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DESIGN, DEVELOPMENT, AND EVALUATION OF THE HELICOPTER SLING LOAD RAPID AERIAL DELIVERY EQUIPMENT

by
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April 2009 – May 2013

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14. ABSTRACT
This report documents a 4-year program, completed in May 2013 by the Natick Soldier Research, Development and Engineering Center (NSRDEC), to develop and verify the capability to deploy multiple parachute systems from a structure suspended beneath a rotary wing aircraft. The concept is to suspend a range of bundle types, rigged for aerial delivery, from a structure and release them remotely. The development and verification process included payload releases from a helicopter and a crane prior to frame design, modeling and finite element analyses during design, and ground testing and flight maneuvers and airdrop tests of the frame and release system to identify shortcomings, make adjustments, and ultimately provide proof of concept. The tests demonstrated that the concept is feasible. Consequently, it is recommended that development of multiple payload airdrop beneath helicopters be continued at varying forward airspeeds to increase the resupply capability and mission flexibility of rotary wing aircraft and their passengers. The continued testing should incorporate payloads with varying densities to identify any further payload interaction issues that need to be addressed. Testing should also incorporate different fielded parachute systems to ensure these are compatible with the multiple payload airdrop concept. It is also recommended to expand the capability to unmanned systems.

15. SUBJECT TERMS

RAPID	PAYLOAD	AERIAL DELIVERY
CARGO	DELIVERY	AIR DROP OPERATIONS
SLINGS	PRECISION	ROTARY WING AIRCRAFT
BUNDLES	PARACHUTES	MULTIPLE BUNDLE AIRDROPS
AIRDROP	HELICOPTERS	HSL(HELICOPTER SLING LOAD)
AIRCRAFT	HIGH ALTITUDE	JPADS(JOINT PRECISION AERIAL DELIVERY SYSTEM)

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DESIGN, DEVELOPMENT, AND EVALUATION OF THE HELICOPTER SLING LOAD RAPID AERIAL DELIVERY EQUIPMENT

1 Introduction

This report documents a 4-year (April 2009 to May 2013) effort by the US Army Natick Soldier Research, Development and Engineering Center (NSRDEC) to develop and verify the capability to deploy multiple parachute systems from a structure suspended beneath a rotary wing aircraft, from concept and prototype generation to ground and flight testing. Bundles rigged for aerial delivery are suspended from a structure and released. Once the bundles are released, the falling payload extracts the parachute from the deployment bag, allowing the parachute to inflate. Once inflated, the payload descends under the control of the parachute to the ground. The tests served as a demonstration of the capability as well as a means to identify payload interactions and potential payload rigging issues associated with the concept.The work began with development of a concept for suspending airdrop payloads on a structure under a helicopter and remotely releasing the payloads, either in an airdrop mission or as part of a Helicopter Sling Load (HSL) operation. In July 2009, a proposal, titled *Helicopter Sling Load of Joint Precision Air Drop Systems (HSL JPADS),* was submitted to the United States Transportation Command (USTRANSCOM) based on the concept. USTRANSCOM then funded the HSL JPADS Program to demonstrate the concept (Chapter 2), develop a design and prototype (Chapter 3), and conduct ground tests (Chapter 4) and tests utilizing military helicopters (Chapter 5). Various tests were conducted to demonstrate this capability. In July of 2012, the HSL JPADS Program was renamed Helicopter Sling Load, Rapid Aerial Delivery Equipment (HSL RADE) in order to avoid the perception that the system is limited to the JPADS family of parachute systems.

The proposal stated all payloads would be attached to a simple structure, Figure 1, and would use currently approved HSL equipment. The Wireless Gate Release System (WGRS), developed at NSRDEC for the Air Force, would be used to suspend the payloads and to release them at the desired calculated air release point (CARP).

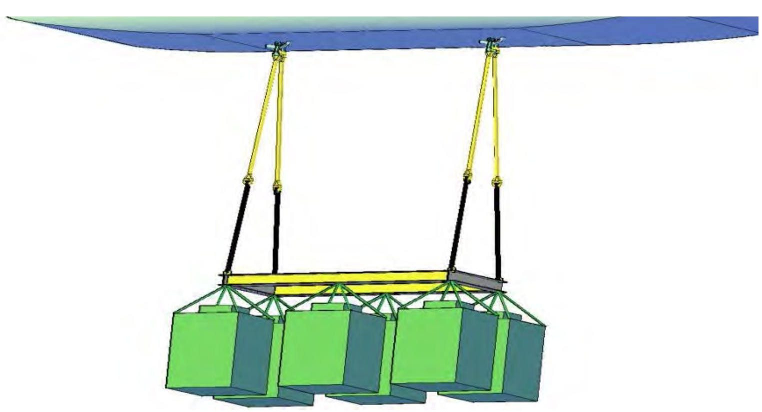


Figure 1: HSL RADE Concept Image

2 Preliminary Testing

While working on the frame design, NSRDEC teamed with Kaman Aerospace to conduct a series of experimental demonstrations of releasing airdrop payloads from a carousel suspended under Kaman's K-MAX helicopter (Section 2.1) and conducted small-scale design exploration tests of the HSL RADE concept under a crane at NSRDEC to verify certain assumptions regarding the deployment of multiple payloads from beneath a helicopter in an HSL configuration (Section 2.2).

2.1 K-MAX Flight Demonstrations

The payload release exercises with the K-MAX were performed under a Cooperative Research and Development Agreement (CRADA) between NSRDEC and Kaman. Three separate airdrop demonstrations with increasing complexity were performed in order to showcase multiple payload airdrops from a helicopter cargo hook.

The primary goal was to exhibit the HSL RADE concept, as well as a multiple bundle airdrop capability from manned and unmanned rotary wing aircraft using guided and unguided parachute systems. The systems demonstrated were a combination of currently fielded technologies and current research and development technology efforts being tested by NSRDEC at the US Army Yuma Proving Ground (YPG).

The K-MAX helicopter (seen in Figure 2) was a dual-rotor aircraft, designed and manufactured by Kaman Aerospace[1], known as a synchropter, which has counter-rotating, intermeshing blades.

Figure 2: K-MAX Helicopter

The carousel used during the K-MAX airdrops was designed and manufactured by Canam Aerospace, Inc. from steel tubes assembled in a pyramidal shape with electric helicopter-style cargo hooks at the corners (Figure 3). The entire structure was suspended from the helicopter via a 50-ft long line manufactured using an ultra-high molecular weight polypropylene sling with an integrated swivel. Each of the cargo hooks had an electrical control line routed along the steel tube of the pyramid and met at the apex. A single control line is attached from the apex to the helicopter. The low clearance under the carousel required some changes to the hook-up process to allow

[1] For more information on the K-MAX contact Kaman Aerospace (http://www.kaman.com)

all payloads to be connected. Payloads that could support the weight of the carousel were positioned under the structure to serve as a base for the carousel. Small payloads that could not support the weight of the carousal were placed on their sides, as seen in Figure 3.

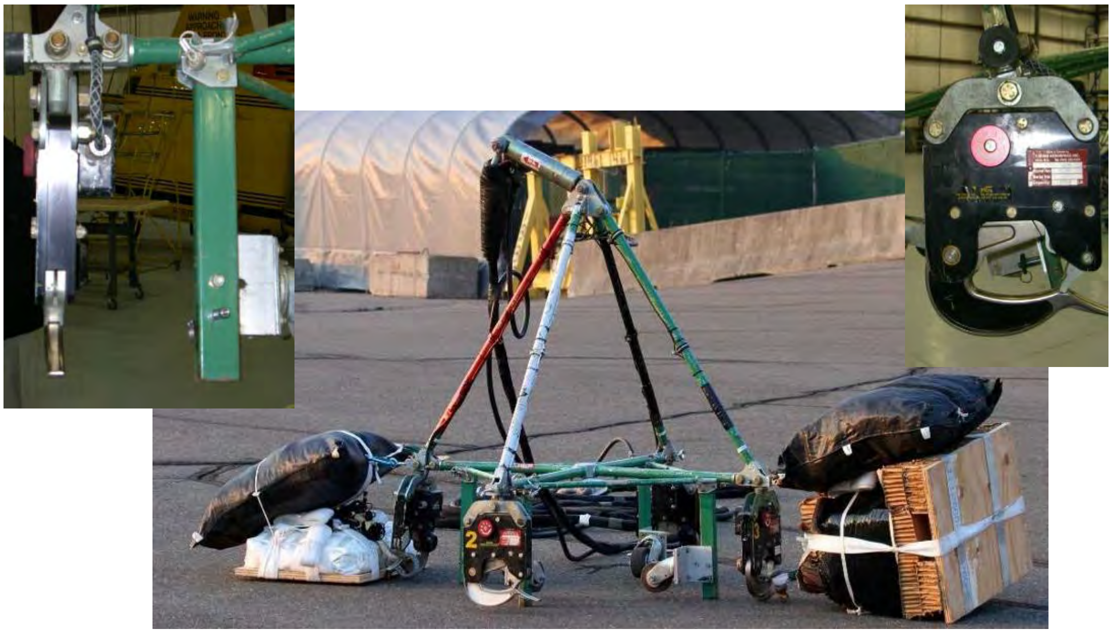


Figure 3: Canam Aerospace Carousel

2.1.1 First Demonstration (21-22 April 2010)

The first K-MAX demonstration used low cost low altitude (LCLA) parachutes and containers. The payloads were rigged per the draft Field Manual FM 4-20.103 *Airdrop of Supplies and Equipment: Rigging LCLA Resupply Loads* with the exclusion of the energy dissipation material (paper honeycomb). Water containers, expired Meal Ready to Eat (MRE) boxes, and sand bags were used as ballast for the six payloads used during the drop. Table 1 contains the rigged payload data for each lift, and Figure 4 shows some of the rigged payloads used during the demonstration.

Table 1: Rigged Payload Data from First K-MAX Demonstration (21-22 Apr 2010)

Lift	Weight (lb)	Number of Parachutes	Carousel Position	Payload Release Order	Payload Material
Day 1					
1	112	1	1	1	Sand Bag
1	118	1	3	3	Sand Bag
Day 2					
1	112	1	1	1	Sand Bag
1	118	1	3	2	Sand Bag
2	219	1	1	1	Water
2	183	2	3	2	Water & MRE
2	119	1	2	3	Sand Bag
2	112	1	4	4	Sand Bag
3	219	1	1	1	Water
3	183	1	3	3	Water & MRE
3	120	1	2	2	Sand Bag
3	119	1	4	4	Sand Bag

Figure 4: Final Rigged Configuration of LCLA Payloads for First K-MAX Demonstration (21-22 Apr 2010)

Airdrop testing was conducted from 21-22 April 2010 at Kaman Aerospace's Bloomfield, CT facility. Each payload was released at approximately 400 ft above ground level (AGL). Day 1 consisted of initial drop tests to validate the process for both the pilot and ground crew members, and Day 2 concentrated on the various rigging styles and alternate configurations. Eleven of twelve airdrops were successful, with one payload failing to release from the carousel due to a rigging error caused by the breakcord tie on the deployment bag being stronger than the total payload weight. The aircraft dropped from a stable hover, and the lack of forward speed of the aircraft was not compensated for when the breakcord tie was rigged. Figure 5 shows the inflation sequence for the LCLA parachute from release to full inflation.

Figure 5: Inflation Sequence of LCLA Parachute during First K-MAX Demonstration (21-22 Apr 2010)

The test report for this demonstration (Tardiff and Matook, 24 June, 2010) outlined some additional configurations to be demonstrated during any subsequent tests. The recommendations stated:

> The continued development of multiple payload airdrop from beneath a helicopter to increase the capability of rotary wing aircraft is recommended. The continued testing should incorporate larger payloads with varying densities to identify any payload interaction issues that need to be addressed. Testing should also incorporate the different parachutes systems and configuration available to ensure that these systems are compatible with the carousel concept. It is also recommended to expand the capability to unmanned systems. Further airdrops should be conducted on a larger DZ with fewer airspace restrictions, allowing the aircraft to have forward speed during the drop.

2.1.2 Second Demonstration (14-15 November 2010)

The second K-MAX demonstration addressed several of the recommendations within the limited available space of the test location. It used LCLA parachutes and A-22 containers. Parachute boxes with equipment and constructed plywood boxes were used for the payloads and each was rigged into an A-22 container per the Field Manual

FM 4-20.103 *Airdrop of Supplies and Equipment*. Table 2 contains the rigged payload data for each lift, and Figure 6 shows one of the rigged carousels used.

Table 2: Rigged Payload Data from Second K-MAX Demonstration (14-15 Nov 2010)

Lift	Weight (lb)	Number of Parachutes	Carousel Position	Static-Line Length (in)	Payload Material
Day 1					
1	560	2 T-10R	1	4	Boxes
1	720	2 T-10	2	4	Boxes
1	20	0	3	N/A	Leaflets
Day 2					
1	520	1	1	1	Boxes
1	350	1	2	3	Boxes
1	320	1	3	2	Plywood
1	320	1	4	4	Plywood
2	100	1	2	1	Leaflets
2	100	1	4	2	Leaflets
2	100	1	1	3	LC HSL Net

Figure 6: Final Rigged Configuration of A-22 Containers for Second K-MAX Demonstration (14-15 Nov 2010)

Airdrop testing was conducted on 14-15 November 2010. Each payload was released at approximately 400 ft AGL. Day 1 consisted of initial drop tests (560 and 720 lb A-22 payloads) to validate the airdrop sequence for both the pilot and ground crew members, and Day 2 concentrated on the demonstration drops. Nine of ten airdrops were successful with one failure due to a rigging error.

During the first lift of Day 1, the 560 lb payload (rigged with two T-10R parachutes) experienced a premature parachute deployment on lift-off because of a mismatch in parachute riser length and suspension sling length. The risers were lengthened for the second lift, which was successful. A leaflet system on Day 1, Lift 2 failed to release from the carousel due to a rigging error. Day 2 consisted of four lifts intended to demonstrate more of the capabilities of a vertical take-off and landing (VTOL), unmanned aerial system (UAS), including a lift of four A-22 containers, a lift of a high altitude low opening (HALO) leaflet system, and a low cost HSL net. All airdrops were successful on Day 2. Figure 7 shows the inflation sequence for the payload with two T-10R cargo parachutes, and Figure 8 shows the inflation sequence for the payload with a single T-10 cargo parachute, from deployment to full canopy inflation.

Figure 7: Inflation Sequence of Two T-10R Cargo Parachutes during Second K-MAX Demonstration (14-15 Nov 2010)

Figure 8: Inflation Sequence of One T-10 Cargo Parachute during Second K-MAX Demonstration (14-15 Nov 2010)

The test report dated 08 March 2011 for this demonstration outlined the same recommendations as the previous test report (24 June 2010) and highlighted the use of the unmanned K-MAX in an operationally similar environment. At the completion of this capabilities demonstration, 2 days of testing were scheduled at YPG.

2.1.3 Third Demonstration (24-25 January 2011)

The third K-MAX demonstration was conducted on 24-25 January 2011 at YPG. These airdrops focused on guided parachute systems, as well as maximizing the lift capacity of the aircraft. The systems demonstrated a combination of currently fielded technologies and current research and development technology efforts being evaluated by NSRDEC. All government fielded systems followed the appropriate technical manual/field manual for rigging and packing with the exception of the secondary suspension slings, which were added solely for the purpose of suspension from the carousel. All non-standard equipment followed manufacturers' rigging and packing procedures with the exception of the secondary suspension slings. Table 3 contains the rigged payload data for each lift, and Figure 9 identifies each of the JPADS systems demonstrated with the associated manufacturer.

Table 3: Rigged Payload Data from Third K-MAX Demonstration (24-25 Jan 2011)

Lift	Pass	System Type	Flight Mode	Ground Speed (KIAS)	~ Altitude (ft MSL)	Suspended Weight (lb)	Carousel Position
Day 1							
1	1	Mosquito	Manual	20	8000	119	2
1	1	Mosquito	Manual	20	8000	29	4
1	2	HALO Leaflet	Auto	0	8000	40	1
1	3	HALO Leaflet	Auto	0	8000	80	3
2	1	Microfly	Manual	40	8000	500	1
2	1	Microfly	Manual	40	8000	450	2
2	1	Microfly	Manual	40	8000	350	3
2	1	Microfly	Manual	40	8000	250	4
Day 2							
1	1	Onyx ULW	Manual	40	8000	400	2
1	1	Onyx ULW	Manual	40	8000	400	4
1	2	Onyx MLW	Manual	50	8000	92	1
1	2	Onyx MLW	Manual	50	8000	56	3
2	1	G-12	Manual	60	2000	1100	2
2	1	G-12	Manual	60	2000	1100	4
2	1	G-12	Manual	60	2000	1100	1
2	1	G-12	Manual	60	2000	1100	3

KIAS = Knots indicated air speed
ULW = Ultra light weight
MLW = Micro light weight

HALO Leaflet
Pioneer Aerospace
(860) 528-0092

Microfly
Wamore
(623) 582-8448

Mosquito
STARA Technologies
(480) 850-1555

Onyx
ATAIR Aerospace
(718) 923-1709

Figure 9: JPADS Parachute System

All payloads were rigged at the aerial delivery facility and transported to the Phoenix Site runway located near Corral Drop Zone (DZ). The Phoenix Site served as the location of the control and monitoring equipment and as a staging site for the K-MAX lifts. The payloads were attached to the carousel and inspected prior to lift-off, which covered rigging of the payloads and GPS satellite lock of the autonomous guidance units (AGUs). The aircraft took off from the runway, proceeded to altitude and prepared to release the payloads. Day 1 consisted of lightweight HALO and JPADS airdrops from approximately 8,000 ft mean sea level (MSL). Day 2 consisted of JPADS systems and heavy unguided parachute systems. Figure 10 shows the inflation sequence of the four G-11 parachutes as the aircraft released all payloads sequentially at 60 KIAS.

Figure 10: Container Delivery System (CDS) Inflation Sequence during Third K-MAX Demonstration (25 Jan 2011)

The test report dated 14 March 2011 for the demonstration outlined recommendations for future tests as well as other potential improvements for the development of an Army-owned carousel system. At the completion of this capabilities demonstration, all goals set prior to the K-MAX demonstration were accomplished. NSRDEC began planning for the USTRANSCOM-funded program, which began after the K-MAX testing was complete, and an Army carousel with wireless capability.

2.2 Small Scale Design Exploration

Five assumptions regarding multiple payloads were tested at NSRDEC by suspending them from a crane on 30 April 2010. Previous experiences conducting HSL certification tests had shown how large items such as High Mobility Multipurpose Wheeled Vehicles (HMMWVs) fly in dual and single point configuration depending on how stable the payload flies. K-MAX testing also identified some payload interactions that may be a problem.

2.2.1 Assumption 1: Single Point Suspension Will Result in Rotation

The assumption is that the frame and the payloads, suspended from a single point, will rotate. Sling loads in a single point configuration typically rotate under a helicopter and stabilize once the aircraft reaches a certain forward velocity. If the frame rotates, the payload orientation will change, making it difficult for the crew chief to identify the correct payload to release.

Additionally, payloads suspended from a single point will rotate with respect to the frame. The rotation of the payloads could create an entanglement between the payload suspension slings and the suspension lines or risers of the parachute.

During testing, the individual payloads hanging from the crane spun, but the adjacent payloads prevented rotation beyond about 20º. Without adjacent payloads, the payload spun enough to cause entanglement with the static line. When conducting actual flight testing, taping the static line to a suspension leg may reduce the risk of a static line entanglement failure. Full system rotations will likely occur, but it is not anticipated to be greater than other HSL single point payloads.

2.2.2 Assumption 2: Dual-Point Suspension Will Prevent Rotation

Suspending the frame under the helicopter in a dual point configuration would be identical to current dual point operations with similar sized payloads. Using dual point suspension for the individual payloads hanging from the frame creates additional challenges. For example, suspending a payload in a dual-point configuration would require two mounting points. If two release mechanisms are used (one per attachment point), any delay in activation time between them would cause the payload to tumble while being released from the suspended structure. The tumbling could cause a malfunction of the released payload or adjacent payloads.

Using dual point HSL operations for the connection of the frame to the aircraft would be the most desired, as it increases flight stability. The CH-47 Chinook is the only Army aircraft capable of dual point HSL missions. Dual point missions decrease payload rotation; however, testing from the crane showed the rigging becomes very complex and increases the potential for failure. Use of the dual point suspension for the payloads to the frame during the proof of concept flight tests was not recommended.

2.2.3 Assumption 3: The WGRS Will Provide Acceptable Wireless Release Capability

The WGRS, a program of record for the Air Force, provides a wireless method of releasing the payloads from the frame. The current configuration of the system was found to be acceptable for demonstration and development purposes.

Multiple release mechanisms and methods, including the WRGS, were tested. The WRGS was found to be the most promising because the connection between the helicopter and payloads would not be fixed to the aircraft. The mechanical release extraction force transfer coupling system mechanism was also tested, and it was determined that any connection to the helicopter is undesirable. Any mechanical method would require physical components to extend into the aircraft and could cause problems if the frame should be cut away during an emergency.

2.2.4 Assumption 4: A Single Cable Will Allow for Self-Centering of the System

A cable strung between two frame hard points was tested as a means of providing a suspension point for payloads and a self-centering capability. The stretched line served as a hookup point for the payloads, similar to an anchor line cable in an aircraft. It was determined that the suspended payloads could be dropped without restricting the order. Once a payload is released from the line, the adjacent payloads should readjust and slide toward the center of the line. Once the payloads move, the center of gravity (CG) of the system would remain relatively constant. Figure 11 shows the test setup for the single cable suspension used for this assumption.

