

**DAHLGREN DIVISION  
NAVAL SURFACE WARFARE CENTER**

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**NSWCDD/TR-07/7**

**INTERIM HEAVY AIRLIFT: SEA BASE  
PROCESSING OF LOGISTICS GLIDERS**

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## FOREWORD

This report describes the Year 2015 Navy Sea base, operating within the interim heavy airlift (iHL) concept first proposed in NSWCDD/TR-06/52. The iHL concept proposes that existing aircraft “snatch pickup” a logistics glider from a Sea base helipad, weather deck, flight deck, or nearby littoral water surface for aerial sustainment of the tactically maneuvering expeditionary warfighter. This report proposes the methods, and models the performance of the Sea base in processing logistics gliders.

iHL was developed by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) at the Testing, Experimentation, Assessment, Modeling and Simulation (TEAMS) Facility.

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## GLOSSARY

|             |                                                                                                                                                |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Processing  | Assembly, movement, loading, unloading, staging, launching, recovery, and disassembly of logistics gliders                                     |
| Assembly    | Collection and attachment of logistics glider components, either all at once or partially with other processing in between                     |
| Loading     | Preflight insertion of payload; includes any mission programming                                                                               |
| Staging     | Parking of the logistics glider, awaiting either its launch window or retrograde processing                                                    |
| Preflight   | Final configuration outside on the helipad or weather deck                                                                                     |
| Launch      | Snatch pickup departure of the logistics glider                                                                                                |
| Retrograde  | Return processing of a logistics glider out on the helipad or weather deck                                                                     |
| Disassembly | Complete or partial component-level breakdown of the logistics glider inside the ship for stowage, repair, or to queue for assembly processing |
|             |                                                                                                                                                |
| ACTD        | Advanced Concept Technology Demonstration                                                                                                      |
| CONREP      | Connected Replenishment                                                                                                                        |
| CONUS       | Continental United States                                                                                                                      |
| DO          | Distributed Operations of small Marine Corps units                                                                                             |
| DZ          | Drop Zone; release point of a towed logistics glider's payload                                                                                 |
| FARP        | Forward Arming and Refueling Point                                                                                                             |
| GVW         | Gross Vehicle Weight of the logistics glider                                                                                                   |
| IED         | Improvised Explosive Device                                                                                                                    |
| EFSS        | Expeditionary Fire Support System                                                                                                              |
| HMMWV       | High Mobility Multi-purpose Wheeled Vehicle                                                                                                    |
| IFAV        | Interim Fast Attack Vehicle                                                                                                                    |
| iHL         | interim Heavy airlift system                                                                                                                   |
| JMIC        | Joint Modular Intermodal Container; a 52x44x42-inch packaging standard                                                                         |
| JMIP        | Joint Modular Intermodal Platform                                                                                                              |
| JOA         | Joint Operating Area; includes the littoral, Sea base, and ashore operations                                                                   |
| LAV         | Light Armored Vehicle                                                                                                                          |
| LMSR        | Large, Medium Speed, Roll-on/Roll-off                                                                                                          |
| LOC         | (sea) Lines Of Communication                                                                                                                   |

**GLOSSARY (Continued)**

|         |                                                                         |
|---------|-------------------------------------------------------------------------|
| LVSR    | Logistics Vehicle System Replacement                                    |
| LZ      | Landing Zone; unimproved, soft, or uneven land used by air vehicles     |
| MAGTF   | Marine Air Ground Task Force                                            |
| MEB     | Marine Expeditionary Brigade; warfighters supported by the Sea base     |
| MHE     | Material Handling Equipments                                            |
| MLP     | Mobile Landing Platform                                                 |
| MPF (F) | Maritime Prepositioning Force (Future)                                  |
| MPS     | Maritime Prepositioning Ships                                           |
| MTVR    | Medium Tactical Vehicle Replacement                                     |
| NM      | Nautical Miles                                                          |
| NSWCDD  | Naval Surface Warfare Center, Dahlgren Division                         |
| STOM    | Ship-To-Objective Maneuver                                              |
| Stons   | Short tons; exactly 2000 lb                                             |
| TEAMS   | Testing, Experimentation, Assessment, Modeling and Simulation           |
| TEU     | Twenty-foot Equivalent Unit; an 8x8.5x20-ft shipping container capacity |
| UNREP   | Underway Replenishment                                                  |
| WWII    | World War II                                                            |

## **EXECUTIVE SUMMARY**

This report describes the Year 2015 Navy Sea base, operating within the interim heavy airlift (iHL) concept first proposed in NSWCDD/TR-06/52. The iHL concept proposes that existing aircraft “snatch pickup” a logistics glider from a Sea base helipad, weather deck, flight deck, or nearby littoral water surface for aerial sustainment of the tactically maneuvering expeditionary warfighter. This report proposes the methods, and models the performance of the Sea base in processing logistics gliders.

Standardized logistics glider processes aboard and beside Sea base platforms are explored, leading to performance-based design criteria for two logistics glider models. Full employment of these gliders in iHL operations derives a maximum lift potential of the Sea base that is triple the 2015 Marine Expeditionary Brigade resupply tonnage in its surge and sustainment phases. Conservative scenarios realistically and favorably compare against conventional air and surface connectors in timeliness of delivery, operational availability, and fuel consumption.



## 1 INTRODUCTION

The Navy Sea base provides sea lines of communication (LOC) for sea-based logistics in Expeditionary Maneuver Warfare of a Marine Air Ground Task Force (MAGTF) performing Ship-To-Objective Maneuver (STOM).<sup>1</sup> STOM provides a significant maneuver advantage in the speed of advance to operational objectives without stopping to seize, defend, and build up beachheads or landing zones.<sup>2</sup> The sea-based supply chain is effectively modeled as a nodal network having the logistical performance metrics of throughput and synchronization.<sup>3</sup> STOM requires not only the throughput in delivery of requisite weight and volume of supply materiel, but by not maintaining traditional LOC open to the rear,<sup>1</sup> STOM implies a synchronization in delivery of only what they want, when they want it, where they want it, and in a manner desired by the maneuvering forces ashore.

A key logistical performance parameter of the Maritime Prepositioning Force (Future) (MPF (F)) component of the Year 2015 Sea base is in sustaining, potentially indefinitely, the employment of its embarked Marine Expeditionary Brigade-sized (MEB) force.<sup>4</sup> Sustainment performance begins immediately upon the initial surge ashore of the Sea Base Maneuver Element of the MEB. This contains a 4,989-Marine,<sup>5</sup> combined arms, Regimental Combat Team. Resupply of this surge equates to delivering 680 short tons daily ashore, and transitions to the sustainment phase for a daily rate of 367 short tons ashore.<sup>6</sup> The employment of tactical units performing Distributed Operations (DO) likely increases close air and indirect fires support and—of interest to sea-based logistics—complicates logistical support.<sup>7</sup> DO necessitates an even greater reliance than initially envisioned upon the persistent, operational availability and synchronization of the Sea base, any Forward Operating Base, and Forward Arming and Refueling Points (FARP) with the maneuvering unit. The individual dismounted Marine's carried weight in supplies or capacity for consumption will not proportionately change, but the technique in resupply delivery can compensate.

Currently, resupply LOC to the maneuvering warfighter traverses the Sea base, littoral water surface, beachhead, and ground. It is supplemented with air connectors as practicable. The organic resupply of the MEB entirely by air is a force multiplier to the speed of advance and the object of this report. All-air resupply is theoretically conceivable with anticipated MV-22 and CH-53 assets, but at most for only a few days due to requirements for considerable engine and rotor maintenance.<sup>8</sup> Any surface-to-air threat inland will inhibit conventional rotorcraft operation. Some limitations to the sea-based supply system's delivery performance via conventional means include:

- Sea base space aboard for crew and vehicle launch, recovery, and maintenance
- The delay, overstocking, and manning in the course of ship-to-ship transfers, surface transport, or ground transport
- Operational availability due to sea state

- Low technology threats on the ground such as ambushes and the Improvised Explosive Device (IED)
- Overall fuel consumption as supplied by the Sea base: connectors consume more gallons than the forces ashore<sup>9</sup>
- Maintenance issues with long term exposure during transport or storage to salt air
- Air delivery range and speed limitations with an external-sling-carried payload
- Density of payload in transit: both in value from delay or catastrophic loss, and in a high processing complexity both afloat and ashore
- Risk to warfighters and expensive vehicles, noisily hovering or flying slowly in an unsecured battle space
- Susceptibility of all air transportation when provided exclusively by a single technology—rotorcraft

### ***1.1 Resupply by Logistics Glider***

“The [NRAC] Panel strongly believes that the MPF (F) should incorporate new connector interfaces that permit high-speed loading and unloading from an automated floating warehouse.”<sup>10</sup> Accordingly the interim heavy airlift (iHL) concept<sup>11</sup> proposes that many organic, fixed-wing cargo vehicles called logistics gliders operate as “trailers” to existing air connectors. Cargo glider technology provides a very high payload percentage in a fixed wing airframe for distributed, reliable, low maintenance, all-weather air delivery as an optional, additive connector capability.

The enabling technology is the snatch pickup of the logistics glider from the operating Sea base. Snatch pickup involves a modified tow craft, at speed and trailing a hook on a cable, intercepting the looped towline of the positioned glider. A winch onboard the tow craft pays out cable while a clutch is programmed to slow down the spinning drum. This causes the nylon towline to elongate, transferring a little of the momentum energy of the tow craft to the glider. Then the glider accelerates into flight behind the tow craft. The tow craft does slow down a little from the pickup, but historical experience indicates it is more so from any tactical climb out.

