CCDoTT
Center for the Commercial Deployment of Transportation Technologies

# TECHNICAL REQUIREMENTS AND FEASIBILITY ANALYSIS REPORT

# CONCEPT EVALUATION OF LARGE HST

**Submitted to:**

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***High Speed Trimaran (HST) Technology Development***

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# High Speed Trimaran Technology Development

## TECHNICAL REQUIREMENTS & FEASIBILITY ANALYSIS REPORT – CONCEPT EVALUATION OF LARGE HST

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Task 8.1 Report
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## INTRODUCTION

This task provides assessment of the operational requirements of seabase for the large high-speed ship with C130 airplanes in a sea basing capability. Seabase ship mission requirements are applied to the large HST concept design. In the course of development of matrix of concepts and configuration variants we've developed series of Heavy Air Lift Seabasing Ship (HALSS) configurations based on various construction and production planning options from commercial shipbuilding practice and various available at different levels of machinery propulsion and structural technologies. In the course of operational analysis we've done the evaluation of the construction time and cost risks by obtaining the construction and production planning inputs from commercial shipbuilding practice to prepare a build strategy and production plan. This part of the work was accomplished through: an analysis of C130 airplanes in seabasing capability concepts of operations and development of a matrix of HST ship configurations that relate to these conops. As result the recommended configuration and HALSS concept was identified for further engineering and more detailed technical feasibility a*nlysis.*

## 1. PROBLEM STATEMENT

With the uncertainty surrounding the United States' ability to operate from the territory of its allies and coalition partners, an alternative capability must be developed. Sea Basing is one such alternative. The proposed objective of Sea Basing is to rapidly get into the theater and seabase heavier lift capability than can currently be provided by existing lift ships and rotary aircrafts. Various studies have already been performed of putting a flight deck on an LMSR, which still leave a 24 knot ship. MPF(F) is currently being evaluated around vertical lift and Short Takeoff and Landing (STOL) aircraft, which will place significant limits on range and payload working from the seabase.

The developing under the present project concept of a Heavy Air Lift Seabasing Ship (HALSS) can quickly get fixed wing heavier lift capability into theater from CONUS, or an advanced base. The ship has the capability to seabase the aircraft (i.e. launch, recover, nurture and feed), plus carry at least a 10 day supply of cargo. The HALSS concept has the size, stability and high speed required for use as a base for C-130J aircraft.

In 1963 a KC-130F was tested onboard the USS FORRESTAL. The testing included a total of 50 landings and takeoffs, of which 29 were touch-and go and 21 were full stops. Since that the C-130J operates from shorter runways than earlier versions of the C-130, and can be further improved to provide STOL capabilities.

The key points of the HALSS concept are the following:

- The military needs a ship which can support "early forcible entry" of combat troops with combat vehicles. HALSS ship would deliver 20 ton vehicles or pallets from at least 100 nm offshore to at least 200 nm inland, at a rate of about 400 tons of dry material and 600 tons of liquids per day. HALSS concept ship is capable to handle C-130J operations to support these two logistic missions.

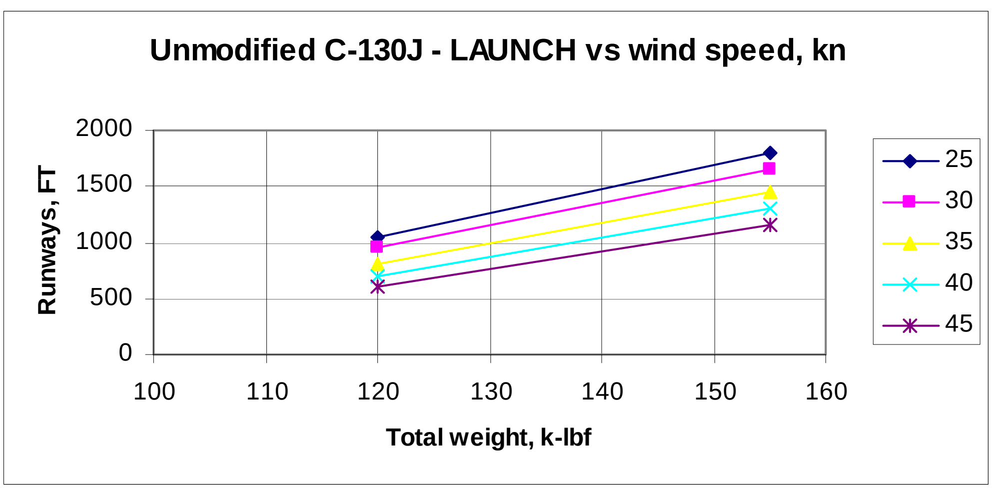
- The forcible entry of 40,000 pound plus lifts needs to start at least 100 nm offshore and be delivered at least 200 nm inland. To get beyond mine fields offshore, position the supplies in the combat theater and avoid the high sea state operational problems offloading by air with long range (over 300 nm one way) is required. The HALSS concept meets these mission requirements.
- The HALSS ship is a large trimaran ship with flight deck sized for secure parking, launching and recovery of the five C-130J airplanes. Notional internal arrangement of the HALSS trimaran ship can suit the stowage and air capable ship requirements; cargo area layouts is based on integrating of the stowage and assemble areas, RoRo cargo area, and material handling and stowage compartments.
- The HALSS Trimaran ship incorporates the results of the high speed trimaran technology developments in series of studies, provided in NSWCCD, SAIC and some other research and ship design companies. These studies include the development of the adequate CFD and naval optimization tools for multihull/trimaran resistance calculations & hull forms optimization; structural loads estimate & structural optimization; advanced machinery propulsion systems; and series of model testing, performed during recent years.
- The HALSS concept development results are aimed to give answers to the primary question "Can we do it technically?" (Design, Build in the USA and Operate a C130 capable high speed seabasing ship).