Figure 11: Single-Cable Suspension

Testing showed that payloads could only be released from the ends of the line and not the middle. The multiple catch points from adjacent payloads, as well as the compressive force of the adjacent payloads, prevented center payloads from separating from the frame. Although the concept is promising in theory, the tests showed it was not practical as implemented. Additional work in this area may yield more promising results.

2.2.5 Assumption 5: Securing the Parachute Directly to the Frame Will Reduce Inadvertent Parachute Activation

The parachute may be secured to the frame, bypassing the use of a static line, to reduce the potential of inadvertent parachute activation during forward flight. This rigging method has the potential to reduce hang-ups, depending on the payload suspension style. Single point suspension could cause twisting of the suspension harness and the parachute suspension lines. Dual point suspension has a lower risk of twisting.

The crane testing showed that suspension directly from a frame is possible; however, it would require changing the rigging procedures for HSL RADE payloads. Potential users of the system liked the idea of allowing the helicopter to perform an HSL landing mission and retaining the parachute with the frame; however, they did not like the change in rigging procedures. This configuration should be further investigated if the concept becomes a program of record.

3 Frame Design

A small integrated product team was created to conceptualize the requirements of the frame and its physical appearance. The group consisted of current Pathfinder qualified soldiers, past users, current special operational forces, and engineers. The group determined the basic functionality requirements of the system, including:

- It must be capable of fitting inside a CH-47 so that it can be transported anywhere and shipped using current methods.
- It must be capable of being broken down into sections that are a four-man lift.
- It must be capable of carrying 8 CDS payloads or 32 door bundle sized payloads or a combination of the two.
- It must interface with standard HSL equipment.
- It must not require aircraft modification.
- It must be capable of releasing airdrop payloads (air drop mission).
- It must be capable of flying without payloads at speeds greater than 70 KIAS.
- It must meet all HSL requirements (MIL-STD-209 and MIL-STD-913).
- If possible, it should be capable of use in HSL, in addition to the required air drop, missions.
- If possible, it should have wireless capability.
- If possible, the total weight should be over 2000 lb to ensure proper flight dynamics.

3.1 Concept Generation

Several computer aided design (CAD) models were created in SolidWorks® design software to better visualize the concepts. These concepts were later refined and given material properties to better understand the final product. Figure 12 shows three of the CAD concepts generated and some of their advantages and disadvantage.

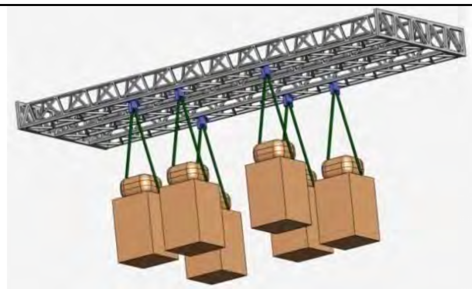
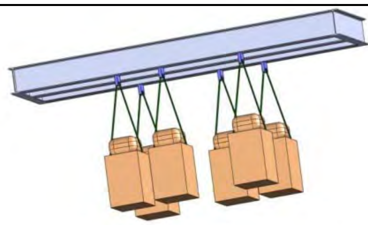
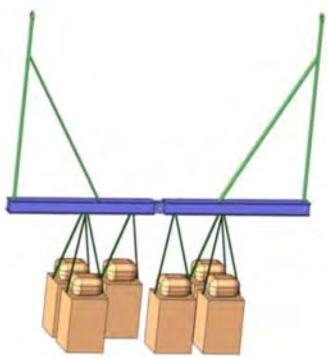
 (a) Lattice Structure	• Release points are not fixed; Soldiers can move payloads wherever needed. • It has potential to be modular. • Estimated manufacturing cost is significantly greater than other concepts. • Overall structure is heavy, reducing the number of payloads that can be used. • Steel is the lightest material that will meet all of the HSL requirements.
 (b) I-Beam Structure	• Release points are fixed. • It has the potential to be modular • Estimated manufacturing cost is mid-range when compared to the other concepts. • Overall structure weight is about average when compared to the other concepts. • Aluminum is the lightest material that will meet all of the HSL requirements.
 (c) Single-Beam Structure	• Release points are fixed. • A limited number of payloads can be attached. • It has no potential to be modular. • Estimated manufacturing cost is low when compared to the other concepts. • Overall structure weight is low when compared to the other concepts. • System design has the potential for instability. • Steel is the lightest material that will meet all of the HSL requirements.

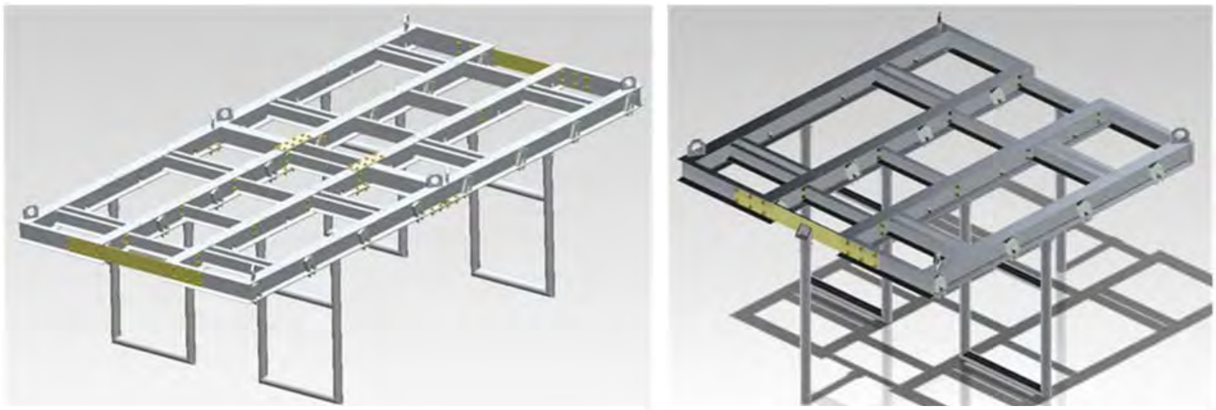
Figure 12: Preliminary HSL RADE Design Concepts: (a) Lattice Structure, (b) I-Beam Structure, (c) Single-Beam Structure

Due to its mid-range weight, cost, and modularity, the I-Beam Structure concept was chosen for full-scale construction. For simplicity, availability of materials, and strength to weight concerns, aluminum I-beams and C-channels were selected for the principal construction. The system is made up of four weldments that are bolted together to create the full assembly. Figure 13 (left) shows the full HSL RADE assembly with the location of lift provisions, as well as the support legs, used to elevate the system to allow for larger payloads.

The full system dimensions are 249 inches long by 112 inches wide by 73.5 inches tall with an estimated system weight of about 1,665 lb when fully assembled. The lift provisions, mounted on the top of the assembly, are 72 inches from the ground, and the gates hang from the lower section of the frame 59 inches from the ground. The full assembly is capable of transporting 8 CDS bundles, 32 door/LCLA bundles, or a combination of the two. The initial design lacked the wireless CDS bundle releases, since they were still in development; however, the physical characteristics of the release were used to create the frame attachment location and method. The leg length was determined by the requirement in MIL-STD-209 that the lift provisions be no more than

72 inches off the ground. Any taller would require integrating a climbing system for the hook-up team.

The system only needs the “H” style legs when in the full system configuration (Figure 13, Left). The four additional legs that are aligned down the center line are used when the full system is split into two half systems (Figure 13, right).



Full System Configuration **Half System Configuration**

Figure 13: HSL JPADS Full System (Left) and Half System (Right) Configurations

The half system dimensions are 124.5 inches long by 112 inches wide by 73.5 inches tall with an estimated system weight of about 780 lb when assembled. The lift provisions, mounted on the top of the assembly, are 72 inches from the ground, and the gates hang from the lower section of the frame 59 in from the ground. The half system is capable of transporting 4 CDS bundles, 16 door/LCLA bundles, or a combination of the two. The leg length was determined in the same manner as the full system.

The system can also be flown in a quarter system configuration (Figure 14) with system dimensions of 124.5 inches long by 42 inches wide by 9 inches tall with an estimated system weight of about 200 lb when assembled. The system would be placed atop the payloads and therefore would not need legs to hold the system up. The quarter system is capable of transporting two CDS bundles, eight door/LCLA bundles, or a combination.

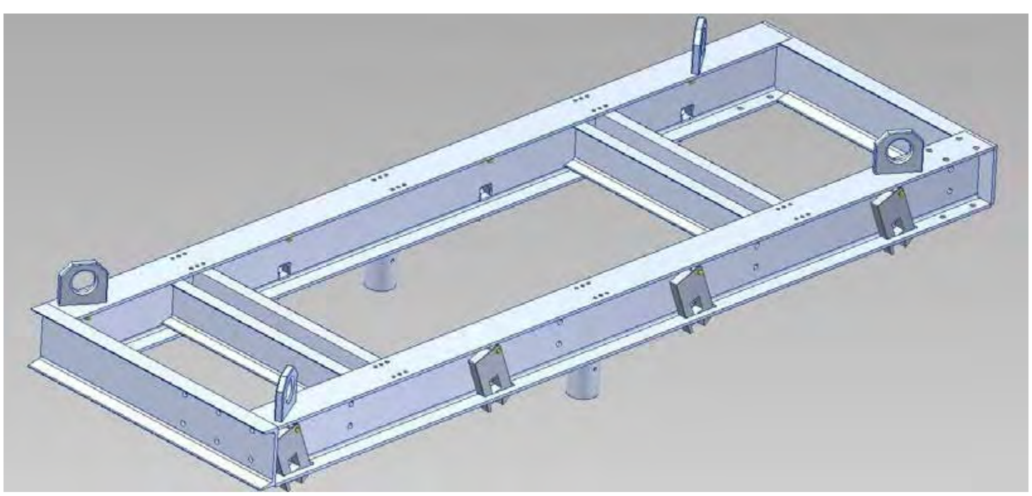


Figure 14: HSL JPADS Quarter System Configuration

The full system can be constructed from two half sections aligned back-to-back, then connected with 6 steel plates and 48 ¾-inch bolts. The initial design effort attempted to keep the full assembly tool-less; however, due to the magnitude of the load factors, a significant moment is placed on the connection point under full load conditions, resulting in material failure. It was determined that the design would be reevaluated at a later date to make the system tool-less. When rigged for operation, the full frame will be flown in a dual-point sling load configuration and will be suspended from the outer-most lift provisions.

For transportability, the entire system can be separated at the bolted connections. The system's minimum volume is 124 inches long by 41 inches wide by 61 inches tall. Each weldment can be stacked top to top with its mate (Figure 15) with the legs and connector beams fitting in the open spaces of the frame.

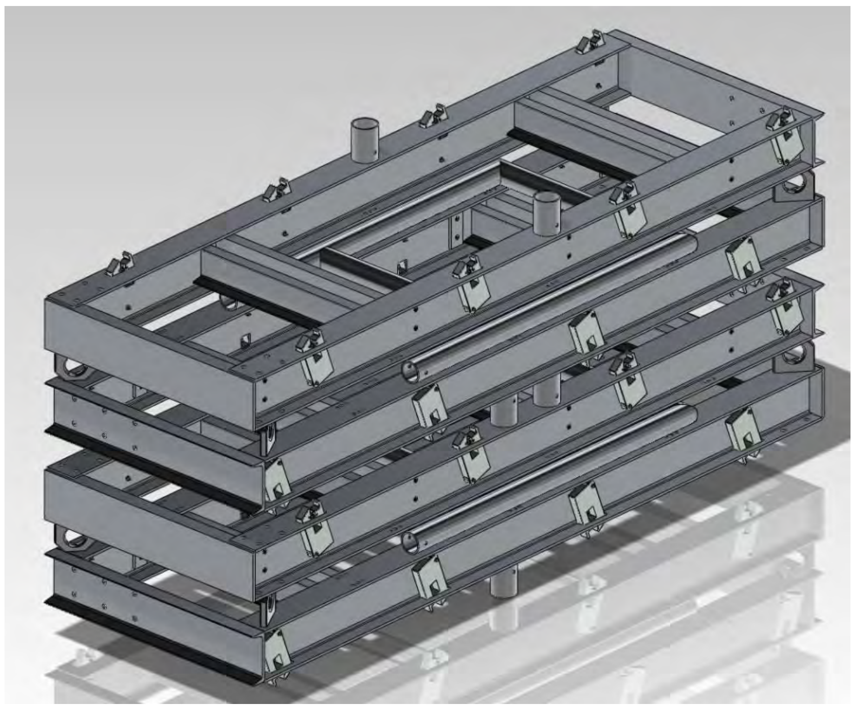


Figure 15: HSL RADE Estimated Shipping Configuration

3.2 Finite Element Analysis (FEA)

Throughout the design process, the SolidWorks® system configuration models were processed through FEA software (Autodesk® Simulation – Mechanical). The multiple model iterations processed through the FEA software showed high stress areas and interface concerns, which could result in material failure or functionality issues. These issues were redesigned and the model was again processed through the FEA software. The load factors were reevaluated once the primary design was completed. The load factors in Table 4 are calculated by including the frame's weight and maximum cross-sectional area with the bundles' weights and maximum cross sectional areas.

Table 4: HSL RADE Load Factors

Bundle Type	Quantity	Wt per Bundle (lb)	System Weight (lb)	Load Factor	Proof Load (lb)
Quarter System Load Factors					
CDS	2	1455	3177	5.89	18713
Door	8	394	3419	5.90	20172
Half System Load Factors					
CDS	4	2400	10380	3.20	33216
Door	16	500	8780	3.20	28096
Full System Load Factors					
CDS	8	2400	20790	2.98	61954
Door	32	500	17590	3.10	54529

3.2.1 Quarter System Configuration

The FEA for the quarter system was conducted on half of the CAD model, cut along the longitudinal center line to simplify the FEA and reduce run times. The final image from the FEA can be seen in Figure 16. The model was set up in the following manner:

- Each payload suspension point was loaded to 2,312 lb (blue arrows).
- Brick elements were sized to fit one per flange thickness.
- Both lift provisions were restrained from moving in the load direction.
- Red circles on surfaces represented surface constraint of symmetry.
- Yield stress limit for the 6061-T6 aluminum was about 37,000 psi..

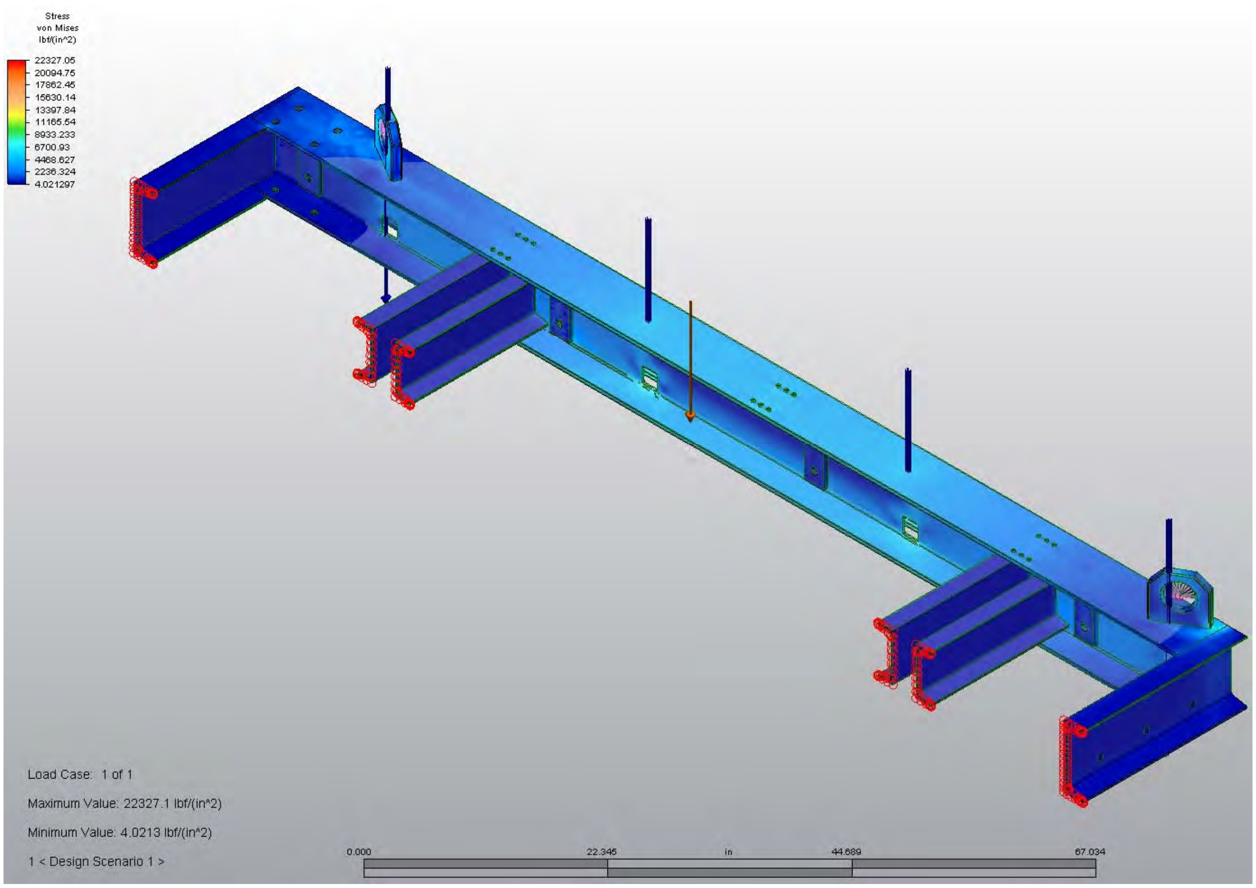


Figure 16: Quarter System FEA

The FEA image does not show any location where the stresses exceed the yield stress of the base material. The greatest loading occurred where the payloads will be attached to the system and is due to the method of attaching the payload in the analysis. However, these stresses are still well below the yield value.

3.2.2 Half System Configuration

The FEA for the half system was also conducted on half of the CAD model, cut along the longitudinal center line to simplify the FEA and reduce run times, but the loading was different from that of the quarter system. The final image from the FEA can be seen in Figure 17. The model was set up in the following manner:

- Each suspension station was loaded to 1,920 lb (blue arrows).
- Brick elements were sized to fit one per flange thickness.
- Outer two lift provisions were restrained from moving in the load direction.
- Red circles on near surfaces represented surface constraint of symmetry.
- Yield stress limit for the 6061-T6 aluminum was about 37,000 psi.
- End plate (bottom of image) was steel with a yield strength of 150,000 psi.

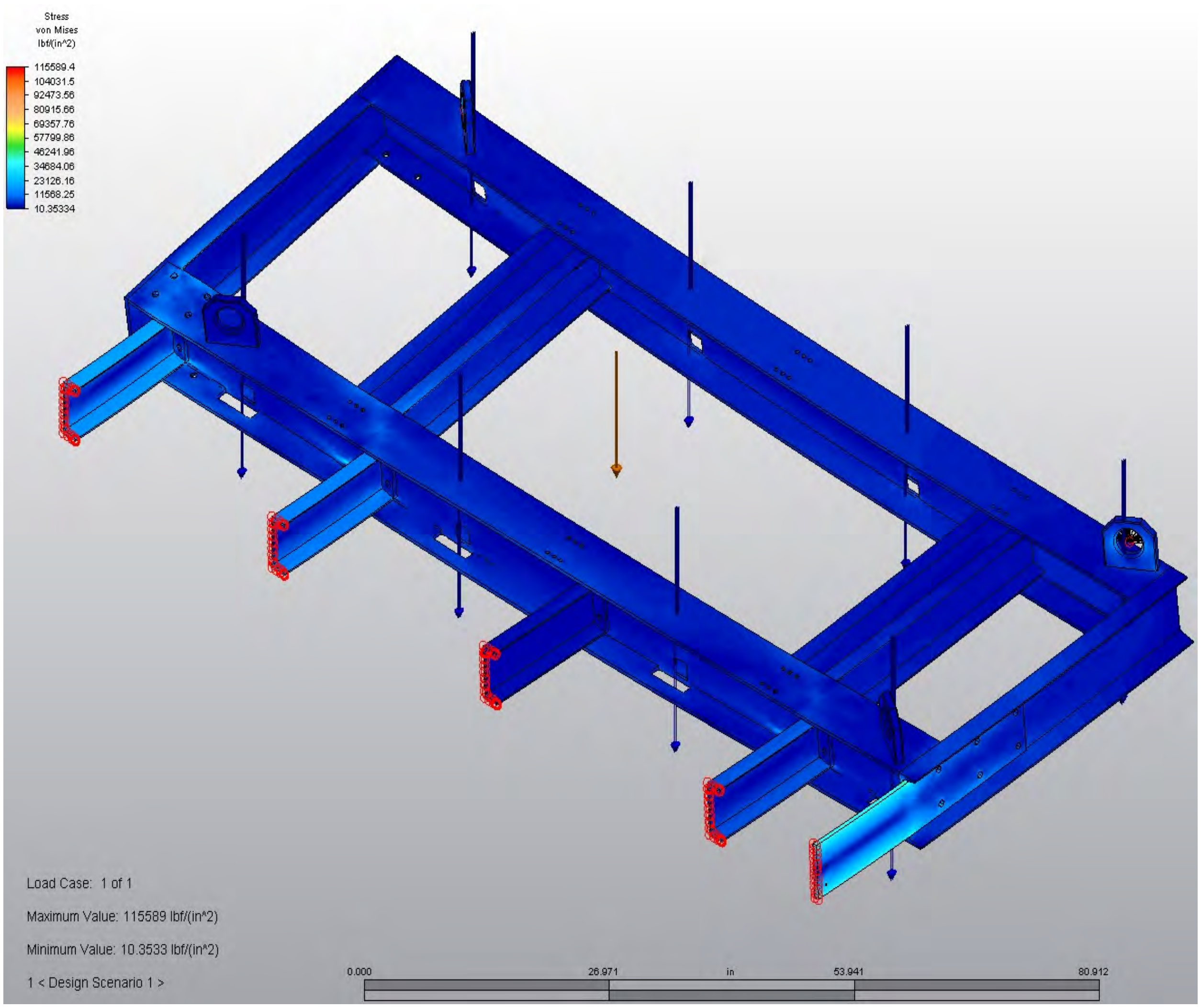


Figure 17: Half System FEA

The FEA image does not show any location where the stresses exceed the yield stress of either of the base materials (aluminum and steel). The greatest loading occurred at the middle of the steel plate at the front of the system. It was identified in the initial design stages that the stresses would be greatest at this location, so the material was changed to steel. The greater yield stress limit of steel will prevent the system from failing at the plate.

