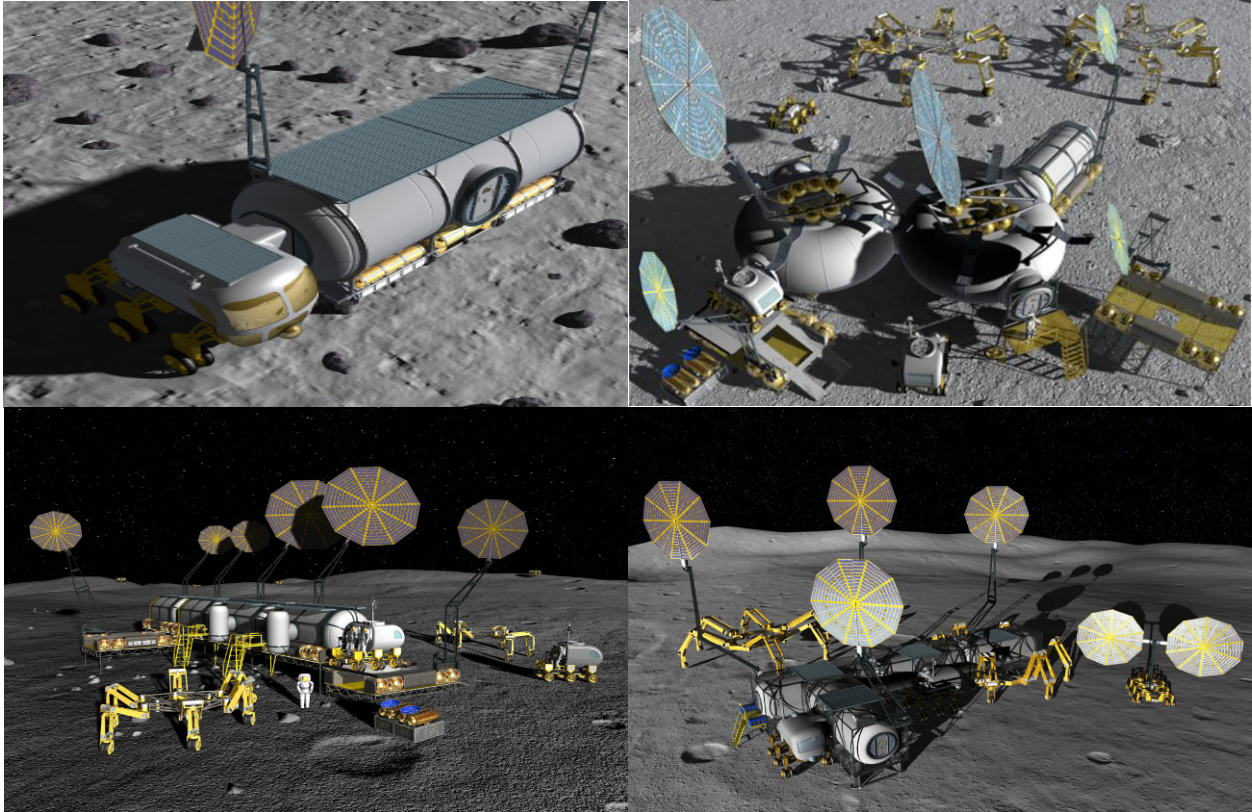


2009 JSC Biennial Research and Technology Report
National Aeronautics and Space Administration
JSC Focused Investment Group
Surface Habitat Systems



*Kriss J. Kennedy, Surface Habitat Systems FIG Lead
Johnson Space Center*

*Systems Architecture & Integration Office
Engineering Directorate*

Submitted: January 16, 2009

The Surface Habitat Systems (SHS) Focused Investment Group (FIG) is part of the National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC) effort to provide a focused direction and funding to the various projects that are working on human surface habitat designs and technologies for the planetary exploration missions. The overall SHS-FIG effort focuses on directing and guiding those projects that: 1) develop and demonstrate new surface habitat system concepts, innovations, and technologies to support human exploration missions, 2) improve environmental systems that interact with human habitats, 3) handle and emplace human surface habitats, and 4) focus on supporting humans living and working in habitats on planetary surfaces. The activity areas of the SHS FIG described herein are focused on the surface habitat project near-term objectives as described in this document. .

The SHS-FIG effort focuses on mitigating surface habitat risks (as identified by the Lunar Surface Systems Project Office (LSSPO) Surface Habitat Element Team; and concentrates on developing surface habitat technologies as identified in the FY08 gap analysis. The surface habitat gap assessment will be updated annually as the surface architecture and surface habitat definition continues to mature. These technologies are mapped to the SHS-FIG Strategic Development Roadmap. The Roadmap will bring to light the areas where additional innovative efforts are needed to support the development of habitat concepts and designs and the development of new technologies to support of the LSSPO Habitation Element development plan. Three specific areas of development that address Lunar Architecture Team (LAT)-2 and Constellation Architecture Team (CxAT) – Lunar habitat design issues or risks will be focused on by the SHS-FIG. The SHS-FIG will establish four areas of development that will help the projects prepare in their planning for surface habitat systems development. Those development areas are the 1) surface habitat concept definition, 2) inflatable surface habitat development, and 3) autonomous habitat operations, and 4) cross-cutting / systems engineering. In subsequent years, the SHS-FIG will solicit a call for innovations and technologies that will support the development of these four development areas. The other development areas will be assessed yearly and identified on the SHS-FIG's Strategic Development Roadmap. Initial investment projects that are funded by the Constellation Program Office (CxPO), LSSPO, or the Exploration Technology Development Projects (ETDP) will also be included on the Roadmap. For example, in one or two years from now, the autonomous habitat operations and testbed would collaborate with the Integrated Systems Health Management (ISHM) and Automation for Operations ETDP projects, which will give the surface habitat projects an integrated habitat autonomy testbed to test software and systems.

The SHS-FIG scope is to provide focused direction for multiple innovations, technologies and subsystems that are needed to support humans at a remote planetary surface habitat during the concept development, design definition, and integration phases of that project. Subsystems include: habitability, lightweight structures, power management, communications, autonomy, deployment, outfitting, life support, wireless connectivity, lighting, thermal, etc.

The SHS-FIG identifies technology gaps and tracks key activities at multiple NASA Centers onto the Roadmap. This effort will help leverage selected work underway in the CxPO, LSSPO, and the ETDP. The SHS-FIG will leverage projects, participants and subject matter experts (SME) from the Ames Research Center (ARC), Glenn Research Center (GRC), Goddard Space Flight Center (GSFC), Langley Research Center (LaRC), Marshall Space Flight Center (MSFC), Kennedy Space Center (KSC), Johnson Space Center (JSC), Jet Propulsion Laboratory (JPL), national labs, and universities (to be determined) as appropriate.

