National Aeronautics and Space Administration

Advanced Exploration Systems

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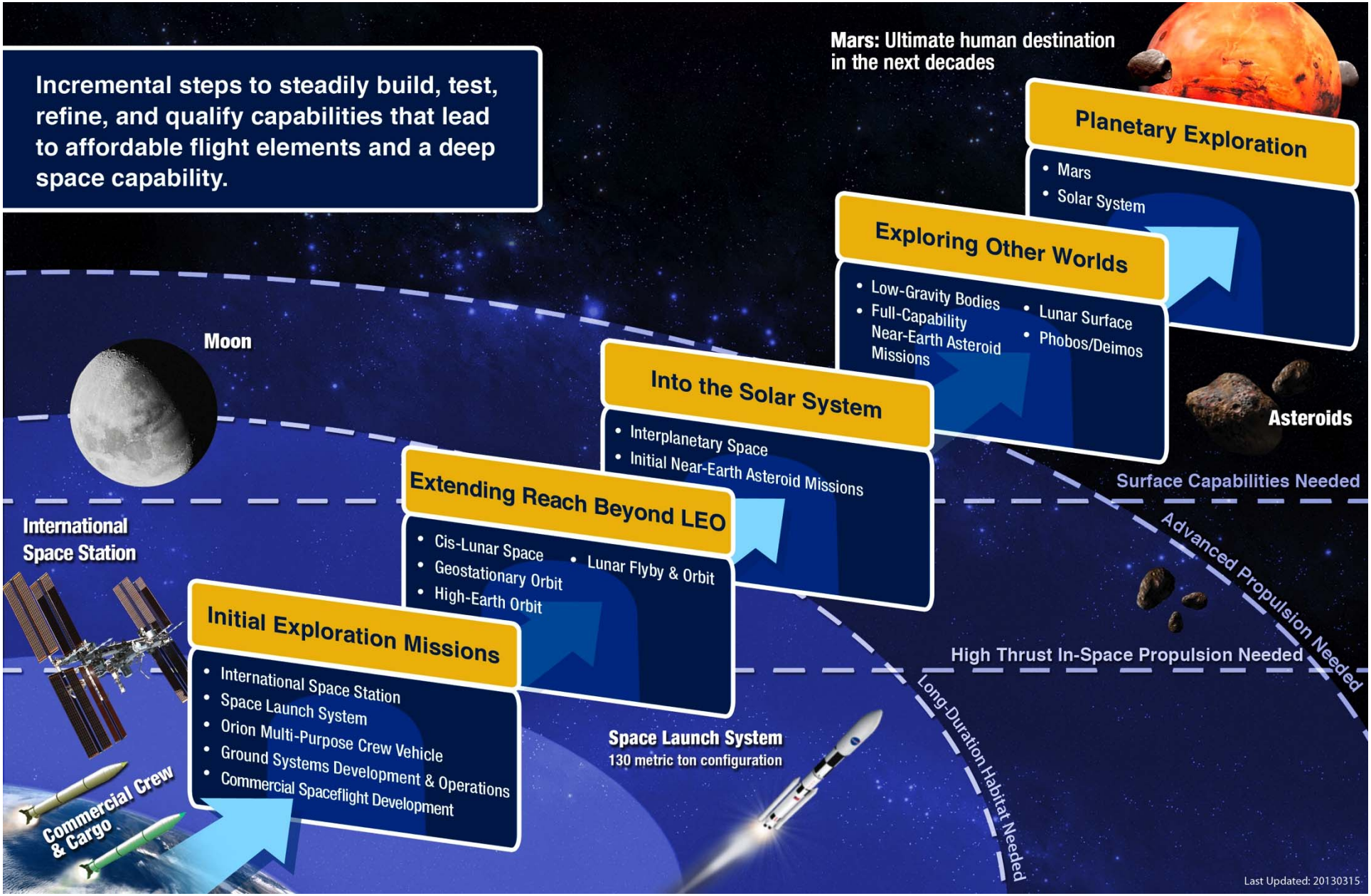
Human Exploration and Operations Mission Directorate • NASA Headquarters

Capability Driven Framework



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 Mars Moons Mission**

Crewed Mars Orbit Mission ***DRM***

Crewed Mars Surface ***DRM***

<u>Note:</u>

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

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

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
- Mobility
- Crew Health & Protection

