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NASA Habitat Demonstration Unit Project – Deep Space Habitat Overview

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Abstract

This paper gives an overview of the National Aeronautics and Space Administration (NASA) led multi-center Habitat Demonstration Unit (HDU) project development of a Deep Space Habitat (DSH) configuration that will be analog field-tested during the 2011 Desert Research and Technologies Studies (D-RATS) field tests. The HDU project is a "technology and innovation pull" rapid prototyping project that integrates technologies and innovations from multiple NASA centers. This project will repurpose the HDU Pressurized Excursion Module (PEM) that was field tested in the 2010 D-RATS by adding habitation functionality to the existing operational prototype unit. The 2011 HDU-DSH configuration will build upon the 2010 HDU effort with added emphasis of crew operations (habitation and living, etc), Extravehicular Activities (EVA) operations, mission operations, logistics operations, and science operations that will be required in a deep space mission to a Near Earth Asteroid (NEA). The HDU project consists of a multi-center team assembled together in a rapid prototyping tiger-team approach to quickly build, test, and validate hardware and operations in analog testing environments. The 2011 analog field test will include Multi Mission Space Exploration Vehicles (MMSEV) and the DSH among other demonstration elements to be brought together in a mission architecture context. This paper will describe an overview of the overall objectives, habitat configuration, strategic plan, and technology integration as it pertains to the 2011 field tests. This paper is intended to provide a context for the HDU project rapid-prototyping efforts rather than a detailed description of a DSH design or architecture.

I. Introduction

A useful exploration architecture and mission operations validation assessment mechanism being utilized by NASA is analog integrated testing of selected human exploration missions. The human exploration design reference missions (DRM) defined by NASA's Human Exploration Framework Team (HEFT) and the Human Spaceflight (HSF) architecture team (HSF-AT) has identified a deep space habitat as a critical element within the capability driven framework (fig. 1) strategy[1]. Simulating mission scenarios with rapid prototype hardware and systems enables engineers, architects, and scientists insight into the utilization and characterization of the proposed systems. The analog simulation testing refines mission architectures and operations concepts during the early definition phase. A series of D-RaTS campaigns have been held in remote locations such as Moses Lake, Washington and Black Point Lava Flow (BPLF), Arizona. The most recent 14-day test in September 2010 was performed with two MMSEVs, the HDU-PEM, and support systems such as communications, power generation, and mission operations. The 2010 D-RaTS configuration of the HDU-PEM represented a surface laboratory module that was used to bring over 20 habitation-related technologies and innovations together in an operational demonstration unit (fig. 2). The 2011 D-RaTS campaign is planned for BPLF where two MMSEVs will operate together with a full scale DSH prototype. A graphic example of the proposed DSH NEA mission under evaluation at the Desert-RaTS 2010 campaign is pictured below in Fig. 3 and Fig. 4. The DSH configuration represented by the 2011 HDU Project is depicted in Fig. 4. This DSH concept version shows a second level inflatable volume for additional habitation and stowage functions.

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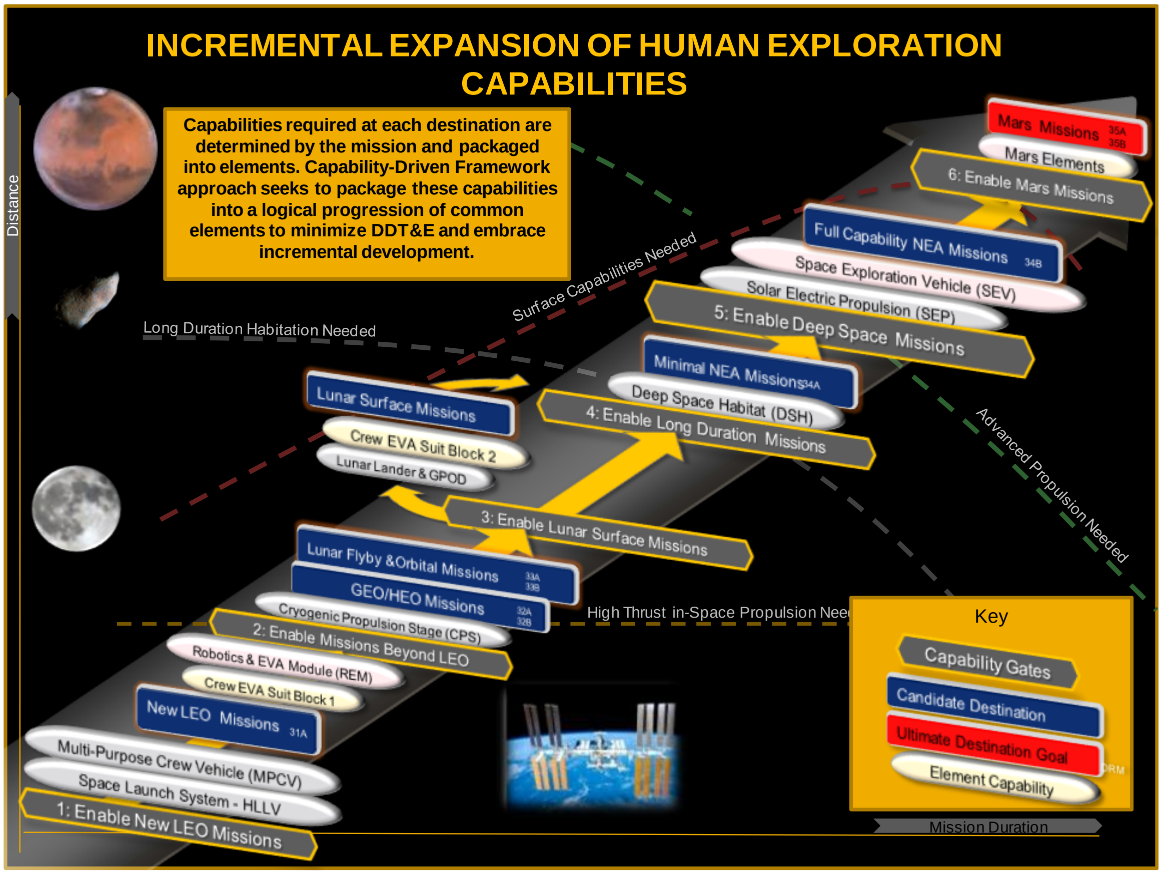

Figure 1. Human Spaceflight Architecture Team Capability Driven Framework

Figure 2. 2010 HDU-PEM at Desert-RaTS

Figure 3. Illustration of Near Earth Asteroid Mission

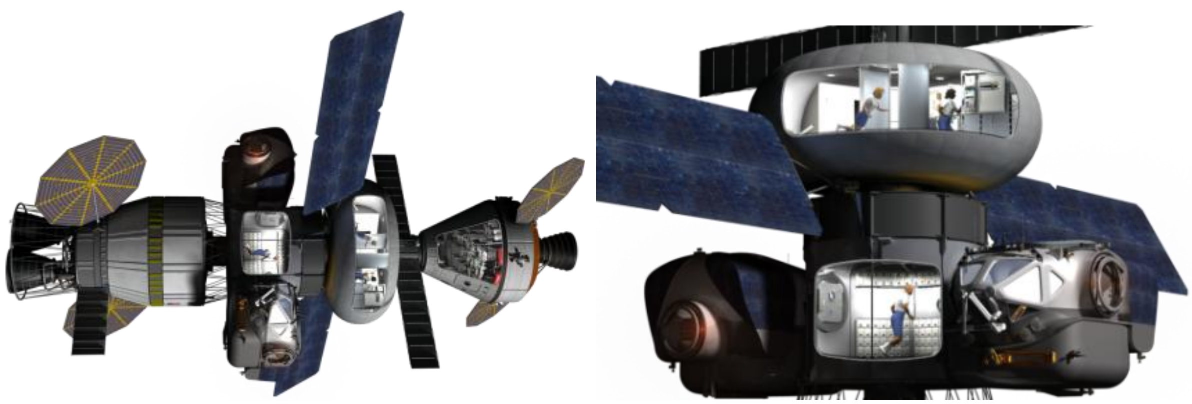

Figure 4. Near Earth Asteroid Deep Space Hab Concept

As part of the HDU Project objective, the team traces habitation test objectives from the mission architecture deep space habitat issues and concerns (Table 1). These architecture element level questions are used to guide prioritization of test objectives and assist in validating mission architecture scenarios and concept of operations. Field analog test objectives are defined within the NASA Analog team and the appropriate supporting element and system demonstrations developed. The 2011 HDU-DSH configuration will focus on several of these architecture questions (Table 1) identified by the check-mark.

