Deep Space Habitat Team: HEFT Phase 2 Efforts

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Human Exploration Framework Team (HEFT) Overview and Deep Space Habitat (DSH) Team Support

- HEFT was a NASA-wide team that performed analyses of architectures for human exploration beyond LEO, evaluating technical, programmatic, and budgetary issues to support decisions at the highest level of the agency in HSF planning.

- HEFT Phase I (April – September, 2010) and Phase II (September – December, 2010) examined a broad set of “Human Exploration of Near Earth Objects (NEOs)” Design Reference Missions (DRMs), evaluating such factors as elements, performance, technologies, schedule, and cost.

- At end of HEFT Phase 1, an architecture concept known as DRM 4a represented the best available option for a full capability NEO mission.
  - Within DRM4a, the habitation system was provided by Deep Space Habitat (DSH), Multi-Mission Space Exploration Vehicle (MMSEV), and Crew Transfer Vehicle (CTV) pressurized elements.

- HEFT Phase 2 extended DRM4a, resulting in DRM4b.
  - Scrubbed element-level functionality assumptions and mission Concepts of Operations.
  - Habitation Team developed more detailed concepts of the DSH and the DSH/MMSEV/CTV Conops, including functionality and accommodations, mass & volume estimates, technology requirements, and DDT&E costs.

- DRM 5 represented an effort to reduce cost by scaling back on technologies and eliminating the need for the development of an MMSEV.
HEFT Architecture Analysis Cycle Approach (Iterative)

DSH Team Support

Technical Design Reference Mission

Investment strategy

Element catalog

Non-optimized cost rollup through 2025

Integrated program schedule & flight manifest

Schedule and cost to develop and operate each element
The Deep Space Habitat provides habitation for crew members for long duration missions. The habitat has connection adapters in order to dock with the SEV, CTV and the propulsion unit(s). There is an internal bulkhead 2m from the aft dome with airlock services to act as a contingent airlock.
Ground Rules & Assumptions For DSH

◆ **Habitat Structure & Mechanisms**
  - Metallic, cylindrical habitat
  - 115 m³ pressurized volume
  - Secondary structure sized as 2.46 kg/m² of habitat structural area
  - Integration structure 2% of habitat gross mass
  - 4 windows, 1 exterior hatch, 4 docking mechanisms

◆ **Protection**
  - 1 ¼” MLI covering external habitat surface for passive TCS
  - Cargo – Radiation Protection
  - 2” water-wall covering crew quarters only
    - Water included

◆ **Power**
  - 2 photovoltaic (3-junction GaAs) arrays each generating 7.5 kW EOL
  - EPCU 28 Vdc PMAD (92% efficient)
  - 3 Li-ion batteries

◆ **Avionics**
  - Leverage CTV for CC&DH, GN&C and communications

◆ **Thermal Control**
  - External fluid loop for heat acquisition using ammonia
  - Internal fluid loop for heat acquisition using 60% prop glycol/water
  - 6.5 kW heat acquired from MM cabin & avionics rejected using ISS-type radiators w/ 10 mil Ag-teflon coating

◆ **Crew Accommodations**
  - Standard suite for 180-360 day deep space transfer (ref. Human Spaceflight Mission Analysis & Design)
  - sink, freezer, microwave oven, hand/mouth wash faucet, washer & dryer, 2 vacuums, laptop, trash compactor, printer, hand tools & accessories, test equipment, ergometer, photography equipment, exercise equipment, treadmill, table

◆ **Reserves**
  - Margin growth Allocation - 20% of basic mass
  - Project Manager’s Reserve - 10% of basic mass

◆ **Internal bulkhead with airlock services**
  - For contingent EVAs after NEO ops
**EXAMINE = EXploration Architecture Model for IN-space and Earth-to-orbit**

