Habitat Demonstration Unit-Deep Space Habitat (HDU-DSH) Integration and Preparation for Desert RATS 2011

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The Habitat Demonstration Unit, or HDU, is a multi-purpose test bed that allows NASA scientists and engineers to design, develop, and test new living quarters, laboratories, and workspaces for the next generation space mission. Previous testing and integration has occurred during 2010 at the annual Desert Research and Technology Studies (Desert RATS) field testing campaign in the Arizona desert. There the HDU team tests the configuration developed for the fiscal year, or FY configuration. For FY2011, the NASA mission calls for simulating a deep space condition. The HDU-DSH, or Deep Space Habitat, will be configured with new systems and modules that will outfit the test bed with new deep space capabilities. One such addition is the new X-HAB (eXploration Habitat) Inflatable Loft. With any deep space mission there is the need for safe, suitable living quarters. The current HDU configuration does not allow for any living space at all. In fact, Desert RATS 2010 saw the crew sleeping in the Space Exploration Vehicles (SEV) instead of the HDU. The X-HAB Challenge pitted three universities against each other: Oklahoma State University, University of Maryland, and the University of Wisconsin. The winning team will have their design implemented by NASA for field testing at DRATS 2011. This paper will highlight the primary objective of getting the X-HAB field ready which involves the implementation of an elevator/handrail system along with smaller logistical and integration tasks associated with getting the HDU-DSH ready for shipment to DRATS.

Nomenclature

NASA	=	National Aeronautics and Space Administration
JSC	=	Johnson Space Center
LaRC	=	Langley Research Center
HDU	=	Habitat Demonstration Unit
HDU-DSH	=	Habitat Demonstration Unit-Deep Space Habitat
Desert RATS	=	Desert Research and Technology Studies
X-HAB	=	eXploration Habitat
HDU-PEM	=	Habitat Demonstration Unit-Pressurized Excursion Module
FY	=	Fiscal Year
LAT	=	Lunar Architecture Team
SEV	=	Space Exploration Vehicle
EVA	=	Extra Vehicular Activity
X-HAB IL	=	X-HAB Inflatable Loft
STEM	=	Science Technology Engineering Mathematics
MOWS	=	Medical Operations Work Station
RFP	=	Request for Proposal
HDU-Lite	=	Easily transportable, inexpensive mockup of HDU
HVAC	=	Heating, Ventilation, and Air Conditioning
Pro-E	=	Pro-Engineer Wildfire 4.0 Computer Aided Design software
WSN	=	Wireless Sensor Node
PDU	=	Power Distribution Unit
BPLF	=	Black Point Lava Flow
LEO	=	Low Earth Orbit
USRP	=	Undergraduate Student Research Program

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I. Introduction

The Habitat Demonstration Unit (HDU) was designed and built beginning in the spring of 2009. The mission called for a rapid prototype build process that would enable NASA engineers and scientists to field test and develop livable and workable habitat modules for deep space analog scenarios. The first design iteration was designated as the HDU-PEM (Pressurized Excursion Module) which consisted of the HDU hard shell lab built by LaRC, and the removable airlock (see Fig. 1). The HDU-PEM module was initially envisioned to be a part of NASA's Lunar Architecture Team (LAT) scenario as LAT 12.1 (see Fig. 2). The HDU-PEM configuration was successfully tested at Desert RATS 2010. However, one of the lessons learned from Desert RATS was the need for a more self sustaining habitat to comply with the deep space scenarios the project wished to evaluate. The crew slept in the Space Exploration Vehicles (SEV) as there were no crew quarters inside the HDU-PEM. Additionally, hygiene facilities were absent. The lack of these accommodations was a factor in the direction of the FY11 configuration. The HDU-DSH (Deep Space Habitat) additions included the X-HAB (eXploration Habitat) inflatable loft, the hygiene module, and the deployable EVA porch attached to the airlock (see Fig. 3, 4).