3.2.3 Full System Configuration

The FEA for the full system was conducted on a quarter of the CAD model, cut along the longitudinal center line and the line where the two half systems join to simplify the FEA and reduce run times. This model is the same as the half system model; however, the FEA was configured differently. The final image from the FEA can be seen in Figure 18. The model was set up in the following manner:

- Each suspension station was loaded to 3,576 lb (blue arrows).
- Brick elements were sized to fit one per flange thickness.

- Outer end-lift provision (top of image) was restrained from moving in the load direction.
- Red circles on near surfaces represented surface constraint of symmetry.
- Red circle on top edge of end surface represented constraint of symmetry with mated half frame.
- Red circle on bottom bolt holes represented constraint of symmetric joining plates with mated half frame (not seen in image).
- Yield stress limit for the 6061-T6 aluminum was about 37,000 psi.
- End plate (right of image) was steel with a yield strength of 150,000 psi.

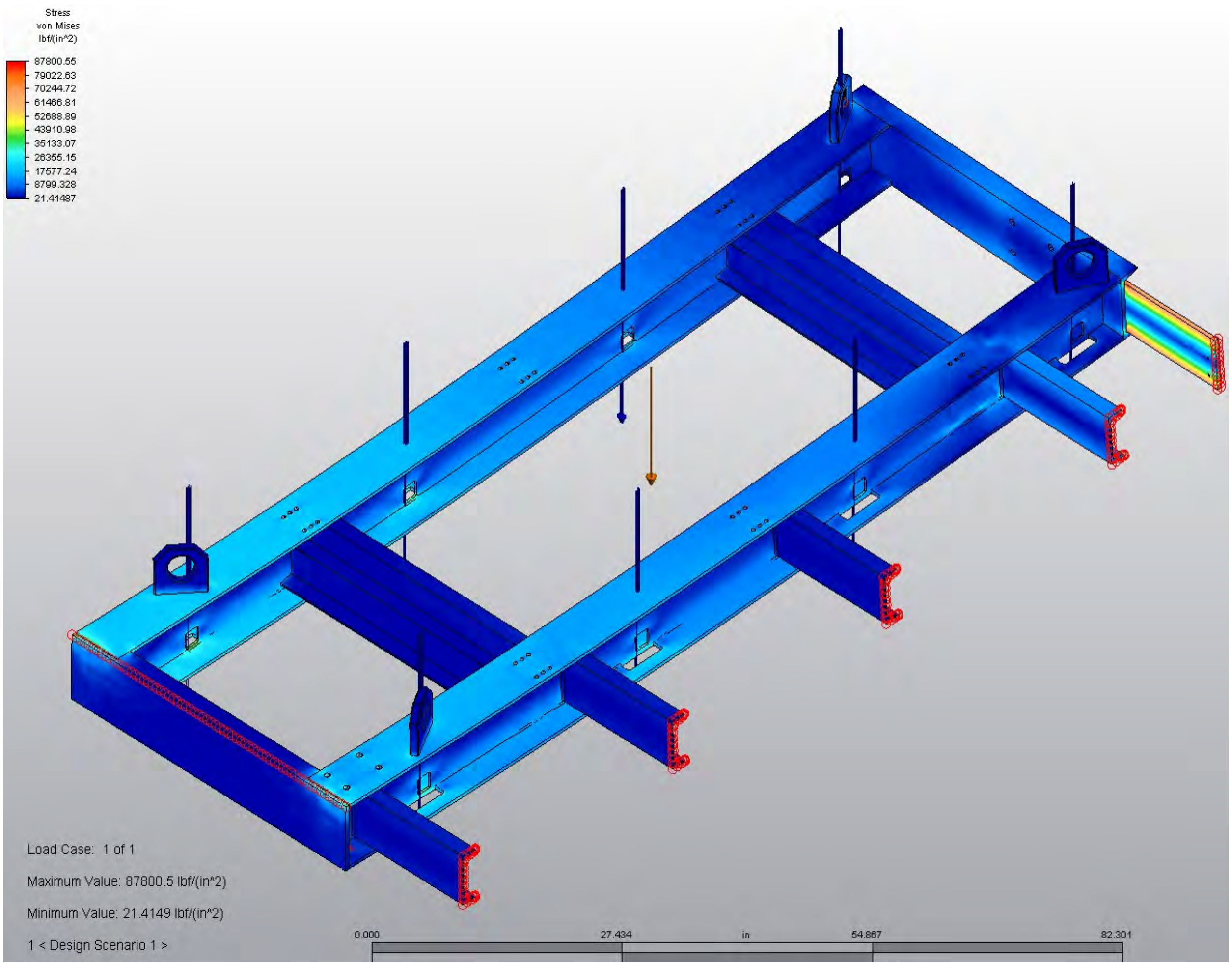


Figure 18: Full System FEA

The FEA image does not show any location where the stresses exceed the yield stress of either of the base materials (aluminum and steel). The greatest loading occurred at the middle of the steel plate at the front of the system, as expected from the results of the half system.

3.3 Wireless Gate Release

Wamore, Inc. created the WGRS for an Air Force program of record for the aft restraint and remote release of CDS payloads within military cargo aircraft. The system is comprised of a wireless gate release mechanism (WGRM), a ratchet strap, and a remote control unit, i.e., a master control station (MCS). The components and rigging are shown in Figure 19. The release assembly is attached to the restraining strap of the payload while the control unit remains in the hands of the loadmaster. At the moment of payload release, the loadmaster activates the control unit, allowing the payload to exit the aircraft.

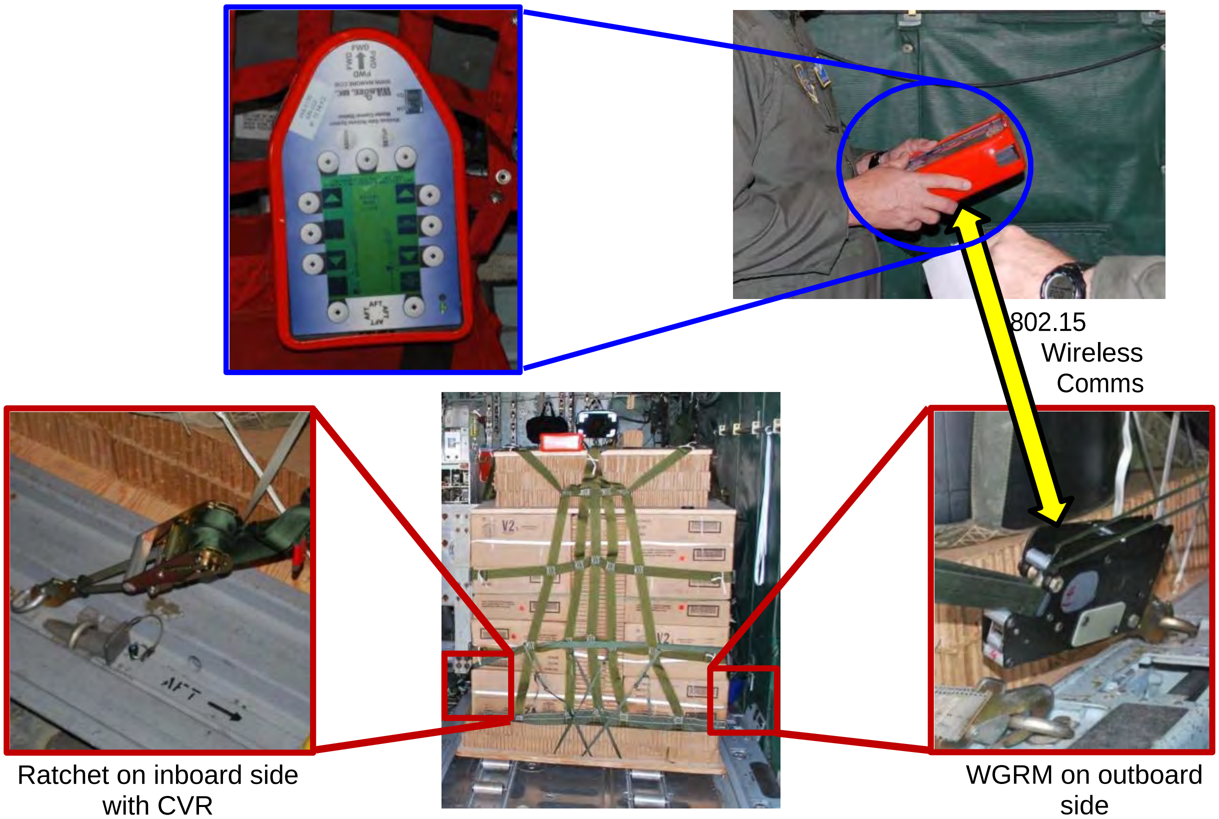


Figure 20: WGRS

The WGRM will serve as the wireless release mechanism for the HSL RADE system. It was chosen for MCS's ability to wirelessly activate the WGRM, as well as having passed all of the Air Force's required testing in order for it to be part of a rapid fielding program. The WGRS successfully passed all of the following tests (conducted at the National Technical Systems test facility in Tempe, AZ):

- Crash Safety Acceleration (MIL-STD-810F Method 513.5, Procedure III)
- Operational Vibrations (MIL-STD-810F Method 514.5)
- Functional Shock (MIL-STD-810F Method 516.5, Procedure I)
- Operational High Temperature (MIL-STD-810F Method 501.4, Procedure II)
- Operational Low Temperature (MIL-STD-810F Method 502.4, Procedure II)
- Altitude (MIL-STD-810F Method 500.4, Procedure II)
- Humidity (MIL-STD-810F Method 507.4)

- Explosion Proofness (MIL-STD-810F Method 511.4, Procedure I)
- Sand and Dust (MIL-STD-810F Method 510.4 Procedure I and II)
- Salt Fog (MIL-STD-810F Method 509.4)
- Rapid Decompression (MIL-STD-810G)
- Explosive Atmosphere (MIL-STD-810G)

The WGRMs were placed in the I-beams of the HSL RADE frame, as shown in Figure 21. In normal airdrop use, a snap hook is attached to the end opposite the release mechanism of the WGRM; however, the snap hooks were removed to bolt the WGRM directly to the frame. The WGRM is attached to the frame with one bolt and sits in a slot cut in the bottom of the I-beam approximately every 34 inches, except for the center two on the full system, which are 30 inches apart.

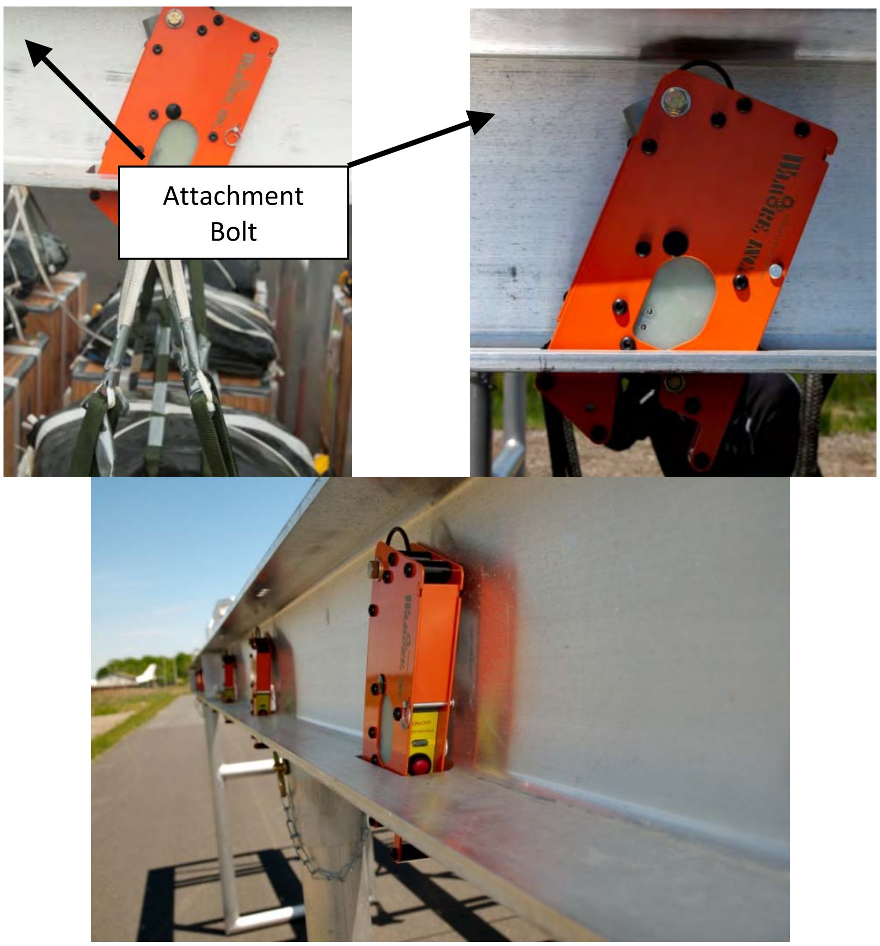


Figure 21: WGRMs Attached to HSL RADE Frame

4 Ground Testing

The 3D model produced by NSRDEC was provided to Capewell Components Company LLC to produce a technical drawing package (TDP), as well as manufacture the first prototype of the HSL RADE system. Capewell transformed the provided model into a TDP using their drawing standards and designated it with P/N C11-1300. This TDP was converted to a government drawing package with P/N X11-1-8486. Capewell followed its TDP to manufacture the first prototype of the HSL RADE system.

4.1 Lift Provision Testing

With the TDP completed, Capewell validated the welding procedures prior to manufacturing the entire HSL RADE system. Capewell isolated the 3D model with the lift provision (including the weld) and then conducted an FEA on the section. (The information in this section is documented fully in Capewell Report TR11121[2].) Figure 22 shows the final image from the FEA.

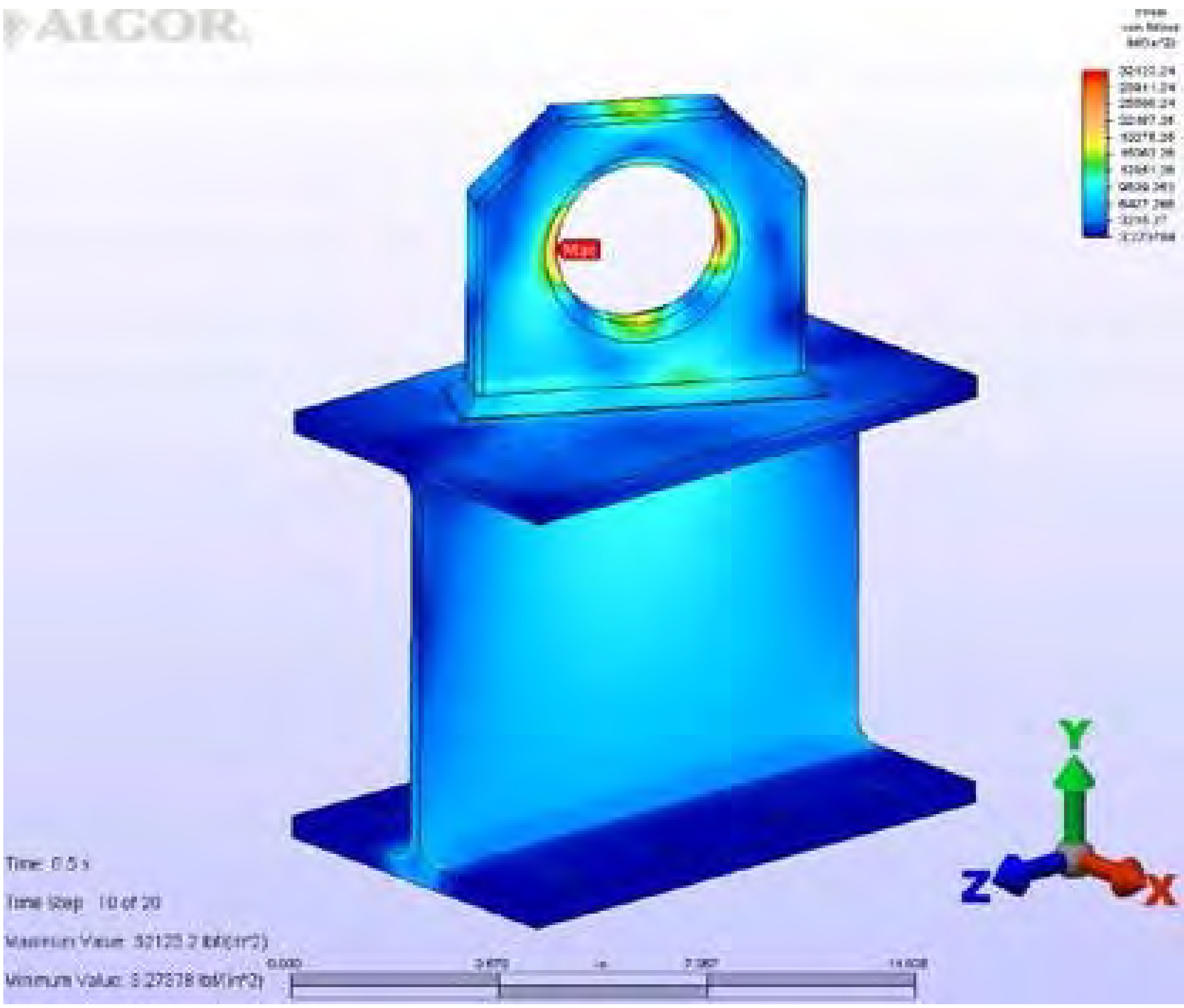


Figure 22: Lift Provision FEA

[2] D. Sienna, HSL Welded Lifting Lug Test Results 2 (TR11121) 06/23/2011

The model was set up in the following manner:

- Lift provision lifted up at 15,500 lb (green arrows).
- Green circles on lower surface restrained the model in the Y direction.
- Green circles in the bolt holes restrained the model in the X and Z directions.
- Yield stress limit for the 6061-T6 aluminum was about 37,000 psi.
- Yield stress limit for the 6061-T6 aluminum (de-rated weld material properties) was about 15,000 psi.

The FEA image does not show any location where the stresses exceed the yield stress of the base material or the weld. The greatest loading of the system occurs at the middle of the lift provision. After the FEA was completed, the weld was isolated to ensure that the weld size was adequate and would not catastrophically fail. The isolated weld FEA, seen in Figure 23, shows that the weld will not exceed the de-rated aluminum yield stress of 15,000 psi.

