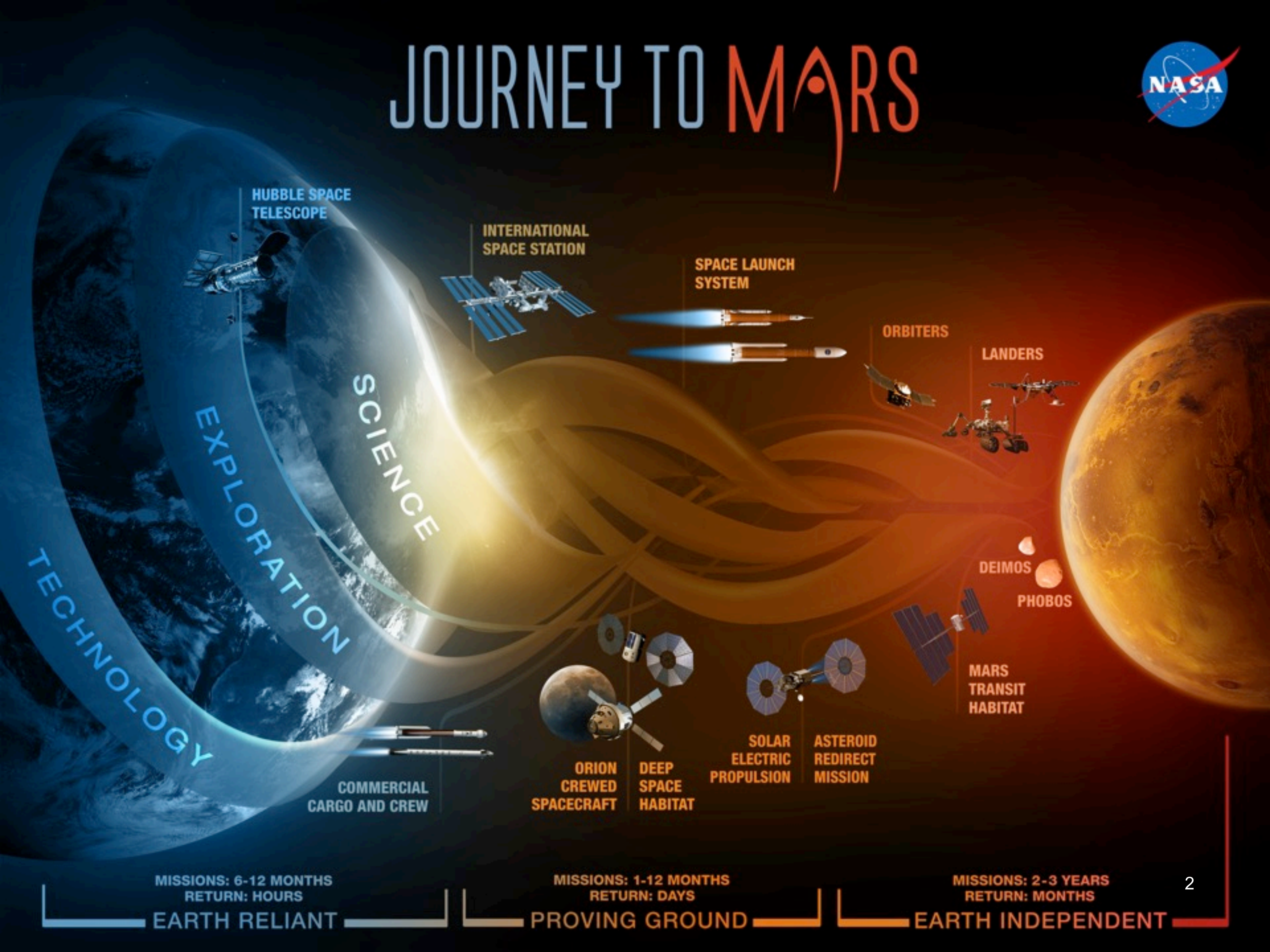

# Habitation Module

**26 July 2016 – NASA Advisory Council, Human Exploration and Operations Committee**

Jason Crusan | Advanced Exploration Systems Director | NASA Headquarters

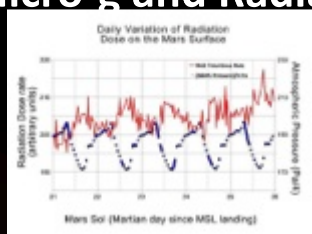

JOURNEY TO MARS
NASA
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
DEIMOS
PHOBOS
MARS TRANSIT HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
ORION CREWED SPACECRAFT
DEEP SPACE HABITAT
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

# Human Exploration of Mars Is Hard

## Common Capability Needs Identified from Multiple Studies

**800-1,100 Days**

Total time crew is away from Earth – for orbit missions all in Micro-g and Radiation




Long Surface Stay

**500 Days**

**Surface Operations**

Dust Toxicity and 100 km Long Range Exploration

**44 min**

Maximum two-way communication time delay – Autonomous Operations

**130 t**

Heavy-Lift Mass

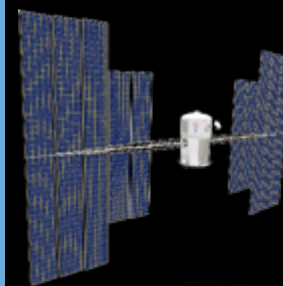
**Multiple**

Launches per mission

**11.2 km/s**

Earth Entry Speed

**Reliable In-Space Transportation**

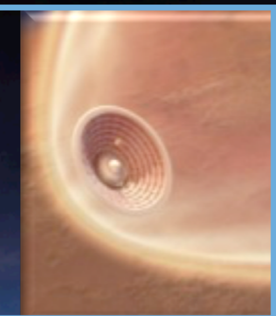


**300 KW**

Total continuous transportation power

**20-30 t**

Ability to land large payloads



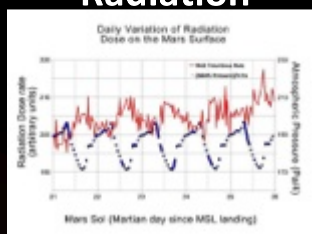
**20 t**

Oxygen produced for ascent to orbit - ISRU

# The Habitation Development Challenge

**800-1,100 Days**

**Total time crew is away from Earth – for orbit missions all in Micro-g and Radiation**




**Long Surface Stay**

**500 Days**

## HABITATATION CAPABILITY

### Habitation Systems – AES/ISS/STMD

- Environmental Control & Life Support
- Autonomous Systems
- EVA
- Fire Safety
- Radiation Protection

