HSF Transition: ISS, LEO and beyond to cislunar space

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Director, International Space Station

“Buona notte” Kelly at 180 days onboard the ISS

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Strategic Principles for Sustainable Exploration

• Implementable in the *near-term with the buying power of current budgets* and in the longer term with budgets commensurate with economic growth;

• *Exploration enables science and science enables exploration*, leveraging robotic expertise for human exploration of the solar system;

• Application of *high Technology Readiness Level* (TRL) technologies for near term missions, while focusing sustained investments on *technologies and capabilities* to address challenges of future missions;

• *Near-term mission opportunities* with a defined cadence of compelling and integrated human and robotic missions providing for an incremental buildup of capabilities for more complex missions over time;

• Opportunities for *U.S. commercial business* to further enhance the experience and business base;

• *Resilient architecture featuring multi-use, evolvable space infrastructure*, minimizing unique major developments, with each mission leaving something behind to support subsequent missions; and

• Substantial *new international and commercial partnerships*, leveraging the current International Space Station partnership while building new cooperative ventures.

• *Continuity of human spaceflight is essential to sustain progress*; we will establish a regular cadence of crewed missions to cis-lunar prior to the end of ISS.
The Bigger Picture

Near-term execution
Planning the transition from ISS to cislunar space

• Instead of declaring a definite end date for ISS, NASA will focus on considerations such as
  – Short term crewed habitation missions are being executed in cislunar space while ISS is still operational and being utilized
  – Exploration research and technology/system development activities requiring ISS as a testbed are essentially complete
  – There is an expanded commercial market and broad private/government/academic demand for LEO-based platforms that are based on private and/or public/private business models
  – Value benefit of the ISS has been sufficiently achieved
  – Maximizing international ISS partnership and participation
  – Safe sustainment of the ISS will remain paramount

• Based on today’s planning and reasonable progress towards our goals, transitioning HSF could be expected in the mid-2020s
  – NASA is working with stakeholders, International Partners and industry to develop plans for transitioning the ISS and the Partnership
  – The Partnership should explore possible outcomes for the ISS platform at its’ end-of-life
    • De-orbit, disassemble, turn over portions to private industry, maintain government ownership, others ideas
### NASA vision for LEO beyond ISS

**Vision:** Sustained economic activity in LEO enabled by human spaceflight, driven by private and public investments creating value and benefitting Earth through commercial supply and public and private demand

<table>
<thead>
<tr>
<th>GOALS</th>
<th>1) LEO commercialization enabled by leveraging ISS</th>
<th>2) The policy and regulatory environment promotes commercialization of LEO</th>
<th>3) A robust, self-sustaining, and cost effective supply of US commercial services to/in/from LEO accommodates public and private demands</th>
<th>4.0 Broad sectors of the economy using LEO for commercial purposes</th>
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<td>User-friendly ISS process improvements</td>
<td>Establish interagency working group to address policy and regulatory issues</td>
<td>Leverage NASA NEXTSteps BAA studies and follow-on to enable commercial LEO capabilities</td>
<td>Establish consortia for potential high-payoff, market-enabling microgravity and LEO applications with public and private funds to support development (e.g., protein crystallization, exotic fibers, lightweight alloys, 3D tissues, earth observing, etc)</td>
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<td>Maximize throughput</td>
<td>Investigate economic cluster potential</td>
<td>Enable Earth-similar laboratory capabilities for ISS that can transition to commercial platforms</td>
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<td>Demonstrate &amp; communicate value proposition of ISS</td>
<td>Address barriers such as IP retention, liability, ITAR</td>
<td>Transition from NASA-supplied to commercially-supplied services and capabilities once available</td>
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<td>Foster “success stories”</td>
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<td>Utilize more commercial acquisition strategies</td>
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Transition framework from ISS to Cislunar Space

Today

Phase 0: Exploration Systems *Testing on ISS*

Mid-2020s

Phase 1: *Cislunar Flight Testing* of Exploration Systems

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

Ends with testing, research and demos complete*

Ends with one year crewed Mars-class shakedown cruise

Phase 2: *Cislunar Validation* of Exploration Capability

2030

*There are several other considerations for ISS end-of-life*
### Phase 0: Exploration Research and Systems Testing on ISS

- Test Mars-capable **habitation systems** – ECLS, environmental monitoring, crew health equipment, exploration generation EVA suit, fire detection/suppression, radiation monitoring
- Complete **human health & performance** research and risk reduction activities
- Demonstrate **exploration related technologies and operations**
  - Autonomous crew operations
  - Docking, prox ops

**enables**

- Robotic manipulation technology and techniques demonstrations
- Remote presence technology development and demonstrations
- Earth/space science
- Enable development of LEO commercial market

### Phase 1: Cis-lunar Flight Testing of Exploration Systems

- Demonstrate that **SLS and launch processing systems** can insert both Orion and co-manifested payloads into cis-lunar space
- Demonstrate that **Orion and mission operations** can conduct crewed missions in cis-lunar space at least for 21 days
- Demonstrate **Mars-extensible systems and mission operations** that reduce risk for future deep space missions (with EVA) beyond 21 days

**enables**

- Validate cis-lunar as staging orbits
- Use of high power SEP for deep space missions
- Asteroid related origins of the solar system science objectives
- Demonstrate real-time robotic lunar surface activities
- In situ resource utilization demonstrations

### Phase 2: Cis-lunar Validation of Exploration Capability

- Validate **Mars class habitation** and habitation system functionality and performance
- Validate **Mars class human health and performance**
- Validate operational readiness to leave Earth-Moon system via **one year+ “shakedown cruise”** (no resupply/crew exchanges, limited ground interaction, etc.)

