DEVELOPMENT OF THE U.S. ARMY'S PONTOON AIR CUSHION KIT (PACK)

By

Daniel L. Wilkins, Band, Lavis & Associates, Inc.
Michael J. Plackett, M.J. Plackett and Associates

1.0 INTRODUCTION

The armed forces of the United States are required to have the capability to conduct amphibious landing operations. The Navy, the Army and the Marines may all be involved in this task of ferrying troops ashore together with their vehicles, arms and equipment. The landing is usually organized into three phases:

> ***The Assault Echelon (AE):*** The AE comprises the initial assault during which marines are carried ashore by helicopters and by tracked amphibians (LVTs). Once the beachhead is secured, these first waves are followed by the Tank Landing Ships (LSTs) and by pre-loaded landing craft, including LCAC's, launched off-shore from the Navy's dock ships.
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> ***The Assault Follow-On Echelon (AFOE):*** The AE accounts for most of the Marine Corps personnel but perhaps only one-third of their vehicles, supplies and equipment. The remaining two-thirds come ashore in the AFOE.
>
> ***The General Offload Phase:*** If the Army is brought into the operation, its personnel, stores and equipment are put ashore in a joint (Army/Navy) logistics-over-the-shore (JLOTS) operation.

The methods used to get the personnel and material from the ocean-going ships to the shore and across the beach to their destination are different for each phase of the landing. During the General Offload phase U.S. Navy craft will be augmented, or replaced, by the Army's two classes of air-cushion vehicle; the LACV-30 and the Lighter, Amphibian, Heavy Lift (LAMP-H) which is currently under development. These amphibious ACVs will be supported by the Army's array of other watercraft which include LCMs, LCUs, causeway ferries, and the LARC LX wheeled amphibian. The displacement craft all require a firm, relatively steep beach in order to effectively offload, as shown in Figure 1. At some point during a general offload over shallow beach gradients, it is highly effective to erect elevated or floating causeways at which some of the ships and displacement craft can be offloaded directly. A floating causeway is shown in Figure 2.

The Army also has a mission for autonomous amphibious assault where all over-the-shore delivery of personnel, equipment, and supplies will rely solely on Army watercraft.

2.0 PACK CONCEPT OF OPERATIONS

The. U.S. Army and Navy presently utilize modular pontoons, which bolt and weld together, to field-assemble causeways, causeway ferries, warping tugs, and RO/RO discharge facilities for use in the JLOTS mission. It is expected that the U.S. Military will soon begin acquisition of 40' x 8' x 4.5' interlocking modular barge sections of the type which have been in commercial use for many years. The U.S. Army will utilize these modules to field-assemble barges and causeways to be employed for Army amphibious offload operations. A typical module and an assembled barge are shown in Figures 3 and 4.