FY08:

1. SHS_FIG Development
 - a. SHS Technology Gap Assessment
 - b. SHS-FIG Roadmap Definition
 - c. FY09 SHS-FIG Plan
2. Concept Definition & Validation:
 - a. Horizontal cylinder diameter evaluation
 - b. Monolithic Habitat - internal architecture evaluation
 - c. Concentric Torus Inflatable Monolithic Habitat: Subsystems Integration & Utilities Distribution
3. Inflatable Habitat Development
 - a. Inflatable Habitat Concept Definition
 - b. Build and Test a Large Port in an Inflatable structure
 - c. Structural Definition: Build and Test the Damage Tolerance of the Inflatable Restraint Layer
 - d. IPP Antarctica Inflatable Habitat Demonstration & Evaluation
4. Habitat Autonomy Development
 - a. Virtual Testbed
 - b. Intelligent Software Development
 - c. Physical Testbed Development

FY09 Surface Habitat Focus Areas and Projects:

1. SHS_FIG Development
 - a. Manage SHS FIG, Reviews, Steering Committee
 - b. Call for Surface Habitat Systems Innovations and Technologies, Award Projects
 - c. SHS Technology Gap Assessment Updates
 - d. SHS-FIG Roadmap Definition Updates
 - e. FY10 SHS-FIG Plan
 - f. Education Outreach & Public Engagement
2. Concept Definition & Validation:
 - a. Lunar Wet-Bath: Concept Development and Evaluation
 - b. CxAT-Lunar Core Habitat Mockup evaluation (not TIPT/FIG Funded)
 - c. Torus Inflatable Habitat: Subsystems Integration & Utilities Distribution (not TIPT/FIG Funded)

3. Inflatable Habitat Development
 - a. Inflatable Structure Hatch Integration
 - b. Inflatable Habitat Concept Definition (not TIPT/FIG Funded)
 - c. Mid-Expandable Engineering Unit (not TIPT/FIG Funded)
4. Autonomous Habitat Operations Development
 - a. Habitat Testbed
 - b. Distributed Computing Architecture Software For Habitat Systems
 - c. Lunar Hab Communications, Command & Data Handling System
5. Cross Cutting / Systems Engineering
 - a. Long-term Lunar Radiation Degradation Effects on Materials
 - b. Lunar Surface Systems Fire Prevention

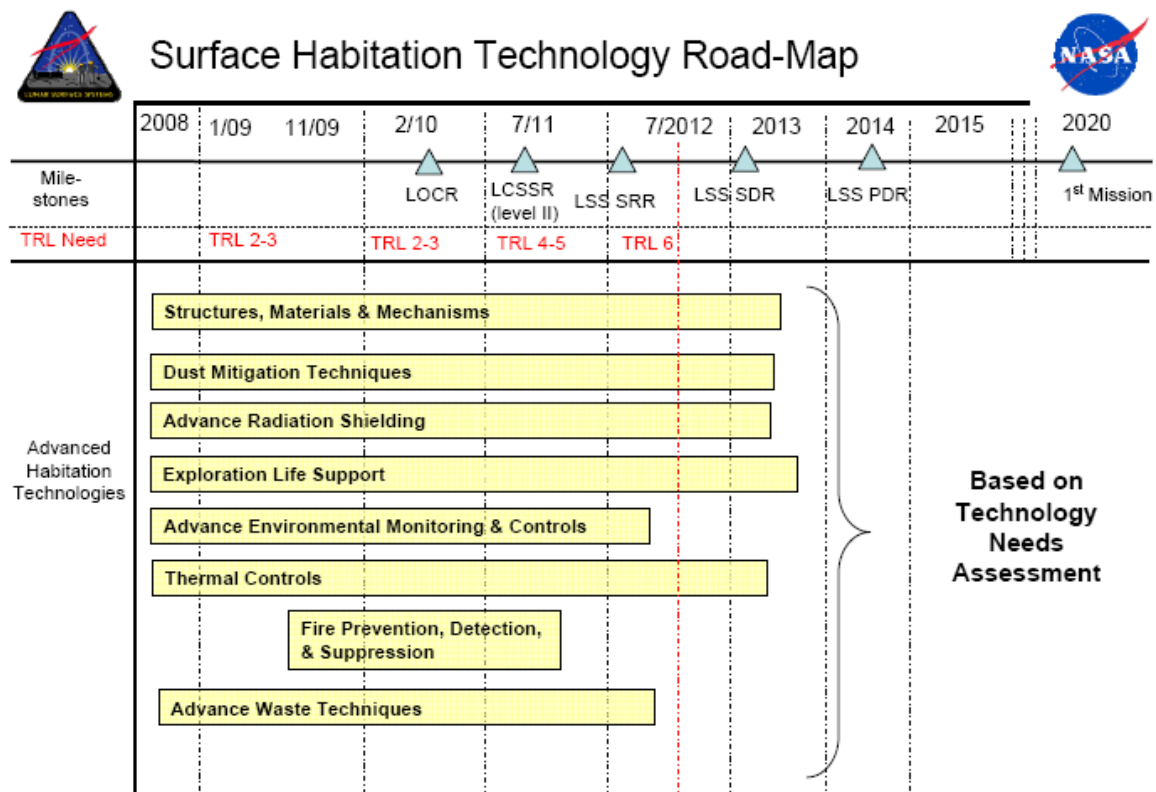


Figure 1-2 Surface Habitation Technology Roadmap

1.3.2 Surface Habitat Concept Definition & Validation

This area focused on providing surface habitat concept definition for delivery, emplacement/ deployment, outfitting, and operations for lunar operations required to make these missions more reliable, safe, and affordable. This Project produced a phased approach of developing and evaluating habitat mockups. The work will continue with higher fidelity mockups thus increasing the design knowledge and understanding of the derived requirements, validation of them and operational constraints. Evaluations will be

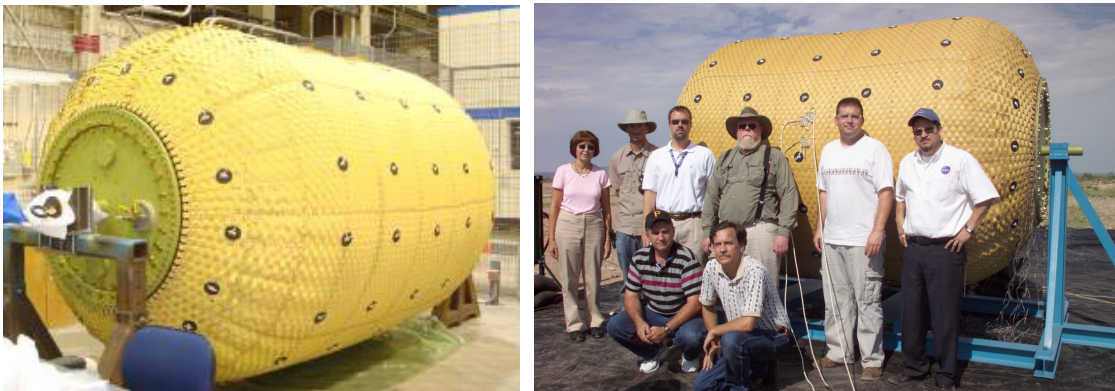
collaborative inviting diverse groups to participate including crew, management, SME, operations, science and safety. Participation includes JSC (EA3, EC, EP, ER, ES, EV, SF, KT, and DX), with leveraging of ARC, LaRC, MSFC, GRC, and ETDP efforts.



