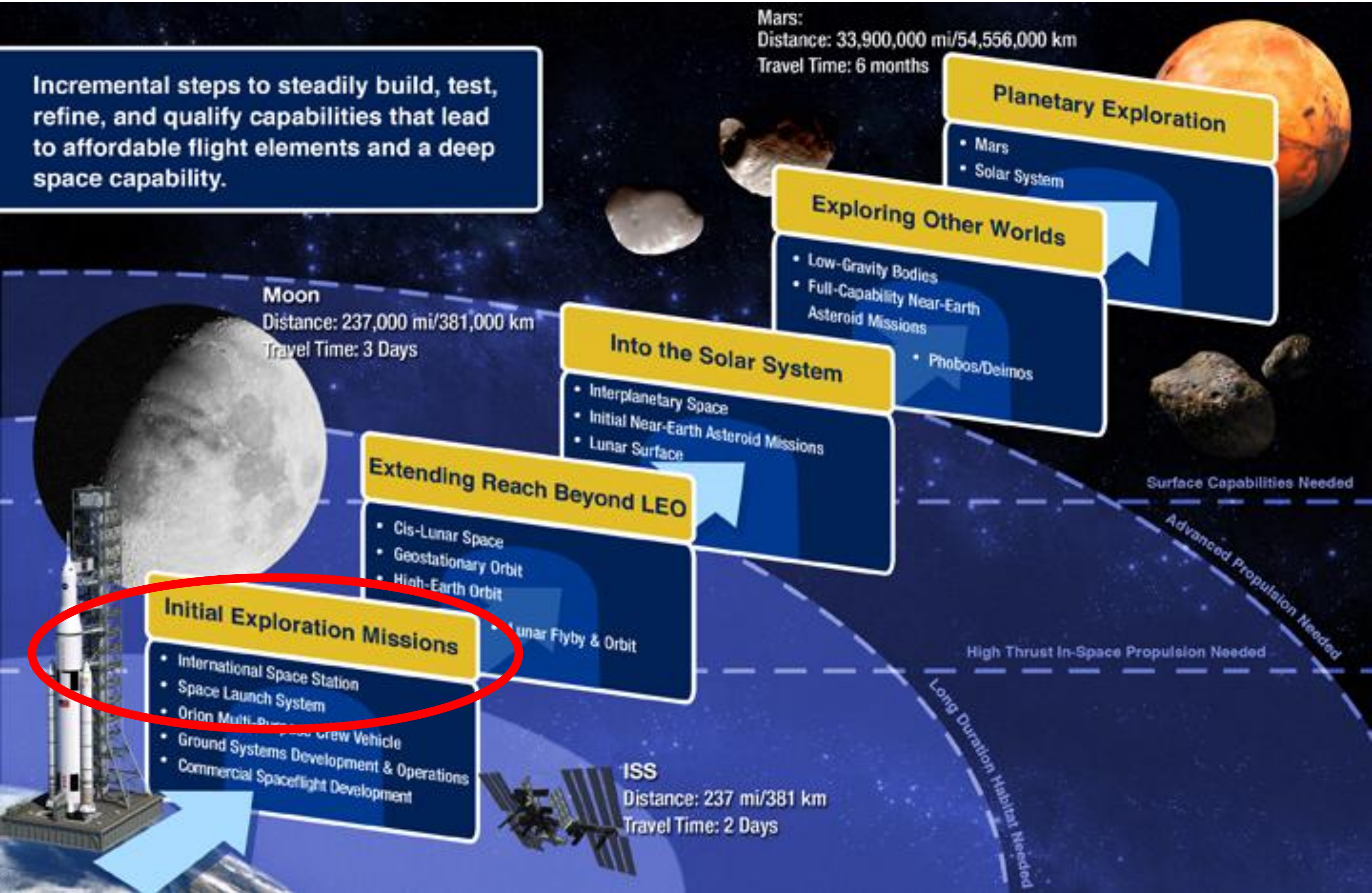
National Aeronautics and Space Administration

Exploration Planning, Partnerships, and Prioritization Summary

6 Mar 2012
Dr. John Olson
Director, Strategic Analysis & Integration Division
Human Exploration & Operations Mission Directorate
NASA Headquarters

Capability Driven Human Space Exploration: ISS as the Foundation and Cornerstone



John Shannon Exploration Assessment Task: Assignment Background

- **Assigned by the NASA Administrator to :**
- **Review all Design Reference Missions (DRMs)**
- **Understand which technologies each of the Center Engineering and Operations organizations believe should be further developed**
- **Understand the capabilities and evolution options for the Multi-Purpose Crew Vehicle and Space Launch System**
- **Work with the ISECG and International Partners to achieve a shared understanding**
- **Product: Provide a recommendation on the specific DRMs that should become the focus of our collective efforts.**

<u>This is a tactical look at what can be done in the near-term to support BEO activities while feeding into a longer-term strategic plan</u>

Risk Areas for Asteroid, Mars System Missions

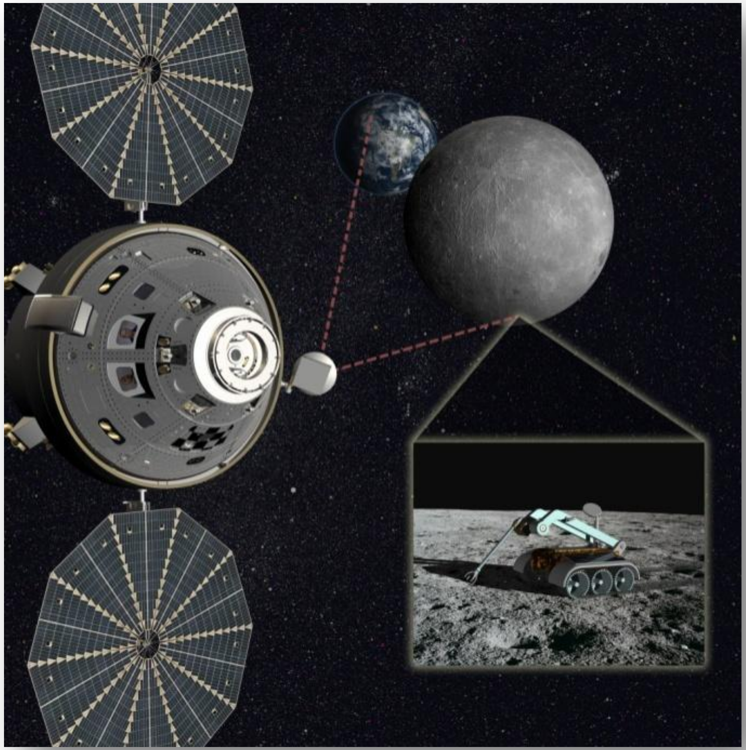
- **Life Sciences**
  - Radiation mitigation – people and hardware
  - Extended periods of lowered pressure
  - Isolation psychology
- **Operations**
  - Deep space navigation
  - "Free Space" rendezvous and docking
  - Communications
  - Untended spacecraft operations
- **Systems Design**
  - Long-term, closed-loop life support
  - Venting control
  - Thermal control in deep space
- **Propulsion**
  - Continuous propulsion – Solar Electric, nuclear