Figure 1. Causeway Ferry Offload On Steep Beach

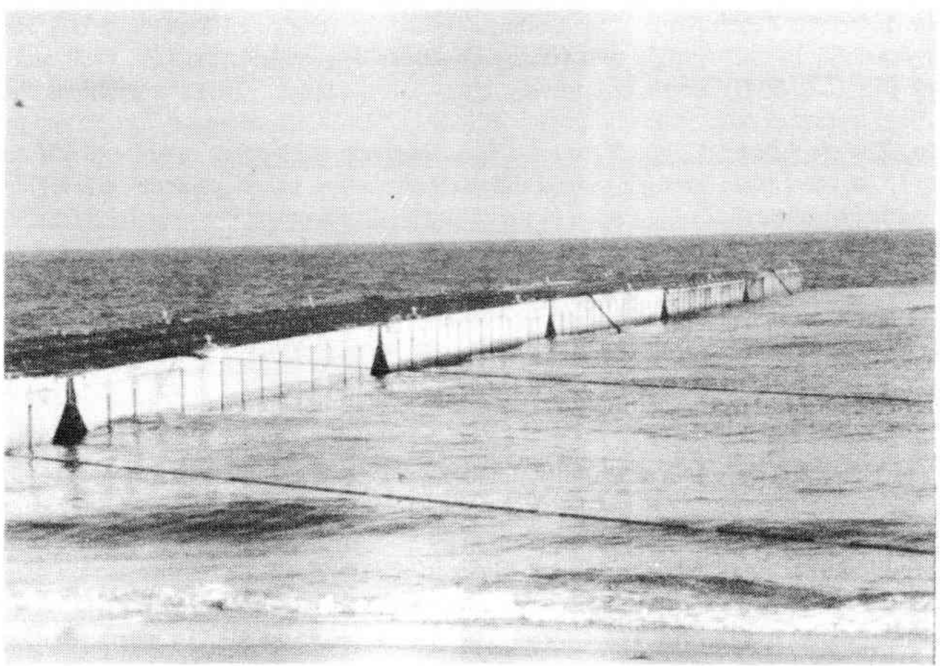

Figure 2. Floating Causeway for Deep-Water Offloading

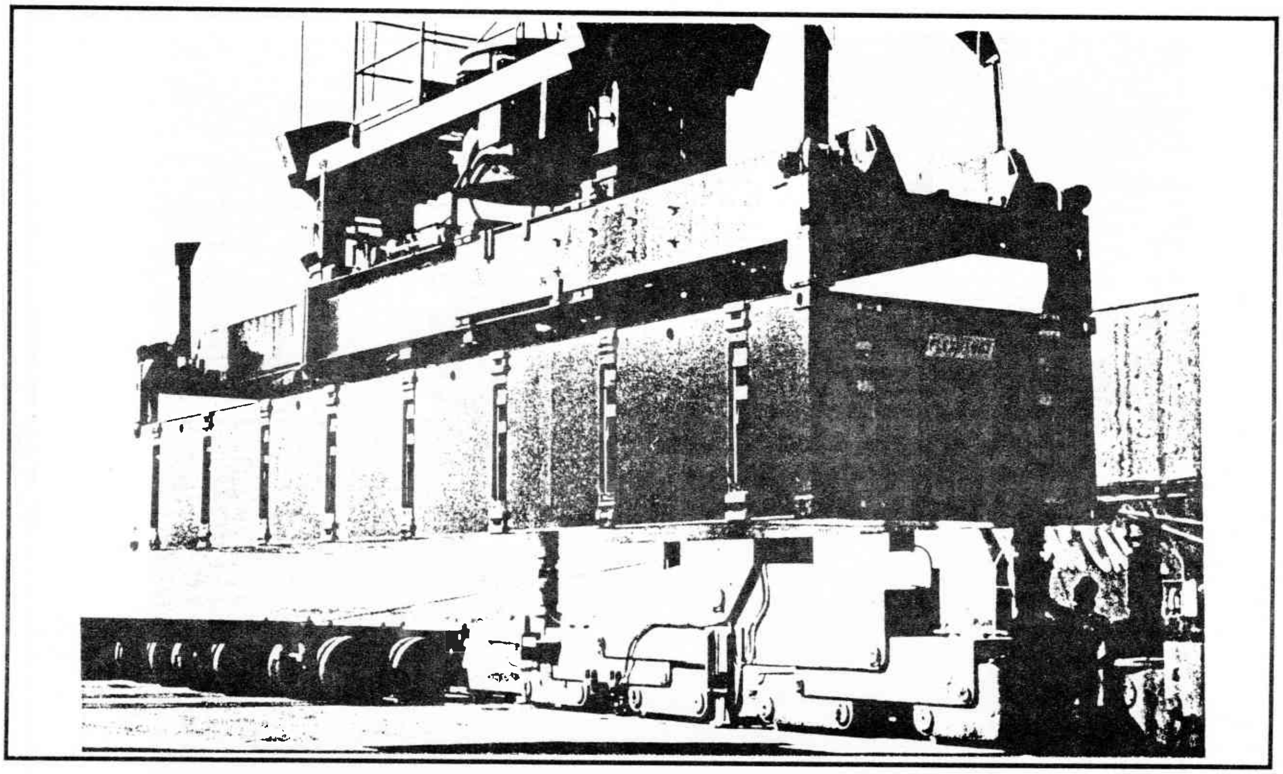

Figure 3. Barge Module Showing Perimeter Connectors

The Pontoon Air Cushion Kit (PACK) has been developed for the purpose of field-outfitting a pontoon barge or causeway section with a peripheral flexible-skirt system and an autonomous air-supply unit which will enable the barge to operate as an amphibious air-cushion supported platform. The value of the PACK system for increasing the military-effectiveness of inventoried U.S. Army assets has been identified for three primary LOTS operations:

1. With the addition of an overwater tug (e.g., displacement lighters or Side-Loadable Warping Tugs) and a surf-zone/overland tow (e.g., bulldozers, trucks, winches), or an amphibious tug such as a LACV-30 or CH-47 Helicopter any modular barge can be converted to a heavy-lift hoverbarge capable of contributing significantly to the Army amphibious offload mission. Figure 5 shows a PACK with a LACV-30 tug. When utilized as an amphibious hoverbarge lighter, an 80' x 24' barge (six 8' x 40' modules) outfitted with the PACK system can transport the largest piece of U.S. Army equipment involved in the amphibious offload, the PH9125 Truck Crane (90.5 short tons). This crane is needed ashore in order to offload LACV-30s and other lighters carrying containerized cargo, yet cannot presently be transported fully-assembled by any U.S. Army amphibians. The PACK can also transport the Army's main battle tank, as shown in Figure 6. At overload condition the 80' x 24' PACK-barge can transport two of the M1E1 tanks.

2. A causeway can be constructed over extremely shallow beach gradients and marginal terrains (mudflats, marsh) by positioning a PACK-equipped causeway section, coming off-cushion, and removing the PACK to outfit a subsequent section. Elevated causeways can presently be erected seaward from the beachhead but the components must first be transported ashore. With the advent of operational LCAC Assault Craft Units, the potential for amphibious assaults over shallow beaches and marginal terrains is greatly increased.

3. The use of a PACK on the lead section, or sections, of causeway ferries may allow the ferries to be pushed over sandbars or up to shallow beaches without grounding.