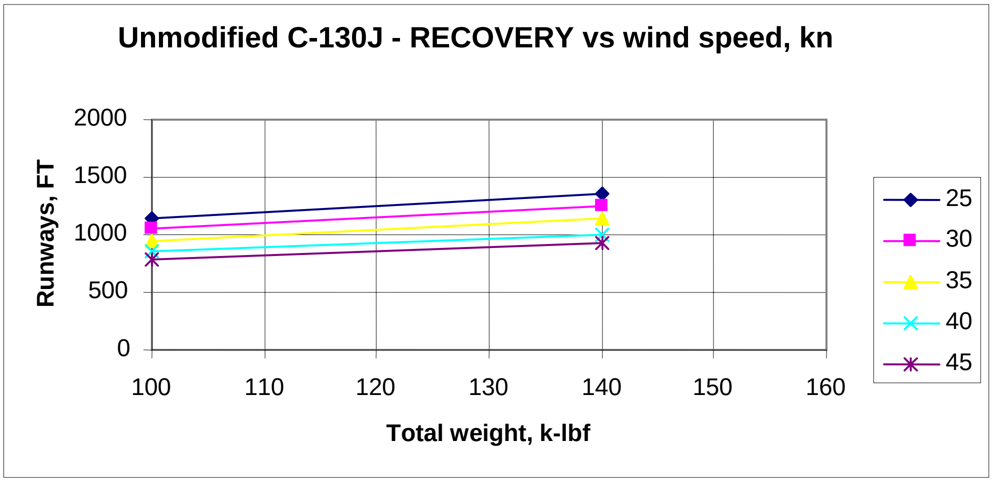
The HALSS concept is developing in cooperation with Lockheed Martin Aeronautics Company as joint SAIC-LMCO HALSS concept, which presents not so much alternative to the various currently developing designs, logistics and operations to meet future demands of the Sea Base, but it is compliment as the near term solution with already existing C-130J airplanes and state of the art high speed trimaran shipbuilding technology.

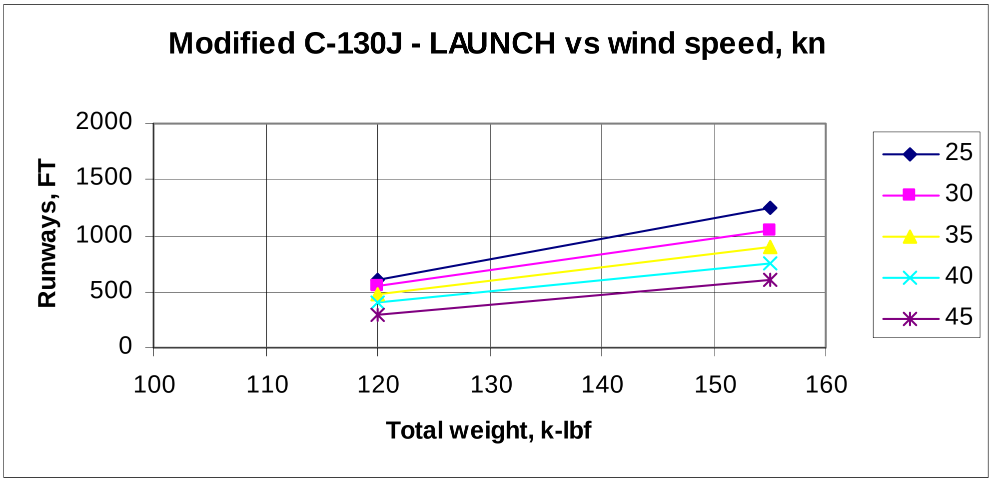
## 2. HALSS CONCEPT REQUIREMENTS

The developing under the present project concept of a Heavy Air Lift Seabasing Ship (HALSS) should quickly get fixed wing heavier lift capability into theater from CONUS, or an advanced base. The ship should have the capability to seabase the aircraft (i.e. launch, recover, nurture and feed), plus carry at least a 10 day supply of cargo. The HALSS concept must have the size, stability and high speed required for use as a base for C-130J aircraft.

We would consider unmodified and modified C-130J airplanes. The difference in runways requirements for theses airplane variants is shown below.





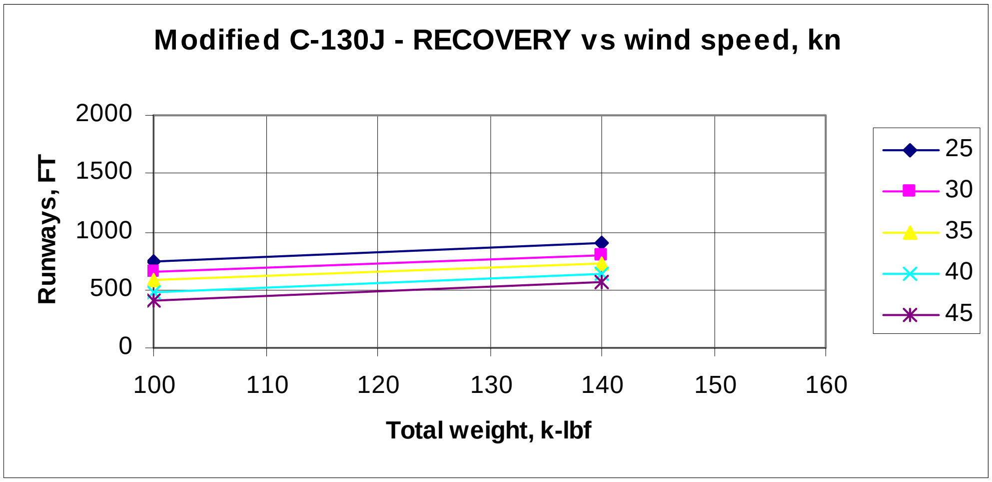




**Figure 1.1-1.4 Relationship for Required Runways and Wind Speed over deck (in knots) at launching and recovery of existing and modified C-130J airplane (LMCO data)**

Since that the C-130J operates from shorter runways than earlier versions of the C-130, and can be further improved to provide STOL capabilities.

The summary of this information is shown in Figure 2.

