The Habitat Demonstration Unit System Integration

T.R.Gill[1], K. J. Kennedy[2], T. O. Tri[3], and A. S. Howe[4]

[1] Engineer, NASA Kennedy Space Center. Mail Code LX-M, Kennedy Space Center, FL 32899; PH (321) 867 5824; email: Tracy.R.Gill@nasa.gov
[2] Architect, NASA Johnson Space Center. Mail Code EA3, 2101 NASA Parkway, Houston, TX 77058; PH (281) 483 6629; email: Kriss.J.Kennedy@nasa.gov
[3] Engineer, NASA Johnson Space Center. Mail Code EA3, 2101 NASA Parkway, Houston, TX 77058; PH (281) 483 9234; email: Terry.O.Tri@nasa.gov
[4] Architect, NASA Jet Propulsion Laboratory. Mail Code EA3, 4800 Oak Grove Drive, Pasadena, CA 91109; PH (818) 354 4492; email: Alan.S.Howe@nasa.gov

Abstract

The Lunar Surface System Habitat Demonstration Unit (HDU) will require a project team to integrate a variety of contributions from National Aeronautics and Space Administration (NASA) centers and potential outside collaborators and poses a challenge in integrating these disparate efforts into a cohesive architecture. To accomplish the development of the first version of the HDU, the Pressurized Excursion Module (PEM), from conception in June 2009 to rollout for operations in July 2010, the HDU project team is using several strategies to mitigate risks and bring the separate efforts together. First, a set of design standards is being developed to define the interfaces between the various systems of PEM and to the payloads, such as the Geology Laboratory, that those systems will support. Scheduled activities such as early fit-checks and the utilization of a habitat avionics test bed prior to equipment installation into HDU PEM are planned to facilitate the integration process. A coordinated effort to establish simplified Computer Aided Design (CAD) standards and the utilization of a modeling and simulation systems will aid in design and integration concept development. Finally, decision processes on the shell development including the assembly sequence and the transportation have been fleshed out early on HDU design to maximize the efficiency of both integration and field operations.

Background

A technique being utilized in NASA’s lunar architecture analysis is analog testing of the lunar environment in desert locales. Running through potential “day in the life” scenarios at a lunar outpost with prototype equipment allows designers insight into the utilization of the proposed systems and refines architecture and operations concepts. A series of Desert Research and Technology Studies (RaTS) have been held in locations such as Moses Lake, Washington and Black Point Lava Flow, Arizona, where the most recent test in September 2009 was performed with a Lunar

Electric Rover, and a fourteen day excursion was practiced. The 2010 session of Desert RaTS is planned again for Black Point Lava Flow where two LERs will operate together and will add a full scale lunar habitat prototype, the Habitat Demonstration Unit to the two LERs to allow for a 14-21 day mission. A graphic example of the proposed lunar architecture under evaluation at the Desert RaTS 2010 campaign is pictured below in Figure 1. The Pressurized Excursion Module (PEM) to be represented by the HDU in 2010 is depicted in the center. One difference in the version of the PEM depicted in that figure from the HDU version of the PEM is that the HDU version will allow for a second story loft rather than accommodate commodity storage tanks on its roof. As the name implies, the application for the PEM is for lunar excursions to provide a mobile facility in which to provide research and habitation functionality in a mobile outpost concept.

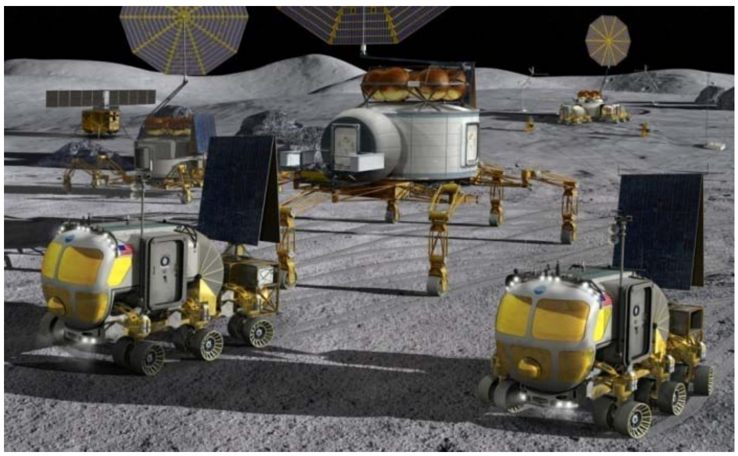

Figure 1 - Example of a lunar architecture analyzed through Desert RaTS campaigns.