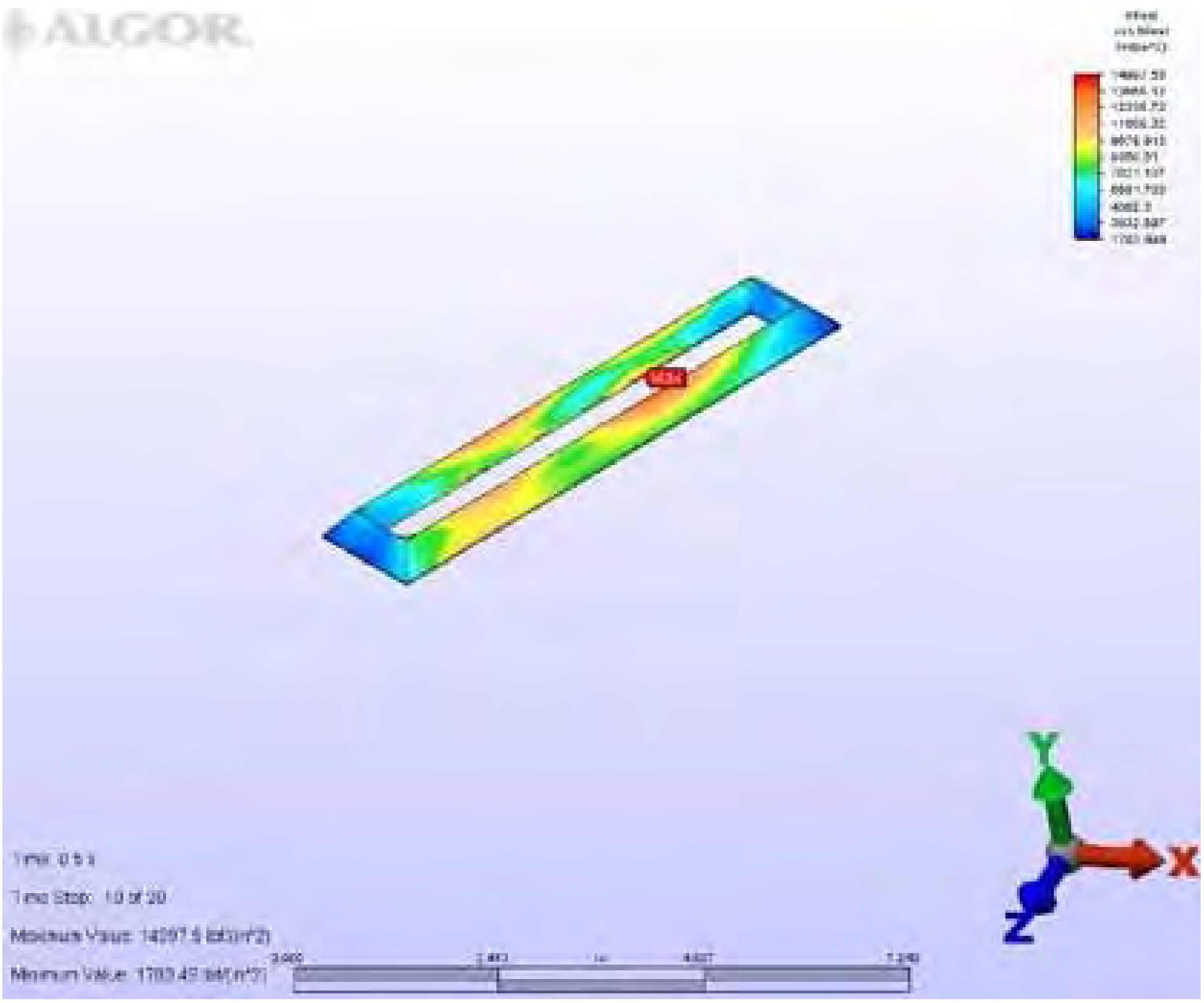


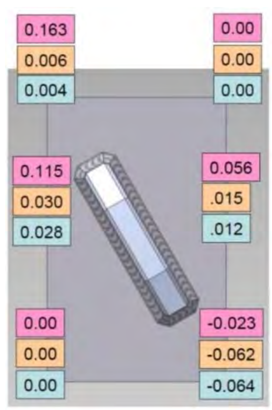
Figure 23: Lift Provision Weld FEA

Capewell manufactured the lift provision as it was modeled and tensile tested the system to validate the FEA. The sample was secured to the base of the tensile testing machine through a series of bolts, and a shackle was attached to the lift provision. The test setup is shown in Figure 24. Dimensions were recorded prior to and after each test load was achieved. These loads were:

- 13,810 lbf, per MIL-STD-209K
- 15,500 lbf, per NSRDEC direction
- 17,893 lbf, per MIL-STD-913A
- 36,380 lbf (rigging restriction)

Figure 24: Lift Provision Tensile Testing Setup

The dimensional test results are documented in Figure 25. All of the measurements were taken using a dial indicator across all corners.



Light blue: Before testing up to 15,500-lbf load case
Tan: 17,893-lbf load case
Pink: 36,380-lbf (maximum due to rigging constraint)

Figure 25: Results of Lift Provision Tensile Testing

The lift provision test showed that the weld strength held to the proof load requirements of the top level design. The FEA models identified that the weld was adequate. The physical results of the test sample validated the FEA findings as well as the strength of the 1/4-inch (partial penetration) bevel flare weld requirements.

4.2 Form, Fit, and Function Testing

Capewell delivered the first prototype to Aberdeen Proving Ground (APG), MD for ground testing. Upon receipt of the prototype, representatives from APG, NSRDEC, and Capewell followed the provided assembly procedures (C11-1300) to ensure the components fit together properly. The assembled half system is shown in Figure 26.

Figure 26: Half System Assembly (Prototype)

It was noted as the system was assembled so that a list of components with pictures or a part description would be helpful. Until the system was fully assembled, it could not be determined if all of the pieces were present. The list of components, with pictures, would also help distinguish the difference between like components. It was also noted that the bolts should be secured to a specified torque value. Further investigation would be needed to identify the proper torque values.

4.3 Proof Load Testing

Proof load testing was conducted at APG. The systems were assembled in the appropriate configuration, with the wireless gates removed to protect them from damage. Each system was secured to the ground with textile slings in positions coinciding with the system's loading positions. Blocks of wood were placed in the webbing of the I-beam to ensure the test slings did not damage the system in a manner which did not represent flight conditions. Load cells were attached to each of the lift provisions to ensure that the system was evenly loaded. The lifting chains were attached to the lift provision load cells on one end and to a larger load cell on the other. The larger load cell was attached to the crane hook. The test setup can be seen in Figure 27.

Figure 27: Proof Load Test Setup

The crane was used to apply a load on the test item that coincided with the proof load values given in Table 4, which was held for 90 seconds, then released. At the completion of testing, the item was inspected for deformation and other damage from testing.

4.3.1 Quarter System Proof Load Tests

The quarter system proof load test was conducted on 01 February 2012. A load of 20,200 lb was maintained on the system for 94 seconds. At the completion of the test the system was inspected, and some brinelling was observed where the load cells contacted the lift provisions. No other damage was identified.

4.3.2 Half System Proof Load Tests

The half system proof load test was also conducted on 01 February 2012. A load of 28,100 lb was maintained on the system for 96 seconds. At the completion of the test, the system was inspected for any deformation. At first glance it was noticed that the system had "sagged" in the middle (Figure 27). Before testing, the system was flush along the red line, but after the test there was a maximum deflection of about 5/8 inch.

Figure 28: Half System Proof Load Test Setup

Upon further investigation, evidence of yielding was seen in the “C” channels that join the two quarter sections (Figure 28). Each of the “C” channels had some degree of the same damage on both sides. It is assumed that, as the system moved, the middle sections experienced some surface yielding. This damage could also have come from the bolts not being secured properly. Since the system did not have a torque value, the bolts were tightened using pneumatic tools.

Figure 29: Damage from Half System Proof Load Test

At the completion of testing, representatives from APG, NSRDEC, and Capewell analyzed potential solutions to the yielding cross member problem. Additional models were created to evaluate the phenomenon that resulted in a deformed cross member. FEA had shown this area to have stresses that were close to but not reaching yield.

The mesh size for this area was reduced to better isolate the stresses, and the FEA was conducted again. The second run showed the cross members would yield under the proof load.

Multiple methods were identified that could resolve the yielding issues, but only two were chosen for implementation. The two methods were incorporated concurrently so as to reduce the program delays. The first was a rapid, short-term solution, which would require two steel plates to be added across the end of the half system (top and bottom), and the second was to re-design of the cross members. The first allowed testing to continue with minimal setbacks. The steel plates added the necessary strength; however, they also added more weight and increased the complexity of setting up the half system. The second was a more permanent solution in reinforcing the “C” channel sections, but would delay the program by 3 to 4 months.

An FEA was conducted using both configurations, and it was determined that reinforcing the “C” channel section was the best approach. The contract was modified to have the contractor change the section while proof load testing was conducted on the system with the steel plates. Once the contractor modifications were completed, a new proof load test would be conducted to validate the new design.

A proof load test with the steel plates was conducted using a previously untested system on 06 March 2012 using the same test setup and procedures as previously noted. Figure 30 shows the test setup, and Figure 31 shows the steel plates secured to the half system.

Figure 30: Half System Proof Load Test Setup with Steel Plates

Figure 31: Half System Steel Plates

At the completion of the test, the system was inspected. Some brinelling was observed where the load cells contacted the lift provisions, but no other damage was identified.

4.3.3 Full System Proof Load Tests

The full system proof load test was conducted on 06 March 2012 with the steel plates from the half section installed. Figure 32 shows a slightly different test setup from the half system proof load test with steel plates. This was due to the working area of the rails used for restraint being smaller than the area of the full system. A 300-ton steel plate with tie-down points was used to restrain part of the system during the test. The load of 62,000 lb was maintained on the system for 95 seconds. At the completion of the test, the system was inspected. Some brinelling was observed where the load cells contacted the lift provisions, but no other damage was identified. This configuration of the system was tested again once the contractor modifications were completed and passed.

Figure 32: Full System Proof Load Test Setup

4.4 Crane Payload Deployment Tests

Prior to testing under a helicopter, a series of payload release tests were conducted under a crane. The half system was suspended under a crane at APG with eight 100-lb payloads attached. The payloads were released in different configurations in order to identify any potential hazard to the aircraft due to rapidly shifting weights that could change the system orientation and CG. The first tests released payloads one at a time and progressed to releasing all of the payloads at the same time. These tests showed that the frame will move with the shifting of the CG, but the oscillations will dampen within the three full cycles.

5 Flight Testing

Flight testing was conducted at ATC Phillips Army Airfield over multiple weeks. The testing started with a helicopter conducting a series of basic maneuvers with the quarter system and concluded with a full system, 32-payload airdrop. The progression of tests from hover to full flight was conducted so the mission aircrew could discern the difference between normal movements resulting from an airdrop versus a critical situation where the payload would need to be jettisoned.

A Lakota UH-72 helicopter was used to conduct maneuvers tests, payload release tests, and three weeks of airdrop tests in June and July 2012. Two weeks of maneuvers tests under Chinook and Super Stallion helicopters were conducted in September 2012. Two weeks of airdrop tests were conducted under a Chinook helicopter in March 2013 to finalize an “air worthiness release” for use of the HSL-RADE.

5.1 Helicopter Maneuvers Flight Tests

The first flight of the HSL RADE was the quarter system under the UH-72 in January 2012. The quarter system was configured with eight 100-lb door bundle sized payloads without parachutes, and the pilot followed the multi-service flight data collection sheet (MSFDCS) for the test. The MSFDCS outlines maneuvers that an aircraft conducts and allows the pilot to rate the performance of the suspended payload. This document is used in the certification process of all HSL payloads.

The helicopter hovered over the frame, and a ground hook-up team made the connection. The first maneuver was a series of small movements in and out of rotor-wash ground effect. During the maneuvers, the ground team observed that the payloads bumped into each other and twisted, as expected. The crew chief did not observe anything unusual compared to normal single-point HSL payload flight. The cameras mounted on the system confirmed that the payloads moved and bumped into each other.

After the maneuvers in and out of ground effect, the pilot conducted turns and banks. The crew chief described the payloads as being more excited during the banking and higher speed turns. The observations were confirmed by the on-board video camera. At the completion of the turns, the pilot performed more advanced maneuvers and transitioned to forward flight for a “high-speed” straight-line run. The pilot increased the speed, documenting the performance of the HSL load until he determined the helicopter had reached the safe maximum speed. Figure 33 shows the helicopter traveling at 70 knots during the high-speed run with eight payloads suspended under the quarter frame.

The helicopter returned to the landing zone (LZ), one payload was released, and the same set of maneuvers was conducted with the system and seven payloads. (Appendix A lists each of the test configurations.) Testing continued in this sequence until all payloads were released (including a test with the empty system) following the MSFDCS. Figure 34 shows the helicopter during the test flight with the empty system.

The crew chief described the individual payload movements as excited due to the payload interactions; however, the HSL RADE system as a whole flew well. The system stabilized around 30 knots and remained stable during the remainder of the test flight. The pilot did not note any unexpected flight characteristics in comparison with other single-point sling loads. The MSFDCSs from the tests can be seen in Appendix B.

Figure 33: Quarter System High-Speed UH-72 Flight with Eight Payloads

Figure 34: Quarter System High-Speed UH-72 Flight with Empty System

Maneuvers testing the full HSL RADE frame in a dual-point configuration was conducted under a CH-47 from 04 to 07 September 2012 and under the CH-53 from 18 to 21 September, following the full range of tests (i.e., maneuvers, payload release, and airdrop) under the UH-72. In both cases, the HSL RADE system had 32 payloads suspended, and the pilots followed the MSFDCS. After the first flight sequence, the helicopters returned to the LZ and released some payloads and then repeated the same tests (as was done using the UH-72). Figure 35 shows the full system under the CH-47 during the flight test. The CH-47 also completed a test with an empty system, but the CH-53 did not because of concerns with the CH-53's auto jettison system and the weight being too low. The pilot was concerned that the helicopter may sense a low/no-load condition and release the cargo hooks. Other than not flying the empty system, the air crews noted that they did not have any issues flying with the full HSL RADE system.

Figure 35: Full HSL RADE System under CH-47 Helicopter

5.2 Helicopter Payload Release Tests

At the completion of the HSL maneuvers flight test under the UH-72, the payloads (100 lb each) were attached to the quarter frame, and the UH-72 helicopter performed a payload release test on 28 March 2012 from 5 ft off of the ground. The payloads were attached to the quarter frame using the WGRSs (eight total, one at each of the defined stations) with the supplemental harness from the maneuvers test. Payloads were individually released and then released in groups. Figure 36 shows the helicopter hovering above the tarmac releasing payloads. This test replicated the crane payload deployment test described in Section 4.4.

Figure 36: Helicopter Payload Release Test

These tests were conducted to identify how the frame moved with a CG change and to determine how the helicopter reacted to the HSL payload's loss of weight and CG change. The frame moved less than what was observed in the crane test, and the ATC test pilots noted that the helicopter did not move when the payloads were released and felt it was possible to conduct parachute airdrops. Any oscillations were damped within about two cycles.

5.3 Helicopter Airdrop Tests

Three weeks of airdrop testing was conducted in 2012 (25-29 June, 10-12 July, and 23-27 July) using the UH-72 (Sections 5.3.1, 5.3.2, and 5.3.3, respectively). Payloads were rigged with parachutes from the family of LCLA parachutes from the Defense Depot Susquehanna Pennsylvania (DDSP). Each payload was rigged in accordance with FM 4-20.103 for LCLA door bundles and then modified with a supplemental suspension harness, which connects the payload to the WGRM. The pilot navigated a desired flight path over the DZ, and the payloads were released in a predefined order. Two consecutive weeks of airdrop testing were conducted (13-23 May 2013) under a Chinook 47D in conjunction with the Aviation Engineering Directorate (Section 5.3.4).

5.3.1 First UH-72 Helicopter Airdrop Test Week (25-29 June 2012)

Two different types of parachutes were used during the 25-29 June airdrop test week with the LCLA payloads (T-10 cargo canopies and LCLA cross canopies). The payloads were rigged in accordance with FM 4-20.103 using the LCLA straps. Once the payloads were rigged, the supplemental suspension harness was attached to each payload. The steps to make and attach the supplemental suspension harness were:

1. Secure a 36-inch section of 1-inch tubular nylon (4,000 lb minimum breaking strength).
2. Form a bite of about 6 inches.
3. Tie an overhand knot forming a 3-inch loop.
4. Tie an overhand knot in the shorter running end.
5. Follow Steps 2-4 for the opposite end of the 1-inch tubular nylon.
6. Girth hitch one end of the 1-inch tubular nylon to one of the top four junctions of two LCLA straps.
7. Repeat Step 6 for each of the other three LCLA strap junctions on the top of the payload.

After the supplemental suspension was attached, the parachutes were secured to the payload by tying the suspension lines or the risers to two diagonally opposite payload strap junctions. A single transportation tie of ¼-inch cotton webbing was used to secure the parachute to the payload during flight. The steps to place the transportation tie were:

1. Secure a 36-inch section of ¼-inch cotton webbing (80 lb minimum breaking strength).
2. Tie one end to one of the LCLA straps in a convenient location using a surging knot and a locking knot.
3. Route the ¼-inch webbing over the top of the parachute, and secure it to an LCLA strap on the opposite side of the payload.
4. Ensure the strap is tight and does not allow the parachute to move.

A second person inspected each of the payloads to ensure proper rigging. Fully rigged payloads can be seen in Figure 37.

T-10 Cargo Canopy　　LCLA Cross Canopy

Figure 38: Final Rigged Configuration of Payloads for First UH-72 Airdrop Test Week (25-29 June 2012): T-10 Cargo and LCLA Cross

The frame was placed on top of the payloads, the supplemental suspension slings were connected to the WGRM, and the static lines were connected to the appropriate anchor positions. LCLA payloads used a standard static line, and the T-10 used a break-away configuration. Figure 39 shows one of the LCLA payloads with the supplemental suspension attached to the WGRM, static line attached to the frame, and the frame resting on top of the payload.

Figure 39: LCLA Payload Attachment to Frame for First UH-72 Airdrop Test Week (25-29 June 2012)

In addition to the LCLA payloads, the independent U.S. Army Humanitarian Airdrop Program (Appendix C) completed several airdrops from the frame to save testing costs. The humanitarian payload was a large bag with straps that wrap around the bag and encapsulate the cargo. For these tests the cargo was either a combination of wood and rubber blocks or water packets encapsulated in a foam pouch. These tests were conducted to demonstrate the additional capability of the HSL RADE system with other systems and other weights.

Because the humanitarian airdrop payload was taller than the LCLA payloads, it was placed next to the frame, and the primary suspension slings were attached to the WGRM with the static line to the appropriate position. Figure 40 shows the final configuration of the sling load. The humanitarian airdrop payload was placed on a skidboard, but not connected to it, to prevent any damage to the bag during the hook-up and initial movement of the helicopter.

Figure 40: Final Rigged Frame for Quarter System for Humanitarian Airdrop During First UH-72 Airdrop Test Week (25-29 June 2012)

During the first airdrop test week (for both standard LCLA payloads and humanitarian payloads), the helicopter moved to the desired altitude and executed the airdrop test schedule found in Appendix D. The first few airdrops were conducted from a hover, releasing one payload at a time so as to replicate the same test conducted at 5 ft. The parachute inflation consisted of the following four steps, which can be seen in Figure 41:

1. Payload was released wirelessly via the MCS.
2. Gravity pulled the payload downward and caused the parachute to separate from the payload.
3. The payload pulled the parachute out of the deployment bag.
4. The parachute began to inflate, and the payload descended under canopy.

Figure 41: Inflation Sequence of LCLA Parachute from HSL RADE

All LCLA payloads were released from the HSL RADE as intended; however, there were some instances where the canopy did not fully inflate prior to ground impact. It was assumed that, since the systems were packed and stored for a long time, the parachutes developed creases that restricted the flow of air into the parachute's air channel. The parachutes were inspected and repacked per the approved packing instructions for the LCLA parachute. In follow-on tests, the repacked parachutes inflated properly prior to ground impact.

Most of the T-10 Cargo parachutes were released properly; however, a few never broke the transportation-tie securing the parachute. Upon examination of the payloads, it was determined that the static line had failed prior to the parachute separating from the payload (Figure 40). The static line anchor point was examined, and it was determined that ¼-inch cotton webbing with a nominal breaking strength of 80 lb was not adequate, even though the payloads were only 100 lb. Follow-on tests used Type II tubular nylon (gutted 550 cord). This rectified the premature static-line failures for break-away static lines.

Figure 42: T-10 Cargo Broken Static Line

This test week resulted in 40 payload separations and 34 airdrops (with 6 premature static line breaks) prior to a jettison of the frame mid-flight. During the last pass of the last flight, a parachute came loose from the transportation tie and separated from the payload. The deployment bag closing tie initially prevented the parachute from opening; however, interaction with the remaining payloads broke the tie and allowed the canopy to inflate. The additional drag from the canopy changed the characteristics of the helicopter, and the pilot followed aircraft emergency procedures and jettisoned the sling load from an altitude of 400 ft AGL. The payload with the inflated canopy broke free from the frame, and it descended to the ground while the frame, with the remaining payloads attached, fell to the ground.

The ground impact of the system caused significant damage to the quarter frame section as well as the remaining payloads. It is suspected that the frame contacted the ground on one corner and tumbled twice before coming to rest. All of the payloads still remained attached (Figure 43) with the exception of the one that caused the incident. The deployment bag for that parachute was damaged, but since it remained with the frame, it was unknown if the damage was from impact or during flight. The onboard equipment was examined for functionality, and it was found that the WGRMs were all functional and the on-frame video cameras had recoverable flight video.

Figure 43: Impact Site for First UH-72 Airdrop Test Week (25-29 June 2012)

The payload that initiated the incident was recovered, and the transportation tie, (see Figure 44) remained intact. In addition, each of the four supplemental suspension slings, which attached the system to the frame, were broken at the connection point. The parachute and suspension lines were inspected and found to be without damage.

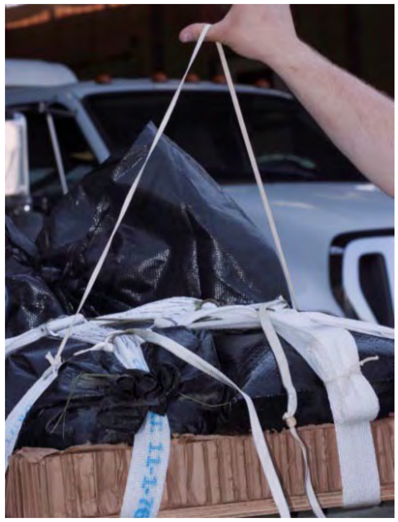


Figure 44: Unbroken Transportation Tie

The camera mounted on the frame captured footage that showed the parachute separate from the payload and interact with the adjacent payloads. Figure 44 shows the unrestrained parachute and the parachute suspension lines, with static line, still secured to the payload and frame, respectively.

Figure 45: Loose Parachute

After about 45 seconds of flight, the loose parachute contacted the rear payloads, breaking the bag-closing tie and allowing the parachute to open. Figure 46 shows the parachute beginning to inflate, prior to the sling load being jettisoned.

Figure 46: Open Parachute

The investigation concluded that the ¼-inch cotton webbing parachute transportation tie was not as tight as it should have been, which during flight allowed the parachute to twist. The video shows the parachute twisting from a “flat” position on top of the payload to a vertical position, perpendicular to the wind stream. This is most likely due to the payloads bumping into each other and the air passing by the payload. Once the parachute became vertical, the additional drag pushed the packed parachute loose. The packed parachute fluttered until the bag-closing tie broke and activated the parachute.