Snatch pickup was a WWII cargo glider recovery technique. It was used much more than any historian realized. iHL expands upon the historical capability. Previously, iHL has been conceptually modeled; indicating that the helipad launch from a supply ship, the surface pickup off the water, and the towed delivery of a custom designed logistics gliders for the Sea base is physically viable. The primary tow craft can be the Sea base-organic MV-22 and CH-53, although other, long range aircraft are not excluded. The logistics glider’s towline may be intercepted by the traditional boom attached to the tow craft over a lofted balloon<sup>11</sup> or by an innovative drogue technology traveling near the logistics glider. There are seven stages of the operating logistics glider in iHL:



1. Sea base processing for logistics glider assembly, movement, loading, unloading, staging, launching, recovery, and disassembly
2. Snatch pickup by a flying tow craft of the logistics glider from a helipad, weather deck, flight deck, or littoral water surface
3. Towed flight of one or more logistics gliders: to a high standoff release altitude, in close to the landing zone (LZ), or across a payload drop zone (DZ)
4. Free flight and landing at an unimproved LZ (if not using the DZ option)
5. Unload of the logistics glider
6. Retrograde snatch pickup and aerial tow out to the Sea base
7. Vertical delivery onto the Sea base helipad or weather deck, or release for free flight onto the littoral water surface, depending on the model of logistics glider

Stages 3 through 6 have occurred before in combat, although improvement is expected for iHL. Stage 7's vertical delivery is unproven, beyond previous experience in the salvage of downed aircraft. The Navy did experiment with several amphibious gliders and performed water takeoffs and landings in 1943.<sup>12</sup> Stage 2 slightly modifies previous ground-based accomplishment of operationally accepted equipments: logistics glider takeoff distance and weight is scaled linearly to maintain previously achieved, applied physical force. Only now the applied force is applied by modern military aircraft of similar mass and speed. This report shows stage 1 to be viable even within the Newtonian physics of WWII-era accomplishment. This scaling is used to model the expected logistics glider capacity in Sea base processing.

iHL may occur exclusively, in conjunction with, or without excluding other resupply approaches. Logistics gliders do not necessarily require any flight deck space. The logistics glider can be autonomous. One general-purpose tow craft can essentially be at six different places at the same time: Two or more lift-equivalent payloads under preparation aboard the Sea base, two in tow, two or more in free flight, while many more can be offloaded directly by the warfighter—all at once. Dual tows are within previous WWII operational achievement. While triple tows are theoretically possible, only previously achieved, documented, and operationally certified WWII cargo glider performance is modeled in this report. A glider has some aspects toward a clandestine delivery to the maneuvering warfighter. Recovery occurs at the commander's choosing.

iHL provides the expeditionary commander with a robust and diverse set of organic expeditionary resupply capabilities. iHL so far has been described as the final delivery leg of a sea-based supply chain to the maneuvering expeditionary warfighter. Additionally, iHL may serve as an interim transport stage for an ashore depot, forward operating base, or may bypass convoy ambush threats, including the IED, by simply flying over them. Logistics gliders provide a large and ubiquitous platform for communication relay, battle space observation, and a lower value decoy for the higher valued rotor assets. Joint and Coalition tow craft may optionally participate.

This report explores salient logistics glider design criteria toward maximizing Sea base performance during iHL operations. These criteria are summarized in Appendix A. Standardized logistics glider processes are proposed in Chapter 2 for its form fit within

each embarked Sea base platform's interior. The fourteen Year 2015 MPF (F) Squadron vessels are examined by ship class platform<sup>4</sup> for their iHL-related flight operations and selective offload as floating warehouses. iHL does not modify the blueprinted ship as constructed, but reconsiders everything else in the resupply of the sea-based expeditionary surge and sustainment phases.

Sea-based tow craft during iHL are shown in Chapter 3 to use significantly fewer flight hours than existing connector rotorcraft. This reduces the associated connector fuel but more critically the maintenance required. A comparison of synchronization metrics<sup>13</sup> with conventional connectors<sup>14</sup> shows iHL having the fastest delivery performance in the average timeliness of daily resupply.

Resupply materiel is launched as cargo inside a logistics glider during snatch pickup. Chapter 3 notionally designs two logistics glider models for best lift performance given the system restraints in this report. The dry logistics glider model is assembled out of embarked storage, loaded inside the supply ship, and snatched into flight across the ship beam width. It is loaded with a standardized payload volume of one to six containers of the Joint Modular Intermodal Container (JMIC<sup>15</sup>) specification. This provides direct delivery to the maneuvering unit with generalized prepackaged materiel or customized and rapid-request items. Bulk liquids are not excluded. However, the other logistics glider model is an amphibious seaplane. It favors the transport of bulk liquids and heavier, irregularly shaped items as big as the Medium Tactical Vehicle Replacement (MTVR). The amphibious logistics glider is either loaded on flight decks supporting its greater size, or primarily filled alongside a wet cargo supply ship via connected replenishment (CONREP). All logistics gliders land ashore for selective offload by the warfighter, or at a DZ, dispensing dry cargo packages out the rear in either free or towed flight to bypass stages 4, 5, and 6.

## ***1.2 All-Air MEB Resupply***

Adhering to published operating conditions and conservative payload models, many resupply scenarios are examined in this report. Provided exclusively by logistics gliders, all-air resupply of the MEB supply requirement is found to be both viable and desirable.

- Either of two iHL scenarios viably provide the MEB supply requirement during the surge phase, which favorably compares against (likely unsustainable) conventional rotorcraft baselines
- The iHL delivery route scenario is the best for the indefinite-length, sea-based sustainment phase with the fewest overall tow craft engine hours affecting down-times for maintenance

It is shown in this report that the MPF (F) Squadron operating iHL exclusively has excess transport capacity of at least triple the MEB supply requirement. Even more may be theoretically possible but are not explored, such as additional wet or dry supply ships, triple snatch pickup tows, or using C-130 for tow craft. iHL modeling shows a surge

capable of 2,200 short tons daily ashore, and almost 1,700 short tons daily in a sustainment cycle. This excess capability can be used for:

- Faster delivery<sup>13</sup> of additional fuel and ammunition
- Overcoming supply chain unavailability, implying smaller depots ashore
- Loss allowances due to hostile action
- Expeditionary ground vehicle and equipment transport
- Supply to concurrent Joint, Coalition, and humanitarian operations

The iHL system is very complex. Key system performance bottlenecks to monitor during concept maturation are the payload capacity of the logistics glider in snatch pickup, the launch cycle time, and retrograde techniques. iHL fielding will likely occur over many loosely related phases. Well-meaning designs and operating approaches could unintentionally result in poorer performance than with conventional approaches. This is mitigated with follow-on tasking to expand upon and verify the models described prior to any requirements and programmatic assessments.

The proposed concepts need verification with an as-built study of ship interior and CONREP function, along with iHL performance optimization. Simulation visualization in software is recommended at first rather than any physical mockup modeling. The proposed modes of operation require both logistics glider aeronautical design, to determine the expected payload capacity of the conceptual vehicles, and simulation, to determine the snatch pickup physics for gross vehicle weight (GVW).<sup>16</sup> These capabilities and necessary models are available at the Dahlgren TEAMS facility and under a Cooperative Research and Development Agreement.<sup>17</sup>

## 2 MPF (F) SQUADRON PROCESSING

Twelve of the fourteen 2015 MPF (F) Squadron vessels have selective offload and flight operations capability with which to support iHL processing. They are grouped into four vessel platforms: T-AKE, LMSR, LH-platform, and MLP. This chapter examines these platforms and proposes two broad categories of iHL processing: the onboard processing of all logistics glider models onboard the Sea base platform, and the wet fill-up of the amphibious logistics glider while afloat.

Logistics gliders are capable of flying, already fully operational, into the Joint Operating Area (JOA). Whenever they are empty, they may be processed by these Sea base platforms. This is one way amphibious logistics gliders are proposed to enter the littoral iHL system; the other is less efficient—parked on flight decks, weather decks, or helipads. More efficiently, however, the dry logistics glider or XG-21 is quickly unpacked from embarked cargo storage and assembled aboard its embarked Sea base platform. Initially an assembly line is prepared for launch in the upcoming flight operations window. XG-21s are assembled, moved, loaded, unloaded, staged, launched, recovered, and disassembled onboard the iHL-capable platforms. This is given appropriate sea state, handling equipment, vehicles, personnel, and training. Sea state 4 operations represent the threshold capability for all stages, with sea state 5 operations being the desired objective.

The XG-21 logistics glider model is moved and staged as necessary between each of the following steps.

1. The XG-21 body is constructed.
2. Its tail is added.
3. Its wings are attached lengthwise to the glider body.
4. Its payload is inserted.
5. It is trucked into launch position on the helipad, weather deck, or flight deck.
6. Simple preflight activities are conducted, including raising its towline to the aerostat overhead.
7. It is snatch-launched.
8. It “retrograde returns” to the weather or flight deck.
9. Any retrograde processing is out on the deck.
10. It is then either reloaded, or taken inside for disassembly and stowage or put into the assembly line for a repeat cycle.

Once this cycle is underway, individual logistics gliders either transit across the deck in a continuous retrograde recovery, load, and launch cycle, or together they are parked and queued between windows of flight operation. This latter option may occur aboard the Sea base, ashore, or in littoral waters (in the case of the amphibious logistics glider). These cycles apply to both the XG-21 and the amphibious logistics glider if the flight deck can support landing and launching the latter model.

The amphibious logistics glider is not intended for any regular assembly or disassembly. Once empty and deposited in littoral Sea base waters, the floating amphibious logistics glider receives a wet cargo CONREP by those ships so capable. Ship cranes might provide an underway catch and tow of amphibious gliders, or a fetch by smaller boats takes place. The amphibious glider may be towed behind or moored either alongside or to a buoy, depending on sea state. There will be sea state limitations to this afloat processing, likely around sea state 4.

After fill-up, the amphibious glider can be released and later surface-launched from the water, independent of ship operations. This requires a self-launching, disposable balloon for intercept. More economically, the amphibious glider is tethered astern with its towline snatched from the same type of reusable aerostat used in helipad launch.

A logistics glider could be filled by a wet cargo vessel while sitting on the deck of another vessel via span line CONREP. However, the MPF (F) Squadron ships reviewed all have indigenous wet cargo capability and would not typically fill a remote logistics glider via ship-to-ship CONREP.

## **2.1 T-AKE Class**



Figure 1. T-AKE 1 *Lewis and Clark* Class

The T-AKE class Sea base platform is examined for iHL-specific capabilities. The many and varied supply interfaces of the T-AKE offer the greatest offload capacity of the Sea base. T-AKE elevators and corridor volume dimensions have the greatest restrictions to processing the XG-21 logistics glider. Chapter 3 will later design the XG-21 for this processing given the restrictions described next.

Three ships<sup>4</sup> of the T-AKE Combat Logistics Force, Underway Replenishment (UNREP) and Auxiliary Dry Cargo Carrier ship class<sup>18</sup> will be in the MPF (F) Squadron. Figure 1 shows a T-AKE. The T-AKE is a standardized blueprint design class for stowing and transferring pallets ranging in size from the JMIC up to QUADCON and VLS canisters. T-AKE movement clearances do not support TEU containers. Figure 2 depicts a JMIC representation,<sup>19</sup> which is a size and volume specification for the standardized means of processing T-AKE cargo.<sup>15</sup>



Figure 2. JMIC Example

Best Sea base performance is achieved when supply ships offload fastest—at or above what the warfighter requires. The T-AKE class offers excellent supply chain throughput performance by providing in parallel wet fill-ups, dry-helipad snatch pickup, and dry cargo CONREPs to other vessels. The first two are described next in iHL operations, followed by the assembly and retrograde processing procedures of the XG-21.

Not used in helipad launch operations are two aft fuel lines to service one astern craft, two helipad-accessible cranes, and four pairs of CONREP stations. Portside CONREP

station 5 and starboard CONREP station 6 are bulk liquid transfer stations with eight-inch span line hoses. Along with the stern fuel lines, they provide one mode of iHL operation.

