National Aeronautics and Space Administration

APPEL Master’s Forum

# The Way Forward – New Pathways for Human Spaceflight


**Dr. John Olson**

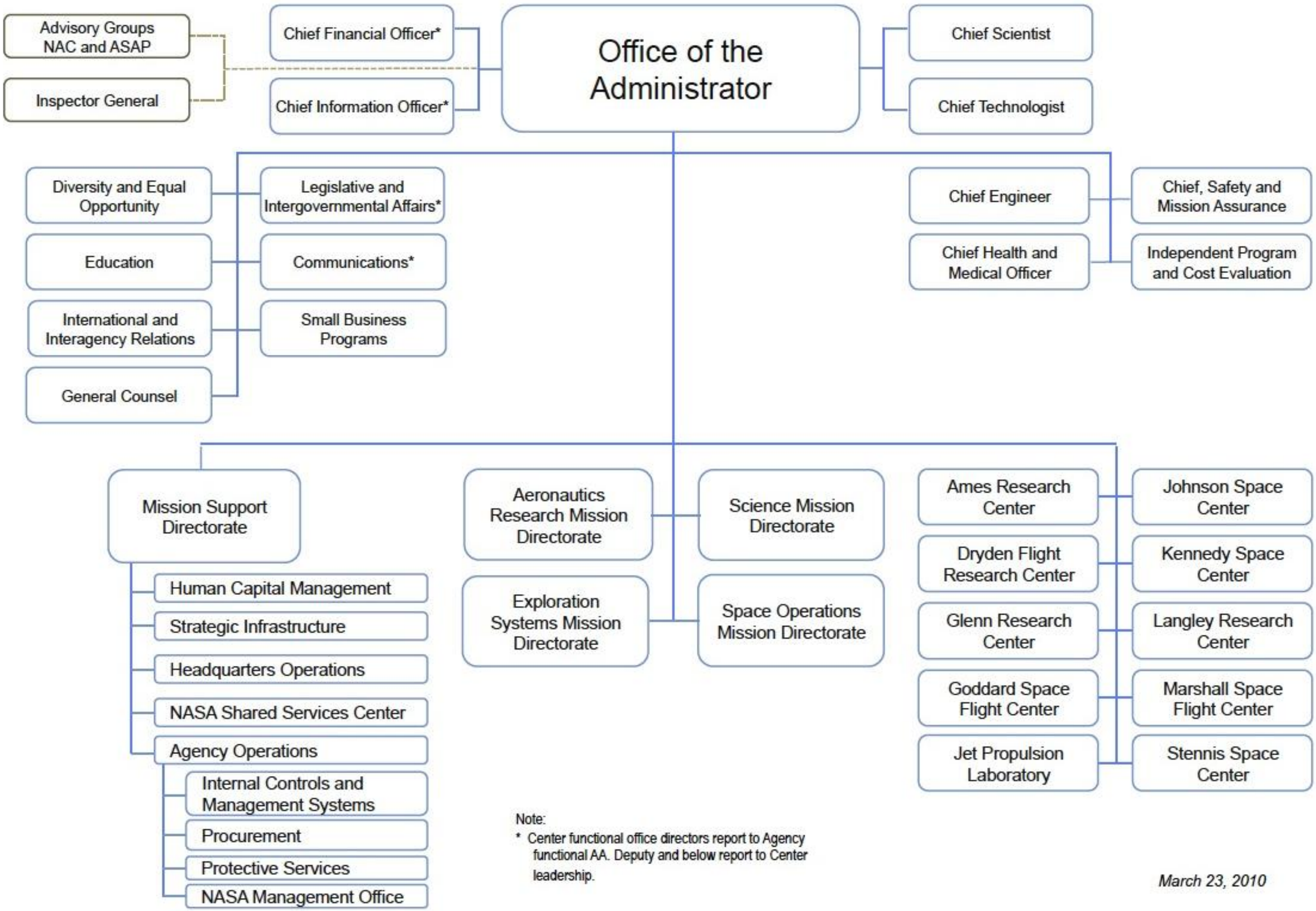
**Exploration Systems Mission Directorate**


**April 2011**

# Outline

- **Organization**
- **Vision**
- **Budget Overview**
- **Capability-Driven Exploration**
  - Key elements and programs
- **Human Exploration Framework Team**
- **Background and Overview**
- **Approach and ConOps**
- **Affordability**
- **Human Spaceflight Architecture Team (HAT)**
- **Summary**

# NASA Organization



# The NASA Vision

To reach for new heights and reveal the unknown, so that what we do and learn will benefit all humankind.

## NASA Strategic Goals

1. **Extend and sustain human activities across the solar system.**
2. **Expand scientific understanding of the Earth and the universe in which we live.**
3. **Create the innovative new space technologies for our exploration, science, and economic future.**
4. **Advance aeronautics research for societal benefit.**
5. **Enable program and institutional capabilities to conduct NASA's aeronautics and space activities.**
6. **Share NASA with the public, educators, and students to provide opportunities to participate in our mission, foster innovation, and contribute to a strong national economy**

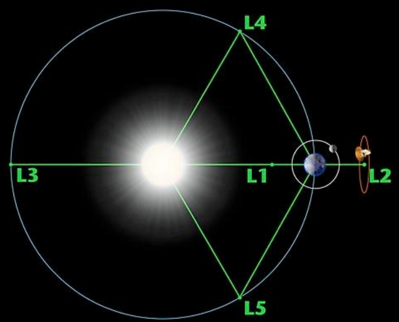
- **Funds Exploration Programs at $3,949M – $243M above FY 2011 Authorized level**
- **The President's FY 2012 Budget Request funds a diversified portfolio of activities in human spaceflight that are designed to maximize our use of current capabilities such as the International Space Station (ISS), execute innovative approaches to ensure U.S. leadership in low Earth orbit (LEO), and position the Agency to explore the frontiers of the inner solar system:**
  - Enables substantial partnership with the commercial space industry to provide safe and cost effective human access to LEO
  - Funds key systems development for exploration through the Space Launch System (SLS) and Multi-Purpose Crew Vehicle (MPCV) capable of traveling to multiple destinations beyond LEO
  - Provides for key human research and critical capability development required for future human exploration beyond LEO

The FY 2012 Budget Request supports all major components of the NASA Authorization Act of 2010.

# Budget Enables Significant Progress on Key Human Spaceflight Activities

- **Specific content of human spaceflight portfolio as reflected in FY 2012 budget request validated by NASA framework studies and highly consistent with the NASA Authorization Act of 2010**
  - ISS being utilized for critical exploration research and demonstrations
  - Cargo and crew access to ISS being developed through innovative partnerships with private sector
  - SLS and MPCV are initial essential capabilities required for NASA and the U.S. to lead exploration beyond LEO
    - These vehicles provide capabilities needed for exploration of many destinations, including cis-lunar space, the moon, asteroids and Mars and its environs
    - Formulation of these programs is proceeding aggressively and progress will be significant in FY 2012
  - Pursuing cutting edge human research and innovative development of needed life support, crew habitat and other future exploration capabilities
    - Exploration of more complex destinations will be enabled as key capabilities are developed over time
  - Leveraging the best of NASA, industry, academia, and partner capabilities while planning innovative, cost-effective approaches to development and future operations