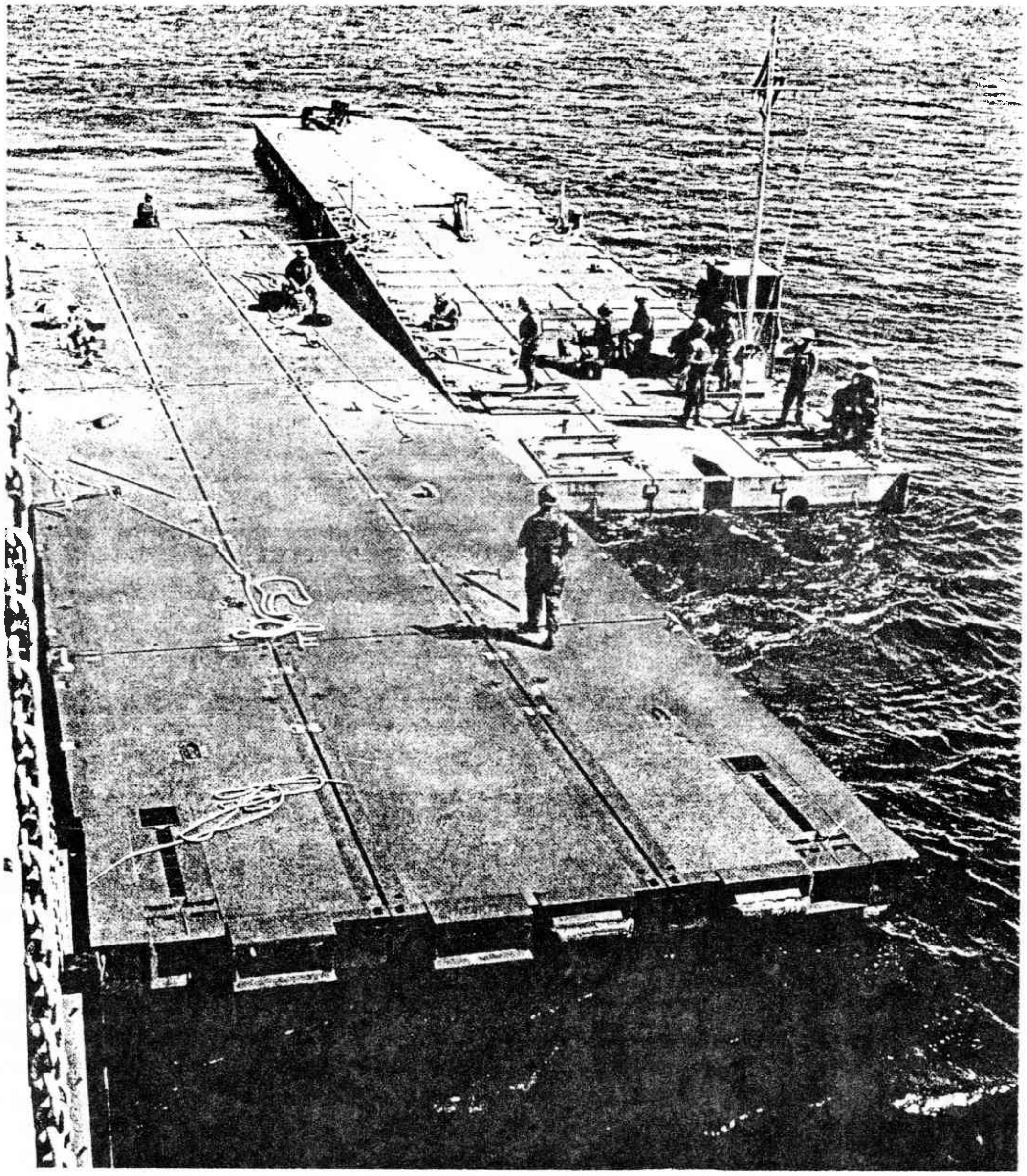

Figure 4. Modular Barge Assembled Alongside Ship

The PACK may also have secondary uses in both combat and non-combat missions relating to construction and salvage operations over marginal terrains and to general heavy-lift and amphibious operations.

The prototype PACK system is being developed to perform critical "one-time" missions such as transporting the Army's 140-ton capacity crane ashore or building a causeway across shallow beaches or marginal terrains. The skirt materials and weights suitable for this type of service-life profile are different and lighter than conventional ACV skirt materials, as will be discussed later in this paper. The PACK concept can be expanded to long-term hoverbarge mission applications by increasing the weight (durability) of the skirt material.