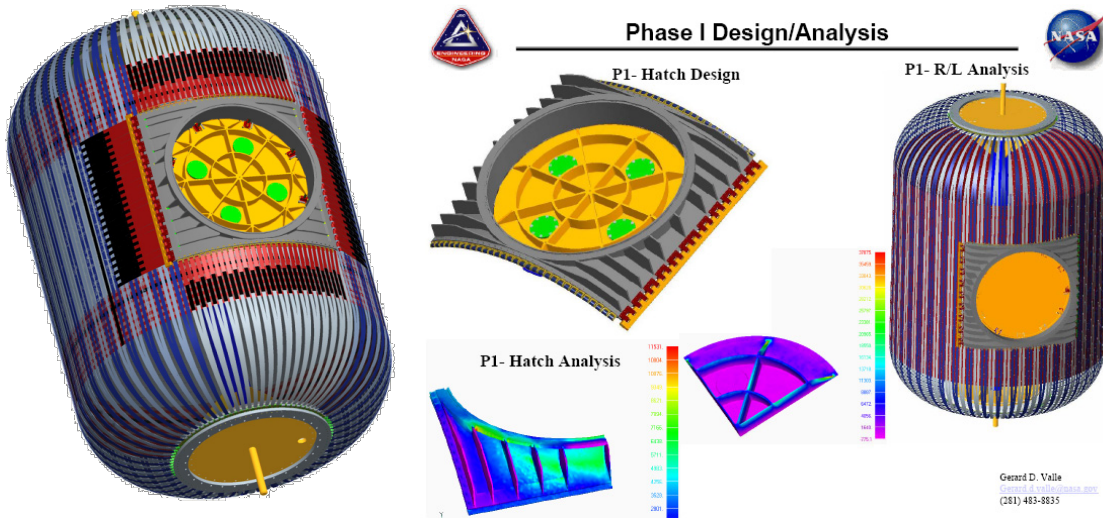
3.0 m and 3.5 m diameter Mini-Ha Mockups Evaluation

1.3.3 Inflatable Habitat Development

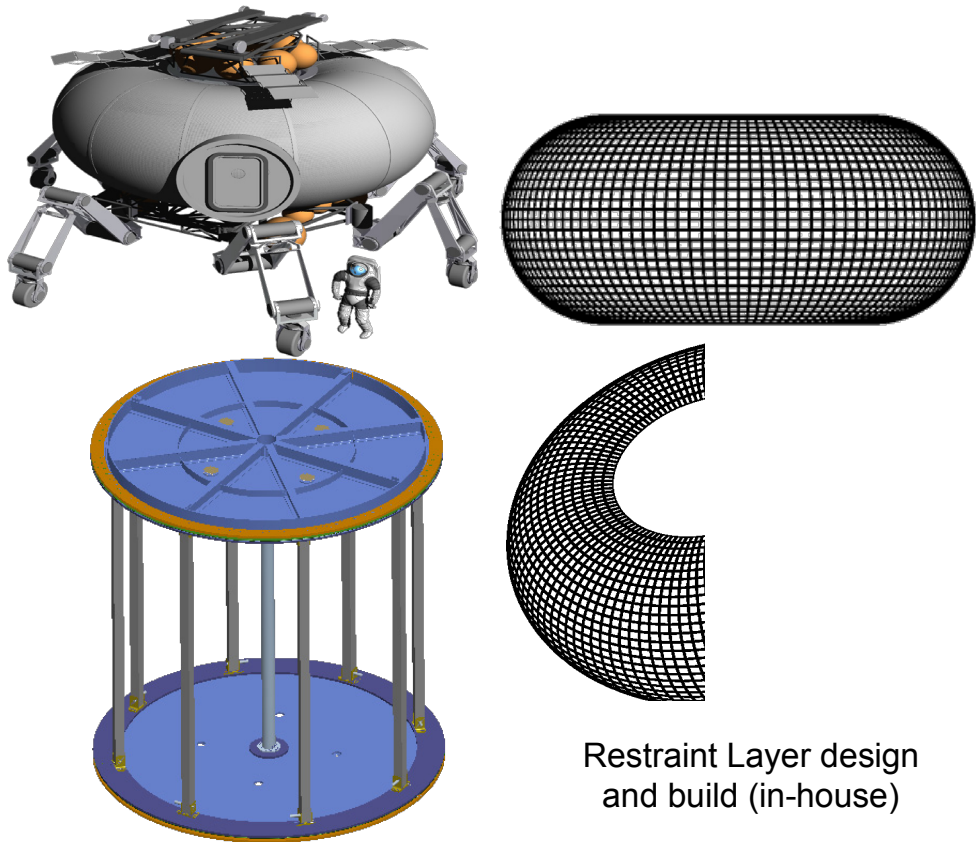
This area focused on providing surface inflatable habitat concepts for delivery, emplacement/ deployment, outfitting, and operations for lunar operations required to make these missions more reliable, safe, and affordable. This Project produced a phased approach of developing and evaluating inflatable habitats focusing on mitigating development risks to ensure that inflatable habitats remain a viable option for lunar surface systems. The work will continue with higher fidelity demonstrations and tests thus increasing the design knowledge and understanding of the derived requirements, validation of them, and operational constraints. Participation includes JSC (EA3, EC, EP, ER, ES, EV, SF, KT, and DX), with leveraging of LaRC and ETDP efforts.



Inflatable Structure: Damage Tolerance Test



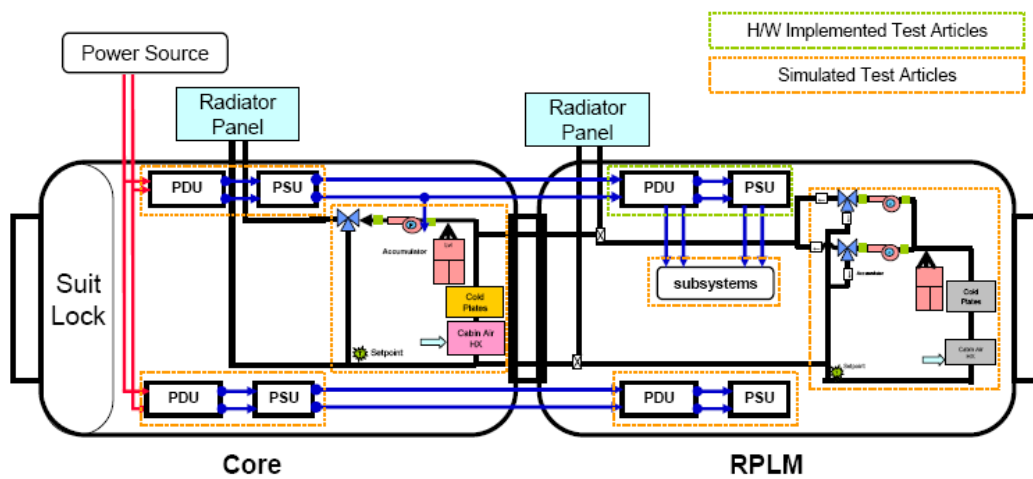
Inflatable Structure: Hatch Integration Phase 1



Phase II Full-Scale Design

1.3.4 Autonomous Habitat Operations Development

This area focused on developing surface habitat capability autonomous delivery, emplacement/ deployment, outfitting, and operations for lunar operations required to make lunar missions more productive, reliable, safe, and affordable. This Project produced a phased approach of developing and evaluating habitat autonomy by developing the intelligent software system that integrates the habitat subsystems, ISHM, sensors, wireless communication, and controls to operate the habitat autonomously with or without crew present; and the relocation and development of the physical testbed. The physical testbed and intelligent software will be integrated together to provide a habitat autonomy testbed that will focus technology developers and integrate their products for continued integrated maturation. Participation includes JSC (EA3, EC, EP, ER, ES, EV, SF, KT, and DX), with leveraging of ARC, LaRC, MSFC, GRC, and ETDP efforts.