Table 1. Deep Space Habitat Element, Mission Architecture Traceability Questions

Arch #	HDU-DSH	**Key Habitat Questions: Deep Space Hab (as defined by mission architecture scenarios)** *(not in priority order)*
DSH-1		EVA Operations: Will the capability of an integrated Airlock, Suitlock, or Suitport enable efficient EVAs for NEO exploration?
DSH-2	√	Autonomous Hab Operations: Will the capability of an autonomously-intelligent habitat management operating system enable efficient operations of a DSH saving mass and power, and increasing crew/mission safety and productivity?
DSH-3		Logistics, Maintenance and Spares Operations: Will the capability to in-situ

	√	manufacture of parts, perform remote repairs, and automated maintenance (such as self-healing or self repairing systems) enable efficient operations of a DSH saving mass and power, and increasing crew/mission safety and productivity?
DSH-4	√	Habitable Volume: Does the DSH provide sufficient long-duration mission functionality and habitable volume to enable efficient operations of increasing crew/mission safety, physiology, psychology, and productivity?
DSH-5	√	Crew Operations: Will the capability to provide more habitable volume using inflatable modules or appendages enable efficient operations of a DSH saving mass, launch volume, and increasing crew/mission productivity?
DSH-6	√	Mission Operations: Will the capability of providing tele-robotic workstation, EVA workstation, and maintenance workstation enable efficient operations of a long-duration mission DSH saving mass and power, and increasing crew/mission safety and productivity?
DSH-7	√	Medical Operations: Will the capability of providing a medical workstation enable efficient operations of a DSH increasing crew/mission safety and productivity?
DSH-8	√	GeoScience Operations: Will the capability to perform glovebox in-situ sample analysis enable efficient EVA and geological science operations for NEO exploration? Planetary Protection sample handling, procedures, practices, and operations.
DSH-9		Life Support Closure: Will the capability to “close” the life support system for a long-duration mission enable efficient operations of a DSH saving mass and power, and increasing crew/mission safety and productivity?
DSH-10	√	Sufficient Stowage Volume: Does the DSH provide sufficient stowage volume and accessibility to enable crew activity, MMSEV resupply, maintenance and housekeeping operations, and conduct overall mission operations for a long-duration mission?
DSH-11		Radiation Protection: Does the DSH provide sufficient long-duration mission radiation protection (SPE and GCR) to enable efficient operations of a DSH increasing crew/mission safety, physiology, psychology, and productivity?
DSH-12		Life Sciences Research: Does the DSH provide the capability for human and other biological life sciences research, inclusive of plant and animal research, necessary to understand the effect of the NEO environment on life processes and crew operations necessary to sustain plant food growth?
DSH-13		Light Weight Structures: Does the use of light weight composite structures (hard and flexible) provide sufficient pressure vessel protection in composite shell while being lighter weight than conventional ISS shell systems?
DSH-14	√	Power Management & Distribution: Does using smart grid and autonomous control technologies provide more efficient resource utilization and thus lower power operations?
DSH-15		Environmental Protection: Does using a “smart” skin multi-functional multi-layers self-healing pressure shell provide sufficient space environmental protection?

II. HDU Deep Space Habitat Configuration

The HDU-DSH configuration is based on the HEFT architecture NEO Mission concept. As shown in fig. 4, the HDU-DSH configuration layout functionally supports crew Intra-Vehicular Activity (IVA) Geology science, medical operations, IVA suit and general maintenance, tele-robotics operations, crew habitation, and logistics stowage. Based on the 2010 HDU pie-shaped sectional shell configuration, the HDU team modified the internal architecture into a DSH functional configuration, figure 5 and 6. From the tests and workstation evaluations last year it was determined that some workstations could operate in a dual-use mode. Therefore the general maintenance workstation and the EVA maintenance workstation have been combined for the DSH configuration. Likewise the Medical Ops workstation is now combined with the Life Sciences lab functions. The Geology Laboratory workstation area remained the same. A tele-robotics functionality and workstation was added to section-B. This is based on the DSH mission operations and functions to operate a robotic free flyer for an asteroid sample collection. Under the floor (as last year) are the core systems which include the power input and distribution, the computer system, wireless nodes, C-RIO, data lines, electric wiring, and air circulation for passive cooling. A heat pump will be used in the interim for environmental conditioning. A HDU-DSH CAD illustration from the systems modeling tool is illustrated in figures 6 and 7.