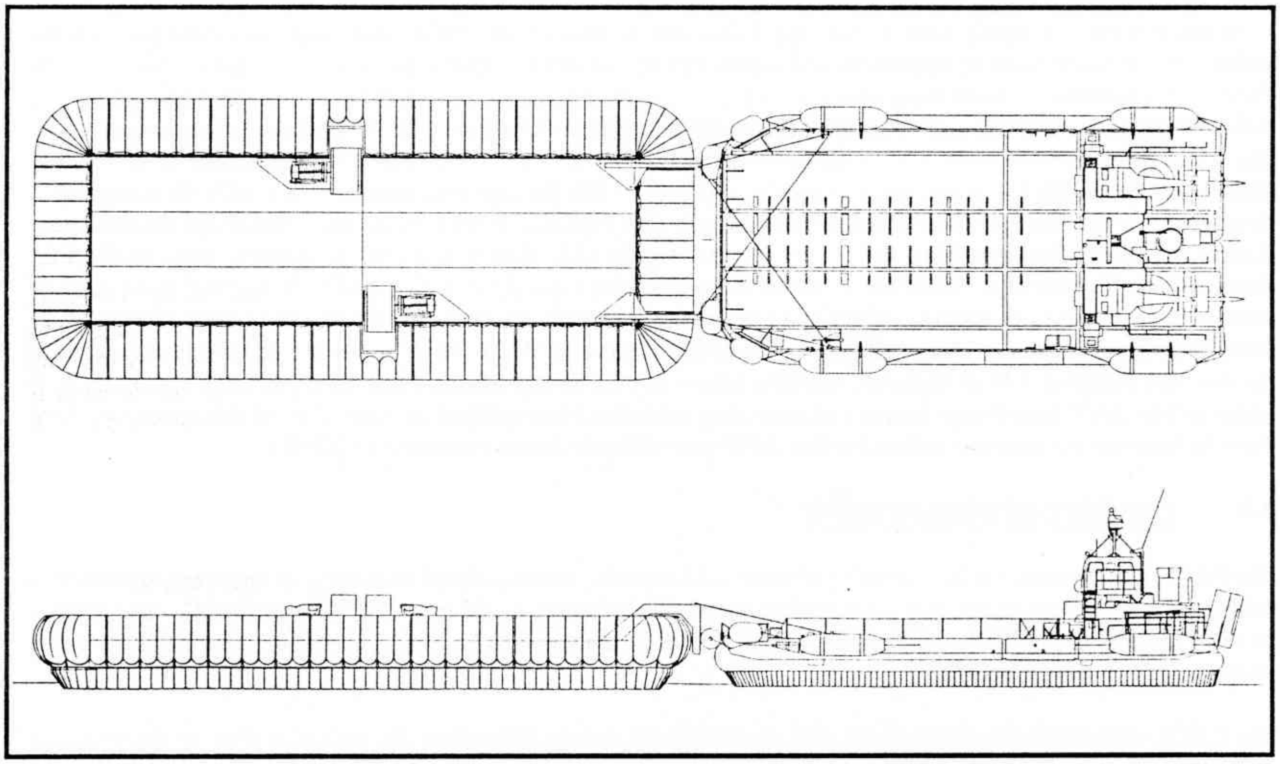

Figure 5. PACK With LACV-30 Tug

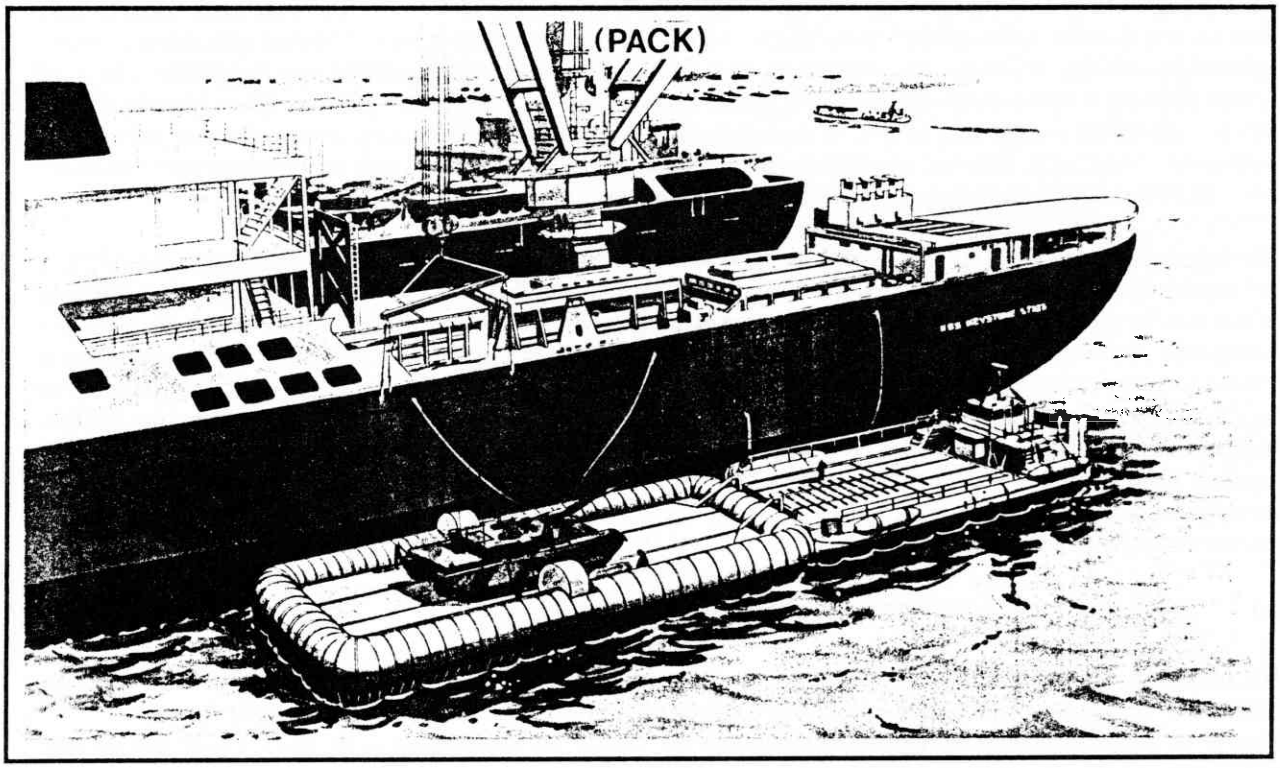

Figure 6. PACK Loading Alongside T-ACS Ship

The PACK-equipped barge will be outfitted with a towing bridle and with push knees. Conventional Army watercraft assets such as warping tugs, LCMs, and LCUs can be utilized for PACK propulsion overwater and conventional vehicle assets such as bulldozers and trucks can be utilized for PACK propulsion overland. However, the "hand-off" operation between these conventional assets in the surf-zone area could be difficult in high-surf or over marginal terrains. Therefore, the primary Army amphibious assets identified as PACK tugs for critical missions are the LARC-LX (firm terrains), LACV-30 ACV and CH-47 helicopter. The LARC LX is capable of developing approximately 20,000 lbs of tow-force overwater and over 50,000 lbs over firm terrain. The LACV-30 is capable of developing 5800 lbs of tow-force and could tow the full-load PACK at 3-knots overwater and through the tidal zone. Recent demonstrations involving the LACV-30 pushing the U.S. Armys D-PAAC hoverbarge have verified the feasibility of this operation. However, overland slope-climbing capabilities with a LACV-30 tug will limit overland transits to near zero-slope terrains. The CH-47 helicopter is capable of generating tow forces of up to 30,000 lbs for short endurance missions. This capability would enable a full-load PACK to be towed at 8 to 10 kts overwater and up overland slopes of 1:14 (4 degrees). Demonstrations of a helicopter towing a displacement barge overwater at 10 knots and an ACV hoverbarge over-ice at more than ten knots have verified the feasibility of this operation. U.S. Navy helicopters are routinely utilized to tow ASW gear with tow forces exceeding 10,000 lbs.

3.0 CONCEPT OF DEPLOYMENT

The PACK skirt system has been developed to be field-assembled and outfitted on a barge or causeway section by a minimum crew of four using only such manual tools and equipment as are provided with the PACK. The deployment of the air-supply lift fan and engine modules will be accomplished utilizing available cargo-handling assets such as small cranes or forklifts.

The PACK system can be deployed on, and removed from, barges located on the deck of a ship, in the water, or overland. All components of the PACK skirt system break down for compact stowage and shipment. Each lift fan and engine module is a skid-mounted, self-contained unit. An entire PACK, including maintenance and support equipment, for a barge 80 feet long and 24 feet wide will likely stow in a MILVAN-sized container (8' x 8' x 20').

All components of the PACK skirt system are readily assembled and deployed. The assemblies and barge connections involved can be accomplished under adverse conditions and weather extremes. The skirt material is relatively lightweight and easy to handle. The attachment of the skirt system to the barge modules is accomplished with a rail system utilizing a modification of the existing barge module-to-module connector systems. These module connectors are inherently rugged and simple in operation, having been designed for long service life and severe field conditions. The PACK rail skirt-attachment system can be designed to interface with any manufacturer's modules, since all modules have some type of perimeter connector system.

The largest components of the PACK skirt system which must be handled and deployed by the crew are five-foot rail segments, with fingers attached, which weigh approximately 160 lbs. The entire skirt system may be deployed or removed by a crew located on the deck of the barge or causeway section. The PACK lift-air supply modules will incorporate aluminum-alloy centrifugal fans powered by GM diesel engines and will weigh about 4000 pounds each. These modules will be deployed by cranes, hoists, or forklifts which may be available onboard ship, on warping tugs, or on the beachhead. The securing of the lift-air supply modules will be accomplished utilizing the multiple attachment and tie-down fittings incorporated in the standard barge modules. The fuel for the lift-fan engine will be supplied from flexible bladder tanks. The bladder tanks can be compactly stowed for transport, can be readily secured at convenient locations on the barge platform, and can be deployed in multiple units in order to meet extended endurance requirements.

4.0 DESCRIPTION AND DEPLOYMENT OF PACK DESIGN

The following discussion relates to the design development of the prototype PACK. The design of the prototype system has been influenced by the selection of a specific commercially available barge module for the proof-of-concept demonstrations and by the consideration that the service lift requirement of the skirt system will be relatively short. Some aspects of the eighth scale PACK model are shown in Figures 7 through 9.