Technologies, Research, and Science

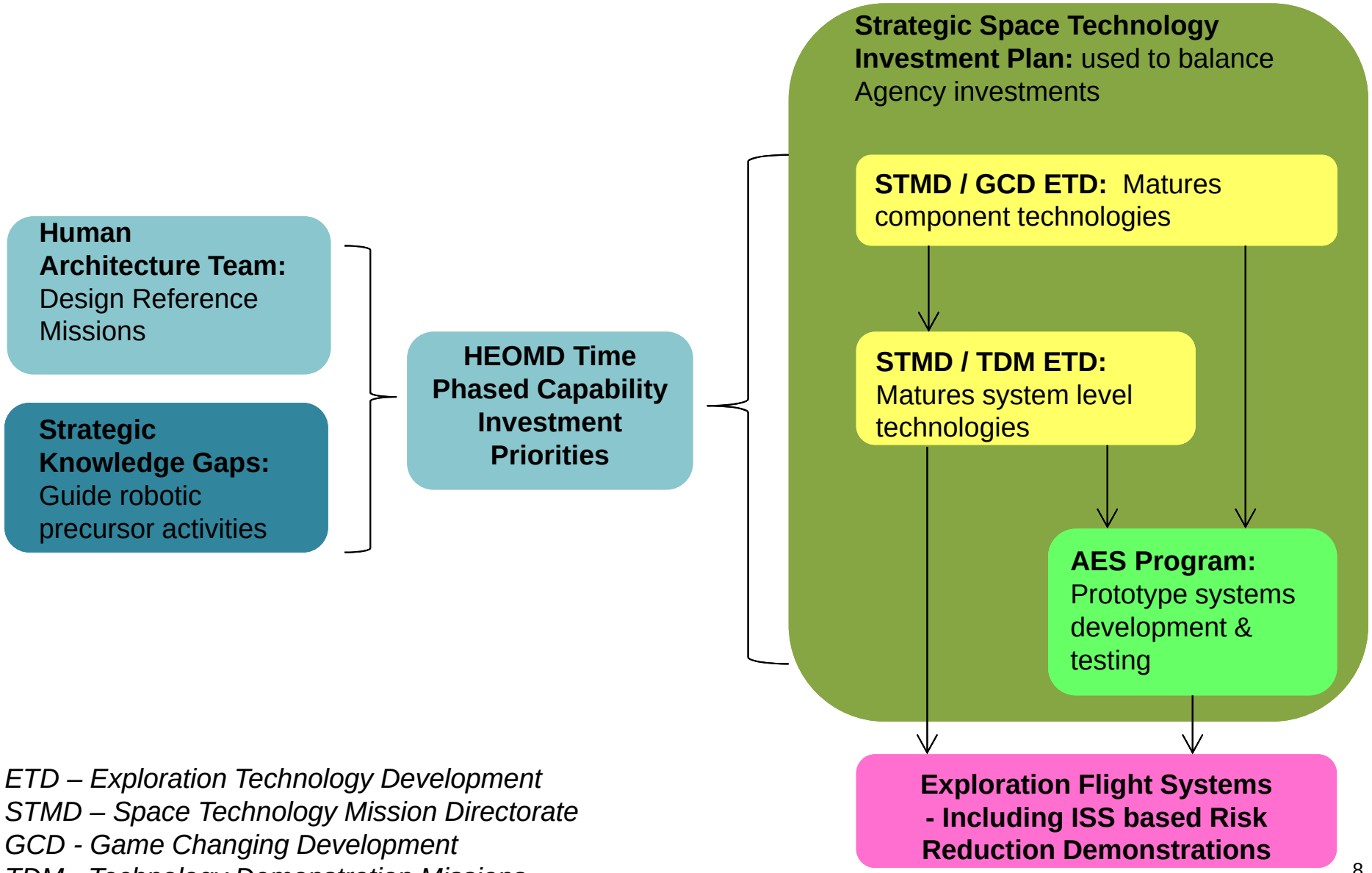
- Autonomous Mission Operations
- Avionics
- Communication / Navigation
- ECLSS
- Entry, Descent and Landing
- In-Situ Resource Utilization
- Power and Energy Storage
- Thermal
- Radiation Protection
- SKGs Measurements / Instruments and Sensors