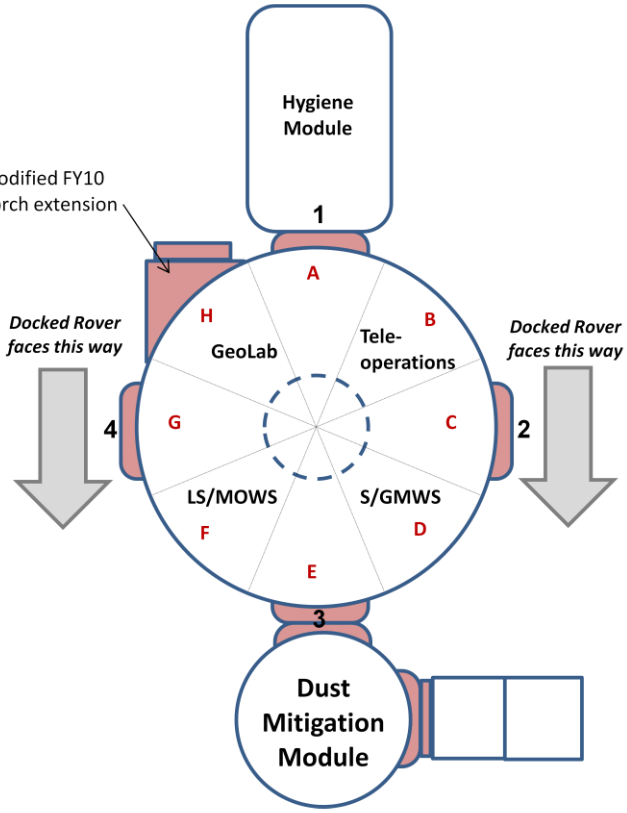

Figure 5. HDU-DSH Plan View

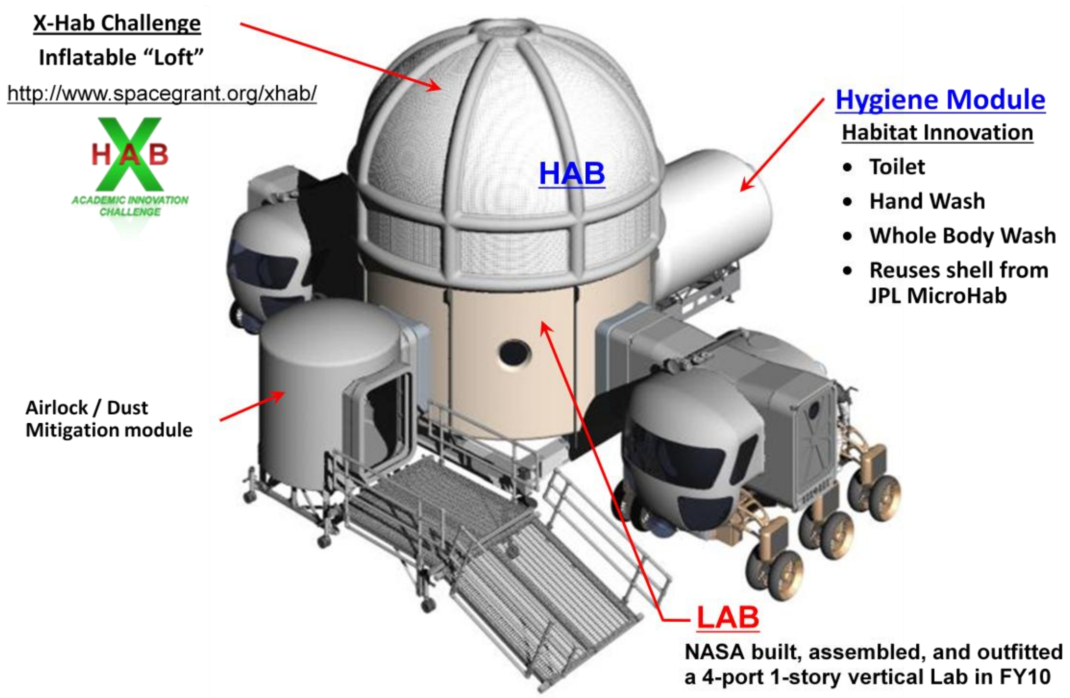

Figure 6. HDU-DSH External View

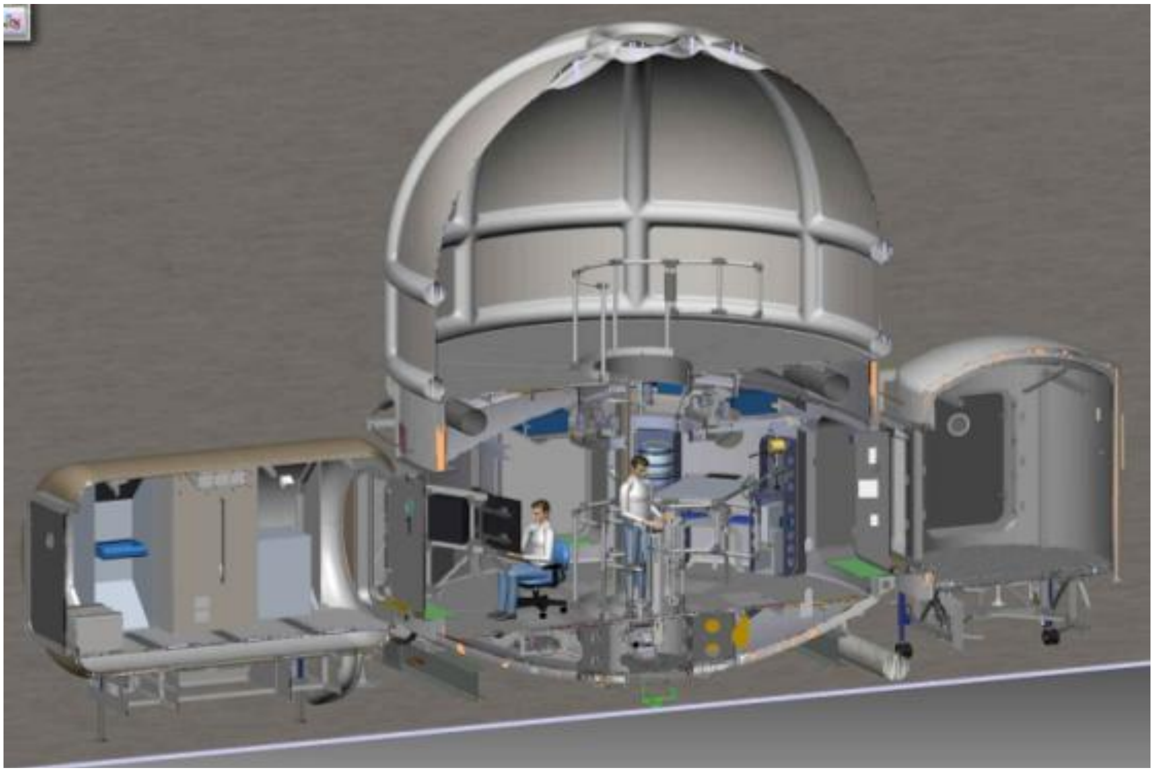

Figure 7. CAD Integration Cross-Section View of HDU-DSH

III. Advanced Habitat Systems Technology Roadmap

The Office of Chief Technologists (OCT) developed 14 strategic capabilities roadmaps (drafts) during 2010. These Space Technology Roadmaps (STR) are strategic roadmap technology investments that will enable sustained human exploration and support NASA's missions and goals for the next 25 years. Technology Area 07 (TA07) focused on Human Exploration Destination Systems (HEDS). HEDS technologies will enable a sustained human presence for exploring destinations such as remote sites on Earth and beyond including, but not limited to, LaGrange points, low Earth orbit (LEO), high Earth orbit (HEO), geosynchronous orbit (GEO), the Moon, near-Earth objects (NEOs)—which > 95% are asteroidal bodies—Phobos, Deimos, Mars, and beyond (fig.8).

The TA07 HEDS Technology Area Breakdown Structure (TABS) is divided into six Level-2 technology focus areas. Figure 9 illustrates the TABS divisions as: 7.1 In-Situ Resource Utilization; 7.2 Sustainability and Supportability; 7.3 Advanced Human Mobility Systems; 7.4 Advanced Habitat Systems; 7.5 Mission Operations and Safety; and 7.6 Cross-Cutting Systems. Within the TA07 technology roadmap is the 7.4 Advanced Habitat Systems capabilities and technology area. Technology Area Six (TA06) also has some habitation related technologies.

The Advanced Habitat Systems (AHS) technology roadmap strategic goals align with the agency's rapid prototyping strategy of low-cost early maturation of exploration deep space habitat systems. The technology roadmaps will develop habitat and related technologies that the HDU Project will infuse into the multi-generation maturation development efforts. These two efforts (roadmap & HDU) are closely coupled in development, integration, and testing. The "Vision" for AHS is to provide a light-weight, safe and reliable "intelligent" habitation system that has the capability of fully-integrated intelligent systems for autonomous operation, failure detection, analysis, and self-repair capabilities to support humans living and working in space and on other planetary bodies. This is analogous to a terrestrial home lasting 25 years with a low-carbon foot-print and net-Zero resource consumption with no maintenance and operations required while seamlessly providing comfortable and safe living capabilities. The AHS development strategy is to make exploration habitats development affordable by leveraging and collaborating with NASA centers, other agencies (US Army), academia, and industry. The goals of this multi-partnership approach are to develop exploration habitats through earth-based testing, to utilize flight demonstrations to increase confidence in exploration habitats, and to incorporate a "sustainability" approach in the design, manufacturing, and testing. These strategic goals are further decomposed into lower level objectives.