# A Bounty of Opportunity for Human Explorers



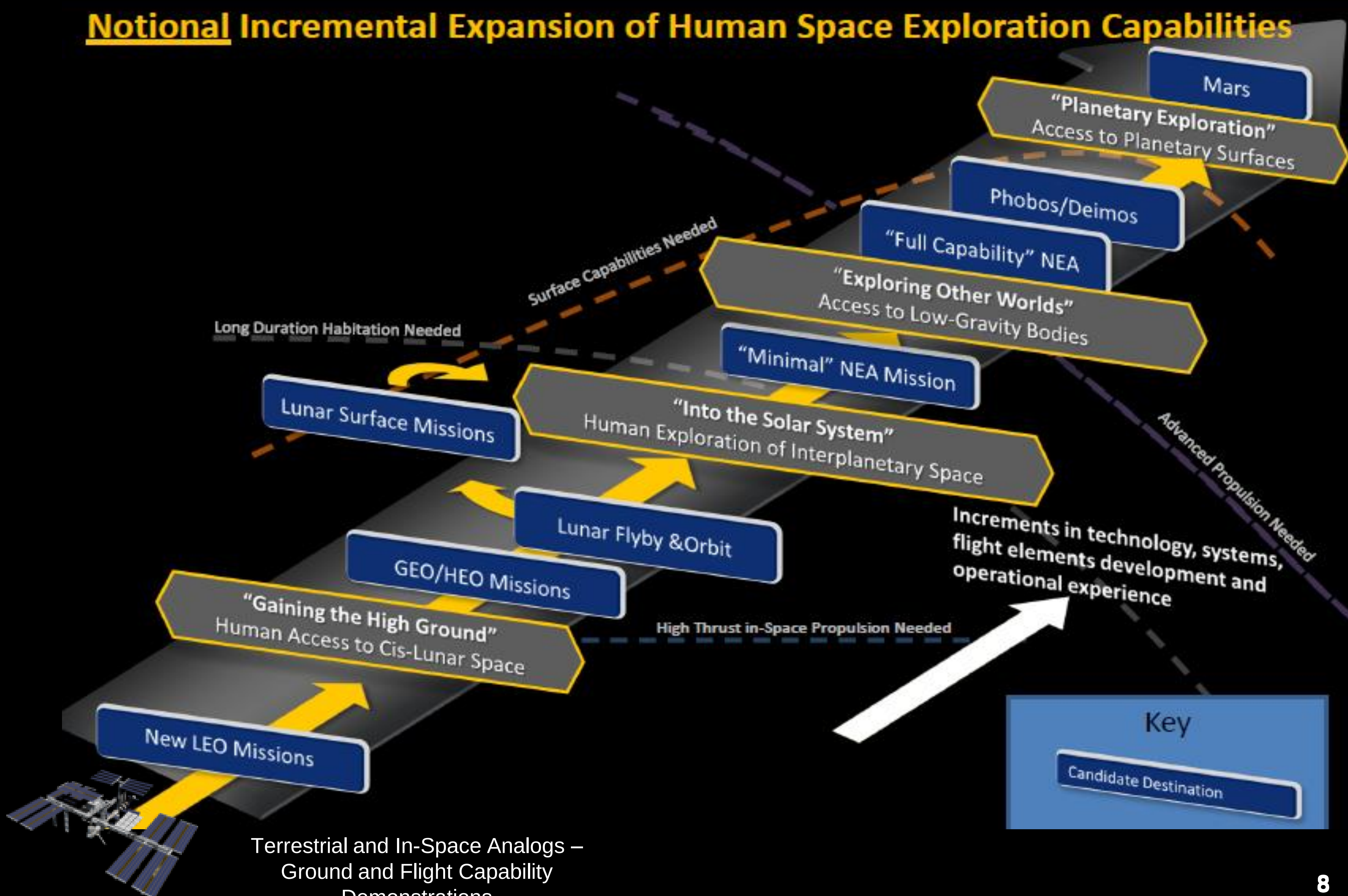

**HEO/GEO/Lagrange Points:**
- Microgravity destinations beyond LEO
- Opportunities for construction, fueling and repair of complex in-space systems
- Excellent locations for advanced space telescopes and Earth observers

**Mars and its Moons:**
- A premier destination for discovery: Is there life beyond Earth? How did Mars evolve?
- True possibility for extended, even permanent, stays
- Significant opportunities for international collaboration
- Technological driver for space systems

**Earth's Moon:**
- Witness to the birth of the Earth and inner planets
- Has critical resources to sustain humans
- Significant opportunities for commercial and international collaboration

**Near Earth Asteroids:**
- Compelling science questions: How did the Solar System form? Where did Earth's water and organics come from?
- Planetary defense: Understanding and mitigating the threat of impact
- Potential for valuable space resources
- Excellent stepping stone for Mars

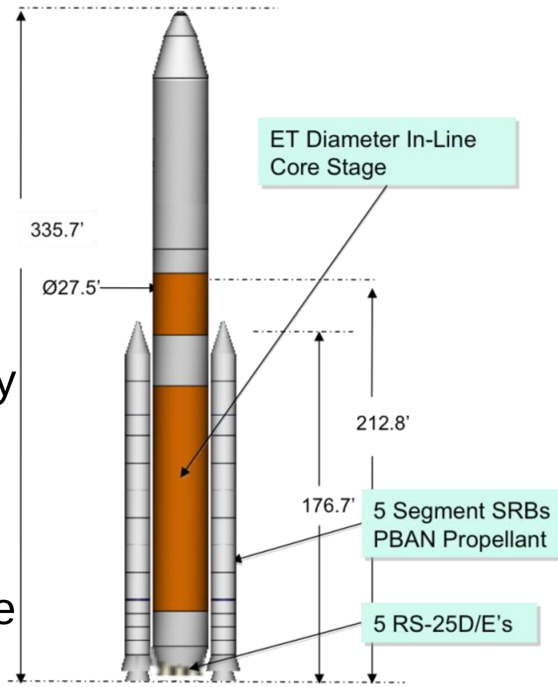
# Capability Driven Exploration

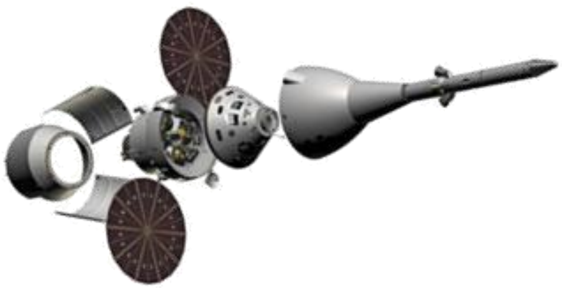



Terrestrial and In-Space Analogs –
Ground and Flight Capability
Demonstrations

# Human Exploration Capabilities Theme Overview

- **Theme budgeted at $2.8B in FY 2012 (with labor)**
- **The Human Exploration Capability (HEC) theme will develop the launch and spaceflight vehicles that will provide the initial capability for crewed exploration missions beyond LEO**
  - Funded at $1.8B (with labor) in FY 2012, the **Space Launch System** (SLS) program will develop the heavy lift vehicle that will launch the crew vehicle, other modules, and cargo for these missions
  - Funded at $1.0B (with labor) in FY 2012, the **Multi-Purpose Crew Vehicle** (MPCV) program develops the vehicle that will carry the crew to orbit, provide emergency abort capability, sustain the crew while in space, and provide safe re-entry from deep space return velocities
  - Required Ground Operations and Mission Operations will largely be funded from these budget lines



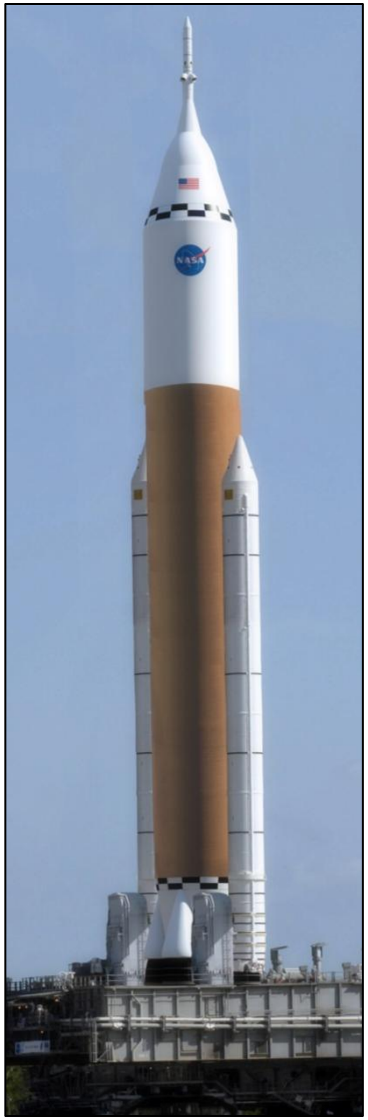



# Space Launch System Overview
# Ares/Shuttle-derived Reference Vehicle Design

- **NASA has selected a Reference Vehicle Design that aligns with the NASA Authorization Act as a starting point for assessment of an affordable, sustainable, and realistic Space Launch System**
  - Heavy Lift Launch Vehicle (HLLV) with an initial lift capability of 70-100mt evolvable to the ultimate capability of 130 mT
  - Reference Vehicle Design is derived from Ares and Shuttle hardware
  - Capability to lift the MPCV

- **SLS Reference Vehicle Design**
  - 27.5' Diameter LOX/LH2 Core Stage
  - Five RS25 based engines using Shuttle assets then RS25E expendable derivative
  - Two 5-Segment Ares derived SRBs
  - Delivers 108.6 tons to 30x130 nmi orbit

- **Performing trades on evolving system to 130mT**
  - Add Upper Stage with one or two J-2X Upper Stage Engines



# Multi-Purpose Crew Vehicle Overview
# Orion-derived Reference Vehicle Design

- **NASA has selected the beyond-LEO version of the Orion design (“block 2”) as the MPCV Reference Vehicle Design**
  - Spacecraft to serve as the primary crew vehicle for missions beyond LEO
  - Capable of conducting regular in-space operations (rendezvous, docking, extravehicular activity [EVA]) in conjunction with payloads delivered by SLS for missions beyond LEO

- Preliminary trace of top-level MPCV requirements suggests that MPCV is within scope of current Orion contract (see next slide)

- Final decisions on NASA’s plans for the MPCV will be made during the Acquisition Strategy review process by Summer 2011

# Commercial Spaceflight Theme Overview

- **Theme is budgeted at $850M in FY 2012 (with labor)**
- **The Commercial Spaceflight theme provides incentives for commercial providers to develop and operate safe, reliable and affordable commercial systems to transport crew and cargo to and from the ISS and LEO**
- **In FY 2012, activities will transition from completing commercial cargo capability milestones* to expanding NASA's efforts to develop commercial crew capability to the ISS and LEO**
- **Objectives of Commercial Crew:**
  - Facilitate the development of a U.S. commercial crew space transportation capability with the goal of achieving safe, reliable and cost effective access to and from LEO and the ISS
  - Once the capability is matured and expected to be available to the government and other customers, NASA could purchase commercial services to meet its ISS crew transportation needs

*Any Commercial Orbital Transportation Services (COTS) activity in FY 2012 will be funded with prior year dollars

# Exploration Research and Development Theme Overview

- **Theme budgeted at $289M in FY 2012 (with labor)**
- **The Exploration Research and Development theme is comprised of the Human Research Program (HRP) funded at $164M in FY 2012(with labor), and the Advanced Exploration Systems Program (AES) funded at $124M in FY 2012 (with labor)**
- **These Programs provide the knowledge and advanced human spaceflight capabilities *required* to undertake human exploration beyond Earth**
  - HRP provides countermeasures, diagnostics, technologies and design tools to keep crews safe and productive on long-duration space missions, and makes extensive use of the ISS
  - AES will focus on continuing current development of key required capabilities for future human exploration beyond the SLS and MPCV including advanced life support, EVA, and prototyping of other beyond LEO exploration systems
    - In future years, AES will support robotic missions of opportunity to obtain required precursor measurements of human spaceflight destinations