- Sea-based sustainment launch of bulk wet supplies. Cyclical amphibious logistics glider CONREP, fill-up, and surface snatch pickup occur. This may occur along either or both sides of the T-AKE, in tow behind the T-AKE, or remotely to a buoy with parked amphibious gliders. Afterwards, floating amphibious logistics glider staging and surface snatch pickup occurs in either of two options.
  - Released for snatch pickup independent of ship operation
    1. Staged at a buoy or sea anchored
    2. By remote activation, it lofts a disposable balloon
    3. Snatch pickup occurs
  - Tethered astern for snatch pickup
    1. The MLP lofts its pickup towline to a reusable aerostat
    2. Release of its tether
    3. Snatch pickup occurs

The T-AKE in iHL operations assembles, loads, and launches XG-21 logistics gliders. This provides both a JMIC dry cargo payload as well as bulk liquids within tanks or bladders inside JMIC. The T-AKE helipad is used to snatch launch, recover, and (using a 2½-in. hose) provide payload fuel to nonamphibious logistics gliders. There are two cargo modes in helipad launch.

- Sea-based surge dry launch of supplies. Cyclical XG-21 assembly, load, and helipad snatch pickup occur.
- Sea-based sustainment dry launch of supplies. Cyclical XG-21 VERTREP delivery, load, and helipad snatch pickup occur.

Once stores are exhausted, CONREP restocking of the T-AKE may be added to this cycle, or more likely, the ship returns to an advanced port for restocking.

Interior to T-AKE Level 1 is the main deck. It has two parallel corridors leading aft to the helipad. The port corridor has the wider minimums. It ends at the hangar door, although the empty hangar could be considered a corridor extension. The port corridor's smallest neck-down occurs only if the Outsized Cargo Stowage area is fully utilized. Otherwise its secondary neck-down is 12½ ft wide. The starboard corridor's smallest neck-down is 9 ft wide due to a protective post; and a secondary minimum is 9½ ft wide. These measurements are between clearance lines 600 mm (nearly 2 ft) off the wall. Six of the ship's eight elevators are between the corridors. Elevators 1 through 4 are large drive-through elevators. Elevators 5 through 8 are smaller, single-opening elevators. Elevators 7 and 8 are only accessible from the starboard corridor. Of interest are cargo holds on deck Levels 2 through 5, below the main deck, with access via the elevators.

XG-21 components for assembly are separately embarked in cargo holds into theater. The corridors then become an assembly line to queue the XG-21. The appropriate components are brought up in elevators 1 through 4 as needed. The body is typically assembled in the port corridor.

Table 1. T-AKE Dimensions on the Main Deck

| Name                                          | Center Line Frame | Clearance Dimension (ft) | Comment                                 |
|-----------------------------------------------|-------------------|--------------------------|-----------------------------------------|
| Helipad                                       | 78 - 101          | 111 L x 105 W            |                                         |
| Hangar                                        | 71 - 78           | 62-6 L x 59-5 W          |                                         |
| Port corridor<br>Hangar door                  | 71                | 15-9 W x 8-2 H           | 110-mm clearances                       |
| Port corridor                                 | 29 - 71           | 417 L                    |                                         |
| Port corridor<br>neck-down                    | 66 - 69           | 7-7 W                    | If outsized cargo<br>Stowage is filled. |
| Port corridor<br>2 <sup>nd</sup> minimum      | 40                | 12-6 W                   | Bump with clearance                     |
| Starboard corridor<br>weather door            | 78                | 12-4 W x 8-2 H           | 110-mm clearances                       |
| Starboard corridor                            | 29 - 78           | 488 L                    |                                         |
| Starboard corridor<br>minimum                 | 74                | 9-0 W                    | 4-in. post, 3 ft high                   |
| Starboard corridor<br>2 <sup>nd</sup> minimum | 68                | 9-6 W                    |                                         |
| Elevators 1 - 4                               | 40,45,50,55       | 30-2 L x 9-6 W x 8-6 H   |                                         |
| Elevators 5 - 8                               | 60,65,67,77       | 10-2 L x 16-3 W x 8-6 H  |                                         |
| Deck Levels 2 - 5                             | -                 | 10-0 H                   |                                         |

Figure 3 depicts to scale seven, green-outlined XG-21 bodies, noses, and tails within the yellow port corridor. Each travels to the forward Pre-Staging Area for a U-turn and then aftward down the starboard corridor where the wings are added. If the two support columns in the center of the Pre-Staging Area prevent a U-turn of this length of the XG-21, then the tail components must be attached after the body turns around rather than before.

The wings are first attached along the lengthwise axis of the glider. Figure 3 shows, to scale, six green-outlined wings staged in the starboard corridor. Wing-assembled logistics gliders can be staged in both corridors. The helipad is used for simple, final pre-flight configuration such as rotating the wing and lifting the tail. The aerostat-based intercept station and the glider towline are lofted from the T-AKE. Then the helipad is used to snatch launch the logistics glider across the helipad.

Once operating in the Sea base sustainment phase, the retrograde delivery of a logistics glider is vertical onto the helipad. It is then queued into the interior corridors for processing. Eleven assembled XG-21s can be parked at once in the corridors between flight operations. The port corridor gliders would then be facing aft. Two more may have their wings removed for parking their bodies in the Outsized Cargo Stowage and against the forward wall in the Pre-Staging Areas, underneath the forwardmost wings. Otherwise they may be disassembled and then stowed.



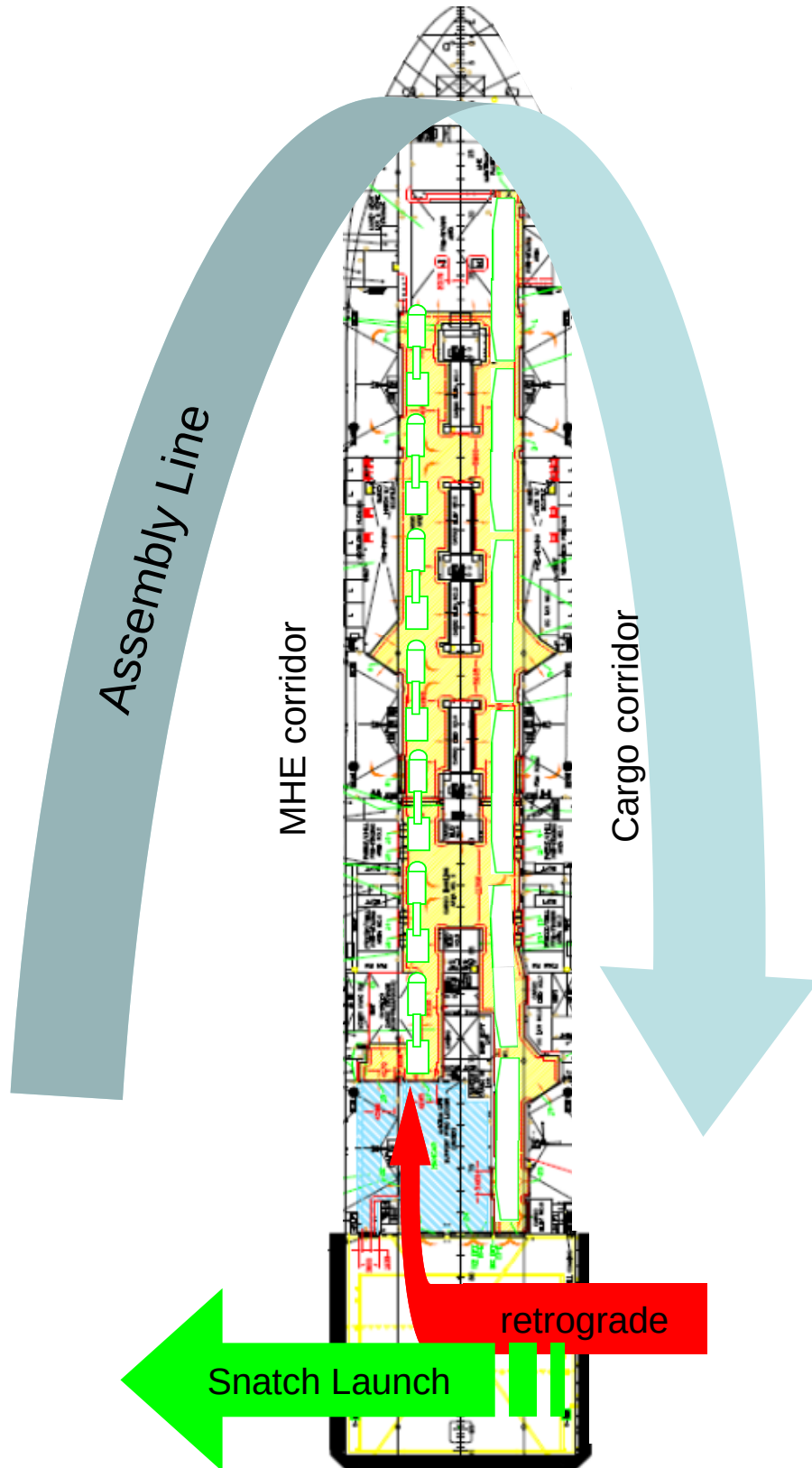


Figure 3. T-AKE Movement Flows with 13 Logistics Gliders

XG-21 loading is by potentially two customizations upon the Advanced Concept Technology Demonstration (ACTD)<sup>20</sup> program's Joint Modular Intermodal Platform (JMIP).<sup>21</sup> The JMIP from the ACTD is conceptually represented in Figure 4. The iHL JMIP is likewise a strong pallet to forklift many JMIC—only designed specifically for their placement into the payload bay of the logistics glider. Depending on payload bay design, the JMIC may sit on top of the iHL JMIP as below, or JMIC may suspend from it via rails, such as for airdrop—or both may be utilized separately with multiple iHL models.



Figure 4. JMIP Supporting Eight JMIC

The XG-21 assembly-to-launch sequence is an assembly line as follows, with each step able to be performed in parallel with others.

1. Retrieve the XG-21 body and tail components via elevator(s) 1, 2, 3, or 4.
  - a. Transfer from the elevator(s) into assembly locations either in the port corridor facing ship forward, or in the starboard corridor facing aft.
  - b. Assemble into one unit.
  - c. Begin system interfacing for built-in-test and mission programming.
2. Truck the body to the wing assembly locations.
  - a. If in the port corridor, U-turn around either in the forward Pre-Staging Area or Cargo Handling Area No. 2 to face aft in the starboard corridor.
  - b. Once in the starboard corridor, prepare space for wing movement out of elevator(s) 1, 2, 3, 4, or Cargo Handling Area No. 2.
3. Retrieve the four unique components comprising the left and right wings.
  - a. Adjust flaps and ailerons to maximum down position.
  - b. Rotate the wing roots on top so as to face forward and aft.
4. Position the left wing in front of the nose and lift to attach over the nose to the front-facing wing root.