Integration Strategy

The HDU project will require integrating a variety of contributions from NASA centers and potential outside collaborators and will pose a challenge in integrating these disparate efforts into a cohesive architecture. The HDU will begin its journey as an emulation of the Pressurized Excursion Module (PEM) for 2010 field testing and then evolve to a Pressurized Core Module (PCM) for 2011 and later field tests. The HDU deployment will not be exactly the same configuration as either the PCM or the PEM as conceived in current lunar architecture plans. There may be some developmental hardware and software items that are not available or are only volumetric simulations. Conversely, there may be additional hardware available for the HDU that will be called opportunities for demonstration, and one of the HDU challenges will be designing to be prepared for the integration of presently unanticipated systems. Results of the HDU field tests will influence future designs of the PCM and PEM.

Design Standards

To be able to accomplish integration and form the foundation for future evolution of the hardware, an interface definition document is being developed for potential current and future contributors to the HDU to communicate design interface standards. To further this effort in the establishment of these interface standards, the HDU project team will attempt to align as much as possible with interfaces, hardware, and experience of Lunar Electric Rover team. Additionally, the HDU project team will rely on Lunar Surface System (LSS) Habitat team to integrate HDU implementation with Habitation planning accomplishments. These standards are not intended to be detailed interface specifications normally seen with flight hardware, but there will be enough definition included to enable a future HDU contributor to build a system that will integrate with HDU systems. This information may be pointers to other documents or references rather than data copied from other sources if and where applicable.

Risk Mitigation

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. Project reviews, milestones, fit-check and bench-top test opportunities, integration and test activities, and field operations are among the items being tracked in a comprehensive HDU master project schedule, managed in Microsoft Project.

Scheduled Activities

Simulation Activities
The HDU project team will utilize simulation early in the development flow across all efforts to test form, fit, integration, assembly and basic functions as sub-system designs develop. It is expected that these simulation opportunities will be present throughout the lifecycle. The first sessions are occurring as soon as HDU shell data and PEM system design data becomes available. Periodic synchronization events will be occurring during development and extending through the field outings. The events will include updates to models and simulations from CAD end item developers and the HDU shell model to reflect current operations concepts and current system and subsystem designs.

Mechanical Activities
The HDU project team will utilize fit-check opportunities in the development flow at JSC to allow hardware to be temporarily installed for form and fit. These opportunities can occur from days to months prior to the hardware delivery date depending on complexity and availability.

Electrical Activities

The HDU project team will utilize the Habitat Test-bed (HaT) in JSC Building 220 as a bench-top platform for early PEM avionics, communications, and power systems prior to final installation of hardware/software within the HDU shell. These opportunities can occur from approximately two weeks to three months prior to the hardware delivery date depending on complexity and availability.

Software Activities

The HDU project team will utilize software integration opportunities early in the development flow at ARC and JSC to allow early integration testing of PEM software. The HDU project team will utilize the Habitat Test-bed (HaT) in JSC Building 220 as a bench-top platform for early avionics, communications, and power systems, prior to final installation of hardware/software within the HDU. These opportunities should be scheduled no later than two weeks prior to the delivery of hardware, but use software models of hardware in order to retire software development risk.

Master Equipment List

The HDU project team will use a Master Equipment List (MEL) adapted from the Pressurized Excursion Module (PEM). This list will be tailored for the HDU implementation of the PEM and will include at least item name, mass, volume, power and a flag whether it is in scope of the PEM or the Pressurized Core Module (PCM), or is an opportunity for demonstration. The latter category will be utilized for items that are not on the PEM or PCM MELs but are available for evaluation during the development, integration, or field operations phases at HDU project team discretion.

Modeling and Simulation Tools

Habitat Demonstration Unit project will utilize a coordinate system to assist in the placement of systems within the HDU during integration analysis and for location labeling of the systems and other equipment during operations. The scheme for the coordinate systems is depicted below in Figure 2.