- An architecture modeling framework developed at NASA LaRC
- Contains a collection of parametric performance and sizing tools and algorithms that enable users to model a variety of architectural element types
- Originated from a collection of existing NASA spacecraft sizing toolsets including JSC’s Envision, MSFC’s MER database, and JSC’s ALSSAT
- Provides detailed architecture element-specific sizing in mass, volume, and power for Levels 1, 2, and (occasionally) 3 detail
- Also provides a framework for integrated sizing across the architecture concept
- Enables trades and studies to improve designs

**DSH Team provided inputs to EXAMINE to size the DSH element, which was then integrated into the sizing of the architecture as a whole**
DSH ECLSS Assumptions for Modeling in EXAMINE (ALSSAT)

◆ **Water Management System**
- Urine Collection System: ISS
- Water Recovery System:
  - Vacuum Compression Distillation: ISS
  - Multifiltration: ISS
  - Volatile Removal Assembly: ISS
  - Ion-Exchange: ISS
- Hygiene/Product Tank: ISS
- Microbial Check Valve: ISS
- Water Quality Management: ISS
- Water Delivery: ISS

◆ **Air Management System**
- CO2 Removal: 4BMS
- CO2 Reduction: Sabatier
- O2 Generation: SPE\ISS
- Trace Contaminate Control: ISS
- Atmosphere Composition Monitoring Assembly: ISS
- N2/O2 Storage: Cryogenic
- Fire Detection/Suppression: ISS

◆ **Solid Waste Management System**
- Waste Storage
- Waste Collection Subsystem: ISS

◆ **Food System**
- Shuttle Training Menu
ECLSS Loop Closure Break-Even Assessment: Mass Mission Durations: 0-500 days

- Loop-closure equipment mass can be offset by resulting consumables savings as mission durations increase.
- Uncertainty (10-20% shown here) clouds predictions of precisely when particular approaches become most beneficial.
- For NEO-class missions (~450 days), distinguishable life cycle mass benefits begin to appear.
The model used to size the DSH was used to generate trendlines for mass, pressurized volume and habitable volume as a function of crew and duration.
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*Additional volume provided by additional elements (MSEV, CTV)*
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*Additional volume provided by additional elements (MSEV, CTV)
(DSH team provided input to Technology team to identify the technologies and research programs which must be undertaken to provide the capability required by the missions outlined in Strategies 1, 2, and 3)

<table>
<thead>
<tr>
<th>Technology Entries for HEFT II (Strategy 3 Initial Mapping): Rev 12/14/10</th>
<th>Applicable System</th>
<th>Tech Dev Element</th>
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</thead>
<tbody>
<tr>
<td>LO2/LH2 reduced boiloff flight demo (FTD-2/Cryostat)</td>
<td>X</td>
<td>CPS</td>
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<tr>
<td>LO2/LH2 reduced boiloff &amp; other CPS tech development</td>
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<td>Energy Storage</td>
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<td>Fire Prevention, Detection &amp; Suppression (for 8 psi)</td>
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<td>CTV</td>
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<td>Environmental Monitoring and Control</td>
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<td>CTV</td>
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<tr>
<td>TPS -- low speed (&lt;11.5 km/sec; Avcoat)</td>
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<td>CTV</td>
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<td>Biomedical Countermeasures Optimized Exercise (Countermeasures H/W)</td>
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<td>Biomedical countermeasures</td>
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<tr>
<td>Space Radiation Protection – Galactic Cosmic Rays (GCR)</td>
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<tr>
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<td>Crew Autonomy</td>
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<td>Mission Control Autonomy</td>
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<td>Common Avionics (Autonomous Systems)</td>
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<td>Thermal Control</td>
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<td>Robots Working Side-by-Side with Suited Crew (w/ Demos)</td>
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<td>Telerobotic control of robotic systems with time delay (w/ Demos)</td>
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<td>Mechanisms for Long Duration, Deep Space Missions</td>
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<td>NEA Auto Rendezvous, Prox Ops, and Terrain Relative Nav</td>
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<td>Dust Mitigation</td>
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<td>CTV</td>
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<td>Solar Electric Propulsion (SEP) Stage</td>
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<td>Suitport</td>
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<td>NEA Surface Ops (related to EVA)</td>
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<td>In-Space Timing and Navigation for Autonomy</td>
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<td>High Data Rate Forward Link (Flight)</td>
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<td>Ground Systems: Cryo Fluid Mgmt</td>
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<td>Ground Systems: Corrosion Detection &amp; Control</td>
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<td>Ground Systems: Wiring Fault Detection &amp; Repair</td>
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<td>Ground Systems: ISHM/FDIR</td>
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Key Technical Architecture Observations To Date

