National Aeronautics and Space Administration

The Big Picture on Exploration Planning and Integration

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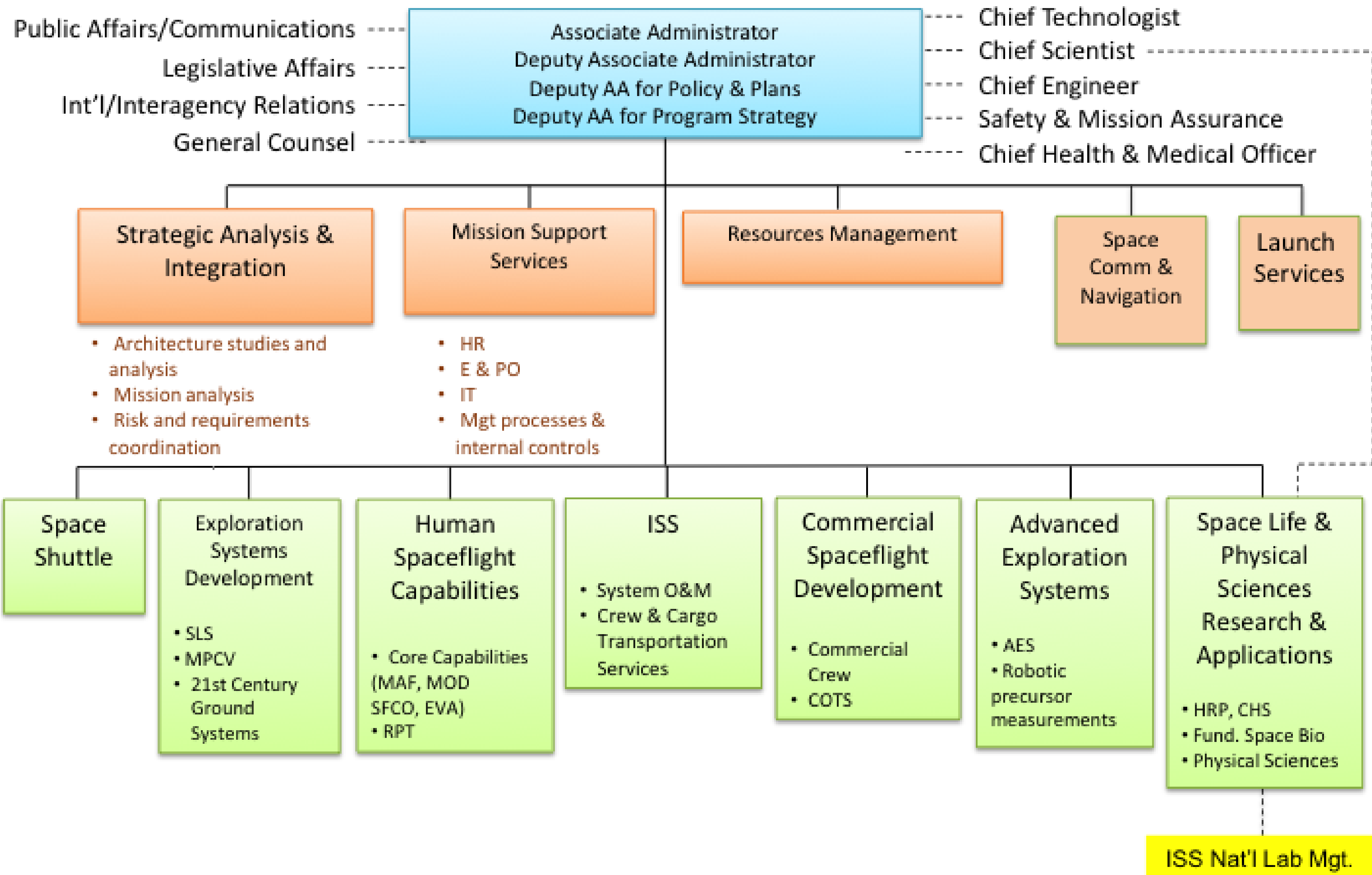
Overview

- Organizational, Policy, and Budget Context
- Architecture Planning
- NASA's Activities: Human Spaceflight Architecture Team (HAT)
- International Partnership Development
- Global Exploration Roadmap Update
- Summary

Organization Structure: Human Exploration and Operations



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.

HEOMD's Strategic Analysis & Integration Division (SAID): Functional Breakdown

Director
Deputy Director
Office Manager

International
- Int'l Partnership Coordination
- ISECG co-lead

Risk & Knowledge Management
- RM/KM, Decision Support

Administration & Management
- Personnel and Cross-Agency Expert Tracking
- Resource Accounting & Allocations
- COTR, Monthly reviews
- Integrated Master Schedule
- SAID Performance Tracking
- Directorate Coordination, Action Tracking/Suspense

Architecture & Strategic Analysis
- HSF Architecture Team
  - DRMs, ConOps, Destination teams, Reqt's Development
  - Analog objectives
- Architecture Cost Analysis
- Studies and Technical Support
- Architecture Science Analysis
- Commonality and Interoperability
- EPO and Strategic comm
- Tech and Capability priorities/intgr
- Exploration Roadmap/Timelines
- Modeling/Simulation

Strategic Integration & Coordination
- Cross-cutting Program Integration
- Interagency coordination
- Industry Partnerships
- Science Coordination/Integration
- Risk and Knowledge Management
- Affordability, sustainability, process innovation, enterprise SE&I
- Industrial Base / SCM coordination
- Enterprise Needs/Goals/Objectives
- Integrated Software Management
- Studies and Technical Support

Enterprise Security & Integration
- Technology Protection
- Security Policies
- Advanced Threats and Vulnerabilities
- SecureCAP/MRCAP
- Cyber Security Coordination
- Secure Systems
- Enterprise Resource Utilization
- Special Projects
- Advanced Integration Tool Dev

Planning Context: Policy, Process, and Law

- **2007: International Space Exploration Coordination Group (ISECG) Created**
- **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)
  - ISECG Reference Architecture for Human Lunar Exploration completed
- **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: Human Space Exploration Architecture Planning (ongoing)**
  - Apr 2011: FY11 CR passed
  - Sep 2011: FY12 CR passed
  - Sep 2011: ISECG Global Exploration Roadmap First Iteration

Budget Lays the Foundation for and Enables Significant Progress on Key Human Space Activities