Integrated testing on ISS

### Habitation Systems - Crew Health – HRP

- Human Research
- Human Performance
- Exercise
- Nutrition

PROVING GROUND

Validation in cislunar space

### Habitation Capability– NextSTEP BAA / Int. Partners

- Studies and ground prototypes of pressurized volumes

# Specific Habitation Systems Objectives

**Habitation Systems Elements**

The systemse toolse and protetions that allow humans to live and work in space and on other worlds.

| # | Element | Sub-elements | TODAY – ISS | FUTURE – Deep Space |
|---|---|---|---|---|
| 1 | LIFE SUPPORT | Atmosphere Management, Water Management, Waste Management, Food Management | 42% $O_2$ Recovery from $CO_2$<br>90% $H_2O$ Recovery<br>< 6 mo mean time before failure (for some components) | 75%+ $O_2$ Recovery from $CO_2$<br>98%+ $H_2O$ Recovery<br>>24 mo mean time before failure |
| 2 | ENVIRONMENTAL MONITORING | Pressure, $O_2$ & $N_2$; Moisture; Particles; Microbes; Chemicals; Sound | Limited, crew-intensive on-board capability<br>Reliance on sample return to Earth for analysis | On-board analysis capability with no sample return<br>Identify and quantify species and organisms in air & water |
| 3 | CREW HEALTH | Monitoring, Exercise, Diagnostics, Treatment, Food Storage | Bulky fitness equipment<br>Limited medical capability<br>Frequent food system resupply | Smaller, efficient equipment<br>Onboard medical capability<br>Long-duration food system |
| 4 | RADIATION PROTECTION | Monitoring, Tracking, Modeling, Mitigation | Node 2 crew quarters (CQ) w/ polyethylene reduce impacts of proton irradiation.<br>RAD, REM – real-time dosimetry, monitoring, tracking, model validation & verification<br>TEPC, IVTEPC – real-time dosimetry<br>CPD, RAM – passive dosimeters | Solar particle event storm shelter, optimized position of on-board materials and CQ<br>Distributed REM/HERA system for real-time monitoring & tracking<br>CPAD – real-time dosimeter |
| 5 | FIRE SAFETY | Detection, Protection, Suppression, Cleanup | Large $CO_2$ Suppressant Tanks<br>2-cartridge mask<br>Obsolete combustion prod. sensor<br>Only depress/repress clean-up | Unified, effective fire safety approach across small and large architecture elements |
| 6 | LOGISTICS | Tracking, Clothing, Packaging, Trash | Manual scans, displaced items<br>Disposable cotton clothing<br>Packaging disposed<br>Bag and discard | Automatic, autonomous RFID<br>Long-wear clothing & laundry<br>Bags/foam repurposed w/3D printer<br>Resource recovery, then disposal |
| 7 | CROSS-CUTTING | Autonomy, Power, Communication, Docking, Common Interfaces | Minimal on-board autonomy<br>Near-continuous ground-crew comm<br>Some common interfaces, modules controlled separately | Ops independent of Earth & crew<br>Up to 40-minute comm delay<br>Widespread common interfaces, modules/systems integrated |

# Human Space Exploration Phases From ISS to the Surface of Mars

Today

Ends with testing, research and demos complete*

Phase 0: Exploration Systems
***Testing on ISS***

Asteroid Redirect-Crewed Mission Marks Move from Phase 1 to Phase 2

Phase 1:
***Cislunar Flight Testing*** of Exploration Systems

Ends with one year crewed Mars-class shakedown cruise

Phase 2: ***Cislunar Validation*** of Exploration Capability

Phase 3: Crewed Missions Beyond Earth-Moon System

Phase 4a: Development and robotic preparatory missions

Phase 4b: Mars Human Landing Missions

Planning for the details and specific objectives will be needed in ~2020

* There are several other considerations for ISS end-of-life

Mid-2020s

2030

# Deep Space Habitat Development Strategy

**NASA has a habitation strategy to develop a long duration, deep space habitat while at the same time stimulate commercial habitats in LEO**

## Deep Space Habitation Systems Development

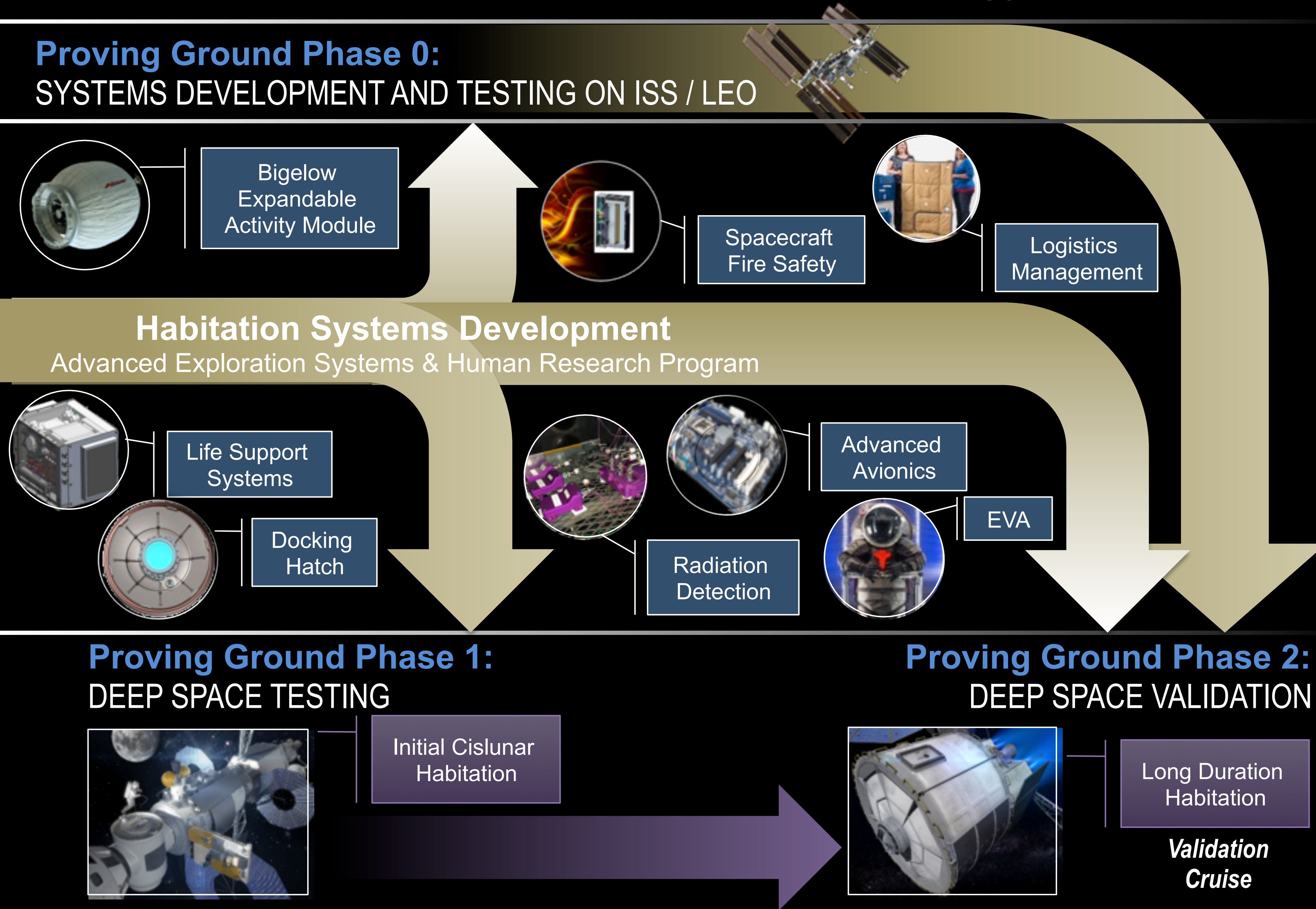
- Existing projects in the AES Habitation Systems Domain are focused on development of key habitat systems such as environmental control and life support systems, radiation monitoring and mitigation, power, avionics and software, fire safety, and logistics management.
- Existing projects and research in the Human Research Program are focus on human health and performance.
- Testing of deep space long duration habitation systems and operational strategies are and will continue to be conducted on the ISS to reduce risk.