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

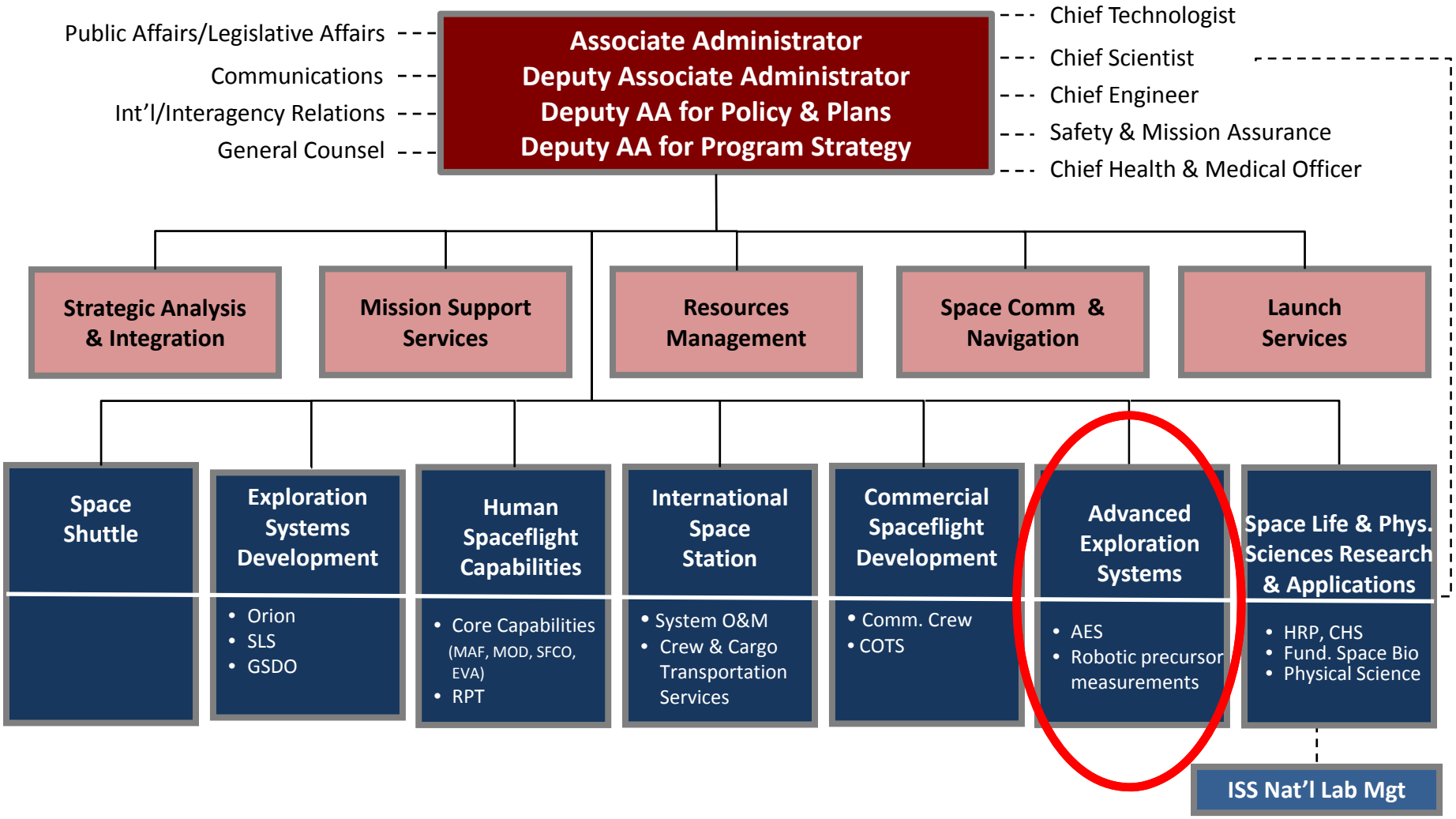
Defining the Combined HEOMD/AES - ETD/STMD Portfolio



ETD – Exploration Technology Development
STMD – Space Technology Mission Directorate
GCD - Game Changing Development
TDM - Technology Demonstration Missions

Human Exploration & Operations Mission Directorate

Organizational Structure



ETD and AES Objectives

Exploration Technology Development (STMD)

- Develop long-range foundational technologies and components to support human exploration needs.
- Conduct flight demonstration missions of high-priority exploration capabilities such as cryogenic propellant storage and solar electric propulsion.
- Mature technologies for infusion into mission-level programs and agency initiatives.
- Leverage synergies with game-changing and crosscutting technologies to support multiple customers and mission applications.

Advanced Exploration Systems (HEOMD)

- Advanced development of exploration systems to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions beyond Earth orbit.
- Demonstrate prototype systems in ground test beds, field tests, underwater tests, and ISS flight experiments.
- Use and pioneer innovative approaches for affordable rapid systems development and provide hands-on experience for the NASA workforce.
- Maintain critical competencies at the NASA Centers and provide NASA personnel with opportunities to learn new and transform skills.
- Infuse new technologies developed by STMD / ETD into exploration missions.
- Support robotic missions of opportunity to characterize potential destinations for human exploration.