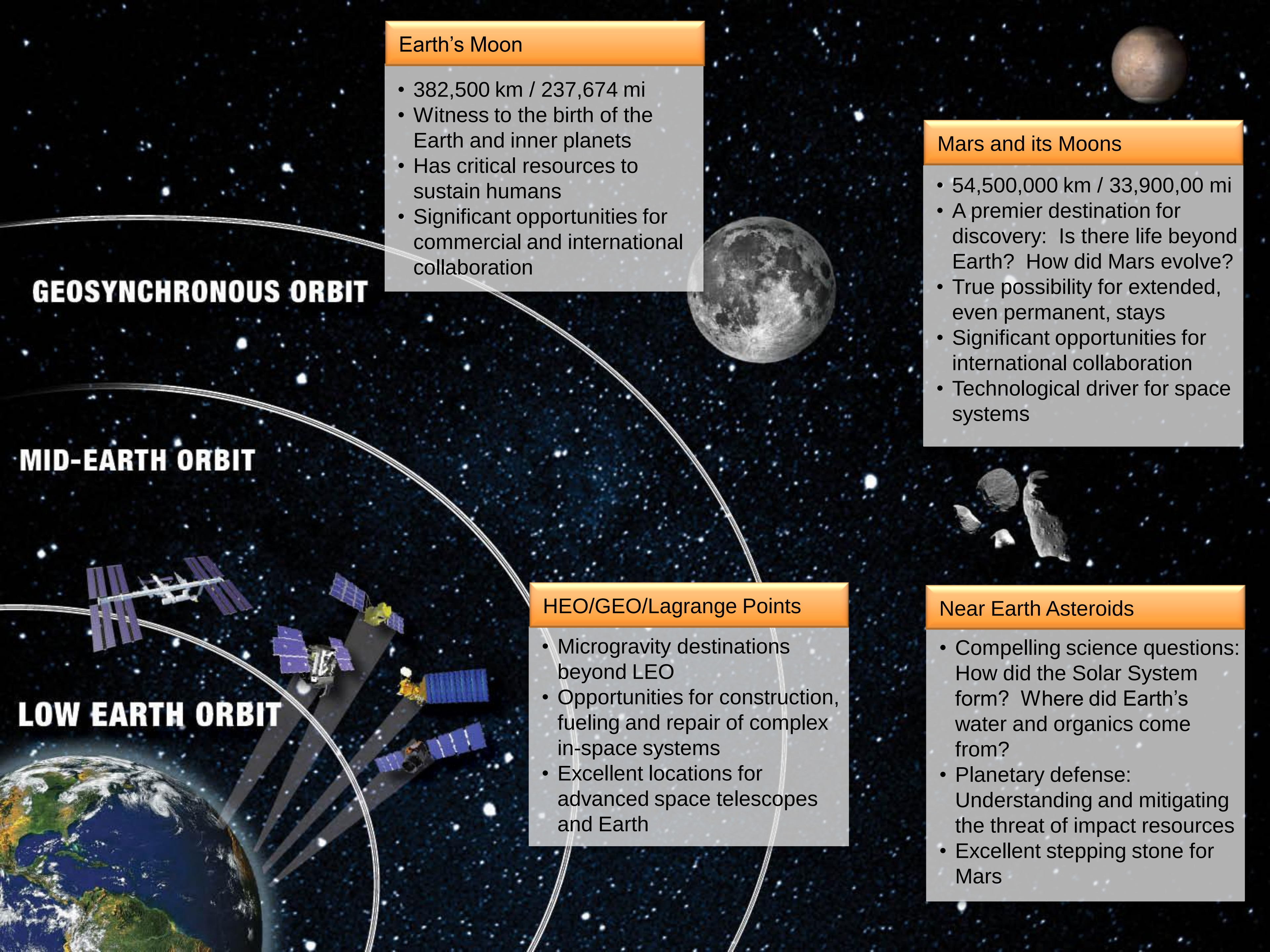
- **Specific content of human spaceflight portfolio (in FY12 budget) validated by NASA framework studies and consistent with NASA Authorization Act of 2010**
  - ISS utilized for critical exploration research and demonstrations
  - Cargo and crew access to ISS developed through innovative partnerships with private sector
  - SLS and MPCV: Initial essential capabilities required for NASA and the U.S. to lead multi-destination human exploration beyond LEO
  - Cutting-edge human research and development of needed life support, crew habitat and other future exploration capabilities
  - Leveraging the best of NASA, industry, academia, and partner capabilities while planning innovative, cost-effective approaches to development and future operations

Affordability is a major challenge: NASA must evolve its traditional approach to human space systems planning and development.

Capability-Driven Framework Overview

- **Objective: Facilitates a capability-driven approach to human exploration rather than one based on a specific destination and schedule**
- **Evolving capabilities would be based on:**
  - Previously demonstrated capabilities and operational experience
  - New technologies, systems and flight elements development
  - Concept of minimizing destination-specific developments
- **Multiple possible destinations/missions would be enabled by each discrete level of capability**
- **Would allow reprioritization of destination/missions by policy-makers without wholesale abandonment of then-existing exploration architecture**

A Capability-Driven Framework enables multiple destinations and provides increased flexibility, greater cost effectiveness, and sustainability.



Earth's Moon

- 382,500 km / 237,674 mi
- Witness to the birth of the Earth and inner planets
- Has critical resources to sustain humans
- Significant opportunities for commercial and international collaboration

Mars and its Moons

- 54,500,000 km / 33,900,00 mi
- 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