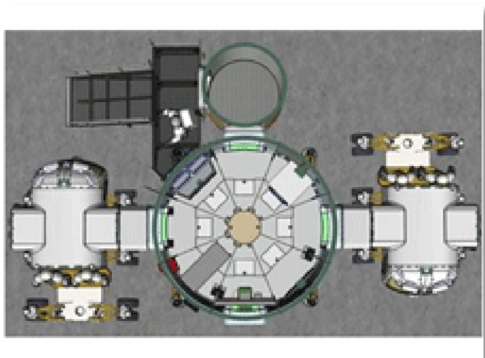

Figure 1. HDU-PEM Configuration

Figure 2. Lunar Architecture Team 12.1 scenario

Figure 3. HDU-DSH Configuration with X-HAB IL, and Hygiene module

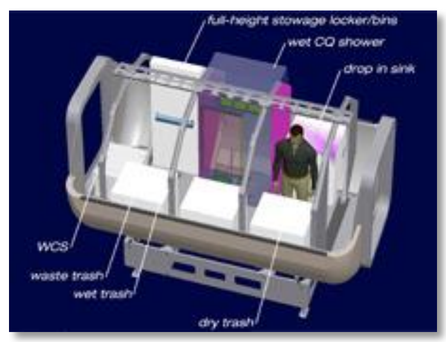

Figure 4. Hygiene Module

II. X-HAB Academic Challenge

One of NASA's most important tasks as an agency is to inspire the youth of the United States to pursue careers in the Science, Technology, Engineering, and Mathematics (STEM) fields. The HDU project has taken a very proactive approach in an effort to accomplish this goal. Many of the subsystems have been designed and built by students and universities across the country. The most significant contributions to date are the following: The University of Michigan's Material Handling System inside the core module, the Medical Operations Workstation (MOWS) designed and built by Rensselaer Polytechnic Institute and Rhode Island School of Design, and the X-HAB IL which will be explained in detail below.

A. X-HAB Challenge 2011

For FY2011 the HDU team ambitiously put out their largest academic RFP yet. The X-HAB Academic Challenge would involve universities across the country competing for the chance to design and build hardware for NASA that was going to be implemented and field tested. The challenge is intended as a senior/graduate level design course. The competition was sponsored by the National Space Grant Foundation. Space Grant allocated $48,000 in initial funding if selected and another $10,000 to the winner to offset costs associated with travel and participation in Desert RATS. The RFP called for an innovative, low-cost inflatable loft that could be easily stowed, transported, and deployed in the field. Specifically the HDU team required the loft to: house four crew members, have a volume of 60 cubic meters, weigh no more than 500kg, have integrated power and cooling, and provide an interior that is human rated (meeting and workspaces). Three finalists were selected to compete in the inaugural competition: Oklahoma State University, University of Wisconsin, and the University of Maryland. The competition took place at JSC during June 2011. University of Wisconsin was selected as the winner of X-HAB 2011. See Fig. 5, 6, and 7 for each team's design as seen atop the HDU.

Figure 5. Oklahoma State University's Inflatable Loft deployed atop the HDU.

Figure 6. University of Maryland's Inflatable Loft deployed atop the HDU.

Figure 7. University of Wisconsin's Inflatable Loft in the phases of deployment/stow atop the HDU.

B. X-HAB Challenge 2012

Building on the success of X-HAB 2011, the HDU management team, along with the National Space Grant Foundation, expanded the X-HAB Academic Challenge to four universities. The approach for the 2012 challenge differs slightly in that it is no longer a competition between teams. The challenge still revolves around the universities collaborating with NASA scientists and engineers to design and build systems that will not only be part of the HDU-DSH project, but will also continue to grow and inspire the STEM workforce. X-HAB 2012 will also allow participating universities to pick their project from a large list that includes: HDU-Lite, EVA Systems, Instrumentation, Science Systems, Food Production, Medical Operations, and Crew Accommodations. NASA has selected Oklahoma State University, University of Maryland, College Park, Ohio State University, and University of Bridgeport, Connecticut for the 2012 challenge.

