National Aeronautics and Space Administration

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)

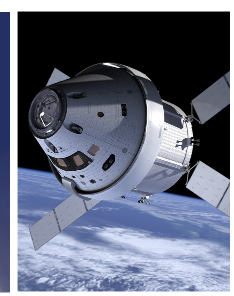
U.S. Law: Authorization, Appropriation, Budget

President Obama at KSC – April 15, 2010

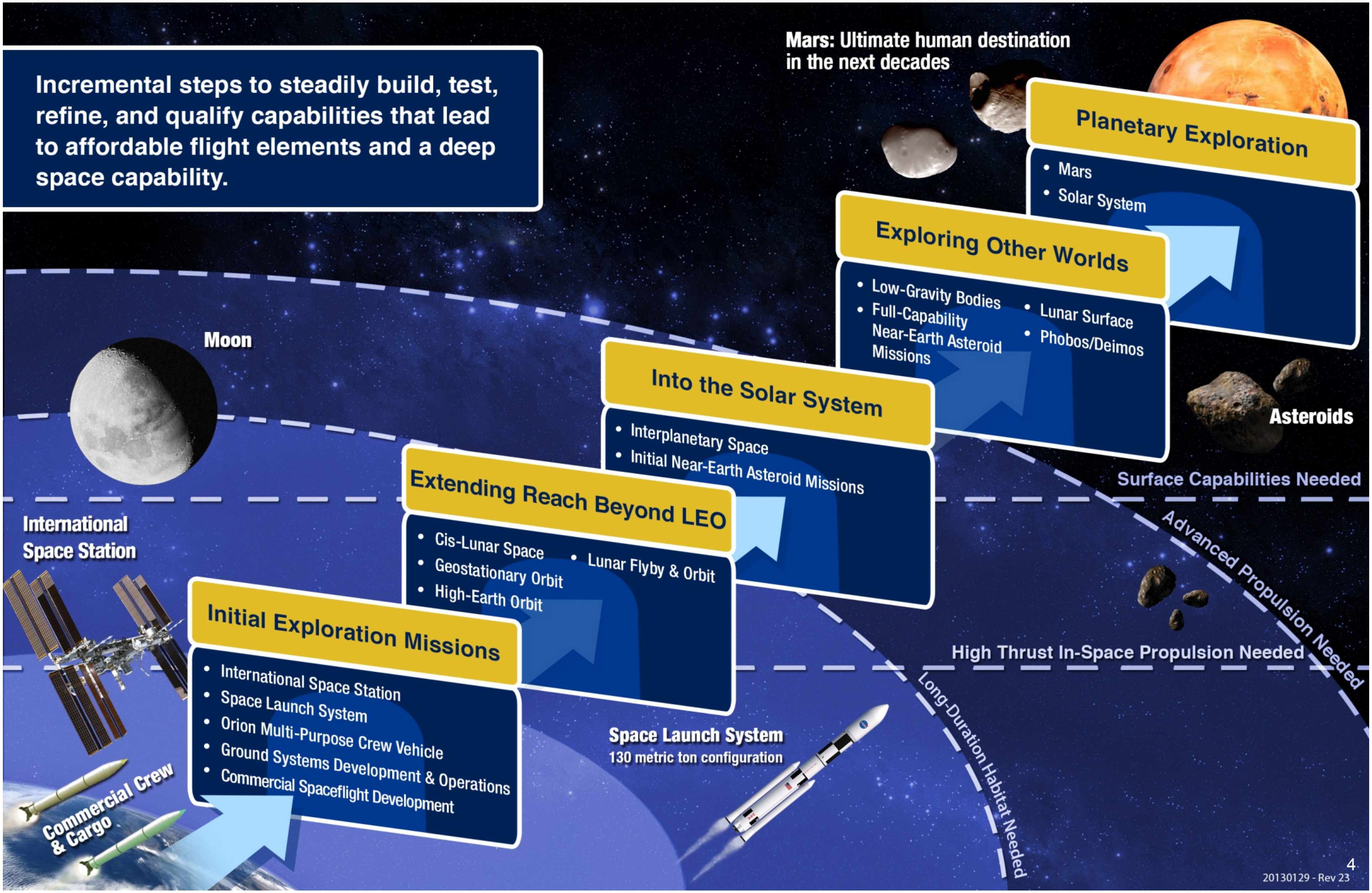
"Early in the next decade, a set of crewed flights will test and prove the systems required for exploration beyond low Earth orbit. And by 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the Moon into deep space. So we'll start -- we'll 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."