- **Further analysis and study ongoing: Some of these risks can be reduced through developments at ISS, others will likely require a BEO testbed. Orion alone is capable of 21 days with 4 crew.**

Waypoint Study Team: Cis-Lunar Detailed Assessment (Study/analysis not complete, no near-term decisions)

Direction To Team: **Study utilization of early configurations of SLS, Orion, and existing upper stage along with existing hardware systems to develop an EML2 exploration platform that will incrementally expand our deep space presence supported by international and commercial launch systems**

- **Extend the Orion capabilities for safety, duration and EVA**
- **Enable long duration testing of exploration technologies**
- **Establish a continuous platform for enabling scientific exploration of Cis-lunar space, NEAs, Mars, and deep space**
- **Expand human presence beyond LEO**
  - 30 to 35 day mission into trans-lunar space as early as 2018
  - Travel farther than Apollo and spend longer time in deep space

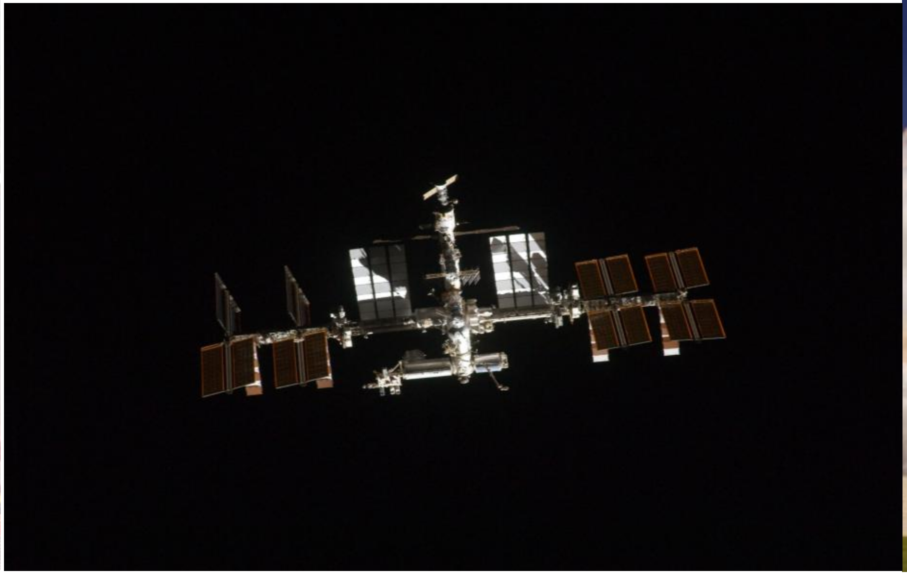


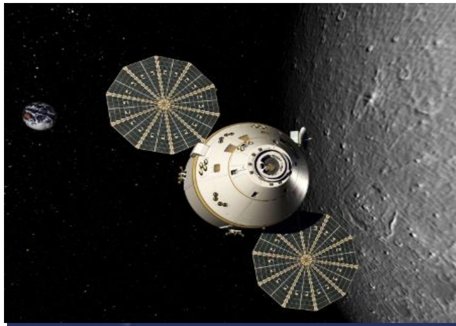
Affordability/Near-Term Executability Principles: Take Advantage of Existing Hardware

- SLS, Orion in development

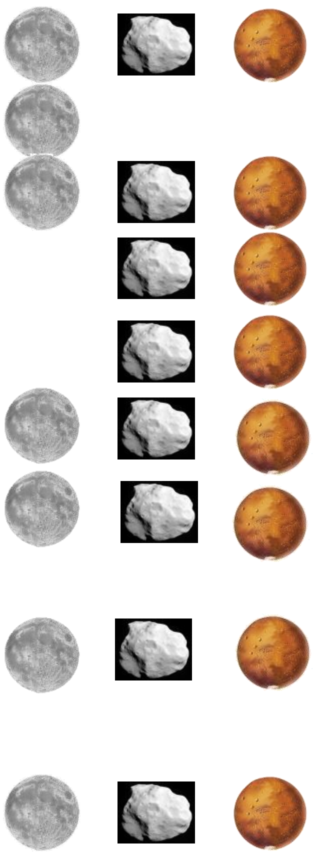
- Various test articles and ISS hardware exist (MPLMs, Docking systems, airlocks, robotics)

- Repurposed US and International ISS components





Potential Linkage to Future Missions



- Transportation system development
- Detailed survey of the Moon, including far side
- Potential staging or aggregation location
- Deep space operations (IVA & EVA)
- Longer crew duration beyond Earth
- Sample acquisition, curation, & return operations
- Longevity of systems while untended in a deep space radiation environment
- Robotic systems as maintenance keepers while facility is uncrewed
- Tele-operations from orbital facility

Cornerstone of Exploration: The International Space Station

Scientific Laboratory • Technology Test Bed •
Orbiting Outpost • Galactic Observatory
New Approach: CASIS

Sustain Human Health and Performance • Ensure Systems Readiness • Validate Operational Procedures

International Space Station:
Research and Technology Applications & Demo Testbed

- **1,200 experiment supporting 1,600 scientists in 59 counties**
  - **ECLSS (environmental control and life support systems)** – Achieved 70-80% water and air recycling on ISS; on the way to reducing logistics to support humans in space by 85%
  - **Human Research** – Advancing knowledge needed to send humans on exploration missions beyond Earth and improve human health on Earth
  - **Materials Testbed** – Better understanding of materials properties has shortened satellite component development time by as much as 50% and is important to future spacecraft design
  - **Earth Observations** – Daily ISS passes over 95% of population centers documenting global change & geographic events
  - **Reaching Students** –30+ million students have participated in human space flight though communication downlinks and interactive experiments with the ISS astronauts
- **ISS Research and Developmental Technologies: Closed-loop life support, Advanced monitoring & control, In-space assembly, Maintainability, supportability and logistics, Solar panels and batteries, EVA technologies, Automated systems, Exercise systems, Medical care, Food systems**