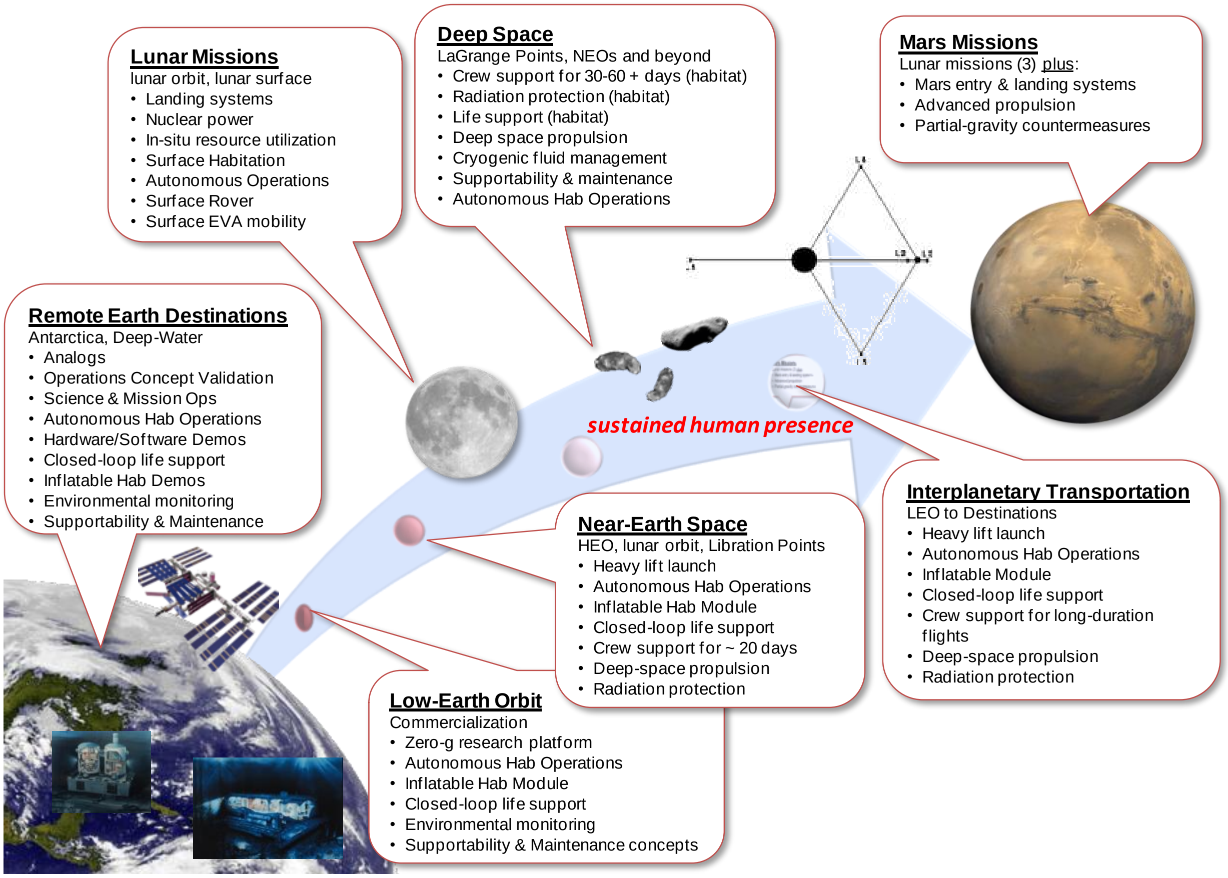

Figure 8. Human Exploration Destination Systems Enable Sustained Human Presence

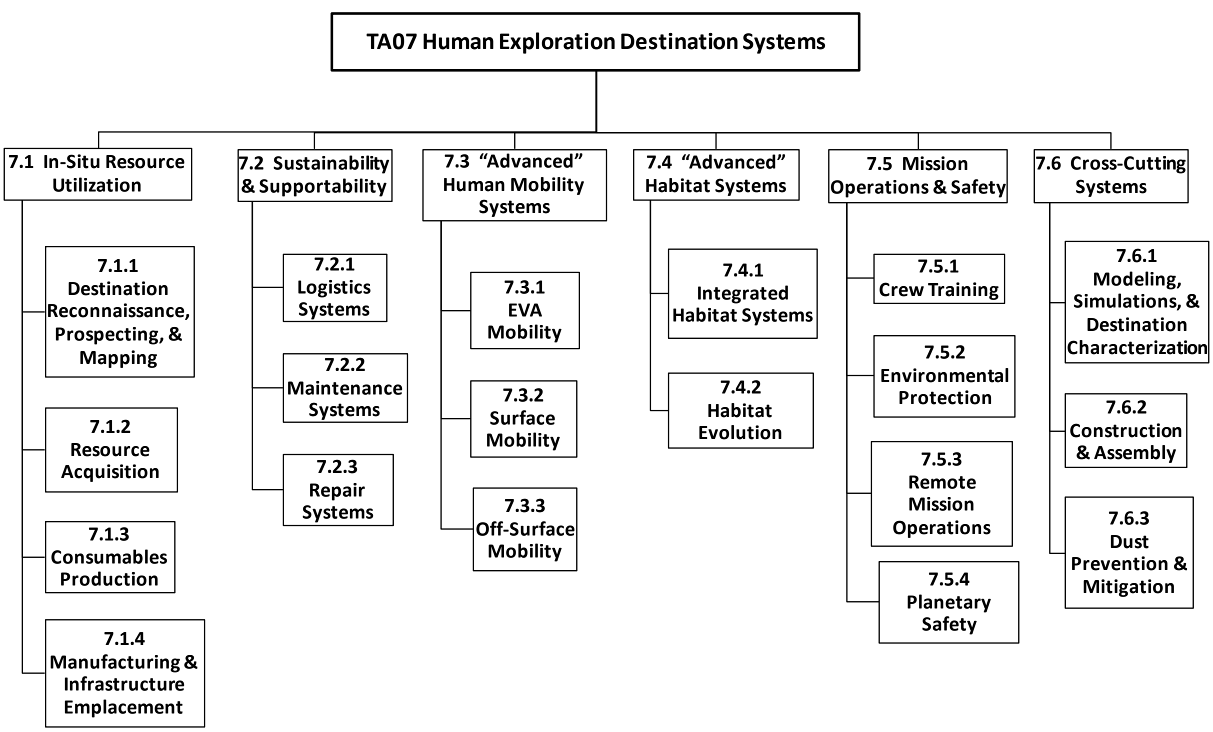

Figure 9. TA07 HEDS Technology Area Breakdown Structure

The HDU Project is collaborating with various technology projects such as Exploration Life Support, Integrated Systems Health Management, Autonomous Systems and Avionics, Dust Mitigation, Intelligent Software Design, Advanced Environmental Monitoring & Control, and Supportability Technologies to "pull" them into the HDU-DSH configuration for integrated testing. These technologies are first integrated into the habitat test-bed and with the Hab software architecture. A habitat technology strategic plan shows the interdependency (fig. 10) of exploration habitat technology development under TA07 for infusion and maturation by the HDU Project prior to final system design into a DSH protoflight demonstration.