5. Position the right wing behind the rear and lift to attach it over the tail to the rear facing wing root.
6. Retrieve JMIC payload from (an) elevator(s).
7. Lower rear ramp.
8. Prepare payload and load the logistics glider in any of three ways:
  - a. Prepare remotely to the logistics glider. This allows payload preparation even in the cargo holds.
    - i. Set up the iHL JMIP-variant in any assembly area.
    - ii. Arrange JMIC on the iHL JMIP in the appropriate offload order.
    - iii. Drive the assembly under the rear wing and up to the logistics glider's rear cargo opening.
    - iv. Lift and insert the assembly into the logistics glider.
  - b. Behind the logistics glider. This is the fastest method for last-minute changes by side-loading directly out of elevators 7, 8, and Cargo Handling Area No. 2.
    - i. Set up the iHL JMIP directly behind the logistics glider's rear cargo opening.
    - ii. Arrange JMIC on the iHL JMIP in the appropriate offload order.
    - iii. Lift and insert the assembly into the logistics glider.
  - c. Individually lift into the logistics glider. This supports fast payload changes or loading of the rear JMIC only.
    - i. Individually lift and insert JMIC in the appropriate offload order.
9. Truck the XG-21 aft for preflight programming and staging.
10. Truck it out of the cargo weather door onto the helipad.
11. Rotate wings into flight position.
12. Lift the tail up into flight position.
13. Close the rear ramp.
14. Back the logistics glider to the beam and chock or brake until launched.
15. Once the helipad is cleared and towline lofted by the aerostat, connect the towline to the logistics glider for launch.

The retrograde sequence starts with the logistics glider delivered to the helipad.

1. Inspect during arrival for major damage to immediately send elsewhere.
2. Disconnect the VERTREP lines to the logistics glider.
3. Wave off the hovering delivery vehicle.
4. Hose off any mud or debris.
5. Rotate the wings.
6. Truck the XG-21 into the ship.
  - a. Back into either the port or starboard corridors. The port corridor does not require flaps and ailerons to be rotated down since the doorways and corridor are wide enough. The starboard corridor is backed into only if the glider is undamaged and to be queued for reloading and launch staging.
  - b. If the logistics glider is damaged, then it should go into the hangar and, if possible, enter via the port corridor weather door.
7. Optional disassembly involves:
  - a. Unload the payload bay.

- b. Separate wing, tail, and body components.
  - c. Components exit via elevator(s) or become queued for next assembly line.
- 8. The launch processing cycle begins again.
  - a. Wings can transfer through Cargo Handling Area No. 2 to final assembly in the starboard corridor.

Problems need quick resolution during iHL operations to maintain minimal launch cycle times for throughput performance. The T-AKE does not have the necessary interior volume for significant component remanufacturing, diagnosis, or testing. If possible, clearly damaged logistics gliders need to be delivered, not to the T-AKE, but either to ashore depots or to other ships with the appropriate facilities. Only limited built-in-test and component replacement is possible. Patching or repairs should be performed with any atypical disassembly done either on the helipad, in the hangar or, if possible, moved to the Outsized Cargo Stowage. This transfer can be accomplished by crane if necessary.

The safe movement of personnel crossways to the assembly line and the blocking of any overhead lighting in the Cargo corridor will need review. When it moves, the XG-21 turns only at:

- Pre-Staging Area or Cargo Handling Area No. 2 for a U-turn
- Cargo corridor bend at Frame 68 for staging
- The helipad for preflight preparations

The XG-21 needs to turn during retrograde to:

- Leave the helipad into the main deck
- Outsized Cargo Stowage (if damaged)

## 2.2 LMSR Platform



Figure 5. T-AK 3015 1st LT Harry L. Martin

Three ships<sup>4</sup> of the Large, Medium Speed, Roll-on/Roll-off (LMSR) vessel platform<sup>18</sup> will be in the MPF (F) Squadron. Figure 5 shows an example of an LMSR. An LMSR consists of several ship classes, each with various blueprints and configurations. They are primarily intended for ground vehicle shipping and offload. All have significant open volume on the five below-deck levels primarily intended for ground vehicle storage and processing. All have helipads in varying locations, which are not served by ramps. Ramps only go as high as the weather deck. Some ship classes have weather decks available for VERTREP operations, but others do not. Some have large cranes to consider with any flight operations on the weather deck.

Those ships that have ramps to VERTREP-capable weather decks are preferred for XG-21 processing. Ramp access to the launch area is highly desirable since it significantly improves iHL system performance by minimizing launch cycle time when compared to flight deck elevators. Ramp openings allow movement and processing of logistics glider models having adjustable wings. No logistics glider model will fit through ramp openings with wings in flight position due to the width of the ramp. A 15-degree ramp angle limits maximum design wingspan in its rotated, lengthwise position during ramp movement.

The LMSR in iHL operations maintains and repairs logistics gliders, in addition to providing payloads of JMIC, ground vehicles, or other irregularly shaped equipments. The Expeditionary Fire Support System (EFSS), High Mobility Multi-purpose Wheeled Vehicle (HMMWV), HMMWV trailer, Interim Fast Attack Vehicle (IFAV), and M777A1 Lightweight 155-mm Howitzer are within XG-21 airfoil design weight capacity, but require a different body(ies) to contain these payload shapes. Movement of

ground vehicles adds an expeditionary warfare nature to the logistics glider. This imparts a new designation of “expeditionary glider” to represent all potential models beyond the two logistics glider models in this paper.

In Figure 6, the A deck of the LMSR<sup>22</sup> is desirable, for its shelter and size, for XG-21 processing in preparation for launch. All lower decks may additionally prepare it or its payload. The components of the XG-21 are embarked below decks either separately or in multiples of TEU volumes densely stowed. For operational construction, an assembly line is established and the XG-21 staged for its launch window. Then it is towed to the weather deck for preflight processing and snatch launch.

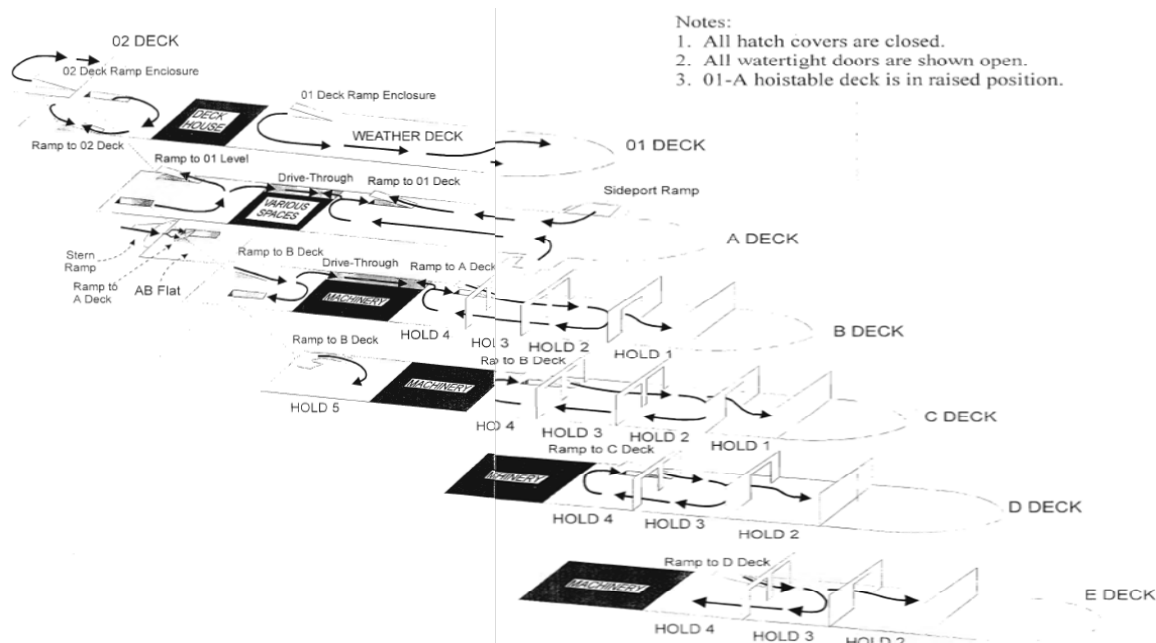


Figure 6. T-AKR Shugart Class Flow Schematic

The XG-21 logistics glider model launches across the LMSR weather deck. There are many expeditionary glider modes for the LMSR.

- Sea-based surge dry launch of supplies, vehicles, and equipments. The XG-21 is assembled and launched just with supplies.
- Sea-based sustainment dry launch of supplies. Cyclical XG-21 VERTREP delivery, load, and snatch pickup occur. Once stores are exhausted, either CONREP restocking of materiel may be added to this cycle or, more likely, the ship will return to an advanced port for restocking.
- Expeditionary glider repairs, maintenance, and diagnosis.

### 2.3 LH - Amphibious Assault Platform



Figure 7. LHA 1 *Tarawa*, LHA 6 Class, LHD 1 *Wasp*

Two Amphibious Assault ships of the LHA 1 class or the LHA 6 class (also known as LHA(R)), and one Multi-purpose Amphibious Assault ship of the LHD 1 class<sup>23</sup> will be in the MPF (F) Squadron.<sup>4</sup> Figure 7 shows existing and proposed platforms. These LH-platform ships have flight deck space over 800 ft long with a flight deck elevator.

LH-platform ships typically support higher priority missions, although they are the traditional source for cargo connectors headed ashore. The LH-platform in iHL operations are acceptable for logistics glider surge launch, recovery, and repair. They are less acceptable for sustained cargo throughput performance when requiring CONREP, due to the lowered supply chain performance from strike up, strike down, and the flight deck elevator. Logistics gliders are usually delivered by air to the LH-platform ships, or otherwise as cargo: CONREP transfers bring logistics glider components and payload aboard. Payloads are brought up on the flight deck elevator either separately for amphibious logistics gliders, or already combined with the XG-21. Loaded logistics gliders are staged on the flight deck awaiting snatch pickup.

All logistics glider models can be supported on the LH-platform flight deck. These ships are good for providing free-flying landing to the Sea base and in the staging of many logistics gliders. There are several modes for the LH-platform operating iHL.

- Logistics glider's organic tow craft operations, maintenance, stowage, refueling, and crew support.
- Sea-based surge dry launch of supplies, vehicles, and equipment. Cyclical logistics glider load, and snatch pickup occur.
- Sea-based sustainment dry launch of supplies. Cyclical landing, loading, and snatch pickup occur.

Once embarked stores are exhausted, the CONREP delivery of materiel must be added to this cycle. It is not likely the ship will immediately return to an advanced port for restocking. Careful iHL design can allow limited processing on the flight deck in parallel with some other deck operations.