- Advanced in-space propulsion (e.g., solar electric propulsion {SEP}) is a big enabler: Reduces launch mass by 50% (factor of 2) and mass growth sensitivity by 60%
- A balance of ELVs and HLLVs is optimal for varying mission needs
- Shuttle-derived HLLV option (100t-class evolvable to ~130t for deep space, full capability missions) meets more current FOMS than other options, although out-year affordability is still a fundamental challenge for long term exploration. Alternative design analysis continues to be part of NASA’s strategy, coupled with an assessment of possible affordability initiatives.
- HLLV and crew vehicle should be a human-rated system
- ELV-only solution not optimal given all factors
- Staging at HEO or Earth-Moon L1 for deep space missions better than LEO
- Crew Transportation Vehicle (CTV) full ascent and entry capability is needed
- Additional capability, such as the MMSEV needed for EVA and robotics capability
- High reliability ECLSS is desired over fully closed loop ECLSS except for Mars missions
- In-Situ Resource Utilization (ISRU) is an enabler, particularly for surface missions
- Modularity and commonality aid key affordability FOM
### Example DRM Mission Space to Common Element Mapping

<table>
<thead>
<tr>
<th>DRM TITLE</th>
<th>Commercial LV</th>
<th>SLS - HLLV</th>
<th>MPCV</th>
<th>CPS</th>
<th>REM/SEV</th>
<th>EVA Suit</th>
<th>Lunar Lander &amp; Elements</th>
<th>DSH</th>
<th>SEP</th>
<th>Mars Elements</th>
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<tr>
<td>LEO missions</td>
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<td>HEO/GEO vicinity without pre-deploy</td>
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<td>HEO/GEO vicinity with pre-deploy</td>
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<td>Lunar vicinity missions</td>
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<td>Low lunar orbital mission</td>
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<td>Lunar surface mission</td>
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<td>Minimum capability NEA</td>
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<tr>
<td>Full capability NEA</td>
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<tr>
<td>Martian moons: Phobos/Deimos</td>
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<td>Mars landing</td>
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* MPCV entry velocity could be driven by these missions for certain targets, if selected.

**Driving:** There is something in this DRM that is "driving" the performance requirement of the element.

**Example:** Entry speeds for MPCV driven by NEO DRM.

**Required:** This element must be present to accomplish this DRM.

**Example:** SEV required for Full Capability NEO, but not for other DRMs

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Flexible mission space analysis validates that several fundamental building blocks, including the SLS and MPCV, are needed to support multiple destinations.
Key Takeaways

◆ The Capability-Driven Framework:
  • Is the most viable approach given the cost, technical and political constraints
  • Provides a foundation for the agency’s needed technology investments
  • Enables common elements to support multiple destinations
  • Provides flexibility, greater cost-effectiveness and easy integration of partnerships

◆ NASA-wide transformational change is required to significantly improve affordability and meet budget constraints

◆ Beyond LEO destinations require:
  • Development of a HLLV and MPCV as the key core elements
  • An investment in advanced space propulsion and long-duration habitation (including high-reliability ECLSS and radiation protection)
  • Robotic precursors for human near-Earth asteroid mission

◆ Authorization Act-driven HSF architecture still presents a fundamental forward challenge to close on budget and schedule

◆ Partnerships are imperative to enabling our exploration goals

◆ Compelling, overarching mission goals are necessary to justify high-risk human spaceflight exploration beyond LEO