Science Enabled by Crew and Infrastructure in the Lunar Vicinity

A Look at Recent Human Space Flight Assessments

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24 July 2014

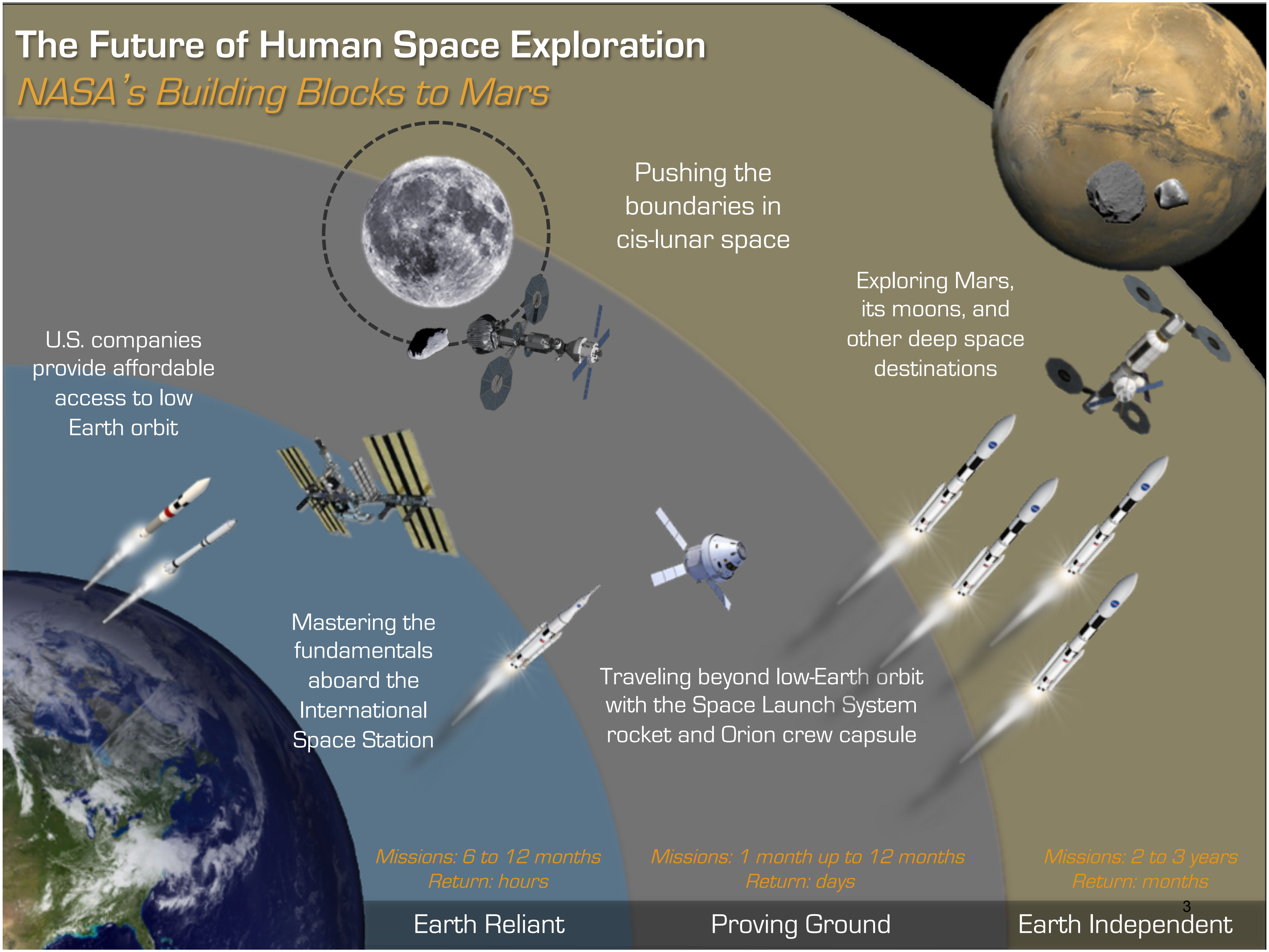
Introduction

- Cis-lunar space provides an excellent 'proving ground' for readying systems, operations concepts and risk mitigation strategies for missions further into space, including missions to Mars
- GER demonstrates how cis-lunar missions are a meaningful step to Mars and a stepping stone to the lunar surface
  - Asteroid Re-direct Mission,
  - Extended Duration Crew Missions