## 2.4 MLP Class

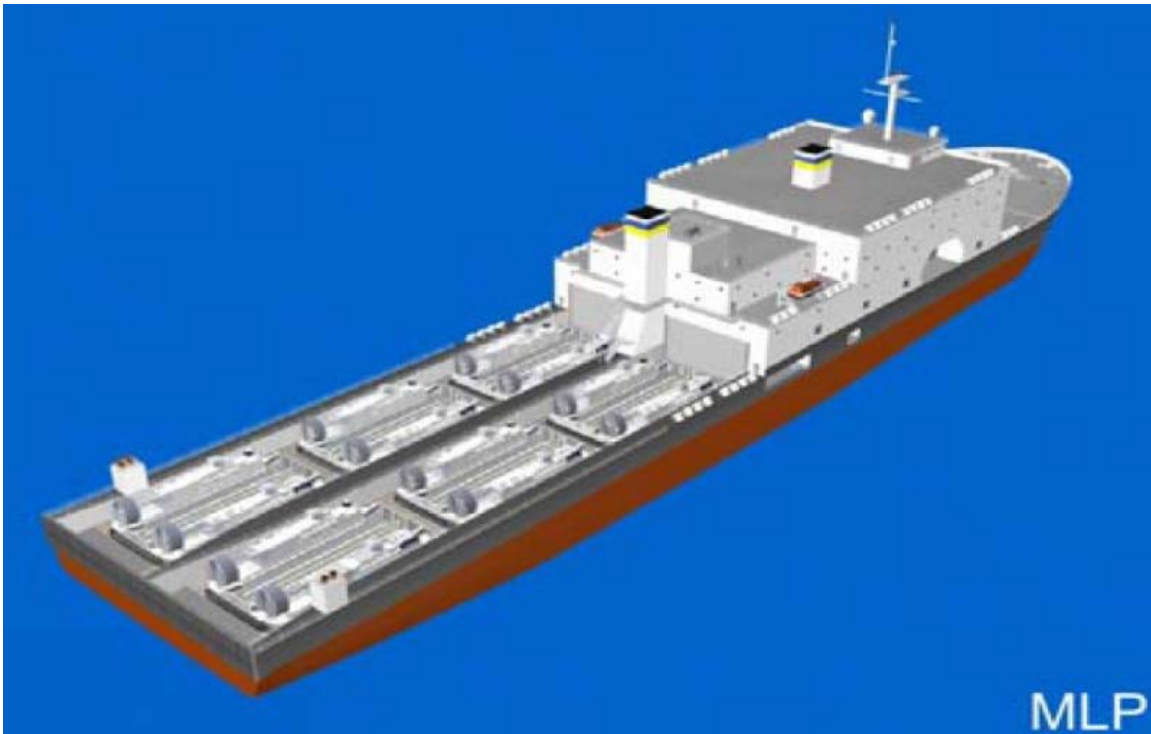


Figure 8. Mobile Landing Platform Concept

Three ships of the Mobile Landing Platform (MLP) class<sup>23</sup> are expected in the MPF (F) Squadron.<sup>4</sup> This class has yet to be designed and built. Figure 8 shows one concept. “The MLP will have limited capacity to store dry cargo sustainment for forces ashore but will have ample fuel capacity and water-making capabilities”...<sup>4</sup> This reduces the reliance ashore on bulk liquids from the traditional resupply via LH-platform ships. The MLP is assumed to have a deck capable of being either dry by pumping upwards or wet by pumping downwards to the surface for LCAC transit.

The MLP has the potential to provide the greatest capacity in iHL modes of operation with all logistics glider models. Some of these modes could potentially operate in parallel. Dry, the MLP flight deck supports XG-21 launch and VERTREP delivery recovery. Wet, it supports amphibious logistics glider recovery and surface release. Alongside, amphibious logistics gliders are filled up.

- Sea-based surge launch of supplies, vehicles, and equipment. Logistics glider load and snatch pickup occur. Everything is staged aboard.
- Sea-based sustainment launch of dry payload. Logistics glider recovery occurs by any dry or wet modes and it is transferred by crane or ramp to the supply ship for processing and launch. Note that this approach is atypical in that it degrades cyclical supply chain performance with transfer complexity and sea state risk.
- Sea based sustainment launch of dry supplies. Cyclical CONREP of payloads, XG-21 VERTREP delivery, load, and snatch pickup occur. Each is loaded with



cargo payloads transferred from supplying ships and then launched directly. Note that while this approach is efficient from a throughput perspective, it is somewhat less efficient with delivery synchronization than the next and last modes.

- Sea-based sustainment launch of wet supplies. Cyclical XG-21 VERTREP delivery, load, and snatch pickup occur. Each is filled with bulk liquids and launched directly.
- Sea-based sustainment launch of any payload. Cyclical connected delivery of payloads (by crane, LMSR ramp, or T-AKE highline), amphibious logistics glider scoop-up, load, and surface snatch pickup occur. The MLP flight deck may recover an amphibious logistics glider by lowering as a ramp to the water surface and hauling it onboard. Any wet, dry, or vehicular payload is then loaded and the glider is returned to the water. For afloat loaded staging and surface snatch pickup, two options are available.
  - Released for snatch pickup independent of ship operation.
    1. Staged at a buoy or sea anchored.
    2. By remote activation, it lofts a disposable balloon.
    3. Snatch pickup occurs.
  - Tethered astern for snatch pickup.
    1. The MLP lofts its pickup towline to a reusable aerostat.
    2. Release of its tether.
    3. Snatch pickup occurs.
- Sea-based sustainment launch of bulk wet supplies. Cyclical amphibious logistics glider CONREP, fill-up, and surface snatch pickup occur. Depending on hose location(s), this may occur along either or both sides of the MLP, in tow behind the MLP, or remotely to a buoy with parked amphibious gliders. The two previous surface staging and snatch pickup options are available.

## 2.5 MPS Platform

T-AK 4296 *Capt Steven L. Bennett* class  
 T-AK 4396 *Maj Bernard F. Fisher*  
 T-AK 4543 *Lt Col John U. D. Page*  
 T-AK 4544 *SSGT Edward A. Carter Jr.*  
 T-AK 4638 *A1C William H Pitsenbarger*  
 T-AK 323 *TSgt John A. Chapman*

Two legacy Maritime Prepositioning Ships (MPS) will be in the MPF (F) Squadron.<sup>4</sup> They lack helipads or selective offloading capability. *In extremis*, a hovering rotorcraft provides emergency service over the bow. MPS are container ships and provide iHL payload and logistics glider components via port facilities only.

### 3 SEA BASE INTERIM HEAVY AIRLIFT

Current expeditionary logistics delivery, including (tilt) rotorcraft, LCAC, and ground vehicles, are not excluded by iHL and may operate in conjunction with iHL. Surface and ground connectors suffer synchronization issues in timely delivery.<sup>24</sup> The most effective ship-to-shore connector system to baseline for a comparison to iHL is a cycle of (tilt) rotorcraft picking up sling-carried cargo off the Sea base, delivery ashore, and returning. iHL improves this concept's performance by separating both the preparation and delivery functions from the towing engines, fuel, and crew.

A robust Sea base iHL system uses the XG-21 and amphibious logistics glider models for ship-to-shore connectors. There are three delivery flight techniques for every logistics glider.

- The WWII technique of tow and release upon final approach into the LZ.
- The standoff release technique at the tow craft's ceiling for a gliding, free flight toward the LZ.
- The airdrop technique to release JMIC at DZ along a delivery route while in flight and remaining in tow.

The airdrop technique is the most efficient concept, when permitted for the given threat environment. For this maneuver, the low-flying tow plane rapidly unwinds the winch to lower the logistics glider near the ground and to slow it down. A JMIC, or smaller multiple of JMIC, is released, perhaps with a static line drogue parachute. Then the logistics glider is reeled back up to speed. Both the container and parachute are disposed without any retrograde recovery intercept. Note that only a single towed XG-21 may be vertically returned onto the Sea base helipad or weather deck after these in-flight delivery missions. Other logistics gliders in retrograde must release to a Sea base flight deck, the littoral water surface, or ashore. Multiple internal columns of JMIC allow containers to be selectively dropped for planned materiel release such as food, water, and batteries, and for contingent delivery of less predictable classes of supply, such as ammunition and fuel. This provides very responsive, local access to essentially an overhead warehouse directly to the maneuvering warfighter without any ground handling of the logistics glider.

During the Sea base surge phase, the standoff release technique requires noticeably fewer towing flight hours than the conventional towed approach, as is shown at the end of this chapter. Once logistics glider recovery begins during the Sea base sustainment phase, the delivery route approach uses the least tow craft flight hours in cyclical logistics glider operations.

The conceptual designs of the two logistics glider models next show key performance considerations and tradeoffs leading to the iHL system performance metrics at the end of the chapter. While their final airframe profile is left to aeronautical design, there may be tactical value in having logistics glider models approximate the MV-22 profile in order to attract hostile fires that might otherwise be directed at the higher value tilt-rotorcraft.

Container and packaging technology improvements need be included in logistics glider development. This includes disposable airdrop JMIC, automated packing technologies, and the previously described iHL JMIP, modified from Figure 4.

### 3.1 XG-21 Logistics Glider

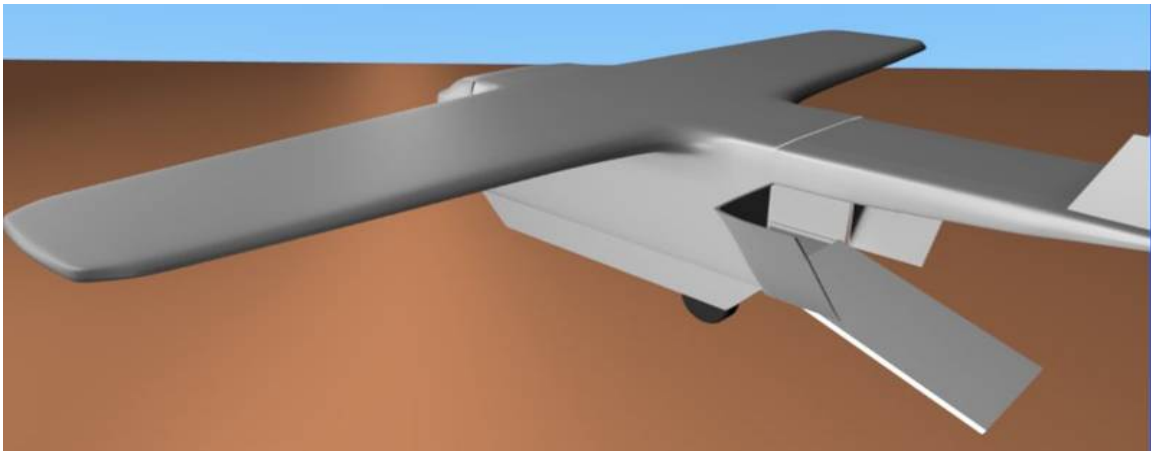


Figure 9. Conceptual XG-21 Logistics Glider

The XG-21 takes features from the XG-21 and XG-22 conceptual models of NSWCDD/TR-06/52.<sup>11</sup> Figure 9 shows one initial concept. Ranges for viable XG-21 logistics glider configurations are examined for:

- Processing restrictions by T-AKE class.
- Movement at the base of an LMSR ramp.
- iHL system performance until realistic aeronautical design refines this model.

iHL performance is sensitive to per-launch logistics glider payload capacity, which is a function of lifting wing area. A larger wing results in fewer launching assets (helipads, tow craft, logistics gliders, and helipad cycles) per tons launched daily. Wing design must support shipboard component movement. Note that the widest part of the wing has flaps that must fit through the 9-ft minimum widths of the T-AKE starboard corridor and elevators. The WWII CG-10A cargo glider had 45-in. flaps with a 60-degree rotation;<sup>25</sup> this report uses 42-in. flaps with at least a 90-degree rotation during T-AKE assembly; with potentially 180-degree movement in its stowed configuration.