As a result of this incident, two major changes were made to the payload rigging procedures and attachment to the frame. First, all parachutes would use two ¼-inch cotton webbing transportation ties routed through the deployment bag retaining loops, forming an “X” over the deployment bag. Figure 47 shows a payload with the new transportation tie method. The new method retained the parachute to the payload and prevent the parachute from moving. The steps to place the new transportation tie were:

1. Secure two 36-inch long sections of ¼-inch cotton webbing (80 lb minimum breaking strength).
2. Tie one end to one of the LCLA straps in a convenient location using a surging knot and a locking knot.
3. Route the ¼-inch webbing through the closest loop on the deployment bag.
4. Route the ¼-inch webbing over the top of the parachute, through the deployment bag loop on the opposite corner.
5. Secure the ¼-inch webbing to a LCLA strap.
6. Follow Steps 2-5 for the opposite corners, making an “X” on top of the parachute.
7. Ensure both straps are tight, and do not allow the parachute to move.

Figure 47: New Parachute Transportation Tie

The second change was to pack/rig all LCLA cross parachutes for a break-away static line and deployment. The LCLA cross parachutes, unlike the T-10 cargo parachutes, are packed by the manufacturer for a non-break-away (traditional) deployment. During a normal aircraft deployment, the static line and deployment bag remain attached to the aircraft and are required to be pulled into the aircraft. When these parachutes are deployed, the static lines with deployment bags become entangled with other payloads and make it difficult for the crew chief to identify a potential problem. All of the LCLA cross parachutes were modified to use break-away static lines to prevent this visual obstruction and reduce the potential hang-up issue.

The inspection process was also changed to increase safety. Previously, payloads were inspected by the rigging team. Once payloads were attached, a second inspection was conducted for the attachment of the payload to the frame. The new inspection procedures require someone not involved with the rigging/payload attachment to inspect the system with a member of the aircrew. The secondary inspection will be annotated on the sling load inspection form, required for each HSL load.

5.3.2 Second UH-72 Helicopter Airdrop Test Week (10-12 July 2012)

The purpose of the 10-12 July test week was to demonstrate the changes and to complete the airdrops from the previous test week. The payloads were rigged similarly to the previous test week with the parachutes secured to the payload using the new transportation tie method. This series of tests used the same two types of LCLA parachutes (T-10 cargo and LCLA cross) as used during the first week of testing. They were attached to payloads weighing between 100 and 250 lb.

Each LCLA cross parachute was repacked and configured for break-away static-line operations. The modification required the apex tie on the parachute to be changed from a single loop of ¼-inch cotton webbing to a single loop of ½-inch tubular nylon (1000 lb minimum break strength) that extends the length of the deployment bag.

Once the payloads were rigged, a second person inspected each of the payloads to ensure proper rigging. The inspection points were:

1. Payload is configured as outlined in FM 4-20.103.
   a. Proper materials are used.
      i. Skidboard
      ii. One sheet of honeycomb
      iii. Proper number of sand bags
   b. LCLA straps are tight and properly buckled and secured.
2. Proper parachute is used for the weight of the payload.
   a. Parachute is attached to the payload.
   b. Parachute is secured to the payload with two pieces of ¼-inch cotton webbing forming an “X”.
      i. ¼ inch webbing goes through the deployment bag securing tabs.
      ii. ¼ inch ties are tight.
   c. Parachute is configured for break-away static-line procedures.

The frame was placed on top of the payloads, the supplemental suspension slings were connected to the WGRM, and the static lines were connected to the appropriate anchor positions. Figure 48 shows eight payloads attached to the frame.

Figure 48: Payloads Attached to Frame for Second UH-72 Airdrop Test Week (10-12 July 2012)

Once the sling load was prepared, but prior to the sling load inspection list being filled out, the system was inspected. The inspection points were:

1. Payload is configured as outlined in FM 4-20.103.
   a. Proper materials are used.
      i. Skidboard
      ii. One sheet of honeycomb
      iii. Proper number of sand bags
   b. LCLA straps are tight and properly buckled and secured.
2. Proper parachute is used for the weight of the payload.
   a. Parachute is attached to the payload.
   b. Parachute is secured to the payload with two pieces of ¼-inch cotton webbing forming an “X”.
      i. ¼-inch webbing goes through the deployment bag securing tabs.
      ii. ¼-inch ties are tight.
   c. Parachute is configured for break-away static-line procedures.
3. Payloads are properly rigged to the frame.
   a. Supplemental suspension slings are in place.
      i. Suspension slings are routed to the sides of the payloads and will not interfere with the ¼-inch cotton webbing.

ii. All supplemental slings are attached to the WGRM.

b. Static line is attached to the frame in a break-away configuration

After the payload was inspected, the helicopter picked up the payload, moved to the desired altitude, and proceeded to execute the details of the airdrop test schedule found in Appendix D. The helicopter completed the first pass by releasing four payloads and then the second by releasing the remaining payloads. All eight payloads released on command. After the first lift was completed, the helicopter returned to the LZ and connected to a second quarter frame. As the helicopter passed over the DZ, only two of the payloads released. It was later determined that the Air Force version of the MCS used for this test was having connection issues with the WGRM. After two failed attempts, the helicopter returned to the LZ.

Most of the LCLA parachutes operated as intended; however, there were instances where the canopy did not fully inflate prior to ground impact. It was assumed that those instances were with parachutes shipped from the US Defense Depot System, where the parachutes developed creases from being packed and stored for a long time. The previously used parachutes that were packed during the previous drop week all functioned as intended. The parachutes were inspected and repacked per the approved packing instructions for the LCLA parachute with the exception of a break-away static line.

Two payloads using LCLA parachutes did not descend under canopy, but rather free-fell to the ground. When the payload was inspected on the ground, the parachute's transportation ties were found to be tied incorrectly. The rigger created a trucker's hitch by routing the ¼-inch cotton webbing through the deployment bag loop and then routing the line around the deployment bag loop. When the "X" ties broke, the transportation tie was still secured to the payload via a ¼-inch cotton webbing loop. The payload with the loop can be seen in Figure 49.

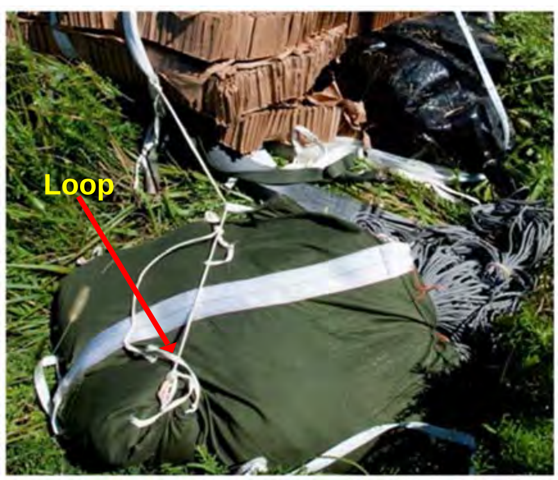


Figure 50: Loop Created during Second UH-72 Airdrop Test Week

The T-10 Cargo parachutes were released properly; however, one never broke the transportation tie securing the parachute. Upon examination of the payload, it was determined that that static line had failed prior to the parachute separating from the payload (Figure 39). The static line anchor point was examined and found to have some sharp edges. Follow-on tests secured a section of one 1-inch tubular webbing surrounded with buffering material to the anchor point with the static line attached to the webbing.

The helicopter crew chief also made a note that the middle section of the static lines were not secured and were flying around during flight. It was felt that excess static line in the air stream may cause a deployment hazard. It was determined that the easiest way to control the excess static line was to ensure it was properly secured to the parachutes via the retaining bands and to use one turn of paper tape to secure the static line to the supplemental suspension slings. The inspection points were modified to reflect this change.

5.3.3 Third UH-72 Helicopter Airdrop Test Week (23-27 July 2012)

The purpose of the 23-27 July test week was to demonstrate the changes and to complete the airdrops from the previous test week. The approximately 250-lb payloads were rigged in accordance with FM 4-20.103 using LCLA straps. The humanitarian airdrop was also conducted during the third test week, and the payload used the same rigging procedures used during the 25-29 June test week. (No humanitarian test drops were made during the second week because the changes initiated following the first week had not been completed.) Once rigged, the supplemental suspension harness was attached to each payload as in the second test week, and the parachutes were secured to the payload using the previous transportation tie procedures.

Once the payloads were rigged, a second person inspected each of the payloads to ensure proper rigging. The frame was placed on top of the payloads, the supplemental suspension slings were connected to the WGRM, and the static lines were connected to the appropriate anchor positions. Prior to the sling load inspection list being filled out, the system was inspected. The inspection points were:

1. Payload is configured as outlined in FM 4-20.103.
   a. Proper materials are used.
      i. Skidboard
      ii. One sheet of honeycomb
      iii. Proper number of sand bags
   b. LCLA straps are tight and properly buckled and secured.
2. Proper parachute is used for the weight of the payload.
   a. Parachute is attached to the payload.
   b. Parachute is secured to the payload with two pieces of ¼ inch cotton webbing forming an “X”.
      i. ¼-inch webbing goes through the deployment bag securing tabs
      ii. ¼-inch ties are tight.
      iii. ¼-inch cotton webbing does not create a loop around the deployment bag securing tabs.
   c. Parachute is configured for break-away static-line procedures.
3. Payloads are properly rigged to the frame.
   a. Supplemental suspension slings are in place.
      i. Suspension slings are routed to the sides of the payloads and will not interfere with the ¼-inch cotton webbing.
      ii. All supplemental slings are attached to the WGRM.
   b. Static line is attached to the frame in a break-away configuration.

c. Static line is taped to one supplemental suspension sling leg with one turn of paper tape.

After the payload was inspected, the helicopter picked up the payload, moved to the desired altitude, and proceeded to execute the details of the airdrop test schedule found in Appendix D. The helicopter completed the first pass by releasing the humanitarian airdrop payload and then a second pass by releasing the remaining payloads. All five payloads released on command. After the first lift was completed, the helicopter returned to the LZ and connected to a second quarter frame. The helicopter passed over the DZ twice before returning to the LZ with all payloads. The MCS shut down and would not turn on. The system was returned to the manufacturer to identify and fix the problem. It was determined to be a faulty charging circuit.

All airdrops conducted during this test week were released from the frame, and the parachutes functioned as designed. All the parachutes inflated and allowed the payload to descend towards the ground. It was recommended that an inspection checklist be generated for the next airdrops. The draft version can be seen in Appendix E. This document is used in conjunction with the standard sling load inspection sheet.

The MCS used was specially designed with three different HSL RADE configurations (one for each frame configuration). The contractor modified the graphical user interface (GUI) and provided additional software capabilities. The HSL RADE MCS allows for the WGRM to be assigned to a specific position and then after a mission be easily re-assigned. The restrictions that the Air Force required were removed to give a greater capability to the HSL RADE Program. Figure 51 shows one of the pages of the HSL RADE MCS. The configuration shown is for a full system. Each number represents a WGRM and a potential payload. The tests conducted used the quarter system GUI, which only has two rows and four columns.

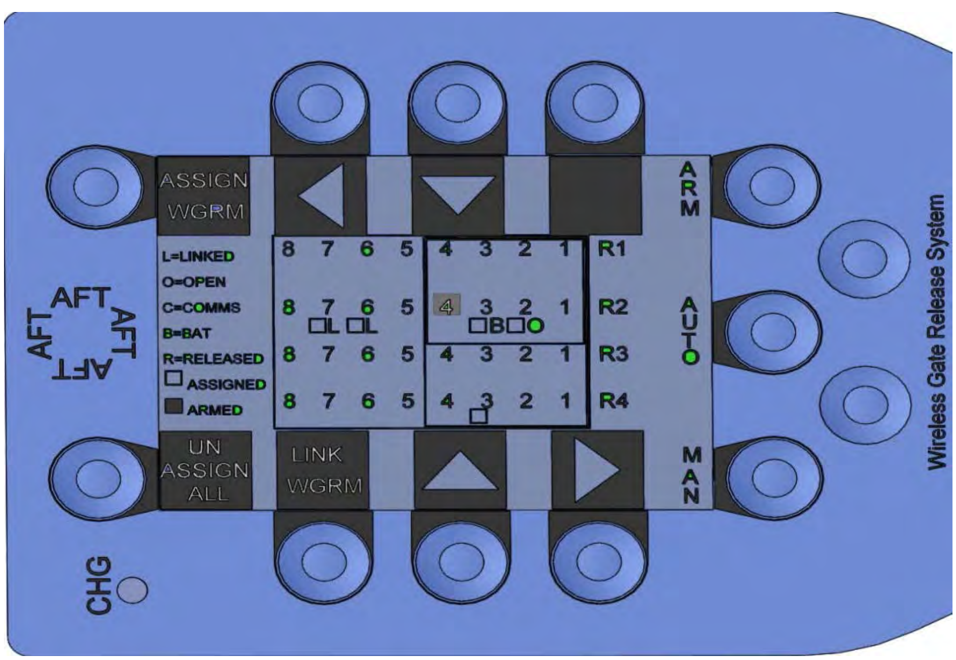


Figure 51: HSL RADE MCS GUI

5.3.4 CH-47 Helicopter Airdrop Tests in Conjunction with Aviation Engineering Directorate (13-23 May 2013)

The purpose of the 13-23 May 2013 testing was to finalize an “air worthiness release” with the U.S. Army Aviation Flight Test Directorate (AFTD) so that non-Soldier-Operator/-Maintainer Test and Evaluation (SOMTE) personnel could use the HSL RADE system. During this test, SOMTE personnel from AFTD flew the half and the full systems under a CH-47D for 15.8 h and completed qualitative electromagnetic compatibility (EMC) checks, MSFDCS maneuvers, and dynamic payload releases. Due to a lack of time and funding, the quarter frame was not evaluated by AFTD personnel. A test report was completed by AFTD[3], and a test record was completed by ATC[4].

EMC checks were completed both on the ground and in flight. Due to poor communications between the MCS and the WGRMs, a slight modification was made to the MCS by the manufacturer to add an external antenna. This directional antenna plugged into the MCS and was clamped to a handle in the “hell hole” of the helicopter (Figure 52). To complete the EMC check, the aircrew operated the WGRS while powering systems on and off in the helicopter to verify no anomalies would occur during operation of the HSL RADE system. Since the same electronic components are used in both the full and half systems, only the full system was checked for EMC compatibility. No anomalies were found during either the ground or the in-flight portions of the EMC checks.

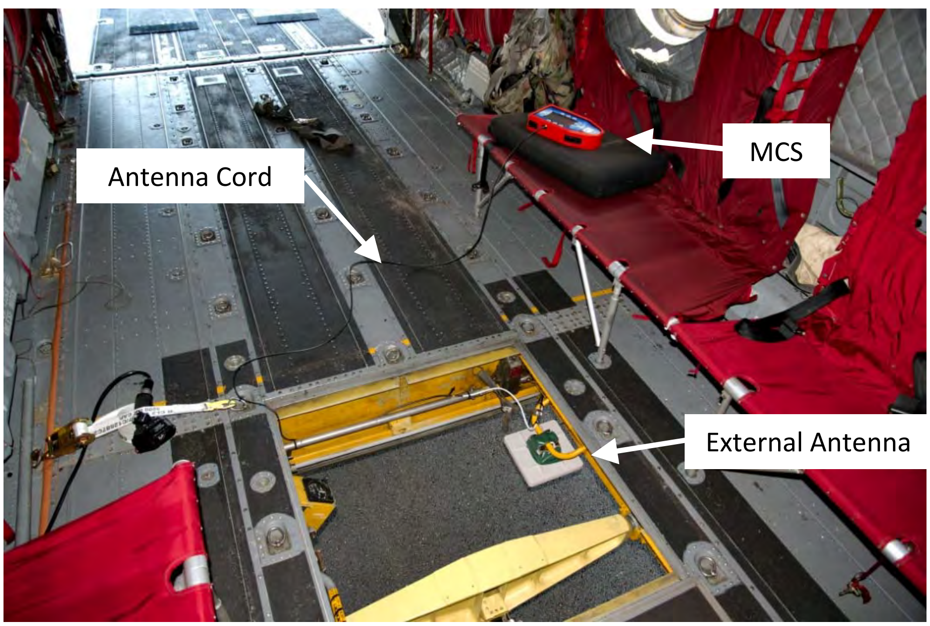


Figure 52: HSL RADE MCS and External Antenna Used in CH-47D Airdrop Tests (13-23 May 2013)

Flight tests were completed with both the half and full HSL RADE systems carrying varying distributions of weights. For these tests, the payloads consisted of plywood boxes filled with sandbags. LCLA straps were used and rigged to maintain the parachute connection methods outlined in previous sections. Payloads weighed 100-

[3] ATEC Project No. 2013-DT-RTC-RDECO-F5433 see references for full citation

[4] ATEC Project No. 2012-DT-ATC-RDECO-F1116 see references for full citation

400 lb in 100-lb increments and are shown in Figure 53, where the number painted on the payload indicated of the approximate increment of weight.

Figure 53: Payloads for CH-47D Airdrop Tests (13-23 May 2013)

The initial flight tests were completed to observe load stability and understand the aerodynamics of the HSL RADE system. MSFDCSs were completed for seven payload arrangements for the full system and two payload arrangements for the half system. The weights and locations of the payloads for each flight can be found in Appendix F. The AFTD SOMTE personnel noted that the flight characteristics of each arrangement for the full frame were positive and noted only three cautions:

1. Flights with the HSL RADE should be limited to airspeeds at or below 110 KIAS. At airspeeds greater than 110 KIAS, excessive aft displacement of the frame may cause the frame to contact the aircraft.
2. Flights with the HSL RADE should be limited to descent rates not greater than 1,500 ft/min.
3. A qualified non-rated crewmember should constantly monitor the load and notify the pilots immediately should the parachutes or riser lines become loose. Pilots will reduce severity of the maneuver and land as soon as practicable for parachutes and riser lines to be secured. If load stability is not possible, an immediate jettison of the load will be performed.

The half system was flown through the entire MSFCDS for the fully loaded system; however, upon pickup the unloaded half system began to spin and did not dampen out within a reasonable amount of time. Due to the light weight, symmetry, and single-point connection (as opposed to dual-point for the full system), the half system was not stable. Also, due to a lack of time, the unloaded system could not be retested. The sling windup is shown in Figure 54.

Figure 54: Half Frame Instability during CH-47D Airdrop Tests (13-23 May 2013)

After the MSFCDSs were complete, a series of airdrops were completed in order to observe the reactions of the frame and the helicopter when different weight payloads were released from varying locations on the frame. A total of 64 payloads were dropped from the frame over two lifts. The frame was loaded with the same weight distribution as the “all” MSFCDS flight (see Appendix F). The payloads were dropped according to the order in Figure 55. The first lift dropped the payloads from a hover, and the second lift dropped the payloads at a forward airspeed of 60 KIAS, which exhibited the most stable load characteristics during the MSFDCS tests.

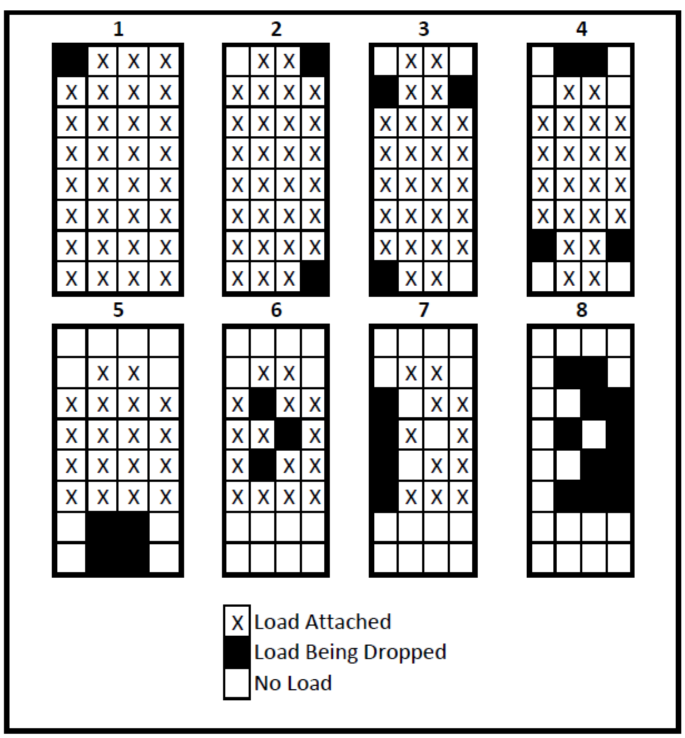


Figure 55: CH-47D Test Airdrop Order (13-23 May 2014)

During both lifts, all payloads successfully released from the frame, and no unfavorable characteristics were noted by the AFTD SOMTE personnel. Since this was the purpose of the test, it was considered a success. During the airdrop from hover, only 11 of the 32 parachutes opened successfully. This may have been due to several causes, including different payloads than previously used, new parachutes from U.S. Army Depot, or flying from a hover instead of forward flight.

During the test, it was noted that the parachutes were not separating from the payloads, indicating that the static-line connection to the RADE was breaking too early and was therefore not strong enough. The rigging was changed slightly for the forward flight airdrop. Instead of using Type III nylon (gutted 550 cord) to attach the static line to the frame, partially gutted 550 cord was used. Normally, 550 cord has eight strands surrounded by a sheath. Gutted 550 cord is only the empty sheath. Due to the lack of materials and time and in order to incrementally strengthen the static line, one strand was left in the 550 cord for the static lines of the 100-lb payloads, and two strands were left in for all other payload static lines. Figure 56 shows a successful parachute opening during forward flight.