Advanced Exploration Systems

Rapid development and testing of prototype systems and validation of operational concepts to reduce risk and cost of future exploration missions:

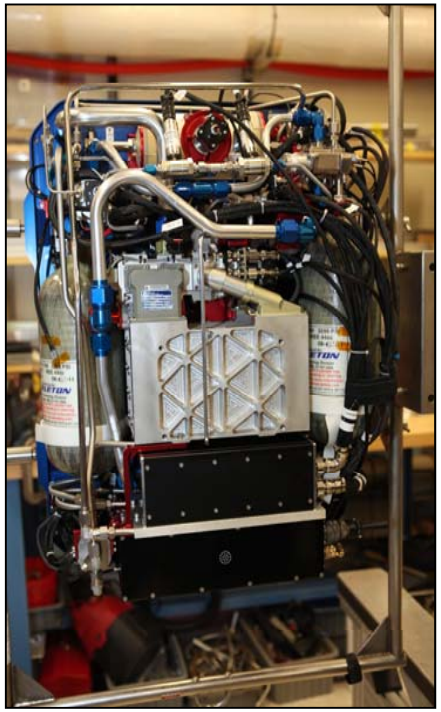
- **Crew Mobility Systems**
  - Systems to enable the crew to conduct "hands-on" surface exploration and in-space operations, including crew excursion vehicles, advanced space suits, and crew egress
- **Deep Space Habitation Systems**
  - Systems to enable the crew to live and work safely in deep space, including deep space habitats, reliable life support, radiation protection, and fire safety
- **Vehicle Systems**
  - Systems for in-space propulsion stages and small robotic landers, including nuclear propulsion, modular power systems, lander technology test beds, and autonomous precision landing
- **Operations**
  - Systems to enable more efficient mission and ground operations, including integrated testing, autonomous mission ops, integrated ground ops, and logistics reduction
- **Robotic Precursor Activities**
  - Acquire strategic knowledge on potential destinations for human exploration to inform systems development, including prospecting for lunar ice, characterizing the Mars surface radiation environment, radar imaging of NEAs, instrument development, and research and analysis

Summary for FY13

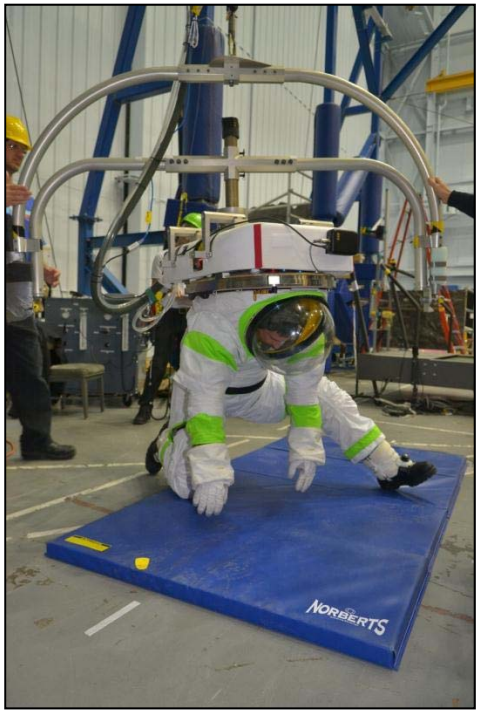
- AES has established 63 project milestones for FY13. Goal is to achieve at least 80%.
- AES is developing 11 flight experiments
- AES is employing 578 civil servants in FY13.

Recent Accomplishments

Crew Mobility Systems Domain



EVA: Completed assembly of the Portable Life Support System (PLSS) 2.0. This is the first new PLSS to be developed since the Shuttle EMU was introduced in 1981. The PLSS 2.0 incorporates new technology components developed by GCD/STMD for CO2 removal, suit pressure regulation, thermal control, and energy storage.



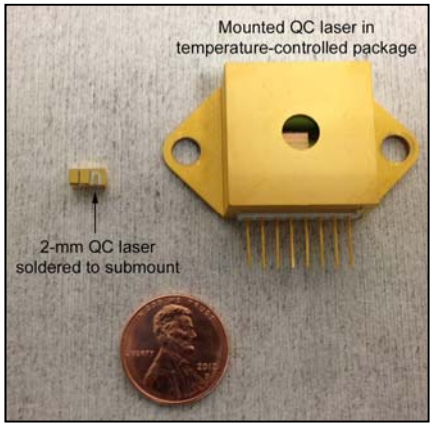
EVA: Assessed mobility of Z-1 suit with ARGOS gravity off-load system.