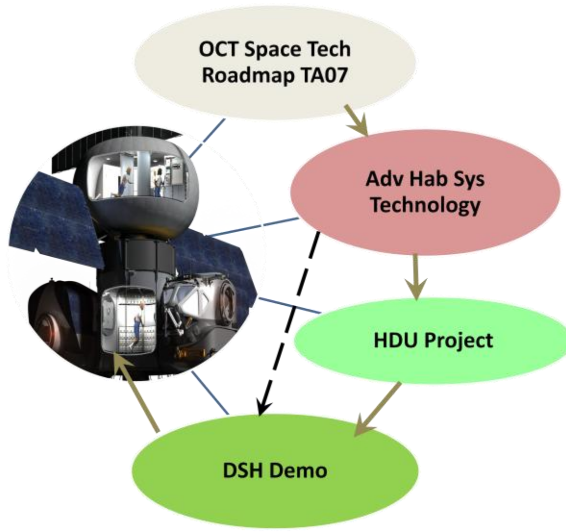

Figure 10. Exploration Habitat Technology Strategic Vision & Interdependency

IV. Habitat Demonstration Unit Project

The HDU project, as previously described, is a rapid prototyping project that performs integrated testing of systems, technologies, and innovations from multiple NASA centers and academia. This project integrates hardware and software to assess habitat and laboratory functions in an operational prototype unit. This approach to integration of hardware and software development forces early interface maturation and risk mitigation. The HDU project was formed to mature habitat systems, provide a test-bed platform for other systems, and stimulate hands-on training of young engineers, architects, and scientists. The value of the HDU project is the cost-effective leveraging of development around the agency while incrementally maturing and testing hardware and software required for human missions. By using the "test objective" approach, the team allows requirements to "float" throughout the testing and evaluation process. Such a process derives a smaller—more focused—set of performance requirements based on tested objectives and concept of operations validation. The HDU project collaborates and leverages each center's internal research and development (IR&D) focused efforts so that the integration of the contributions provides a sum benefit that is greater than the parts. This project is sponsored as part of the rapid prototyping development approach initiated by the Directorate Integration Office's (DIO) strategic vision to utilize analog testing for architecture, operations concept and element definition, fig. 11.

The project leverages previous 2009-2010 investments of the Habitat Bench-top Test-bed, Hab Systems Management Software, Hab Command, Communications, and Data Handling (CC&DH), Instrumentation, power management & distribution system (PM&D), LED lighting, geology lab glovebox, and workstations hardware. The bench-top test-bed capability is used as a stepping stone to mature the hardware and software, perform interface definition, and hardware checkout prior to installation. The HDU strategy is an evolutionary approach of build-a-little test-a-little to a higher-fidelity surface analog multi-element integration and testing capability.

The Project "*Vision*" is to develop a fully autonomous habitat system that enables human exploration of space. This will be accomplished by development, integration, testing, and evaluation of advanced habitat systems. The HDU is utilized as a technology pull, testbed, and as an integrated test capability to advance NASA's understanding of alternative mission architectures, operations concepts, and requirements definition and validation. The Project "*Mission*" is to develop a Deep Space Habitat configuration that will operationally "*roll-out*" ready for remote testing in July 2011. The Project team defined numerous goals and objectives as listed below.

Figure 11. Illustration of NASA Analog Strategic Vision

Project Goals: The HDU will be utilized to accomplish the following goals:

1) Be a Habitation Technology Pull and Testbed for the Exploration Technology Development Program (ETDP) and Human Research Program (HRP) projects and research.
2) Advance the NASA (Smart Buyer/Partner) understanding of surface architectures.
3) Advance the NASA understanding of surface architecture requirements definition and validation.
4) Advance the NASA understanding of surface architecture operations concepts definition and validation.
5) Establish a focused multi-center effort on advanced habitation systems.
6) Understand the key driving mission requirements and limitations that result from use of a lunar habitat
7) Incorporate agency wide Habitat-related assets. ETDP, Mockups, Mid-expandable Engineering Development Unit, Micro-Hab, etc.
8) Incorporate Sustainability and Green Engineering strategies and approaches into the project

Project Objectives: The HDU will be utilized to accomplish the following objectives:

- …provide a capability (platform) for lean management team & approaches, rapid prototyping, and "skunk works" environment to develop and validate mission architectures, concept of operations, and requirements
- …provide a capability (platform) for integration of internal subsystem hardware and software needed for Exploration Habitats (DSH)—independent of shell shape.
- …provide a platform for implementation of autonomous operations, monitoring, and control of those subsystems
- …provide a platform for Participatory Exploration, X-Hab University Competition
- …provide a platform for maturing Hab Integration Team of future Habs (DSH).
- …provide a "ground based" platform to integrate ISS subsystems with future technologies.
- …provide a "ground based" platform to assess the "Affordability" approach of modularity, commonality, reusability, and repurposing
- …provide a "ground based" platform for technology infusion…

A. HDU Project Strategic Development

The Project development strategy is to focus rapid prototyping effort to build and test various DSH technologies and innovations early in the conceptual definition cycle, while leveraging collaborations of low-cost development efforts. This approach utilizes the agency's best and brightest engineers, architects, and scientists. This early life-cycle tiger-team approach will help NASA to understand human exploration architectures, validate various concept-of-operations, derive habitat requirements, infuse—while maturing—technologies, and engage other agencies, academia, and industry. The Project strategically links exploration habitat strategic goals and technology development with the agency's rapid prototyping strategy of low-cost early maturation of deep space systems. The Project enables early integration of exploration habitation operational developmental hardware and software systems independent of the exploration destination or habitat shape and size. In FY12 the HDU project will transition to the Advanced Exploration Systems (AES) DSH habitation systems development project. It will primarily utilize NASA's civil servants coming off the Shuttle and Constellation programs. Figure 12 shows the AES Habitation Systems Project multi-year multi-generation development strategy for development of a deep space habitat. The near-term focus of this effort will develop smaller achievable demos for early deployment on International Space Station (ISS).