- **NASA Authorization Act of 2010 & 2012 Appropriations**
  - 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






Capability Driven Framework



Strategic Principles for Incremental Building of Capabilities

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
6. Significant ***International participation***, leveraging current International Space Station partnerships

Human Exploration Design Reference Missions

Initial Exploration Missions	Extending Reach Beyond LEO	Into The Solar System	Exploring Other Worlds	Planetary Exploration

ISS Utilization →

SLS/ORION (EM1, Uncrewed Mission)

SLS/ORION (EM2, Crewed Mission)

DRM Crewed Mission to Asteroid

DRM Crewed NEA 3 SLS Class Mission

DRM Crewed Mars Moons Mission

Crewed Mars Orbit Mission *DRM*

Crewed Mars Surface *DRM*

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

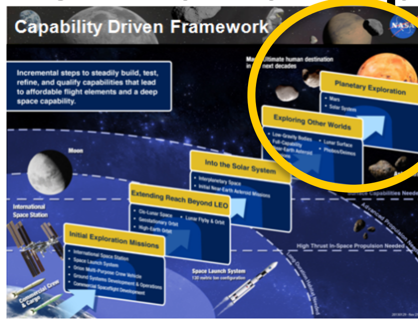
Elements Required By Potential Destination

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

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"

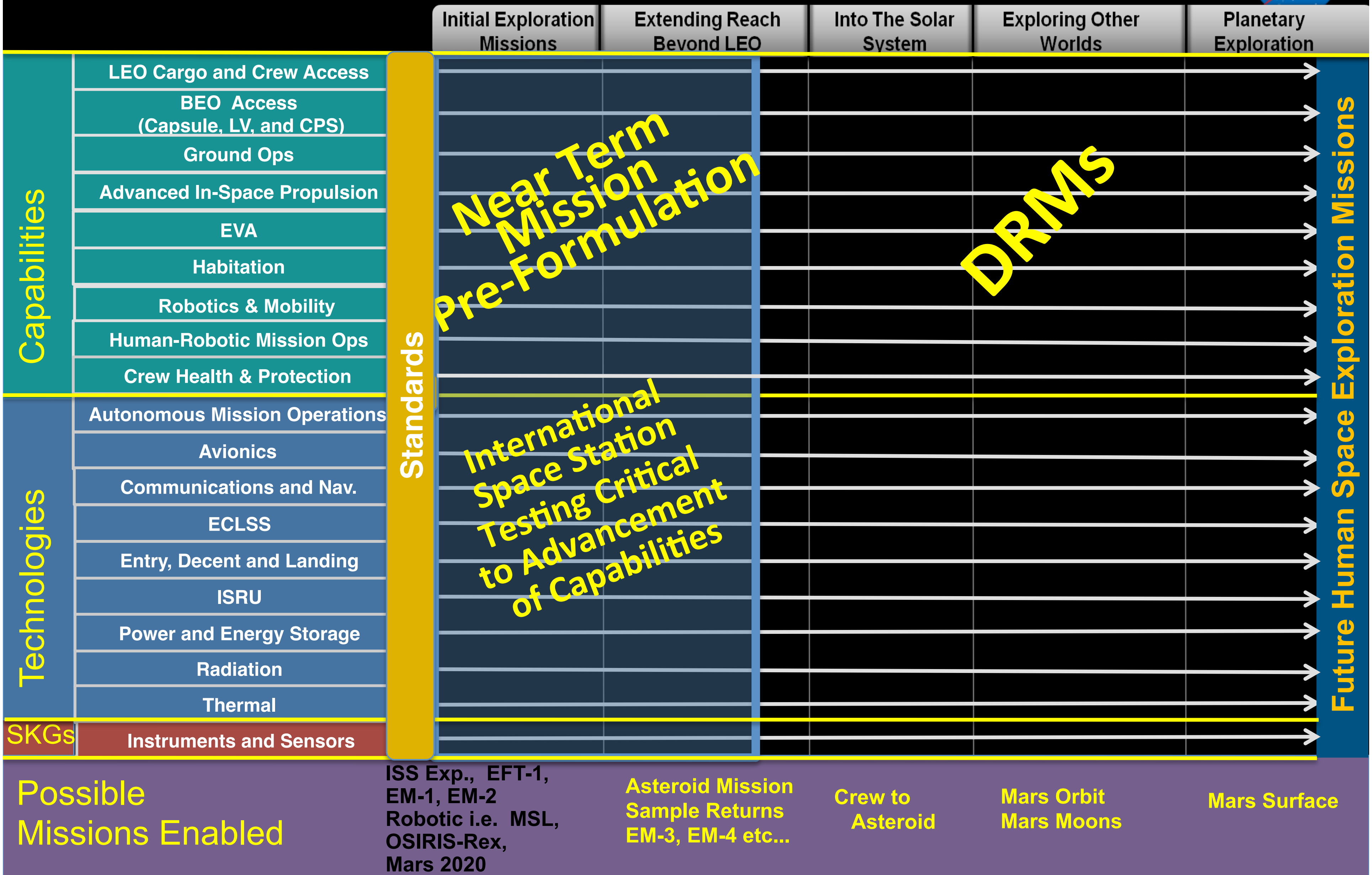
Architecture Common Capabilities (Mission Needs)