Habitable Airlock: Fabricated and assembled composite crew cabin for Habitable Airlock.

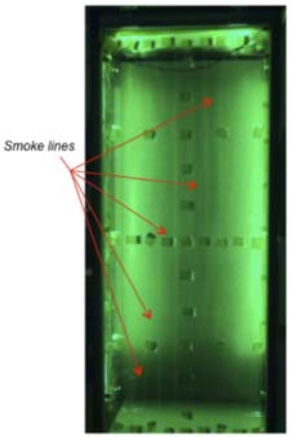
Recent Accomplishments

Deep Space Habitation Systems Domain

Life Support: Completed integrated chamber tests of ISS-derived Carbon Dioxide Removal Assembly, Trace Contaminant Control System, Sabatier reactor, and Oxygen Generation Assembly



Life Support: Fabricated quantum cascade laser with 4.75 µm wavelength for carbon monoxide detection.



Spacecraft Fire Safety: Large Scale fire propagation experiments – Conducted on ISS Cargo vehicle (Cygnus)

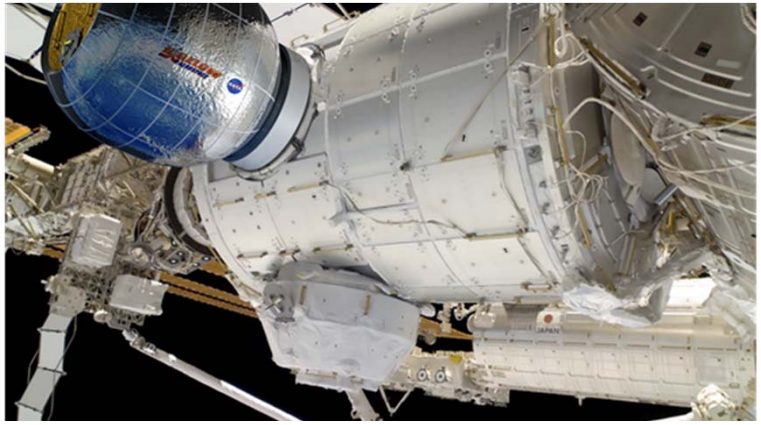
Radiation Protection: Completed CDR for the radiation environment monitors that will fly on the EFT-1 mission in 2014.

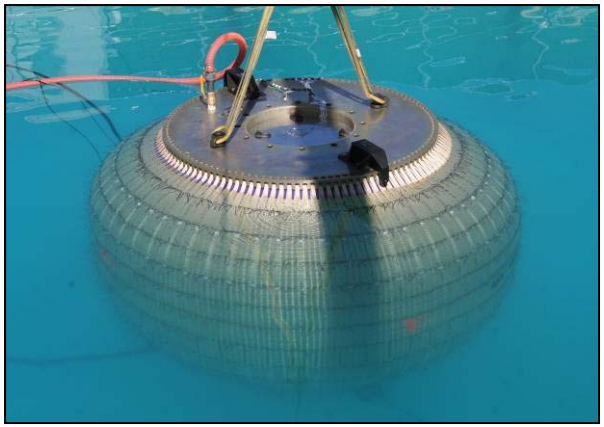
Recent Accomplishments

Deep Space Habitation Systems Domain

Habitat Systems: Refurbishing MPLM mockup for integration of crew accommodations, life support, power, and avionics.

Radiation Protection: Launched 5 radiation monitors to ISS and collecting data





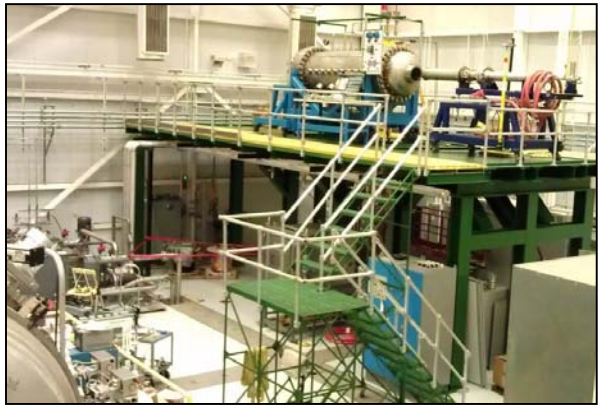
BEAM: Signed contract with Bigelow Aerospace to develop inflatable module for demonstration on ISS in 2015. Completed burst test to 8x operating pressure.

