSTRACT

During the late 1960's and early 1970's the British Army pioneered the use of air cushion vehicles (ACV) to carry high speed, tracked, oversnow vehicles on NATO's northern flank. Today several new ACV's are being developed which use marine construction techniques and diesel engines and which could provide the same mobility developed earlier but at reduced across-the-board costs. A replacement for the original tracked vehicle has also entered production to further enhance the mobility combination offered by the ACV and oversnow vehicle.

INTRODUCTION

In recent years an increased emphasis has been placed on the defense of the northern flank of NATO, the northern coast of Norway in particular. Nato planners have devoted much attention to the mobility (or lack of it) of NATO troops who must be prepared to fight there. Exercises have been held in Norway almost yearly to develop the capability to fight there and evolve techniques to move men and materiel in a cold and wet environment.

The Norwegian coast is characterized by deep fjords extending many miles inland, which are seldom frozen over completely but often have stationary ice at the inland end. The climate is cold and wet; i.e., snowfalls are heavy, but the Gulf Stream keeps temperatures high enough to make the snow heavy and wet--very difficult for ground vehicles. It is also frequently overcast and foggy, making aviation, particularly helicopters, of marginal value.

BACKGROUND

One of the more significant mobility experiments in this area has been the use by the British Army of ACV's in combination with light-tracked oversnow vehicles. During the early 1970's the British Army decided to modify two SR.N5-6 class ACV's by providing a central well deck capable of accepting a BV-202 articulated oversnow vehicle or a land rover and a light 105 mm howitzer or other vehicles and equipment dedicated to north flank operations.

The British Army's use of ACV's in Norway was not only pioneering but startlingly successful. During one of its exercises it employed two standard SR.N6 craft troop carriers, two of the MK5's (central well deck), and two smaller fan-propelled CC-7 eight-seater vehicles. During field tests troops, vehicles, cargo, and light artillery were transported from shore to shore and ship to shore, with some of these exercises being conducted at night and in weather totally unsuitable for flight operations. In many cases the ACV performed missions that would have been impossible for displacement landing craft, and in all cases the men and equipment were landed dry shod, an extremely important factor considering the climate. The ACV saved time not only because of their speed but also because of their ability to move along the coast rather than follow the few circuitous and vulnerable roads in the Norwegian fjord country.

One US Marine Corps observer of the test reported: "Results of that test showed that because of bad weather the helicopter could only operate 50 percent of the time, while the hovercraft operated 100 percent of the time. Because of its ability to operate year round 100 percent of the time, and the outstanding water accesses to, or near, the populated and tactically important areas, the hovercraft's value in northern Norway is immeasurable. Its advantages are many and its disadvantages almost nonexistent." There are, of course, disadvantages--money, for instance. ACV's are expensive both to build and operate. Today, 10 years later, the problem is the same, the requirements are the same, and the basic solutions are the same. Only the hardware has changed, and with it has come some solutions to the primary disadvantage.

In 1982 the amphibious prime mover could be either the British AP.1-88 or the Finnish PUC 22, and the oversnow vehicle is the Swedish BV-206. All are new state-of-the-art diesel-powered vehicles, which in combination could provide the improvement in mobility needed on the northern flank but at a cost that would be acceptable.

AP.1-88

The AP.1-88 is a diesel-powered ACV being built by the British Hovercraft Corporation (BHC). It is a general-purpose ACV designed to replace the SR.N6-type craft built since the early 1960's. The basic design is for an 80-passenger amphibious ferry; however, plans exist for military versions (e.g., a vehicle to carry 60 fully-equipped troops or an open-decked vehicle capable of carrying two long-wheelbase landrovers, a BV-202 or 206 oversnow vehicle and trailer, or up

to 7 tonnes of cargo). The basic structure is built of light marine alloys, which are welded. The propulsion and lift will be provided by four air-cooled diesel engines driving two shrouded propeller and eight centrifugal lift fans. Bow-mounted swiveling thrusters (similar to those on the US Navy experimental JEFF B AALC) will aid in directional control as well as providing forward thrust while underway. Trim is provided by fuel ballast transfer as well as differential lift engine throttling since the lift and propulsion systems are not integrated as they were on the SR.N6.