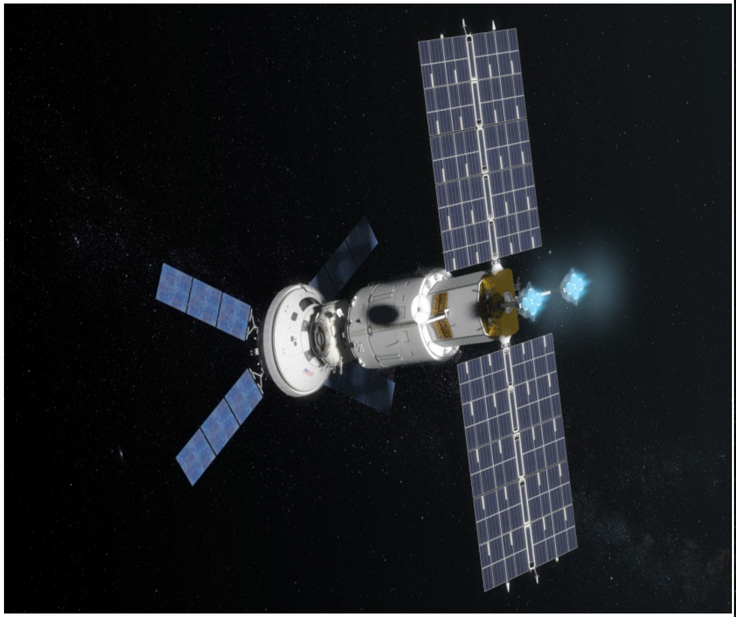
● (green) Full utilization in relevant environment ● Sufficient risk reduction in relevant environment ⊙ Initial feasibility validation/partial validation	Earth	ISS/Low-Earth Orbit	Lunar Vicinity (Earth-Moon Lagrange Point (EML), Moon Orbit)	Moon Surface	Mars Vicinity	Mars Surface (Robotic Mission)
Beyond Low-Earth Orbit Crew Transportation			●	●	● (green)	
Heavy Lift Launch			⊙	●	● (green)	
Reduced Supply Chain		⊙	●	●	● (green)	
Autonomous Crew Operations	⊙	⊙	●	●	● (green)	
Deep Space Staging Operations			● (green)		● (green)	
Mars Ascent	⊙			⊙		⊙
Space Radiation Protection/Shielding		⊙	●	●	● (green)	
Life Support & Habitation Systems		●	●	●	● (green)	
Entry, Descent, & Landing Systems	⊙			⊙		●
Surface Power and Energy Management	⊙			● (green)		● (green)
Surface Mobility	⊙			●		●
Human Robotic Integration	⊙	●	● (green)	● (green)	● (green)	● (green)
Mars In-Situ Resource Utilization	⊙			⊙		●
Long Duration Human Health	⊙	●	●	●	●	
Deep Space Operation Techniques	⊙	⊙	●		● (green)	

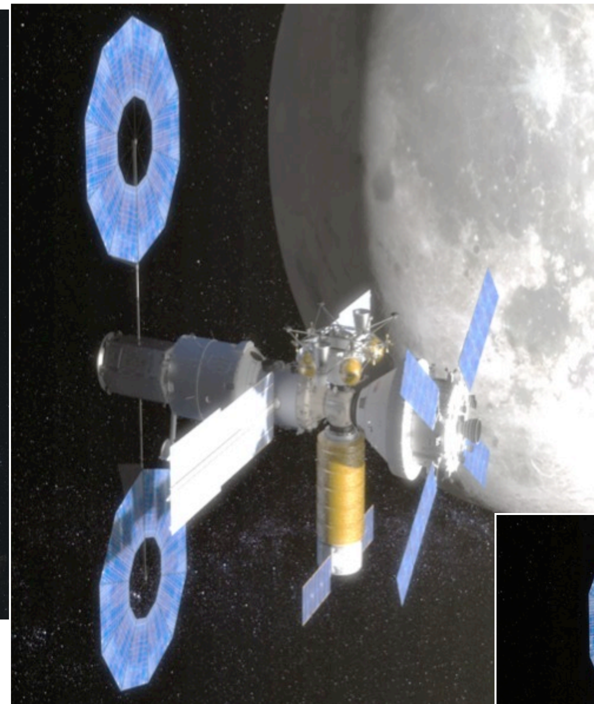
Note: This table assumes critical capabilities will be provided by multiple agencies.