Recent Accomplishments

Vehicle Systems Domain

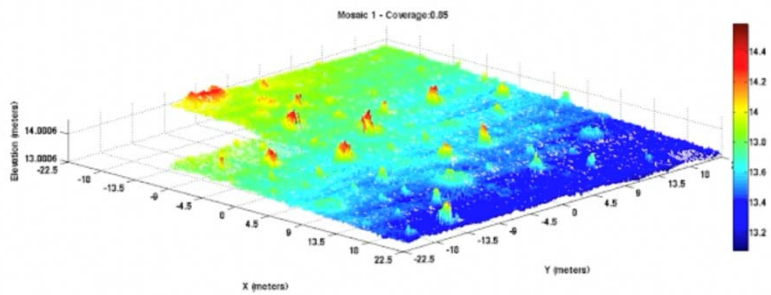
Morpheus: Completed assembly of new 1.5B vehicle with HD4 engine.

Composites: Tested 8 ft by 12 ft composite panel for SLS payload fairing to 33,000 lbf compressive load.



Nuclear Thermal Propulsion: Upgrading NTRESS test facility for operation at 1.5MW for fuel element testing

ALHAT: Advancing precision landing capabilities Recently completed helicopter flight tests of integrated ALHAT system at KSC to demonstrate hazard detection and safe landing site selection.



ALHAT: Digital elevation model of hazard field acquired by flash lidar

Recent Accomplishments

Operations Domain

Ka-Band Objects Observation & Monitoring (KaBOOM): Next Generation system for Radar for NEA characterization. Recently completed installation of three 12 m antenna dishes at KSC.

Integrated Ground Ops: Installed a 33,000-gallon LH2 tank (left) and 2,000-gallon LOX tank (right) at KSC to demonstrate zero boil-off cryogenic propellant storage, and autonomous control of propellant loading.

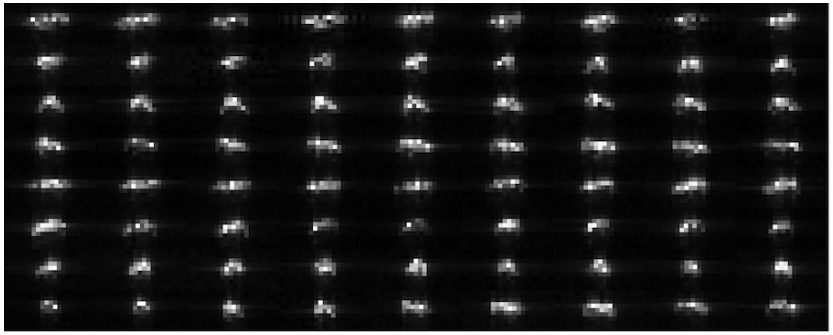
Recent Accomplishments

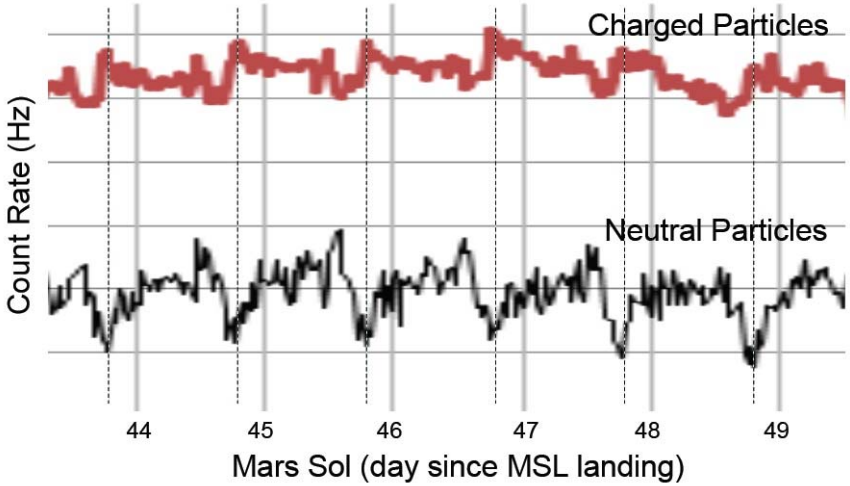
Operations Domain

Disruption Tolerance Network: Demonstration next generation networking protocol. Recently used DTN protocols to control ESA robot on ground from ISS, and to teleoperate SPHERES free flyers on ISS from the Mission Control Center. A smartphone attached to SPHERES was used for wireless communications. DTN is supporting the STMD Human Exploration Telerobotics project.