Its engines are easier to repair and much easier to filter than gas turbines. Although the entire craft is heavier (engines and structure), more efficient engines and the more efficient tapered low-pressure ratio skirt make its performance nearly that of the SR.N6 while burning much less fuel. The disposable load is 43 percent of the empty weight of the AP.1-88 as compared with 45 to 55 percent on gas-turbine craft. Nevertheless, the only performance criterion sacrificed is dash speed, which the diesel craft will not have. Its cruise speed, however, will remain competitive. The bottom line is cost. It is estimated to be less than half of a comparable turbine machine with similar operating costs. Although maintenance is more frequent, it is cheaper and the type of labor required is cheaper. While fuel consumption is only somewhat higher at cruise speeds, a real savings is expected for the periods of idle while being unloaded and loaded. It is during this idle period the diesel has an exceedingly better fuel consumption, a point that should not be passed over in military considerations.

One of the most important military considerations is the drain of ACV's on qualified military personnel. It should be pointed out that turbine maintenance personnel are very much more difficult to find and replace than diesel mechanics. Watercraft hull maintenance people are also easier to find and hold than airframe mechanics. In short, the AP.1-88 is less expensive to build, operate, and maintain. Details of the AP.1-88 follow:

Length (m)	20.7
Width (m)	10.1
Height Static (m)	4.3
Height on cushion (m)	4.9
Cabin (or well) length (m)	12.8
Cabin (or well) width (m)	4.0
Max weight (kg)	27 200
Max disp load (kg)	8 160
Empty weight (kg)	19 040
Fuel cap (L)	1 705
Fuel consumption (L/h)	273
Endurance (h)	6
Max hover height (m)	1.1
Max speed	100 at 0 wave height (m)
	80 at 0.5 wave height (m)
	60 at 1.0 wave height (m)
	50 at 1.5 wave height (m)
Power:	
Propulsion	2 - Deutz air-cooled V-12 diesels, 419 kW each (BF 12L 413 FC)
	2 - 2.6-meter-diam ducted props
	2 - Bow thrusters
Lift	2 - Deutz air-cooled V-10 diesels, 192 kW each (BF 8L 413 F)
	8 - 0.84-meter centrifugal fans

Polar Utility Craft

Several years ago Wartsila of Finland announced the development of a new series of air cushion vehicles under the general heading of Polar Utility Craft or PUC. The series includes both self-propelled vehicle ferries and towed air-cushion barges for lighterage from ships lying off shore.

Three points of particular interest make the PUC series notable for the Norwegian task. First, they are diesel powered and like the AP-1.88 have all of the advantages that characteristic brings. Second, also like the AP-1.88, they employ a marine construction technique requiring fewer parts, cheaper labor, and have a more robust (but heavier) structure. The third feature makes the PUC series uniquely suited among ACV's for the northern NATO role in that they were designed for use in, on, and over ice and ice-covered seas. Indeed the barges are on order for use as lighters for ice-working cargo ships.

The PUC 22-2500SP or Larus was designed as a ferry for transport of motor vehicles including commercial trucks between islands in the Baltic during the winter period when normal displacement ferries cannot operate. Of particular interest is its skirt which is designed to operate over ice which has refrozen after the passage of ice-breakers which operate in the Baltic. This type of ice is extremely abrasive and damaging to skirt material and early reports show the PUC 22 skirts to be standing up well.