HEO/GEO/Lagrange Points

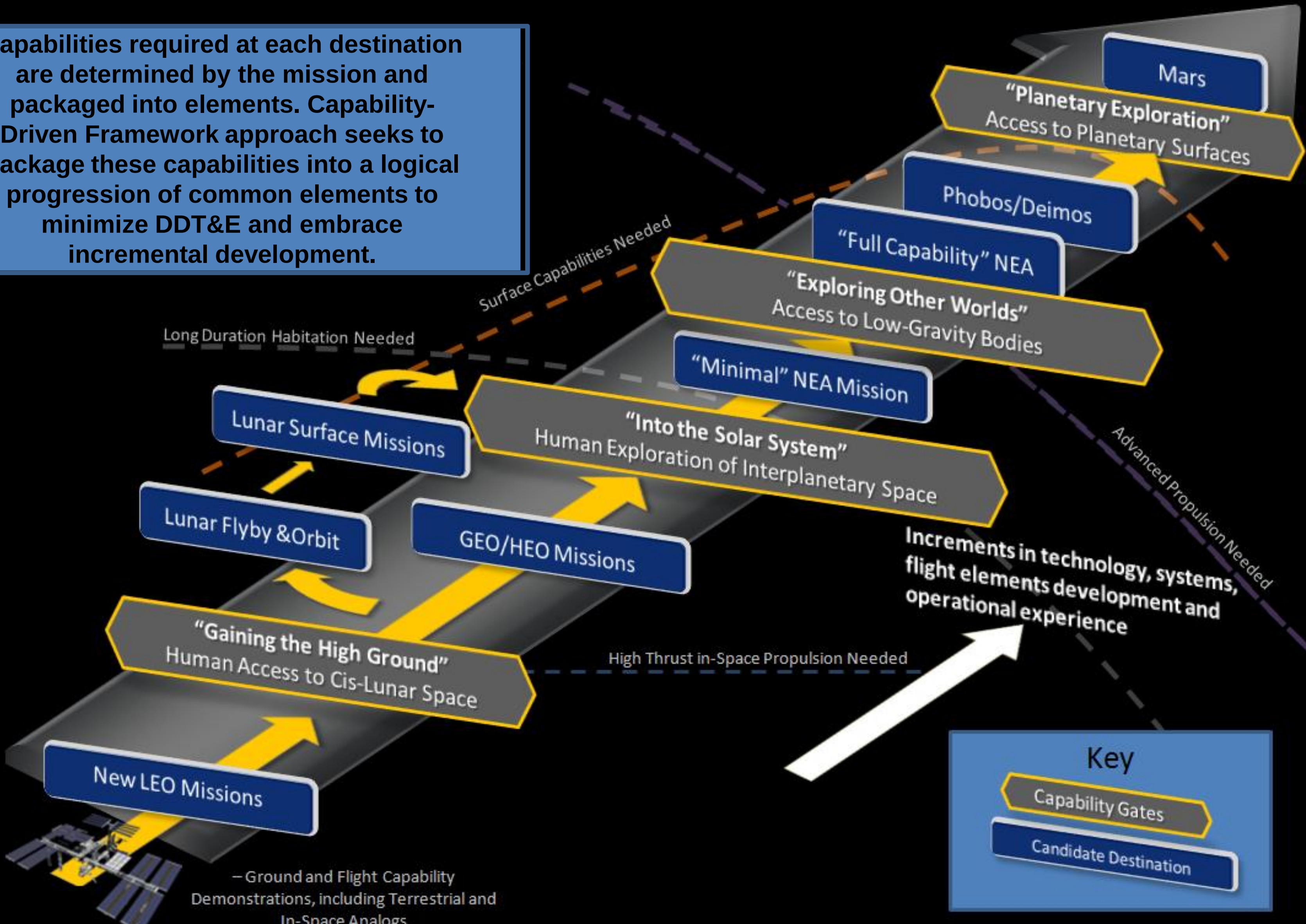
- Microgravity destinations beyond LEO
- Opportunities for construction, fueling and repair of complex in-space systems
- Excellent locations for advanced space telescopes and Earth

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 resources
- Excellent stepping stone for Mars

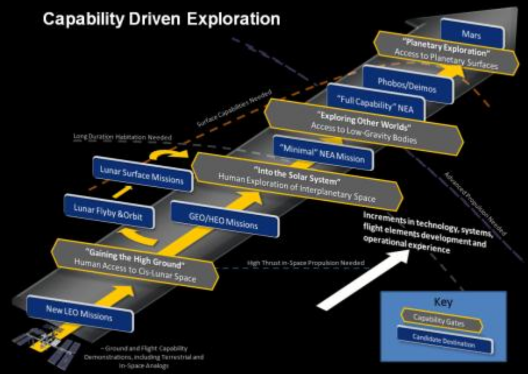
Capability Driven Exploration

Capabilities required at each destination are determined by the mission and packaged into elements. Capability-Driven Framework approach seeks to package these capabilities into a logical progression of common elements to minimize DDT&E and embrace incremental development.



Common Capabilities Identified for Exploration

Capability Driven Human Space Exploration



Architecture Common Capabilities (Building Blocks)

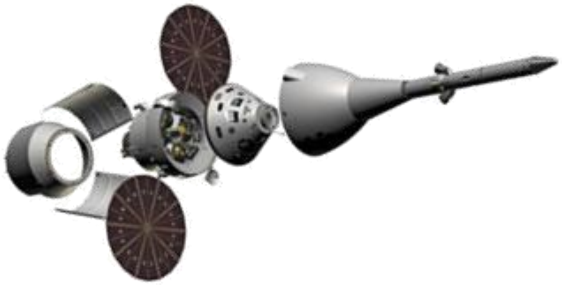
Low Earth Orbit Crew and Cargo Access	Human -Robotic Mission Ops	In-Space Propulsion	Adv. In-Space Propulsion	Deep Space Habitation	Ground Operations
Beyond Earth Orbit Crew and Cargo Access	Robotic Precursor	EVA	Mobile EVA and Robotic Platform	Destination Systems	Autonomous Mission Operations