Recent Accomplishments

Robotic Precursor Activities Domain





Goldstone Radar: Imaged 10 NEAs including 2012 DA14 when it passed within 35,000 km of Earth on February 15. Determined size is 40 m x 20 m, and rotation rate is about 8 hours. Installed digital receiver at Arecibo to enable 4-meter resolution

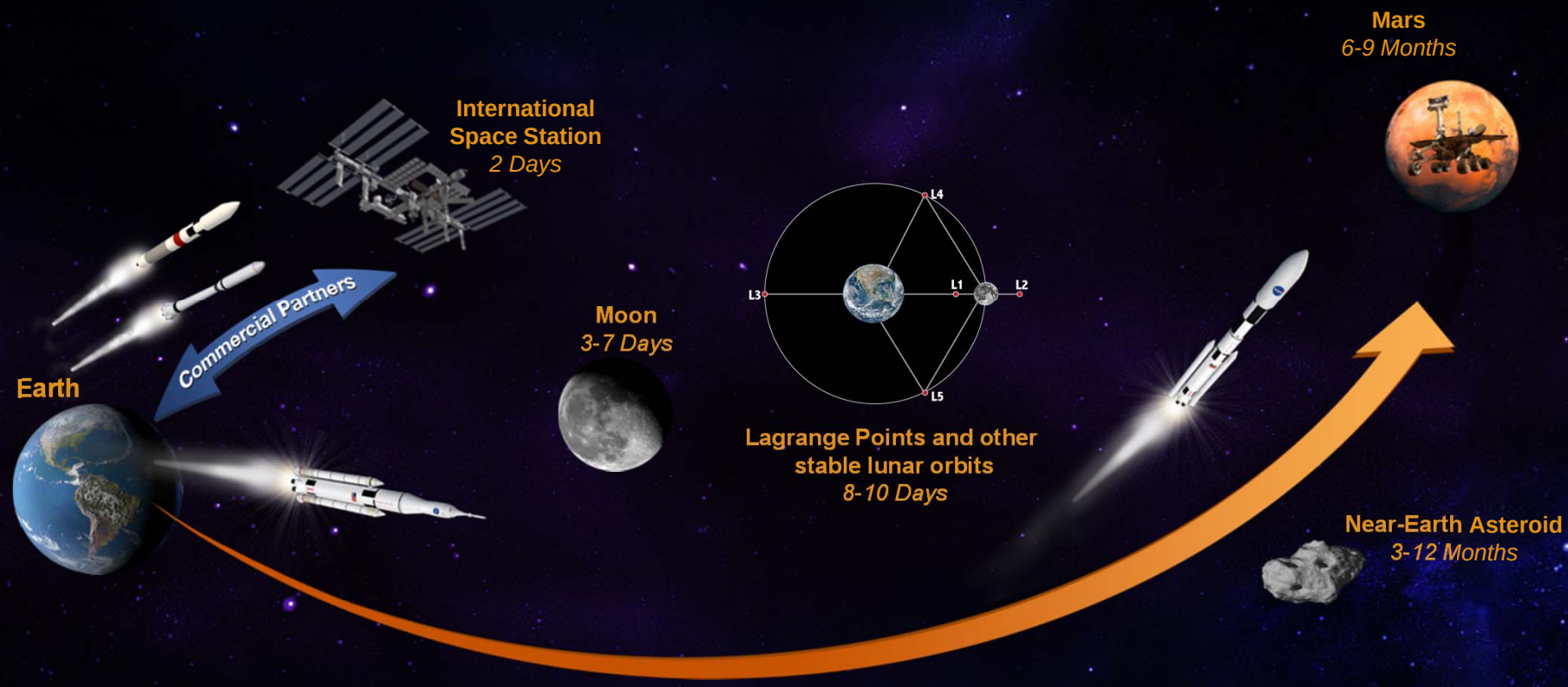
Radiation Assessment Detector (RAD): Operating for 230+ sols on Mars. Discovered that neutron flux is anti-correlated with charged particle flux.