- 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

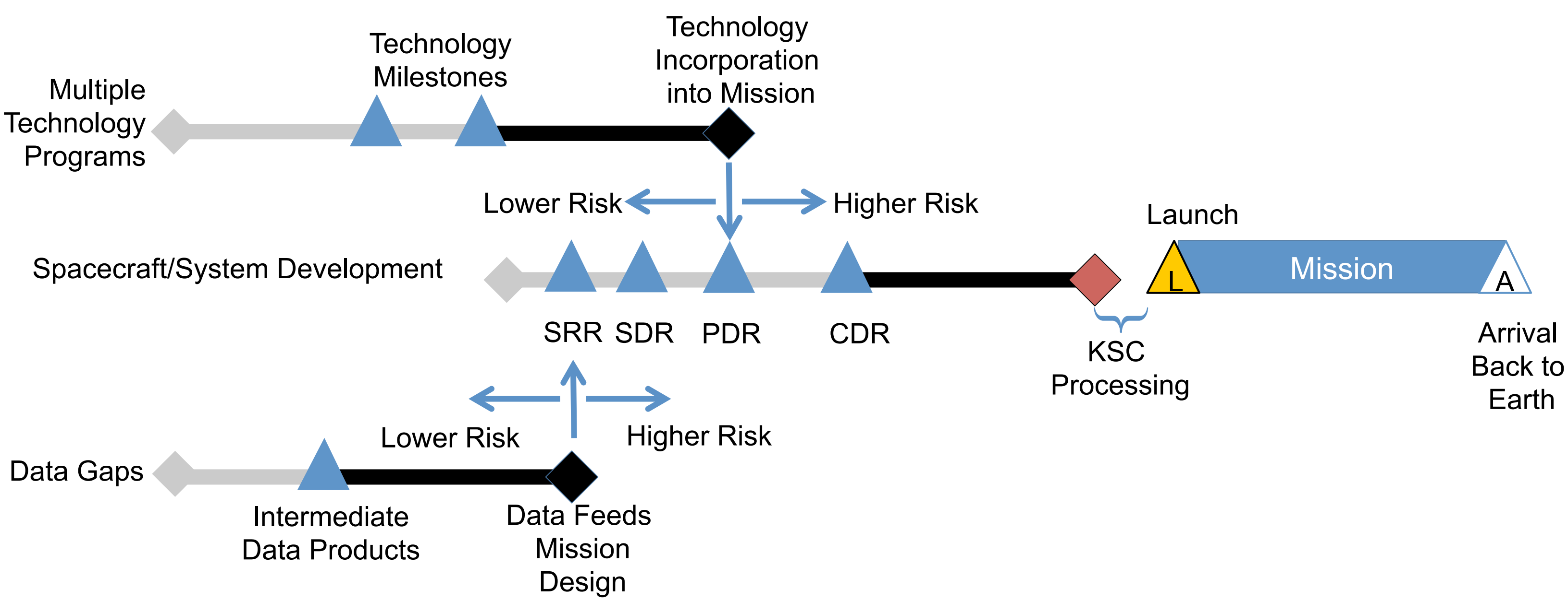
Future Mission Capability Development with Focus on Near Term Cadence of Missions



Each mission makes incremental progress in advancing our capabilities to enable additional potential missions.

Integrated Capability Schedule Example

- 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



NASA Set of Vetted Strategic Knowledge 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 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 incorporated into the Global Exploration Roadmap 2.0**

SKGs are publically available at: http://www.nasa.gov/exploration/library/skg.html

Note Other 2013 Deliverables Include:

Integrated Strategic Knowledge Gaps – NET October

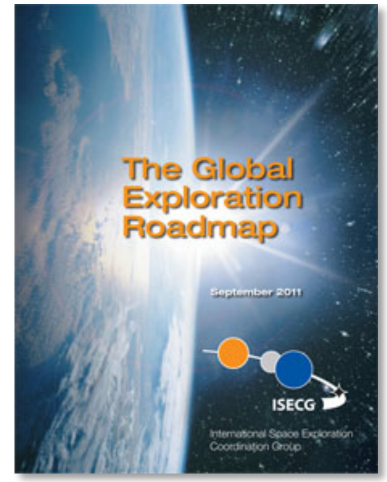
Global Exploration Roadmap (GER) 2.0 – NET July