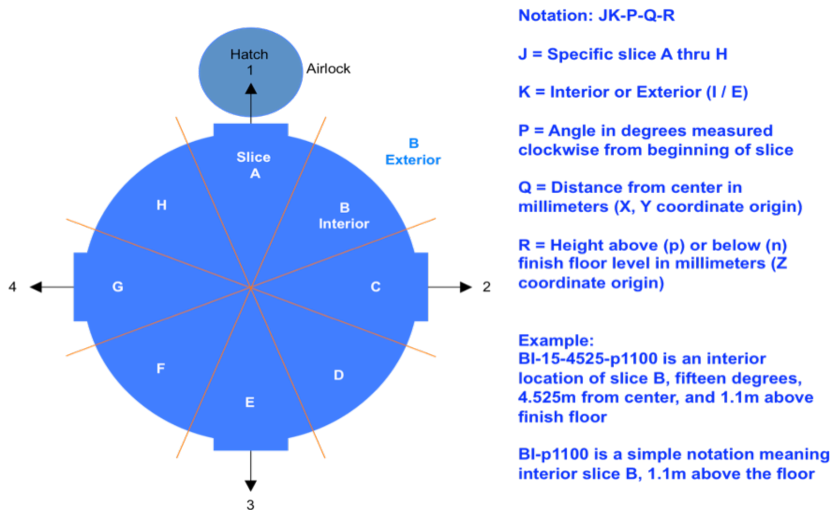

Figure 2 - HDU Coordinate System

Additionally, the HDU project team will make use of Constellation simulation tools to assist in the design layout of HDU systems, factoring in both the intended layouts of the PEM and the systems available for the HDU project. Computer Aided Design (CAD) representations of the various HDU systems will be used during an Integration Review process to determine where the systems will be located internal and external to the HDU shell prior to beginning the touch-labor integration effort. After coordinating with each system for initial recommendations on placing systems most effectively and conveniently, two of these reviews will be held to include the entire team where virtual model of the HDU will be evaluated.

The specific tools used to support HDU will vary throughout the project lifecycle. Initial work will utilize Data Presentation and Visualization (DPV) capabilities in the Exploration Visualization Environment (EVE) and Distributed Observer Network (DON) to integrate and share system concepts. Data within these environments will consist of engineering models and other CAD data and will be updated regularly to ensure that the simulations match current designs. As HDU matures, the simulation team will work more and more with the JSC Habitat Test-bed (HaT) and the Constellation Modeling and Simulation Team (MaST). The HaT is already using the base simulation tool provided by the MaST Integrated Mission Simulation (IMSim) team for system and subsystem simulation. Adding the distributed IMSim capabilities to support HAB and HaT interactions in the field should not be a significant challenge.

Finally, the HDU project team will make use of Constellation software simulation and verification and validation tools to assist in the design, verification and validation and integration of HDU Flight Software and Habitat Systems Management software systems, factoring in expected command and telemetry interfaces as well as software-to-software interfaces.

Manufacturing and Integration Process

The HDU shell is being manufactured in eight shell slices at Langley Research Center. Those slices will be shipped to the Johnson Space Center for assembly and then outfitting with the various PEM systems for the 2010 Desert RaTS campaign. The original concept was to manufacture all the slices and then ship to JSC for assembly prior to installing any system hardware. However, because of the predicted length of the manufacturing schedule for the slices and the desire to make maximum use of the relatively short window for the integration process, the HDU team took the approach of integration by sections where interim deliveries of several slices will be set to JSC as they become available, and those slices will be assembled and then outfitted as they arrive. This approach spreads the integration process out over a longer window, allowing for a more gradual process and effective applications of the lessons learned from the early efforts to the later ones.

The HDU shell slices are a composite structure and each of the slices has a steel rib on either end to attach it to the next slice. Thus there is a double steel rib at the joint of each slice to slice interface. The shell slices are made from one common mold that is modified for the variations of a smooth slice or a slice with a door opening. The smooth slices also include one slice that has a window opening and thus requires a slight modification to the mold. To minimize down time in modifying the mold, the HDU team is trying to optimize the production by making several smooth slices and then the slices with door openings to the extent possible that production still allows that the earliest slices that are delivered are the ones required for the earliest phases of integration. Examples of an HDU rib and the mold for the shell slices are seen below in Figure 3.