## Deep Space Habitation Capability Development

- To ensure NASA gains innovative habitation concepts from industry, NASA is in the process of using the Broad Agency Announcement contracting mechanism to implement a phased approach for the deep space habitat development, including ground-based testing by 2018.
  - BAA allows greater opportunity than an RFP would to accomplish dual objectives of deep space habitat development and commercial market stimulation in LEO.
  - AES awarded the NextSTEP Phase 1 public-private partnerships for industry-led studies to define deep space habitat design concepts while maximizing synergy with commercial applications in LEO.
  - AES issued NextSTEP Phase 2 BAA that acts as if it were an on ramp for additional Phase 2 providers at the same time as we conduct the decision for any existing Phase 1 awards to proceed to Phase 2.

**NextSTEP BAA Phase 2, on-going technology development, and discussions with potential international partners all feed into decision(s) on acquisition approach for habitation for deep space and for commercial investment in LEO capability.**

# Deep-Space Habitation Development Strategy



Expandable Habitat Demonstration on Space Station:

# Bigelow Expandable Activity Module

# BEAM Expanded on Space Station – May 28, 2016

# Astronauts Enter BEAM – June 6, 2016

# Habitation Capability Development Approach

# Habitation Capability Development Approach

Ends with Industry Developed Concepts – Decision on contract(s) continuation

Ends with: 1) Industry Developed Ground Prototype Module performing integrated tests, 2) identified standards and common interfaces, and 3) identified what would be provided as GFE from NA – Decision point on contract continuation and if so, what contractor specific element(s) focus and NAS A provided GFE

Ends with Deployment and Operational Status of Deep Space Habitat

**2015-2016**

- Obtain Innovative Cislunar Habitation Concepts that leverage Commercialization Plans for LEO (NextSTEP Phase 1)
- Develop required deliverables include Concept Description with concept of operations, Phase 2 proposal and SOW
- Initial discussions with international partner contributions

**2016 - 2018**

Continue concept refinement and development of domestic ground prototype module(s) and lead the development of standards and common interfaces domestically and international

- **Contractor(NextSTEP Phase 2)**: Concept description with concept of operations, provide Phase 3 proposal and SOW, delivery of ground prototype module(s)

- **NASA**: Define reference habitat architecture based on contractor and international concepts and identified GFE in preparation for Phase 3

**2018+**

**Phase 3**

- Determine acquisition approach including domestic and international partnerships
- Development of Deep Space Habitat for Proving Ground Phase 1 Objectives
- Deliverables include Flight Unit(s) (note may be multiple modules integrated via common interfaces and standards)

# NextSTEP BAA Phase 1 – Habitation Capability Objectives

- An important part of NASA's exploration strategy is to stimulate the commercial space industry while leveraging those same commercial capabilities through public-private partnerships and potentially future contracts to deliver mission capabilities at lower costs.

- NextSTEP BAA Phase 1 objectives are to develop innovative concepts and perform technology investigations for an initial habitation capability in cislunar space with extensibility for in-space transit habitation such as those being considered by NASA or the capabilities that enable a potential use of commercial Low Earth Orbit (LEO) habitation capabilities coupled with government-provided exploration in-space habitation capabilities in cisunar space.

  – This initial habitation capability will serve as the first foundational cornerstone of a future deep space transit mission and may include multiple elements developed over a phased build out as the architecture and the commercial / international partnership strategy is further refined.

  – Of particular interest are habitation capabilities that can be implemented in a modular way that could gradually build up tor a deep space transit capability.

  – This initial cislunar habitat is expected to be used to augment planned cislunar missions to provide the function of proving ground habitation for testing and validating future systems in support of human exploration beyond cislunar space.

# NextSTEP BAA Phase 1 – Habitation Capability Objectives (cont'd)

- The type of missions that could be supported by the initial habitation capability include:
  - Long Duration Exploration Systems Testing
  - Automation, Tele-operations, and Robotics
  - Human Assisted Sample Return
  - In Situ Resource Utilization (ISRU) Demonstration Missions
  - Human Research in Deep Space
  - Logistics Support
  - General Science
  - Mars Spacecraft Assembly, Refurbishment and Validation

- Depending on the results from the initial studies, NASA may decide to award follow-on contract options for further development of a ground test article and physical mock-up and the manufacturing of the proposed subsystem or Protoflight vehicle. A proposed statement-of-work for the further development option shall be developed during the initial study phase.