Technologies, Research, and Science

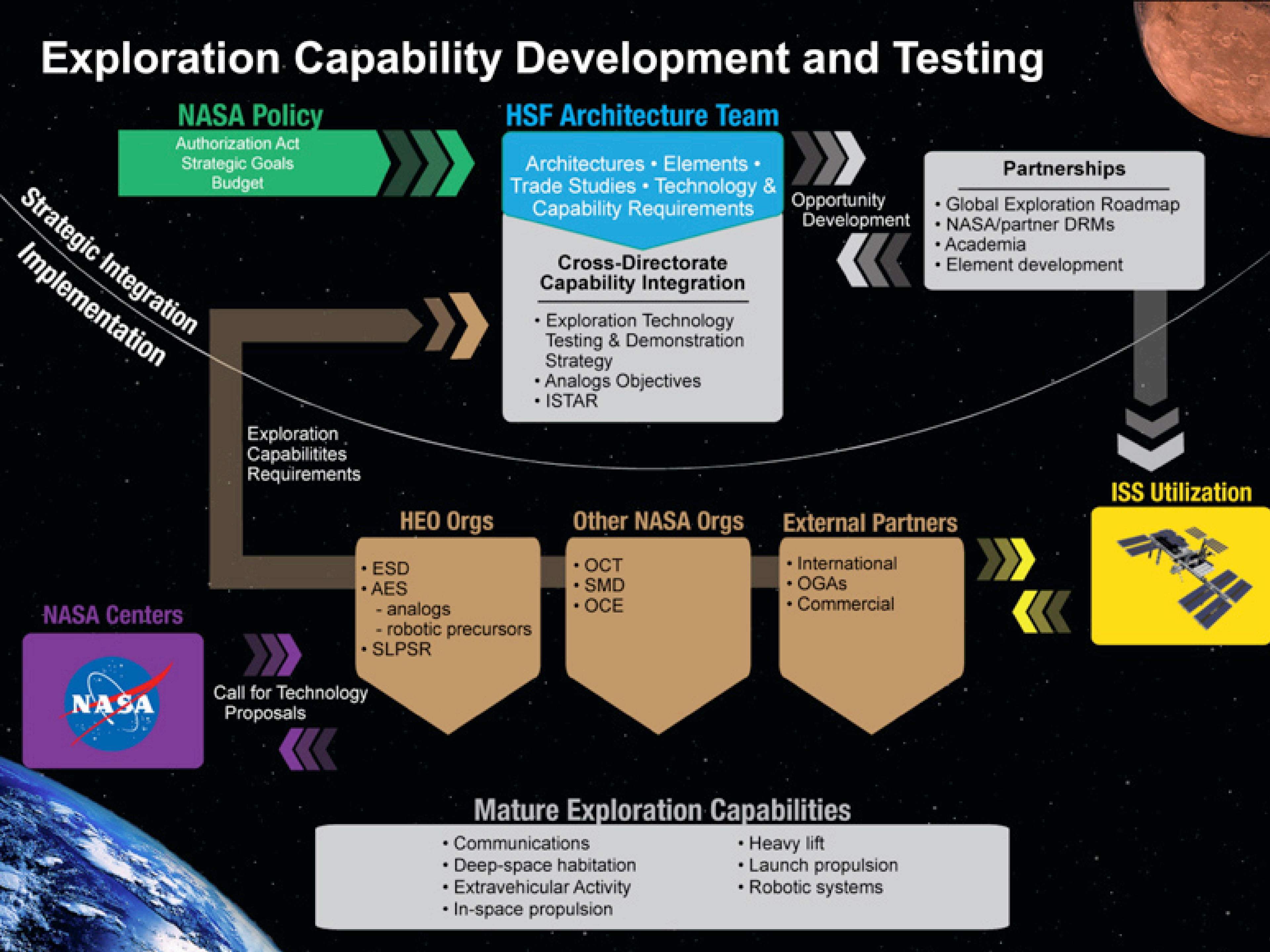
OCT Technology Development Efforts	AES Proposals
HEO and SMD Cross Cutting Research & Science	Human Exploration Specific Technologies

SLS & MPCV: Key, Initial Enablers for Exploration Beyond LEO

- **NASA will develop the launch and spaceflight vehicles that will provide the initial capability for crewed exploration missions beyond LEO**
  - 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
  - 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



SLS and MPCV are the cornerstones of the Exploration Enterprise, but Concurrent Beyond-LEO Capability Development is vital


Exploration Capability Development and Testing
NASA Policy
Authorization Act
Strategic Goals
Budget
HSF Architecture Team
Architectures • Elements • Trade Studies • Technology & Capability Requirements
Cross-Directorate Capability Integration
• Exploration Technology Testing & Demonstration Strategy
• Analogs Objectives
• ISTAR
Opportunity Development
Partnerships
• Global Exploration Roadmap
• NASA/partner DRMs
• Academia
• Element development
Strategic Integration
Implementation
Exploration Capabilitites Requirements
ISS Utilization
HEO Orgs
• ESD
• AES
- analogs
- robotic precursors
• SLPSR
Other NASA Orgs
• OCT
• SMD
• OCE
External Partners
• International
• OGAs
• Commercial
NASA Centers
NASA
Call for Technology Proposals
Mature Exploration Capabilities
• Communications
• Deep-space habitation
• Extravehicular Activity
• In-space propulsion
• Heavy lift
• Launch propulsion
• Robotic systems

NASA's Human Spaceflight Architecture Team (HAT)

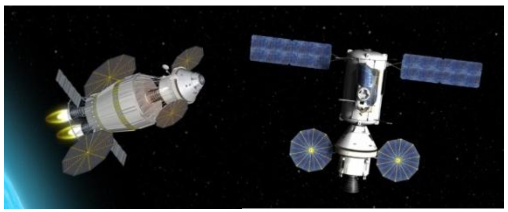
- **Multi-disciplinary, cross-agency study team that conducts strategic analysis cycles to assess integrated development approaches for architectures, systems, mission scenarios, and concepts of operation for human and robotic space exploration.**
  - During each analysis cycle, HAT iterates and refines design reference mission (DRM) definitions to inform integrated, capability-driven approaches for systems planning within a multi-destination framework.
- **Sample Activities in 2011 – Cycles A, B, C**
  - Prepared Design Reference Missions that frame key driving requirements for SLS & MPCV
  - Developed technical content & mission definitions for discussion with the international community developing the Global Exploration Roadmap
  - Advanced Capability Driven Framework concept including more extended reviews of both capabilities needed and development options.
  - Provided technical links between Capability Driven Framework and level 1 requirements for MPCV and SLS

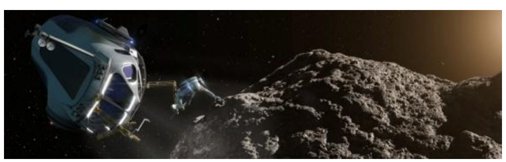
HAT Cycle C Updates from Cycle B

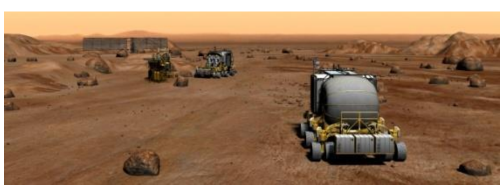
- **Cycle C work by the HAT team continued to refine the DRMs to improve both consistency and technical feasibility. Some key changes:**
  - Direct injection to destination when possible
    - Removed circularization burn to 407 km x 407 km where applicable
  - Clarified boil-off requirements and identified usable propellant and dry mass of propellant units separately
  - Continued to add depth to the definition of human activities while at destinations
  - Developed and utilized consistent operational timeline assumptions
    - See back-up for assumptions
  - Improved consistency of margin analysis for many elements and phases, such as MPCV propulsive burns
  - Resolved station keeping problems
    - Deep Space Hab always attached to another element for ACS/RCS
  - Shifted DRMs between primary and supporting, added new DRMs to primary
    - To improve alignment with programmatic activities in preparation for on-going SRR