Current, Planned, or Proposed ISS Technology Demonstrations as Example of Exploration Capabilities

Robotics

- Next Gen Canadarm testing
- Robotic Assisted EVA's (Robonaut)
- METERON and Surface Telerobotics
- Delay Tolerant Network Robotic Systems
- Robotic Refueling Mission
- Robotic assembly to optical tolerances (OPTIIX)
- Robotic Free Flyer Inspector
- RCS Sled with Robotic Manipulators
- Highly Dexterous, Semi-autonomous Systems (IVA/EVA)

Comm and Nav

- OPALS – Optical Communication
- X-Ray Navigation, (NICER/SEXTANT)
- Software Defined Radio (CoNNeCT/SCAN)
- Delay and Disruption Tolerant Space Networks
- Autonomous Rendezvous & Docking advancements
- Advanced optical metrology (sensing/materials)

Power

- Regenerative fuel cells
- Advanced solar array designs [FAST, IBIS, or other]
- Advanced photovoltaic materials
- Battery and energy storage advancements [Li-Ion or other]
- Other Modular Power Systems (fuel cells, flywheels, etc)

Thermal Control

- High efficiency radiators
- Cryogenic propellant storage & transfer
- Advanced materials testing

Closed Loop ECLSS

- Atmospheric monitoring: ANITA2, MIDASS, AQM
- Air Revitalization: Oxygen production, Next Gen OGA [Vapor Feed or other]
- Contaminated gas removal
- Carbon Dioxide recovery: Amine swingbed and CDRA bed advancements
- Advanced Closed-loop Life Support ACLS
- Water/Waste: Electrochemical disinfection, Cascade Distillation System, Calcium Remediation, [Electrodialysis Metathesis or other]
- Bioregenerative systems

Other

- Spacecraft Fire Safety Demonstration,
- Radiation protection/mitigation/monitoring
- On-board parts repair and manufacturing
- Autonomous vehicle systems management
- Suit Ports
- Exploration Atmosphere Physiological Effects
- Radiation Mitigation Testing
- Advanced Logistics and Waste Management
- Advanced Medical Operations
- Advanced Docking Systems
- Cryogenic Propulsion Stage with Cryo Mgt and Transfer
- Time Delayed/Autonomous Mission Operations

A History of Collaboration and Cooperation
- ISS as a Stepping-Stone for Deep-Space Exploration
- International Cooperation = Vital

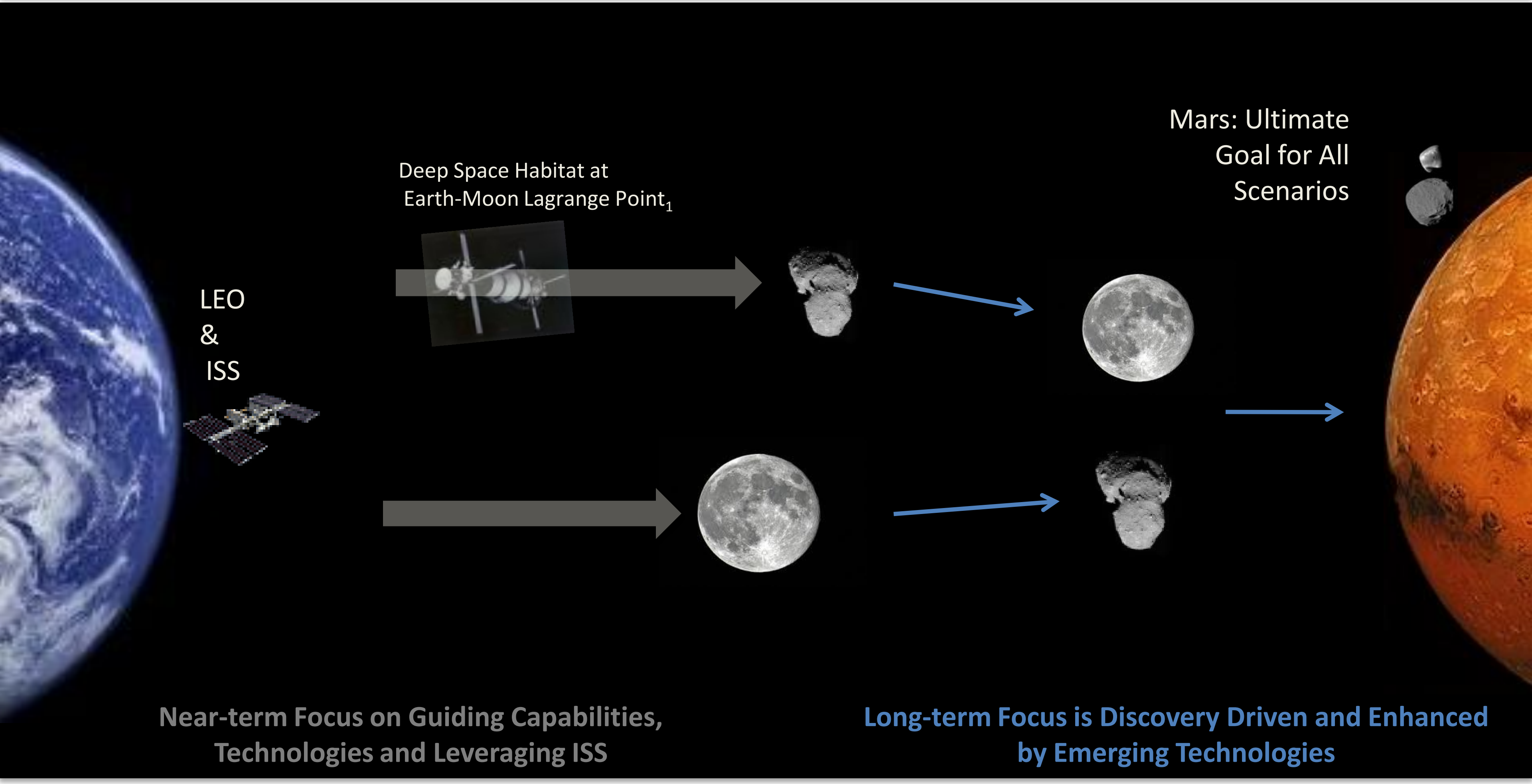
Long-Range Strategy and Mission Scenarios