Habitat Autonomy Development (FIG)

Hab System Management Software

Habitat Integration Testbed

1.3.5 Cross Cutting and Systems Engineering

This area focused on cross-cutting innovations and technologies and systems engineering tasks for surface habitats. This focus area will focus on mitigating Lunar Surface Habitat Systems risks as identified by the LSSPO-Surface Habitat Element Team. Enclosed is a notional list of these tasks

- Sensor commonality technologies and methods
- Weight Reduction Strategies: e.g. reduce wires/connectors and associated weight
- Safety & Hazards related technologies
- Structural degradation of materials due to the lunar environment
- Advanced Habitat Composites Structures Concepts
- Advanced Habitability
- High Fidelity Analysis Models and Tools
- IVA Crew Work Index system
- Light-Weight Docking Systems
- Lunar Environmental Protection Integration (Radiation, Regolith/Dust, Thermal,
- Surface Element Mating Mechanisms and Hatch Integration
- Airlock and Suitlock Systems Concepts & Integration
- Logistics and Supportability Systems. Packaging, Reuse, multi-functional





Material Flammability Testing

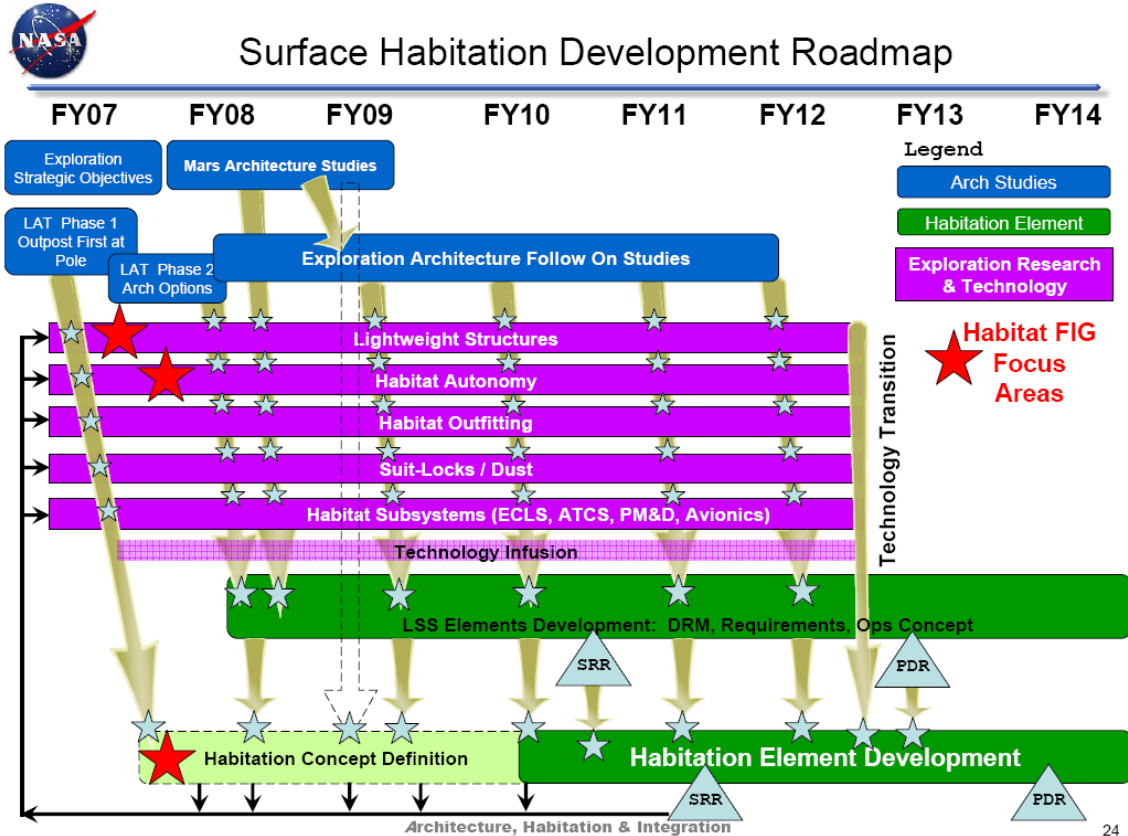


Figure 2-1 Surface Habitation Top-Level Development

This project will provide the opportunity for a One-NASA approach by offering participation and collaboration with other NASA Centers, National Labs, industry and universities. Participation may include the concept definition and mockup development with LaRC, MSFC, JPL, and several universities to be named later. Inflatable Habitat development will include the collaboration via Innovative Partnership Program with industry and LaRC. The Habitat Autonomy & Testbed development will include several ETDP technology projects including, but not limited to, Exploration Life Support, Active Thermal Control, Intelligent Systems Health Management (ISHM), Avionics, sensors, Automation for Operations, and several corresponding NASA centers.

FY09 Hab FIG Projects

The Habitat FIG projects selected FY09 are grouped the four hab FIG focus areas. Seven projects were selected based on the solicitation, review, scoring, and ranking by the SHS-Hab Steering Committee, table 2-1. The review criteria was included as part of the solicitation process and weighted accordingly. A brief description of each project is provided herein.

Table 2-1 Surface Habitat Systems FIG FY09 Projects

WBS	Hab_FIG_Plan- FY09
1.0	Hab FIG Management
2.0	Habitat Concept Definition & Validation
2.1	Lunar Wet-Bath: Concept Development and Evaluation
3.0	Inflatable Habitat Development
3.1	Expandable Structure/ Hatch Integration
4.0	Autonomous Habitat Operations
4.1	Habitat Testbed (HaT)
4.2	Distributed Computing Architecture Software For Habitat Systems
4.3	Lunar Hab Communications, Command & Data Handling System
5.0	Cross Cutting / Systems Engineering
5.1	Long-term Lunar Radiation Degradation Effects on Materials
5.2	Lunar Surface Systems Fire Prevention

2.2.1 Lunar Wet-Bath

Objective:

Find a viable solution to the unique challenges that come with combining waste, hygiene, and shower functions into a single compartment.

Scope:

Design, mockup, and evaluate compact wet-bath concepts (applicable to any Lunar Habitat architecture) that minimize volume and mass, preclude the buildup of mold and mildew, facilitate cleaning, and combine the functionality of a waste compartment, hygiene compartment, and shower.

Anticipated Outcomes:

A final report will be delivered with findings and recommendations that can be utilized to develop requirements, design guidelines, and a next generation wet-bath design.

Scope and Relevance

- Design, mockup, and evaluate compact wet-bath concepts (applicable to any Lunar Habitat architecture) that minimize volume and mass, preclude the buildup of mold and mildew, facilitate cleaning, and combine the functionality of a waste compartment, hygiene compartment, and shower.
 - Addresses LSS Habitat Focused Area 1 (subsystem packaging, mockup evaluations, deployable internal systems); Area 2 (crew accommodations packaging and deployment); Area 3 (waste & hygiene systems integration); Area 4 (weight reduction strategies, advanced habitability)
- Relevance and Value to LSS Habitat:
 - Innovative, validated wet-bath design concepts will help derive requirements and design guidelines for Lunar Habitat waste management,

hygiene, housekeeping, maintenance, and preservation of Net Habitable Volume – and could be evolved into a next generation design.

- Current TRL = 1 [basic principles observed and reported]

Infusion and Value

- Credible Long-Term Infusion Strategy = Wet-Bath project deliverables are applicable to any habitat architecture - will help derive meaningful requirements and design guidelines - and provide a jumping off point for a next generation design.
- Value to LSS-Habitation = Introducing innovation and creative wet-bath design solutions with the goal of minimizing mass and volume, preserving crew time (facilitating use, cleaning, and maintenance), and precluding the buildup of mold and mildew .
- Return-on-Investment = Final report will include findings and recommendations that can be utilized to develop future requirements, design guidelines, and a next generation wet-bath design.
- Education Outreach and Public Engagement strategy = HDC plans to leverage relationship with Rhode Island School of Design and integrate their winter session interns into the design process.