# Exploration Research and Development Changes from FY 2011

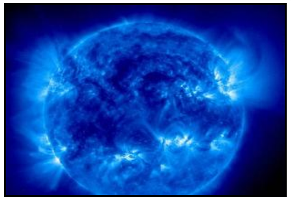
- **In FY 2012, the Exploration Technology Development and Demonstration (ETDD) Program will be transferred to the Office of Chief Technologist (OCT) to place it in a technology-focused organization**
  - ETDD includes technology demonstration flight missions and long-range exploration technology development projects that will be integrated with similar activities in the OCT Space Technology Program.
  - AES activities remaining in Exploration are uniquely related to crew safety and strongly coupled to current and future vehicle development
- **Exploration Precursor Robotic Missions have been deferred in FY 2012**
  - In FY 2013, a new activity, jointly funded by ESMD and Science Mission Directorate (SMD) will pursue missions of opportunity to gather required data on potential destinations for human exploration

# Human Research Program Overview

- **HRP supports risk-driven space biomedical research critical to crew health and safety:**
  - Investigates and mitigates the highest risks to astronaut health and performance to support NASA human exploration missions
  - Conducts fundamental and applied research on the human system to provide countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration
  - Uses the ISS and ground-based research facilities to study the effects of prolonged spaceflight on human physiology and behavior
- **Objectives and research goals:**
  - Exploration-enabling projects in biomedical technologies and development, space radiation research, behavioral health and performance
  - Research and technology to fully utilize ISS as a biomedical laboratory
  - Enhance science, technology, engineering and mathematics (STEM) education, projects that return Earth benefits
  - International collaborations

# Human Research Program
# Plans for FY 2012

- **ISS utilization**
  - ISS is critical for mitigating human health risks relevant to exploration and is an important test bed for space biomedical technology
  - Implement 15-20 ISS biomedical flight experiments per each 6-month mission
  - Deliver the next-generation space biomedical ultrasound device to enhance human research facility capability on the ISS
- **Develop space biomedical capabilities**
  - Provide space medical imaging capability for diagnosis of crew fractures
  - Submit approach for preventing bone loss in space by using pharmaceuticals in conjunction with an in-flight exercise
- **Enhance crew radiation safety**
  - Deliver design tool for vehicle radiation shielding assessments
  - Release the acute radiation risk model update
- **Engage the national research community**
  - NASA research announcements that address crew health risks and space radiation safety



# Advanced Exploration Systems Program Overview

- **Although a new title, AES continues ongoing work to develop and demonstrate prototype systems for human spaceflight capabilities critical for safe human exploration beyond LEO**
  - Focus areas include life support, habitation, extravehicular activity
  - AES demonstrates these prototype systems in ground test beds, Earth-based field and underwater tests, and ISS flight experiments
  - In future years, AES will support robotic missions of opportunity to future human spaceflight destinations in collaboration with SMD and international partners
  - AES will leverage large numbers of civil servants on in-house, exciting development work

- **AES Objectives:**
  - Advanced development of required exploration capabilities and systems to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions beyond Earth orbit
  - Use innovative approaches for rapid systems development and provide hands-on experience for the NASA workforce
  - Infuse new technologies into exploration missions
  - Support robotic missions of opportunity to characterize potential destinations for human exploration

# Advanced Exploration Systems Program Plans for FY 2012

- **Develop a ground-based test bed for demonstrating highly-reliable life support systems to enable long-duration missions**

- **Develop and test components for an advanced spacesuit to improve the ability of astronauts to assemble and service in-space systems, and to explore the surfaces of the moon, Mars and asteroids**

- **Develop design concepts for future space exploration vehicles and deep space habitats**

- **Conduct ISS and ground-based analog testing to validate operational concepts for long endurance space missions including exploration of near-Earth asteroids**

- **Plan for future robotic missions of opportunity for precursor measurements with SMD and international partners**

National Aeronautics and Space Administration

# Human Exploration Framework Team Summary

## The Capability-Driven Framework

# Human Space Exploration Architecture Planning

- Human spaceflight (HSF) programs are complex and can occur on decadal timescales, yet funding is annual and political cycles occur on two-, four-, and six-year intervals.
- Since 1969, 24 blue-ribbon panels have (re)assessed HSF strategy, and exploration concepts and technologies and national priorities have continued to evolve.
- Planning and program implementation teams established in February 2010, after the FY11 President's Budget Request and the NASA Authorization Act of 2010, needed integrated guidance.

**NASA uses an ongoing, integrated HSF architecture decision-support function to develop and evaluate viable architecture candidates, inform near-term strategy and budget decisions, and provide analysis continuity over time.**

# Context: Policy, Process, and Law

- **2009: Review of U.S. HSF Plans Committee [Augustine Committee]**
- **2010: National Space Policy (28 June 2010)**
- **2010: NASA Human Exploration Framework Team (HEFT)**
  – Phase 1 (Apr-Aug 2010)
  – Phase 2 (Sep-Dec 2010)
- **2010: NASA Authorization Act**
  – Long-term goal: “To expand permanent human presence beyond low Earth orbit and to do so, where practical, in a manner involving international partners.”
- **2011: NASA Human Space Exploration Architecture Planning (ongoing)**
  – Apr 2011: FY11 CR passed

# About the Human Exploration Framework Team (HEFT)

- **HEFT provided decision support to NASA senior leadership for planning human spaceflight exploration beyond LEO**
- **Decision support informs potential decisions**
  - Objective, consistent, credible, and transparent analyses
- **Multi-layered team tapped from throughout NASA**
  - From Strategic Management Council to technical subject matter experts
  - From all centers and headquarters
- **Analysis scope included all architecture aspects: technical, programmatic, and fiscal**
  - Destinations, operations, elements, performance, technologies, safety, risk, schedule, cost, partnerships, and stakeholder priorities
- **HEFT prepared architecture decision packages for NASA senior leadership**
  - Objective sensitivity analyses, inclusive trade studies, integrated conditional choices
  - Draft multi-destination architectures that are affordable and implement stakeholder priorities
  - Neither “point solution” architectures, decision recommendations, nor decisions

# NASA Guidance for its HSF Strategy

- Make affordability a fundamental requirement that obligates NASA to identify all content/milestones in budget, all content/milestones exceeding the available budget, and all content/milestones that could be gained through budget increases in a prioritized structure. Create and refine a culture of value, fiscal prudence, and prioritization.
- Reward value-conscious performance, prudent risk assumption, and bold innovation, and incentivize the executive leadership team to further create a “can-do” culture of excellence and a team of scientists, engineers, pioneers, explorers, and shrewd mission implementers.
- Employ an executive leadership team to seek consensus that is fully empowered, capable and willing to make decisions in the absence of consensus. Build a culture of empowerment, accountability, and responsibility.
- Build on and apply design knowledge captured through previously planned programs. Also seek out innovative new processes, techniques, or world-class best practices to improve the safety, cost, schedule, or performance of existing and planned programs, thereby enhancing their sustainability.
- Leverage existing NASA infrastructure and assets, as appropriate, following a requirements-based need and affordability assessment.

# Human Space Exploration Guiding Principles

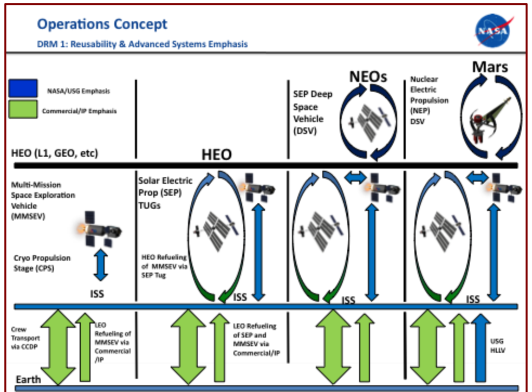
- Conduct a routine cadence of missions to exciting solar system destinations including the moon and NEAs with Mars' surface as a horizon destination for human exploration
- Build capabilities that will enable future exploration missions and support the expansion of human activity throughout the inner Solar System
- Inspire through numerous "firsts"
- Fit within projected NASA HSF budget (affordability and sustainability)
- Use and leverage the International Space Station
- Balance high-payoff technology infusion with mission architectures and timeline
- Develop evolutionary family of systems and leverage commonality as appropriate
- Combine use of human and robotic systems
- Exploit synergies between Science and HSF Exploration objectives
- Leverage non-NASA capabilities (e.g., launches, systems, facilities)
- Minimize NASA-unique supply chain and new facility starts
- Pursue "lean" development and operations "best practices"

# What Did HEFT Do?

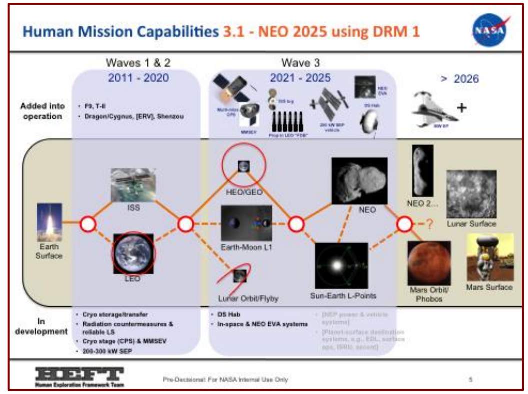
- HEFT was chartered in April 2010. The first phase concluded in early September 2010, and the second phase concluded in December 2010.
- HEFT established and exercised a consistent method for asking questions, comparing architecture alternatives, integrating findings and fostering cross-agency discussions.
- HEFT examined a broad trade space of program strategies and technical approaches in an effort to meet priorities from the White House, Congress, and other stakeholders.
- HEFT explored new affordability options and applied a refined cost analysis approach to do relative comparison of alternatives in order to hone and narrow the trade space.
- A smaller HEFT-like effort will continue for the foreseeable future since the HSF technical and programmatic environment will continue to evolve

**NASA HSF architecture must provide the flexibility to accommodate technical, programmatic, economic and political dynamics while enabling a safe, affordable and sustainable human space exploration program.**