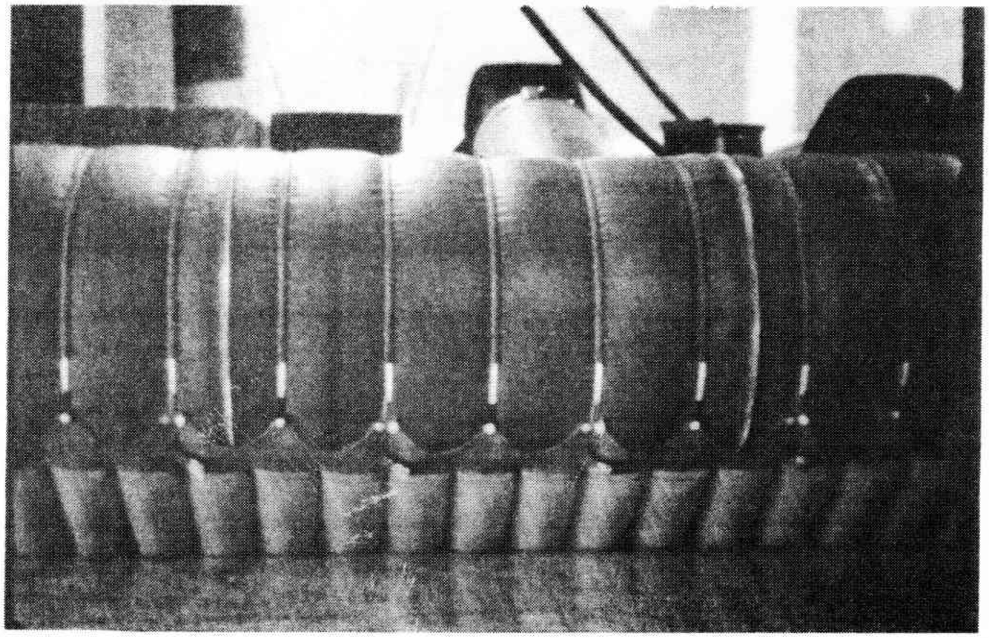

Figure 7. Side View of PACK Skirt

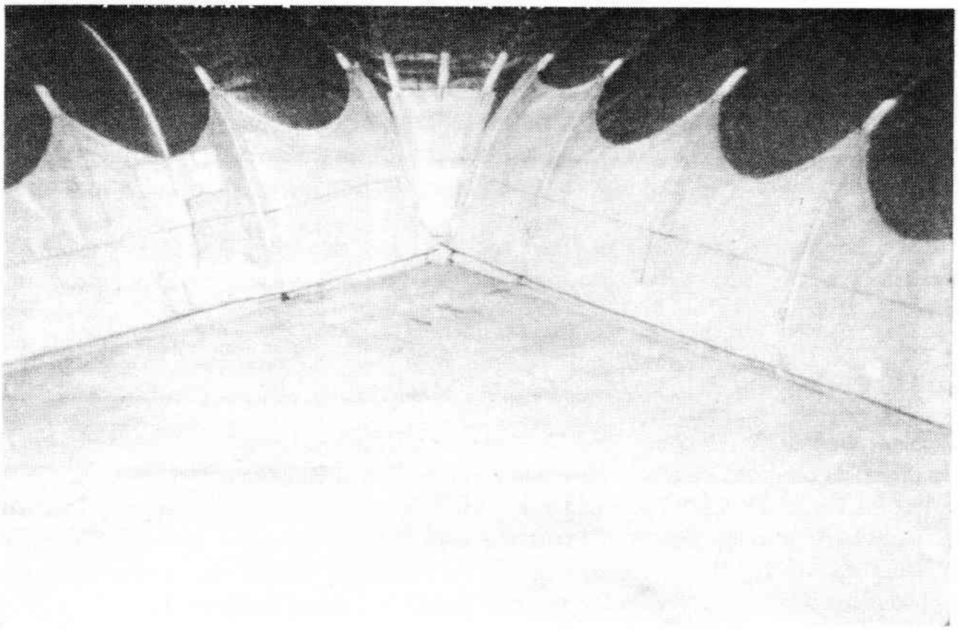

Figure 8. Deck View of PACK Bag

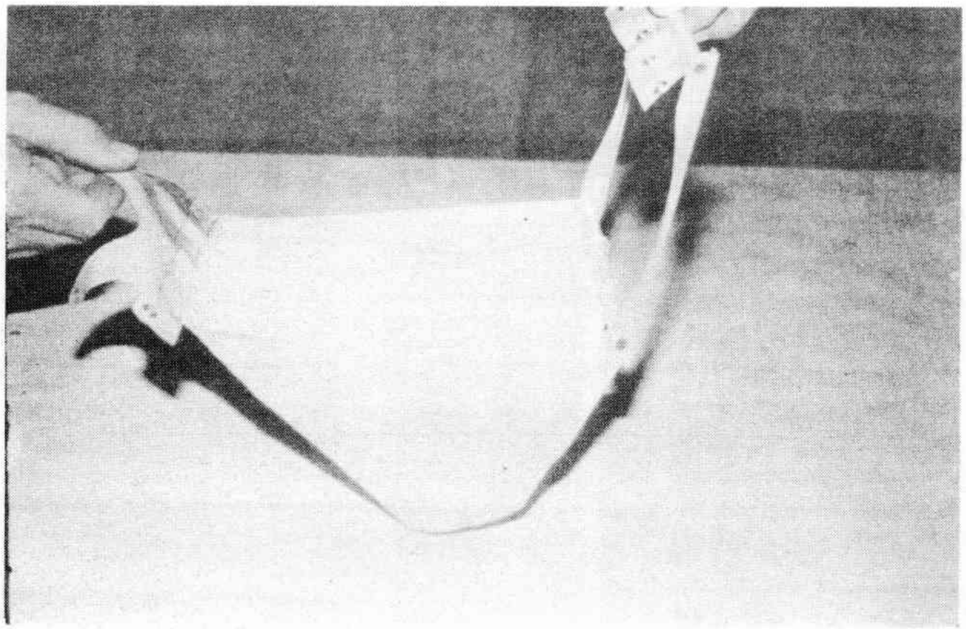

Figure 9. PACK Finger Module

4.1 Rail System

The rail system for the prototype PACK has been developed to interface with the Isolog barge modules manufactured by Robishaw Engineering. The Isolog modules utilize a double-ended bayonet-type pin and a steel-plate guillotine retainer integral with each module for fastening modules together. Pins are located at the top and the base of the module with each pair spaced every five feet around the perimeter (with some closer spacings at the ends of the modules). The rails supporting the PACK skirt system are fabricated in segments comprising a top rail, bottom rail, rail holders, and locking pins integral with the rail holders which replicate the Isolog Connector pins. This system allows for the sequential deployment of each rail segment utilizing the standard Isolog locking system.