III. X-HAB 2011 Integration

For FY2011 and Desert RATS 2011, the HDU-DSH will have many new capabilities and features. The summer months leading up to Desert RATS are the preferred dry run testing windows for installing and tuning these systems. Notable features that were added and integrated during the summer 2011 were: X-HAB IL, Hygiene Module, man-lift/elevator, upgraded software and avionics, food production, instrumentation and sensors, and ruggedized HVAC. The integration of the man-lift/elevator was the main focus of this project. However, work was performed on additional subsystems that include: avionics, instrumentation, and logistics.

A. Elevator/Man-lift

With the addition of the X-HAB IL, the need for a safe ingress/egress is required. Previously, to access the roof of the HDU-DSH (now second story) a ladder was used. But, with the X-HAB IL adding crew accommodations and workspaces, a ladder was deemed unsafe and non-functional. So, an elevator/man-lift system was designed to not only transport the crew to the second story, but also supplies and equipment that would be too tiresome to lift manually.

The elevator/man-lift is designed using two types of winches, both powered and unpowered. This ensures adequate safety and redundancy allowing operation without power. The lift consists of a work platform between two structural I-beams that is able to traverse up and down through a system of cables and pulleys that run inside each beam. The operator has access to control panels throughout the HDU-DSH. In addition to controls located on the work platform itself, a panel exists on the floor level to provide added capability when lifting equipment to and from the first and second floors. The lift is designed to support 250 lbs and moves at a pace no greater than eight feet per minute. See the figures below for the winch setup and an early prototype in action.

Figure 8. Elevator/Man-lift winch system

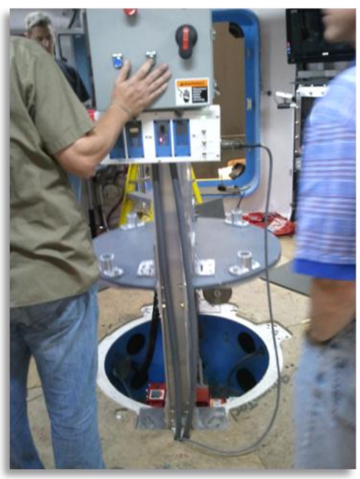

Figure 9. Elevator/Man-lift

B. Elevator/Man-lift Handrail System – Work Platform

A major design focus for this project was the addition of a handrail system for the elevator/man-lift. Two sets, the core module and X-HAB handrails are designed to a 250 pound sustained load. The railing is made out of 0.4 inch thick aluminum piping. The design called for three different sets of handrails. Each set is nearly identical, but at different locations. The primary is the work platform where the operator would be stationed which includes two separate rails located at 21 inches and 42 inches from the work platform. A latching gate is also made out of the same piping, bent to create the gate shape. The X-HAB hatch can be seen atop the vertical supports. This moves up and down along with the platform, acting as a seal when the lift is stationary on the core module floor. See fig. 10 and 11 for the work platform handrail design in Pro-E.

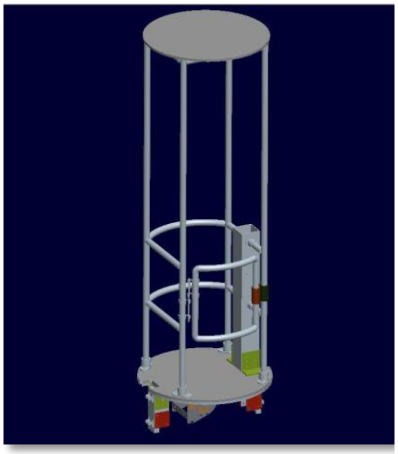

Figure 10. Work platform handrail – with X-HAB hatch

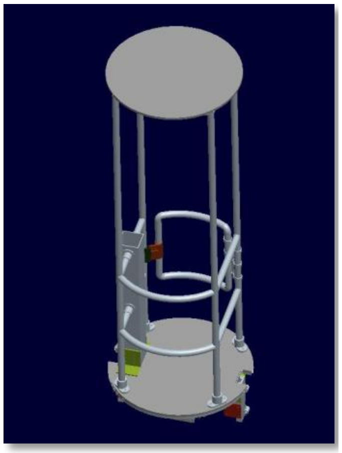

Figure 11. Work platform handrail – with X-HAB hatch

C. Elevator/Man-lift Handrail System – Core Module

When the lift is in operation, requirements dictate that there must be precautions in place to prevent injury due to the gap in the floor space. The proposed solution is another set of guardrails/handrails to prevent tripping/falling. Designated as the core module guardrails, they are designed to support a 250 pound sustained load. In order to meet the load requirement, vertical support braces were added.