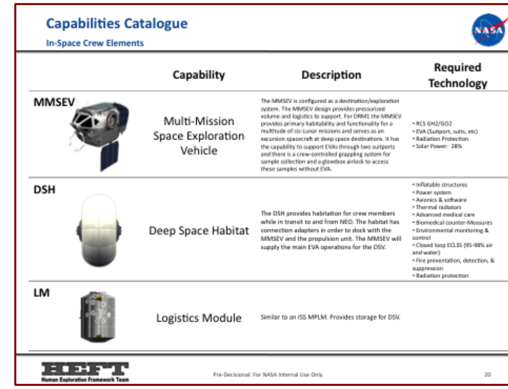
# HEFT Architecture Analysis Cycle Approach (Iterative)



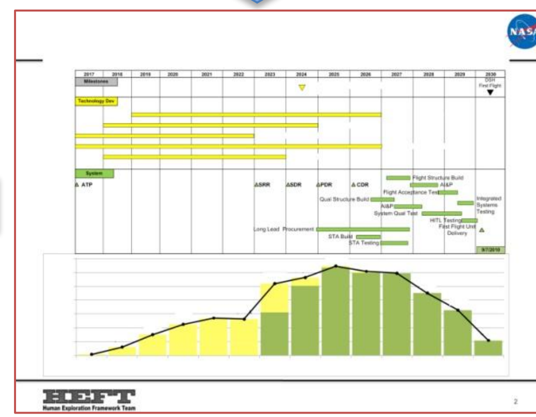

Technical Design Reference Mission



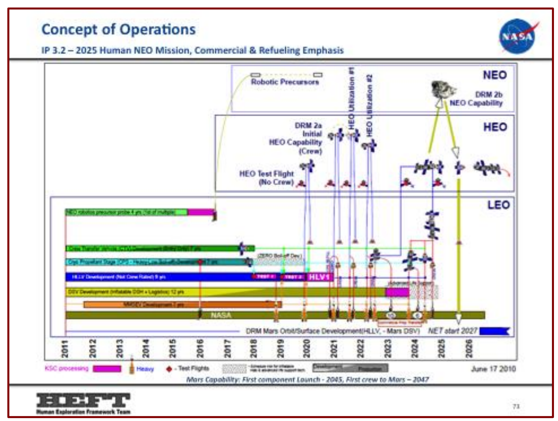

Investment strategy



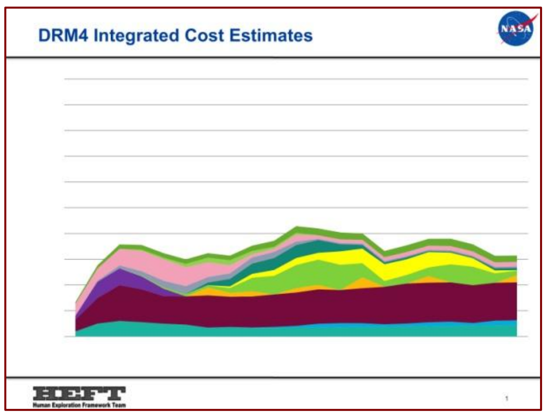

Element catalog




Schedule and cost to develop and operate each element




Integrated program schedule & flight manifest




Non-optimized cost rollup through 2025

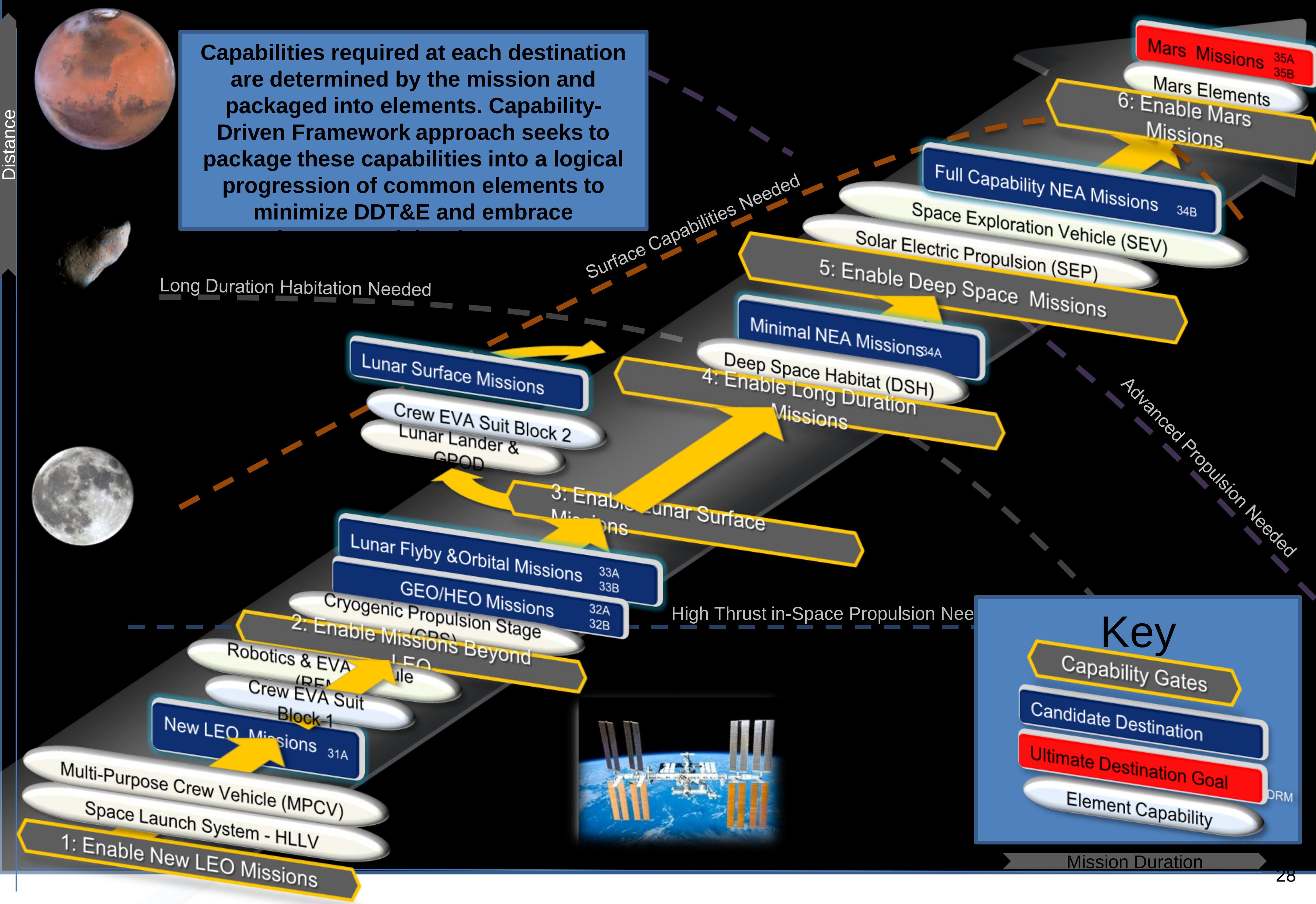
ectives & constraints

# Capability-Driven Framework Approach

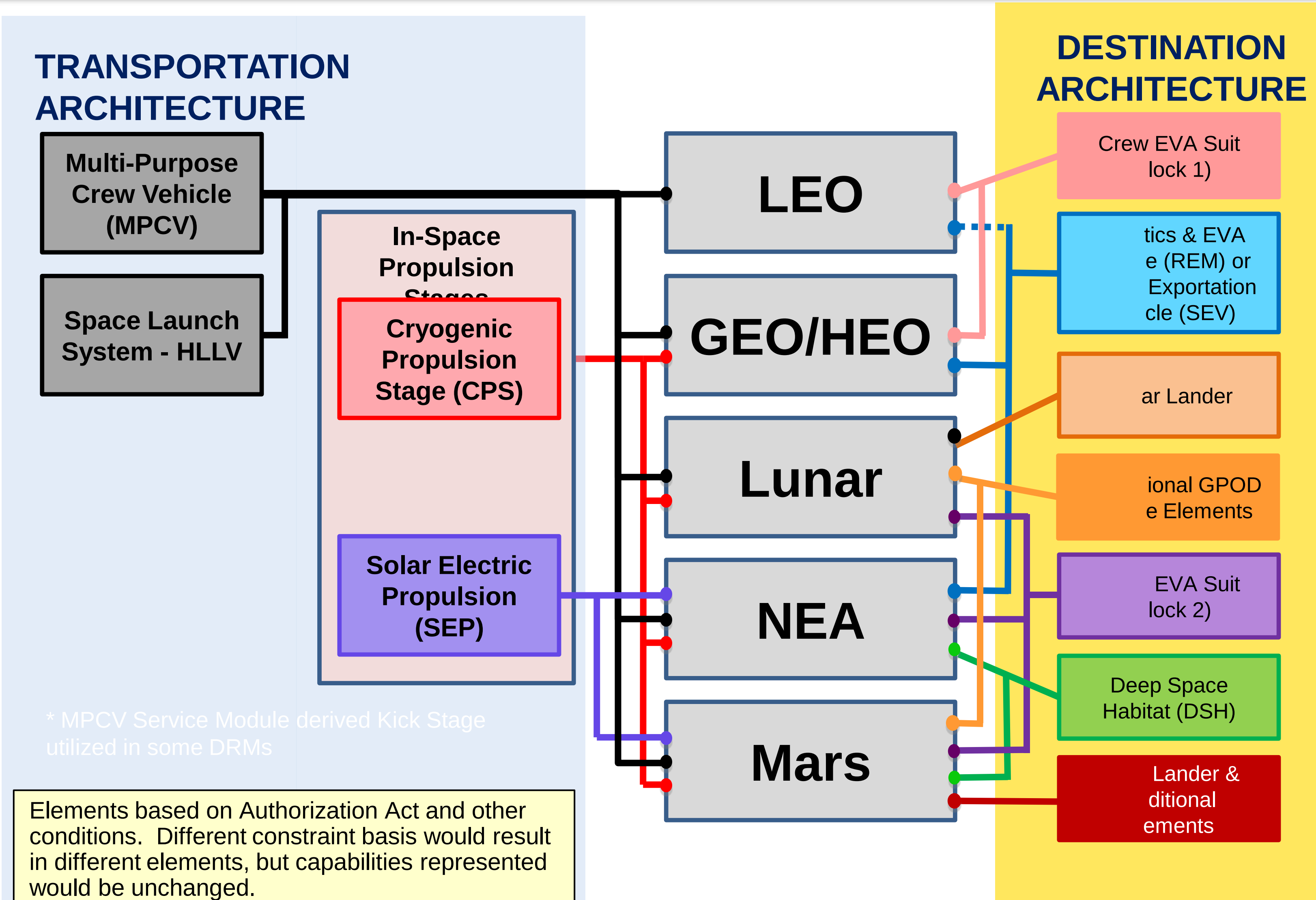
- **Establish "Mission Space" defined by multiple possible destinations**
  - Define Design Reference Missions to drive out required functions and capabilities
- **Utilize common elements across all DRMs**
  - Size element functionality and performance to support entire mission space
  - Common element and DRM analyses still in work, appears feasible
- **Assess key contingencies and abort scenarios to drive out and allocate any additional key capabilities to element(s)**
  - Iterate element sizing and functionality to ensure key contingency and abort scenarios are addressed
- **Establish key driving requirements for common elements**
  - Establish technology needs for each element
- **Identify key decision points for element/capability phasing**
  - Decision trees/paths for transportation architecture and destination architecture
- **Assess various manifest scenarios for costing and other constraint analysis**
  - Select various strategies for acquisition approach and affordability
- **Actively seek international and commercial involvement where possible**

