Center Independent Research & Development: JSC IRAD

Common Habitat for Long Duration Transit and Surface Operations

Completed Technology Project (2019 - 2019)

Project Introduction

This concept is based on the Skylab II concept, which proposes using a SLS propellant tank as the primary structure of a habitat. Common Habitat takes this a step further, proposing an interior architecture that is equally viable as a lunar surface hab, transit hab, and Mars surface hab, thus enabling a single development to support all three long duration habitat roles. Common Habitat has been pursued by the PI and co-investigators at MSFC and other centers in a spare time / funding available basis, often with heavy student intern support. Student resources have developed preliminary concepts, but these models must be refined to reflect accurate vehicle subsystems, utilities, stowage, workstations, and other crew systems. This investigation applies NASA civil servant and contractor expertise to correct errors in the most recent student concepts in order to prepare them for future human-in-the-loop evaluations to determine the most viable configuration for a Common Habitat.

In prior studies there was never an opportunity to trade both crew size and internal orientation. Prior work has been a series of point designs with inconsistent design constraints, making apples to apples comparisons impossible. The most recent student work produced CAD models of four habitat variants for future use in a trade study, but the student products contain model construction and geometry errors, inaccurate subsystems design and placement, and unrealistic structural elements and outfitting. These must be corrected before the models can be moved into a VR environment for human-in-the-loop testing. Through consultation with SMEs throughout the Agency, the fidelity of these designs will be upgraded to a level of quality sufficient to make a comparative analysis of crew size sensitivity and internal orientation.

The product of this activity is four upgraded CAD models, each reflecting a different configuration of the Common Habitat. One is a horizontal configuration using the full length of the SLS LOX tank. One is a vertical configuration using the same tank dimensions. The third is a horizontal configuration using a truncated SLS LOX tank (half the barrel length). The fourth is a vertical configuration of the half-length SLS LOX tank.

Anticipated Benefits

Traditionally, each habitat is a unique design with its own program offices and development efforts, often with timelines in excess of a decade from concept to operational status. A significant return to the Moon and human travel to Mars will require at least three different long duration space habitats: lunar surface, Mars surface, and Mars transit. A common habitat approach combines these into one development effort with three identical units, one for each destination, potentially saving decades of time and tens of billions of dollars. But it is not known if a common design can be made acceptable from a subsystems or human performance perspective. This investigation will make progress towards collecting objective test data to determine the viability of a common hab approach. If successful, it may enable the human lunar return to go beyond

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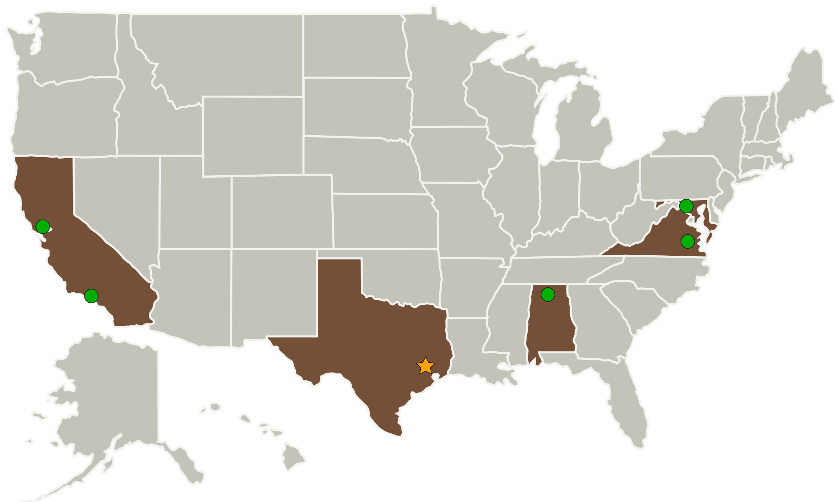
brief surface stays and may accelerate the availability of deep space habitats for Mars.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, TX
Ames Research Center(ARC)	Supporting Organization	NASA Center	Mountain View, CA
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, MD
Jet Propulsion Laboratory(JPL)	Supporting Organization	NASA Center	Pasadena, CA
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, VA
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, AL