Primary Transportation DRMs

Select destinations used to drive transportation systems requirements and assess impacts of changes in mission assumptions

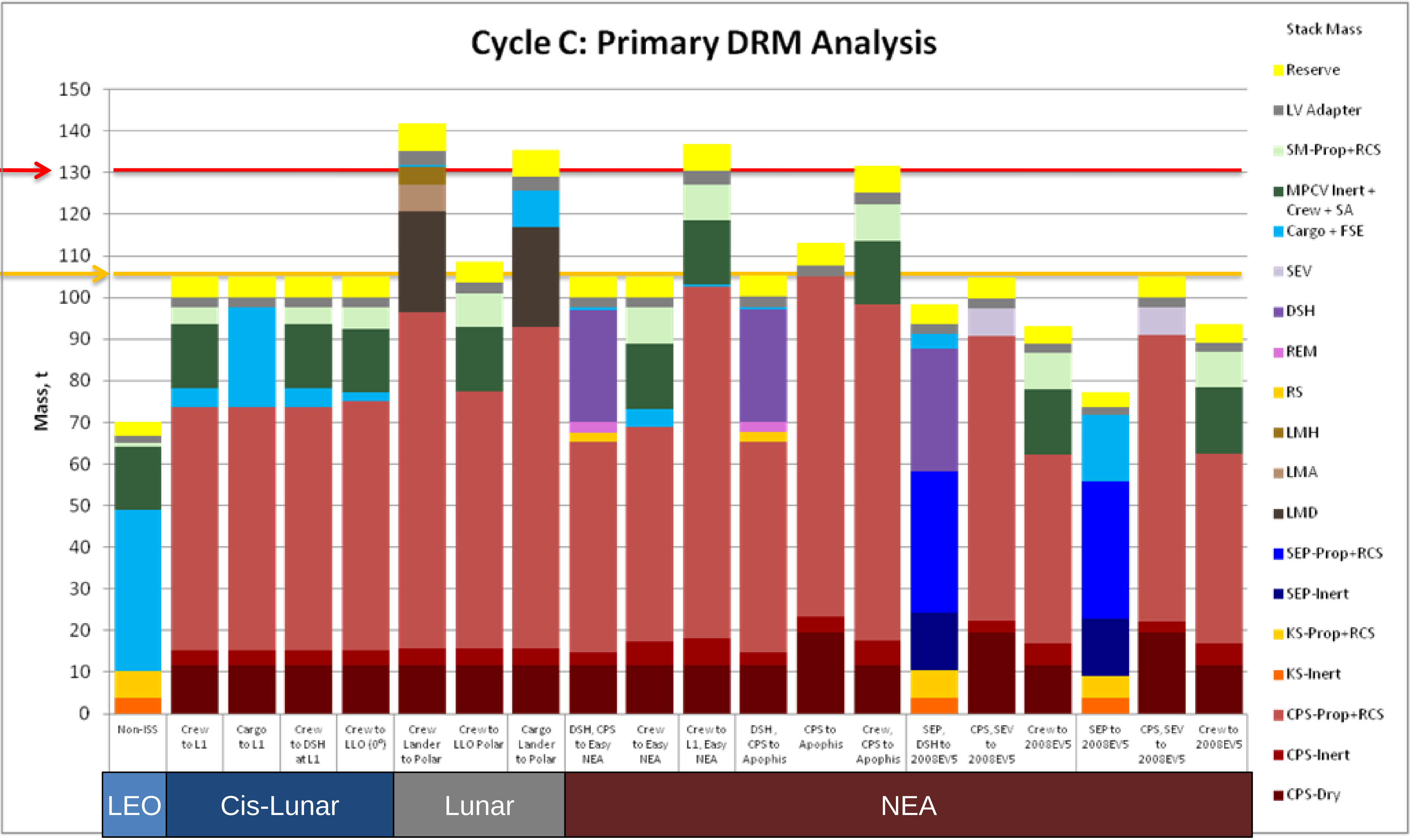






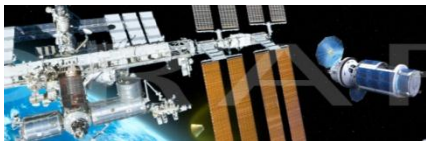
Proposed Status	ISECG	DRM ID	DRM Title	Dest.
Cycle-C	N	LEO_UTL_2A	LEO Utilization - Non-ISS	LEO
Cycle-C	Y	CIS_LP1_1A	Lunar Vicinity - EM L-1	E-M L1
Cycle-C	Y	CIS_LP1_1B	Lunar Vicinity - EM L-1 DSH Delivery	E-M L1
Cycle-C	Y	CIS_LP1_1C	Lunar Vicinity - EM L-1 with Pre-deployed DSH	E-M L1
Cycle-C	Y	CIS_LLO_1A	Low Lunar Orbit	LLO
Cycle-C	Y	LUN_SOR_1A	Lunar Surface Polar Access - LOR/LOR	Moon
Cycle-C	Y	LUN_CRG_1A	Lunar Surface Cargo Mission	Moon
Cycle-C	N	NEA_MIN_1A	Minimum Capability, Low Energy NEA	NEA
Cycle-C	Y	NEA_MIN_1B	Minimum Capability, Low Energy NEA with Pre-deployed DSH	NEA
Cycle-C	N	NEA_MIN_2A	Minimum Capability, High Energy NEA	NEA
Cycle-C	N	NEA_FUL_1A	Full Capability, High Energy NEA with SEP	NEA
Cycle-C	Y	NEA_FUL_1B	Full Capability, High Energy NEA with SEP and pre-deployed DSH	NEA
Forward Work	N	MAR_PHD_1 A	Martian Moon: Phobos/Deimos	Mars Moon
Forward Work	N	MAR_SFC_1A	Mars Landing	Mars Surface

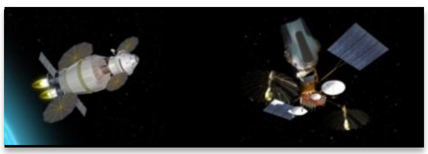
DRM Comparison

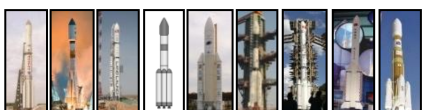


Supporting DRM Descriptions

Supporting – Approaches to transporting crew and cargo to destinations that inform updates to the Primary DRMs