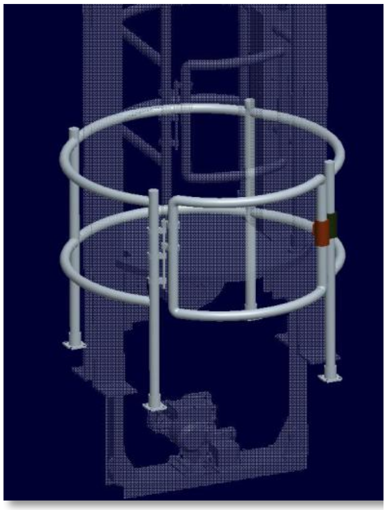

Figure 12. Core module handrail – with winch assembly

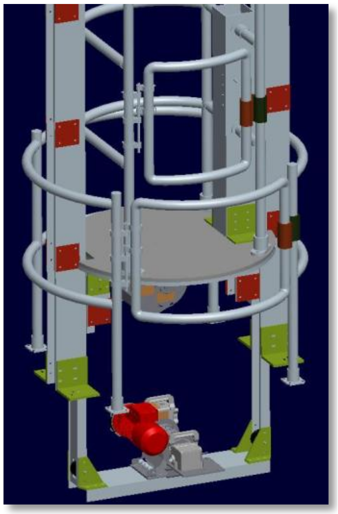

Figure 13. Core module handrail – with winch assembly

D. Elevator/Man-lift Handrail System – X-HAB

The final guardrail/handrail assembly sits atop the HDU floor inside the X-HAB IL. It serves the same purpose as the core module railing, to prevent injury and the falling hazard that is present when the lift is in operation. There is another 250 pound load requirement that must be met as well. The same vertical support structure is used to meet the load requirement. The figures below illustrate the final handrail assembly and the installed work platform. Unfortunately, at the time of this paper, installation was not finished due to integrated testing that prevented technicians from accessing the core module and X-HAB.

Figure 14. X-HAB handrail – without assembly

Figure 15. X-HAB handrail – with entire assembly

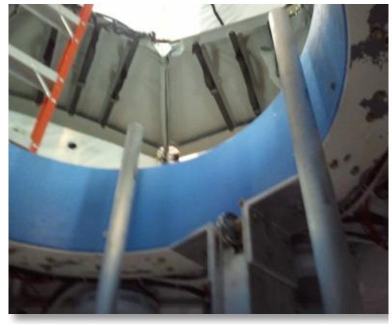

Figure 16. Work Platform Vertical Support

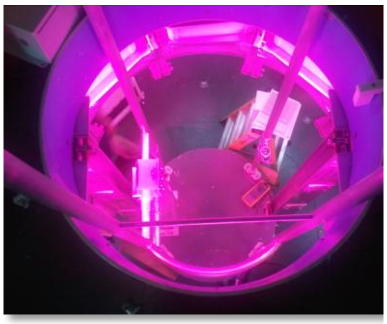

Figure 17. Work Platform view from X-HAB IL – NOTE: Food Production light source on

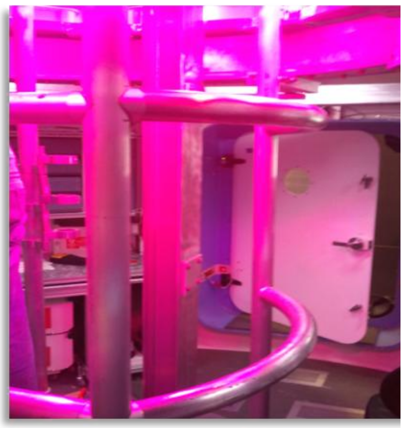

Figure 18. Work Platform Handrail installed – NOTE: Food Production light source on

E. Instrumentation, Avionics and Logistics

In addition to design work on the man-lift handrail system, time was spent working on the fabrication and installation of instrumentation panels along with avionics wiring and the logistics associated with readying HDU-DSH assets for Desert RATS. As with any human rated environment at NASA, instrumentation must be present to ensure the safety of the occupants. With the addition of the X-HAB IL, the life support instrumentation needed to be implemented. There are a collection of sensors that include: oxygen, carbon dioxide, carbon monoxide, humidity, and finally WSNs that read and collect the sensor data. The instrumentation panels are mounted throughout the HDU-DSH and the X-HAB IL, see fig. 19 below.

