NASA’s Human Space Exploration
Capability Driven Framework

Briefing to the National Research Council
Committee on Human Spaceflight
Technical Panel
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Overview

Setting the stage:
• Policy
• Capability Driven Framework
• Common Capability Challenges
• Strategic Knowledge Gaps

Later, a closer look at the technical challenges:
• Crew health medical, and safety (Steve Davison, NASA HQ)
• Habitation and destination systems (John Connolly, NASA JSC; Robyn Carrasquillo, NASA MSFC)
• In-space propulsion and space power (Les Johnson, NASA MSFC)
• Robotics and autonomous systems (Rob Ambrose, NASA JSC)
• Entry, descent, and landing (Michelle Munk, NASA LaRC)
• Deep-space extravehicular activities (EVA) (Mike Hembree, NASA JSC)
“Early in the next decade, a set of crewed flights will test and prove the systems required for exploration beyond low Earth orbit. And by 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the Moon into deep space. So we’ll start -- we’ll start by sending astronauts to an asteroid for the first time in history. By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth. And a landing on Mars will follow.”

  – Bipartisan support for human exploration beyond low Earth orbit, signed by President Barak Obama

• The law authorizes:
  – Extension of the International Space Station until at least 2020
  – Support for a commercial space transportation industry
  – Development of a Multi-purpose Crew Vehicle and heavy lift launch capabilities
  – A “flexible path” approach to space exploration opening up vast opportunities including near-Earth asteroids (NEA), moon, and Mars
  – New space technology investments to increase the capabilities beyond low Earth orbit

• FY13 President’s Budget Request
  • Asteroid by 2025, Mars orbit by mid-2030s
Incremental steps to steadily build, test, refine, and qualify capabilities that lead to affordable flight elements and a deep space capability.
Six key strategic principles to provide a sustainable program:

1. Executable with current *budget with modest increases*.
2. Application of *high Technology Readiness Level* (TRL) technologies for near term, while focusing research on technologies to address challenges of future missions.
3. *Near-term mission* opportunities with a defined cadence of compelling missions providing for an incremental buildup of capabilities for more complex missions over time.
4. Opportunities for *US Commercial Business* to further enhance the experience and business base learned from the ISS logistics and crew market.
5. *Multi-use* Space Infrastructure.
Human Exploration Design Reference Missions

<table>
<thead>
<tr>
<th>Initial Exploration Missions</th>
<th>Extending Reach Beyond LEO</th>
<th>Into The Solar System</th>
<th>Exploring Other Worlds</th>
<th>Planetary Exploration</th>
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<tr>
<td>ISS Utilization</td>
<td>SLS/ORION (EM1, Uncrewed Mission)</td>
<td>SLS/ORION (EM2, Crewed Mission)</td>
<td>DRM Crewed Mission to Asteroid</td>
<td>DRM Crewed NEA 3 SLS Class Mission</td>
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<td></td>
<td>DRM Crewed Mars Moons Mission</td>
<td>Crewed Mars Orbit Mission</td>
<td>DRM Crewed Mars Surface</td>
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**Note:**
Design Reference Missions serve to define bounding cases of capabilities required to conduct missions.

They are intended to serve as a framework for understanding the capabilities and technologies that may be needed, but are not specific actual missions to be conducted.

Updated Design Reference Missions – Late FY2013
## Elements Required By Potential Destination

<table>
<thead>
<tr>
<th>Phase</th>
<th>Capability</th>
<th>Potential Required Element</th>
<th>For Potential Destinations</th>
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<tbody>
<tr>
<td></td>
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<td>L1/L2</td>
<td>Asteroid</td>
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<tr>
<td>Getting There</td>
<td>BEO Access</td>
<td>Space Launch System (SLS)</td>
<td>X</td>
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<td></td>
<td>Crew</td>
<td>Orion</td>
<td>X</td>
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<tr>
<td></td>
<td>High Thrust/Near Earth</td>
<td>Cryo Propulsion Stage (CPS)</td>
<td>X</td>
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<tr>
<td></td>
<td>Low Thrust/Near Earth</td>
<td>Solar Electric Propulsion (SEP)</td>
<td>Option</td>
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<td></td>
<td>High Thrust/Beyond LEO</td>
<td>Nuclear Thermal Propulsion (NTP)</td>
<td>Option</td>
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<tr>
<td></td>
<td>Low Thrust/Beyond LEO</td>
<td>Nuclear Electric Propulsion (NEP)</td>
<td>Option</td>
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<tr>
<td></td>
<td>Habitation</td>
<td>Habitat</td>
<td>Option</td>
</tr>
<tr>
<td></td>
<td>Descent</td>
<td>EDL / Landers</td>
<td>X</td>
</tr>
<tr>
<td>Working There</td>
<td>Habitation</td>
<td>Habitat</td>
<td>X</td>
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<tr>
<td></td>
<td>Micro-g Sortie and Surface Mobility</td>
<td>Robotics and Mobility</td>
<td>X</td>
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<td></td>
<td>In Situ Resource Utilization</td>
<td>In-Situ Resource Utilization (ISRU)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Surface Power</td>
<td>Fission Surface Power System</td>
<td>X</td>
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<td></td>
<td>EVA (nominal)</td>
<td>EVA Suits</td>
<td>X</td>
</tr>
<tr>
<td>Coming Home</td>
<td>Ascent</td>
<td>Ascent Vehicle</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Crew Return</td>
<td>Orion</td>
<td>X</td>
</tr>
</tbody>
</table>