It is considered that a rail system can be readily developed to interface with any module system which the U.S. Army might eventually procure. The connector designs of potential suppliers have been reviewed and suitable rail system designs have been identified.

4.2 Air Supply System

The air-supply units for the PACK will comprise a diesel engine driving an aluminum-alloy centrifugal fan through a clutch with all components mounted on a transportation and tie-down skid. The diesel proposed for the prototype system will be a Detroit Diesel 8V 92-TA producing 365 MCP hp at 1800 rpm and weighing approximately 2500 lbs. A GM diesel has been selected due to low cost and high ILS compatibility with the GM diesels currently installed in other Army watercraft. The air-supply modules for the PACK will be very similar to the unit developed as an experimental emergency recovery system for the JEFF B ACV as shown in Figure 10.

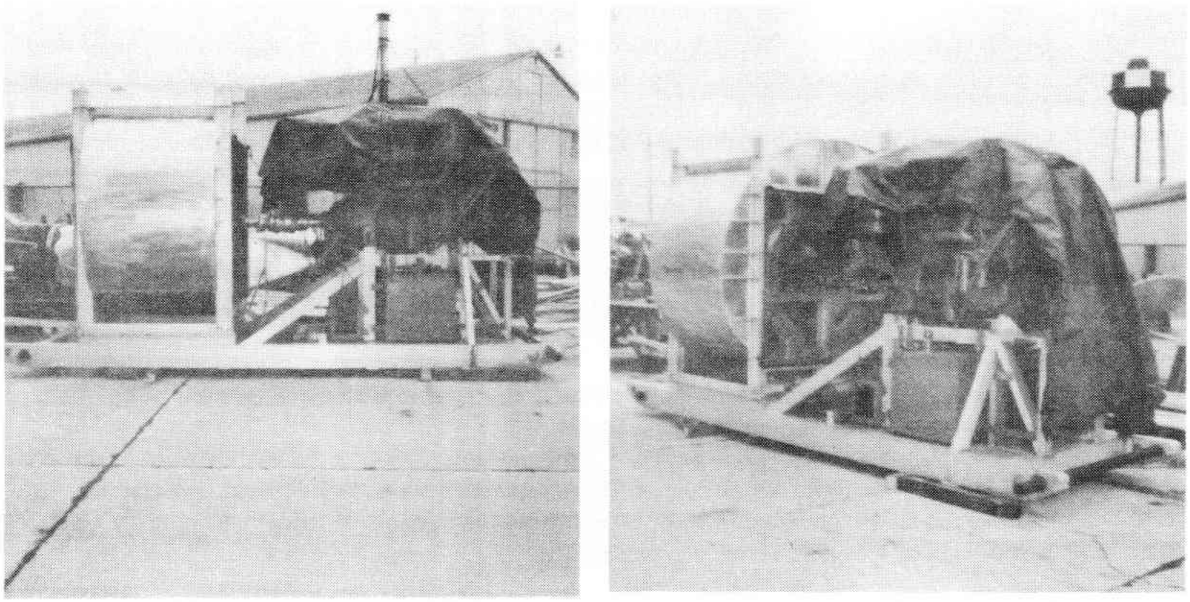

Figure 10. Lift-Air Supply Module for JEFF B Emergency Recovery System

The exact characteristics of the PACK lift fan will be determined after extensive tests with a one-eighth scale model PACK-equipped barge. A maximum required air flow of about 2000 cfs at 160 psf fan discharge pressure is anticipated for the full-load pack and this flow will be provided by two air supply units. When utilizing the PACK to emplace a barge as part of a causeway (no payload) it is probable that only one air-supply unit will be required.

4.3 Skirt System

4.3.1 Design Criteria and Constraints

The operational and deployment requirements for the PACK skirt system were formulated during the initial design studies conducted during mid-1987. From these studies the principle design criteria were established and are discussed briefly below:

- Cushion Area: The skirt system contains an area basically dictated by the area of the hard-structure platform configuration. Increasing the cushion area within feasible limits is desirable to reduce cushion pressure requirements.

- Cushion Height: For the baseline 80' x 24' platform configuration, a nominal cushion height of 3 foot is considered a minimum to meet the operational requirements of the PACK.

- Cushion Pressure: The skirt system should be capable of maintaining a range of pressures up to a nominal 140 PSF with structural integrity for spike pressures of 420 psf.

- Terrain: The skirt system must provide adequate sealing under full payload over water, through the surf, and over mud, sand, marsh, and scrub vegetation.

- Deployment Flexibility: The skirt system shall be capable of being adapted to a range of platform sizes using multiples of standard barge modules. A nominal platform size of 80' x 24' (6 modules) with two air supply units will be treated as baseline. The capability to increase the length and/or the width of the platform with additional PACK modules and air supply units will be incorporated.

- Modular Components: The skirt system shall be designed as a series of modular components that can be easily handled for deployment by several crew. As a goal, individual components should weigh less than 160 lbs. A minimum number of dissimilar components with a maximum degree of interchangeability will be achieved. The skirt system attachments must integrate with the rail system provided around the platform periphery.

- Air Supply Flexibility: The design of the PACK skirt system shall allow for multiples of air-supply units as necessary for various operating modes.

- Skirt System Assembly: Quick connect/disconnect type fittings shall be used. All components will be designed for simple attachment by crewmen wearing gloves under extreme climatic conditions. A minimum of specialized tools will be required.

- Packing and Storage: The entire PACK skirt system, including attachment rails and air supply ducting for a 80' x 24' platform configuration shall be capable of being packed in a standard 20' x 8' x 8' ISO container.

4.3.2 Design Approach

The skirt design requirements as outlined above have dictated a departure from the conventional skirt systems such as the bag and finger, pericell and loop, and segment types primarily because of the requirements for rapid deployment of modular components to suit a variety of platform configurations. The requirement to operate at relatively high cushion pressure also presents a structural concern which could be solved with heavier skirt fabric. However, heavy skirt fabric such as used on prior ACV's would prove extremely difficult to assemble and deploy. Other design constraints include the fixed positions for attaching the skirt to the platform (upper and lower rails), and the need to provide multiple access to the skirt system for additional air supply units.