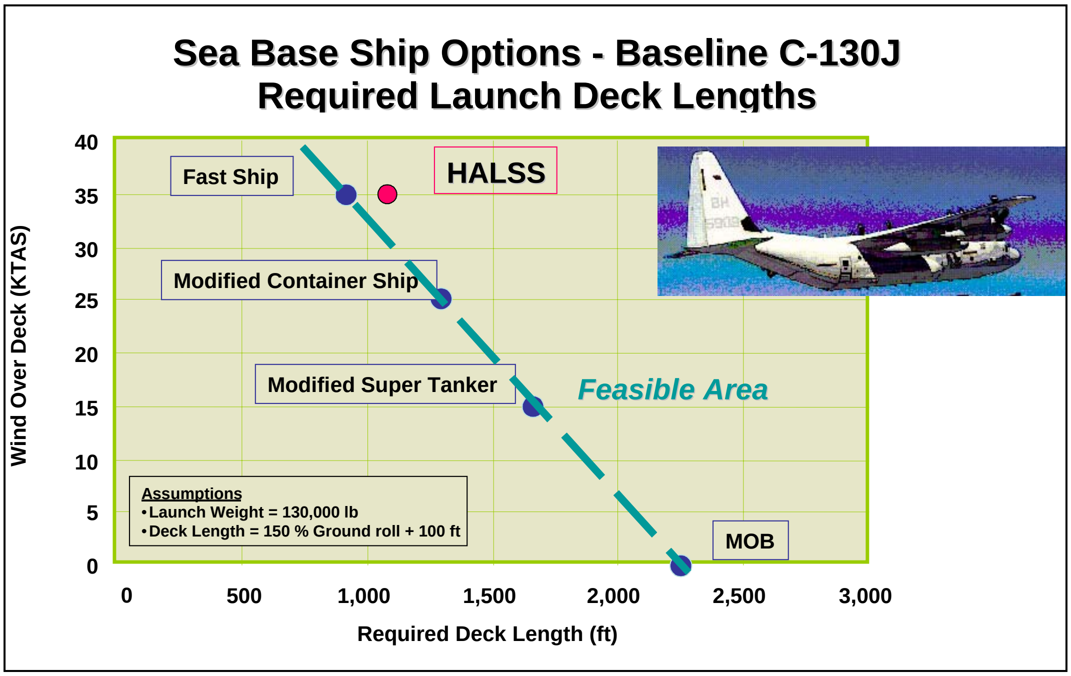



**Figure 2. Summary of Required Deck Length (Runway) vs. Wind Speed relationship**

Basic payload/total weight and runway requirements are summarized in the data presented in the Task 8.1 Technical Report “Matrix of Concepts and Configurations”.

In calculations of the HALSS payload and sizing the following requirements were taken into account:

- HALSS ship would deliver 20 ton vehicles or pallets from at least 100 nm offshore to at least 200 nm inland, at number of Sorties of each C-130J airplanes - 2-3 per day (sustain) and 4-6 (surge) with number of C-130J airplanes - 5+ on board of the HALSS, and with Endurance in JOA - up to 10 days.
- The forcible entry of 40,000 pound plus lifts needs to start at least 100 nm offshore and be delivered at least 200 nm inland. To get beyond mine fields offshore, position the supplies in the combat theater and avoid the high sea state operational problems offloading by air with long range (over 300 nm one way) is required.

The HALSS concept should meet these mission requirements.

## 3. HALSS CONCEPT PARAMETRICS

Evaluation of the above requirements had led to the parametric analysis, which resulted in the sizing definition. This analysis is summarized in the tables of the previous technical report “Matrix of Concepts and Configurations”.

The result of the parametric analysis of payload requirements had led to the following sizing estimates, shown below:

| | |
|---|---|
| **Flight Deck Length** | **1,100FT** |
| **Flight Deck Width / Docking Hull Beam** | **308 FT / 180 FT** |
| **Payload (Combat forces sustainment)** | **8,000 LT** |
| **Aircraft Fuel Supply** | **2,300 LT** |
| **Range of Sea Voyage - CONUS to Advanced Base or to JOA** | |
| **Diesel machinery option,** | **10,000 NM at 35 knots** |
| **Without refueling** | **>15,000 NM at 25 knots** |
| **Endurance in Joint Operations Area** | **up to 10 days** |
| **Cargo Planes / Empty weight** | **Five C-130 / 5 x 34 MT** |
| **Speed** | **35 knots** |

The mission capability of the HALSS is shown in Figure 3.

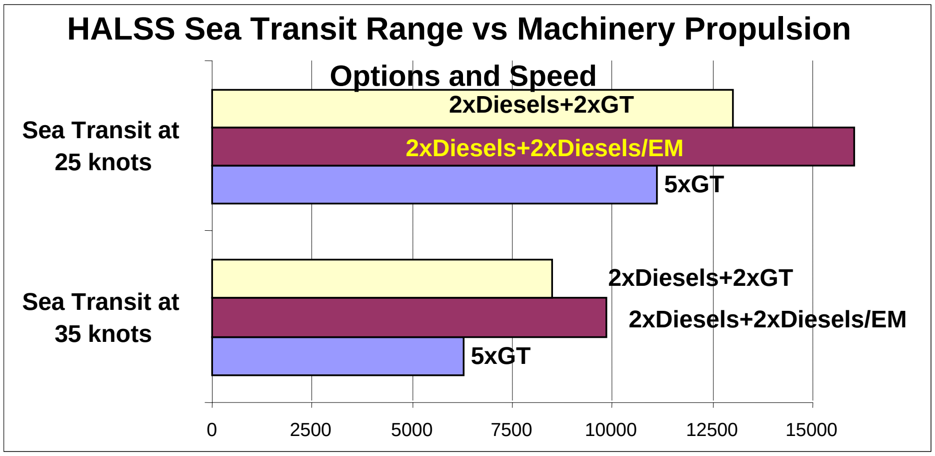



**Figure 3. HALSS Available range vs. Transit Speed and Machinery option.**

In 10 days Operating Scenario HALSS is able to transit without refueling to the Joint Operation Area at a distance about 10,000 nm at speed 35 knots. Diesel machinery option adds 3,000 nm range in comparison with the Gas Turbine option.