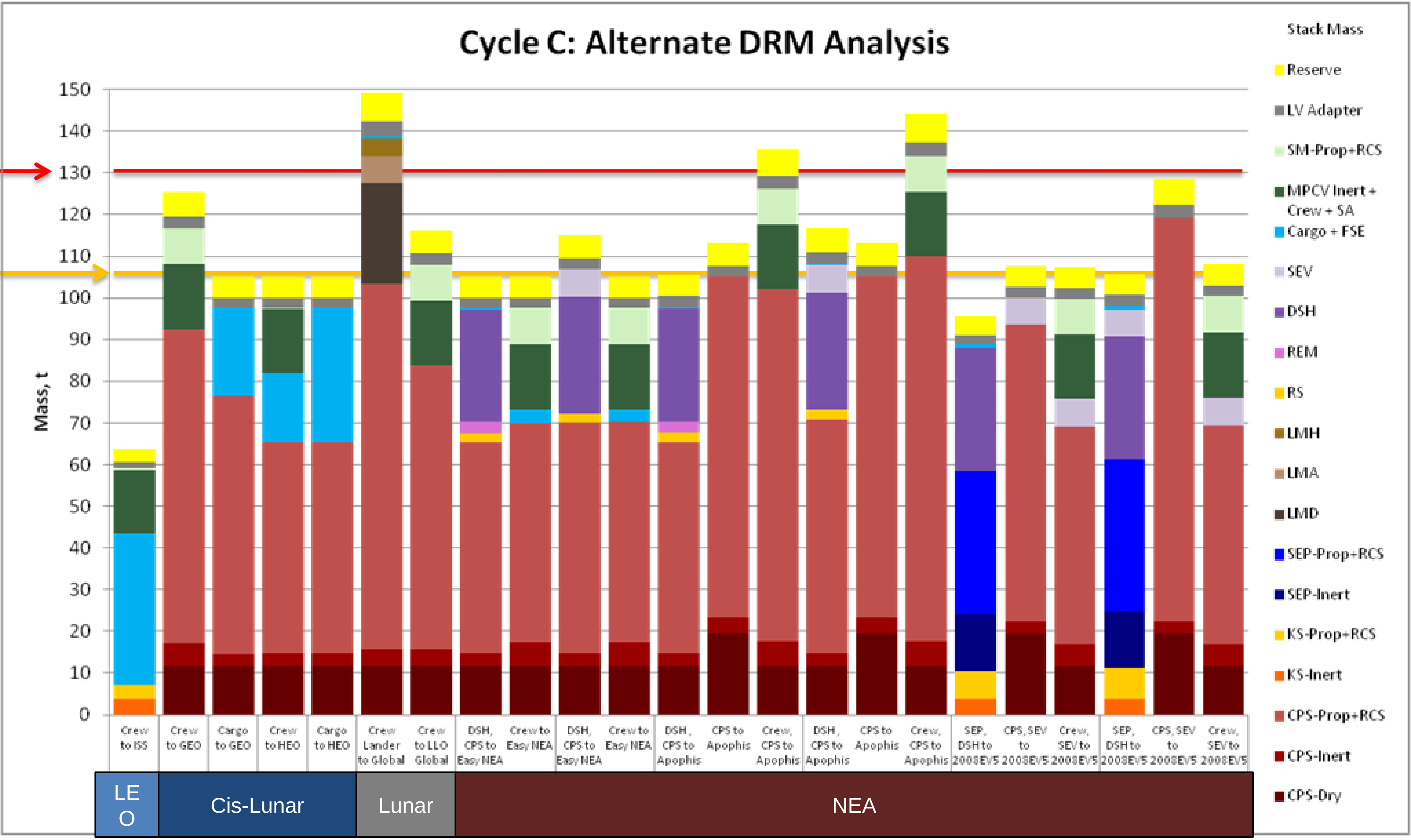






Status	ISECG	DRM ID	DRM Title	Dest.
Cycle-C	N	LEO_UTL_1A	LEO Utilization - ISS	LEO
Future work	N	LEO_DEP_1A	LEO CPS-Based Propellant Depot Delivery with ELV Resupply	LEO
Cycle-C	N	CIS_GEO_1A	GEO Vicinity	GEO
Cycle-C	N	CIS_GEO_1B	GEO Vicinity Cargo Mission	GEO
Cycle-C	N	CIS_HEO_1A	HEO Vicinity	HEO
Cycle-C	N	CIS_HEO_1B	HEO Vicinity Cargo Mission	HEO
Cycle-C	N	LUN_SOR_1B	Lunar Surface Polar Access - LOR/LOR with LEO Propellant Resupply	Moon
Cycle-C	N	LUN_SOR_1C	Lunar Surface Polar Access - EOR/LOR with LEO Propellant Resupply	Moon
Cycle-C	N	LUN_GBL_1A	Lunar Surface Global Access - LOR/LOR	Moon
Cycle-C	N	LUN_GBL_1B	Lunar Surface Global Access - LOR/LOR with LEO Propellant Resupply	Moon
Cycle-C	N	LUN_GBL_1C	Lunar Surface Global Access - EOR/LOR with LEO Propellant Resupply	Moon
Cycle-C	N	LUN_CRG_1B	Lunar Surface Cargo Mission with LEO Propellant Resupply	Moon
			Lunar Trade Matrix (Roland)	
Cycle-C	N	NEA_MIN_1C	Minimum Capability, Low Energy NEA, with LEO propellant resupply	NEA
Cycle-C	N	NEA_MIN_1D	Minimum Capability, Low Energy NEA	NEA
Cycle-C	N	NEA_MIN_1E	Minimum Capability, Low Energy NEA, with SEV	NEA
Cycle-C	N	NEA_MIN_2B	Minimum Capability, High Energy NEA	NEA
Cycle-C	N	NEA_MIN_2C	Minimum Capability, High Energy NEA with SEV	NEA
Cycle-C	N	NEA_FUL_1C	Full Capability, High Energy NEA with LEO Propellant Resupply	NEA
Cycle-C	N	NEA_FUL_1D	Full Capability, High Energy NEA with 2nd SEV AND CARGO	NEA
Cycle-C	N	NEA_FUL_1E	Full Capability, High Energy NEA with 2nd SEV AND CARGO	NEA