**Costing not completed, additional work required to complete integration of Capability-Driven Framework assessment**

# INCREMENTAL EXPANSION OF HUMAN EXPLORATION CAPABILITIES



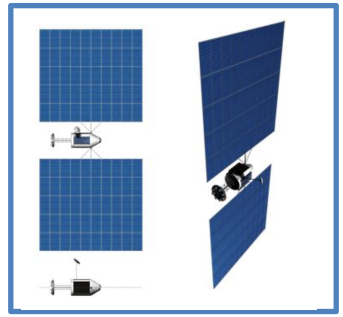
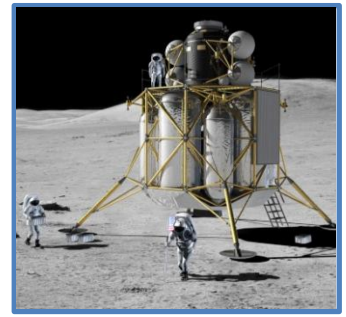
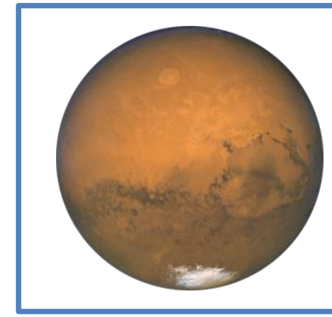
# Transportation and Destination Architectures for Flexible Path



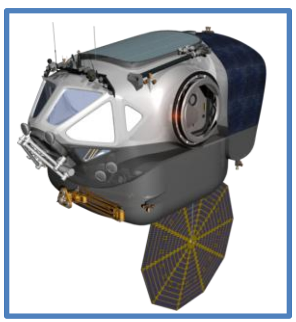
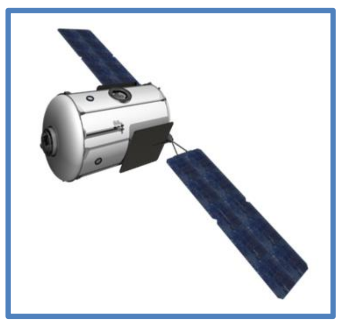

Elements based on Authorization Act and other conditions. Different constraint basis would result in different elements, but capabilities represented would be unchanged.

# Notional Architecture Elements



**Graphics are Notional Only – Design and Analysis On-going**



# Technology Applicability to Destination Overview (1)

| | LEO (31A) | Adv. LEO (31B) | Cis-Lunar (32A,B & 33A,B) | Lunar Surface - Sortie (33C) | Lunar Surface - GPOD (33X) | Min NEA (34A) | Full NEA (34B) | Mars Orbit | Mars Moons (35A) | Mars Surface (35B) |
|---|---|---|---|---|---|---|---|---|---|---|
| LO2/LH2 reduced boiloff flight demo | | | | | | | | | | |
| LO2/LH2 reduced boiloff & other CPS tech development | | | | | | | | | | |
| LO2/LH2 Zero boiloff tech development | | | | | | | | | | |
| In-Space Cryo Prop Transfer | | | | | | | | | | |
| Energy Storage | | | | | | | | | | |
| Electrolysis for Life Support (part of Energy Storage) | | | | | | | | | | |
| Fire Prevention, Detection & Suppression (for 8 psi) | | | | | | | | | | |
| Environmental Monitoring and Control | | | | | | | | | | |
| High Reliability Life Support Systems | | | | | | | | | | |
| Closed-Loop, High Reliability, Life Support Systems | | | | | | | | | | |
| Proximity Communications | | | | | | | | | | |
| In-Space Timing and Navigation for Autonomy | | | | | | | | | | |
| High Data Rate Forward Link (Ground & Flight) | | | | | | | | | | |
| Hybrid RF/Optical Terminal (Communications) | | | | | | | | | | |
| Behavioral Health | | | | | | | | | | |
| Optimized Exercise Countermeasures Hardware | | | | | | | | | | |
| Human Factors and Habitability | | | | | | | | | | |
| Long Duration Medical | | | | | | | | | | |
| Biomedical countermeasures | | | | | | | | | | |
| Space Radiation Protection – Galactic Cosmic Rays (GCR) | | | | | | | | | | |
| Space Radiation Protection – Solar Proton Events (SPE) | | | | | | | | | | |
| Space Radiation Shielding – GCR & SPE | | | | | | | | | | |
| Vehicle Systems Mgmt | | | | | | | | | | |
| Crew Autonomy | | | | | | | | | | |
| Mission Control Autonomy | | | | | | | | | | |
| Common Avionics | | | | | | | | | | |
| Advanced Software Development/Tools | | | | | | | | | | |
| Thermal Management (e.g., Fusible Heat Sinks) | | | | | | | | | | |
| Mechanisms for Long Duration, Deep Space Missions | | | | | | | | | | |
| Lightweight Structures and Materials (HLLV) | | | | | | | | | | |
| Lightweight Structures and Materials (In-Space Elements) | | | | | | | | | | |

| | | | |
|---|---|---|---|
| Not applicable | | Probably required | |
| May be required | | Required technology | |

# Technology Applicability to Destination Overview (2)

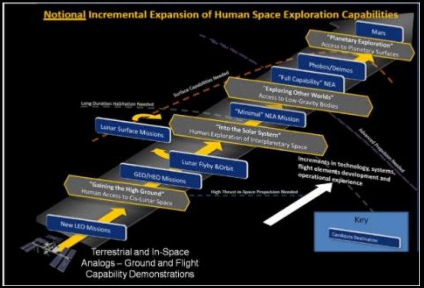
| | LEO (31A) | Adv. LEO (31B) | Cis-Lunar (32A,B & 33A,B) | Lunar Surface - Sortie (33C) | Lunar Surface - GPOD (33X) | Min NEA (34A) | Full NEA (34B) | Mars Orbit | Mars Moons (35A) | Mars Surface (35B) |
|---|---|---|---|---|---|---|---|---|---|---|
| Robots Working Side-by-Side with Suited Crew | | | | | | | | | | |
| Telerobotic control of robotic systems with time delay | | | | | | | | | | |
| Surface Mobility | | | | | | | | | | |
| Suitport | | | | | | | | | | |
| Deep Space Suit (Block 1) | | | | | | | | | | |
| Surface Space Suit (Block 2) | | | | | | | | | | |
| NEA Surface Ops (related to EVA) | | | | | | | | | | |
| Environment Mitigation (e.g., dust) | | | | | | | | | | |
| Autonomously Deployable very large Solar Arrays | | | | | | | | | | |
| SEP demo | | | | | | | | | | |
| Solar Electric Propulsion (SEP) Stage | | | | | | | | | | |
| Fission Power for Nuclear Electric Propulsion (NEP) | | | | | | | | | | |
| Nuclear Thermal Propulsion (NTP) Engine | | | | | | | | | | |
| Fission Power for Surface Missions | | | | | | | | | | |
| Inflatable Habitat Flight Demo (flight demo launch) | | | | | | | | | | |
| Inflatable Habitat Tech Development (including demo) | | | | | | | | | | |
| In-Situ Resource Utilization (ISRU) | | | | | | | | | | |
| TPS -- low speed (<11.5 km/sec; Avcoat) | | | | | | | | | | |
| Thermal Protection System (TPS) -- high speed | | | | | | | | | | |
| NEA Auto Rendezvous, Prox Ops, and Terrain Relative Nav | | | | | | | | | | |
| Precision Landing | | | | | | | | | | |
| Entry, Decent, and Landing (EDL) | | | | | | | | | | |
| Supportability and Logistics | | | | | | | | | | |
| LOX/Methane RCS | | | | | | | | | | |
| LOX/Methane Propulsion Stage - Pressure Fed | | | | | | | | | | |
| LOX/Methane Propulsion Stage - Pump Fed | | | | | | | | | | |
| In-Space Chemical (Non-Toxic Reaction Control System) | | | | | | | | | | |
| HLLV Oxygen-Rich Staged Combustion Engine | | | | | | | | | | |

| | | | |
|---|---|---|---|
| Not applicable | | Probably required | |
| May be required | | Required technology | |


perations
ploration Partnerships
Exploration Human System Risk Mitigations
Space Exploration begins with ISS