SKGs: Common Themes and Some Observations

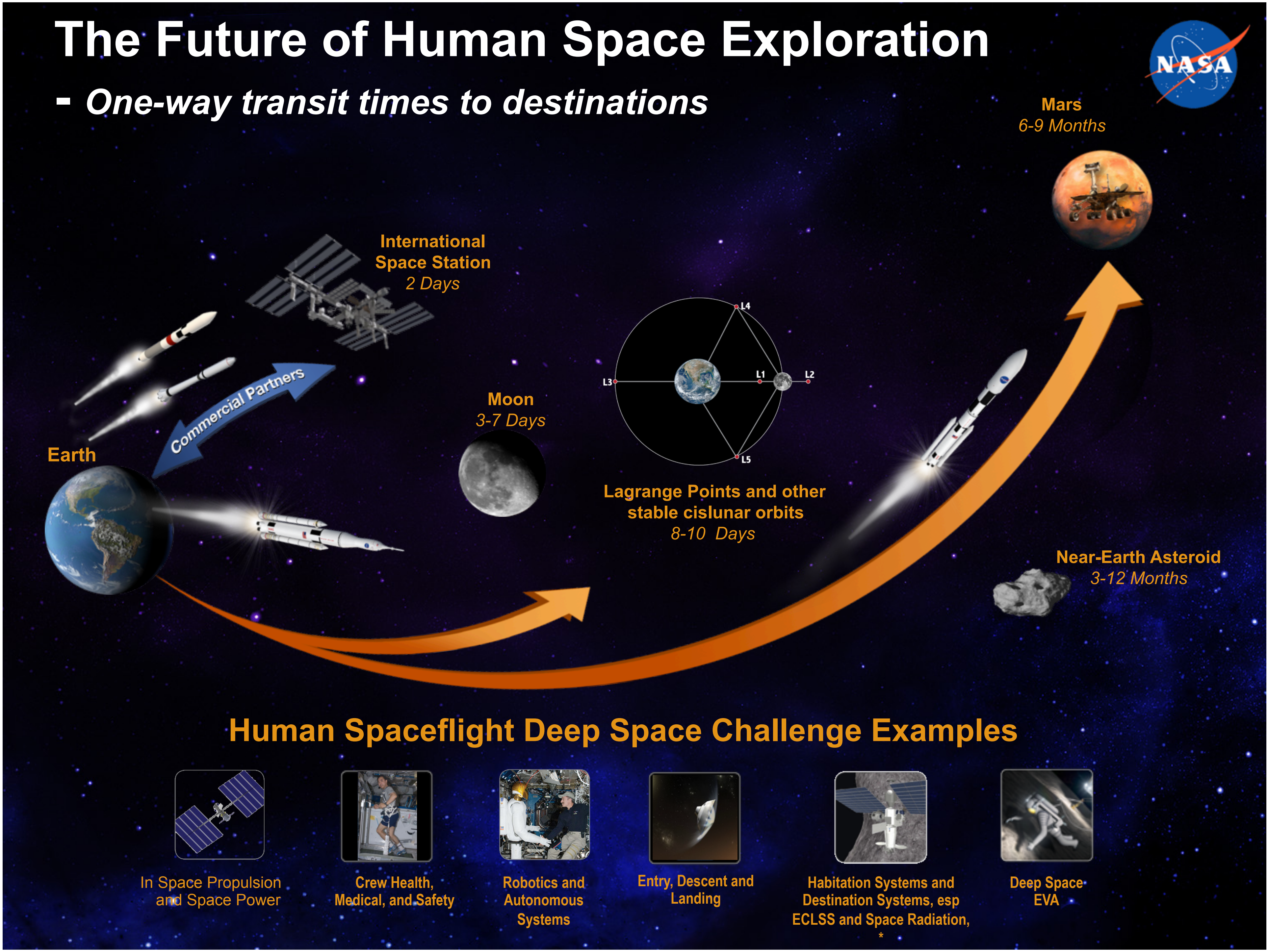
- **There are common themes across potential destinations (not in priority order)**
  - The three R's for enabling human missions
    - Radiation
    - Regolith
    - Reliability
  - Geotechnical properties
  - Volatiles (i.e., for science, resources, and safety)
  - Propulsion-induced ejecta
  - In-Situ 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
NASA
Mars
6-9 Months
International
Space Station
2 Days
Commercial Partners
Earth
Moon
3-7 Days
L4
L3
L1
L2
L5
Lagrange Points and other
stable cislunar orbits
8-10 Days
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