DRM Comparison



HAT Forward Work

1. **Near Term decision support**
   - Analysis of options for missions that can be fulfilled using 70 mT launch vehicles, then 100 mT analysis
   - Analysis of ways to effectively integrate early SLS upper-stage options into DRMs; can we eliminate or delay the need for an in-space propulsion stage and the associated cryogenic technology investments?
2. **As HEOMD completes the on-going SRR, continue to evolve broad range of DRMs to facilitate planning for upcoming MPCV and SLS milestones to preserve flexibility for future mission options**
3. **Support ISS Program discussions of options for near term use of ISS for Exploration, ensure linkages to the scenarios adopted in the Global Exploration Roadmap**
   - Identify any resultant GER updates by next summer to inform GER Iteration 2
4. **Continue steady progress on updating Mars mission concepts, both Mars moons and Martian surface**
   - Low level effort aimed at setting framework for discussions with international community next summer on how future Mars missions need ton influence early activities

HEOMD Exploration Systems Development DRM Summary

- **DRMs are divided into 3 planning categories**
  - Tactical Timeframe
    - Use initial capability or “early block” deliveries of capability that may not meet current ESD requirements, but are on the development path towards those capabilities
  - Strategic Timeframe
    - Defines the next significant level of capability beyond “early block deliveries”.
  - Architectural
    - Provide the long term view (e.g. Mars) necessary to guide effective development strategies
- **… and one “Other” category**
  - “For Analysis”
    - A staging area for candidate DRMs pending analysis against planned capability.
      - DRM’s would be promoted to one of the three time frames or discarded based upon the analysis results.

Current ConOps DRMs (Still Evolving)

- **Tactical**
  - BEO Uncrewed Lunar Flyby
  - BEO Crewed Lunar Orbit
- **Strategic**
  - Low Lunar Orbit
  - Initial Capability NEA
- **Architecture**
  - Lunar Sortie
  - Advanced NEA
    - Maintained in DRM set to illustrate 3 launch DRM capability
  - Full Capability NEA
  - Mars Orbit and Surface – remain a placeholder at this time
- **Analysis**
  - Backup ISS Crew Rotation
  - GEO Servicing

International Space Exploration Coordination Group

- **NASA has been a leader in the International Space Exploration Coordination Group (ISECG) effort to develop a Global Exploration Roadmap (GER)**
  - ISECG is a non-binding forum for sharing goals, objective and plans for human space exploration
- **The ISECG forum enables agency discussions on key topics such as**
  – Long-range mission scenarios which lead to sustainable human missions to Mars
  – Near-term opportunities to coordinate and partner on exploration preparatory activities

- NASA views the ISECG as an effective forum for setting the stage for future international exploration missions
- The first version of the GER reflects consensus of 12 agencies that human exploration will be an international endeavor
  – The GER was endorsed by Senior Agency Managers in August 2011
  – It reflects current policies and plans of participating agencies
  – A second iteration is planned for late 2012

ISECG Terms of Reference

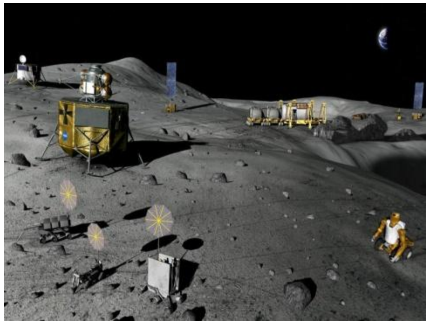
- **Work collectively in a non-binding, consensus-driven manner towards advancing the Global Exploration Strategy**
  - Provide a forum for discussion of interests, objectives and plans
  - Provide a forum for development of conceptual products
  - Promote interest and engagement around the world
  - Enable the multilateral or bilateral partnerships necessary to accomplish complex exploration missions

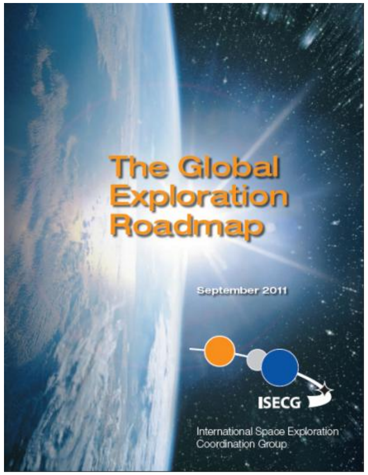
- **ISECG operating principles**
  - Open and inclusive
  - Flexible and evolutionary
  - Effective
  - Mutual interest