Leveraging and Collaboration

- The project proposes leveraging
 - Funding: SF3's Habitability Design Center (HDC) and Usability Testing and Analysis Facility (UTAF) have collaborated on 13 similar 'design-mockup-evaluate-report' projects in the past year – and have found a number of efficiencies in carrying these projects out cost-effectively and on-time. [see 'Additional Space' for some examples of collaborations]
 - Research: HDC and UTAF have direct access to SME's of current waste and hygiene systems here at JSC - and operational habitability observations of the current systems collected through crew debriefs.
 - Knowledge: HDC and UTAF have extensive experience and knowledge with design and evaluation of past and current waste and hygiene systems – and the design and evaluation of future concepts.
- The project proposes collaboration
 - Between HDC, UTAF, SME's on NASA Waste and Hygiene systems, Experts on commercially available Waste and Hygiene systems.
 - With Astronauts and Waste and Hygiene SME's and Stakeholders – utilizing them as subjects during the evaluation phase

Product

- Technical Approach = (1) Analyze existing systems; (2) Characterize desired attributes; (3) Develop and refine wet-bath design concepts; (4) Evaluate concepts; (5) Build low-fidelity mockup; (6) Coordinate and perform evaluation of mockup and identify design deficiencies; (7) Document findings into final report
- Objective is to find a viable solution to the unique challenges that come with combining waste, hygiene, and shower functions into a single compartment.

- Deliverables will include a low-fidelity volumetric mockup (integrating system volume data provided by NASA SMEs) that would demonstrate innovative design solutions; and a final report detailing evaluation of the unit, its usability, and deficiencies.
- Anticipated Outcomes = a final report with findings and recommendations that can be utilized to develop requirements, design guidelines, and a next generation wet-bath design.
- Completed TRL = 3 ["proof-of-concept" validation of the applications/concepts formulated]

2.2.2 Expandable Structure Hatch Integration

The objective of the Expandable Structure Hatch Integration Phase II is to design, analyze, fabricate, and integrate a size-equivalent hatch to the Phase I hatch into a full scale inflatable torus module. In addition, this phase will involve the preparation of Phase III hybridization.

Phase II Objectives are summarized below:

- [1] Design, fabricate, and integrate a hatch into the full scale inflatable torus module.
- [2] Scar the internal core longerons and hatch frame for a future addition of a hatch deployment system in Phase III.
- [3] Inflate the module in a 1-G environment.
- [4] Inflate the module to 11.25 psid (Lunar and Mars surface pressures 9.0 psig * 1.25 Proof).
- [5] Compare hatch frame and bulkhead clevis strain measurements with analytical predictions.

Scope and Relevance

- Scope
 - Addresses LSS Habitat Focused Area #2- Inflatable Habitat Development (Large Hatch Integration/ Packaging and Deployment)
- Relevance and value to LSS Habitat:
 - The Phase II test article is an engineering development unit of the LSS Trade Study (TS-1) inflatable torus Habitat option.
 - Expandable Structure design, analysis, hatch integration, and testing to Lunar surface pressures will benefit LSS
 - Customer Supplier Agreement (CSA) with LSS identifies this technology as a “significant benefit” and gives the LSS “endorsement” of this development.
- This development will advance the design, analysis and testing of inflatable structures, develop and verify the integration of a large scale hatch penetration.
- Current Technology Readiness Level (3)

Infusion and Value

- This project is a first order engineering development that directly feeds into the LSS architecture.
- ESAS has identified lightweight structures as a critical need.
- CSA w/ LSS endorses this project and identifies it as a significant benefit.
- Expandable Structure/Hatch Integration and Mating feed into the Expandable Structure Roadmap which directly feeds into the Habitat Roadmap.
- Education Outreach and Public Engagement efforts have already been demonstrated with the Inflatable Antarctic Habitat and will continue with the Damage Tolerance Test (DTT) and Inflatable Structure/Hatch Integration and Mating.

Leveraging and Collaboration

- The project proposes leveraging
 - FY08 IPP Seed Funding will support this effort
 - Hatch frame (s.g.), core (s.g.) and R/L (photogrammetry) will be instrumented to correlate analytical models.
 - Internal Partnership with LaRC, JSC ES, and JSC EA3
 - Phase I Hatch will be fabricated by Boeing Phantom Works under a Space Act Agreement (SAA)
 - Will seek a continued partnership with Boeing for fabrication of the Phase II Hatch under a Cooperative Agreement (CA)
 - May seek partnership with either Thin Red Line, ILC Dover, Bigelow Aerospace, or Oceaneering for fabrication of the bladder/ restraint layer assembly.
 - Completion of this phase will enhance JSC's knowledge in the design, analysis, integration, and testing of inflatable structures

Product

- Phase II Expandable Structure/ Hatch Integration- Integrate 40" diameter hatch into a full scale inflatable TS-1 torus habitat
- Integrated unit will be proof load tested to Lunar Surface Pressures (9 psid x 1.25 FS)
- Supports three phase approach with phase III mating of Phase I and Phase II modules. With proper funding Phase III can support hatch deployment and hatch mating dust mitigation techniques.
- Will seek Phase III funding from LSS, ETDP, and alternate funding sources.
- Completed TRL & rational (post Phase II): TRL 5-6; Pressurization testing on a full-scale inflatable habitat with an integrated hatch.