# Capability Priorities Traced to Architecture/ConOps

loration




## Capability Driven Architecture Elements (Building Blocks)


Ground Operations


Commercial Cargo/Crew


SLS

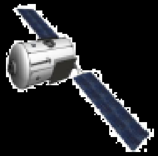

MPCV


Robotic Systems


SEV

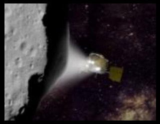

EVA Systems


CPS


DSH


SEP


Destination Systems


Mission Operations

## Cross Cutting Systems

- Small Payload Return
- Robotic Free Flyer inspection
- Satellite Servicing Robot
- Standardized Energy Storage
- Suit Port
- ECLSS
- Logistics to Living
- Prop. Mgt and Storage
- Power Module
- Modular Solar Arrays
- ISRU
- Radiation Protection
- Comm/ Nav
- Light Weight Long-Life Universal Docking System
- Personal Space Mobility System
- Robotic Assistant
- EP Thrusters
- Prop from Waste Gasses
- EVA Suit
- EVA Suit Exoskeleton
- Asteroid Anchoring Tools
- Self-Healing Systems
- Thermo-electric Generation
- Modeling and Simulation
- Autonomous Ops
- Surface Stairs / Ramp System

## Technologies, Research, and Science

Human Exploration Specific Research

s ECLSS, EVA)

Specific Technologies

# Partnership Opportunities

- **Partnerships = International, Interagency, Commercial**

- **The Capability-Driven Framework enables on-ramps for:**
  – Partnerships that ***Expand*** the architecture
    - Characterized by adding elements and functional capabilities to the architecture that would not be otherwise funded for development, thus enabling missions that otherwise would not be possible

  – Partnerships that ***Enable*** the architecture
    - Characterized by partners that develop elements that enable missions sooner than could otherwise be accomplished

  – Partnerships that ***Enhance*** the architecture
    - Characterized by partners developing technologies or systems that enhance the existing or planned element capabilities within the architecture

# Human Space Exploration Themes and Common Goals – International Agreement


A Sustained Presence - Extending Human Frontiers


New Knowledge in Science and Technology

Economic Expansion


Global Partnerships


Inspiration and Education

- **Common goals build on the Global Exploration Strategy Themes**
  - Search for Life
  - Extend Human Presence
  - Fundamental Science
  - Science to Support Human Exploration
  - Exploration Technologies and Capabilities
  - Economic Expansion
  - Earth Safety
- **The themes of global partnerships, inspiration and education are reflected in strategic principles**

# International, Interagency, and Commercial Partnerships







- **Interagency partnership opportunities: DoD/IC, FAA, DOE, NSF, DHS, NIST**
- **DoD/IC promising potential partnership areas:** In-space propulsion (Solar Electric Propulsion), range modernization, Technologies, Industrial base, Landing, recovery, and medical operations support, communications
- **Commercial partnerships:** "Traditional," Entrepreneurial, and "Non-Traditional"
- **Key Areas of Potential Interest:** Cargo and crew transportation, in-space habitation, communications, in-situ resource utilization, propellant transfer, storage, and re-supply

- DoD=Department of Defense
- IC=Intelligence Community
- FAA=Federal Aviation Administration
- DOE=Department of Energy
- NSF=National Science Foundation
- DHS=Department of Homeland Security
- NIST=National Institute for Standards and Technology

# Affordability - Most Significant Challenge Moving Forward

- **Affordability: The ability of NASA to safely execute missions within the available funding constraints (long term and short term).**
  - Program/Project Management, Risk Management Culture, Systems Engineering, Workforce/Infrastructure, Acquisition Approaches
- **Opportunities to address affordability in program/project formulation and planning**
  - Levy lean development approaches and “design-to-cost” targets on implementing programs
  - Identify and negotiate international partner contributions
  - Identify and pursue domestic partnerships
- **Traditional development**
  - Balance large traditional contracting practices with fixed-price or cost challenges coupled with in-house development
  - Use the existing workforce, infrastructure, and contracts where possible; address insight/oversight, fixed-costs, cost analysis and cost estimation
- **Adopt alternative development approaches**
  - Leverage civil servant workforce to do leading-edge development work
  - Attempt to minimize use of NASA-unique infrastructure, seeking instead to share infrastructure costs where feasible.
  - Specifically, take advantage of existing resources to initiate the development and help reduce upfront costs on the following elements: Multi-Mission Space Exploration Vehicle, Solar Electric Propulsion Freighter, Cryo Propulsion Stage, Deep Space Habitat

**In order to close on affordability and shorten the development cycle, NASA must change its traditional approach to human space systems acquisition and development.**

# Industry Affordability Input – Major Themes

- **Key tenets and recurring themes identified in industry submissions:**
  - Systems engineering is more than requirements tracking and documents
  - Model, test and fly early and often
  - Use small lean projects with highly competent empowered personnel
  - Push decision authority to the lowest level. Trust them to implement and don't second guess (over-manage)
  - Maintain aggressive schedules
  - Manage cost & schedule, plus technical performance (maybe even more so)
  - Keep it simple
  - Dramatically minimize fixed costs (the key driver of mission cost)
  - Oversight/Insight model has to change

**Focused, Realistic and Stable Requirements + Capable, Connected and Incentivized Lean Teams + Short Schedules = Low cost**

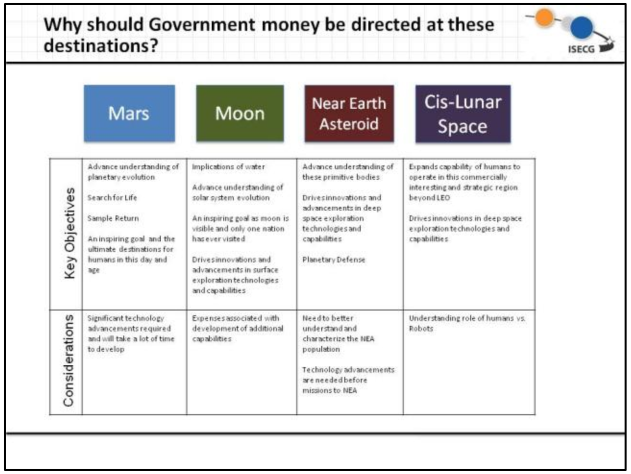
Industry input received from: Aerojet, ATK, Ball, Blue Origin, Dynetics, SpaceX, Hamilton Sundstrand, Honeywell, Georgia Tech, Paragon, L3 Communications, Space Partnership International, Valador, Lockheed Martin, KT Engineering, Boeing, Pratt and Whitney Rocketdyne, Orbitec, Northrop Grumman, United Launch Alliance, Florida Turbine Technologies, Johns Hopkins University Applied Physics Lab, RAND, Space Partnership, and United Space Alliance

# HEFT Key Takeaways

- **The Capability-Driven Framework:**
  - Is the most viable approach given the cost, technical and political constraints
  - Provides a foundation for the agency’s needed technology investments
  - Enables common elements to support multiple destinations
  - Provides flexibility, greater cost-effectiveness and easy integration of partnerships
- **NASA-wide transformational change is required to significantly improve affordability and meet budget constraints**
- **Beyond LEO destinations require:**
  - Development of a HLLV and MPCV as the key core elements
  - An investment in advanced space propulsion and long-duration habitation (including high-reliability ECLSS and radiation protection)
  - Robotic precursors for human near-Earth asteroid mission
- **Authorization Act-driven HSF architecture still presents a fundamental forward challenge to close on budget and schedule**
- **Partnerships are imperative to enabling our exploration goals**
- **Compelling, overarching mission goals are necessary to justify high-risk human spaceflight exploration beyond LEO**

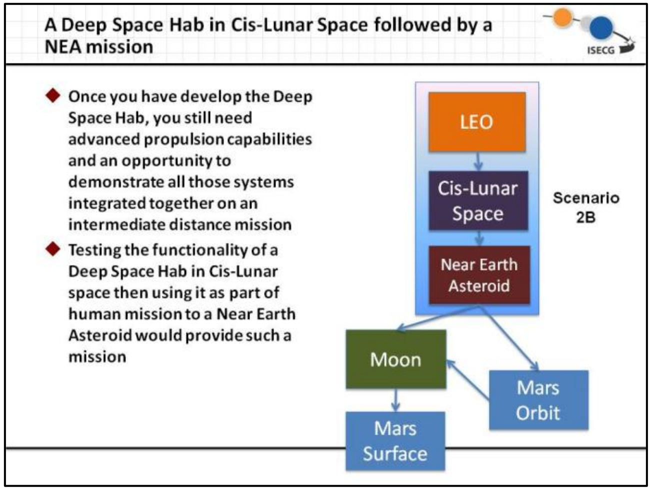
# Human Spaceflight Architecture Team (HAT)

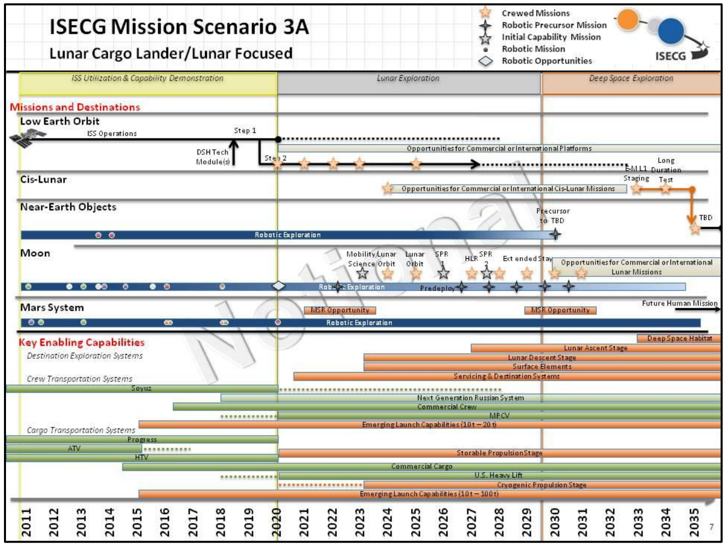
- **Focus of recent architecture team work has been joint development of options for international exploration scenarios**
- **11 space agencies working together to define ‘next steps’ for human exploration**
- **Products are headed towards an senior agency manager review this summer**