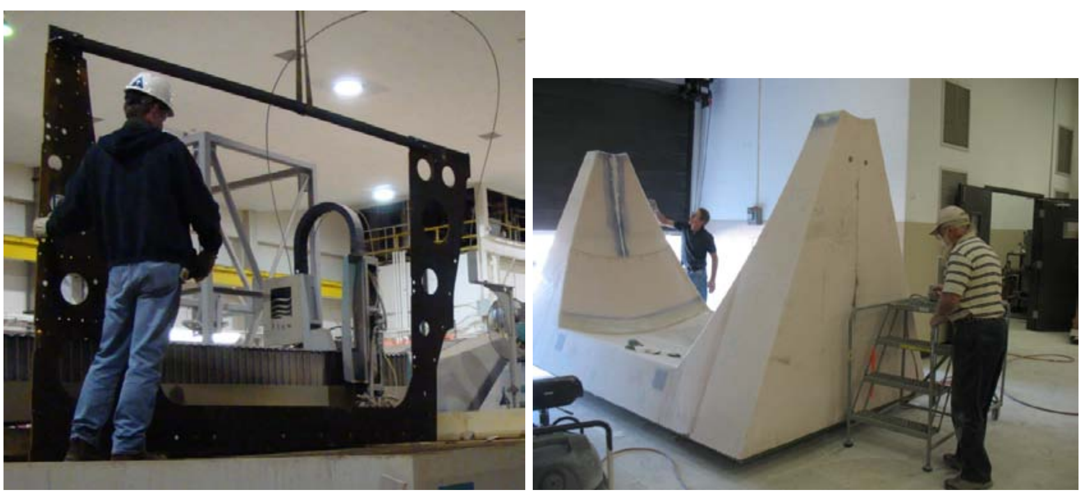

Figure 3 - An HDU Rib being removed from the water-jet machine (left) and the HDU shell slice mold during its fabrication (right)

To accomplish this goal, the strategy is to designate the earliest sections as those in the vicinity of the General Maintenance workstation, Section F, and by the placement of the core systems of the HDU in that area. The General Maintenance workstation is one of four quadrants of the PEM layout with the other three being an Extravehicular Suit Maintenance area, a Medical Operations workstation, and a Geology Laboratory area. The proposed layout of HDU PEM Systems is seen in Figure 4 - HDU PEM Layout. Core systems include the power input and distribution, the computer system, and the heat pump which will be used for environmental conditioning. Those systems are the key elements to support all other elements in HDU, and the heat pump in particular may have the longest installation time. By placing these systems within or, as in the case of the heat pump, on the exterior of Section F, the more difficult tasks of the integration are accomplished first and those systems are postured to be able to support the addition of the other sections and further system integration. The current sequence of delivery of slices of HDU from LaRC to JSC is in four installments: (1) F-G-H (2) A-E (3) B-C (4) D. But this sequence may be adjusted and the number of installments reduced once production begins in November 2009 if the intent of the timeline for integration can still be met even if the order of production is further altered to produce the four smooth slices and then the four with door openings. A virtual representation in a modeling tool of the HDU PEM layout from the CAD integration activities is pictured in Figure 5.