Surface Hab Focus Investment Group

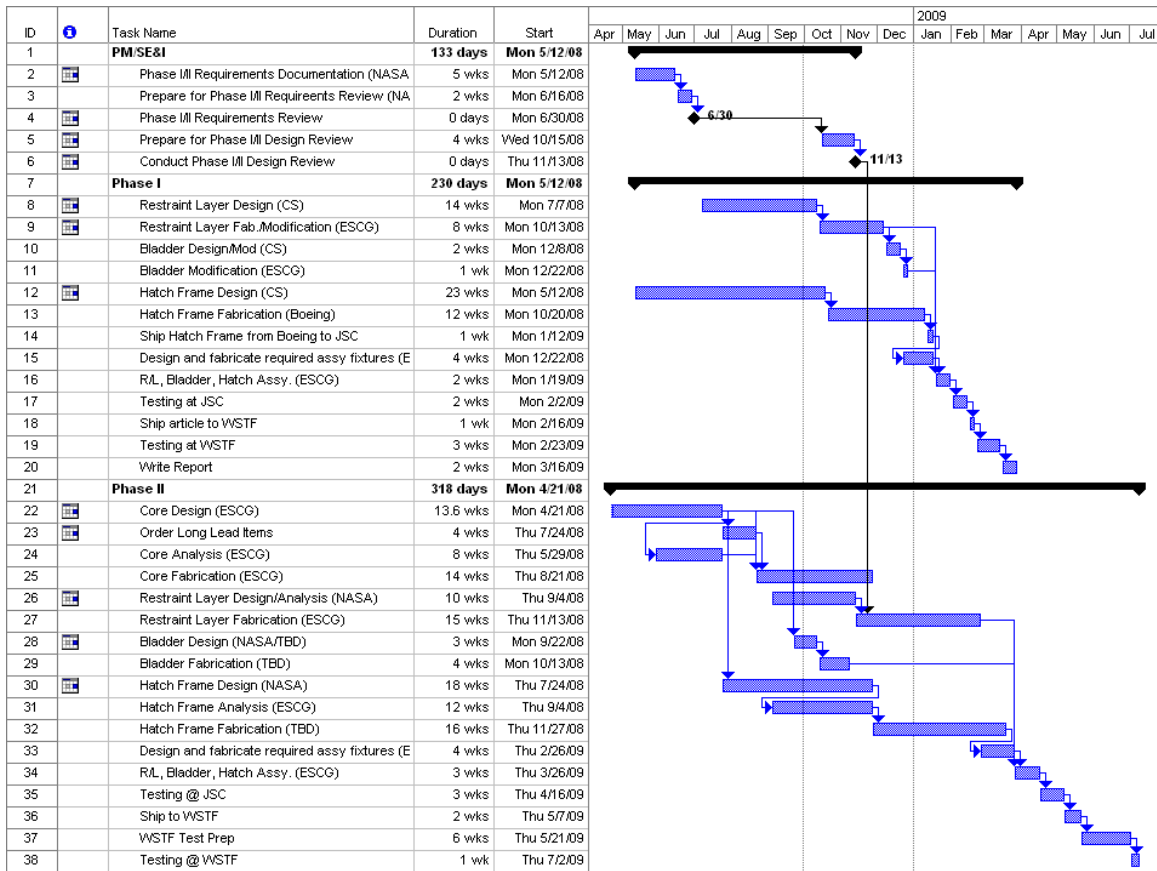


Figure 2-4 Hatch Integration Project Schedule

2.2.3 Habitat Testbed

This project will develop the capabilities of the Lunar Surface Systems (LSS) Habitat Testbed as a working nucleus of major subsystems including, but not limited to, Hab structure, Hab ECLSS, Hab power systems, Hab communication systems, rover and support systems, EVA systems, etc. This test bed will be used to perform integrated testing and operations scenarios.

Scope and Relevance

- Scope
 - Addresses LSS Habitat Focused area
 - Autonomous Habitat Operations: Hab Systems Mgmt SW (SMS), Habitat Integration Test bed, Power Mgmt & Dist, Wireless Hab Comm Networks – Test bed integration, ECLSS Integration, ATCS Integration, Lunar Surface Hab Sim SW to validate requirements and automation strategies
 - Cross Cutting/Systems Engineering: Sensor commonality technologies and methods, Safety and Hazard related technologies
- Relevance and value to LSS Habitat:

- This project provides a method to develop and test Surface Hab Autonomy and System Management Software and a point of integration for other systems
- This project will develop the capabilities of the HaT as a working nucleus of major subsystems to directly support Surface Habitat Autonomy and Habitat SMS
- Current Technology Readiness Level (TRL) 3

Infusion and Value

- The Habitat Test bed will be a foundation for developing and validating LSS Habitat systems.
- The project has value to LSS-Habitation as a central integration point for major Hab subsystems.
- Return-on-Investment is credible because HaT will be able to demonstrate its capabilities as a test bed flexible enough to allow multiple technology tests.
- The Habitat Test bed will be a visible beacon for future plans of lunar missions to the Center and the public.

Leveraging and Collaboration

- The project proposes leveraging
 - Seek funding from IR&D
 - CxP Compliance – tools, C3I I/F standards
 - Leverage existing Power Line Communication (PLC) research (EV). Leverage existing X-38 PMAD hardware for habitat power system (EP) Programmable Load Banks (PLB) and CEV Thermal Control System (TCS) hardware (EC)
- The project proposes collaboration
 - Collaboration with ER, EV, EP, and EA3 to design and build a closed loop system capable of integrating subsystems as prototype or simulation
 - The test bed will allow other systems to integrate into the Hab System to define and validate their Hab capabilities and further develop the LSS Habitat

Product

- Collaborate with ER, EV, EP, and EA3 to build general infrastructure of the HaT including SMS and interfaces to external systems.
- Objectives and product deliverables
 - A phased build up of the HaT - Integration of Hab structure, ECLSS, power systems, comm systems, rover and support, EVA, etc.
- Anticipated outcomes
 - Demonstration of HaT capabilities to perform Autonomous Habitat Systems Management
- Completed TRL: 5

Surface Hab Focus Investment Group

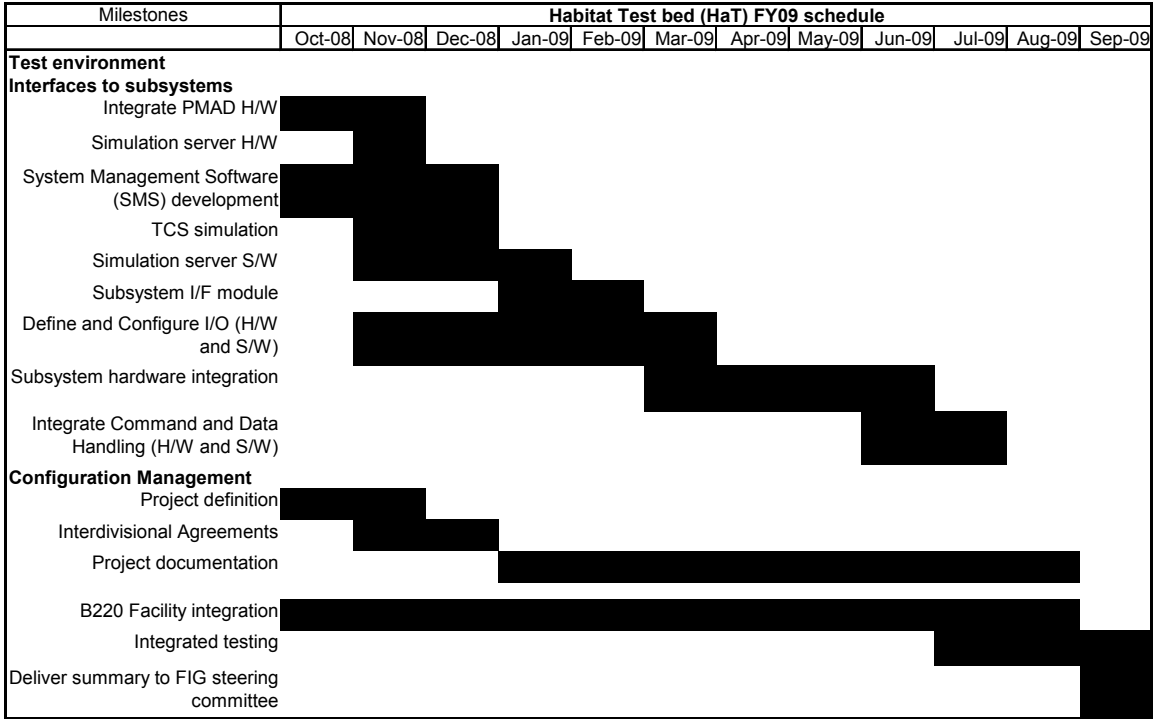


Figure 2-5 Habitat Testbed Project Schedule

2.2.4 Distributed Computing Architecture Software for Habitat Systems

Scope and Relevance

- Scope
 - Autonomous Habitat Operations (Habitat System Management Software, Habitat testbed Integration, Avionics Integration)
- Relevance and value to LSS Habitat:
 - Prototype design of habitat S/W architecture for a distributed computing architecture
 - Determine how to use ARINC 653 compliant RTOS functionality on distributed processing environment
 - Determine best S/W I/F with low power computing elements
- Current Technology Readiness Level: 3