Following a design study, a hybrid skirt approach was selected utilizing the loop and segment (or bag and finger) skirt geometry as a basis. Having established a geometry equilibrium for a bag-to-finger pressure ratio of 1.2, the skirt was separated into distinct modules. Instead of attaching the segments (fingers) to the loop (bag), the fingers are attached to a special harness. The harness is independent of the bag and is designed to transmit the finger loads through straps circumventing the outer bag. The fingers are attached inboard at the lower rail. The bag is a continuous loop of fabric with a continuous attachment at the upper rail. The bag is constrained in position by the straps which are also attached via a harness at the upper rails. By employing straps to transmit the major loop tension loads around the bag to the upper attachment, lightweight fabrics can be employed throughout the bag system.

As designed, the basic skirt system consists of three major components as follows:

(1) Finger segment components attached inboard to the lower rail and outboard to a special harness

(2) Support harness and straps which transmit the primary loads from the bag and fingers to the upper attachment, and

(3) The bag, consisting of a continuous loop of fabric attached at the upper rail and having bleed holes located over the finger segment to supply the cushion air.

These components can be seen in Figure 11. Figure 12 shows details of the skirt system as initially developed for the proof-of-concept PACK model. It should be noted that the current design has increased the width of the fingers (to reduce system weight) and integrated the finger-harness straps into the bag.

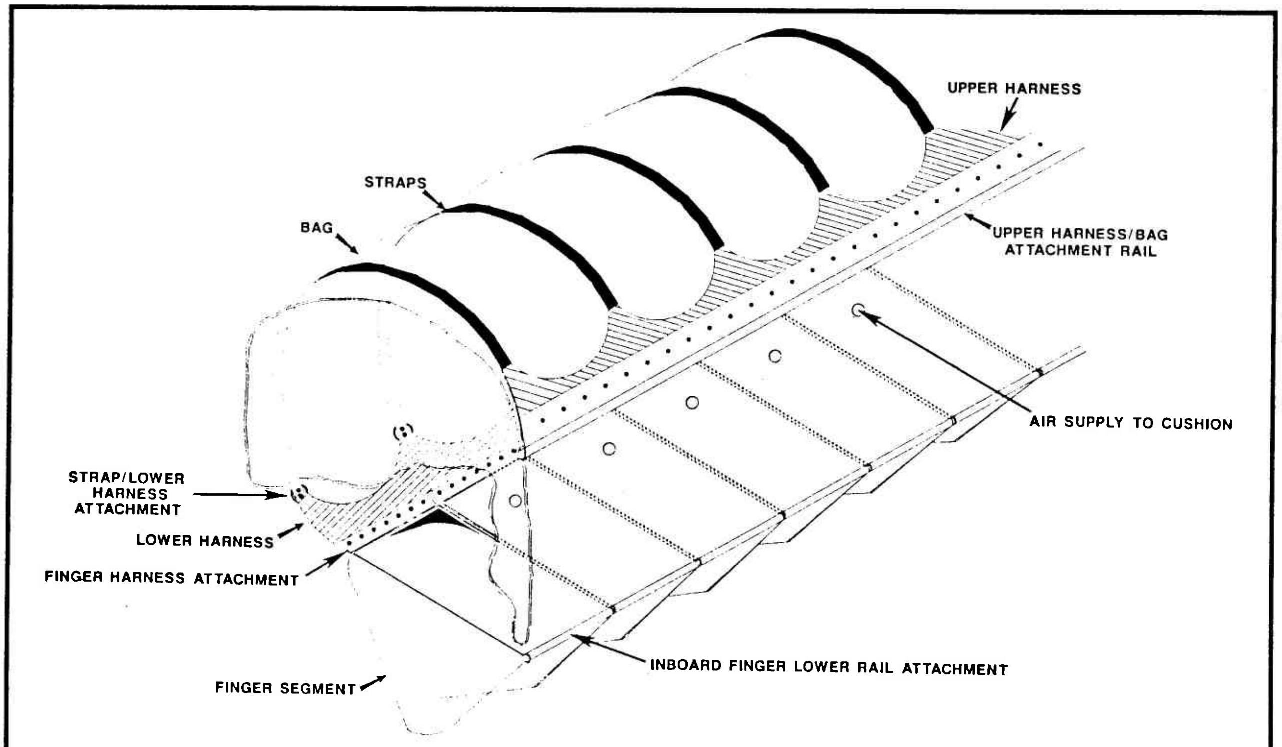

Figure 11. Details of PACK Skirt System

As previously discussed, a basic frame module sixty inches wide, having an upper and lower rail at forty-eight inch centers, is provided for attaching the skirt. A finger segment width of 20" was selected to allow three fingers per 60" wide frame. The 60" wide frame is a standard, interchangeable module around the platform. There are two corner modules (left and right handed) and a narrow (36") module for the forward and aft longitudinal connection of the platform modules. The corner modules employ six special 20" wide tapered fingers, a single 18" finger, and two 15" fingers. The change in finger widths, while undesirable from standardization requirements, is necessary because of the fixed constraints of the attachment frame. The narrow frame modules (36") used at the longitudinal module connection have two eighteen inch wide fingers.

The harness comprises three components: a lower harness where the outboard fingers are attached, a series of straps mechanically fastened to the lower harness, and an upper harness permanently attached to the straps. The straps are located in special pockets provided in the bag modules. The straps are free to move inside the pockets. The upper harness is continuously fastened to the bag.

The bag is formed of a continuous loop of material approximately 30 ft. long. Bag modules are broken into 20 ft. wide sections consisting of four 60" wide fabric sections bonded together. An industrial-type heavy duty zipper is used to fasten the modules together to form a continuous bag surrounding the platform. Special corner bag modules fabricated from flat pattern curved sections provide the transition from the sides to the fore and aft bag modules.