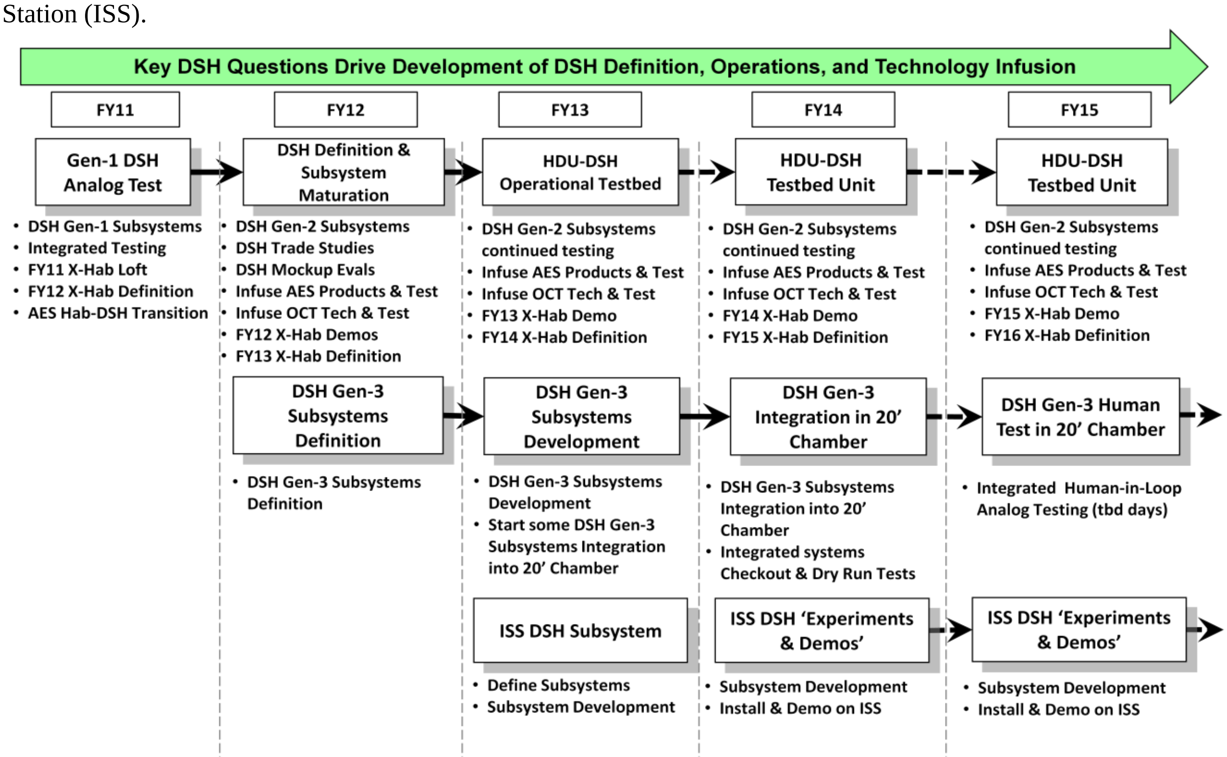

Figure 12. Habitation Systems Rapid Prototyping Strategy

The Project top-level milestones are centered primarily on developing a HDU unit (Gen-1) that will be utilized for integrated testing. This unit will be used to develop various configurations each year based on the needs of the program and architecture being developed. For FY10 the first generation unit (Gen-1 Unit) focused on the PEM configuration. For FY11 the HDU Gen-1 will demonstrate an alternate Deep Space Habitat configuration comprised of a vertically oriented 5 meter diameter hard shell with an integrated inflatable volume. This FY11 HDU configuration will have some of the Gen-1 subsystem upgraded. In parallel, during FY11 and FY12 the DSH flight design configuration will be further defined. Gen-2 subsystems will be developed, integrated and tested during FY12. Gen-3 subsystems will be defined during FY12 with a FY13 development for integrated testing. The Gen-3 subsystems could either be tested in the 20ft chamber at JSC or flown to ISS for DSH analog testing. The DSH shell orientation (vertical or horizontal), shape and size will be determined from inputs based on the architecture team. The systems development of the hardware and software integration will be the key to habitat early maturation and will be applicable to all configurations. The Gen-1 HDU shell will continue to be used in conjunction with subsystem upgrades and academia for additional integrated testing. The Gen-3 subsystems will be high fidelity utilizing flight like hardware and software integrated into a simulated DSH configuration so crew will be able to simulate multi-day missions such as a 30 or 60 day mission. This will lead to a protoflight unit demonstration of a DSH at the ISS or LEO.

B. Risk Mitigation

The HDU Project utilizes a risk-based approach to manage the project development and progress. The HDU management team and system leads determined the areas of risks and developed strategies to mitigate their impact to the project's success. A 5 x 5 matrix is used to track the likelihood and consequence of these HDU-DSH risks. In concert with the establishment of the interface definitions, the HDU team will utilize scheduled pre-integration activities, integration tools, and the habitat test-bed to buy-down risk prior to integration of systems within the HDU shell. The HDU project uses Continuous Risk Management (CRM) to monitor and control risk. CRM is an iterative and adaptive process that promotes the successful handling of risk. Each step of the process builds on the previous step leading to improved technical, cost and schedule control.

C. HDU Project Integration

Design Integration

The HDU team focuses early design integration through a series of early design concepts with Computer-Aided Design (CAD) and Simulations in the development flow across all efforts to test form, fit, integration, assembly, and basic functions as subsystem designs mature. Periodic synchronization gateway reviews occur during development and validate the hardware/software align with the test objectives.

Systems Integration

Successfully deploying the HDU PEM, from paper concepts to actual demonstration hardware in just over one calendar year, required the HDU project team to utilize a rapid prototyping approach at the core of the integration strategy. The team focused energy on shell design initially as that design paved the way for the manufacturing and guided operations. The design review and integration processes and collaborative tools utilized were also critical to the rapid prototyping approach. For a more detailed description please see reference #2.

Operations Integration

The HDU mission operations integration focuses on the concept of operations, test objectives integration, crew procedures, HDU-DSH operations manual, crew and operators training, and field test operations.

Demo Unit Integration

The HDU team will utilize the Habitat Test-Bed (HaT) in JSC Building 220 as a bench-top platform for early avionics, communications, power systems hardware, and software integration prior to final installation of components within the HDU-DSH. This early integration utilizing the test-bed will occur from weeks to three months prior to the hardware final installation into the demo unit. This process will be the same as last year's HDU Pressurized Excursion Module integration. For a more detailed description please see reference #3.

Assembly Integration

The HDU team will utilize the assembly integration team along with the JSC Building 220 facility for rapid-prototyping development and installation of components into the HDU-DSH. These opportunities will occur from approximately two weeks to three months prior to the hardware delivery date depending on complexity and availability. A Test Configuration Review is held prior to installation of components and a series of Test Readiness Reviews are held for the JSC B220 test and the analog field test.

Technology Integration

The HDU Team will utilize and leverage the Exploration Technology Development (ETD) projects expertise, technologies, and products to infuse those applicable technologies that are deemed ready for inclusion and that meet deep space habitat test objectives. Below is a list of FY11 HDU-DSH technology and innovations being integrated and tested.

1. Inflatable Loft (X-Hab Competition)
2. Logistics-to-Living
3. Autonomous Ops: "Intelligent" Habitat System Management Software
4. iHab Digital Double (D^2)
5. Power management systems
6. Environmental Protection Technologies
    - 6.1. Dust Mitigation Technologies
        - 6.1.1. Electrodynamic Dust Screen to repel dust from surfaces
        - 6.1.2. Lotus Coating
        - 6.1.3. Vent Hood at the General Maintenance Workstation
        - 6.1.4. Operational Concept for End-to-End Dust Contamination Management

6.1.5. Vacuum Cleaner
6.2. Micrometeoroid Mitigation Technologies
6.2.1. Micrometeoroid Detection
6.3. Radiation
6.3.1. Operational Demonstration of Cargo Transfer Bags to deployable blankets for Radiation Protection
7. HDU Core Computing, Wireless Communication and RFID
8. Standards-based Modular Instrumentation System: Wireless Sensor Nodes
9. Flat Surface Damage Detection system
10. MMOD Hab impact monitoring system
11. Delay Tolerant Networking
12. Telerobotic Workstation
13. General Maintenance/EVA Workstation
14. Medical Ops/Life Science Workstation
15. Geo-Science Lab Glovebox/Workstation
16. Material Handling
17. Food Production: Atrium concept
18. LED Lighting
19. 3-D Layered Damage Detection System for Surfaces
20. Habitability / Habitation
21. Hygiene Module

D. Project Organization

The project team implements a one-NASA multi-center distributed team approach to manage the project's objectives, resources and execution. The HDU Management team uses a horizontal management and organizational style as shown in figure 13. The management team is comprised of focused-integration functions of Mission Architecture Integration, Larry Toups/JSC; Design Integration, Scott Howe/JPL; Systems Integration, Tracy Gill/KSC; Mission Operations Integration, Sotirios Liolios/JSC; Demo Unit Integration, Terry Tri/JSC; and Assembly Integration, Ed Walsh/JSC. Each HDU subsystem functional area has an "Integration Lead" that coordinates between the design, technology, and assembly integration to ensure both the latest system updates and configuration are being incorporated into the demo unit test objectives.

E. Project Milestones

The Project milestones are established as check points aligned with the fast pace rapid-prototyping approach of developing configurations for the yearly September analog testing. Accordingly, the project manages its objectives, resources, assembly, and check-out prior to the July and August pre-test dry-runs. The milestone list below highlights the year long progression check-points that focus the team on development. Figure 14 is a high level gant chart showing the swim lanes of the parallel development activities. The HDU Project has a ~300 line project schedule that is updated and maintained throughout development.