- **The GER defines a common long-range exploration strategy**
  - Start with ISS and work towards humans sustainably exploring the surface of Mars
- **The common long-range strategy identifies two feasible pathways**
  - Asteroid Next and Moon Next
- **Each pathway is elaborated through a "mission scenario" to enable discussions of exploration concepts and approaches which meet our common objectives**

Common International Space Exploration Coordination Group (ISECG) Goals

- Common goals are needed, but recognized individual agency goals are what is important to an agency
  - Search for Life
  - Extend Human Presence
  - Perform Space, Earth, and Applied Science
  - Perform Science to Support Human Exploration
  - Develop Exploration Technologies and Capabilities
  - Stimulate Economic Expansion
  - Enhance Earth Safety
  - Engage the Public in Exploration
- GER reflects common goals and supporting objectives
- These are to be iterated and will reflect agency/national priorities

ISECG Exploration Roadmap:
Two Exploration Pathways in a Common Strategy

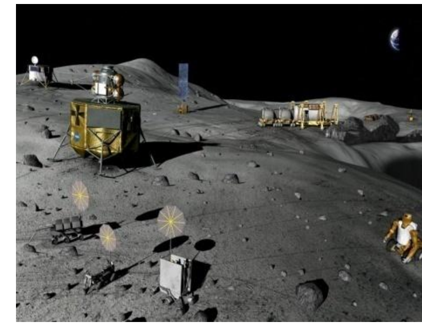


Given their broad-based benefits, International Partnerships are essential. The Global Exploration Roadmap is consistent with NASA's Capability-Driven Framework for Human Space Exploration.

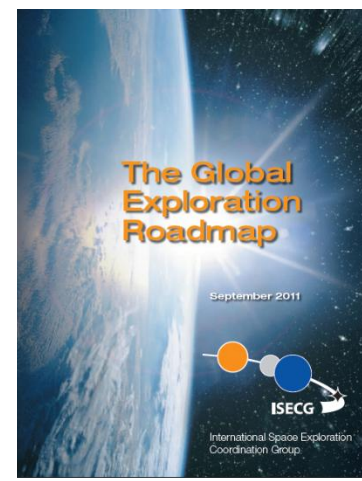
ISECG Products

- **To date, ISECG has released two technical products informing 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 multilaterally developed human space exploration architecture
  - The Global Exploration Roadmap
    - A tool to facilitate coordination of agency long-term planning and near-term preparatory activities

ISECG Reference Architecture for Human Lunar Exploration



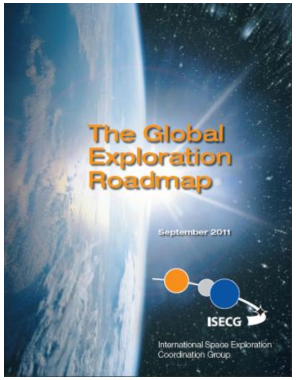
Released in July 2010



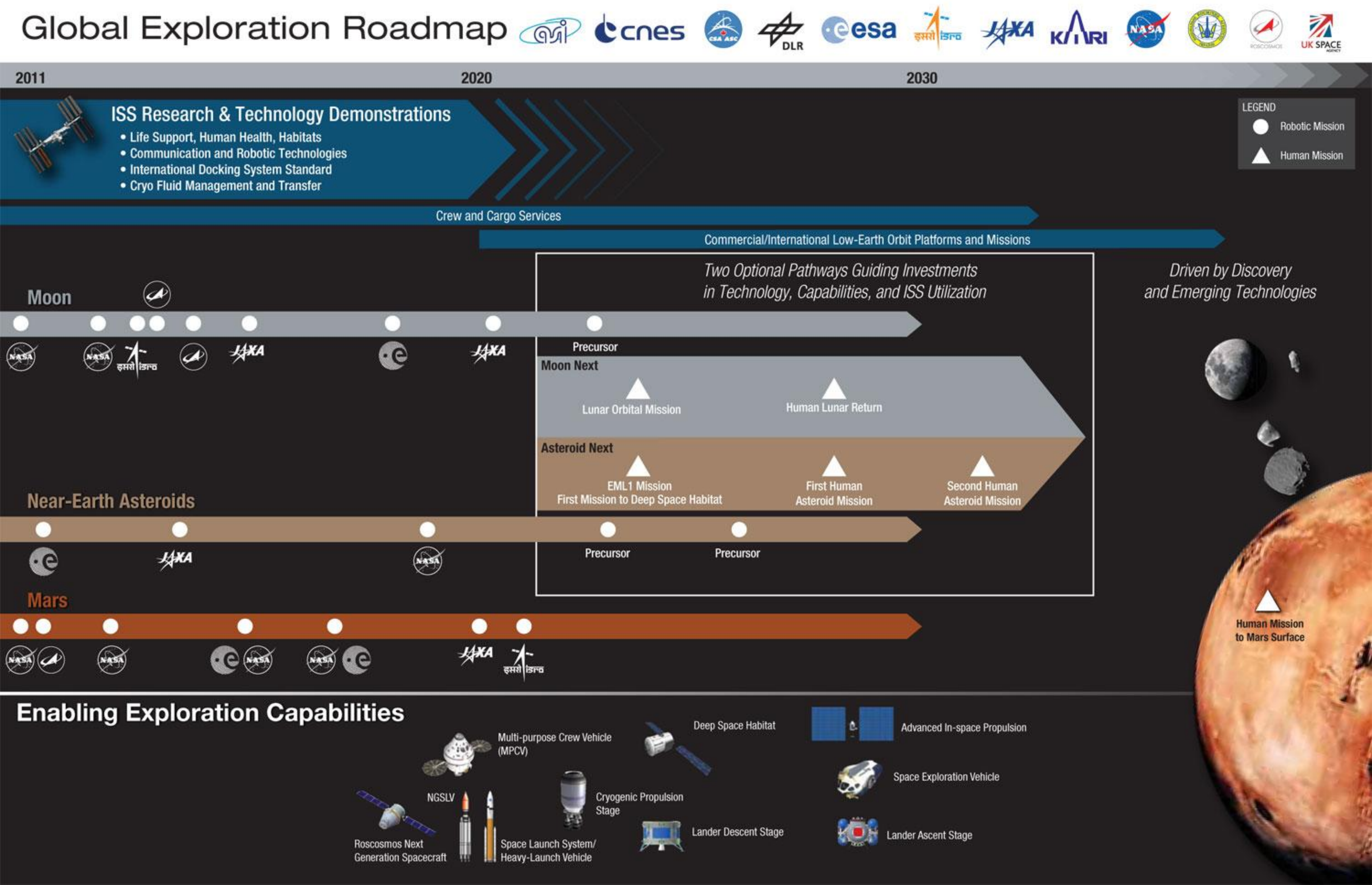
First iteration released in September 2011