Why should Government money be directed at these destinations?

| | Mars | Moon | Near Earth Asteroid | Cis-Lunar Space |
|---|---|---|---|---|
| Key Objectives | Advance understanding of planetary evolution<br>Search for Life<br>Sample Return<br>An inspiring goal and the ultimate destinations for humans in this day and age | Implications of water<br>Advance understanding of solar system evolution<br>An inspiring goal as moon is visible and only one nation has ever visited<br>Drives innovations and advancements in surface exploration technologies and capabilities | Advance understanding of these primitive bodies<br>Drives innovations and advancements in deep space exploration technologies and capabilities<br>Planetary Defense | Expands capability of humans to operate in this commercially interesting and strategic region beyond LEO<br>Drives innovations in deep space exploration technologies and capabilities |
| Considerations | Significant technology advancements required and will take a lot of time to develop | Expenses associated with development of additional capabilities | Need to better understand and characterize the NEA population<br>Technology advancements are needed before missions to NEA | Understanding role of humans vs. Robots |

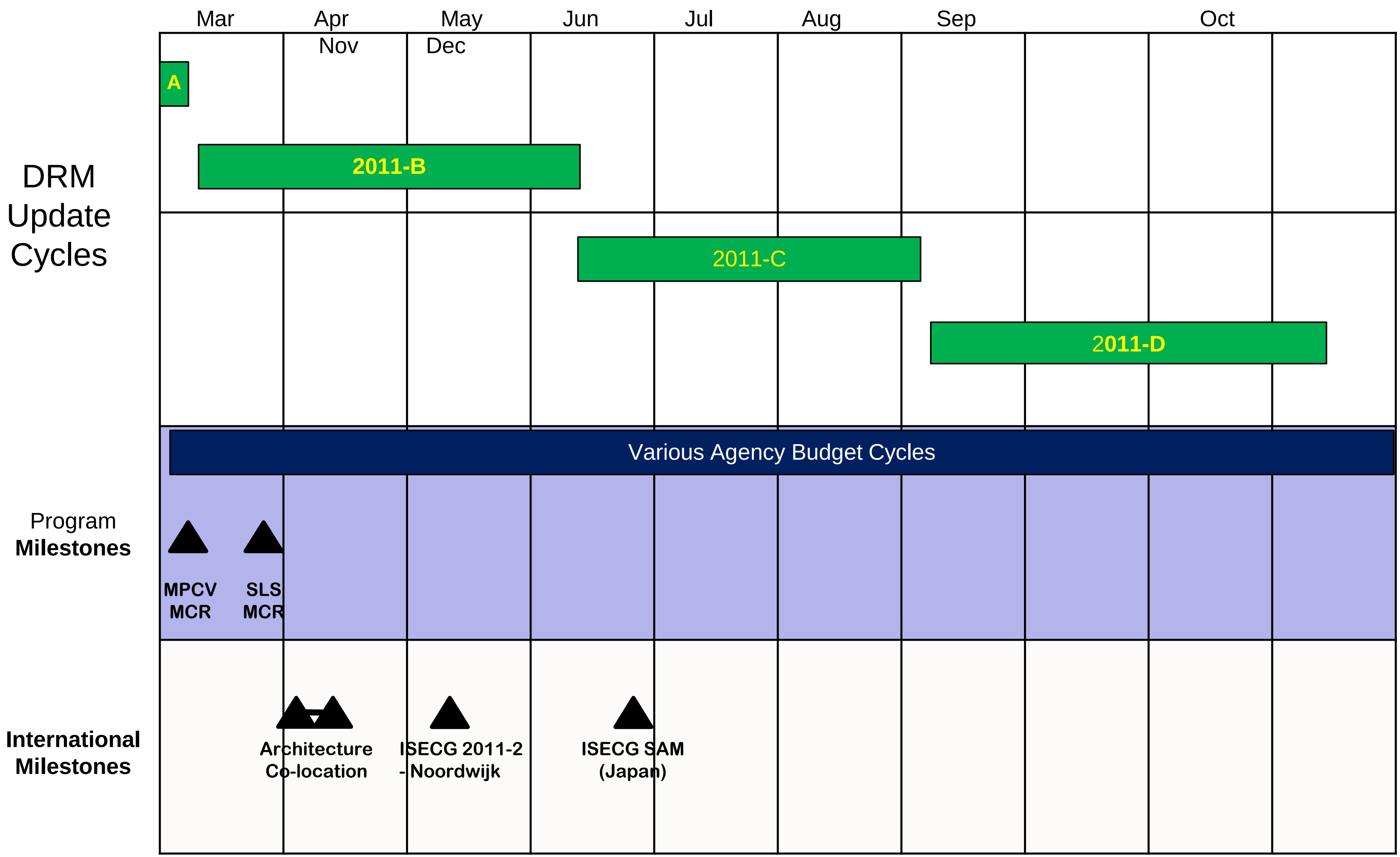


# HAT Recent Activities

- Developed content material to back definition of level 1 program requirements for SLS and MPCV
- Finished Margin Policy document
- Defined roles for Element leads and Destination leads
- Developed 2011-A cycle data
- Update scenario options and DRM definitions for ISECG Exploration Roadmap Working Group; face to face coming in early April
- Developed technology needs update cycle with OCT; review setup for early April

# Architecture Team 2011 Schedule




As of Jan 13, 2011

# Trends/Updates from Cycle A

## Cycle-A Trends:

- **Lunar cases most "out of the box" when consistent margins and analysis methods are applied (when constrained to two SLS launches)**
- **Only slight element capacity issues identified in cycle-A**
- **Going from 3 to 4 crew for lunar and NEA missions results in IMLEO creep of ~ 3 to ~10%**

## Analysis Philosophy/Assumption changes from Cycle-A

- **CPS capacity will be driven by "fixed" locations (ie GEO 1 launch/Lunar 2 launch) instead of select NEA missions**
- **4 crew for all NEA, Lunar & Mars Missions**
- **Crew access to GEO, L1, LLO, L2 performed with one SLS**
- **Lunar Missions 2 SLS + 1 ELV(if needed) for 105t SLS, or 2 130t SLS**
- **"Easy" NEA missions done with 3 or less 105t SLS, a SEV if it "fits", and no SEP**
- **Hard NEA mission will use two SEVs , SEP, no more than three 130t SLS + 1 ELV (if needed)**
  - Try to decouple chemical & SEP for C3 burn
  - Factor in limited shroud length of SLS
- **Phobos/Deimos/Mars Orbital as time permits – no more than four 130t SLS**

# Cycle –B DRM Descriptions

| TION | | | |
|---|---|---|---|
| LEO | DRM_31 A | LEO Utilization | Deliver and return Crew with a utilization package to LEO (ISS) to serve as an exploration demonstration and testing bed |
| LEO | DRM_31 B | LEO Utilization | Deliver and return Crew with a utilization package to LEO (Hubble) to serve as an exploration demonstration and testing bed |
| HEO/GEO | DRM_32 A | HEO/GEO Vicinity without Pre-Deploy | HEO/GEO satellite servicing missions. |
| HEO/GEO | DRM_32 B | HEO/GEO Vicinity with Pre-Deploy | HEO/GEO satellite servicing missions. In this DRM, some elements are pre-deployed using commercial assets. |
| LUNAR | DRM_33 A | Lunar Vicinity Missions | Missions to Lagrange Points or Lunar Free Return missions. |
| LUNAR | DRM_33 B | Low Lunar Orbital Mission | Low lunar orbit missions. |
| LUNAR | DRM_33 C | Lunar Surface Sortie | 7 day equatorial Lunar surface mission. Exploration in phases consistent with the ISECG Reference Architecture for Human Lunar Exploration approach. Includes Lunar surface cargo delivery mission for extended duration stays. |
| LUNAR | DRM_33 D | Lunar Surface Global Access | Lunar surface mission to destinations beyond the equatorial region. Exploration in phases consistent with the ISECG Reference Architecture for Human Lunar Exploration approach. |
| NEO | DRM_34 A | Minimum Capability NEO (s) | Minimum capability exploration missions to a NEO. |
| NEO | DRM_34 B | Full Capability NEO | Full capability exploration missions to a NEO. |
| MARS | DRM_35 A | Martian Moon : Phobos/Deimos | Exploration missions to Martian Moons Phobos and Deimos. In this DRM, some elements are pre-positioned in Mars orbit. |
| MARS | DRM_35 B | Mars Landing | Exploration missions to the surface of Mars. Some elements are pre-positioned in Mars orbit. |

| # of Crew | Launch Vehicles | Staging Points | ISECG |
|---|---|---|---|
| 4 | TBD | | |
| 4 | TBD | | |
| 3 | 105t SLS | NA | X |
| 3 | 105t SLS | NA | X |
| 4 | 105t SLS | NA | X |
| 4 | 105t SLS | NA | X |
| 4 | 105t SLS 130t SLS ELV | LLO | |
| 4 | 105t SLS 130t SLS ELV | L1, L2 | X |
| 4 | 105t SLS | L1, HEO | X |
| 4 | 130t SLS ELV | L1 | X |
| 4 | 130t SLS | L1? | |

***Note: Green Shaded DRMs were run for Cycle A, Red shaded DRMs will not be run for Cycle-B***

# Proposed Cycle B Mid-Term Deliverables

- **EACH element (DSH, SEV, Lander, CPS, SEP, Depot, etc)**
  - Updated configuration and MEL
  - Updated Functional requirements (for CCD)
  - Suggested growth margin based on HAT margin policy
  - Impacts of 3 or 4 crew
  - Updated driving technologies
  - Assumed dependencies on other elements
  - List of proposed future studies

- **For each Destination (servicing/deployment, NEA, Lunar & Mars)**
  - Sample destination missions (independent of transportation legs)
  - Enabling elements/capabilities at destination
  - Implications of three or four crew
  - Return payload requirements (mass at minimum)
  - Destination Environment challenges
  - Questions to be addressed by Analogs
  - List of proposed future studies

# Role of Leads

- **Propose that the Architecture Team define roles for two groups of leads:**

  – Destination leads help organize and coordinate development of data about humans activities and plans at various destinations. Focus will be on what happens at the destination; the DRM team will assess transportation and architecture closure. These leads will interface with other groups around the agency as needed to develop products. We do not plan on creating standing destination teams, but ad hoc working groups may be stood up to create a specific product. Destination leads are expected to be knowledgeable about all DRMs associated with their destination.