PUC 22 has an all-up weight of about 100 tonnes with a payload of 22 tonnes and 50 passengers. The cargo is carried on a drive-through well deck, and propulsion and steering come from four swiveling shrouded propellers--one on each corner. The configuration is reminiscent of the Aerojet JEFF A AALC. PUC 22 LARUS details follow:

Length (m)	33.0
Width (m)	14.7
Cushion height (m)	0.8
Max weight (t)	100
Cargo weight (t)	22
Passenger capacity	50
Max speed (km/h)	35
Power	4 - diesel 650 kW each

BV-206

The Hagglunds BV-206 2-tonne, oversnow, adverse-terrain vehicle is now in production for the Swedish, Finnish, Norwegian, British, and Netherlands armies. The first production vehicles were delivered to the Swedish Army in October 1980, and full production began in 1981. The vehicle has met its original objectives; primarily, similar performance to the BV-202 it is to replace, but with a 2-tonne rather than 3/4-tonne payload, a higher road speed, and significantly lower maintenance requirements. The characteristics of the BV-206 follow:

Length (mm)	6890
Width (mm)	1850
Height	2400
Ground contact length (mm)	4000 approx
Track width (mm)	635
Ground clearance (mm)	350
Payload weight (kg)	2000
Seats	16-17
Curb weight (kg)	4200
Gross weight (kg)	6200
Towed weight (kg)	2500 approx
Speed (km/h)	55
Range (km)	330 on roads
Gradient (%)	60 hard slope, 30 deep snow
Ground pressure (kPa)	12
Engine type	Spark ignition, V-6
Power (km at r/min)	100 at 5200
Torque (N·m at r/min)	216 at 3000
Fuel type	Gasoline
Fuel capacity (L)	80

The current state-of-the-art in oversnow vehicles is the Swedish BV-206. Although this is a rather sweeping statement, in many ways the 206 is both the current state-of-the-art and, for the foreseeable future, the forecast state-of-the-art. The BV-206 uses a combination of mobility aids that places it in a unique high-mobility category. It is the only production vehicle in the world using both three-axis articulation and powered articulation as a steering method. Although a diesel engine has been listed as an option on the BV-206 for several years, it had only existed on an early first-batch prototype chassis. A diesel version will now enter production.

The diesel will be a Mercedes-Benz five-cylinder, in-line, turbocharged, prechamber engine, the OM 617A. It produces 85 kW at 4200 r/min.

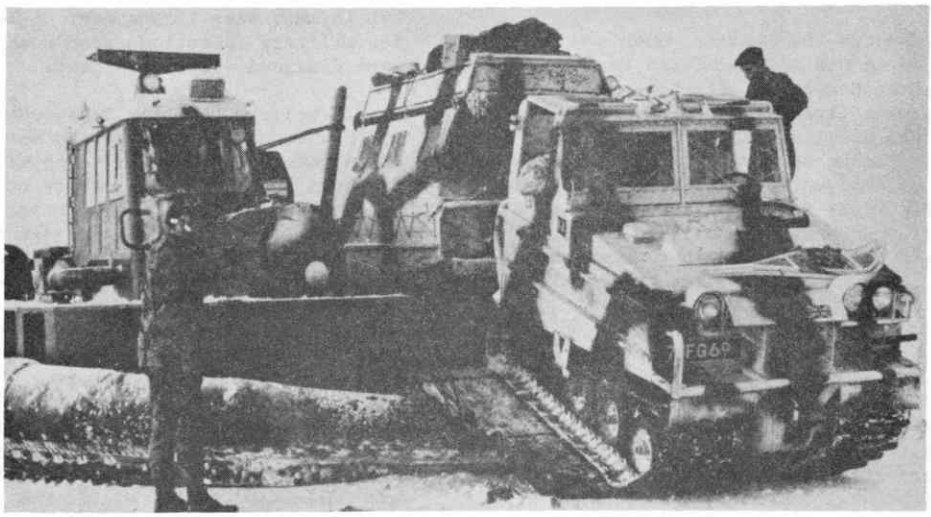
With the beginning of production and acceptance of the 206 by the Swedish Army, the 206 can now be said to be a fully tested, production, off-the-shelf item.