The XG-21 is now designed for processing aboard the Sea base. The requirement to stow its unassembled components within an exact multiple of TEU stowage footprint is relaxed as necessary. However, pre-embarkation USTRANSCOM and port facility handling requires its unassembled components to be packaged for ISO-standard handling. A dense stowage capability is still encouraged as logistics glider components and spares do reduce the consumable stowage capacity across the Sea base.

JMIC specification packaging is the only XG-21 payload: likely four maximum filled containers by weight, up to six partially filled containers by volume, or potentially even fractions of six JMIC volumes for customized, small unit distribution. Helipad launches require increased launch acceleration from 0.7 G to 0.93 G.<sup>26</sup> This is due to the shorter takeoff roll than that measured in WWII.<sup>26</sup>

The XG-21 has a lifting body, mono wing, and a high tail over rear cargo access. The nose cone has a retractable wheel for flight. The assembled body fairings, rear wheels, and folded wing over lowered tail must traverse through the narrowest T-AKE corridor sections and bulkhead doorframes, which are 9 ft wide by 8 ft, 2 in. high after safety clearances. The tail and wingtips must not touch the LMSR floor, ramp, or opening when moving on a 15-degree ramp.

The wing is attached to a 90-degree rotating base above the body. Four wing components are attached lengthwise to the logistics glider and are not rotated into flight position until they are on the helipad or deck. The flaps rotate 90 degrees downward to minimize wing width during shipboard movement through the narrowest section of the T-AKE starboard corridor. The ailerons are not rotated so as to allow space for the tail assembly. The tail boom runs just underneath the wing. The tail component's horizontal stabilizer is limited to the corridor minimum width and its vertical stabilizer to the height under the wing. Potentially, two vertical stabilizers in an upside down "U" shape allow forklifts through to load into the cargo entrance in the rear. They are hinged up all the way once on the helipad, or partially up on the LMSR ramp. The payload bay within the body allows the temporary insertion of an iHL JMIP variant to load JMIC. The rear wheels are fixed and the rear ramp adjustable. The iHL JMIP may be inserted with all JMIC at once, or each JMIC may be individually loaded and removed. JMIC are likely placed in a 2x3 pattern, passing over the rear wheel wells.

For retrograde VERTREP onto the helipad, the XG-21 needs to transition from towed flight to a sling carry under the (tilt) rotorcraft. The XG-21 is potentially rigged with dual integral harness lines designed into the top edges of its body down to under the tow hook at the nose.

The optimal fit of the XG-21 wingspan during assembly processing is a critical design consideration. Table 2 uses exact multiples of staged XG-21 lengths to calculate the quantity staged in the T-AKE corridors and each option's maximum payload per launch. A 10-ft buffer between assemblies is assumed (between fully assembled gliders' wingtips in the starboard corridor and nose-to-tail in the port corridor). Vehicles will need to maneuver underneath the assembled wings and tail.

The "Max Payload" follows the model of 62% of GVW achieved by two production WWII cargo gliders.<sup>27</sup> (Both were of non-aluminum construction). Wing lifting surface area determines the flyable GVW of an airframe. The XG-21 maximum payload is thus modeled using a linear extrapolation from the CG-10A wing area-to-payload ratio of 1180 sq ft for 20,000 lb.<sup>28</sup>

Table 2. T-AKE Corridor Staging

| Port Corridor<br>Staged Qty      | Glider Length<br>(ft)   | Max Payload<br>(lb) |
|----------------------------------|-------------------------|---------------------|
| 11                               | 27                      | -                   |
| 10                               | 31                      | -                   |
| 9                                | 36                      | -                   |
| 8                                | 42                      | -                   |
| 7                                | 49                      | -                   |
| Starboard Corridor<br>Staged Qty | Glider Wingspan<br>(ft) |                     |
| 9                                | 44 x 12.5               | 7,800               |
| 8                                | 51 x 12.5               | 9,000               |
| 7                                | 59 x 12.5               | 10,400              |
| 6                                | 71 x 12.5               | 12,500              |
| 5                                | 87 x 12.5               | 15,400              |

An 87-ft x 9-ft object is the maximum shape that can be towed through the bend in the T-AKE starboard corridor at its minimum width. Fortunately, the opening leading to Cargo Station 7 widens to support this maneuver, although “follow-me” floor paint is recommended in both directions. The helipad does not have any obstructions aft or abeam, so a wing spanning over the side, or in excess of the largest listed in the table, could theoretically be launched.

To show some system performance characteristics, critical assembly times and daily short tons of payload launched are projected in Table 3 using the following assumptions. The combining of both corridors’ glider staged quantities from Table 2, and assuming a 30-minute launch cycle, shows that the queue assembled overnight is cleared in the hours listed. Thereafter the remaining gliders to surge must be assembled on the main deck while launch operations are underway. Launching within a ten-hour flight operation<sup>29</sup> window gets a daily launch surge of 20 gliders. The “Staged Quantity” is assembled in the 14 previous hours, while the “Remainder Each” uses the shown average hours to assemble and launch. These parameters estimate the maximum short tons of payload one selective offload ship could launch in daily surge.

Table 3. Twenty-Assembly Surge

| Staged Qty<br>(buffered) | Clear Staged<br>(hrs) | Remainder Each<br>(hrs) | Max Surge<br>(stons) |
|--------------------------|-----------------------|-------------------------|----------------------|
| 20                       | 10.0                  | 14.0                    | 78                   |
| 18                       | 9.0                   | 5.00                    | 90                   |
| 16                       | 8.0                   | 2.50                    | 104                  |
| 14                       | 7.0                   | 1.67                    | 125                  |
| 12                       | 6.5                   | 1.43                    | 154                  |

The combination of wingspan and length is an aeronautical design consideration not performed here. All lengths from Table 2 add up to within practical ranges of “Staged

Quantity” in Table 3. Wingspan is less arbitrary to iHL system performance. The 71-ft wingspan model is selected at this juncture for two reasons.

- The bottom of the wingtip is 7½ ft high, which supports the 15-degree LMSR ramp slope from the rear wheels.
- Its “Max Payload” in pounds is nearest to the equivalent achieved in the WWII launch force modeled in Section 3.3.

Staying within the WWII model, the XG-21 can be launched with a payload of 11,667 lb. This is equivalent to five JMIC averaging 2,333 lb each out of a maximum JMIC specification of 3,000 lb. However, an external MV-22 sling carry model<sup>30</sup> with an average sortie of 7,767 lb<sup>31</sup> of consumable payload is now used for equal comparison. This model may be reasonable for a generalized sling cargo system, but is overly conservative for a specifically designed, internally transported cargo. It is recommended that detailed inventory control, efficient iHL processing techniques, and optimization technology significantly increase this. This payload model allows the overhead of JMIC tare weight of 300 lb per container as well as any packaging inefficiency inside the JMIC.

The surge scenarios in this study do not bring the logistics gliders back to the Sea base as part of the flight window cycle. They can still be processed ashore or elsewhere.

The 20 surged XG-21s can be retrograded, for example, if an additional 5 hours each day are similarly spent in retrograde flight operations. This allows 15 minutes to VERTREP deliver the retrograde XG-21 and clear the deck before the next VERTREP. If, rather, the flight operation window is limited to a total of 10 hours daily, then Table 4 first repeats the surge data with the sling carry model and then shows the short tons supplied daily in an endless sustaining cycle supporting the retrograde of fewer logistics gliders.

Table 4. Ten-Hour Helipad Operations

| Sea base Phase | Launch Cycles<br>(30-minute) | Retrograde Cycles<br>(15-minute) | Daily Consumables<br>(stons) |
|----------------|------------------------------|----------------------------------|------------------------------|
| Surge          | 20                           | 0                                | 78                           |
| Sustain        | 13                           | 14                               | 50                           |

This iHL performance metric is just for dry cargo launched off the one ship. It does not include any additional bulk liquids that the T-AKE and MLP may supply in parallel to external amphibious glider fill-ups described next.

The modeled values are sensitive to the launch cycle time and its flight operations window. A three-minute change to the average launch cycle time can change daily cargo tons by 20%. Ten minutes is given from the commencement of flight operations to the first snatch pickup and 20 minutes after the last. The T-AKE is the worst case with its main deck assembly restrictions. Allowing over an hour to prepare each XG-21, all 12 selective offload ships in iHL operations can daily surge and sustain in excess of one MEB’s requirement of consumables (680 and 367 short tons, respectively) directly to the maneuvering warfighter.

Some iHL-specific MHE will need to be designed for XG-21 processing. This is influenced by the system's processing speeds as it affects launch cycle. All functions need to be performed in sea state 5 and under. Note that rapid requests, payload change outs, and final payload insertion are likely to occur after the glider is assembled. MHE suggestions include deck trucks for moving assemblies, forklifts to maneuver components out of T-AKE elevators and onto the glider, or assembly stations to attach wings lengthwise.

### 3.2 Amphibious Logistics Glider

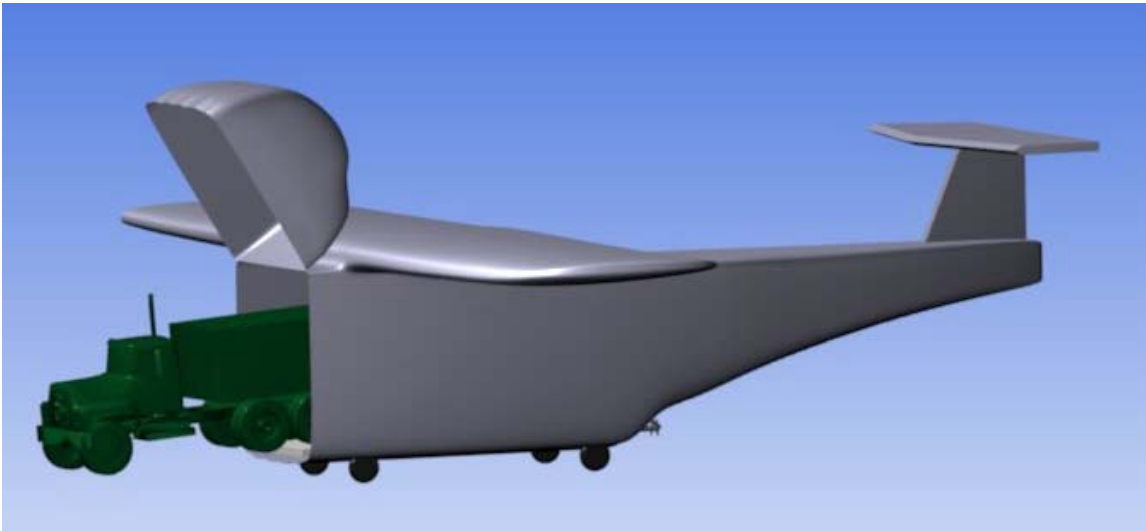


Figure 10. Conceptual Amphibious Logistics Glider

The amphibious logistics glider is a seaplane that flies into the JOA via a long-range tow. It has an expeditionary vehicle-sized, general purpose payload capacity and is not intended for routine VERTREP, assembly, or disassembly. It is a fixed-wing, high-tail glider with the ability to land on water, flight decks, and austere ground. Figure 10 shows one loading concept similar to the CG-4A and R3Y-1 Convair Tradewind. The Tradewind beached ashore to disgorge its payload. Another approach might include otherwise sealed tanks with access portals. An air drop capability implies rear cargo doors placed like the CG-10A, C-130, C-17, or MV-22.