The same calculations show the available range from 10,500 to 14,000 nm at speed 25 knots. Diesel option adds 4,500 nm.

## 4. HALSS DESIGN SOLUTIONS AND BASIC TRADEOFFS

HALSS concept is developing as near term variant to meet basic Sea Base operational requirements.

In the course of this study the following tasks were accomplished:

- Developed design based on public-domain C-130J data, discussed with NSWCCD, incorporated their comments.
- Discussed design with Lockheed-Martin Co, obtained relevant C-130J data, revised design accordingly

- Discussed design with General Electric Co, obtained relevant gas turbine and gear data, revised design accordingly
- Obtained information on Large Slow-Speed Diesels and developed this design option
- Discussed design with Wartsila Lips Inc, obtained relevant propeller and waterjet data, revised design accordingly

**4.1 HALSS Hull Forms Development**

Hull Forms development was based on previous studies:

- VHSST-50 hull forms development and model tests experience;
- DASH slender and SWAT hulls form development, calculation results, MQLT verification and analysis and DASH model tests results:
- Trimaran SSS trailership hull forms optimization results, in which SWA type of side hulls were developed and proved by comprehensive CFD analysis.

The HALSS hull forms are the result of choosing the balance of the following design criterions and requirements:

- High Speed Performance & Structural Requirements Compromise
- Excellent Seakeeping & Structural Support
- Enough Area/Volume for all of Propulsion Machinery Options

In Figure 4 the hull lines of the HALSS baseline design are shown.

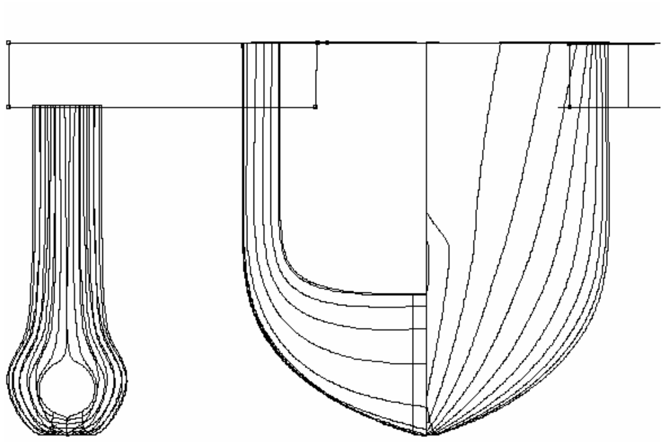


**Figure 4. HALSS hulls lines.**

The 3D view is shown in Figure 5.

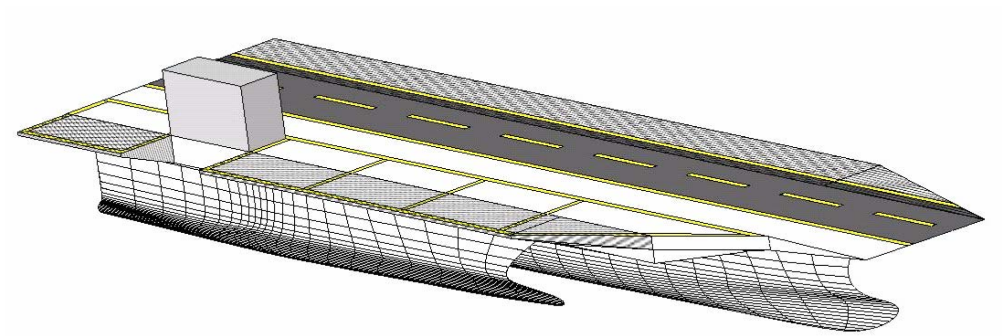


**Figure 5. HALSS hull forms.**

Further HALSS aft sections would refined for Diesel/Electric @ Propeller Option in order to accommodate shafts skegs.

**4.2 Speed – Power**

The results of power prediction are shown in Figure 6. These results are obtained with use of MQLT CFD codes, whicg were verified with previous series of model tests in NSWCCD during 1999-2002 CCDOTT and ONR/DASH projects.