The Global Exploration Roadmap

- **First iteration released in Sept 2011**
  - Reflected work of agencies to collaboratively plan and prepare for human exploration missions
- **Agencies have continued dialog within ISECG on topics considered timely for informing near-term decisions**
  - Decision to extend ISS to 2020 drives priority on ISS use in support of exploration
- **Results of this work will be reflected in the Second iteration of the GER**
  - Currently planned for end 2012/early 2013



ISECG Global Exploration Roadmap Iteration 1: Sept 2011



Priority GER Discussion Topics for 2012

- **Maximize use of ISS in support of exploration**
  - Technology demonstration
  - Demonstrating reliability and maturity of critical capabilities
  - Human health management for long duration missions
  - Operational simulations
- **Early design reference missions in both Asteroid Next and Moon Next scenarios**
  - Inform requirements development and agency studies
- **Sharing agency priorities for advanced technology investment areas**
  - Look for partnership opportunities and areas considered underfunded
- **Defining human space exploration knowledge gaps for each destination**
  - Increase synergy between human and robotic science exploration
  - Increase awareness of role of robotic missions as precursors

Benefits of Space Exploration

- **ISECG also discussing a common approach to describing the benefits of exploration missions**
- **Approach includes narratives to capture established and projected benefits and a performance evaluation system to inform definition of programs, enable articulation of benefits and facilitate future measurement of benefits delivery**
- **Results of this work will be used by participating agencies, within their discretion, to engage stakeholders, decision makers**

Common Capabilities Identified for Exploration

Capability Driven Human Space Exploration

ISS

SLS

Orion MPCV

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

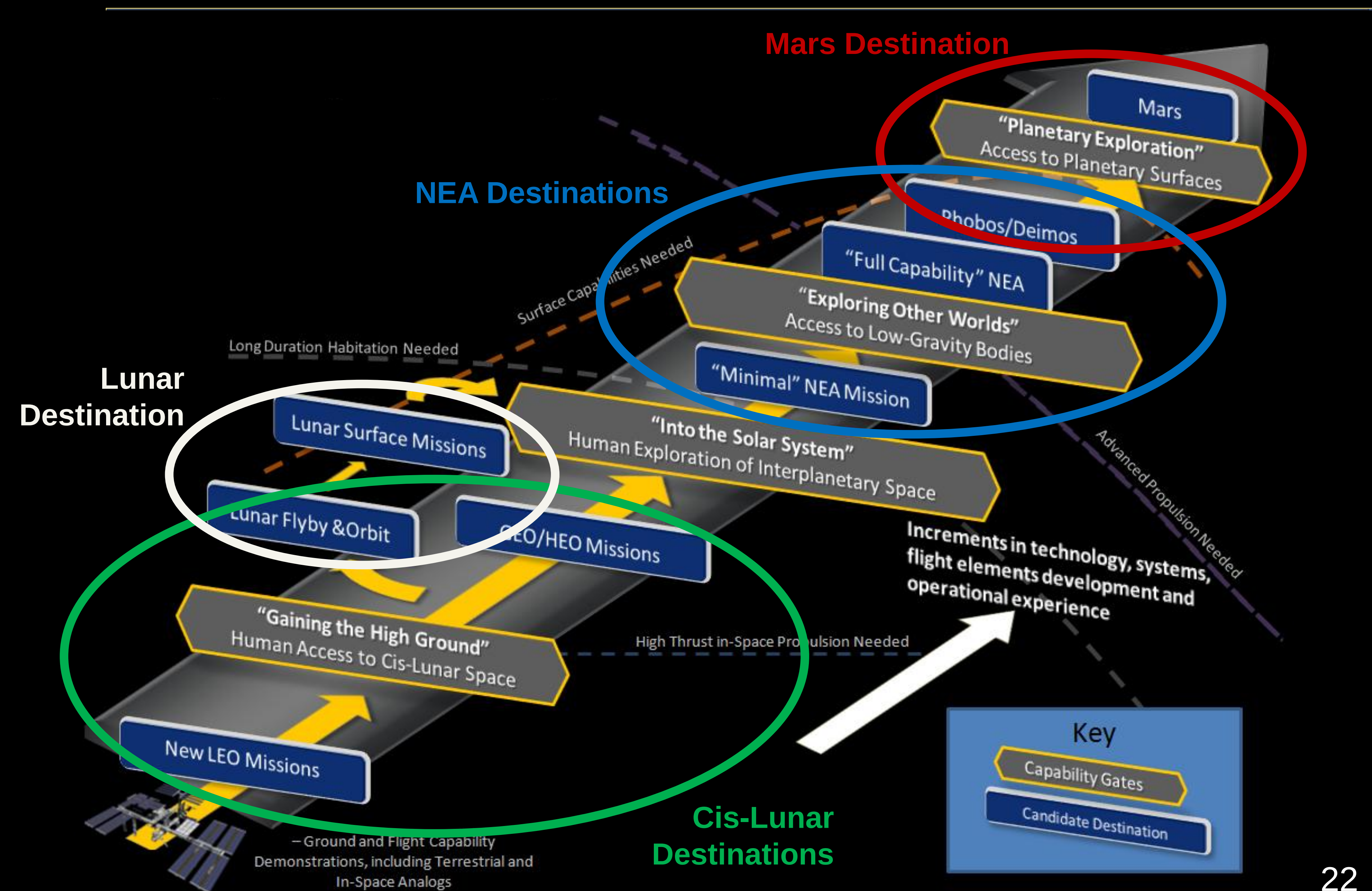
OCT Technology Development Efforts	AES Proposals
HEO and SMD Cross Cutting Research & Science	Human Exploration Specific Technologies

ISS, SLS, and MPCV are the cornerstones of the Exploration Enterprise, but concurrent, innovative, and extremely lean Beyond-LEO incremental capability development is vital.