During the forward flight airdrop, 27 of the 32 parachutes opened successfully. Some parachute deployment bags, however, remained attached to the frame (separating at the apex of the parachute instead of the static line), indicating a weak stitch point at the crown of those canopies. Further testing is needed to determine the appropriate static-line connection material, as it is cumbersome to partially gut Type III nylon cord and this could introduce a failure mode through user error.

Figure 56: CH-47D Test Forward Flight Airdrop (13-23 May 2013)

6 Conclusions

The primary goal of this series of tests was to develop and demonstrate the capability of multiple bundle airdrops from an HSL. The previous demonstrations under the K-MAX had shown it was feasible for up to four payloads. This program developed a frame that was capable transporting up to 32 multiple sized payloads, external to the helicopter, that are traditionally transported internally.

The tests conducted at ATC and with the K-MAX demonstrated the feasibility of conducting multiple bundle airdrops from the cargo hook of a helicopter. Over 100 payloads of varying size, weight, parachute system, altitude, and drop configuration were demonstrated from rotary wing aircraft, of which several would not be capable of conducting an airdrop resupply mission. While further testing is needed with a variety of aircraft utilizing heavier payload weights and with additional airdrop systems, these successful demonstrations provide a sound basis for continued research and development in this area.

7 Recommendations

The continued development of multiple payload airdrop from beneath manned and unmanned helicopters to increase the capability of rotary wing aircraft is recommended. The continued testing should improve the rigging procedures, incorporate payloads with varying densities, and deploy payloads from varying forward airspeeds to identify any payload interaction and static line issues that need to be addressed.

Continued testing utilizing the military helicopters including the Sikorsky UH-60, CH-47, and CH-53 should be pursued. Testing should continue to incorporate different fielded parachute systems to ensure that these systems are compatible with the multiple payload airdrop concept.

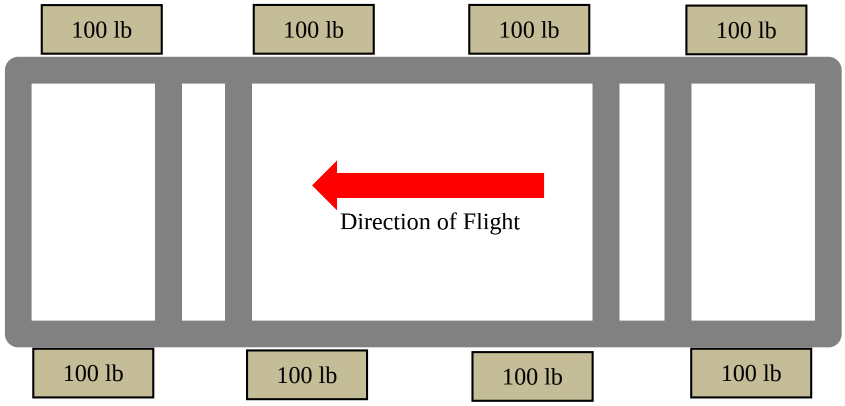
It is also recommended to expand the capabilities of the HSL RADE. The system could be integrated with unmanned systems. This would require additional integration and validation testing, followed by an operational test using an unmanned aircraft. The larger WGRS would allow for the release of CDS-sized payloads (up to 2328 lb). This release method should be incorporated into existing HSL RADE prototypes to increase payload delivery capability. Prior to program initiation, there was a concept generated to create a method to join the systems without the use of tools. Integrating a tool-less joining method for the system would decrease the complexity and setup time of the current system.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR- 15/030 in a series of reports approved for publication.

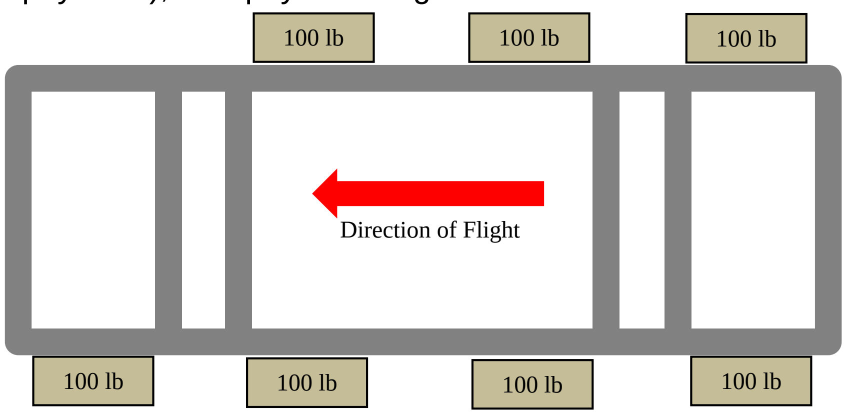
Appendix A
Payload Flight Configurations

Two sand bags weighing about 50 lb each were secured to an airdrop skidboard with paper honeycomb energy dissipating material. Each payload was suspended from the wireless gate. The total payload weight and locations for each of the nine flights were:

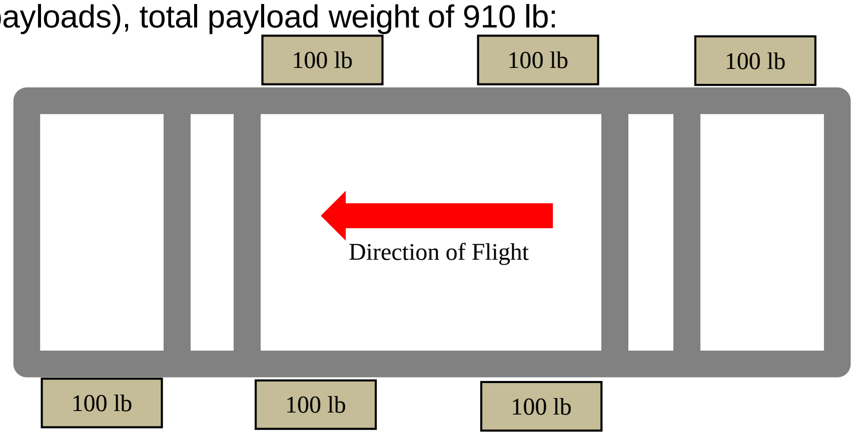
Flight 1 (full system), total payload weight of 1130 lb:



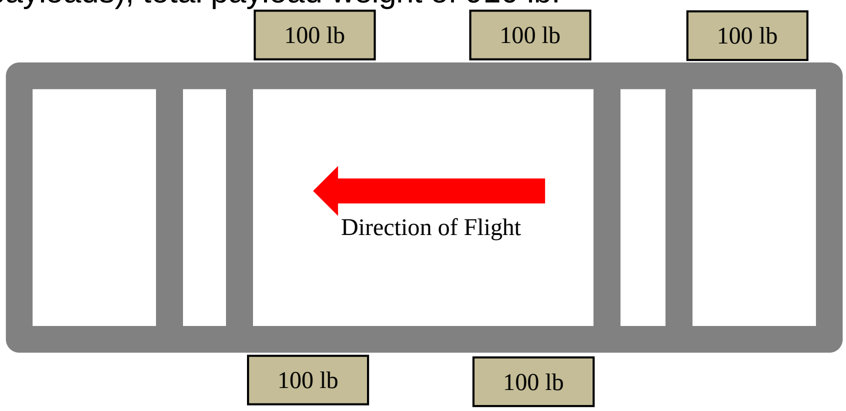
Flight 2 (seven payloads), total payload weight of 1020 lb:



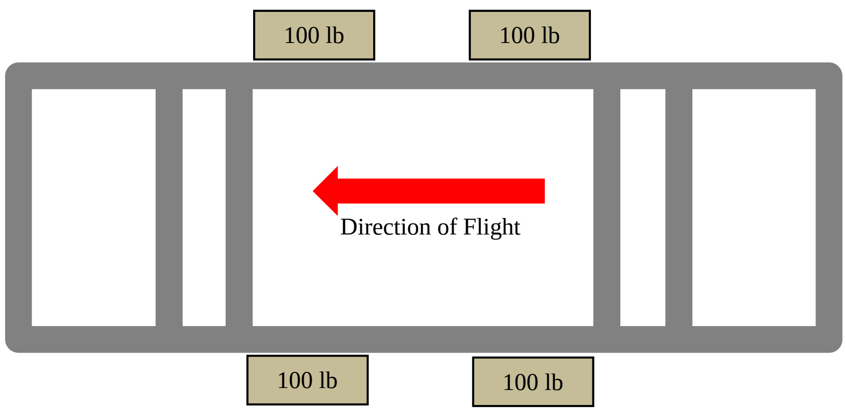
Flight 3 (six payloads), total payload weight of 910 lb:



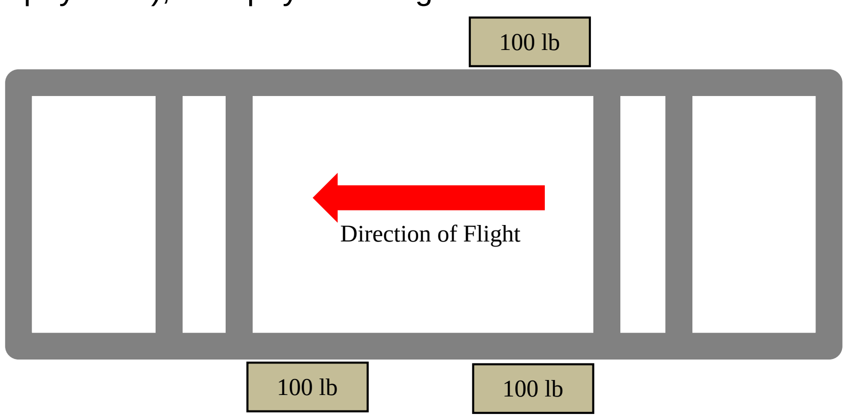
Flight 4 (five payloads), total payload weight of 910 lb:



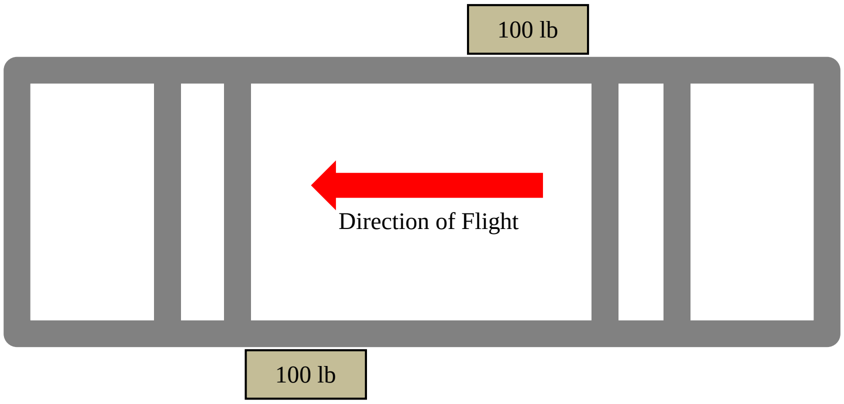
Flight 5 (four payloads), total payload weight of 690 lb:



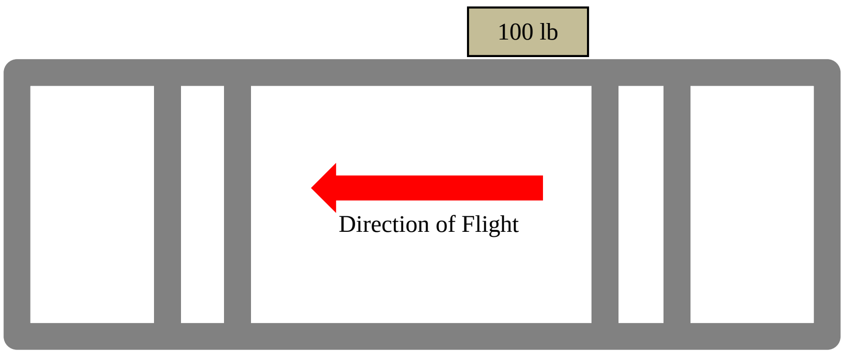
Flight 6 (three payloads), total payload weight of 580 lb:



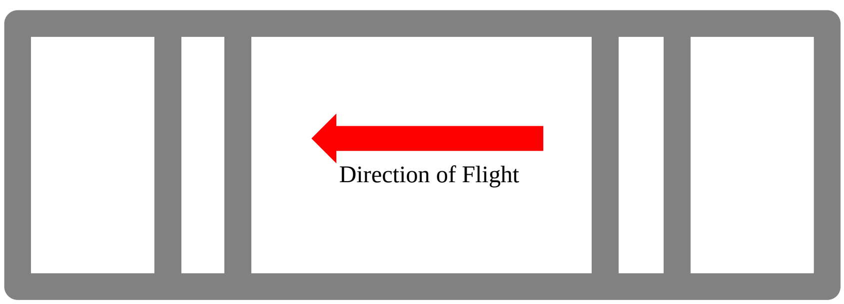
Flight 7 (two payloads), total payload weight of 470 lb:



Flight 8 (one payloads), total payload weight of 360 lb:



Flight 9 (empty), total payload weight of 360 lb:



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Appendix B
Multi-Service Flight Data Collection Sheets for the Quarter Frame HSL Test
(Reprint of original)

MULTI-SERVICE FLIGHT DATA COLLECTION SHEET

For Flight Evaluation Testing of Equipment to be Sling Loaded by Helicopter

Page 1 of 7 (Single/Dual)

Pre-Mission Data (Test Director)

Date of Test: **Test #:** Ø /

Test Location: PAAF

NSC Representative at Test:

Load Description (NSN, Model, LIN, etc.):
HSL JPADS Quarter

Load Weight (lbs.):

Sling Set: 10K ● 15K ○ 25K ○ 40K ○ MEAT* ○ Other* ○

*Only if authorized by U.S. Army Natick Soldier Center

Rigging Configuration: Single / Dual Point

Link Counts:

If additional chain sets are used, enter the number of additional sets used for each sling leg in the center box. Enter "0" for no extra chain.

(Attach Rigging Procedures)

Front Left	3 / 0	3 / 0	Front Right
Rear Left	0 / 3	0 / 3	Rear Right

U.S. Army Natick Soldier Center 3 May 2002

Page 2 of 7

PRE-MISSION DATA

Date & Test #:

Pre-Test Notes:

Pre-Mission Data (Pilot)

Ambient Temperature (deg. C):

Pressure Altitude (ft.) at PZ:

Wind Direction (deg.):

Wind Speed (kts.):

Aircraft Type:

Aircraft Serial Number:

Aircraft Operational Weight (lbs.):

Fuel Load (lbs.):

U.S. Army Natick Soldier Center 3 May 2002

SECTION I

Date & Test #:

HOVER & TRANSITIONAL

MANEUVERS	Response Rating (See page 7 for criteria) Better ←→ Worse A B C D F
Hover in Ground Effect (HIGE)	A B C D F
Left Turn on Spot, HIGE	A B C D F
Right Turn on Spot, HIGE	A B C D F
Left Slide, 10 deg. AOB, HIGE	A B C D F
Right Slide, 10 deg. AOB, HIGE	A B C D F
Hover Out of Ground Effect (HOGE)	A B C D F
Left Turn on Spot, HOGE	A B C D F
Right Turn on Spot, HOGE	A B C D F
Left Slide, 10 deg. AOB, HOGE	A B C D F
Right Slide, 10 deg. AOB, HOGE	A B C D F
Transition to Forward Flight	A B C D F
Transition from Forward Flight	A B C D F

SECTION II

Date & Test #:

STRAIGHT & LEVEL FLIGHT

AIRSPEED	Do Slings Go Slack?	Is There Sling Interference?	Response Rating (See page 7 for criteria) Better ←→ Worse A B C D F
50 (KIAS)	Yes No	Yes No	A B C D F
60 (KIAS)	Yes No	Yes No	A B C D F
70 (KIAS)	Yes No	Yes No	A B C D F
70 (KIAS)	Yes No	Yes No	A B C D F
75 (KIAS)	Yes No	Yes No	A B C D F
80 (KIAS)	Yes No	Yes No	A B C D F
90 (KIAS)	Yes No	Yes No	A B C D F
(KIAS)	Yes No	Yes No	A B C D F
(KIAS)	Yes No	Yes No	A B C D F

Reason(s) for stopping at the highest airspeed:

- A/C Limitations
- Load Instability
- Excessive Fleet Angle
- Other (explain on reverse side)

Page 5 of 7 **SECTION III** Date & Test #:

CLIMBING/DESCENDING & TURNING

All Maneuvers Listed Below Performed at: (KIAS)

Max. Authorized Angle of Bank (AOB max.):

Max. Authorized Rate of Descent (FPM):

Note: The maneuver AOB's and rates given below are recommended. DO NOT EXCEED OPERATIONAL LIMITATIONS

Aircraft Gross Weight: (lbs.)

Response Rating (See page 7 for criteria.)

Better ⟷ Worse

MANEUVERS

MANEUVERS	A B C D F
STRAIGHT CLIMB, minimum 500 FPM	A B C D F
STRAIGHT DESCENT, minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F
SMALL CONTROL REVERSALS (All 3 Axes)	A B C D F
COORDINATED LEVEL RIGHT TURN, 15 deg. AOB	A B C D F
COORDINATED LEVEL RIGHT TURN, 30 deg. AOB	A B C D F
COORDINATED LEVEL RIGHT TURN, AOB max.	A B C D F
CLIMBING RIGHT TURN, 30 deg. AOB, minimum 500 FPM	A B C D F
CLIMBING RIGHT TURN, AOB max., Minimum 500 FPM	A B C D F
DESCENDING RIGHT TURN, 30 deg. AOB, min. 500 FPM	A B C D F
DESCENDING RIGHT TURN, AOB max., Minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F
COORDINATED LEVEL LEFT TURN, 15 deg. AOB	A B C D F
COORDINATED LEVEL LEFT TURN, 30 deg. AOB	A B C D F
COORDINATED LEVEL LEFT TURN, AOB max.	A B C D F
CLIMBING LEFT TURN, 30 deg. AOB, minimum 500 FPM	A B C D F
CLIMBING LEFT TURN, AOB max., Minimum 500 FPM	A B C D F
DESCENDING LEFT TURN, 30 deg. AOB, min. 500 FPM	A B C D F
DESCENDING LEFT TURN, AOB max., Minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F

Maximum Attained AOB: (Deg.)

Maximum Attained Rate of Descent: (FPM)

Were the climbing/descending maneuvers conducted at a minimum rate of 500 FPM? (If no, explain in comments section on page 6.) Yes No

U.S. Army Natick Soldier Center 3 May 2002

Page 6 of 7 **SECTION IV** Date & Test #:

OVERALL PERFORMANCE

Maximum Recommended Straight and Level Airspeed for HSL Certification: (Knots)

Response Rating (See page 7 for criteria.)

Better ⟷ Worse

	A B C D F
Flight Characteristics of Aircraft	A B C D F
Flight Characteristics of Load	A B C D F

Were there any problems with hook-up or drop-off of the load? (If Yes, comment in Comments section.) Yes No

Did the load cause any interference with the radar altimeter? Yes No

Comments:

Pilot Name (print):

Telephone: ( ) DSN

Signature:

U.S. Army Natick Soldier Center 3 May 2002

RATING CRITERIA FOR AIRCRAFT FLIGHT CHARACTERISTICS WITH EXTERNAL LOADS

A. Excellent handling qualities. Effects of the load upon the aircraft performance are negligible at the prescribed airspeed.

B. Good handling qualities. Effects of the load on the aircraft performance are noticeable, but require little or no effort from the pilot to maintain control of the aircraft at the prescribed airspeed.

C. Fair handling qualities. Effects of the load on the aircraft performance are moderate, but readily controllable. The pilot should exercise moderate caution and pay close attention to the effects of the load on the aircraft in order to maintain control of the aircraft at the prescribed airspeed.

D. Poor handling qualities. Effects of the load on the aircraft performance are significant and require constant attention from the pilot to control the aircraft. Caution must be maintained at all times in order to control the aircraft at the prescribed airspeed.

F. Unacceptable handling qualities. Flight under these conditions is dangerous and requires constant attention from the pilot to avoid loss of control of the aircraft. Aircraft is constantly unstable. Flight at this or higher air speed is not recommended.

RATING CRITERIA FOR EXTERNAL LOAD STABILITY CHARACTERISTICS DURING FLIGHT

A. Excellent Load Stability: Load maintains directional stability throughout maneuvers. Minimal load oscillation and/or minimal load rotation or weathervaning. Requires minimal concentration by the flight crew.

B. Good Load Stability: Load maintains directional stability for most maneuvers. Only moderate load oscillation and/or moderate load rotation or weathervaning occurs. Requires minimal concentration by the flight crew.

C. Fair Load Stability: Load may oscillate, rotate and/or weathervane during most maneuvers. Directional orientation is not stable throughout maneuvers. However the load remains stable in its rotational state, the rotation does not continue to wind up the sling legs, and the load does not pose a threat to the aircraft.

D. Poor Load Stability: Load oscillates, rotates, or weathervanes during all maneuvers. Directional instability may become severe and require immediate action by the flight crew to prevent damage to the load and/or aircraft, or danger to personnel.

F. Unacceptable Load Stability: Load is uncontrollable for most or all of the maneuvers. Directional instability is unpredictable and dangerous. Transport of the load at the prescribed airspeed is not recommended.