- DRaTS 2010 Lessons Learned and Report: November 2010
- HDU Deep Space Habitat (DSH) System Design Review: October 2010
- HDU-DSH System Implementation Review: November 2010
- EVA Incapacitated Crewmember & Donn/Doff Airlock Test: January 2011
- HDU-DSH Preliminary Integration Review: January 2011
- HDU-DSH Final Integration Review: February 2011
- HDU-DSH Test Configuration Review: April 2011
- X-Hab Academic Challenge head-2-head Competition: June 2011
- HDU-DSH Integrated Systems TRR: June 2011
- HDU-DSH Field Test TRR: July 2011
- HDU-DSH VIP & DIO Tour: July 2011
- HDU-DSH "Roll-Out" to Rock Yard: July 2011
- HDU-DSH Rock Yard Dry Run: July-August 2011
- D-RATS Field Analog Testing: August-September 2011

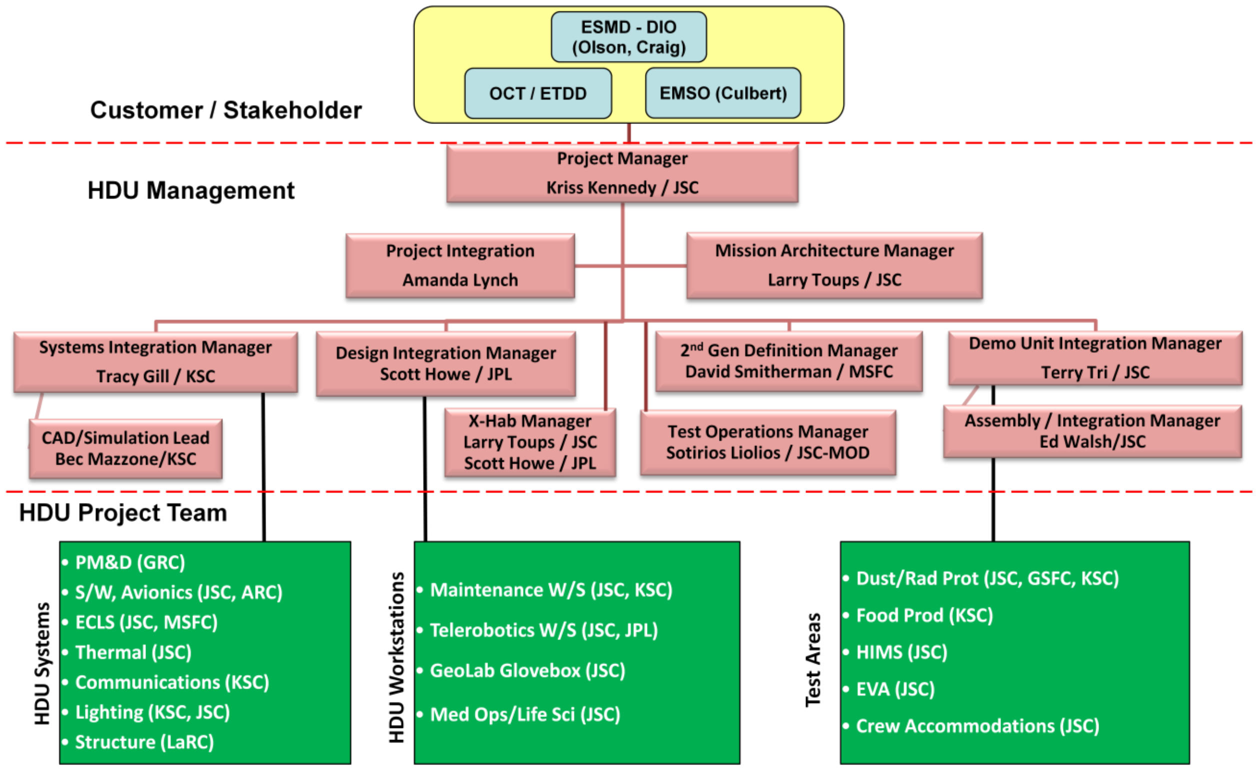

Figure 13. HDU Project Organization

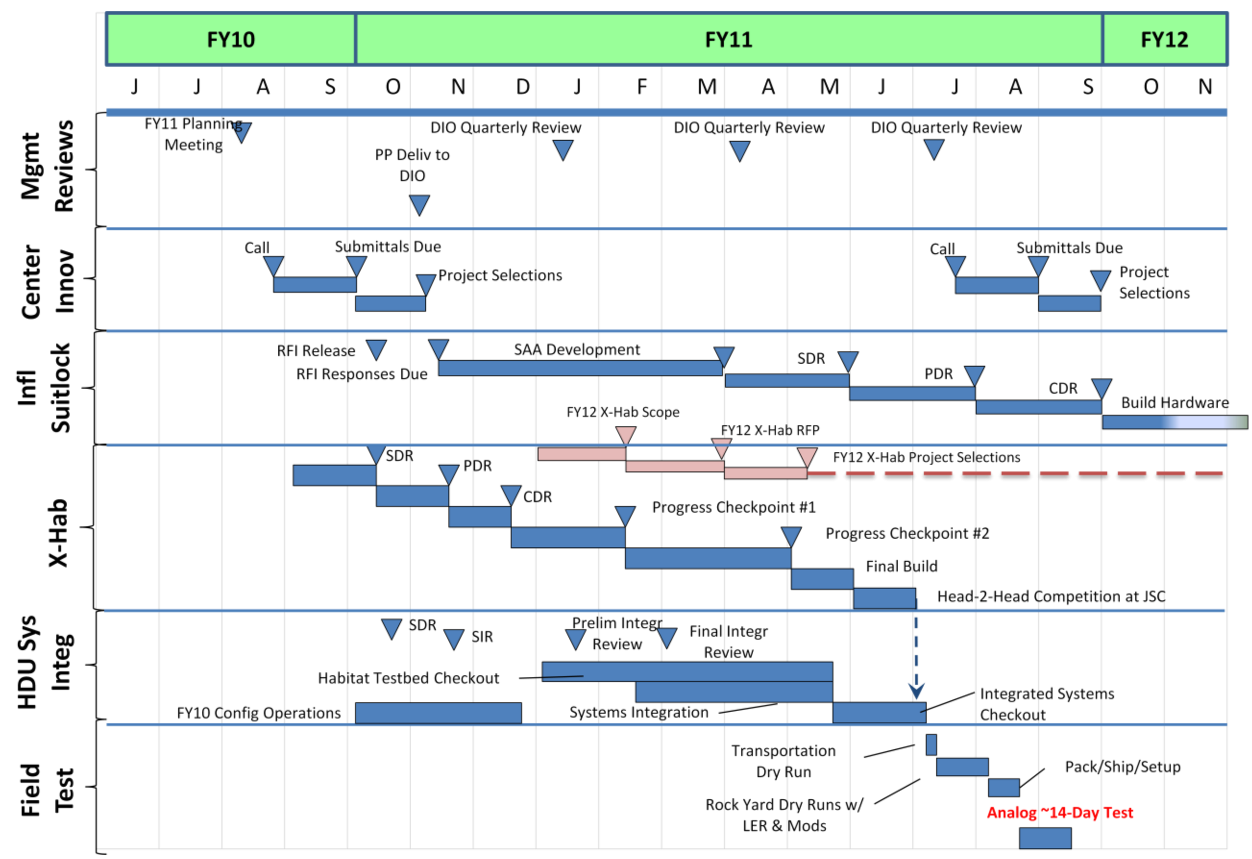

Figure 14. FY11 HDU Project Schedule

V. eXploration Habitat (X-Hab) Academic Innovation Challenge

The HDU Project sponsored the inaugural 2011 eXploration Habitat (X-Hab-2011) Academic Innovation Challenge this past year. Three university teams were selected to design, manufacture, assemble, and test an inflatable loft that will be integrated on top of the HDU shell. The three universities selected are Oklahoma State University (fig. 15), University of Maryland (fig.16), and the University of Wisconsin-Madison (fig. 17) which will compete in a head-to-head competition in June 2011 at the NASA Johnson Space Center. The winner will be integrated with the HDU-DSH for the D-RaTS 2011 analog field test at Black Point Lava Flow, Arizona. The X-Hab 2011 occurred during the academic year of Fall-2010 and Spring-2011. The HDU Project has established the X-Hab Challenge as a way to engage, stimulate, and inspire students in Science, Technology, Engineering and Mathematics (STEM). The challenge is intended to link senior and graduate-level design curricula emphasizing hands-on design, research, development, and manufacture of functional prototype habitation subsystems. Not only do the students learn valuable leadership and teamwork skills, they also become more job-marketable