  – Element leads will be responsible for defining the data the Architecture Team uses for specific elements or capabilities. Ultimately, they are responsible for developing, trading, and defining the details used in the architecture for all the basic building blocks of elements used in each DRM. Element leads will participate in DRM development and the creation of element baseball cards. Element leads will also support the cost team as it develops cost models for each element.

# Destination Leads

- **In Space Servicing & Deployment**
  - Marianne Bobskill – LaRC
  - Lee Graham – JSC
  - Mike Weiss – GSFC

- **Lunar**
  - John Connolly – JSC
  - Rob Mueller – KSC

- **NEO**
  - Victoria Friedensen – HQ
  - Dan Mazanek - LaRC

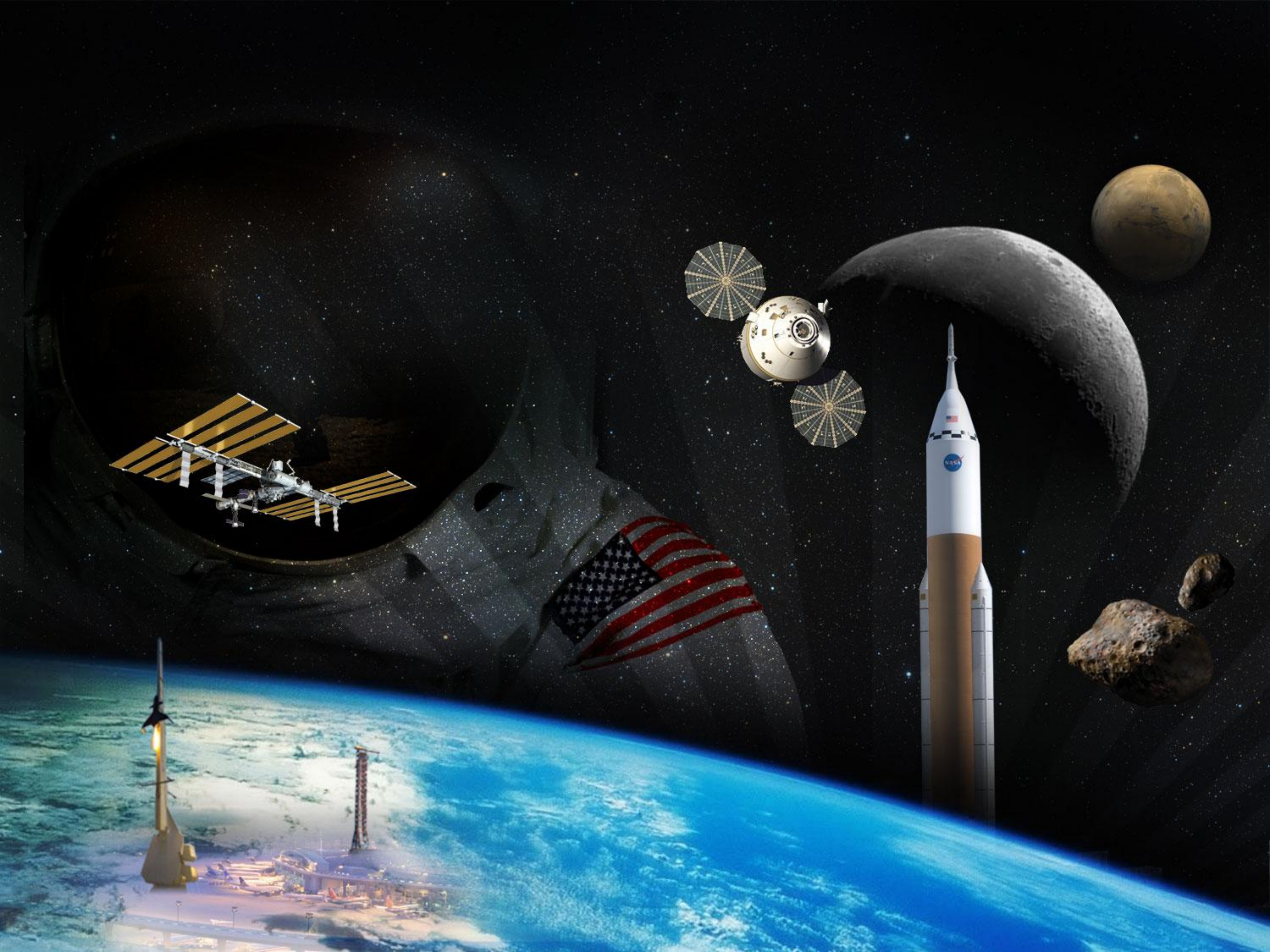
- **Mars**
  - Bret Drake – JSC
  - John Baker – JPL

# Architecture Team Element Support

- **MPCV**
  - Charlie Lundquist, JSC
- **SLS**
  - Fred Bickley, MSFC
  - Steve Creech, MSFC
- **Electric Propulsion**
  - John Brophy, JPL
  - TBD, ARC
  - Mike Meyer, GRC
- **Solar Arrays**
  - Tom Kerslake, GRC
- **Fission Reactor**
  - Lee Mason, GRC
  - John Warren, HQ
- **CPS**
  - David Jones, MSFC
  - Ian Dux, GRC
  - Kurt Hack, GRC
- **Deep Space Hab**
  - Larry Toups, JSC
  - David Smitherman, MSFC
  - Marianne Bobskill, LaRC
  - Matt Simon, LaRC
- **Nuclear Thermal Rocket**
  - Stan Borowski, GRC
  - John Warren, HQ
- **ECLSS**
  - Bob Bagdigian, MSFC
- **Radiation**
  - Frank Cucinotta, JSC
- **SEV**
  - Mike Gernhardt, JSC
- **Robotics**
  - Rob Ambrose, JSC
  - Brian Wilcox, JPL
- **Medical**
  - Dave Liskowsky, HQ
- **HRP**
  - Steve Davison, HQ
- **Lander**
  - Kendall Brown, MSFC
  - John Lenius, JSC
- **Cargo Hauler**
  - Gary Spexarth, JSC
  - Mark Lupisella, GSFC
- **Comm/Nav**
  - Marc Siebert, KSC
  - Jim Schier, HQ
  - Steve Rader
- **EVA tools & suits**
  - Peggy Guirgis, JSC
- **ISRU**
  - Gerry Sanders, JSC
  - Bill Larson, KSC
- **Software**
  - Mike Lowry, ARC
  - Dave Korsmeyer, ARC
- **Depot**
  - Dave North, LaRC
  - Dave Chato, GRC

# NASA Exploration: Going Beyond

- **NASA's human spaceflight program dares to <u>imagine extending human presence throughout the solar system</u>**
- **The FY 2012 Budget Request supports all critical aspects of a vibrant human spaceflight program, and all components of the NASA Authorization Act of 2010:**
  - Safe, affordable LEO access with Commercial Crew and leveraging ISS for future exploration
  - Significant progress on NASA's beyond-LEO vehicles – the SLS and MPCV
  - Investment in required research and capabilities development for beyond LEO human missions
- **Affordability measures are key to a successful future**
- **NASA Exploration accepts the challenge to execute our programs within available budgets – we will leverage prior investments creatively to enable a sustained, exciting future for human exploration**



# Acronym List

**AES – Advanced Exploration Systems**
**BAA – Broad Agency Announcement**
**CCDev – Commercial Crew Development**
**CEV – Crew Exploration Vehicle**
**COTS – Commercial Orbital Transportation Services**
**CTS – Crew Transportation System**
**DM-2 – Development Motor Test 2**
**DRM – Design Reference Mission**
**ECLSS – Environmental Control and Life Support System**
**ESMD – Exploration Systems Mission Directorate**
**ETDD – Exploration Technology Development and Demonstration**
**EVA – Extravehicular activity**
**FOM – Figure of Merit**
**GEO – Geosynchronous Orbit**
**HEC – Human Exploration Capability**
**HEO – High Earth Orbit**
**HLLV – Heavy Lift Launch Vehicle**
**HRP – Human Research Program**
**ISS – International Space Station**

KDP A – Key Decision Point
LEO – Low Earth Orbit
LOC/LOM – Loss OF Crew/Loss of Mission
LOX/LH2 – Liquid Oxygen/Liquid Hydrogen
LoX/RP – Liquid Oxygen/Kerosene
MPCV – Multi-Purpose Crew Vehicle
NEA – Near Earth asteroids
OCT – Office of Chief Technologist
PBR – President's Budget Request
PORT – Post-landing Orion Recovery Test
RAC – Requirements Analysis Cycle
SAA – Space Act Agreements
SLS – Space Launch System
SMD – Science Mission Directorate
SNC – Sierra Nevada Corporation
SOMD – Space Operations Mission Directorate
SRB – Solid Rocket Booster
STEM – Science Technology Engineering and Mathematics
ULA – United Launch Alliance