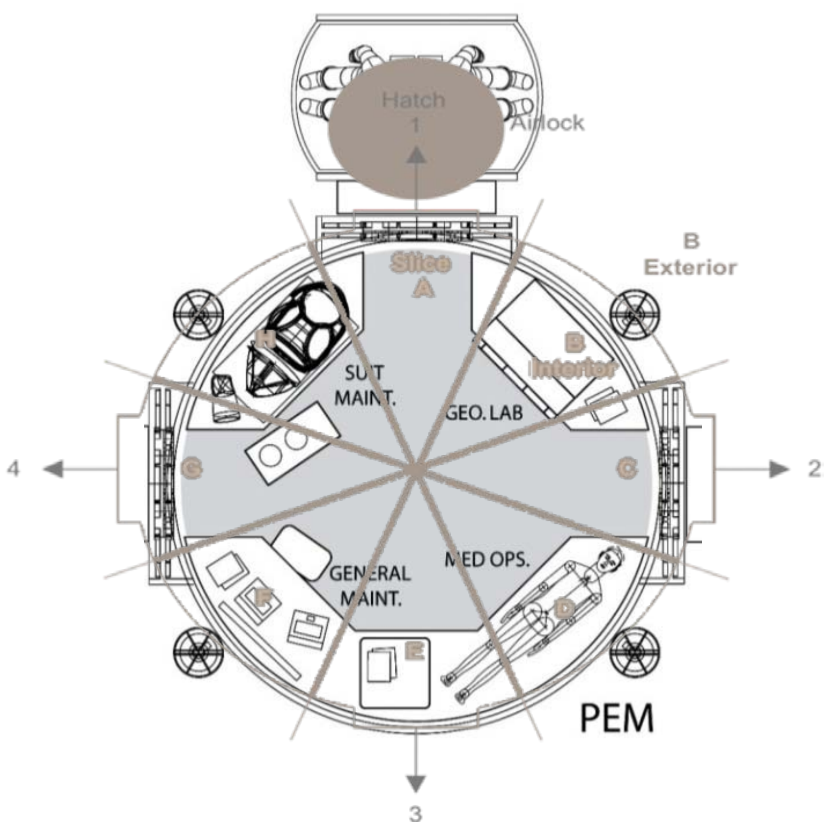

Figure 4 - HDU Pressurized Excursion Module Layout

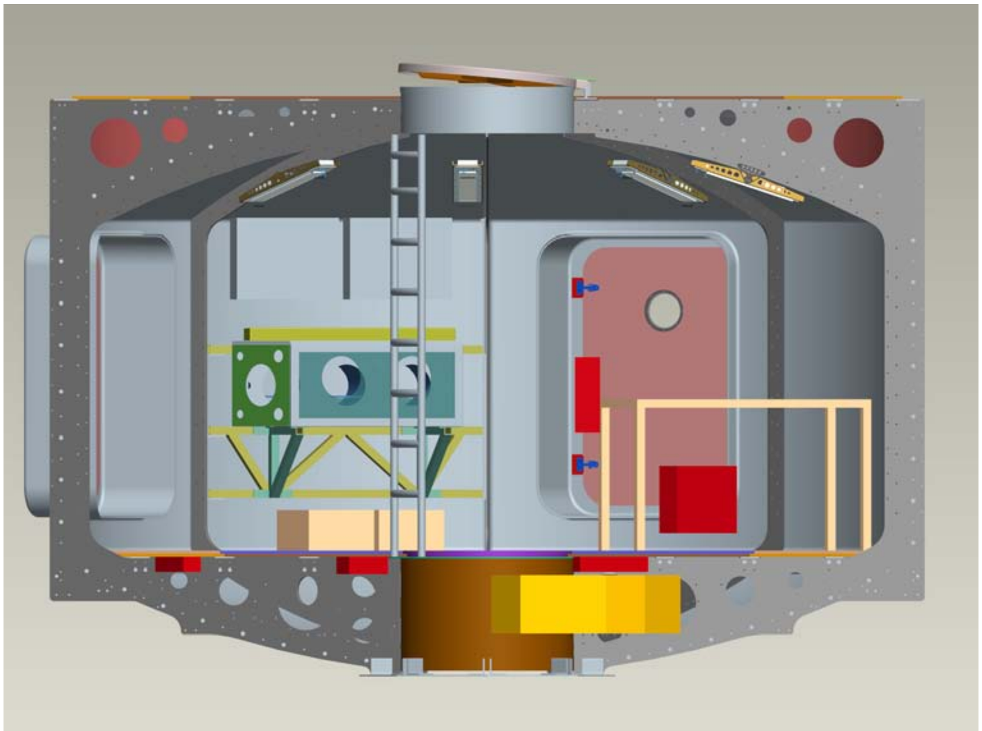

Figure 5 – Virtual Representation of HDU layout in modeling tool

Transportation Configuration

The HDU project performed a trade analysis to select a preferred transportation configuration. The HDU project is planning on 1 or 2 transport round trips per year. The transportation configuration was important in deriving the HDU shell design and manufacturing requirements. An HDU Shell Design and Manufacturing Requirements Document was developed to ensure the HDU shell would meet the project expectations and requirements. The transportability trade assessed three options of 1) transporting the HDU as a fully assembled unit, 2) transporting the HDU as a single-split unit configuration, and 3) transporting the HDU as a dual-split unit. Each configuration affected the design and manufacturing of the shell. Evaluation criteria were defined, and an evaluation matrix was developed for the analysis.

The assessment determined that the cost for manufacturing a more complex split configuration shell, its in-field assembly, special transport support equipment and coverings, additional ground support equipment, and added risks out-weighed the cost of transporting a super-size load. The benefits of shipping an integrated HDU as a super-size load were great enough to overcome that fact that a super-size load is about 10 times more costly than a standard tractor trailer load.

The decision outcome of the trade study was to manufacture the shell in the “orange slice” mold approach, to ship in sections, quarter panels or fully-assembled to JSC, to integrate subsystems at JSC, and to transport to the field analog site as a fully integrated unit - not in a split and disassembled configuration.