Figure 19. X-HAB Instrumentation Panel

The avionics package is a complex system of network racks, switches, and PDUs that all require a thorough check out prior to shipment to Desert RATS. The FY2011 HDU-DSH configuration called for the addition of new subsystems, which in turn requires a re-work of the current avionics package. Work was performed on the wiring and installation of new PDUs and network racks. See fig. 20 and 21 below.

Figure 20. HDU-DSH Avionics Bay

Figure 21. HDU-DSH Avionics Bay

Logistically speaking, the HDU-DSH comes with heavy baggage. Assets must be prepped well in advance and meet stringent shipping requirements, most notably the HDU-DSH itself. On its way to BPLF in Arizona, the HDU-DSH is designated as a super-wide load. In turn, the HDU-DSH is restricted to traveling on specific roads at specific times. The trip will take upwards of a week as a super-wide load. In reality, a normal truck can make the trip in 48 hours. To ensure that support equipment arrives on time, a large forty foot shipping container was used to pack assets. A manifest was created along with specific layouts that will allow each subsystem team to organize and pack their support gear. This will encourage a more organized environment when out in the field. See below for the suggested shipping container layout.

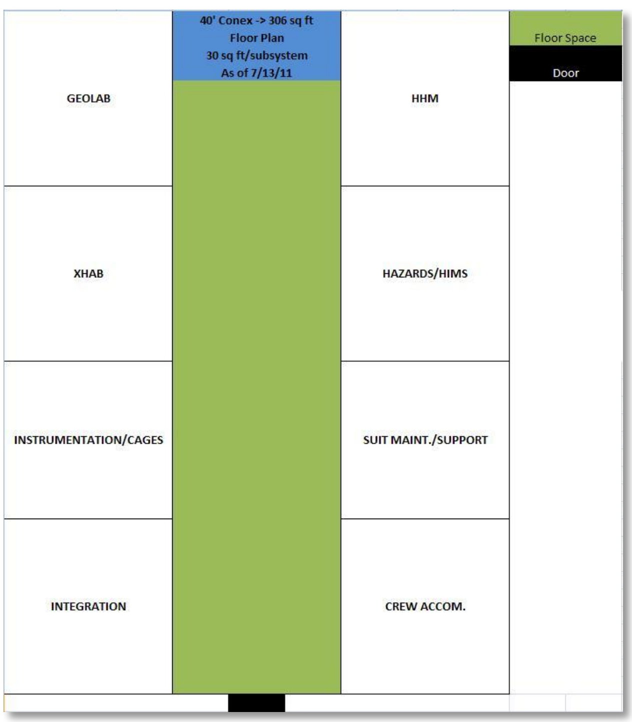

Figure 22. HDU-DSH Shipping Container Layout

	A	B	C	D	E	F	G	H
1	Checklist	Subsystem	Container Type	Cont. #	Description	Item Qty	NASA Tag	Fragile
2								
3		HAZARDS CASE:	None	n/a	Plastic Hazardous Material Container	1	None	No
4		Support:	Plastic Container	n/a	Cutter Advanced Sport Insect Repellant (6 oz)	2	None	No
5		Support:	Plastic Container	n/a	Cutter Backyard Bug Control Outdoor Fogger (16 oz)	3	None	No
6		Instrumentation:	Plastic Container	n/a	Blow Off Freeze Spray (10 oz)	2	None	No
7		Instrumentation:	Plastic Container	n/a	CRC Duster (8oz)	3	None	No
8		Instrumentation:	Plastic Container	n/a	American Recorder CO2 Dust Remover (12 grams ea.)	5	None	No
9		Support:	Plastic Container	n/a	Rust-Oleum Ultracover Semigloss White 2x (12 oz)	4	None	No
10		Support:	Plastic Container	n/a	Krylon Fusion for Plastics (12 oz)	3	None	No
11		Support:	Plastic Container	n/a	Great Stuff Insulating Foam Sealant (12 oz)	1	None	No
12		Support:	Plastic Container	n/a	Great Stuff Big Gap Filler Insulating Foam Sealant (12 o	1	None	No
13		Support:	Plastic Container	n/a	Smoke-in-a-Can (10 oz)	1	None	No
14		HIMS:	Plastic Container	n/a	Crosman CO2 Cartridges (12 grams ea.)	4	None	No
15		Support:	Plastic Cylinder	n/a	Lysol Disinfecting Wipes	1	None	No
16		ECLSS:	Cardboard Box	n/a	Fire Extinguisher	2	None	No
17								
18								
20								
21		GEOLAB:	Zero Case	1	Leica Stereomicroscope	1	None	YES