# AES FY16 Habitation Capability - NextSTEP Phase 1

- **Awarded Late Summer / Fall CY2015.**

  Orbital - July 2015
  Lockheed - September 2015
  Boeing - December 2015
  Bigelow - September 2015

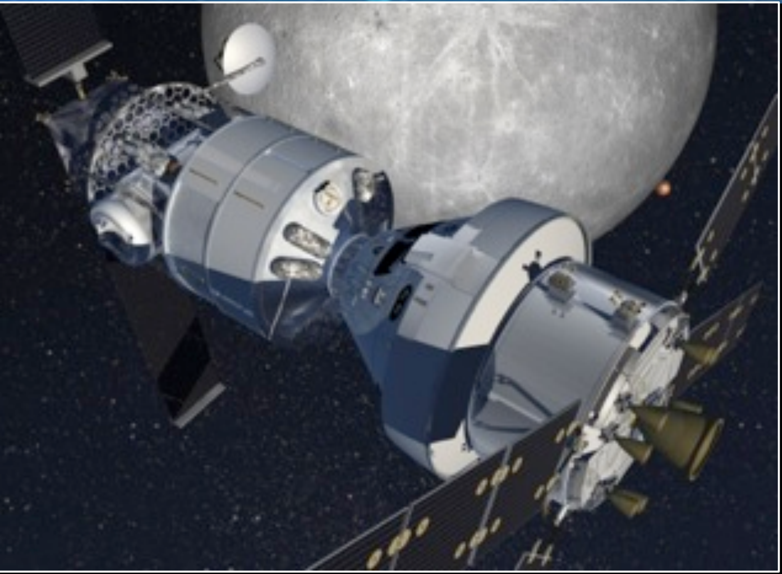
- **Each Award has a ~10/12 Month period of performance.**

- **Accelerating Phase 1 efforts to be complete before the end of FY16 to enable transition to Phase 2 awarded efforts.**

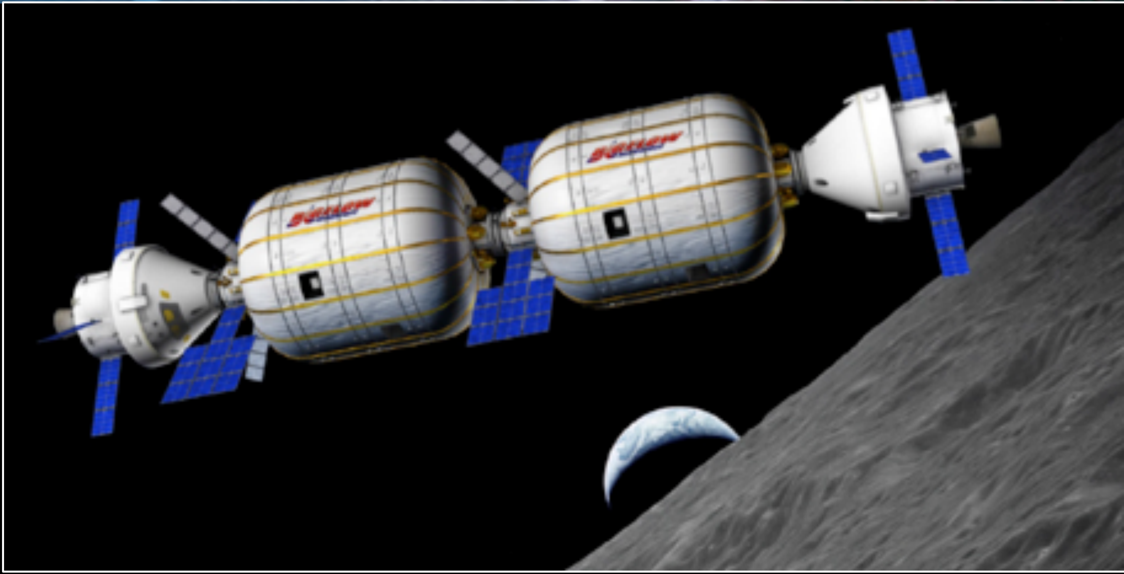
- **Phase 1 includes deliverables to scope proposed Phase 2 efforts.**
  - Options for proposed Statement of work, Milestone, and Costs

# Phase 1: Habitation Awards for Design Concept Studies

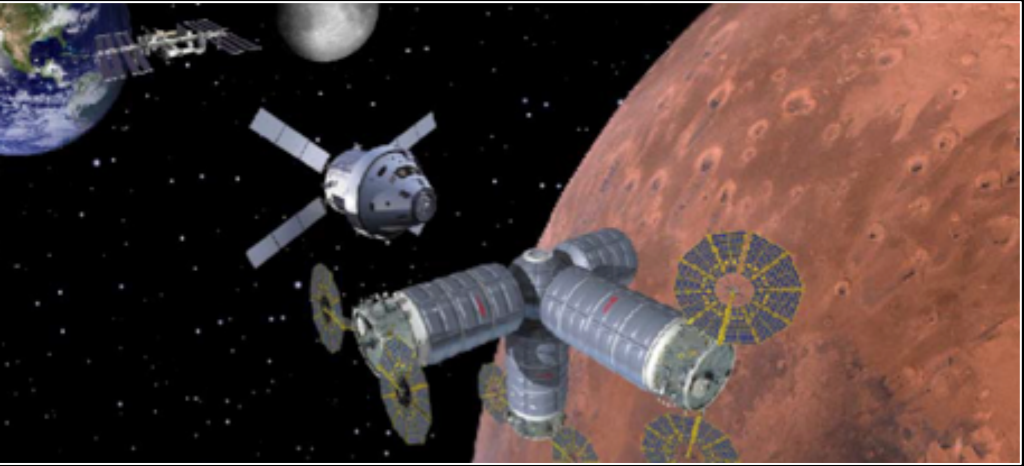
NextSTEP
Next Space Technologies for Exploration Partnerships