NASA's Human Spaceflight Architecture Team (HAT)

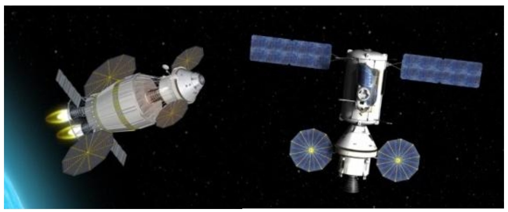
- **On-going, cross-Agency, multi-disciplinary, study team that conducts strategic analysis cycles to assess integrated development approaches for architectures, systems, mission scenarios, and Conops for human and related robotic space exploration.**
  - During each analysis cycle, HAT iterates and refines design reference mission (DRM) definitions to inform integrated, capability-driven approaches for systems planning within a multi-destination framework.
- **Key Activities in 2011 – Cycles A, B, C, D**
  - Prepared DRMs that frame key driving level 1 requirements for SLS & Orion MPCV
  - Developed technical content & mission definitions for discussion with the international community developing the Global Exploration Roadmap
  - Advanced Capability Driven Framework (CDF) concept including more extended reviews of both capabilities needed and development options.
  - Provided technical links between CDF and level 1 requirements for SLS/MPCV
  - Developed performance data for key decisions on SLS initial capability and upper stage options

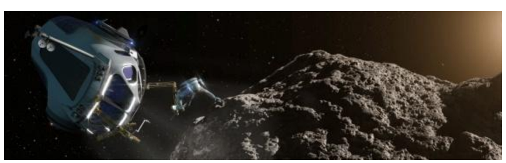
Capability Driven Roadmap – Destinations

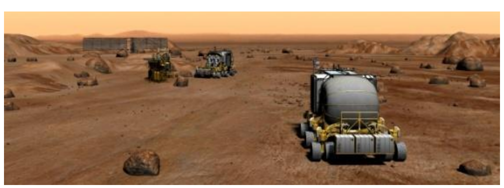


Primary Transportation DRMs

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_1A	Martian Moon: Phobos/Deimos	Mars Moon
Forward Work	N	MAR_SFC_1A	Mars Landing	Mars Surface

Elements Required By Destination

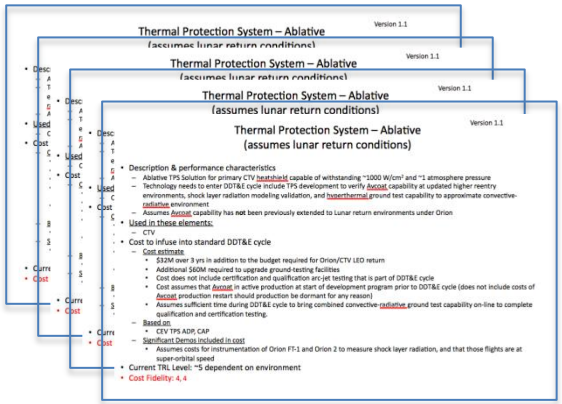
Phase	Required Element	Capability	For Destinations				
			L1/L2	Lunar Surface	Asteroid	Mars Orbit	Mars Surface
Getting There	**Space Launch System (SLS)**	Launch	X	X	X	X	X
	Cryo Propulsion Stage (CPS)	High Thrust/Near Earth	X	X	X	Option	Option
	Solar Electric Propulsion (SEP)	Low Thrust/Near Earth			Option	Option	Option
	Nuclear Thermal Propulsion (NTP)	High Thrust/Beyond LEO			Option	Option	Option
	Nuclear Electric Propulsion (NEP)	Low Thrust/Beyond LEO			Option	Option	Option
	Depot	In-Space Logistics	Option	Option		Option	Option
	Deep Space Habitat (DSH)	In-Space Habitation	X		X	X	X
	Landers	Descent		X			X
Working There	**Surface Hab**	Surface Habitation		X			X
	Multi-Mission Space Exploration Vehicle (MMSEV)	Micro-g Sortie			X	X	
	Cargo Hauler	Cargo Mobility	Option	Option	Option	Option	Option
	Robotics and EVA Module (REM)	Logistics/Resupply	Option		Option	Option	
	In-Situ Resource Utilization (ISRU)	In Situ Resource Utilization		X			X
	Fission Surface Power System	Surface Power		Option			X
	Surface Rover	Surface Mobility		X			X
	EVA Suits	EVA (nominal)	X	X	X	X	X
Coming Home	**Ascent Vehicle**	Ascent		X			X
	Orion	Crew Return	X	X	X	X	X

Technology Development Assessment: Technology Development Data Capture Process

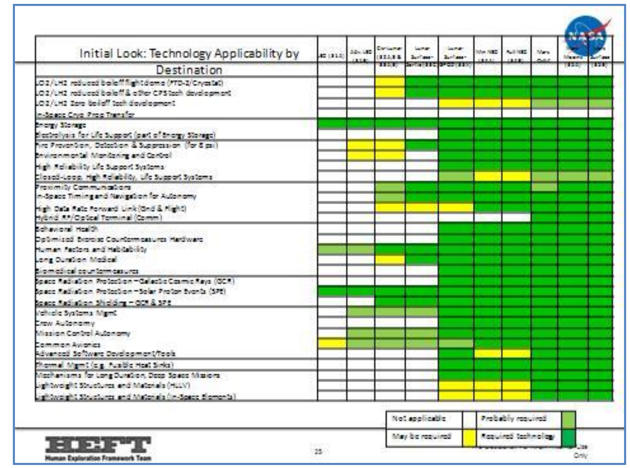
Strategy & DRMs

Element Data

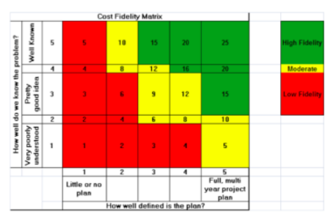
Tech Dev 'One-Pager' Sheets



'Tech Dev' Summary Spreadsheet
(per Strategy/DRM)



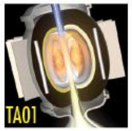
Cost Fidelity



Subject Matter Expert POCs
(e.g. ETDD/OCT, HRP, Element Leads, SE, etc.)