22				1	HD camera	1	2569020 (Camera)	YES
23			Zero Case	2	Mass Balances	2	None	YES
24			Zero Case	3	Axis 211M Network Cameras	2	2283318 & 2283319	YES
25			Zero Case	4	Network Switch	1	None	YES
26				4	Spare Cables	1	None	YES
27			Zero Case	5	Lab Jack Stands	2	None	No
28				5	Petri dishes	4	None	No
29			Zero Case	6	Rock Trimmers	2	None	No
30			Zero Case	7	Glovebox Stainless Steel Tools	1	None	No
31			Zero Case	8	Teflon Rapid Transfer Port (RTP) Container	1	None	YES
32			Zero Case	9	Microscope Fiber Optic Lighting	1	None	YES
33			Cardboard Shipping Box	10	HP1 Touchsmart Computer	1	2283352	YES
34			Cardboard Shipping Box	11	HP2 Touchsmart Computer	1	2283353	YES
35			Cardboard Shipping Box	12	Axis 214 PTZ Network Camera	1	2283306 (camera)	YES
36				12	Glovebox Radiation Box	1	None	YES
37			Cardboard Shipping Box	13	Axis 215 PTZ-E Network Camera	1	2283317 (camera)	YES
38			Vortex Hard Black Case	14	XRF Spectrometer	1	2283613	YES
39			Cardboard Shipping Box	15	GeoLab Spare Parts	1	None	No
40			Cardboard Shipping Box	16	IPA Wipes	1	None	No
41			Zero Case	17	GeoLab Schematics & Manuals	1	None	No
42			Zero Case	18	Rock Box 1	1	None	No
43			Zero Case	19	Rock Box 2	1	None	No
44			Zero Case	20	Rock Box 3	1	None	No
45			Contico Black Hard Case	21	Rock Box 4	1	None	No
46				21	Rock Tools	1	None	No
47			No Box (need one)	22	Dell Dimension 9100 CPU	1	2282664	YES

Figure 23. HDU-DSH Shipping Manifest

IV. Conclusion

HDU-DSH field testing will take place at Desert RATS in Arizona at the Black Point Lava Flow site where NASA will not only be testing the HDU-DSH, but also a wide range of other future technologies such as the Space Exploration Vehicles, advanced communication and data uplinks, and the Centaur robotic vehicle assistant. Desert RATS provides a unique opportunity to test these technologies in an effort to prepare for future exploration like a near-Earth asteroid. The HDU-DSH is an integral part of NASA's efforts to go beyond LEO and open the future of human space exploration. Without this type of testing, manned missions beyond LEO would not be possible. The sense of pride and accomplishment that comes with being a part of this project is hard to match.

In addition to contributions made to the future of space exploration, time spent on this project has provided the Author with invaluable skills that have greatly benefited his professional development as an engineer. Hands on experiences are hard to come by in college, let alone experience at NASA. Moving forward, this internship has provided the Author with the necessary motivation to continue on the path to becoming a future spaceflight and space exploration innovator at the National Aeronautics and Space Administration.

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