MULTI-SERVICE FLIGHT DATA COLLECTION SHEET

For Flight Evaluation Testing of Equipment to be Sling Loaded by Helicopter

Pre-Mission Data (Test Director)

Date of Test:

Test #: 2

Test Location: PAAF

NSC Representative at Test:

Load Description (NSN, Model, LIN, etc.):

HSL JPADS Quarter

Load Weight (lbs.):

Sling Set: 10K ● 15K ○ 25K ○ 40K ○ MEAT* ○ Other* ○

*Only if authorized by U.S. Army Natick Soldier Center

Rigging Configuration: Single / Dual Point

Link Counts:

If additional chain sets are used, enter the number of additional sets used for each sling leg in the center box. Enter "0" for no extra chain.

(Attach Rigging Procedures)

Front Left	3	3	Front Right
	0	0	
	0	0	
Rear Left	3	3	Rear Right

PRE-MISSION DATA

Date & Test #:

Pre-Test Notes:

Pre-Mission Data (Pilot)

Ambient Temperature (deg. C):	
Pressure Altitude (ft.) at PZ:	
Wind Direction (deg.):	
Wind Speed (kts.):	
Aircraft Type:	
Aircraft Serial Number:	
Aircraft Operational Weight (lbs.):	
Fuel Load (lbs.):	

SECTION I

Date & Test #:

HOVER & TRANSITIONAL

Response Rating
(See page 7 for criteria)

Better ⟷ Worse

MANEUVERS	A B C D F
Hover in Ground Effect (HIGE)	A B C D F
Left Turn on Spot, HIGE	A B C D F
Right Turn on Spot, HIGE	A B C D F
Left Slide, 10 deg. AOB, HIGE	A B C D F
Right Slide, 10 deg. AOB, HIGE	A B C D F
Hover Out of Ground Effect (HOGE)	A B C D F
Left Turn on Spot, HOGE	A B C D F
Right Turn on Spot, HOGE	A B C D F
Left Slide, 10 deg. AOB, HOGE	A B C D F
Right Slide, 10 deg. AOB, HOGE	A B C D F
Transition to Forward Flight	A B C D F
Transition from Forward Flight	A B C D F

SECTION II

Date & Test #:

STRAIGHT & LEVEL FLIGHT

Response Rating (See page 7 for criteria)

Better ⟷ Worse

AIRSPEED	Do Slings Go Slack?	Is There Sling Interference?	A B C D F
40 (KIAS)	Yes No	Yes No	A B C D F
50 (KIAS)	Yes No	Yes No	A B C D F
60 (KIAS)	Yes No	Yes No	A B C D F
65 (KIAS)	Yes No	Yes No	A B C D F
70 (KIAS)	Yes No	Yes No	A B C D F
75 (KIAS)	Yes No	Yes No	A B C D F
80 (KIAS)	Yes No	Yes No	A B C D F
85 (KIAS)	Yes No	Yes No	A B C D F
90 (KIAS)	Yes No	Yes No	A B C D F

Reason(s) for stopping at the highest airspeed:

- A/C Limitations
- Load Instability
- Excessive Fleet Angle
- Other (explain on reverse side)

SECTION III

Date & Test #:

CLIMBING/DESCENDING & TURNING

All Maneuvers Listed Below Performed at: (KIAS)

Max. Authorized Angle of Bank (AOB max.):

Max. Authorized Rate of Descent (FPM):

Note: The maneuver AOB's and rates given below are recommended. DO NOT EXCEED OPERATIONAL LIMITATIONS

Aircraft Gross Weight: (lbs.)

Response Rating (See page 7 for criteria)

Better ⟷ Worse

MANEUVERS	A B C D F
STRAIGHT CLIMB, minimum 500 FPM	A B C D F
STRAIGHT DESCENT, minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F
SMALL CONTROL REVERSALS (All 3 Axes)	A B C D F
COORDINATED LEVEL RIGHT TURN, 15 deg. AOB	A B C D F
COORDINATED LEVEL RIGHT TURN, 30 deg. AOB	A B C D F
COORDINATED LEVEL RIGHT TURN, AOB max.	A B C D F
CLIMBING RIGHT TURN, 30 deg. AOB, minimum 500 FPM	A B C D F
CLIMBING RIGHT TURN, AOB max., Minimum 500 FPM	A B C D F
DESCENDING RIGHT TURN, 30 deg. AOB, min. 500 FPM	A B C D F
DESCENDING RIGHT TURN, AOB max., Minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F
COORDINATED LEVEL LEFT TURN, 15 deg. AOB	A B C D F
COORDINATED LEVEL LEFT TURN, 30 deg. AOB	A B C D F
COORDINATED LEVEL LEFT TURN, AOB max.	A B C D F
CLIMBING LEFT TURN, 30 deg. AOB, minimum 500 FPM	A B C D F
CLIMBING LEFT TURN, AOB max., Minimum 500 FPM	A B C D F
DESCENDING LEFT TURN, 30 deg. AOB, min. 500 FPM	A B C D F
DESCENDING LEFT TURN, AOB max., Minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F

Maximum Attained AOB: (Deg.)

Maximum Attained Rate of Descent: (FPM)

Were the climbing/descending maneuvers conducted at a minimum rate of 500 FPM? (If no, explain in comments section on page 6.) Yes No

SECTION IV

Date &
Test #:

OVERALL PERFORMANCE

Maximum Recommended Straight and Level Airspeed for HSL Certification:	Response Rating (See page 7 for criteria.)
(Knots)	Better ⟷ Worse (A)(B)(C)(D)(F)
Flight Characteristics of Aircraft	(A)(B)(C)(D)(F)
Flight Characteristics of Load	(A)(B)(C)(D)(F)
Were there any problems with hook-up or drop-off of the load? (If Yes, comment in Comments section.)	Yes No
Did the load cause any interference with the radar altimeter?	Yes No

Comments:

Pilot Name (print):

Telephone: (   )   DSN

Signature:

RATING CRITERIA FOR AIRCRAFT FLIGHT CHARACTERISTICS WITH EXTERNAL LOADS

A. Excellent handling qualities. Effects of the load upon the aircraft performance are negligible at the prescribed airspeed.

B. Good handling qualities. Effects of the load on the aircraft performance are noticeable, but require little or no effort from the pilot to maintain control of the aircraft at the prescribed airspeed.

C. Fair handling qualities. Effects of the load on the aircraft performance are moderate, but readily controllable. The pilot should exercise moderate caution and pay close attention to the effects of the load on the aircraft in order to maintain control of the aircraft at the prescribed airspeed.

D. Poor handling qualities. Effects of the load on the aircraft performance are significant and require constant attention from the pilot to control the aircraft. Caution must be maintained at all times in order to control the aircraft at the prescribed airspeed.

F. Unacceptable handling qualities. Flight under these conditions is dangerous and requires constant attention from the pilot to avoid loss of control of the aircraft. Aircraft is constantly unstable. Flight at this or higher air speed is not recommended.

RATING CRITERIA FOR EXTERNAL LOAD STABILITY CHARACTERISTICS DURING FLIGHT

A. Excellent Load Stability: Load maintains directional stability throughout maneuvers. Minimal load oscillation and/or minimal load rotation or weathervaning. Requires minimal concentration by the flight crew.

B. Good Load Stability: Load maintains directional stability for most maneuvers. Only moderate load oscillation and/or moderate load rotation or weathervaning occurs. Requires minimal concentration by the flight crew.

C. Fair Load Stability: Load may oscillate, rotate and/or weathervane during most maneuvers. Directional orientation is not stable throughout maneuvers. However the load remains stable in its rotational state, the rotation does not continue to wind up the sling legs, and the load does not pose a threat to the aircraft.

D. Poor Load Stability: Load oscillates, rotates, or weathervanes during all maneuvers. Directional instability may become severe and require immediate action by the flight crew to prevent damage to the load and/or aircraft, or danger to personnel.

F. Unacceptable Load Stability: Load is uncontrollable for most or all of the maneuvers. Directional instability is unpredictable and dangerous. Transport of the load at the prescribed airspeed is not recommended.

MULTI-SERVICE FLIGHT DATA COLLECTION SHEET

For Flight Evaluation Testing of Equipment to be Sling Loaded by Helicopter

Pre-Mission Data (Test Director)

Date of Test:

Test #: 4

Test Location: PAAF

NSC Representative at Test:

Load Description (NSN, Model, LIN, etc.):

HSL JPADS Quarter

Load Weight (lbs.):

Sling Set: 10K ● 15K ○ 25K ○ 40K ○ MEAT* ○ Other* ○

*Only authorized by U.S. Army Natick Soldier Center

Rigging Configuration: Single / Dual Point

Link Counts:

If additional chain sets are used, enter the number of additional sets used for each sling leg in the center box. Enter "0" for no extra chain.

(Attach Rigging Procedures)

Front Left	3	3	Front Right
	0	0	
	0	0	
Rear Left	3	3	Rear Right

PRE-MISSION DATA

Date & Test #:

Pre-Test Notes:

Pre-Mission Data (Pilot)

Ambient Temperature (deg. C):

SECTION I

Date &
Test #:

HOVER & TRANSITIONAL

Response Rating
(See page 7 for criteria.)
Better ⟵⟶ Worse

MANEUVERS	A B C D F
Hover in Ground Effect (HIGE)	A B C D F
Left Turn on Spot, HIGE	A B C D F
Right Turn on Spot, HIGE	A B C D F
Left Slide, 10 deg. AOB, HIGE	A B C D F
Right Slide, 10 deg. AOB, HIGE	A B C D F
Hover Out of Ground Effect (HOGE)	A B C D F
Left Turn on Spot, HOGE	A B C D F
Right Turn on Spot, HOGE	A B C D F
Left Slide, 10 deg. AOB, HOGE	A B C D F
Right Slide, 10 deg. AOB, HOGE	A B C D F
Transition to Forward Flight	A B C D F
Transition from Forward Flight	A B C D F

SECTION II

Date &
Test #:

STRAIGHT & LEVEL FLIGHT

Response Rating
(See page 7 for criteria.)
Better ⟵⟶ Worse

AIRSPEED	Do Slings Go Slack?	Is There Sling Interference?	A B C D F
20 (KIAS)	Yes No	Yes No	A B C D F
40 (KIAS)	Yes No	Yes No	A B C D F
50 (KIAS)	Yes No	Yes No	A B C D F
60 (KIAS)	Yes No	Yes No	A B C D F
70 (KIAS)	Yes No	Yes No	A B C D F
75 (KIAS)	Yes No	Yes No	A B C D F
80 (KIAS)	Yes No	Yes No	A B C D F
85 (KIAS)	Yes No	Yes No	A B C D F
(KIAS)	Yes No	Yes No	A B C D F

Reason(s) for stopping at the highest airspeed:

- A/C Limitations
- Load Instability
- Excessive Fleet Angle
- Other (explain on reverse side)

SECTION III

Date & Test #:

CLIMBING/DESCENDING & TURNING

All Maneuvers Listed Below Performed at: (KIAS)

Max. Authorized Angle of Bank (AOB max.):

Max. Authorized Rate of Descent (FPM):

Note: The maneuver AOB's and rates given below are recommended. DO NOT EXCEED OPERATIONAL LIMITATIONS

Aircraft Gross Weight: (lbs.)

Response Rating (See page 7 for criteria.)

Better ⟵⟶ Worse

MANEUVERS

MANEUVERS	A	B	C	D	F
STRAIGHT CLIMB, minimum 500 FPM	A	B	C	D	F
STRAIGHT DESCENT, minimum 500 FPM	A	B	C	D	F
PULL OUT, STANDARD RATE	A	B	C	D	F
SMALL CONTROL REVERSALS (All 3 Axes)	A	B	C	D	F
COORDINATED LEVEL RIGHT TURN, 15 deg. AOB	A	B	C	D	F
COORDINATED LEVEL RIGHT TURN, 30 deg. AOB	A	B	C	D	F
COORDINATED LEVEL RIGHT TURN, AOB max.	A	B	C	D	F
CLIMBING RIGHT TURN, 30 deg. AOB, minimum 500 FPM	A	B	C	D	F
CLIMBING RIGHT TURN, AOB max., Minimum 500 FPM	A	B	C	D	F
DESCENDING RIGHT TURN, 30 deg. AOB, min. 500 FPM	A	B	C	D	F
DESCENDING RIGHT TURN, AOB max., Minimum 500 FPM	A	B	C	D	F
PULL OUT, STANDARD RATE	A	B	C	D	F
COORDINATED LEVEL LEFT TURN, 15 deg. AOB	A	B	C	D	F
COORDINATED LEVEL LEFT TURN, 30 deg. AOB	A	B	C	D	F
COORDINATED LEVEL LEFT TURN, AOB max.	A	B	C	D	F
CLIMBING LEFT TURN, 30 deg. AOB, minimum 500 FPM	A	B	C	D	F
CLIMBING LEFT TURN, AOB max., Minimum 500 FPM	A	B	C	D	F
DESCENDING LEFT TURN, 30 deg. AOB, min. 500 FPM	A	B	C	D	F
DESCENDING LEFT TURN, AOB max., Minimum 500 FPM	A	B	C	D	F
PULL OUT, STANDARD RATE	A	B	C	D	F

Maximum Attained AOB: (Deg.)

Maximum Attained Rate of Descent: (FPM)

Were the climbing/descending maneuvers conducted at a minimum rate of 500 FPM? (If no, explain in comments section on page 6.) Yes No

SECTION IV

Date & Test #:

OVERALL PERFORMANCE

Maximum Recommended Straight and Level Airspeed for HSL Certification: (Knots)

Response Rating (See page 7 for criteria.)

Better ⟵⟶ Worse

A B C D F

	A	B	C	D	F
Flight Characteristics of Aircraft	A	B	C	D	F
Flight Characteristics of Load	A	B	C	D	F

Were there any problems with hook-up or drop-off of the load? (If Yes, comment in Comments section.) Yes No

Did the load cause any interference with the radar altimeter? Yes No

Comments:

Pilot Name (print):

Telephone: ( ) DSN

Signature:

RATING CRITERIA FOR AIRCRAFT FLIGHT CHARACTERISTICS WITH EXTERNAL LOADS

A. Excellent handling qualities. Effects of the load upon the aircraft performance are negligible at the prescribed airspeed.

B. Good handling qualities. Effects of the load on the aircraft performance are noticeable, but require little or no effort from the pilot to maintain control of the aircraft at the prescribed airspeed.

C. Fair handling qualities. Effects of the load on the aircraft performance are moderate, but readily controllable. The pilot should exercise moderate caution and pay close attention to the effects of the load on the aircraft in order to maintain control of the aircraft at the prescribed airspeed.

D. Poor handling qualities. Effects of the load on the aircraft performance are significant and require constant attention from the pilot to control the aircraft. Caution must be maintained at all times in order to control the aircraft at the prescribed airspeed.

F. Unacceptable handling qualities. Flight under these conditions is dangerous and requires constant attention from the pilot to avoid loss of control of the aircraft. Aircraft is constantly unstable. Flight at this or higher air speed is not recommended.

RATING CRITERIA FOR EXTERNAL LOAD STABILITY CHARACTERISTICS DURING FLIGHT

A. Excellent Load Stability: Load maintains directional stability throughout maneuvers. Minimal load oscillation and/or minimal load rotation or weathervaning. Requires minimal concentration by the flight crew.

B. Good Load Stability: Load maintains directional stability for most maneuvers. Only moderate load oscillation and/or moderate load rotation or weathervaning occurs. Requires minimal concentration by the flight crew.

C. Fair Load Stability: Load may oscillate, rotate and/or weathervane during most maneuvers. Directional orientation is not stable throughout maneuvers. However the load remains stable in its rotational state, the rotation does not continue to wind up the sling legs, and the load does not pose a threat to the aircraft.

D. Poor Load Stability: Load oscillates, rotates, or weathervanes during all maneuvers. Directional instability may become severe and require immediate action by the flight crew to prevent damage to the load and/or aircraft, or danger to personnel.

F. Unacceptable Load Stability: Load is uncontrollable for most or all of the maneuvers. Directional instability is unpredictable and dangerous. Transport of the load at the prescribed airspeed is not recommended.

MULTI-SERVICE FLIGHT DATA COLLECTION SHEET

For Flight Evaluation Testing of Equipment to be Sling Loaded by Helicopter

Pre-Mission Data (Test Director)

Date of Test:

Test #: 6

Test Location: PAAF

NSC Representative at Test:

Load Description (NSN, Model, LIN, etc.)**:**

HSL JPADS Quarter

Load Weight (lbs.):

Sling Set: 10K ● 15K ○ 25K ○ 40K ○ MEAT* ○ Other* ○

*Only if authorized by U.S. Army Natick Soldier Center

Rigging Configuration: Single / Dual Point

Link Counts:

If additional chain sets are used, enter the number of additional sets used for each sling leg in the center box. Enter "0" for no extra chain.

(Attach Rigging Procedures)

Front Left	3	3	Front Right
	0	0	
	0	0	
Rear Left	3	3	Rear Right

PRE-MISSION DATA

Date &
Test #:

Pre-Test Notes:

Pre-Mission Data (Pilot)

Ambient Temperature (deg. C):	
Pressure Altitude (ft.) at PZ:	
Wind Direction (deg.):	
Wind Speed (kts.):	
Aircraft Type:	
Aircraft Serial Number:	
Aircraft Operational Weight (lbs.):	
Fuel Load (lbs.):	

SECTION I

Date &
Test #:

HOVER & TRANSITIONAL

Response Rating
(See page 7 for criteria.)

Better ⟷ Worse

MANEUVERS	A	B	C	D	F
Hover in Ground Effect (HIGE)	A	B	C	D	F
Left Turn on Spot, HIGE	A	B	C	D	F
Right Turn on Spot, HIGE	A	B	C	D	F
Left Slide, 10 deg. AOB, HIGE	A	B	C	D	F
Right Slide, 10 deg. AOB, HIGE	A	B	C	D	F
Hover Out of Ground Effect (HOGE)	A	B	C	D	F
Left Turn on Spot, HOGE	A	B	C	D	F
Right Turn on Spot, HOGE	A	B	C	D	F
Left Slide, 10 deg. AOB, HOGE	A	B	C	D	F
Right Slide, 10 deg. AOB, HOGE	A	B	C	D	F
Transition to Forward Flight	A	B	C	D	F
Transition from Forward Flight	A	B	C	D	F

STRAIGHT & LEVEL FLIGHT

Response Rating
(See page 7 for criteria.)
Better ⟷ Worse

AIRSPEED	Do Slings Go Slack?	Is There Sling Interference?	A B C D F
40 (KIAS)	Yes No	Yes No	A B C D F
50 (KIAS)	Yes No	Yes No	A B C D F
60 (KIAS)	Yes No	Yes No	A B C D F
65 (KIAS)	Yes No	Yes No	A B C D F
70 (KIAS)	Yes No	Yes No	A B C D F
80 (KIAS)	Yes No	Yes No	A B C D F
50 (KIAS)	Yes No	Yes No	A B C D F
40 (KIAS)	Yes No	Yes No	A B C D F
20 (KIAS)	Yes No	Yes No	A B C D F

Reason(s) for stopping at the highest airspeed:

- A/C Limitations
- Load Instability
- Excessive Fleet Angle
- Other (explain on reverse side)

CLIMBING/DESCENDING & TURNING

All Maneuvers Listed Below Performed at: (KIAS)

Max. Authorized Angle of Bank (AOB max.):

Max. Authorized Rate of Descent (FPM):

Note: The maneuver AOB's and rates given below are recommended. DO NOT EXCEED OPERATIONAL LIMITATIONS

Aircraft Gross Weight: (lbs.)

Response Rating
(See page 7 for criteria.)
Better ⟷ Worse

MANEUVERS	A B C D F
STRAIGHT CLIMB, minimum 500 FPM	A B C D F
STRAIGHT DESCENT, minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F
SMALL CONTROL REVERSALS (All 3 Axes)	A B C D F
COORDINATED LEVEL RIGHT TURN, 15 deg. AOB	A B C D F
COORDINATED LEVEL RIGHT TURN, 30 deg. AOB	A B C D F
COORDINATED LEVEL RIGHT TURN, AOB max.	A B C D F
CLIMBING RIGHT TURN, 30 deg. AOB, minimum 500 FPM	A B C D F
CLIMBING RIGHT TURN, AOB max., Minimum 500 FPM	A B C D F
DESCENDING RIGHT TURN, 30 deg. AOB, min. 500 FPM	A B C D F
DESCENDING RIGHT TURN, AOB max., Minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F
COORDINATED LEVEL LEFT TURN, 15 deg. AOB	A B C D F
COORDINATED LEVEL LEFT TURN, 30 deg. AOB	A B C D F
COORDINATED LEVEL LEFT TURN, AOB max.	A B C D F
CLIMBING LEFT TURN, 30 deg. AOB, minimum 500 FPM	A B C D F
CLIMBING LEFT TURN, AOB max., Minimum 500 FPM	A B C D F
DESCENDING LEFT TURN, 30 deg. AOB, min. 500 FPM	A B C D F
DESCENDING LEFT TURN, AOB max., Minimum 500 FPM	A B C D F
PULL OUT, STANDARD RATE	A B C D F

Maximum Attained AOB: (Deg.)

Maximum Attained Rate of Descent: (FPM)

Were the climbing/descending maneuvers conducted at a minimum rate of 500 FPM? (If no, explain in comments section on page 6.) Yes No

SECTION IV

Date &
Test #:

OVERALL PERFORMANCE

Maximum Recommended Straight and Level Airspeed for HSL Certification:

(Knots)

Response Rating
(See page 7 for criteria.)