CONCLUSIONS

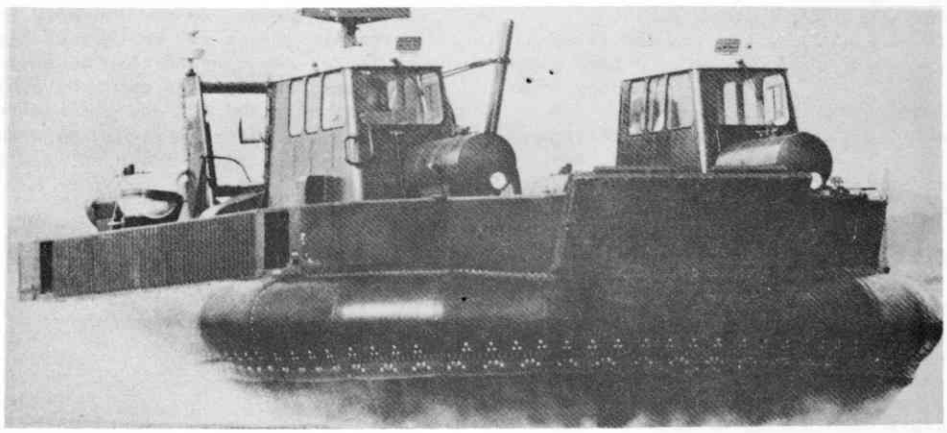
It should be emphasized here that these vehicles represent a direction of development to produce vehicles which are practical for military use. Neither of the ACV's were designed for or are currently being built for use by the military, but in many ways they appear to be more suitable for military operations than some of those which were designed for the purpose.

I believe that the emergence of the British and Finnish ACV's heralds the most significant ACV developments in 20 years. The air-cushion industry has been hobbled with aircraft structures and aircraft engines since the invention of the ACV by aircraft structures and aircraft engines since the invention of the ACV by aircraft companies in the 1950's and 1960's. We have now reached a point where we are crossing to marine technology to use welded marine structures and diesel engines. The results are craft that are much more robust and easier to maintain and repair.

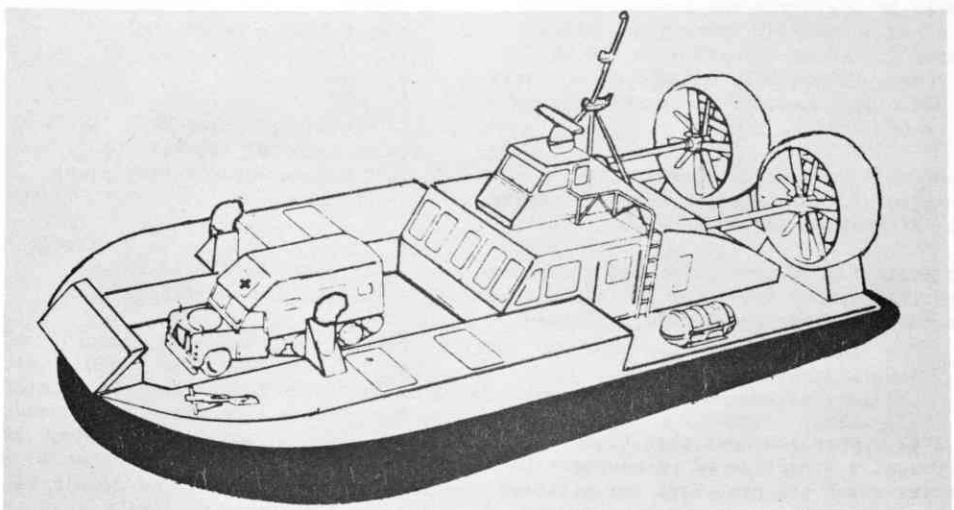
The vehicles described here can measurably increase mobility on the battlefield while saving both money and manpower resources. They are well-thought-out, viable systems, which bespeak current state-of-the-art thinking in their respective fields. But it is in combination as a mobility system that they may be of their greatest utility to NATO. As the British Army once did in northern Norway, so now can NATO forces be transported in almost any weather at high speeds and be landed dry shod to then be moved and supported at high speed in deep snow and other adverse conditions. The ACV and tracked vehicle mobility combination offers a viable solution to a number of long-standing problems on NATO's northern flank.