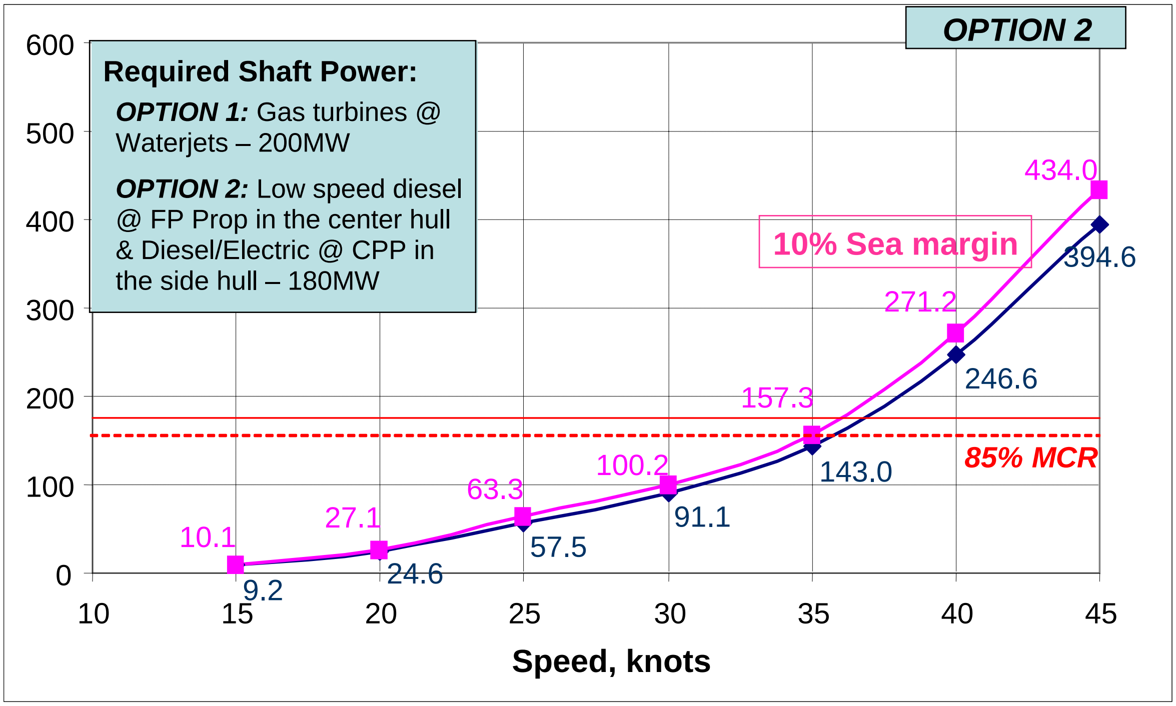



**Figure 6. Speed vs. Power**

In these calculations wave resistance, viscous-inviscid interaction, which results in transom drag and dynamic trim, and scaling correlation factor are calculated by MQLT. Total propulsion efficiency coefficient as assumed to be 0.65 for waterjet propulsion option and 0.7 for propeller option.

**4.3 Propulsion Machinery Options**

The following Machinery Propulsion Options were considered:

a. Gas Turbine & Waterjets

This option is traditional for high speed trimarans developed in previous studies. Three GE LM6000 are the machinery for the Center hull coupled each through the gears with fixed flow waterjet of LJ290 type or axial waterjets, and the same LM6000 coupled with waterjets is the machinery propulsion system for each of the side hulls. Each waterjet would absorb 40MW full power. Machinery propulsion arrangement of this option is shown in Figure 7.

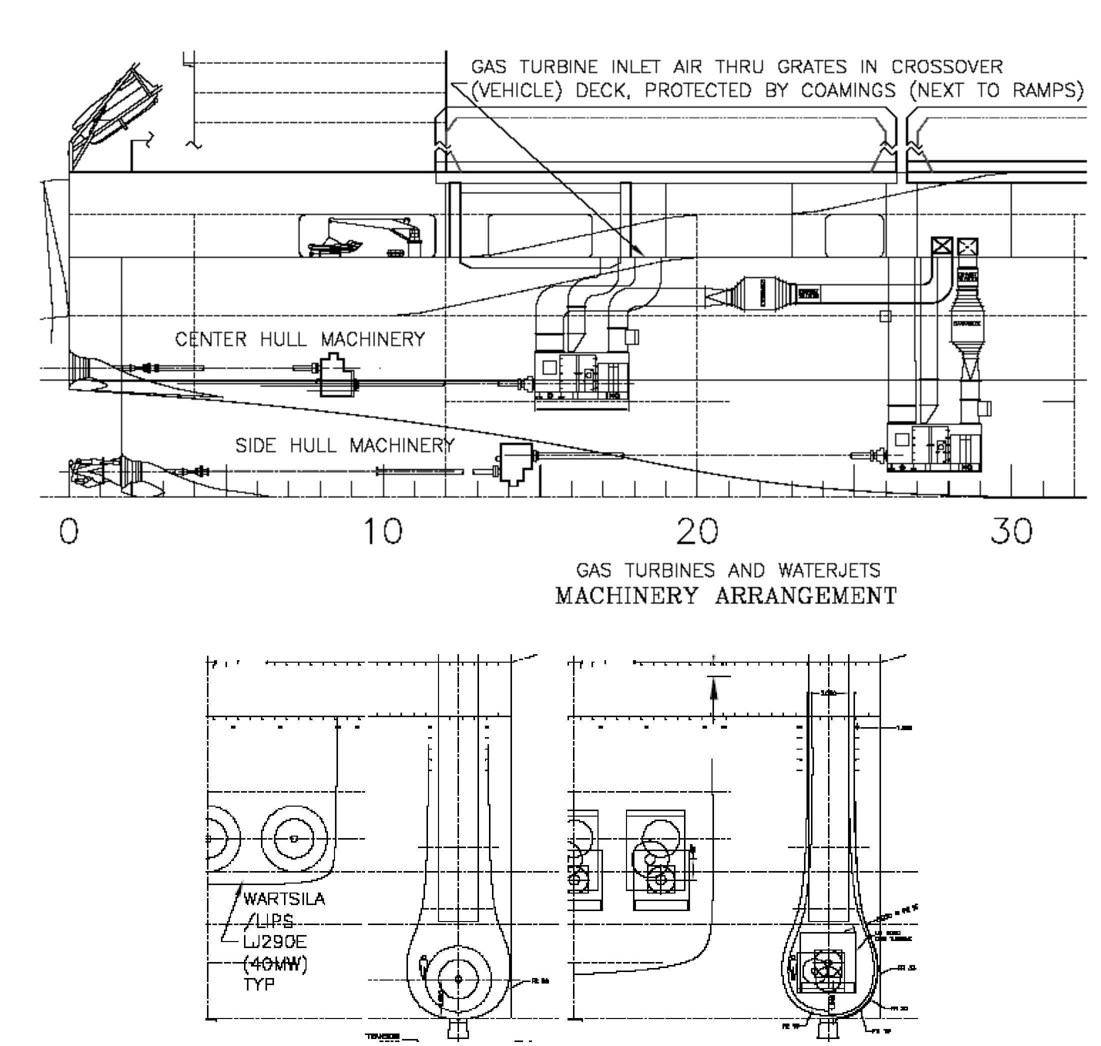



**Figure 7. GT & LJ propulsion option.**

b. Diesel/Electric and Propellers Option

This option is based on large slow-speed diesels 2 x Sulzer RTA 96 (102 RPM) and Fixed Pitch Propellers (FPP) in the Center hull and conventional electric motors geared with Controllable Pitch Propellers (CPP) or Lips waterjets in the side hulls. The rational is the substantial fuel saving at long sea trials, which can fully compensate the increased engines weight and higher ptopulsion efficiency coefficient. In this option FPP would have about 8.5-8.7 meters diameter, CPP would have about 4.8 meters diameter, and alternative to CPP waterjet would be of LJ200-LJ210 type. The machinery propulsion arrangement is shown in Figure 8.