Infusion and Value

- Report results and S/W design recommendations to LSS Habitat Design team.
- Provides early determination of impacts (advantages and challenges) of probable CxP legacy program direction to utilize trusted ARINC 653 compliant S/W implementations
- Provides CxP program with additional evaluation of alternative ARINC 653 compliant RTOS

Leveraging and Collaboration

- ER division includes the Software Architect role for the Orion Project. We will utilize this technical expert as a technical consultant for addressing known challenges with a space/time partitioned architecture

- Potential leveraging of engineering analysis testbed experience and techniques (Kedalion)
- Collaboration with Orion and Ares Software Architects

Product

- Technical approach: Design, implement and test a distributed computing software architecture based on the use of a ARINC 653 RTOS, several compatible PC-104 computers and at least one FPGA w/ serial I/F for control (e.g., TCS). Testing include one embedded computer failure and subsequent function redistribution to other computers.
 - Design a ARINC 653 compliant software architecture, exposing the unique distributed space/time computational environment of Habitat (Orion and Ares are centralized not distributed)
 - Upgrade PC104's: VxWorks 653, compat. PPC CPU set.
 - Design and implement network integration unit (NIU)
 - Rehost current HaT S/W to upgraded computers
 - Redesign and implement to handle S/W function redistribution upon failure
 - Integrate FPGA with testbed via NIU
 - Test and evaluate results
- Objectives and product deliverables:
 - Determine S/W partitioning via ARINC 653
 - Address risks and challenges unique from Orion and Ares, including reliability and low power moding
 - Final Report on results
- Anticipated outcomes: Results will address requirements for habitat S/W on distributed computing architecture.
- Completed TRL & rational: 5

2.2.5 Lunar Hab Communications, Command & Data Handling System

Scope and Relevance

- Scope
 - Habitat Systems Integration Testbed
 - Avionics Integration
- Relevance and value to LSS Habitat:
 - Computer system that controls the Lunar Hab Environmental and Operations Controls as well as the Communication system on the lunar surface supporting the Habitat Testbed activity.
- This system will integrate all the active subsystems within the habitat and allow the testing of system management software on the integration activities.
- Current Technology Readiness Level (TRL - 4)

Infusion and Value

- Infusion will be accomplished by integrating the C&DH design into the Habitat Testbed and actively supporting the habitat simulations and integration activities.

- The C&DH system is paramount to the integration of the actively controlled components of the habitat design.
- Return-on-Investment will be evident in the early risk mitigation of integrating the Habitat in early simulations. Any apparent risk can be mitigated early on.
- Outreach will be accomplished by encouraging the involvement of universities and colleges to test and expand the capabilities of the Habitat Testbed. This involvement will be through ESMD, and State of Texas Educational Grants.

Leveraging and Collaboration

- The project proposes leveraging the following:
 - Time Triggered Gbit Ethernet Network work being developed for CEV, as a basis for critical timed events for Lunar habitat.
 - a. EV has purchased a beta TTGb test kit for evaluation purposes of the CEV deterministic network architecture. The results of this work can be leveraged by the Hab project.
 - b. Integrate redundant computing structures, and hardware architecture from the CEV C&DH and D&C to Lunar Habitat. This will facilitate the possibility of Common Services Assembly (CSA) which will allow reconfiguring of Lunar Lander avionics and controls to be re-utilized for the Lunar Habitat.
 - Work with developers of Common Service Assembly to derive architectures that will easily migrate from Lander to Hab.
- The project proposes collaboration
 - JSC/ER will provide software for Hab. Command and Control
 - JSC/EC & Glenn Research Center- Suit Integration with Hab network and com.
 - JPL- Integration with Chariot, rovers and other robotics

Product

- Technical approach
 - 1) To design and build an early version of the C&DH system to support early integration testing in the Habitat testbed
 - 2) To perform trade studies, analysis, design and build a next generation C&DH system that is consistent with the system design being used to scope the LSS design.
 - Deliverables:
 - 1) Prototype computer system with interfaces to support the Habitat Testbed.
 - 2) Next generation C&DH system prototype operating in EV lab to test interfaces and software. This system will be ultimately integrated into the Habitat Testbed as an upgrade to the prototype computer system.
 - Outcomes:
 - This project is being coordinated with the CEV avionics system manager (C&DH) and will be used to ring out any risk areas in that design.
 - Completed TRL : 5