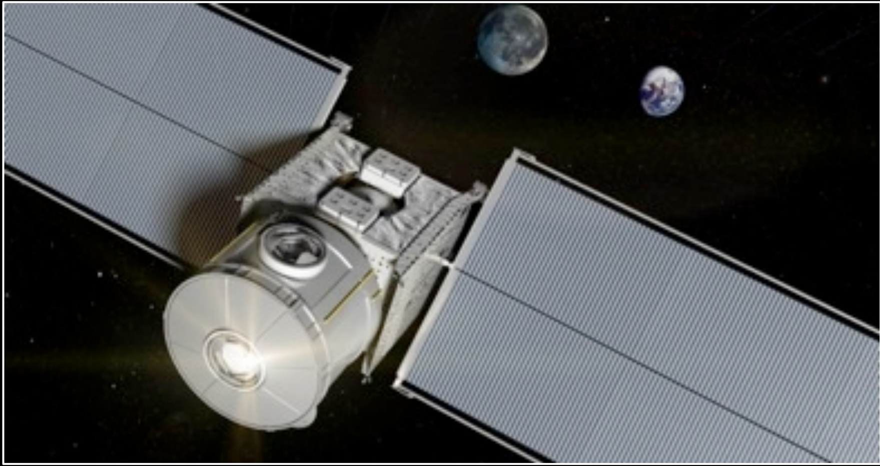
**Lockheed Martin|** Denver, CO



**Bigelow Aerospace LLC |** Las Vegas, NV



**Orbital ATK |** Dulles, VA

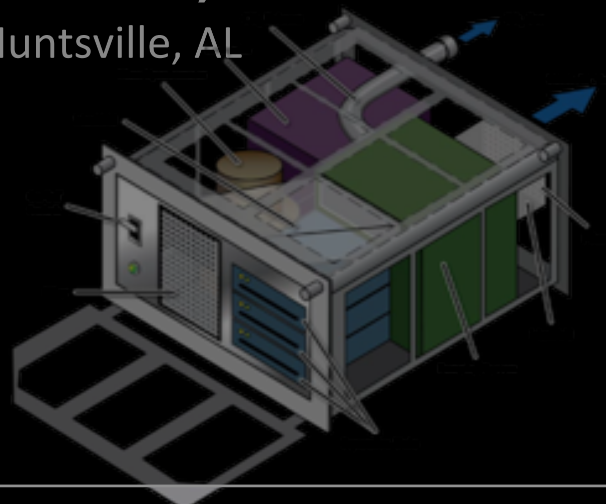


**Boeing |** Houston, TX

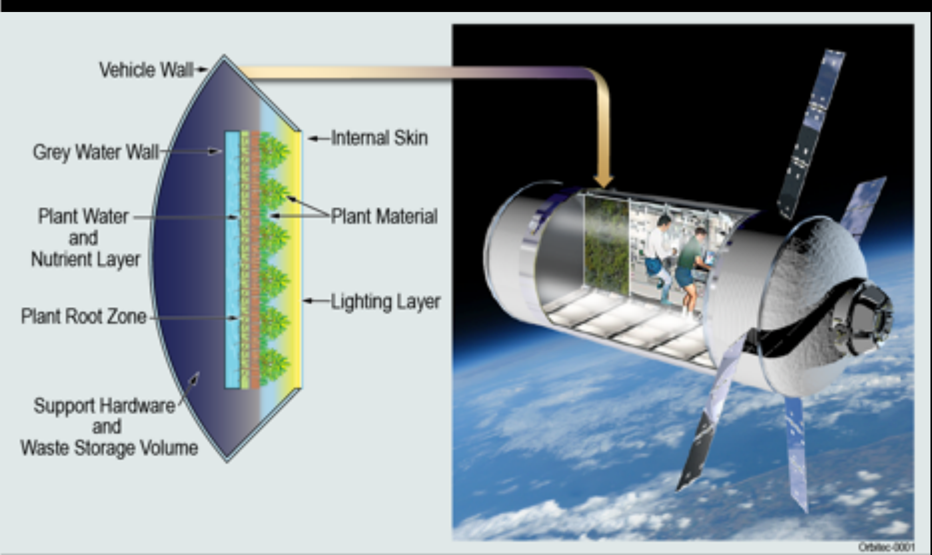
# Phase 1: Habitation Awards for Environmental Control and Life Support Systems (ECLSS)

NextSTEP
Next Space Technologies for Exploration Partnerships

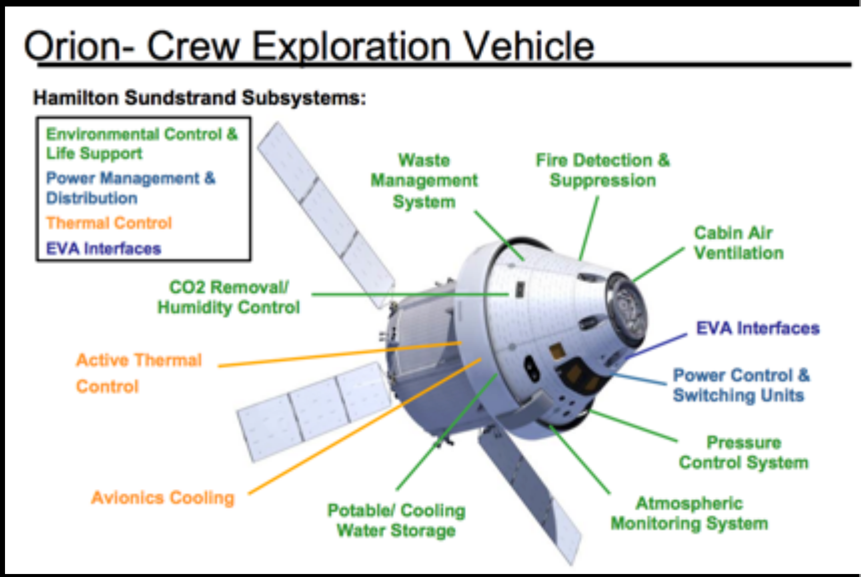
**Dynetics, Inc** | Huntsville, AL



**Orbitec** | Madison, WI



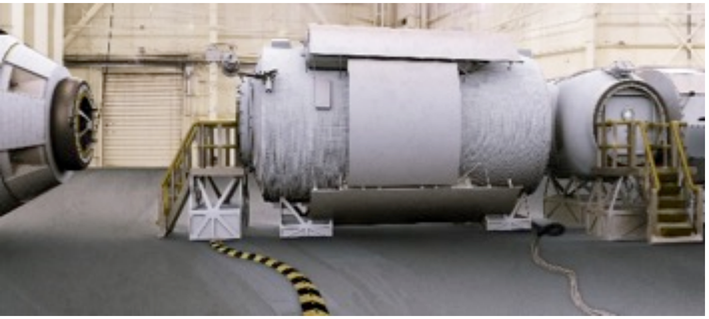

**UTC Aerospace Systems (UTAS)**
Windsor Locks, CT



# NextSTEP BAA Habitation Capability Phase 2 - Goal

**Develop a deep space habitat with fully functional systems for ground-based testing by 2018, while at the same time stimulating commercial habitats in LEO**

- **Develop long duration deep space habitation capabilities that lead towards a deep space transit habitat and can be flown on SLS flight(s) (or alternative launch vehicles) starting by the early to Mid 2020s.**
- **Advance the long duration deep space habitation capability concepts and mature the design and development of the integrated system(s) to achieve a high level of fidelity.**
  - Developing prototype deep space habitation capability options to test a full size ground prototype unit(s) by the end of Phase 2 in 2018 to support first flight opportunities in Early to Mid 2020s
- **Potential for different capabilities from domestic and international suppliers will require standards and common  interfaces for aggregation.  NASA led standards working group will be implemented during Phase 2.**