- Tech Dev Data for HAT Cost Team:
  - Cost, Schedule, Phasing
  - Applicable Elements (per DRM)
- ETDD/OCT/HRP Data Inputs
- HEDS Data Inputs (e.g. AES priorities, Analogs, ISS demo candidates, etc.)
- ISECG Technology Dev Inputs

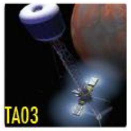
NASA Space Technology Roadmap (STR)
Technology Area Breakdown Structure

TA01


- LAUNCH PROPULSION SYSTEMS

TA02


- IN-SPACE PROPULSION TECHNOLOGIES

TA03


- SPACE POWER & ENERGY STORAGE

TA04


- ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS

TA05


- COMMUNICATION & NAVIGATION

TA06


- HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

TA07

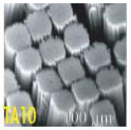

- HUMAN EXPLORATION DESTINATION SYSTEMS

TA08


- SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

TA09


- ENTRY, DESCENT & LANDING SYSTEMS

TA10


- NANOTECHNOLOGY

TA11


- MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

TA12


- MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

TA13


- GROUND & LAUNCH SYSTEMS PROCESSING

TA14


- THERMAL MANAGEMENT SYSTEMS

Technology Development Assessment: 2011-C TechDev Summary (per OCT TA grouping)

TA#	Technology Area (TA) Description	Tech Dev Entries	Element Driving (Pull)	ISS Demo Candidates
1	Launch Propulsion	2*	2*	0
2	In-Space Propulsion	8	7*	5
3	Space Power & Energy Storage	8	8	2
4	Robotics, Tele-Robotics, and Autonomous Systems	6	6	5
5	Communication & Navigation	4	4	2
6	Human Health, Life Support, & Habitation Systems	16	16	12
7	Human Exploration Destination Systems	6	6	2
8	Science Instruments, Observatories & Sensor Systems	N/A	N/A	N/A
9	Entry, Descent, & Landing (EDL)	3	2	0
10	Nanotechnology	0	0	0
11	Modeling, Simulation, IT & Processing	1	0	0
12	Materials, Structures, Mechanical Systems & Mfg.	6	2*	1
13	Ground & Launch Systems Processing	4	4	0
14	Thermal Management Systems	4	4	2
	*Note: * indicates Element trade-space dependent*	68	61	32

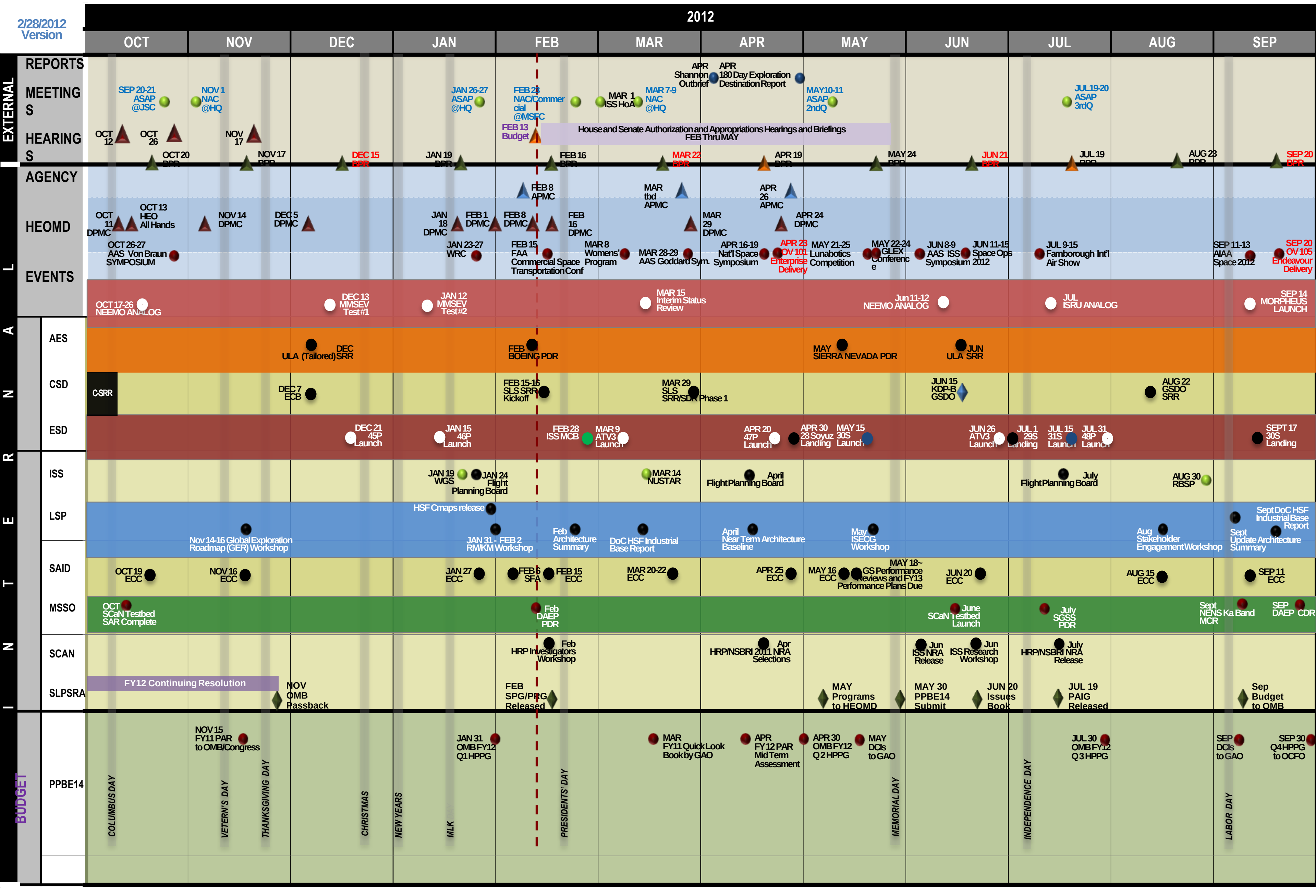
Technology Development Assessment: 2011-C TechDev Summary (per Element)

Element	Driving Technologies	OCT Technical Areas
MPCV	5	Autonomous Systems, Comm & Nav, In-Space Prop
SLS	3*	Autonomous Systems, Launch Prop
CPS	5	In-Space Prop, Thermal Mgmt, Comm & Nav, Power & Energy Storage
SEV	8	Autonomous Systems, Human Health/Life Support, Comm & Nav, Tele-Robotics
SEP	2	In-Space Prop, Power & Energy Storage
DSH	14	Human Health/Life Support/Hab, Comm & Nav, Tele-Robotics, Power & Energy Storage
EVA	8*	Human Health/Life Support, Destination Systems, Power & Energy Storage
Lander	9	In-Space Prop, Entry-Descent-Landing (EDL), Human Health/Life Support
In-Space Robotics	3*	Power & Energy Storage, Robotics/Tele-Robotics
Cargo Hauler	0	N/A
Surface Elements	24*	Autonomous Systems, Human Health/Life Support/Hab, ISRU, Power & Energy Storage, Robotics/Tele-Robotics
Other	9	Element Examples (NTP, NEP, Ground Ops, In-Space Comm Relays)