- **ISECG is open to new members**

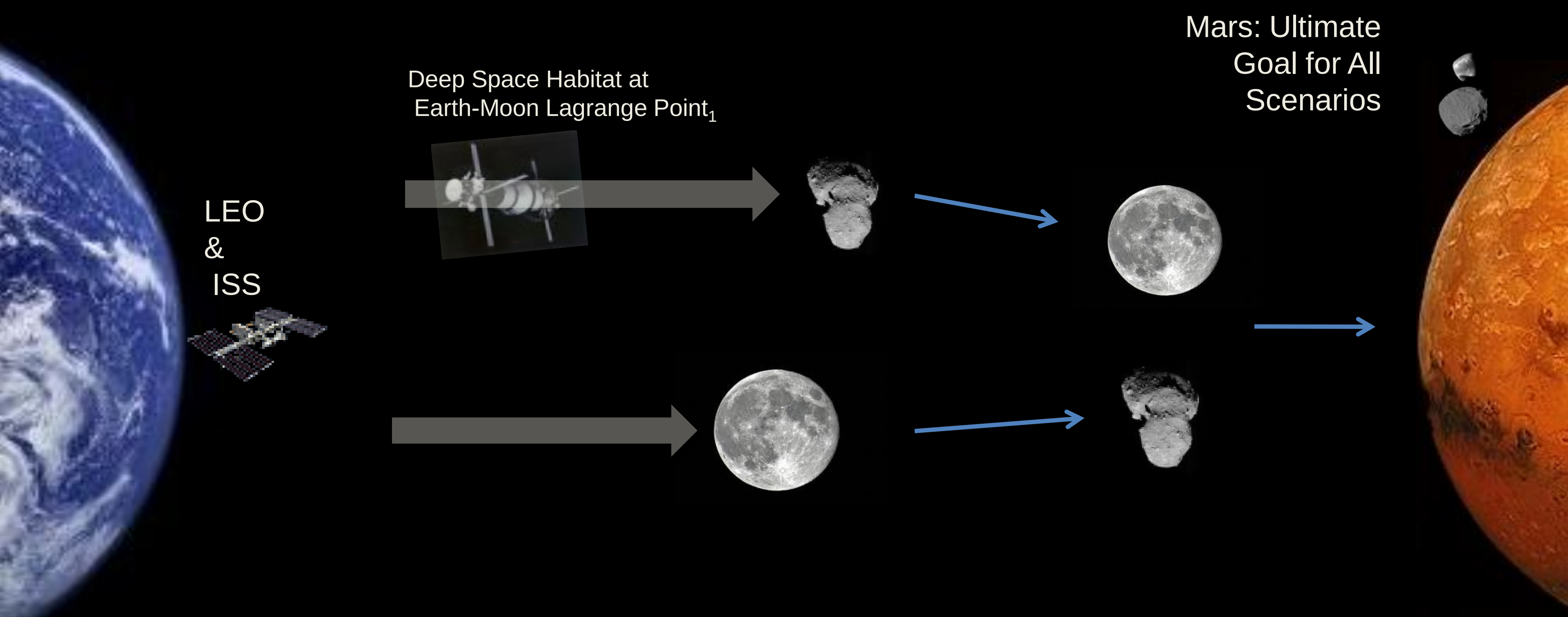
ISECG Products

- **To date, ISECG has released two technical products considered important to inform near-term decision making within participating agencies**
- **Both products reflect a shared interest to collaboratively plan future human exploration in an open and inclusive manner**
  - The ISECG Reference Architecture for Human Lunar Exploration
    - The first internationally developed human space exploration architecture
  - The Global Exploration Roadmap
    - A tool to facilitate coordination of agency long-term planning and near-term preparatory activities
- **Forward work focused on the Global Exploration Roadmap**
  - Second iteration planned for September 2012





Global Exploration Roadmap:
Exploration Pathways

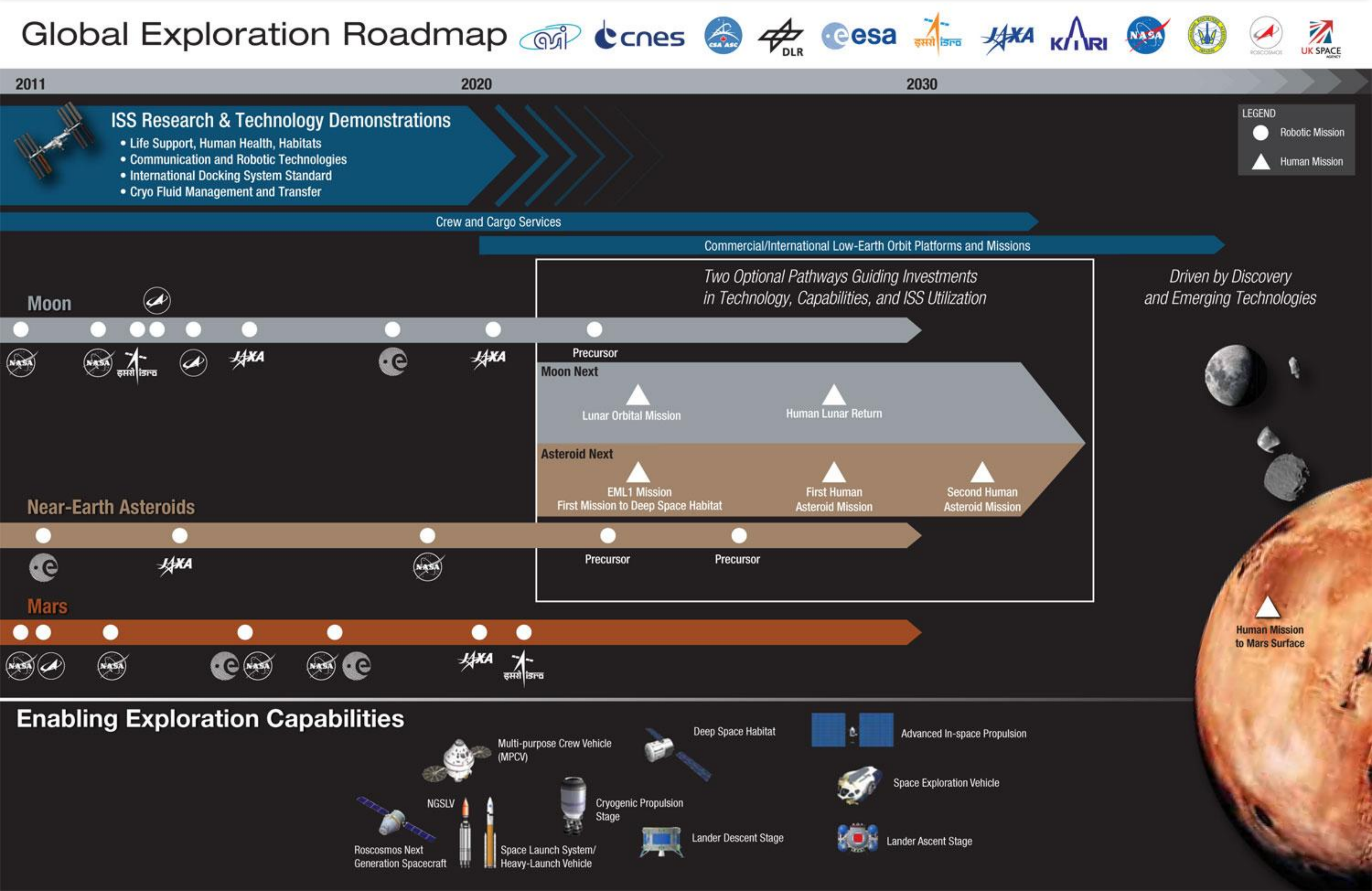


Near-term Focus on Guiding Capabilities, Technologies and Leveraging ISS

Long-term Focus is Discovery Driven and Enhanced by Emerging Technologies

International Partnerships are Essential Because of the Inherent and Broadbased Benefits and the Global Exploration Roadmap is consistent with NASA's Capability-Driven Framework for Human Space Exploration.

Global Exploration Roadmap: Released Sept 2011



NASA Exploration Plans: Boldly Going Beyond

- **NASA's human spaceflight program dares to imagine extending human presence throughout the solar system**
- **Significant NASA Architecture Analysis and Planning On-going**
- **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
- **International partnerships and joint planning are essential elements**
- **Integration across the architecture and planning elements is vital to an affordable, executable, and sustainable Exploration enterprise**

Questions?