**Note:**
- **X** – Required Elements/Capabilities for these potential destinations
- **Option** – Element/Capability may be needed or multiple options could exist to enable missions for that specific potential destination or could be for verification for future needs.
Common Capabilities Identified for Exploration

Capability Driven Human Space Exploration

Human Exploration of Mars
The “Horizon Destination”

Architecture Common Capabilities (Mission Needs)

- Low Earth Orbit Crew and Cargo Access
- Human - Robotic Mission Ops
- Adv. In-Space Propulsion
- Habitation
- Ground Operations
- Beyond Earth Orbit Crew and Cargo Access
- EVA
- Robotics & Mobility
- Crew Health & Protection

Technologies, Research, and Science

- Autonomous Mission Operations
- Avionics
- Communication / Navigation
- ECLSS
- Entry, Descent and Landing
- In-Situ Resource Utilization
- Power and Energy Storage
- Thermal
- Radiation Protection
- SKGs Measurements / Instruments and Sensors
Future Mission Capability Development with Focus on Near Term Cadence of Missions

Each mission makes incremental progress in advancing our capabilities to enable additional potential missions.
Flight system development for large human systems is 5-8 years
- Timeline varies across destinations, flight systems, and technology programs
New technologies incorporated into spacecraft design at PDR if TRL 6 or greater
  - Early incorporation of new technologies and data sets reduces mission risk
Planetary mechanics may limit launch opportunities and transit windows
Developing integrated capabilities dependent on mission design, technology readiness and resolving data gaps
To inform mission/system planning and design and near-term Agency investments
- Human Spaceflight Architecture Team (HAT) Destination Leads were asked to identify the data or information needed that would reduce risk, increase effectiveness, and aid in planning and design
- The data can be obtained on Earth, in space, by analog, experimentation, or direct measurement

NASA’s Analysis/Assessment Groups devoted considerable time to assessing SKGs
- External assessment groups vetted and refined the draft SKGs from HAT and identified pertinent measurements that would fill the identified gaps
- As part of the Mars Program Planning Group, Mars-related SKGs were further evaluated with respect to the formulation of future robotic Mars science-driven missions and their support for human exploration goals.

The Strategic Knowledge Gaps (SKGs) were further assessed:
- Provide NASA’s foundation for achieving an internationally developed and accepted set of integrated and prioritized SKGs through the International Space Exploration Coordination Group’s (ISECG) Strategic Knowledge Assessment Team
- ISECG’s SKG-Assessment Team developed and applied an algorithm to prioritize SKGs within and across destinations

The SKGs will provide a framework for coordinating key measurements by international robotic missions to support human exploration and will be incorporated into the Global Exploration Roadmap 2.0

SKGs are publicly available at: http://www.nasa.gov/exploration/library/skg.html
SKGs: Common Themes and Some Observations

- **There are common themes across potential destinations (not in priority order)**
  - The three R’s for enabling human missions
    - Radiation
    - Regolith
    - Reliability
  - Geotechnical properties
  - Volatiles (i.e., for science, resources, and safety)
  - Propulsion-induced ejecta
  - In-Situ Resource Utilization (ISRU)/Prospecting
  - Operations/Operability (all destinations, including transit)
  - Plasma Environment
  - Human health and performance (critical, and allocated to HRP)

- **Some Observations**
  - The required information is measurable and attainable
  - These measurements do not require “exquisite science” instruments but could be obtained from them
  - Filling the SKGs requires a well-balanced research portfolio
    - Remote sensing measurements, in-situ measurements, ground-based assets, and research & analysis (R&A)
    - Includes science, technology, and operational experience
ISECG and the Global Exploration Roadmap

• Consistent with existing policy and the NASA Strategic Plan, human exploration beyond low-Earth orbit will be an international effort with many space agencies contributing
  – Current partners, New partners
• An effective, non-binding coordination mechanism has been established to advance concepts of mutual interest
  – The ISECG and its Global Exploration Roadmap (GER)
• The non-binding GER enables agency discussions on important topics such as
  – Common goals and objectives for exploration
  – Advancing long-range mission scenarios and architectures which lead to sustainable human missions to Mars
  – Opportunities for near-term coordination and cooperation on preparatory activities

Updated GER 2.0 is expected to be complete in NET July 2013
The Future of Human Space Exploration

- One-way transit times to destinations

Earth

International Space Station 2 Days

Moon 3-7 Days

Lagrange Points and other stable cislunar orbits 8-10 Days

Mars 6-9 Months

Near-Earth Asteroid 3-12 Months

Human Spaceflight Deep Space Challenge Examples

- In Space Propulsion and Space Power
- Crew Health, Medical, and Safety
- Robotics and Autonomous Systems
- Entry, Descent and Landing
- Habitation Systems and Destination Systems, esp. ECLSS and Space Radiation
- Deep Space EVA