Better ⟵⟶ Worse

A B C D F

Flight Characteristics of Aircraft A B C D F

Flight Characteristics of Load A B C D F

Were there any problems with hook-up or drop-off of the load?
(If Yes, comment in Comments section.)
Yes No

Did the load cause any interference with the radar altimeter?
Yes No

Comments:

Pilot Name (print):

Telephone: ( ) DSN

Signature:

RATING CRITERIA FOR AIRCRAFT FLIGHT CHARACTERISTICS WITH EXTERNAL LOADS

A. Excellent handling qualities. Effects of the load upon the aircraft performance are negligible at the prescribed airspeed.

B. Good handling qualities. Effects of the load on the aircraft performance are noticeable, but require little or no effort from the pilot to maintain control of the aircraft at the prescribed airspeed.

C. Fair handling qualities. Effects of the load on the aircraft performance are moderate, but readily controllable. The pilot should exercise moderate caution and pay close attention to the effects of the load on the aircraft in order to maintain control of the aircraft at the prescribed airspeed.

D. Poor handling qualities. Effects of the load on the aircraft performance are significant and require constant attention from the pilot to control the aircraft. Caution must be maintained at all times in order to control the aircraft at the prescribed airspeed.

F. Unacceptable handling qualities. Flight under these conditions is dangerous and requires constant attention from the pilot to avoid loss of control of the aircraft. Aircraft is constantly unstable. Flight at this or higher air speed is not recommended.

RATING CRITERIA FOR EXTERNAL LOAD STABILITY CHARACTERISTICS DURING FLIGHT

A. Excellent Load Stability: Load maintains directional stability throughout maneuvers. Minimal load oscillation and/or minimal load rotation or weathervaning. Requires minimal concentration by the flight crew.

B. Good Load Stability: Load maintains directional stability for most maneuvers. Only moderate load oscillation and/or moderate load rotation or weathervaning occurs. Requires minimal concentration by the flight crew.

C. Fair Load Stability: Load may oscillate, rotate and/or weathervane during most maneuvers. Directional orientation is not stable throughout maneuvers. However the load remains stable in its rotational state, the rotation does not continue to wind up the sling legs, and the load does not pose a threat to the aircraft.

D. Poor Load Stability: Load oscillates, rotates, or weathervanes during all maneuvers. Directional instability may become severe and require immediate action by the flight crew to prevent damage to the load and/or aircraft, or danger to personnel.

F. Unacceptable Load Stability: Load is uncontrollable for most or all of the maneuvers. Directional instability is unpredictable and dangerous. Transport of the load at the prescribed airspeed is not recommended.

MULTI-SERVICE FLIGHT DATA COLLECTION SHEET

For Flight Evaluation Testing of Equipment to be Sling Loaded by Helicopter

Pre-Mission Data (Test Director)

Date of Test:

Test #: FULL

Test Location: PAAF

NSC Representative at Test:

Load Description (NSN, Model, LIN, etc.):

HSL JPADS Quarter

Load Weight (lbs.): 1100

Sling Set: 10K (●) 15K (○) 25K (○) 40K (○) MEAT* (○) Other* (○)

*Only if authorized by U.S. Army Natick Soldier Center

Rigging Configuration: Single / Dual Point

Link Counts:

If additional chain sets are used, enter the number of additional sets used for each sling leg in the center box. Enter "0" for no extra chain.

(Attach Rigging Procedures)

Front Left	3	3	Front Right
	0	0	
	0	0	
Rear Left	3	3	Rear Right

PRE-MISSION DATA

Date & Test #:

Pre-Test Notes:

Pre-Mission Data (Pilot)

Ambient Temperature (deg. C):

Pressure Altitude (ft.) at PZ:

Wind Direction (deg.):

Wind Speed (kts.):

Aircraft Type:

Aircraft Serial Number:

Aircraft Operational Weight (lbs.):

Fuel Load (lbs.):

Page 3 of 7 **SECTION I** Date & Test #:

HOVER & TRANSITIONAL

MANEUVERS	Response Rating (See page 7 for criteria.) Better ⟷ Worse A B C D F
Hover in Ground Effect (HIGE)	A B C D F
Left Turn on Spot, HIGE	A B C D F
Right Turn on Spot, HIGE	A B C D F
Left Slide, 10 deg. AOB, HIGE	A B C D F
Right Slide, 10 deg. AOB, HIGE	A B C D F
Hover Out of Ground Effect (HOGE)	A B C D F
Left Turn on Spot, HOGE	A B C D F
Right Turn on Spot, HOGE	A B C D F
Left Slide, 10 deg. AOB, HOGE	A B C D F
Right Slide, 10 deg. AOB, HOGE	A B C D F
Transition to Forward Flight	A B C D F
Transition from Forward Flight	A B C D F

Page 4 of 7 **SECTION II** Date & Test #:

STRAIGHT & LEVEL FLIGHT

AIRSPEED	Do Slings Go Slack?	Is There Sling Interference?	Response Rating (See page 7 for criteria.) Better ⟷ Worse A B C D F
20 (KIAS)	Yes No	Yes No	A B C D F
40 (KIAS)	Yes No	Yes No	A B C D F
50 (KIAS)	Yes No	Yes No	A B C D F
60 (KIAS)	Yes No	Yes No	A B C D F
70 (KIAS)	Yes No	Yes No	A B C D F
(KIAS)	Yes No	Yes No	A B C D F
(KIAS)	Yes No	Yes No	A B C D F
(KIAS)	Yes No	Yes No	A B C D F
(KIAS)	Yes No	Yes No	A B C D F

Reason(s) for stopping at the highest airspeed:

- A/C Limitations
- Load Instability
- Excessive Fleet Angle
- Other (explain on reverse side)

SECTION III

Date & Test #:

CLIMBING/DESCENDING & TURNING

All Maneuvers Listed Below Performed at: (KIAS)

Max. Authorized Angle of Bank (AOB max.):

Max. Authorized Rate of Descent (FPM):

Note: The maneuver AOB's and rates given below are recommended. DO NOT EXCEED OPERATIONAL LIMITATIONS

Aircraft Gross Weight: (lbs.)

Response Rating (See page 7 for criteria.)

Better ← → Worse

MANEUVERS

MANEUVERS	A	B	C	D	F
STRAIGHT CLIMB, minimum 500 FPM	A	B	C	D	F
STRAIGHT DESCENT, minimum 500 FPM	A	B	C	D	F
PULL OUT, STANDARD RATE	A	B	C	D	F
SMALL CONTROL REVERSALS (All 3 Axes)	A	B	C	D	F
COORDINATED LEVEL RIGHT TURN, 15 deg. AOB	A	B	C	D	F
COORDINATED LEVEL RIGHT TURN, 30 deg. AOB	A	B	C	D	F
COORDINATED LEVEL RIGHT TURN, AOB max.	A	B	C	D	F
CLIMBING RIGHT TURN, 30 deg. AOB, minimum 500 FPM	A	B	C	D	F
CLIMBING RIGHT TURN, AOB max., Minimum 500 FPM	A	B	C	D	F
DESCENDING RIGHT TURN, 30 deg. AOB, min. 500 FPM	A	B	C	D	F
DESCENDING RIGHT TURN, AOB max., Minimum 500 FPM	A	B	C	D	F
PULL OUT, STANDARD RATE	A	B	C	D	F
COORDINATED LEVEL LEFT TURN, 15 deg. AOB	A	B	C	D	F
COORDINATED LEVEL LEFT TURN, 30 deg. AOB	A	B	C	D	F
COORDINATED LEVEL LEFT TURN, AOB max.	A	B	C	D	F
CLIMBING LEFT TURN, 30 deg. AOB, minimum 500 FPM	A	B	C	D	F
CLIMBING LEFT TURN, AOB max., Minimum 500 FPM	A	B	C	D	F
DESCENDING LEFT TURN, 30 deg. AOB, min. 500 FPM	A	B	C	D	F
DESCENDING LEFT TURN, AOB max., Minimum 500 FPM	A	B	C	D	F
PULL OUT, STANDARD RATE	A	B	C	D	F

Maximum Attained AOB: (Deg.)

Maximum Attained Rate of Descent: (FPM)

Were the climbing/descending maneuvers conducted at a minimum rate of 500 FPM? (If no, explain in comments section on page 6.) Yes No

SECTION IV

Date & Test #:

OVERALL PERFORMANCE

Maximum Recommended Straight and Level Airspeed for HSL Certification: (Knots)

Response Rating (See page 7 for criteria.)

Better ← → Worse

	A	B	C	D	F
Flight Characteristics of Aircraft	A	B	C	D	F
Flight Characteristics of Load	A	B	C	D	F

Were there any problems with hook-up or drop-off of the load? (If Yes, comment in Comments section.) Yes No

Did the load cause any interference with the radar altimeter? Yes No

Comments:

Pilot Name (print):

Telephone: ( ) DSN

Signature:

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Appendix C
Humanitarian Airdrop Program Details

The humanitarian airdrop system currently in development is a High Altitude Low Opening (HALO) delivery system that utilizes a 15-ft ring slot parachute, a timing device (Improved Wireless Activation Device (iWAD)), a bag containing aid items and a skidboard with foam. Upon deployment from the aircraft, the 15-ft ring slot deploys and stabilizes the system. After descending to a specified altitude (or after a pre-set time), the iWAD triggers the release of a four-ring release mechanism, a point in the drop which is referred to as “transition”. This causes the bag to flip over due to the pull from an activation line attached between the bottom of the bag and the parachute risers. The bag contents are dumped out, a point which is referred to as “dispersion”. The aid items that fall to the ground are designed to be small enough and fall slowly enough that, if one of them hits a person on the ground, the risk of injury is minimal to none. The release at transition also allows the skidboard to fall away from the bag and rotate to orient the foam side towards the ground, which provides cushioning if the skidboard hits people on the ground.

POC for this effort is:

Andy Meloni
Research Aerospace Engineer
U.S. Army Natick Soldier RDEC
Email:
andrew.w.meloni.civ@mail.mil
Office: 508-233-5254 / DSN 256-5254

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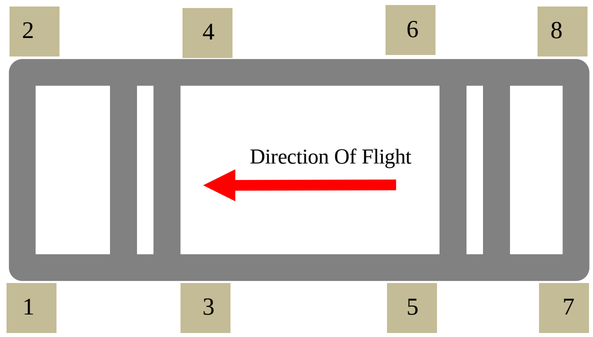
Appendix D
Payload/Flight Data for Testing at APG



Lift	Weight (lb)	Number of Parachutes	Type of Parachute	Frame Position	Air Speed (KIAS)	Payload Release Pass	Altitude (ft AGL)	Payload Material
26 June 2012								
1	115	1	LCLA	1	0	4	400	Sand Bag
1	115	1	LCLA	3	0	6	400	Sand Bag
1	115	1	LCLA	5	0	5	400	Sand Bag
1	115	1	LCLA	6	0	7	400	Sand Bag
1	115	1	LCLA	7	0	2	400	Sand Bag
1	115	1	T-10 Cargo	8	0	3	400	Sand Bag
1	560	1	15-Ft Ring Slot	4	0	1	3000	Rubber & Wood
1	0	N/A	N/A	2	N/A	N/A	N/A	N/A
2	115	1	LCLA	1	40	3	400	Sand Bag
2	115	1	LCLA	3	40	4	400	Sand Bag
2	115	1	T-10 Cargo	5	40	6	400	Sand Bag
2	115	1	LCLA	6	40	5	400	Sand Bag
2	115	1	T-10 Cargo	7	40	1	400	Sand Bag
2	115	1	LCLA	8	40	2	400	Sand Bag
2	560	1	N/A	4	40	7	400	Rubber & Wood
2	0	N/A	N/A	2	N/A	N/A	N/A	N/A
27 June 2012								
1	115	1	LCLA	1	60	3	500	Sand Bag
1	115	1	LCLA	3	60	2	500	Sand Bag
1	115	1	T-10 Cargo	5	60	6	500	Sand Bag
1	115	1	T-10 Cargo	7	60	5	500	Sand Bag
1	115	1	LCLA	6	60	7	500	Sand Bag
1	115	1	LCLA	8	60	4	500	Sand Bag
1	560	1	15-Ft Ring Slot	4	60	1	2000	Rubber & Wood
1	0	N/A	N/A	2	N/A	N/A	N/A	N/A
2	115	1	T-10 Cargo	1	70	2	500	Sand Bag
2	115	1	LCLA	8	70	3	500	Sand Bag
2	115	1	LCLA	3	70	6	500	Sand Bag
2	115	1	T-10 Cargo	4	70	4	500	Sand Bag
2	115	1	LCLA	6	70	5	500	Sand Bag
2	115	N/A	N/A	2	70	N/A	N/A	Sand Bag
2	580	1	N/A	5	70	1	500	Rubber & Wood
2	0	N/A	N/A	7	N/A	N/A	N/A	N/A

KIAS = Knots indicated air speed

Lift	Weight (lb)	Number of Parachutes	Type of Parachute	Frame Position	Air Speed (KIAS)	Payload Release Pass	Altitude (ft AGL)	Payload Material
28 June 2012								
1	115	1	LCLA	1	70	1	500	Sand Bag
1	115	1	T-10 Cargo	2	70	1	500	Sand Bag
1	115	1	LCLA	3	70	3	500	Sand Bag
1	115	1	LCLA	4	70	3	500	Sand Bag
1	115	1	LCLA	5	70	4	500	Sand Bag
1	115	1	LCLA	6	70	4	500	Sand Bag
1	115	1	LCLA	7	70	2	500	Sand Bag
1	115	1	LCLA	8	70	2	500	Sand Bag
2	115	1	LCLA	1	70	1	500	Sand Bag
2	115	1	LCLA	2	70	1	500	Sand Bag
2	115	1	LCLA	3	70	3	600	Sand Bag
2	115	1	LCLA	4	70	N/A	N/A	Sand Bag
2	115	1	LCLA	5	70	N/A	N/A	Sand Bag
2	115	1	LCLA	6	70	N/A	N/A	Sand Bag
2	115	1	LCLA	7	70	2	500	Sand Bag
2	115	1	LCLA	8	70	2	500	Sand Bag
11 July 2012								
1	115	1	LCLA	1	70	1	400	Sand Bag
1	115	1	LCLA	2	70	1	400	Sand Bag
1	215	1	T-10 Cargo	3	70	2	400	Sand Bag
1	115	1	LCLA	4	70	2	400	Sand Bag
1	115	1	LCLA	5	70	2	400	Sand Bag
1	215	1	T-10 Cargo	6	70	2	400	Sand Bag
1	115	1	LCLA	7	70	1	400	Sand Bag
1	115	1	LCLA	8	70	1	400	Sand Bag
2	115	1	LCLA	1	70	1	400	Sand Bag
2	115	1	LCLA	2	70	1	400	Sand Bag
2	115	1	LCLA	3	70	X	400	Sand Bag
2	115	1	LCLA	4	70	X	400	Sand Bag
2	115	1	LCLA	5	70	X	400	Sand Bag
2	115	1	LCLA	6	70	X	400	Sand Bag
2	115	1	LCLA	7	70	X	400	Sand Bag
2	115	1	LCLA	8	70	X	400	Sand Bag
25 July 2012								
1	690	1	N/A	4	70	1	500	Water Packets
1	215	1	LCLA	1	70	2	400	Sand Bag
1	215	1	LCLA	2	70	2	400	Sand Bag
1	215	1	T-10 Cargo	7	70	2	400	Sand Bag
1	215	1	LCLA	8	70	2	400	Sand Bag
1	0	N/A	N/A	3	N/A	N/A	N/A	N/A
1	0	N/A	N/A	5	N/A	N/A	N/A	N/A
1	0	N/A	N/A	6	N/A	N/A	N/A	N/A
2	720	1	15-Ft Ring Slot	4	70	X	500	Water Packets
2	215	1	LCLA	1	70	X	400	Sand Bag
2	215	1	T-10 Cargo	2	70	X	400	Sand Bag
2	215	1	LCLA	7	70	X	400	Sand Bag
2	215	1	LCLA	8	70	X	400	Sand Bag
2	0	N/A	N/A	3	N/A	N/A	N/A	N/A
2	0	N/A	N/A	5	N/A	N/A	N/A	N/A
2	0	N/A	N/A	6	N/A	N/A	N/A	N/A

Appendix E
HSL RADE Sling Load Inspection Form
(Reprint of Original)

HSL RADE SLING LOAD INSPECTION RECORD			
THIS RECORD IS TO BE USED FOR HSL RADE SLING LOADS ONLY AND SUPPLEMENT DD FORM 7382-R			
1. SUPPORTED UNIT	2. SYSTEM USED	3. TOTAL SYSTEM WEIGHT	
4. SUPPORTING AVIATION UNIT	5. TYPE OF AIRCRAFT	6.RIGGED IAW	

INITIAL ONLY ITEMS APPLICABLE TO YOUR SPECIFIC LOAD	PAYLOADS INSPECTED BY	SYSTEM RIGGED BY	SYSTEM INSPECTED BY
13. LOAD			
A. PAYLOADS ARE RIGGED IAW FM 4-20.103			
B. LCLA/A-7A/A-22 STRAPS ARE PROPERLY BUCKLED, TIGHT AND SECURED			
C. PARACHUTE IS ATTACHED TO THE PAYLOAD			
D. PARACHUTE IS PACKED IN BREAK-A-WAY CONFIGURATION			
E. PARACHUTE IS SECURED PROPERLY			
F. SUPPLEMENTAL SUSPENSION SLINGS ATTACHED TO THE PAYLOAD			
14. FRAME			
A. SUPPLEMENTAL SUSPENSION SLINGS ARE SECURED TO WGRM			
B. SUPPLEMENTAL SLINGS ARE CLEAR OF THE TRANSPORTATION TIE			
C. STATIC LINE IS ATTACHED TO THE FRAME IN BREAK-A-WAY CONFIG			
D. STATIC LINE IS SECURED TO ONE SUSPENSION SLING			
15. MASTER CONTROL STATION			
A. ALL WGRM ARE PROGRAMED INTO THE MCS			
B. WGRM HAVE BEEN TURNED ON			
C. WGRM HAVE BEEN RESET			
REMARKS:			

16. PAYLOAD INSPECTED BY:			
UNIT (PRINT)	NAME (PRINT)	INITIALS	RANK
SIGNITURE		DATE	
17. SYSTEM RIGGED BY:			
UNIT (PRINT)	NAME (PRINT)	INITIALS	RANK
SIGNITURE		DATE	
18. SYSTEM INSPECTED BY:			
UNIT (PRINT)	NAME (PRINT)	INITIALS	RANK
SIGNITURE		DATE	

HSL RADE SLING LOAD INSPECTION RECORD (10 OCTOBER 2012)

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Appendix F
Weights and Locations of Payloads for Each Flight

Full HSL RADE

All

100	100	100	100
200	200	200	200
300	300	300	300
400	400	400	400
400	400	400	400
300	300	300	300
200	200	200	200
100	100	100	100

Empty

Front 8

100	100	100	100
200	200	200	200

Rear 8

200	200	200	200
100	100	100	100

Left Front

100	100		
200	200		
300	300		
400	400		

Right Rear

		400	400
		300	300
		200	200
		100	100

Left

100	100		
200	200		
300	300		
400	400		
400	400		
300	300		
200	200		
100	100		

Half HSL RADE

All

100	100	100	100
200	200	200	200
200	200	200	200
100	100	100	100

Empty

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List of Acronyms

AGL – Above Ground Level
AGU – Airborne Guidance Unit
APG – Aberdeen Proving Grounds
ATC – Aberdeen Test Center
AFTD – Aviation Flight Test Directorate
CAD – Computer Aided Design
CARP – Calculated Air Release Point
CDS – Container Delivery System
CG – Center of Gravity
CH – Cargo Helicopter
CRADA – Cooperative Research and Development Agreement
CVR – Center Vertical Restraint
DDSP – Defense Depot Susquehanna Pennsylvania
DZ – Drop Zone
EMC – Electro-Magnetic Compatibility
FEA – Finite Element Analysis
FM – Field Manual
ft - Feet
GPS – Global Positioning Satellite
GUI – Graphical User Interface
HALO – High Altitude Low Opening
HMMWV – High Mobility Multipurpose Wheeled Vehicle
HSL – Helicopter Sling Load
HSL JPADS – Helicopter Sling Load of Joint Precision Aerial Delivery Systems
HSL RADE – Helicopter Sling Load, Rapid Aerial Delivery Equipment
JPADS – Joint Precision Aerial Delivery System
KIAS – Knots Indicated Air Speed
lb - Pounds
LCLA – Low Cost, Low Altitude
LLC – Limited Liability Company
LZ – Landing Zone
MCS – Mater Control Station
MIL - Military
MLW – Micro Light Weight
MRE – Meal Ready to Eat
MSFDCS – Multi-Service Flight Data Collection Sheets
MSL – Mean Sea Level
NSRDEC – Natick Soldier Research Development and Engineering Center
P/N – Part Number
psi – Pounds per square inch
SOMTE – Soldier Operator/ Maintainer, Test and Evaluation
STD – Standard
TDP – Technical Drawing Package
UAS – Unmanned Aerial Vehicle

UH – Utility Helicopter
ULW – Ultra Light Weight
USTRANSCOM – United States Transportation Command
VTOL – Vertical Take-Off and Landing
WGRM – Wireless Gate Release Mechanism
WGRS – Wireless Gate Release System
YPG – Yuma Proving Ground