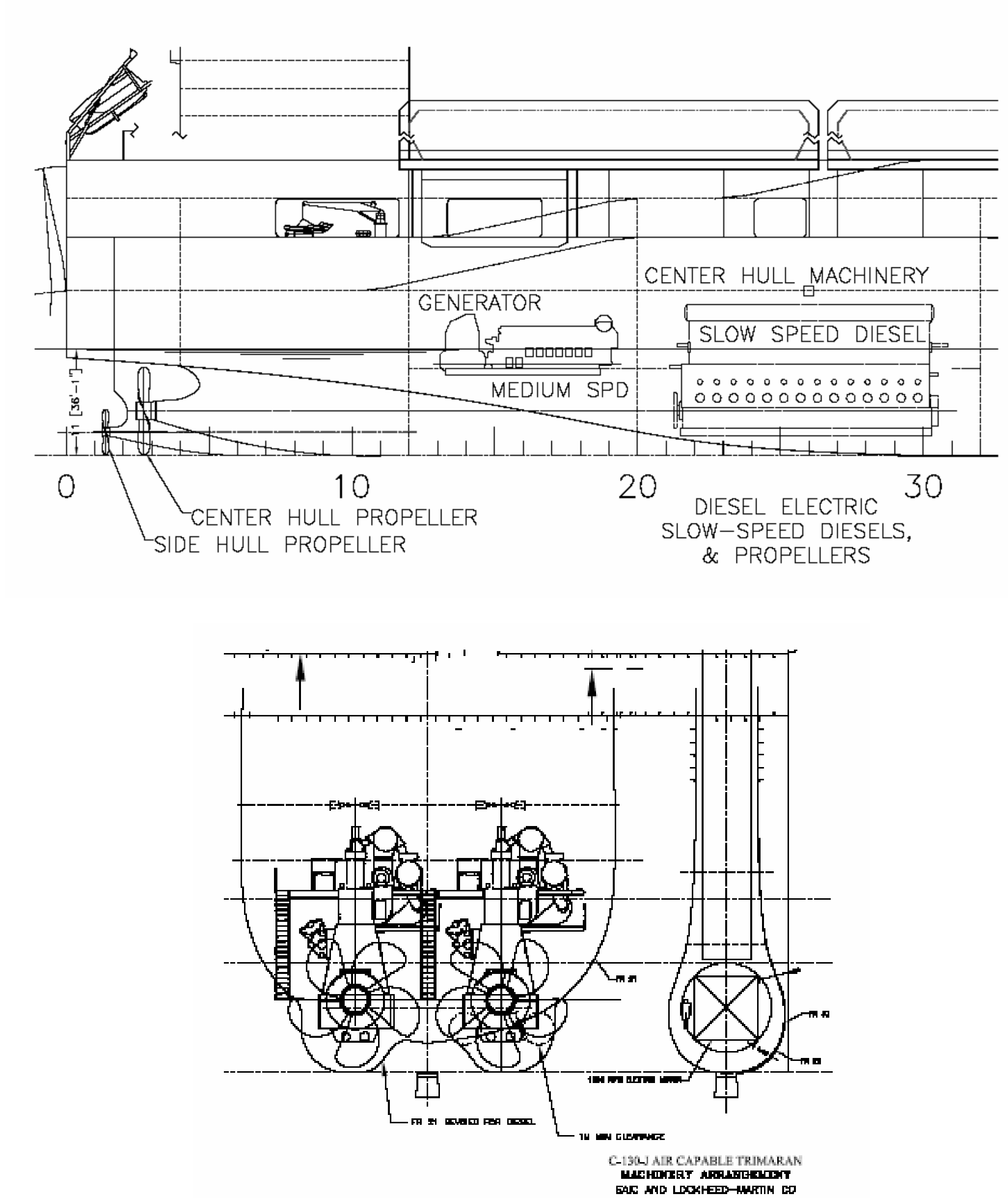



**Figure 8. Diesel/Electric & Propellers Option**

The analysis of these options showed the following:

- Diesels are better suited to the proposed service than gas turbines because (a) their better fuel efficiency permits greater range at lower cost despite a substantial weight penalty, and (b) maintenance costs are much lower since the desired operation requires full power for more than one week.
- There is insufficient room in the side hulls to fit a diesel engine of any reasonable size or a direct-connected conventional electric propulsion motor.
- Putting any prime mover in the side hulls will make maintenance difficult due to space and access considerations. Recommended propulsion power for the side hulls is an electric motor developing 18MW at about 1200 RPM, with a reduction gear driving a

waterjet or CPP. While slightly more expensive than a direct-connected electric motor at 200-250RPM, this connection fits much better into the long slender side hull configuration which is desired to provide a stable platform with minimal motions in a seaway.

- Recommended propulsion is a pair of 80MW slow-speed diesel engines driving ~9m diameter fixed-pitch propellers in the center hull, and a pair of 18MW diesel generators in the center hull providing electric power to a high-rpm (900 to 1200rpm) electric motor in each side hull. Side hull propulsion would only be used to boost speed from 31kts to 34kts, and for maneuvering at speeds below 13kts, with the center hull engines shut down. For speeds between 13 and 31kts, side hull propulsion would be shut down and only the center hull engines would drive the ship; steering would be provided by a centerline rudder. This configuration is shown in enclosures B.1 and B.4.
- Each side hull motor would drive a reduction gear connected to either a 4.6m diameter Controllable-Pitch Propeller or a waterjet. The CPP has the advantage of permitting a single-speed electric motor which is simpler and more economical, but will provide substantial drag at medium-speed operations using only the center hull engines; this option is shown in enclosures B.1 and B.3. Waterjets could eliminate this drag, but may require multi-speed motors for maneuvering. The waterjet option is under evaluation and analysis with Wartsila Lips Inc.
- A High-Temperature Superconducting motor could be directly connected to the side hull propulsor and fits easily in the side hull. This is a mid-term option since the largest such motor presently available is only 5MW.