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

Center Independent Research & Development: JSC IRAD

Project Management

Program Manager:

Christopher Culbert

Project Manager:

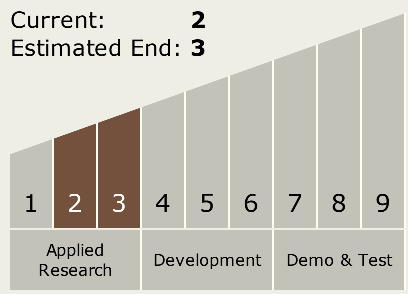
Ronald G Clayton

Principal Investigator:

Robert L Howard

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Co-Funding Partners	Type	Location
University of Houston System	Academic	

Primary U.S. Work Locations	
Alabama	California
Maryland	Texas
Virginia	

Closeout Summary

Numerous improvements were made to the student-developed CAD models. The four spacecraft variants were all converted to the same layer structure, so they are more easily comparable to one another. The pressure shells were remodeled based on actual SLS LOX tank dimensions. Some of the internal architecture has been converted to a more flight-like design. An example is removal of rectangular windows with 90-degree angles from the pressure vessel.

Additionally, work performed leveraged Rhino's block instancing in order to optimize the workflow. This involved conversion to Rhino blocks any complex objects that appear multiple times. That way bulk edits can be made by only needing to edit a single block. It also optimizes the workflow for conversion from CAD to VR.

Model construction errors were also corrected. The models were converted from vertex meshes to the more useful non-uniform rational basis splines (NURBS) for the purposes of design and analysis. Conversion to NURBS not only prepares the model for mathematical analysis, but it also makes the model easier to manipulate in CAD. Meshes are cumbersome to work with and are not typically used in CAD design. They are also incompatible with many computer-based analyses. Mesh to NURBS conversions make the CAD model compatible with the various analyses (e.g. radiation ray tracing) that could potentially be performed in Creo. Due to the mathematical nature of NURBS models, they are ideal for these types of analyses. Further, it makes the model more accessible to other teams here at NASA because most teams do not design using meshes.

Some of the objects were not the "correct" size—meaning they are not the same size as our CAD models or presumably the size of objects currently in use. Whether by error or in an attempt to make components fit, several of the component models used by the students were scaled up or down from their actual sizes. For instance, NORS tanks were discovered to be

Technology Areas

Primary:

- TA6 Human Health, Life Support, and Habitation Systems
  - └ TA6.1 Environmental Control and Life Support Systems and Habitation Systems
    - └ TA6.1.4 Habitation

Other/Cross-cutting:

- TA6 Human Health, Life Support, and Habitation Systems
  - └ TA6.3 Human Health and Performance
    - └ TA6.3.1 Medical Diagnosis and Prognosis
    - └ TA6.3.2 Long-Duration Health
    - └ TA6.3.3 Behavioral Health
    - └ TA6.3.4 Human Factors
- TA7 Human Exploration Destination Systems
  - └ TA7.2 Sustainability and Supportability
    - └ TA7.2.2 Maintenance Systems
    - └ TA7.2.3 Repair Systems
    - └ TA7.2.4 Food Production, Processing, and Preservation
  - └ TA7.4 Habitat Systems
    - └ TA7.4.2 Habitat Evolution

reduced in size, enabling two of them to be stacked to fit under a work surface of a particular height. A CEVIS-like device was found to be larger than the CEVIS model pulled from the CAD for the US Lab on ISS. Other examples include various equipment like MDLs, science equipment, etc.

Finally, instances of overlapping geometry were corrected. This included instances of utilities ducting where pipes that should have intersected instead overlapped. Correcting the geometry fixes two issues. One, the overlapping geometries would have yielded inaccurate ray tracing data where the rays would have appeared to go through multiple objects at the same time, which would not occur in reality. Second, the pipes now act as they would in reality, meaning fluids could actually flow from one pipe to the other.

In addition to the CAD model corrections, several evaluation tools were prepared under this ICA to be utilized in future analysis studies to down select a single common habitat. With the four variant CAD models brought to a level of equivalent viability, these tools (along with others) can be used to determine which variant provides the best value to NASA.