Forward Work Issues and Concerns

- **In Space Propulsion**
  - Wide variety of options for how to provide in-space burns:
    - Cryo Propulsion Stage, new stage developed for long life in-space
    - Initial Cryo Propulsion Stage; off the shelf capability, limited life in space
    - Low thrust options for cargo like Solar Electric Propulsion
  - Trade space of mission capture, affordability, and partnerships is likely to be very complex
- **Technology & Capability priorities**
  - What are the best ways to utilize the agencies limited technology funding to enable a wide variety of future human spaceflight capabilities?
  - Early emphasis on ECLSS reliability and cryo technologies looks relevant to almost all destinations
- **Earth Moon Lagrange Point 2 Mission**
  - How does an L2 waypoint enable missions to other destinations?
  - Reviewing multiple approaches for how to take best advantage of capabilities deployed in cis-lunar space to prepare for missions to other destinations
- **Mars Mission**
  - How should eventual Mars mission influence earlier missions and investments?
  - Build Mars Design Reference Architecture 6.0; likely to take into FY13
  - Look at manned missions to Martian moons and how those can reduce mission risk and prepare for eventual human missions to Mars surface

HEOMD FY12 Milestones Overview



Looking Toward the Future: Making Progress Now

- ISS will be the centerpiece of human spaceflight activities until at least 2020
- Research and technology breakthroughs aboard ISS will facilitate travel to destinations beyond low Earth orbit
- A capability driven framework will enable affordable and sustained human spaceflight exploration
- Destinations for human exploration remain ambitious: the moon, asteroids and Mars
- Continue to undertake world-class science missions to observe our planet, reach destinations throughout the solar system and peer even deeper into the universe
- Continue to inspire the next generation of scientists, engineers and astronauts by focusing on STEM education initiatives

Backup Slides

Assumptions

- **iCPS-1**
  - Using data from Barney Holt received on Oct. 26th, 2011
    - thrown: 31,257 kg
    - Usable Main Propellant: 27,216 kg
    - Burnout: 4,038 kg
    - Engine: Single RL10B-2
    - Isp: 462 s
  - ~8 hour lifetime
- **iCPS-2**
  - Using data from Barney Holt received on Oct. 27th, 2011
    - thrown: 64,445 kg
    - Usable Main Propellant: 57,833 kg
    - Burnout: 6,605 kg
    - Engine: 2 x NGE
    - Isp: 465 s
  - ~6 day lifetime
- **MPCV**
  - MPCV-SM propellant is offloaded as needed for each mission
  - Engines
    - Shuttle OMS: Isp of 315.1 and Thrust of 26.7 kN
    - Aux: Isp of 308, Thrust of 8 x 490 N
    - For sizing purposes, assumed OMS for first burn and Aux engines for all subsequent burns to cover contingencies
  - 1,800 m/s and 2,700 m/s MPCV sizings provided by Wayne Jermstad, Dec 02, 2011
- **SLS Upper Stage**
  - Upper Stage capabilities provided by David Anderson, Dec 6, 2011
  - US performs sub-orbital burn and Earth departure only
- **Block – 1 CPS as Upper Stage**
  - Capabilities provided by David Anderson TBD
  - CPS performs sub-orbital burn and Earth departure only
- **FPR**
  - iCPS
    - 5% added to each DV
  - MPCV
    - 2% added to each DV
    - 2.5% of max prop stored as reserve to account for ACS and additional FRP considerations
- **Launch Vehicle Capability**
  - 3xRS-25 SLS
    - 70 t thrown capability to -87 km x 241 km orbit
    - 50.6 t thrown capability to -93 km x 1,806 km orbit (“Lofted MECO”)
  - 4xRS-25 SLS
    - 81 t thrown capability to -87 km x 241 km orbit
    - 61.7 t thrown capability to -93 km x 1,806 km orbit (“Lofted MECO”)
  - Net capability assumes:
    - 5% Level 1 Customer Reserve (3.33 t)
    - LV adapter: 10,000 lbm (4.54 t)
      - HAT’ uses 2.5% adapter (1.63 t)
    - 3.2% CEV adapter
    - 18 meter SLS shroud barrel
- **Cargo Cases**
  - Assumes off-loaded MPCV-SM is used to perform insertion for iCPS-1 and Upper Stage cases
  - SM to payload adapter is included in payload mass

Evolution of Key Assumptions that Drive Transportation System Performance

HEFT	Cycle-A	Cycle-B	Cycle-C
10% Architecture Reserve • on wet cargo stack (+ adapter) mass	**5% Level I Customer Reserve** • on wet cargo stack (+ adapter) mass	**5% Level I Customer Reserve** • on wet cargo stack (+ adapter) mass	**5% Level I Customer Reserve** • on wet cargo stack (+ adapter) mass
2.5% launch vehicle adapter mass • on wet cargo stack mass	**2.5% launch vehicle adapter mass** • on wet cargo stack mass	**2.5% launch vehicle adapter mass** • on wet cargo stack mass	**2.5% launch vehicle adapter mass** • on wet cargo stack mass
1% Flight Performance Reserve (FPR) on ΔVs	**5% Flight Performance Reserve (FPR) on ΔVs**	**5% Flight Performance Reserve (FPR) on ΔVs**	**5% Flight Performance Reserve (FPR) on ΔVs** • Except for MPCV burns
Elements Margins • MPCV: data provided • Other elements: 30% MGA	**Elements Margins** • MPCV: data provided • CPS BLK1: 15% • Other elements: 30% MGA	**Elements Margins (Derived from AIAA Standards)** • MPCV: data provided • Other elements: 30% MGA	**Elements Margins (Derived from AIAA Standards)** • MPCV : data provided • CPS: BLK1 - 18.8%, BLK 2- 21.2% • Lander: Margin remains on lunar surface • Other elements: 30% MGA
Insertion orbit: • 55.56 x 240.76 km	**Insertion orbit:** • 55.56 x 240.76 km	**Insertion orbit:** • -87 km X 241 km	**Insertion orbit:** • -87 km X 241 km
Crew of 3 on Lunar & NEA missions	**Crew of 3 on Lunar & NEA missions**	**Crew of 4 on Lunar & NEA missions**	**Crew of 4 on Lunar & NEA missions**
25 meter SLS shroud barrel	**25 meter SLS shroud barrel**	**18 meter SLS shroud barrel**	**18 meter SLS shroud barrel**