**4.4 Weight Breakdown Estimate**

Preliminary weight breakdown is shown in the following Table:

| **Category** | **Weight (Long Tons)** |
|---|---|
| Structure | 22,000 |
| Payload | 8,000 |
| Aircraft | 170 |
| Aircraft Fuel | 2300 |
| Supplies | 500 |
| Personnel | 40 |
| Propulsion/Electrical | 8,000 |
| Outfit and Furnishing | 1,000 |
| Fuel | 14,000 |
| Water | 400 |
| Margin | 3,590 |
| **Total** | **60,000** |

**4.5 General Arrangement**

HALSS general arrangement is shown in Figure 9.

An Employee-Owned Company

## HALSS Arrangement

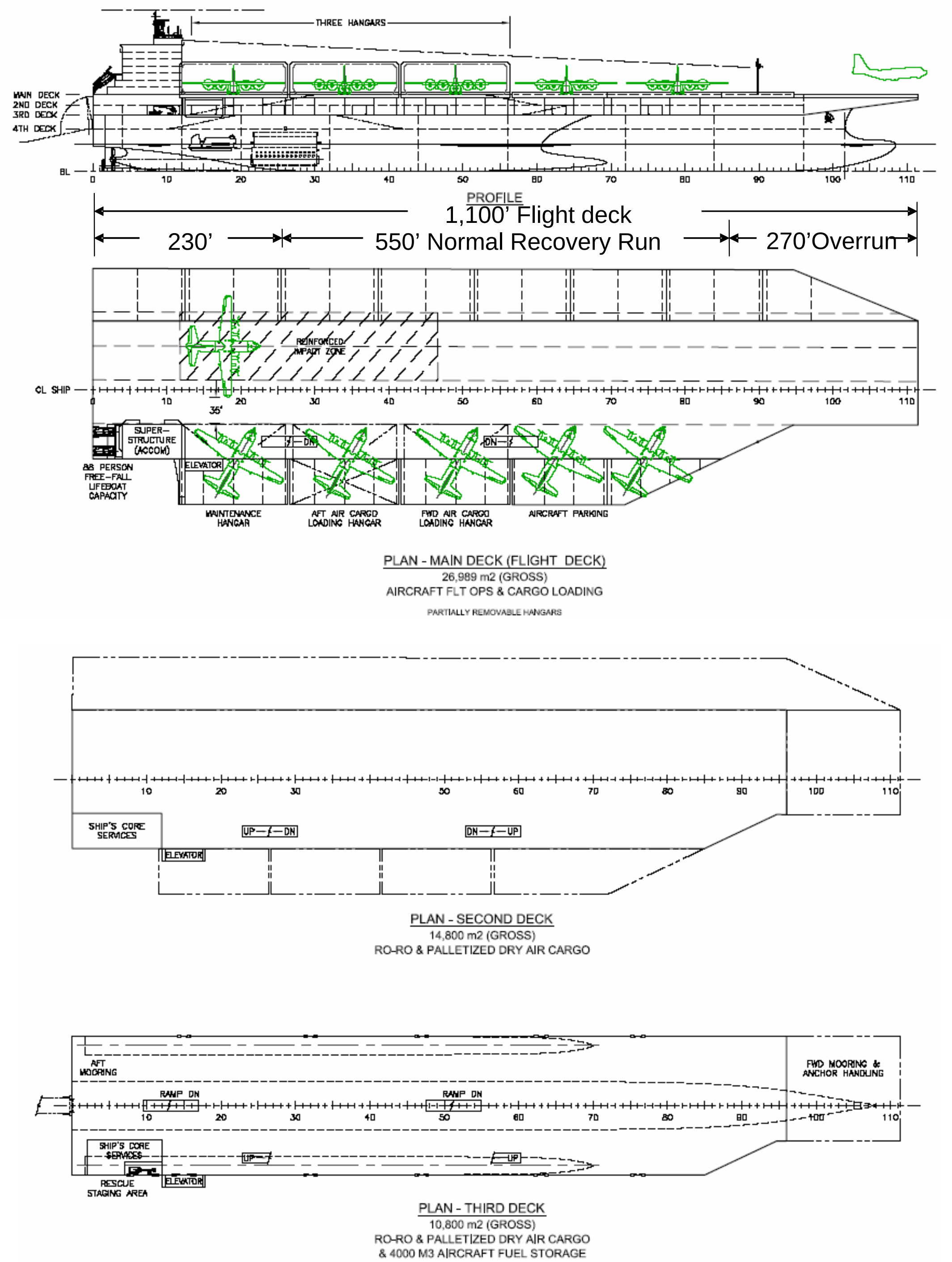



**Figure 9. HALSS profile and deck plans.**

Shaded area of Deck is removable or hinged for drydocking. The crosshatched area is the landing zone. Shaded areas outside the wheel track are very lightweight construction, corrugated sheet metal, just for wind protection, similar to hangars. Hangars are also hinged. The single plane shown aft of the house is in the loading area; the other four are stored. It is possible to make the first storage area fwd of the house into another loading area by lengthening the hangar slightly. House provides navigation, accommodations, and air intakes. Exhaust is through the crossover deck into the space between the hulls. Anchoring & mooring gear is on the crossover deck. Side ports for cargo transfer from replenishment ships are between the crossover deck and the 2nd deck.

The aircraft can back up unassisted. During trials onboard USS FORRESTAL in 1963 the aircraft was successfully backed on at least two occasions. The USS FORRESTAL testing indicated having a centerline reference point is very helpful in backing the aircraft. Utilizing taxi directors on deck also improved the backing characteristics. Lockheed Martin C-130J test pilots agree that the backing the aircraft unassisted at reasonable speeds is a reasonable approach."

The two aircraft with the tails inboard are not just parked, they are being loaded with pallets from fork-lift trucks coming up the ramps indicated. Our intent was to show the ship in a normal operating condition – aircraft would not normally be parked on the ship except during loading and unloading or emergency field maintenance.

**4.6 Construction**

The sections view is shown in Figure 10 and HALSS Maintenance Approach is shown in Figure 11.