The amphibious logistics glider is intended to deliver the maximum weight and volume of an unloaded Medium Tactical Vehicle Replacement (MTVR). This means the airframe is too long and heavy for helipad launch and it lands either on the littoral water surface or LH-platform deck. Its primary payload is bulk liquids (fuel, oil, or water) from those wet cargo supply ships that support CONREP. During iHL operations, it is estimated to take two hours to connect to, fill up, release, and snatch pickup each floating amphibious glider. Both the T-AKE and MLP should each process at least two at once, one on each side. The T-AKE has the potential for two rear-fueling stations, while the details of the MLP are yet to be designed.

The amphibious logistics glider can transport up to 32,000 lb of palletized cargo or irregular shapes. The largest irregular shapes include one MTRV, Logistics Vehicle System Replacement (LVS), or Light Armored Vehicle (LAV). There are several techniques for loading irregular payloads into amphibious logistics gliders. These specialized loading techniques are for the aerial transit of vehicles and irregularly shaped items, not the typical delivery of daily resupply materiel ashore.

- Load at an advanced base and, together, they are brought into the littoral waters and staged for surface snatch pickup when needed.
- Load on the LH-platform flight deck and snatch. The amphibious logistics glider arrives on the flight deck by free flight.
- Load on the LMSR weather deck and crane transfer to the water for surface snatch pickup. The amphibious logistics glider arrives on the weather deck by crane lift.
- With the two platforms alongside, the payload is either crane-lifted by the LMSR to the MLP wet deck or traverses the proposed ramp connecting the LMSR to the MLP. The amphibious logistics glider is loaded on the deck of the MLP and surface snatched.

For afloat loaded staging and surface snatch pickup, two options have been previously described in the T-AKE and MLP sections.

A shorter wingspan, higher-speed airframe than the XG-21 or CG-10A models is encouraged given the unlimited takeoff distance available. This likewise needs a longer ground takeoff clearance. The shortest wingspan that is aerodynamically allowed increases stability in rough seas—and the risk in hitting ground obstacles during delivery. This configuration needs a higher speed to reach flight rotation with a greater towline elongation during snatch pickup. The higher redline speed is highly desirable for greater range inland in delivery.

Specialized MHE will need to be developed or modified for processing amphibious logistics gliders in each mode of operation. Some concepts include surface tugs to gather and position amphibious gliders, cranes that can ensnare them alongside for CONREP, and remotely operated bulk liquid CONREP technology when the amphibious logistics glider is afloat.

### **3.3 iHL Performance Summary**

Table 5 summarizes the two logistics glider models. It is assumed for this study that the maximum WWII force measured<sup>32</sup> in snatching a glider is the practical maximum, and that this  $F=M*A$  physics formula is linear to GVW. The CG-10A model is now hypothetically redesigned slightly smaller so as to carry its maximum payload in snatch pickup, yet keeping its 62% payload capacity<sup>27</sup> to the WWII snatch pickup GVW of 25,000 lb.<sup>32</sup> This is the baseline WWII redesigned glider model in Table 5.



Next it is assumed the maximum achieved snatch pickup force can be engineered in two directions for the two logistics gliders. For the XG-21 the shorter helipad takeoff distance requires a greater acceleration  $A$ .<sup>33</sup> Hence the mass  $M$  of the logistics glider and, consequently, its payload are proportionally reduced. This is used for the XG-21 design. For the amphibious logistics glider, a payload greater than twice the WWII redesign is desired. So  $M$  is increased for a proportional reduction in acceleration  $A$  and consequent increase in takeoff distance. It has the entire littoral water surface to launch across. This is used for the design of the amphibious logistics glider.

Table 5. Glider Maximum Payload Model

| Glider Model  | Max Snatch Payload (lb) | JMIC Qty | Fuel (gal) | Water (gal) |
|---------------|-------------------------|----------|------------|-------------|
| WWII Redesign | 15,500                  | -        | -          | -           |
| XG-21         | 11,667                  | 4 - 6    | 1,900      | 1,400       |
| Amphibious    | 32,000                  | 12 +     | 5,300      | 4,000       |

This example uses a modern tow craft such as the MV-22 or CH-53. As snatch pickup tow craft, both of these can have a mass and velocity roughly equivalent to tow craft used in the measured WWII snatch pickups. A C-130 could increase WWII velocity and, more significantly, triple the mass, potentially increasing the force applied to the logistics glider at launch. This has the potential to increase payload capacity during each snatch pickup.

### 3.3.1 Throughput Processing

Throughput performance of Sea base iHL surge and sustainment by logistics glider model are paired in Table 6 in a ten-hour iHL operations window within four surge and sustainment scenarios by processing vessels. The logistics glider populations by model are listed for each surge and sustainment scenario. XG-21 models are processed onboard two LH-platform, three LMSR, and three T-AKE ships. Amphibious logistics gliders are processed on one LH-platform and three MLP decks, and afloat by CONREP to MLP and T-AKE. Note that the T-AKE and MLP are counted twice in the ship count, once for onboard and once for liquid CONREP that they process in parallel [the second count is in brackets]. One LH-platform launches at 75% of the other's full rate in order to support tow craft refueling.

The conservative model for consumable materiel delivered is again the MV-22 sling-carry model<sup>30</sup> averaging 7,767 lb, well within the XG-21 payload range. The amphibious logistics glider is assumed to triple the MV-22 model as its consumable payload. For comparison, the equivalent number of sorties via MV-22 is shown (in parentheses) under each scenario's total (stons).

Table 6. Sea Base Daily Launch

| Ship Qty | Ship Platform            | Logistics Glider | Gliders Surge | Surge (stons) (eqv.) | Gliders Sustain | Sustain (stons) (eqv.) |
|----------|--------------------------|------------------|---------------|----------------------|-----------------|------------------------|
| 8        | LH-platform, LMSR, T-AKE | XG-21            | 155           | 2,233                | 104             | 1,693                  |
| 4        | LH-platform, MLP         | Amphib           | 80            | (575)                | 52              | (436)                  |
| [6]      | MLP, T-AKE               | Amphib           | 60            |                      | 60              |                        |
| 4        | LH-platform, LMSR, T-AKE | XG-21            | 75            | 990                  | 52              | 722                    |
| 2        | LH-platform, MLP         | Amphib           | 40            | (255)                | 26              | (186)                  |
| [2]      | MLP, T-AKE               | Amphib           | 20            |                      | 20              |                        |

Liquids make up 70% of 2015 MEB surge tonnage going ashore.<sup>34</sup> Short tons going ashore daily in this very simple example range between 71% and 77% supplied via amphibious glider, with the remainder supplied by XG-21.

The highest throughput scenario in the table has all twelve iHL-capable ships surging in iHL operations. The smallest scenario in the table, with just six iHL-capable ships, shows that half of the Sea base can perform daily MEB sustainment with the rest of the Sea base unavailable, such as away getting restocked. Even without payload optimization or improvement over WWII capability, these tons of consumables launched in a limited operations window are substantially greater than the one MEB ashore requirement. There is a trade space available for system design and operational variations.

If, instead, as listed in the table, all LH-platform vessels were to surge with just amphibious-sized logistics gliders, then the maximum tons daily ashore goes even higher. However, a homogenous logistics glider inventory is in general discouraged as described next.

### **3.3.2 Throughput versus Synchronization**

A casual glance at Table 6 may infer that the three times greater throughput capacity of the amphibious glider over the XG-21 may compensate in removing the XG-21 from developmental consideration—or vice versa from Table 4. Perhaps under certain ideal field conditions this may be possible. This is the throughput metric of Sea base performance. Its synchronization metric means exactly what is needed is delivered, when it is needed, where it is needed.

Despite their overlap, the two logistics glider model's payload delivery characteristics are quite different. Removal of the XG-21 significantly weakens the supply chain by again requiring ship-to-ship transfers and its associated strike up and strike down processing times and sea state vulnerabilities. The amphibious logistics glider cannot synchronize dry cargo as quickly, nor in the same manner, as the XG-21, any more than the XG-21 alone should wholly provide bulk liquid tons ashore. One large tanker is often more

efficient for handling and securing by the ground combat support element ashore than 3-4 smaller logistics gliders—for instance at a FARP.

Two to four bulk liquids dominate the resupply tons sent daily ashore. It is easier to forecast their required usage window and stage them in the supply chain accordingly. Dry cargo has potentially thousands of part numbers, with hundreds of these having the potential of being part of a rapid resupply request, where timely and precise delivery of the exact quantity is of the essence. Being closest to the warehoused source, the XG-21 is specifically intended for fast payload change outs, customized payloads, and immediate launch. It is not significantly slower than the amphibious glider when towed within the JOA. The XG-21's lower landing speeds and lighter weight require a smaller landing zone than the amphibious glider. They would have similar drop zones.

Wasteful delivery to the warfighter is never encouraged, and is explicitly discouraged as the maneuvering warfighter must assume responsibility in its processing, accounting, carrying, or otherwise appropriately disposing of the excess. As the population of an operational Marine unit varies considerably, this implies that customized payloads are built at the Sea base, rather than simply transferring standardized embarked packages into logistics glider payload. At the receiving end of the supply chain, it is much easier for the small unit warfighter to selectively pump the necessary bulk liquids, rather than asking him to selectively unpack his dry cargo needs.

### **3.3.3 Rotorcraft Hours**

Significant operational costs for Sea base-to-shore connectors are fuel consumption and maintenance. Maintenance has an influence on operational availability, with rotary wing vehicles requiring very high maintenance-to-flight hour ratios. Connector fuel consumption is a major issue: LCAC use more than rotorcraft, which still use more than the forces being supplied need ashore.<sup>9</sup> For planning purposes, the MV-22 is estimated to use 400 gallons of fuel per hour, the CH-53 uses 600 gallons of fuel per hour, and the LCAC 1,000 gallons of fuel per hour.<sup>35</sup>

Connector maintenance and fuel take up much Sea base capacity. In the following comparison, these are measured together in terms of engine hours in each day's flight operation. One significant advantage that iHL has over conventional rotorcraft connectors is reduced flight hours of its tow craft. Table 7 lists the specifications used to afterwards compare conventional baseline approaches to iHL.