**Ground Prototype units delivered to NASA for testing and integration of NASA developed habitation systems**

- Testing includes form, fit, volumetric, subsystem integration, and interface standards
- May use NASA-developed node/airlock and hab mockups for integration testing with contractor modules
- Ensures consistent test and interface verification approach, allows us to incorporate and test other AES subsystems, facilitates crew training and feedback on human factors, shows stakeholders progress

# Ground Prototype Integration Testing (fidelity/functionality)

***The habitation prototypes will be used for three primary purposes:***
***supporting system integration, human factors and operations, and system functionality.***
***Top level objective of testing is Phase 3 requirement refinement and risk reduction.***

- Systems Integration: The prototypes will, at a minimum, serve as an integration platform at the form and fit level:
  - Flight unit mockups of systems (not necessarily functional)
    - Standard interfaces for mechanical, power, thermal and data tested
    - layoute installation, fit access tested
- Human Factors & Operations: The prototypes will enable mission simulations with humans in the habitation environment:
  - Habitability
  - Mission Operations (Command and Control, Science, Teleops, Robotics, Crew Training, Maintenance and Repair)
  - Health and Medical
  - Logistics and Waste Management Operations
  - EVA operations
  - Contingency/Emergency Scenarios
- System Functionality: Testing may incorporate combinations of crew (human-in-the-loop) mission simulation, analytical modeling, laboratory analysis, computer based simulation, or other testing techniques.

# NextSTEP BAA Habitation Capability - Phase 2 Objectives

- **NASA expects proposals submitted to be based upon rigorous concept development, architecture and trade studies. Early milestones in proposals may include validation of concepts relative to NASA's long duration deep space habitation system strategy.**

- **Develop complete deep space long duration architecture designs.**
  - Evolvable, modular architecture, functional allocation options
  - Co-developed standards, common interfaces required to enable interoperability of the aggregate system
  - Testing approaches

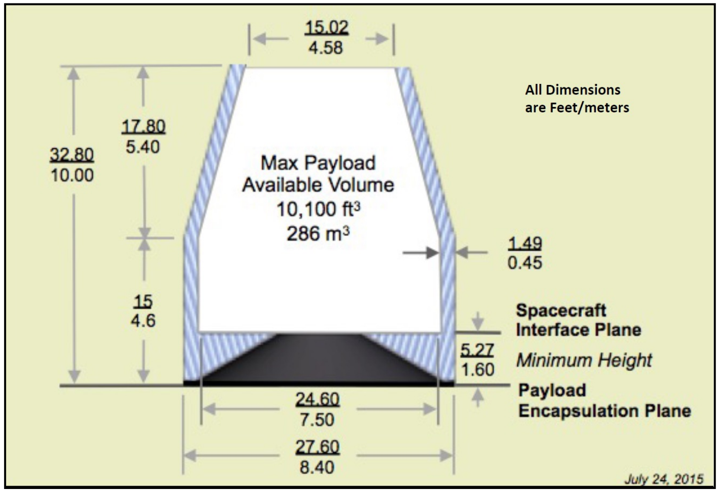
- **Stimulate commercial capabilities for LEO, enable capability development that intersects NASA long duration deep space habitation requirements and commercial LEO habitation.**

- **Mature the design of the overall deep space integrated system(s) and, at a minimum, develop a full size, ground prototype for integrated testing of the form, fit, and partial functions of the design.**

- **Achieve level of fidelity in concepts for confidence that protoflight vehicle(s)/ modules can be produced for flight in the early to mid 2020s.**
  - Potential for different suppliers for the multiple capabilities needed with standard interfaces for aggregation. (e.g. service module from one, habitation from another, airlock from another)

# NextSTEP BAA Habitation - Phase 2 Objectives (cont'd)

- Further define and develop deep space habitation capabilities that can be flown as co-manifested payloads on SLS Block 1B with an initial SLS co-manifesting capability of 4 – 6 metric tons starting in early-to-mid 2020s, or later in the 2020s on a cargo-only version of SLS, or on alternative launch vehicles. Note the habitation system concept can be separated into multiple integrated modules with distributed functions. If the habitation concept is not flown on SLS, provide details of the launch vehicle assumptions.




**SLS Co-manifested Cargo Volume**

- Provide information on company end-to-end development effort and ROM costs for flight development - companies to provide a proposal, SOW, and fully priced Appendix A efforts and ROM costs for subsequent phases for engineering and flight unit development.

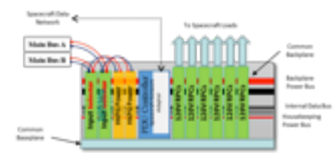
- Determine the level of government furnished contribution to overall habitation capability and habitation systems (e.g. life support systems, power systems, etc…).

# Potential GFE to Be Reviewed During Phase 2

- **Environmental Control & Life Support Systems**
  - Highly reliable, ISS-derived life support systems, including carbon dioxide removal, oxygen generation, waste water processing, trace contaminant control, and environmental monitoring for atmosphere, water and surfaces.
  - Universal Waste Management System - development of compact toilet for smaller volumes of exploration vehicles.
  - Ground test bed for integrated ECLSS systems that could be linked to prototype habitat.

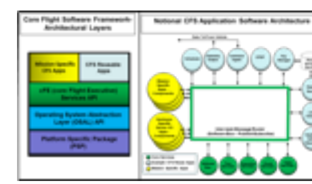
Integrated ECLSS test bed at MSFC

- **Modular Power Systems**
  - Modular power systems standards and interfaces to provide commonality across a variety of exploration vehicles.
  - Interchangeable modular power distribution units and power converters.
  - Autonomous power system fault detection and recovery.
  - Integrated modular power systems test bed at JSC that could be linked to prototype habitat.



Modular PDU

- **Avionics and Software**
  - Common avionics architectures based on an open source Time Triggered Ethernet data bus that can be used by a variety of exploration vehicles.
  - High performance processors, voting flight computers, and wireless instrumentation.
  - Core Flight Software certified for human missions.
  - Integrated avionics and software test bed at JSC that could be linked to prototype habitat.

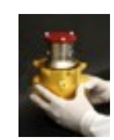


Core Flight Software

- **Docking Hatch**
  - Prototype lightweight docking hatch that can be used as a standard interface between exploration vehicles.

Exploration Docking Hatch

- **Radiation Monitoring, Modeling, and Protection**
  - Development radiation sensors and concepts for storm shelters.