**enables**

- Origins of the universe, lunar rover volatile sample return
- Other scientific or research objectives?
Phase 0 Research and Technology Development that feeds forward to the Proving ground
<table>
<thead>
<tr>
<th>System</th>
<th>Includes</th>
<th>Today</th>
<th>Mars Goal</th>
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<tbody>
<tr>
<td>Life Support</td>
<td>Air revitalization, water recovery, waste collection and processing</td>
<td>42% recovery of O2 from CO2; 90% recovery of H2O; &lt;6 mo MTBF for some components</td>
<td>&gt;75% recovery of O2 from CO2; &gt;98% recovery of H2O; &gt;2 yr MTBF</td>
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<td>Environmental Monitoring</td>
<td>atmosphere, water, microbial, particulate, and acoustic monitors</td>
<td>Limited, crew-intensive on-board capability; rely on sample return to Earth</td>
<td>On-board analysis capability with no sample return; identify and quantify species and organisms in air &amp; water</td>
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<td>Crew Health</td>
<td>exercise equipment, medical treatment and diagnostic equipment, long-duration food storage</td>
<td>Large, cumbersome exercise equipment, limited on-orbit medical capability, food system based on frequent resupply</td>
<td>Small, effective exercise equipment, on-board medical capabilities, long-duration food system</td>
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<td>EVA</td>
<td>Exploration suit</td>
<td>ISS EMU’s based on Shuttle heritage technology; not extensible to surface ops</td>
<td>Next generation spacesuit with greater mobility, reliability, enhanced life support, operational flexibility</td>
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<td>Fire</td>
<td>Non-toxic portable fire extinguisher, emergency mask, combustion products monitor, fire cleanup device</td>
<td>Large CO2 suppressant tanks, 2-cartridge mask, obsolete fire products. No fire cleanup other than depress/repress</td>
<td>Unified fire safety approach that works across small and large architecture elements</td>
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<td>Radiation Protection</td>
<td>Low atomic number materials including polyethylene, water, or any hydrogen-containing materials</td>
<td>Node 2 CQ’s augmented with polyethylene to reduce the impacts of trapped proton irradiation for ISS crew members</td>
<td>Solar particle event storm shelter based on optimized position of on-board materials and CQ’s with minimized upmass to eliminate major impact of solar particle event on total mission dose</td>
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Human Health and Performance Research
Transition from ISS to Cis-Lunar Space

ISS Goals for Space Exploration
(investigate, develop, and test)

- Human health risks and capabilities to mitigate these risks
- Exploration biomedical technologies and tools
- Extend mission durations to one-year to test six-month research and countermeasures
- Visual impairment/intracranial pressure risk and assess countermeasures
- Space radiation protection/monitoring systems
- Long-duration spaceflight stressors to the immune system and microbiome
- Exploration food system technologies
- Crew habitation standards and models

Mars Goals for Cis-lunar Space
(validate)

- Advanced countermeasures against deconditioning (bone, muscle, cardiovascular)
- Crew performance, psychological well-being, and intervention for Mars flight operations
- Integrated medical capabilities (autonomous medical diagnosis and treatment)
- Human and environmental health in a closed Mars spacecraft (immune system, microbiome)
- Mars mission food system
- Space radiation protection/monitoring systems
- Crew habitation systems (human computer/robotic/vehicle interfaces)
- Robustness/reliability of crew exercise systems
Next slides will focus on a discussion of Phase 1 objectives
Phase 1: *Cislunar Flight Testing* of Exploration Systems

**OBJECTIVES:**

- Demonstrate integrated SLS/Orion capability from launch through recovery in cis-lunar space
- Obtain ascent and in-space environments data
- Demonstrate performance of communications, network, and tracking capabilities
- Demonstrate ground processing and operational support
- Deploy secondary payloads

**MISSION ELEMENTS AND CAPABILITIES:**

- SLS Block 1 (EM-1)
- Orion
- Secondary Payload deployment

Asteroid Retrieval Crewed Mission Marks Move from Phase 1 to Phase 2

Considerations, Constraints, and Unknowns:

- Initial mission design driven by need to meet flight test objectives
Phase 1: *Cislunar Flight Testing* of Exploration Systems

**OBJECTIVES:**
- Demonstrate SLS/Orion crewed cislunar transportation and trajectory capability in cislunar space up to 21 days w/ 4 crew
- Demonstrate co-manifested payload capability in cis-lunar space (~5MT or better)

**MISSION ELEMENTS AND CAPABILITIES:**
- SLS Block 1B (EM-2 and subsequent)
- Orion
- Co-manifested capability (in work)

**Considerations, Constraints, and Unknowns:**
- Initial mission design driven by need to meet flight test objectives
- Initial co-manifesting planning driven by conservative analysis
- Proximity operations under evaluation

Asteroid Retrieval Crewed Mission Marks Move from Phase 1 to Phase 2
Phase 1: *Cislunar Flight Testing* of Exploration Systems

**OBJECTIVES:**

- Demonstrate extended crewed operations in cis-lunar space with 4 crew beyond 21 days
- Demonstration of crew health and performance systems particularly exercise, medical, and radiation protection
- Demonstrate deep space EVA capability
- Deploy co-manifested element(s) in cislunar space
- Perform ARCM mission objectives

**MISSION ELEMENTS AND CAPABILITIES:**

- SLS Block 1B
- Orion
- Co-manifested element(s) with docking, power, propulsion and mission augmentation capabilities to support increasingly ambitious missions in Phase 2
- (ARM robotic spacecraft)

**Considerations, Constraints, and Unknowns:**

- Mission(s) orbit driven by ARCM mission objectives
- Co-manifesting capability under analysis
- Partner discussions continue on execution of ARM and ARCM missions and co-manifested elements
- Number of additional missions required to execute ARCM dependent on risk buy-down of previous missions and eventual co-manifesting capability

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