Furthermore, a transportation cradle has been designed to support three purposes for the HDU: (1) integration and test at Johnson Space Center, (2) transportation to field locations, to other centers, or to outreach activities, and (3) field operations in the desert analog locations. For field operations, the cradle will allow a flatbed trailer to transport the HDU as an analog substitute for the All-Terrain Hex-Legged Extra-Terrestrial Explorer (ATHLETE) rover depicted in the Figure 1 lunar architecture concept. The cradle, pictured in Figure 6, should be delivered with the first few sections of the HDU shell that arrive at JSC from LaRC. While in the field, the HDU will be transported on a flatbed trailer to its deployment locations, supported by this cradle.

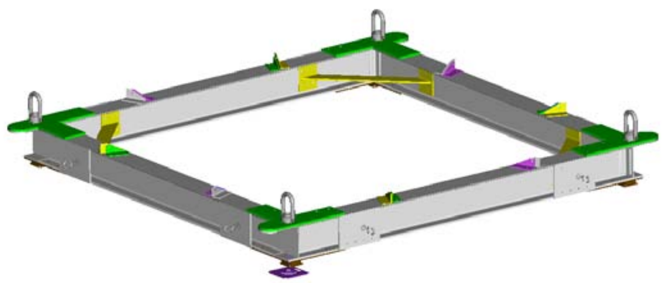

Figure 6 - HDU Cradle

Centennial Challenge Incorporation

The HDU project has proposed three Centennial Challenge opportunities and is awaiting the outcome of the internal NASA selection process to see if they will go forward for competition. The challenges are to build and demonstrate innovations and technologies focused on lunar surface habitation. The three challenges are for an inflatable upper level for the habitat, an inflatable airlock for extravehicular activity, and logistics to living which takes elements of packaging and utilizes them for living accommodations such as curtains, dividers, work surfaces, insulation, etc. Notional concepts and proposals may be of a different innovative shapes or sizes. The HDU has been designed to accommodate these challenge opportunities and the winners will have their contribution integrated with the HDU during the Desert RaTS 2010 campaign.

Conclusion

The Habitat Demonstration Unit project is constructing a habitat shell to act as a test bed for instances of a habitation architecture. For 2010, the instance represented by the HDU will be the Pressurized Excursion Module of the lunar architecture, and it will be put to test in the 2010 NASA Desert Research and Technology Studies

(RaTS) campaign as depicted in Figure 7. Significant challenges to accelerate from a project start to a field deployment in just over a year are being addressed with several facets of the HDU integration strategy. Significant effort is being made to define and document standards for system integration which will be valuable for not only the PEM but future versions of the HDU. Additionally, the HDU project has planned scheduled activities including the use of computer aided design in the layout of systems, the use of fit-check opportunities, and the utilization of a Habitat Test-bed avionics platform to mitigate the risk of integration the systems together for the first time within the HDU. Finally, the entire concept of operations from the planning of the manufacturing, shipment, and integration to the field operations have all been factored into the design of the HDU to streamline the integration activities to enable to project to meet the ambitious timeline for deployment of a PEM for Desert RaTS 2010.

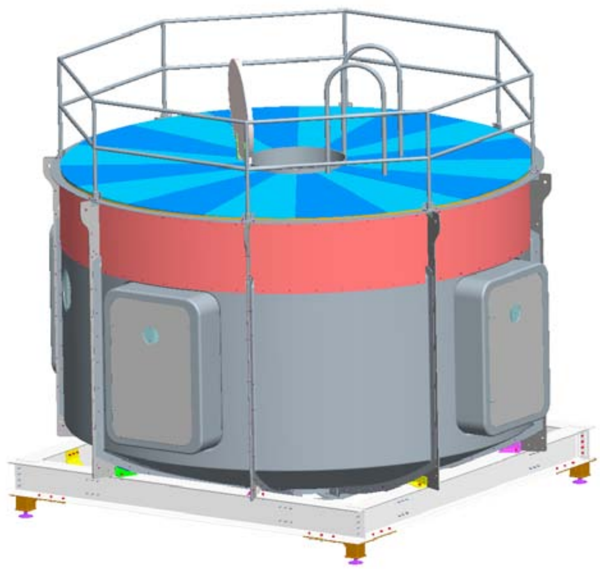

Figure 7 - Assembled HDU Mounted on Cradle in Configuration for Desert RaTS 2010

References

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