Radiation Assessment Detector

# NextSTEP BAA Habitation Capability Phase 2

- **Phase 2 to start NET Aug 2016 with FY16 funds**
  - Phase 2 PoP: Aug 2016 - June 2018 split into options
  - Currently projected FY16 & 17 funding: $65M

- **Provide “on ramp like” opportunity for additional industry partners**
  - Using NextSTEP #2 umbrella BAA – Appendix A covering habitat concepts
  - Proposer to deliver Phase 2 Proposal and SOW (same content as required for the Phase 1 contractors)

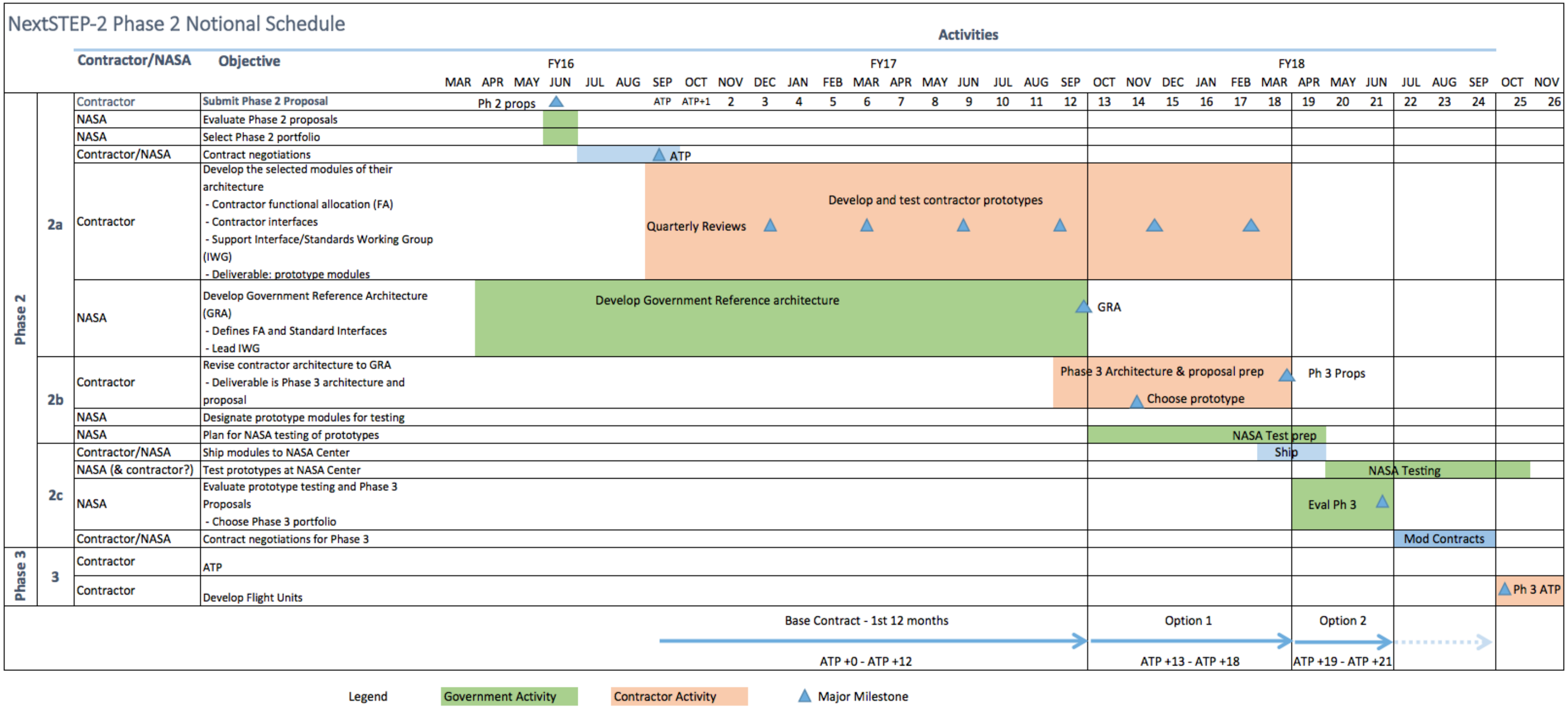
# NextSTEP BAA Habitation Capability Phase 2 Award Information

- Will award multiple contracts by Sept 2016. Funding levels depend on FY16 - FY18 appropriations and proposed content.
  - Will mitigate budget uncertainty with structured options from proposal and resulting structured CLINs on the contract that can be incrementally funded.
    - CLINs will be activated on availability of funding.
- An estimated $65M will potentially be available in FY16 and FY17 with potential of additional funding in FY18.
- Estimated period of performance ~NTE 18 months with an additional 6 month no cost option period to support NASA test and negotiate potential follow on phase(s).
  - 18 months would mean going from Aug/Sep 2016 – April 2018.
  - Follow-on activities in the 6 month no cost phase includes the shipment of selected contractor modules to NASA for integration and testing.
- **30% minimum corporate contribution with at least half during the period of performance.**
  - Only can look back one year for partner contribution.

# NextSTEP Phase 1 to Phase 2 Schedule

| Milestone | Schedule Estimate |
|---|---|
| Release Solicitation for new Proposals | April 19 Completed |
| Release Final Guidance to Phase 1 Performers | April 20 Completed |
| Phase 2 Proposals Due | June 15 Completed |
| Evaluation Period (Including Due Diligence/Fact Finding) | June/July |
| Selection | August |
| Negotiate and Award Contracts | September |

# Notional Phase 2 Schedule



# NASA NextSTEP BAA Management

- **COR** – contract monitoring and Phase 2 contract development
- **Technical Monitoring** – One Monitor for each contractor, supporting weekly meetings, setting up Technical Interchange Meetings (TIMs) with NASA subject Matter Experts, support the assessment of Phase 2 SOW and proposal, HEO interface POC to contractors
- **Integrated Analysis / Assessments** – Reviews contractor concepts against NASA's objectives and long term Mars campaign, Master Equipment List (MEL) capture, integrated testing
- **Interface Standards** – Identifies interface standards such that we can select module concepts for Power/Propulsion Bus, Node/Airlock, Habitat, and logistics module from different contractors and they will work together
- **Subject Matter Experts / TIMs** –NASA experts supporting technical interchanges with contractors
- **AES Coordination** with HEOMD, other programs, projects, and STMD

# AES FY16 Execution and FY17 Habitation Plans

## Budget Breakdown

| $M | FY 2015 Actuals | FY 2016 IOP | FY2017 PBR |
|---|---|---|---|
| **Habitation Systems** | **$50.9** | **$70.92** | **$90.3** |
| Bigelow BEAM | $3.6 | $2.31 | $0.7 |
| Exploration Docking Hatch | $6.7 | $1.16 | $0.0 |
| Life Support | $16.4 | $15.48 | $14.8 |
| Logistic Management | $4.6 | $8.23 | $5.3 |
| Radiation Mitigation and | $9.8 | $9.34 | $10.0 |
| Monitoring Spacecraft Fire Safety | $8.0 | $9.40 | $9.5 |
| **Habitation Capability** | | | |
| NextSTEP Activities | $1.8 | $25.0 | $50.0 |

In FY16, of the $25.0M for NextSTEP activities $7.4M is for the ongoing support of Phase 1 awards and $15M is for new awards under NextSTEP Phase 2.