with this experience. The HDU team is proud to be mentoring our next generation of architects and engineers. NASA directly benefits from the X-Hab challenge by sponsoring the development of innovative habitation-related concepts and technologies from academia. This results in innovative ideas and solutions that embrace participatory exploration. For more details on the X-Hab 2012 challenge please reference http://www.spacegrant.org/xhab/. Be Inspired—Inspire Others!

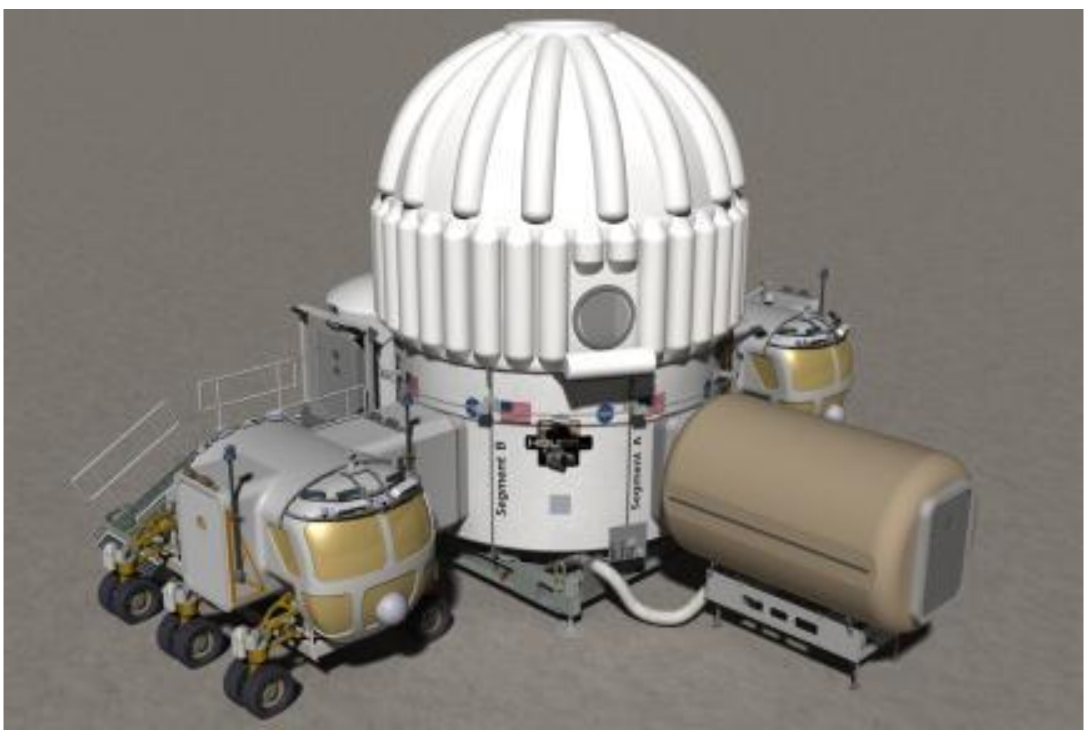

Figure 15. Oklahoma State University X-Hab Loft

Figure 16. University of Maryland X-Hab Loft

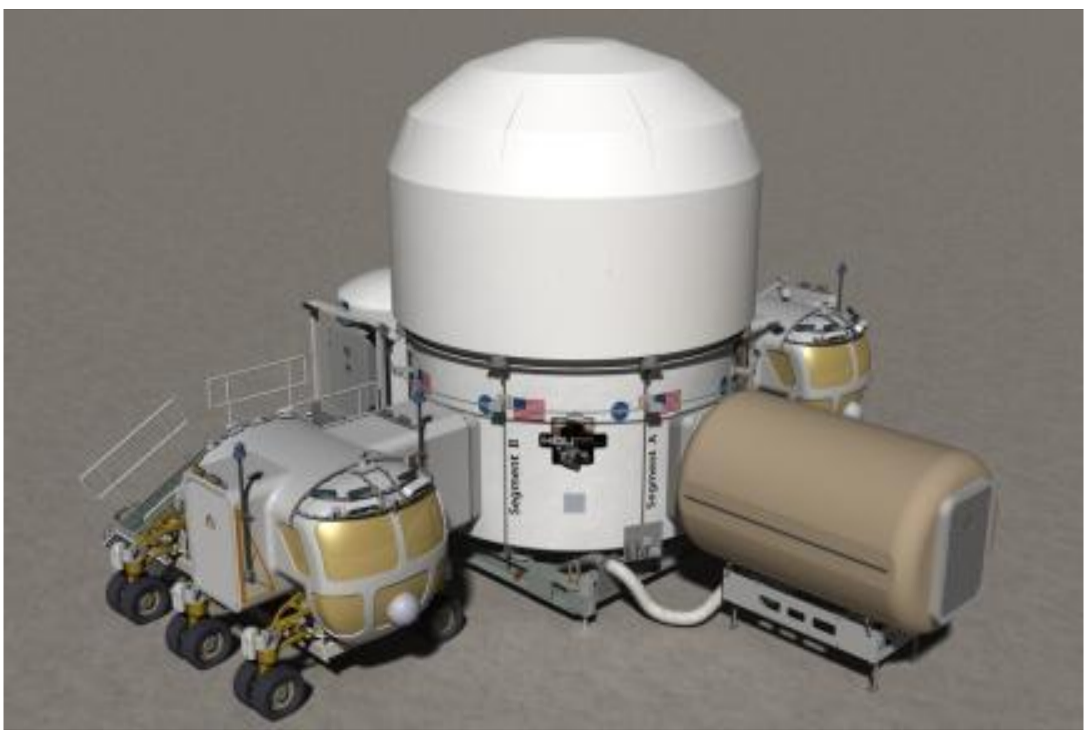

Figure 17. University of Wisconsin-Madison X-Hab Loft

VI. Summary

The Habitat Demonstration Unit project has established a multi-center rapid prototyping capability for maturing exploration habitat configurations that are used for infusion of technologies and innovations early in the development life cycle—thus mitigating integration risks of future space habitats. The HDU aides the exploration architecture team by defining and validating various mission architectures, validating concepts of operation, and deriving habitation requirements. For 2011, the configuration represented by the HDU-DSH is the Deep Space Habitat of the asteroid mission architecture. This DSH configuration will be tested in the 2011 NASA Desert Research and Technology Studies campaign. The HDU project uses computer aided design for the design and integration of systems, and double checked using fit-check opportunities with the unit to mitigate integration challenges. The utilization of a Habitat Test-bed with integrated avionics capability helps reduce the risk of integrating the systems together for the first time within the HDU-DSH. Finally, the entire HDU project Concept of Operations—from the planning of the manufacturing, assembly and integration, dry-run testing, shipment, and integration to the field operations—have all been factored into the team's approach of a streamlined rapid prototyping of a DSH.

VII. References

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