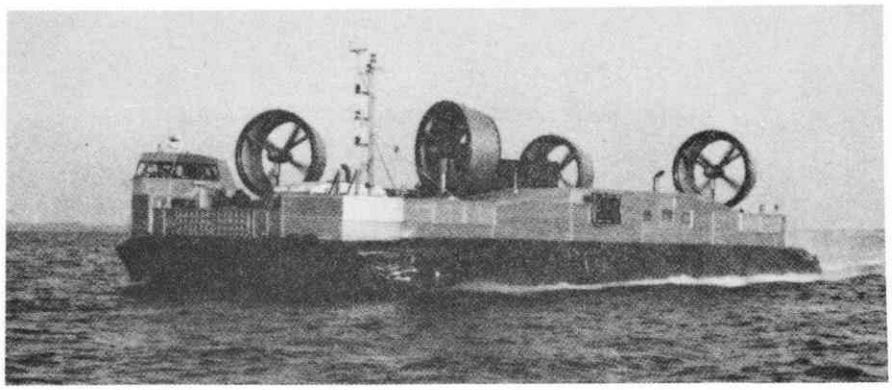
SR.N6 MK5 OFF-LOADING BV-202



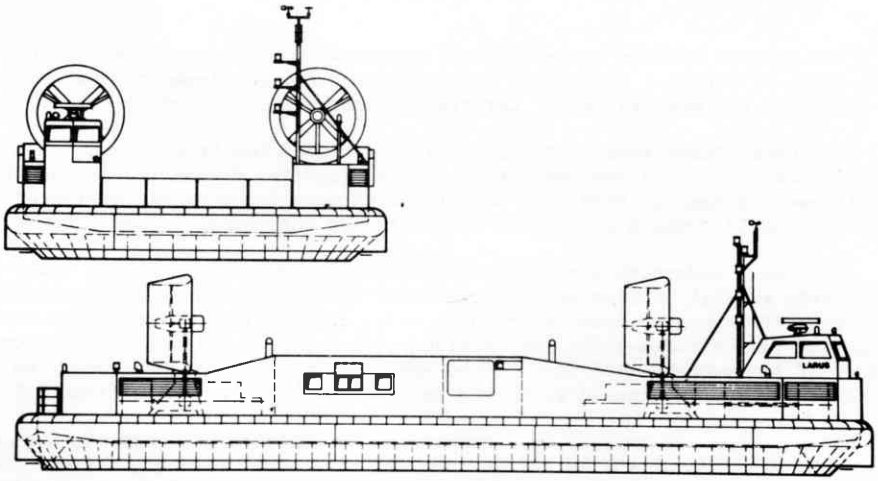
SR.N6 MK5 WITH WELL DECK



AP.1-88 WITH PROPOSED WELL DECK



PUC 22 "LARUS"



PUC 22 "LARUS"



BV-206 OVERSNOW VEHICLE

WEST COAST UPDATE - CANADIAN COAST GUARD

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ABSTRACT

Air Cushion vehicle activities are progressing at a steady pace on the West Coast of Canada. This paper will cover our new developments and serve to introduce new members to our thriving and successful operation.

The Coast Guard base at Vancouver International has been designed for A.C.V's and reflects a combination of modern practical design. Vehicles are maintained and managed from this facility with many ideas being incorporated into the facility which will serve as a standard for future Canadian bases.

This base undertook a major refurbishment program when a NTL N6 was completely rebuilt to best possible SAR specifications. The vehicle had many new ideas incorporated into the rebuild and a combination of long range fuel tanks and rear bleed sealing has provided a fast easily trimmed SAR hovercraft. Slides of the vehicle will show before and after configurations. The rebuilt vehicle has been designated as CG 045 and will be based at Parksville, B.C.

A cost comparison study was produced to demonstrate the economic and practical benefits of the N6 ACV as compared to a similar length vessel. One benefit was the cost of the base. Parksville base is an indication of such a cost effective facility. Drawings and slides will show this facility.

A course was introduced to demonstrate to senior CG officers the benefits and economics of the ACV in the CG role.