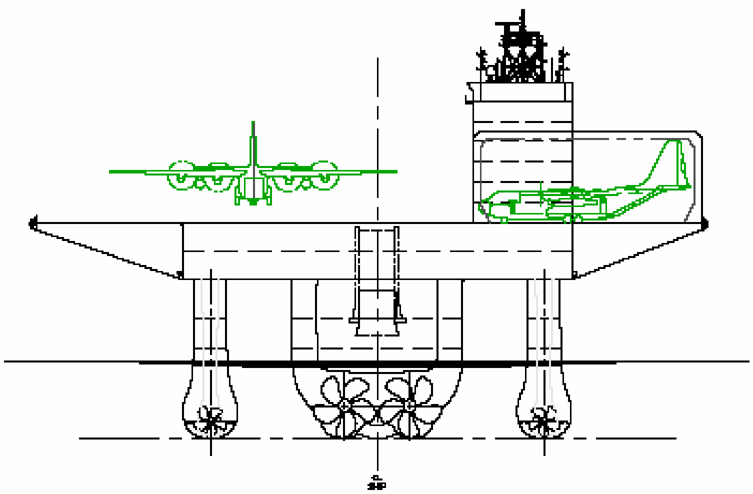



**Figure 10. HALSS Structural Configuration**

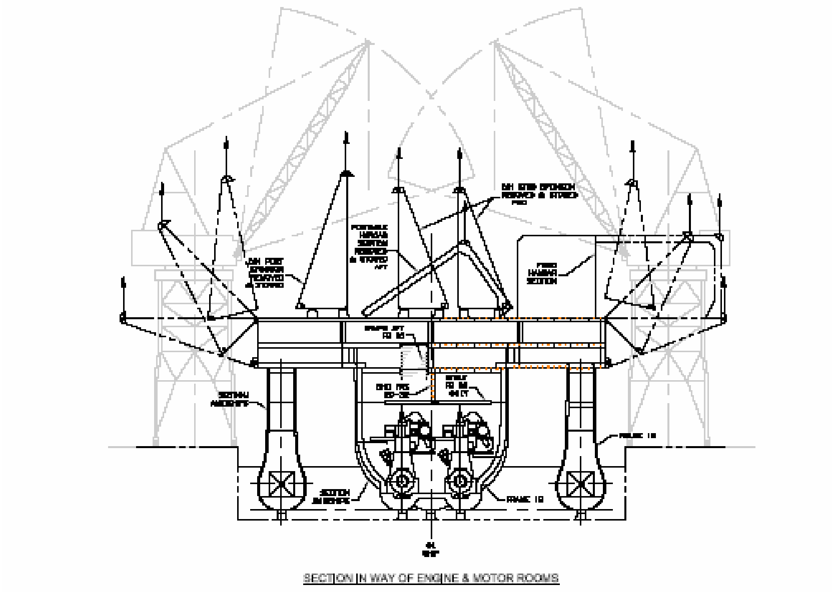
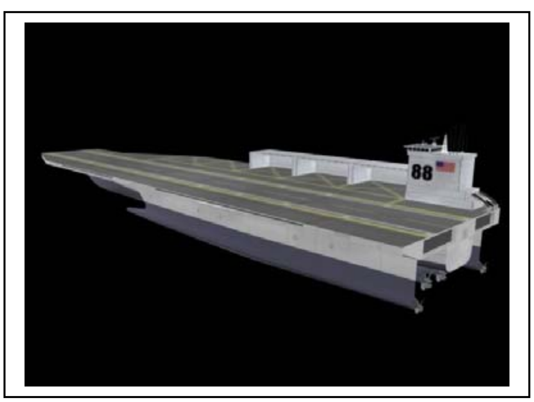


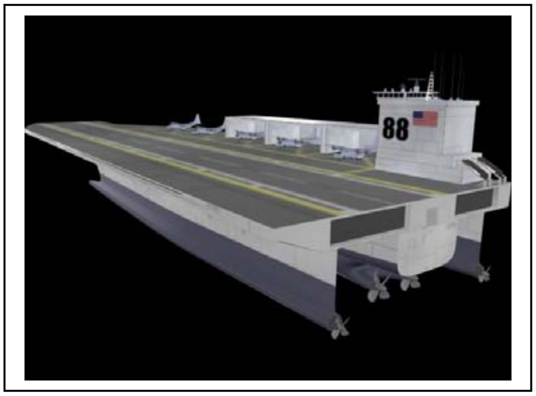

**Figure 11. HALSS maintenance approach.**

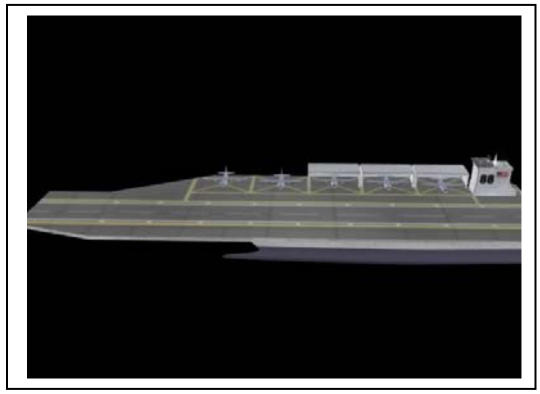
Sponson deck is hinged to keep the beam reasonable during construction and during repair drydockings. The outboard portion of the hangar is also hinged for the same reason. Deck extensions can be relatively light as they do not have to support aircraft weight. Exhaust is through the crossover deck into the space between the hulls. Freeboard deck is the crossover deck for unimpeded access for cargo handling.

The port side extension is there to block winds coming up the side of the deck, and the starboard extension is there to support fuel and electrical lines, loading vehicles, and support the hangars. Designing it to support loading vehicles will require heavier structure to handle fork-lift-truck wheel loads.

#### 4.7 3-D Visualization





**5. CONCLUSIONS**

- It is both technically and economically feasible to build and maintain a trimaran in the United States which can support C-130J seabase operations. Maximum guaranteed sustained speed would be 34 kts, requiring a flight deck length of 1100 feet.
- The preferred propulsion option is two 80MW slow-speed diesels driving fixed-pitch propellers, and two 18MW diesel-generators driving CPPs or waterjets.

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