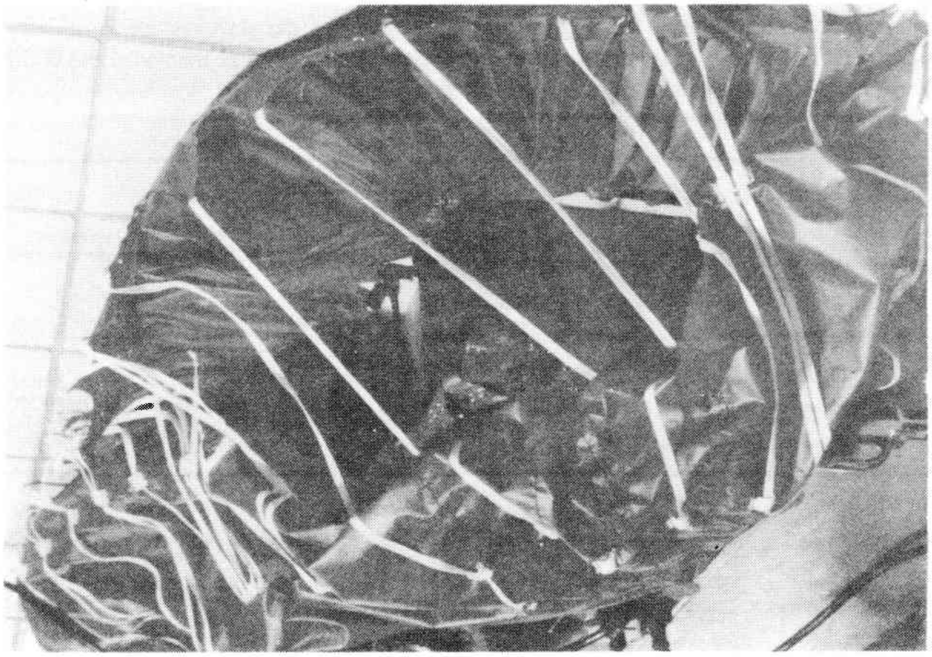

Figure 12. Initial Skirt System Configuration

The 20 ft. bag modules are interchangeable along the sides of the platform both port and starboard. The fore and aft modules are broken into 8 ft. wide modules which are also interchangeable fore and aft.

The skirt air supply is ducted into the bag via a special module which has a flexible fabric duct integrated with the bag. The duct bag module replaces a standard bag module along the side of the platform. The lift fan volute will be very close-coupled to the bag and the fabric duct will only be long enough to facilitate attachment of the bag to the rigid volute.

A major consideration for this design is the handling and deployment of the skirt system. A basic analysis of the primary bag hoop tension loads using an overpressure in the bag of 420 PSF indicates a hoop tension load of approximately 146 lbs. per inch tensile. This figure does not consider any loads transmitted into the straps. Employing a safety factor of 2.0 to the tensile load suggests a base fabric of 300 lbs. per inch tensile strength would be adequate. Using the same load factors, and considering three straps per 60" modular section transmitting the total load (i.e. no load transmitted through the bag), a strap load of 2,926 lbs. would be seen. A two inch wide woven strap with a tensile strength of 8,000 lbs. will be a conservative selection.

Typically, an ACV skirt system employs materials that will give the maximum length of service under rugged, full-time operations. However, the prototype PACK skirt system is primarily intended for a "critical mission" use during an amphibious landing with several sorties to and from a beach zone. The skirt longevity and service life can therefore by sacrificed to a certain extent in favor of the more dominant requirements of transportability, deployability and cost.

A preliminary selection for the skirt fabric is a 400 lb. per inch tensile basket weave scrim with a blended Urethane/ PVC elastomer coating. All skirt components will be formed from flat pattern layouts and electronically heat sealed. Stitching will be employed where necessary to resist peeling loads. The selected coating has high abrasion resistance, high environmental and storage degradation resistance, and lends itself to low-cost fabrication techniques.

5.0 PACK DEVELOPMENT PROGRAM

The PACK has been developed by Band, Lavis & Associates, Inc. under contract to the U.S. Army Belvoir Research, Development and Engineering Center (BRDEC) Marine Development Team. M.J. Plackett and Associates have contributed substantially to the development and design of the unique skirt system.

Concept exploration of the PACK was initiated in late 1986. The initial studies verified a promising technical approach and identified several mission needs for the system. In late 1987, a preliminary design and fabrication of a concept demonstration model were funded. The model was eighth-scale but represented only a 20' x 16' hard structure barge. Although the fans available for this initial model provided less than the required air flow, the results were extremely encouraging. In 1988, an effort was funded to refine the skirt design and fabricate an eighth-scale engineering model of an 80' x 24' PACK-equipped barge. This model was completed in late August, 1988 and its initial operation has been entirely satisfactory.

The PACK has been extensively briefed to cognizant U.S. Army commands by the PACK Program Manager, Mr. Brian David of the BRDEC Marine Development Team and has received widespread support. The planned PACK development program through the fall of 1989 comprises:

- Extensive testing and analysis of the eighth-scale model
- Modification of the PACK design as indicated by test results or additional mission requirements
- Fabrication and testing of full-scale PACK components
- Design of the lift-air supply units
- Fabrication of a full-scale PACK system for a 80' x 24' barge
- Demonstration and operational testing of complete PACK system installed on an 80' x 24' modular barge.

6.0 CONCLUSION

The PACK has been developed to meet a real and immediate mission need for the U.S. Army LOTS operation and also has considerable potential for other military and commercial applications. The PACK system comprises a unique skirt system and innovative attachment hardware and exploits the use of advanced materials and fabrication-techniques. However, the PACK technology is basically state-of-the-art. Under the sponsorship of the U.S. Army, the program should proceed to full-scale prototype testing within a year with no major development obstacles.

Discussion on presentation by Daniel Wilkins

Q The picture of the LACV-30 pushing the hoverbarge. What was the hoverbarge?

A That was the U.S. Army's E-PACK hoverbarge, a bogie wheeled, twin propellered thing that they purchased a couple of years ago and have used as a test and demonstration platform for a variety of applications.

Q Is it planned to have control of the PACK's lift system from the tug.

A No. There will be personnel on the PACK who will be in charge of operating and controlling the lift fan engines. There will probably be some shut off vanes on the lift fan and the like. They will have control from the PACK itself.

Q Is there a time expectation for deployment of a PACK system on a barge module?

A We have not specifically designed to a time constraint. Our best estimate as the moment is that with a crew of four men the system can be deployed in one shift, that is, in eight hours.

Q Must it be assembled on deck or in the water?

A Either, provided its calm water. It can be put on deck of a ship and off loaded or it can be done overland. But not in sea state 3.

Q What is the air cushion power requirement?

A Right now it looks like maybe a 360 hp diesel fan for full load applications. We think we can get by with less airflow than we have currently predicted depending on the mission and the like. We're expecting to learn a lot from our 1/8th scale model tests. About 2000 cf/s maybe.