Table 7. Surge Scenario Specifications

| Description                   | Value  | Units                     |
|-------------------------------|--------|---------------------------|
| Sea base flight operations    | 10     | hours                     |
| LZ distance from Sea base     | 110    | NM                        |
| Surge requirement             | 189    | MV-22 equivalent lifts    |
| Surge requirement, liquids    | 70.2   | percent                   |
| MV-22 consumable payload      | 1      | equivalent lifts / sortie |
| MV-22 speed, empty            | 240    | knots                     |
| MV-22 speed, external load    | 110    | knots                     |
| CH-53 consumable payload      | 2 or 3 | equivalent lifts / sortie |
| CH-53 speed, empty            | 150    | knots                     |
| CH-53 speed, external load    | 110    | knots                     |
| XG-21 consumable payload      | 1      | equivalent lifts / glider |
| Amphib consumable payload     | 3      | equivalent lifts / glider |
| Logistics Gliders towed       | 2      | per sortie                |
| Logistics Glider speed, towed | 140    | knots                     |
| Refuel cycle, approximate     | 1.5    | hours                     |

A comparison of delivery approaches is shown in Table 8. It contrasts conventional air delivery scenarios A and B with iHL scenarios C and D. Scenario A is a CNA baseline of a theoretically ideal conventional surge.<sup>36</sup> Scenario B is a “less optimistic” JMS variation<sup>37</sup> of scenario A. The day’s averaged consumable weight delivered per sortie is estimated as integer multiples of MV-22 lift equivalents. The total flight times that rotorcraft would spend daily in surge delivery operations are then compared.

Table 8. 189-Lift Surge Delivery Scenario Comparison

| Surge Delivery Scenario |                  | MV-22 average sortie (lb) | CH-53 average sortie (lb) | Rotorcraft Round Trip (NM) | Daily Surge Rotorcraft (hrs) |
|-------------------------|------------------|---------------------------|---------------------------|----------------------------|------------------------------|
| A                       | CNA baseline     | 7,760                     | 23,280                    | 220                        | 176 <sup>38</sup>            |
| B                       | JMS variant      | 7,760                     | 15,520                    | 220                        | 321 <sup>38</sup>            |
| C                       | Standoff release | 28,784                    | -                         | 58                         | 34                           |
| D                       | Delivery route   | 28,784                    | 28,784                    | 220                        | 109                          |

For equal comparison, all scenarios refuel after a flight time of one conventional round trip (approximately 1.5 hrs). Scenarios A and B both have the same mix of CH-53 sorties to MV-22 sorties, with each scenario totaling 189 equivalent MV-22 lifts.<sup>39</sup>

iHL scenarios C and D likewise deliver the same 189 equivalent MV-22 lifts, only using a mix of logistics glider models. The XG-21 is simply treated as averaging one lift equivalent and the amphibious logistics glider as averaging three lifts. The proportion of wet to dry cargo for 2015 MEB surge tonnage model is carried into the ratio of amphibious to XG-21 launched. Every sortie snatches and delivers two logistics gliders. So with this wet-dry ratio, the average sortie weight is skewed in the direction of six times the MV-22 lift equivalent. iHL delivery processing and free-flight times are treated independently of glider model for these comparisons.

The iHL Standoff release scenario C has only MV-22 (no CH-53) towing to 24,500 ft altitude before releasing two logistics gliders on a glide slope of 20:1 in order to land 110 nautical miles (NM) from the Sea base. The MV-22 does not travel farther than 29 NM from the Sea base to reach release altitude. This scenario does not mandate same-day logistics glider retrograde to the Sea base. Rather, retrograde to the Sea base may occur at a later time of choosing, with at most 113 “borrowed” flight hours per surge day for later recoveries. This is not depicted in the table. The listed flight hours involve just Sea base surge delivery operations, not necessarily any ashore flight operations which could stage any recovery of these surged gliders sooner.

There likely will be a transition from the surge phase as low-altitude flights become viable, into a hybrid mode between scenarios C and D. Delivery route scenario D is a comparable, 220-NM surge circuit with either the airdrop of cargo or the release of two gliders. It can be converted into a sustainment scenario with the en route release of two gliders and then pickup of two gliders for the least overall rotorcraft flight hours.

Queued flight paths and higher-priority delivery process interruptions can significantly inhibit the maximum performance of any scenario. The queuing delay associated with LH-platform refueling is assumed to be zero for this simplified example. In reality, this significantly worsens as the number of operating aircraft increases given a restricted resource such as LH-platform flight deck space. That resource is highly sensitive to queuing delays, with aircraft that are low on fuel must wait to land at sea. iHL design minimizes reliance upon the LH-platforms for both payload and refueling, rather, spreading payload across all flight capable platforms with fewer refueling tow craft in between.

Scenario C has a roundtrip time for the tow craft of just under logistics glider helipad, weather deck, and flight deck launch cycles. It is simply modeled to show a queuing delay of 1.5 minutes during its return to the Sea base. However this does not occur when amphibious gliders are snatched from the surface, since this technique does not necessarily require launch from ship helipads, weather decks, or flight decks. Scenario D is easily staggered to avoid queues since there are few tow craft on long routes.

## 4 CONCLUSIONS

Performance modeling of the Sea base during iHL operations is summarized in Figure 11 for six comparable, all-air resupply scenarios in a ten-hour operations window. It is based upon conservative payload models and previously achieved Newtonian force during cargo glider snatch pickup. The left two columns show the Sea base with excess connector capacity of several times the daily SBME MEB delivery requirement during both its surge and sustainment phases.

In just meeting the surge requirement, four resupply scenarios are compared to the right. The first two models are red for rotorcraft-only approaches flying what is considered an unrealistic number of hours per day from the Sea base. The two glider approaches in green are highly desirable for daily rotorcraft flight hours. They additionally use 57 XG-21 logistics gliders across helipads, weather decks, and flight decks, and 44 amphibious logistics gliders across flight decks, wet decks, and the littoral water surface. LH-platform flight decks and hangars are not necessarily required for any logistics glider stowage or parking. The best case described here allows for either postponing logistics glider recovery operations (white box) to whenever it becomes convenient or not using Sea base resources for that.

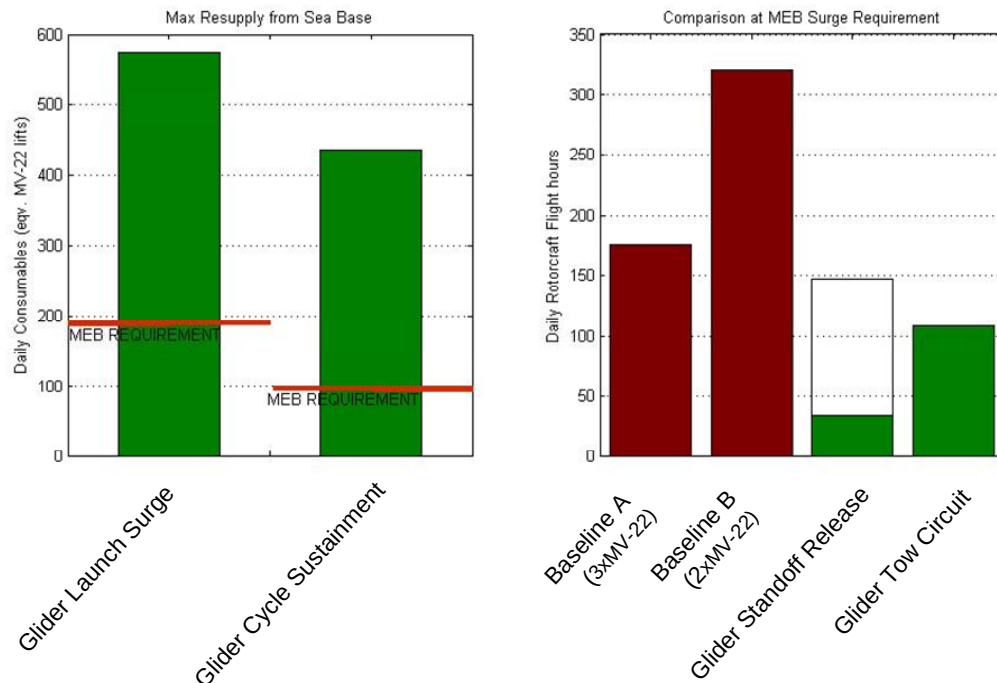


Figure 11. Summary of Performance Scenarios

These scenarios show significant throughput capacity by a Sea base in supplying forces ashore during key phases of expeditionary operation. In addition to the throughput metric comes significantly reduced flight operating times by organic sea-based (tilt) rotorcraft.

- Fewer engine flight hours reduce critical maintenance down times, fuel consumption, and free the rotorcraft for higher priority missions.
- Gliders have fewer mechanical parts for fewer maintenance issues.
- iHL performance models are based upon previously measured and operationally accepted WWII accomplishments, except for the vertical retrograde stage of the dry logistics glider.
- iHL distributes the resupply payload across lower costing, simpler-to-maintain airframes, and reduces the risk and wear to expensive, high-maintenance, crewed airframes.
- Distributing the payload allows simultaneous and independent cargo preparations, deliveries, and unloading while tow craft always are flying in transit, essentially placing the equivalent of a conventional rotorcraft at six different places at the same time.
- iHL supports pre-loading of cargo payloads prior to its transfer onto the helipad, weather, or flight deck.
- The tow craft remains at speed and clear above the ship and ground during pickup and delivery, except for the vertical retrograde stage of the dry logistics glider.
- Logistics gliders, even with several in tow, provide a higher transit speed with less drag as compared to external sling loads.
- The risk to materiel from crushing and pounding during flight is reduced when compared to external sling loads.
- Multiple towed logistics gliders easily match, if not significantly exceed, external sling load capacities per sortie.

The iHL system provides a long-range heavy airlift connector directly from the supplying Sea base platform, bypassing shortcomings in surface, beachhead, and ground distribution chains, for delivery to the maneuvering expeditionary warfighter. The Sea base processing of logistics gliders is shown in this report to be viable. The iHL system is highly desirable with the fastest average delivery rate and a capacity of triple the SBME MEB requirement.

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**APPENDIX A**  
**LOGISTICS GLIDER MEASURES**



| Measure                        | XG-21 Logistics Glider | Amphibious Logistics Glider             |
|--------------------------------|------------------------|-----------------------------------------|
| Maximum dimensions             | 42' L x 71' W x 15' H  | <i>any</i>                              |
| Minimum assembly cross section | 9' W x 8' 2" H         | <i>any</i>                              |
| Wheel footprint                | 15.0' L                | <i>any</i>                              |
| Minimum wheel-to-wingtip angle | 15 degrees             | <i>any</i>                              |
| Minimum wingtip height         | 7.5' H                 | <i>any</i>                              |
| Wing area                      | 743 sq ft              | 1,890 sq ft                             |
| Flaps length                   | 42 inch                | <i>any</i>                              |
| Flaps movement                 | 90 degree              | <i>any</i>                              |
| Stowed cube                    | 2 - 2.5 TEU            | N/A                                     |
| Gross vehicle weight           | 20,300 lb              | 51,600 lb                               |
| Maximum payload weight         | 12,500 lb              | 32,000 lb                               |
| Maximum payload volume         | 6 JMIC                 | MTVR<br>5,300 gal fuel<br>10-32 pallets |
| Assembly time                  | 1 hr                   | Factory                                 |
| Fill cycle, wet                | N/A                    | 2 hrs                                   |
| Launch preparation, dry        | 30 min                 | 30 min                                  |
| Takeoff distance               | 90 ft                  | <i>any</i>                              |
| Launch acceleration            | 0.93 G                 | 0.33 G                                  |
| Retrograde dry processing      | 15 min                 | 15 min                                  |



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