AES Flight Experiments in Development

- **ISS**
  - Additive Manufacturing (2014)
  - Autonomous Mission Operations (2014)
  - BEAM: Bigelow Expandable Activity Module (2015)
  - Delay Tolerant Networking (2012)
  - EVA Suit Demo (2019)
  - Medipix Radiation Sensors on ISS (2012)
  - OPALS: Optical Payload for Lasercom Science (2013)
  - Spacecraft Fire Safety (2015)
- **EFT-1**
  - Advanced Caution and Warning System (2014)
  - Radiation Environment Monitors (2014)
- **Mars**
  - Radiation Assessment Detector (2012)

The Future of Human Space Exploration

Exploration Destinations and One-Way Transit Times

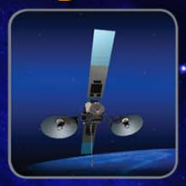


Human Spaceflight Capabilities


Mobility Systems


Deep Space Habitation


Advanced Spacesuits


Advanced Space Communications


Advanced In-Space Propulsion

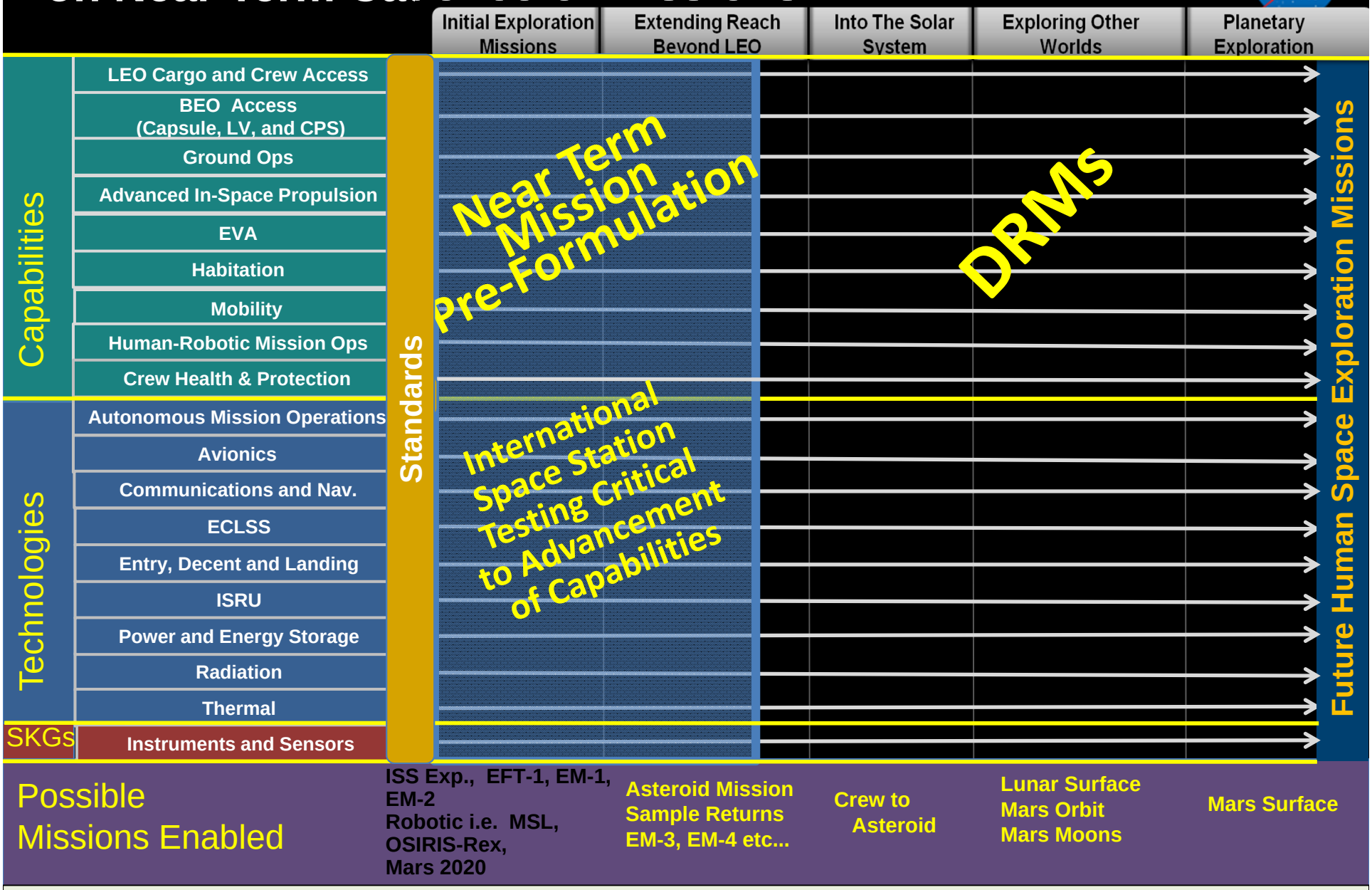

In Situ Resource Utilization


Human-Robotic Systems

Last updated:
04/15/2013

Backup

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.