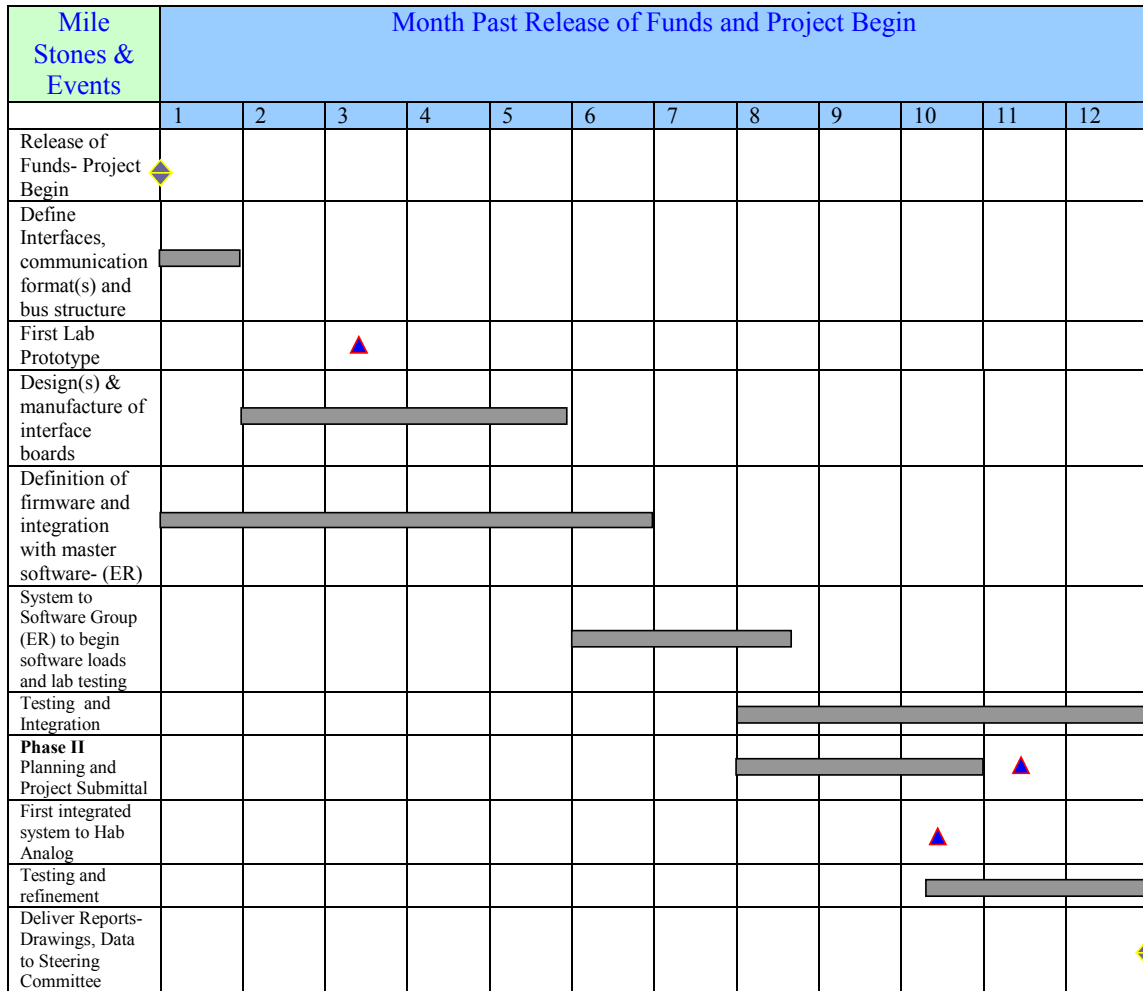


Figure 2-6 Hab C&DH Project Schedule

2.2.6 Long-term Lunar Radiation Degradation Effects on Materials

Scope and Relevance

- Scope
 - Structural degradation of materials due to lunar environment
 - Advanced habitat composite structures
- Relevance and value to LSS Habitat
 - Directly addresses technology development in structures and materials by testing new materials’ durability towards the lunar radiation environment
 - This study will advance materials for use in the habitat and develop a viable list of materials
- Current Technology Readiness Level: 2-3

Infusion and Value

- At the end of the study, a list of feasible materials for lunar habitats will be completed and there will be a greater understanding of materials’ durability within the lunar radiation environment

- This information will be infused into the habitats through materials selection throughout the design
- Education Outreach
 - Math Engineering Science Achievement (MESA) at USC → work with K-12 educationally underprivileged students and teachers
 - Presentations at USC → connection with Materials Science professor, Steve Nutt
 - Texas Space Grant Consortium

Leveraging and Collaboration

- The project proposes leveraging
 - Knowledge from current EA3 radiation analysis work
 - Knowledge and research from ES4 Materials and Processes Branch/Space Environment Effects (ES4 M&P/SEE) team – test methods, test design, and materials selection
 - Research through literature search on new materials
- The project proposes collaboration with
 - ES4 M&P/SEE –provide materials procurement, testing (pre and post radiation exposure), and analysis
 - Texas A&M cyclotron facility - perform ionizing radiation exposure
 - University of Southern California - may provide materials testing facilities, if needed

Product

- Technical approach
 - Literature search, radiation analysis, and materials selection
 - Materials exposed to simulated long-term radiation environment and aging effects
 - Materials tested pre- and post- radiation exposure to determine degradation
- Objectives – understand structural degradation of materials subjected to lunar radiation environment
- Goal – materials will meet requirements after exposure to operational environment for duration of mission
- Deliverables – test analysis results, suggested materials list, “go forward” recommendations
- Anticipated outcomes – complete any other environmental degradation testing on the final candidate materials and incorporate into habitat design; develop background for man-rating
- Completed TRL – 4, testing proves material viable

Task	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Literature search of materials													
Detailed radiation analysis													
Materials selection													
Materials Procurement													
Materials Processing/Cure													
Pre-exposure materials testing													
Radiation Exposure													
Post-exposure materials testing													
Quarterly Review with SHSC													
Data Analysis													
2nd Materials Procurement													
2nd Materials Processing/Cure													
2nd Pre-exposure materials testing													
Quarterly Review with SHSC													
2nd Radiation Exposure													
2nd Post-exposure materials testing													
2nd set of data analysis													
Quarterly Review with SHSC													
Final Report													
Final Review													

Figure 2-7 Lunar Radiation Degradation Effects on Materials Project Schedule

2.2.7 Lunar Surface Systems Fire Prevention

This area will focus on the development of the SHS-FIG definition, operating procedures,

Scope and Relevance

- Scope
 - To develop cross-cutting improved safety and hazard evaluation of fire risk at elevated oxygen atmospheres.
 - The oxygen atmosphere for the lunar lander a maximum oxygen concentration of 34%. The atmosphere of lunar habitation has not been established, but is likely to be at a similar oxygen concentration.
 - Preliminary results show that there is a trend to negative margins of safety on normal gravity flammability limits relative to microgravity flammability limits.
- Current Technology Readiness Level (TRL - 3)

Infusion and Value

- An improved understanding of the material flammability thresholds and safety factors in ventilated microgravity and lunar environments will allow flexibility in operational design of vehicles and habitats.
- The possibility of safe operations from a flammability point of view will lessen the burden on other operations, such as pre-EVA acclimatization or possibility for quicker emergency response.

- College interns will be hired to participate in the project

Leveraging and Collaboration

- The project proposes leveraging the expertise and existing resources of both WSTF and GRC to address the issue of material flammability in lunar habitats at the proposed elevated oxygen concentrations.
- WSTF and GRC have had successful collaborations in related areas, and the proposed PI's have worked together on prior material flammability research

- WSTF will conduct the ground 1-g testing, while NASA GRC will evaluate microgravity and other variable effects.
- Data analysis will be performed jointly.

Product

- Acquire additional correlation on 1g flammability limits with actual flame behavior in microgravity and lunar gravity environments, to evaluate a factor of safety to apply to the 1g test results to ensure fire prevention on lunar missions.
- Evaluate O2 flammability limits of selected materials in ground tests at various total pressures.
- Evaluate O2 flammability limits of the same materials in spacecraft-specific environments (microgravity, lunar g levels).
- The effects of microgravity and lunar gravity, oxygen concentration, total pressure, velocity and direction, on the flammability threshold would be evaluated.
- Correlate the 1g flammability data with reduced gravity flammability data to estimate the safety factors involved when selecting spacecraft materials based on ground testing.

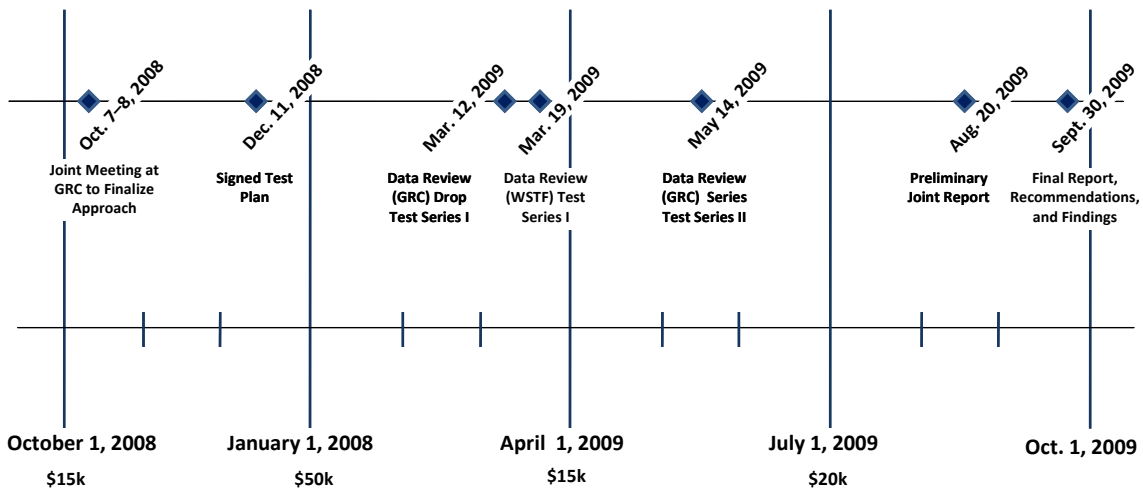


Figure 2-8 Lunar Surface System Fire Prevention Project Schedule