In FY17, NASA plans to utilize up to $50M for NextSTEP Phase 2 activities including selected contractors. However, this is pending final appropriations for Exploration Research and Development which includes the AES budget.

## CONCLUSION:

- NASA's habitation capability strategy is accomplishing  dual objectives of developing a deep space habitat capability while at the same time stimulating a robust commercial market in LEO
- NASA has a well structured, affordable habitation development strategy in place
- Habitation systems required for deep space are being developed and tested now – both on the ground and on ISS
- Development of Standards and Common Interfaces is critical to domestic and international habitation development
- NextSTEP Phase 2 and on going international partner discussions will provide the basis for Phase 3 acquisition plan.

# Backup

# Phase 2 Proposal Content (1 of 2)

- **NASA requires proposals for Phase 2 activities for deep space habitat architectures and ground prototypes . Proposals shall structure the SOW tasks, sub-system development and associated deliverables into severable CLINs and sub-CLINs integrated with priced milestones such that the government can quickly negotiate and activate CLINs based on programmatic priorities and funding availability. Inclusion of No Later Than Start dates for each CLIN will facilitate government decisions.**
  - Because contract is over $750K, a full certified cost or pricing data will be required
- Contractors are to propose fixed price performance based milestones that mature the design and development of ground prototype unit(s)
  - Technical Milestones should include entrance and success criteria
  - Payment milestones should occur approximately every quarter
    - Payment milestones should reference technical milestones
    - Exemplar technical milestones include: subsystem development and test, hardware or software testing, design reviews, integration milestones, etc.
    - May use NASA NPG 7123 as reference/lessons learned on design review content

# Phase 2 Proposal Content (2 of 2)

- **May propose optional fixed price performance base based milestones that provide additional system maturation or risk reduction**
- **Phase 2 focus is on data deliverables and development of selected hardware**
  - Architecture design with functional allocation, interfaces and common standards
  - Hardware/software design documentation (including safety and health plans)
  - Contractor ground prototype test results
  - Final reports of integrated performance
  - Development of selected full size ground prototype modules
- **In addition to the fixed price performance based milestones, contractors should propose routine deliverables as well as the technical data and engineering reports on the development:**
  - Quarterly project status/technical briefings (past quarters activities, upcoming activities, risks retired, financials, other)
  - Quarterly technical reports (NASA intends to provide a format)
  - Monthly progress/status reports (NASA will provide an abbreviated format)
  - Bi-weekly telecons with NASA

# Phase 2 Contract Structure and Schedule (notional)

- **18-month development effort comprised of 12-month base and 6-month option 1.**
  - Phases 2a and 2b
  - Option provides flexibility to match work with available government resources and funding
- **3-6 month no-cost extension**
  - Provides period of government test and evaluation of results from Phases 2a and 2b
  - Allows for transition to potential follow on phases
- **Government Testing**
  - At the end of Phase 2a, certain modules will be designated for additional government test
  - Contractors shall price a CLIN/option for developing a shipping concept, preparing and packaging designated modules for shipping
  - Government will pay for shipping

# Phase 2 Additional Proposal Guidance

- **The proposals shall identify all requests for Government furnished equipment, property, facilities or in-kind contributions required for successful completion of each CLIN**
  - GFP/GFE must identify specific resources with pre-coordinated full account costing by the identified resource
  - Government tasks must be captured as separate SOW items
  - Potential areas for GFE include but not limited to Modular Power Systems, Avionics and Core Flight Software, Autonomous Systems, Delay Tolerant Networking
- **Proposals should describe how the proposed system is on the path to a Mars class deep space transit habitat**
- **If choosing to launch on SLS, need to fit within 4-6MT. If not, need to include other launch vehicle assumptions, including SLS cargo version.**
- **Phase 2 deliverables shall include ground prototype module(s), Proposal and SOW for Phase 3 milestones (and schedule), deliverables and price**
- **NASA will provide ongoing technical expertise via TIMS or other forums to provide lessons learned and expertise. Proposal shall include an estimate of requested subject matter experts and/or documentation**
- **The contractors shall support an interface working group lead by NASA**
  - Known requirements at this time include: NDS docking, exploration atmospheric environment, – links will be provided to reference materials

# Phase 2 Proposal Content (1 of 2)

1. **Executive Summary (2-4 pages)**
   - No proprietary content (can be made public)

2. **Engineering Addendum (15 pages for both the Engineering and Business sections)**
   - Concepts of Operations and concepts description
   - Overview of enveloping engineering approach with supporting test campaign
   - What interface standards need to be identified before Phase 3
     - Contractors shall support a NASA-lead interface and standards working group
   - Include brief summary of past activities/tests
   - Technical Risks

3. **Business Addendum**
   - Business overview
   - Define customer/partnership model
   - List business case(s) that are leveraged by the hardware development
   - Identify overlap between LEO and cislunar capabilities/technologies and how investing in cislunar supports/enables LEO commercial activities
   - Overview of end-to-end development schedule with estimated price
   - Business risks

# Phase 2 Proposal Content (2 of 2)

4. **Financial Addendum (no limit)**
   - Corporate resource contributions
   - Detailed Price
   - Requested GFE/GFP
5. **Appendices (no limit)**
   - Statement of Work
     - Technical and Payment Milestones
     - Deliverables
     - Requested GFE/GFP
   - Key Personnel
   - Corporate Contribution Documentation (as needed)
   - Additional phase I study results (as needed)

# Evaluation Factors

- **Factor 1: Relevance**
  - NASA Strategic Goals, Technology Roadmap, or SKGs
  - Future commercial benefit
  - Contributes to growth of US industrial Capacity or Economy
- **Factor 2: Technical Merit**
  - Intrinsic Merit
  - Technical Approach
  - Feasibility
  - Schedule/Milestones
  - Technical Objectives/Deliverables (may be tailored)
  - Skills/Capabilities
- **Factor 3: Price**
  - Reasonableness
  - Corporate Resource Contribution
- **Factor 4: Business**
  - Enables/stimulates commercial activity in low Earth orbit
  - Capability intersection among initial cis-lunar habitation and commercial LEO habitation