Based on work performed for the NextSTEP BAA Gateway Habitat commercial habitat solicitation, including both a physical versus virtual reality mockup evaluation performed on the NASA "smart buyer" habitat and the physical mockup evaluations performed on the mockups supplied by Lockheed Martin, Boeing, Northrop Grumman, Sierra Nevada, and Bigelow Aerospace, a Virtual Reality Questionnaire was developed for test subjects to use in a "walk-through" evaluation of each of the four Common Habitat variants in a VR environment.

Sixty-five parameters were defined for use in the VR Questionnaire. These include parameters such as, "Work surfaces in the habitat to prepare and conduct scientific research," "Separation for private human waste collection," "Translation paths maximize traffic efficiency and flow," etc. These parameters assess the habitats from the perspective of a potential crew member. Each parameter will be evaluated by three scales.

A VR Quality Scale indicates whether the Virtual Reality environment (including the imported CAD model) is of sufficient quality to enable valid assessment of the parameter. A Capability Assessment Rating determines the extent to which the parameter is an enabling or detrimental aspect of the habitat. Finally, an Acceptability Rating identifies whether or not improvements are needed to the parameter in question. Additionally, two open-ended (short response) questions will be asked about each habitat variant and three open-ended questions will be asked about the four habitats as a whole.

The ICA Funding also enabled an evaluation tool to be prepared that

Target Destinations

The Moon, Mars

Supported Mission Type

Projected Mission (Pull)

builds on recent work to define function capabilities. For instance, NASA-STD-3001 includes a requirement to provide "private quarters" for missions greater in length than 30 days, but there are no standards to define what constitutes a "private quarters." Functional capabilities identifies a function of private habitation, but then defines in a matrix various capabilities that may or may not be present in a given spacecraft (e.g. auditory separation, radiation protection, sleep accommodation, etc.). Functional Analysis Matrices were developed for 15 work and habitation functions: EVA Operations, Exercise, Group Socialization and Recreation, Human Waste Collection, Hygiene, Logistics, Maintenance and Fabrication, Meal Consumption, Meal Preparation, Medical Operations, Mission Planning, Private Habitation, Robotics and Teleoperation, Scientific Research, and Spacecraft Monitoring and Commanding. Each matrix defines a series of capabilities associated with its specific function and incorporates an Acceptability Scale for a Subject Matter Expert to rate the acceptability of that particular capability within the Common Habitat variants.

The data points in the VR Questionnaire and the Functional Analysis Matrices will enable relative scores to be calculated for each Common Habitat variant. Other analysis tools remaining as forward work include crew time assessment, logistics analysis, science productivity analysis, maintenance capacity analysis, contingency responsiveness analysis, and radiation exposure analysis.

This project was elevated to TRL 2 with the peer-reviewed publication of the paper, "Opportunities and Challenges of a Common Habitat for Transit and Surface Operations," which documented work performed in the summer of 2018 and was presented at the 2019 IEEE Aerospace Conference. The student creation of four common habitat variants that were subsequently refined under the funding of the 2019 ICA as previously described yielded sufficient documented description of the concept and addressed feasibility and benefit, meeting the exit criteria to move beyond TRL 2 and into TRL 3. While the framework for analytical studies were developed under the ICA funding, the funding was not sufficient to enable those studies to be performed, thus the project's final technical maturity is firmly within TRL 3.

Forward work includes eight analyses to compare the four Common Habitats to determine which variant provides the best value for human space exploration: Crew Time Assessment, Logistics Analysis, Function Capabilities Analysis, Science Productivity Analysis, Maintenance Capacity Analysis, Contingency Responsiveness Analysis, Radiation Exposure Analysis, and Virtual Reality Questionnaire. Following the down-select of a single Common Habitat, additional forward work includes design modifications based on the aforementioned analyses and additional subsystems and crew systems design maturity. The resulting habitat will then be compared with recent design concepts for Mars transit habitats, lunar surface outposts, and Mars surface outposts.

Closeout Documentation

Technology Showcase Poster - Common Habitat for Long Duration Transit and Surface Operations *(https://techport.nasa.gov/file/38076)*