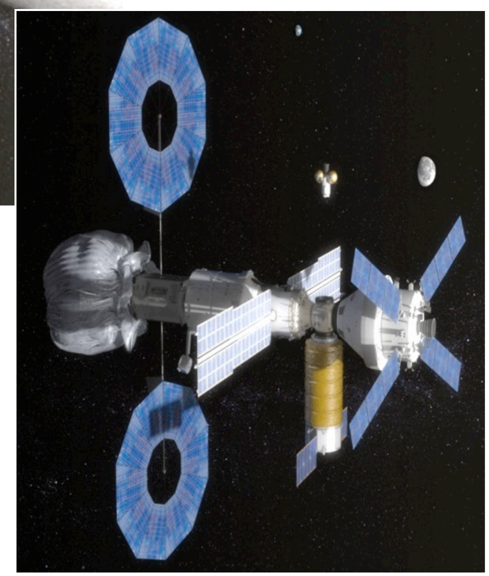
- ISECG working to understand the full scope of opportunities provided by these missions, consistent with common goals/objectives and the 6 principles drive the GER mission scenario
  - Affordability, Exploration value, International partnerships, Capability evolution, Human/Robotic partnership, Robustness
- The purpose of the presentation is to encourage innovative ideas to support ISECG roadmapping work


The Future of Human Space Exploration
NASA's Building Blocks to Mars
Pushing the boundaries in cis-lunar space
Exploring Mars, its moons, and other deep space destinations
U.S. companies provide affordable access to low Earth orbit
Mastering the fundamentals aboard the International Space Station
Traveling beyond low-Earth orbit with the Space Launch System rocket and Orion crew capsule
Missions: 6 to 12 months
Return: hours
Missions: 1 month up to 12 months
Return: days
Missions: 2 to 3 years
Return: months
Earth Reliant
Proving Ground
Earth Independent

Conceptual Cis-Lunar Infrastructure







<u>Possible Characteristics:</u>
High Efficiency Solar Arrays
Solar Electric Propulsion
EVA Capability
Man-tended, increasing duration
Pressurized Resupply
Relocatible In Cis-Lunar Space
Internal/External payload accommodations
Communication Relay

Past Studies

- **Three complementary studies in the recent past have been reviewed:**
  - NASA L2 Study Team (2012)
  - ISS Program (2012)
  - ISECG Exploration Roadmap Working Group (2013)
- **Each study concludes that the presence of crew and their support infrastructure will create opportunities for basic and applied science**
  - Secondary payloads on SLS, Orion
  - Deep Space Hab hosted payloads
  - Crew operated payloads
  - Crew assisted payloads
  - Communication relay capability
- **In particular, space agencies look for ways to build on synergies with human and robotic explorers to create fundamentally new exploration opportunities. Concept examples:**
  - Telepresence
  - Human-assisted sample return

Areas Highlighted

- Applied human research to support beyond LEO exploration
- Technology demonstration
- Solar studies/space weather monitoring
- Earth observation
- Space biology
- Fundamental physics
- Moon/asteroid studies

Summary of Exploration Science & Technology (EST) Opportunities at Earth-Moon L1/L2 Waypoint

Discipline	Total	Types of Opportunities	
Human Research Program	22	• Radiation (EST-HRP-1) & microgravity (EST-HRP-2) • Human physiology in deep space (EST-HRP-3) • Microbial (EST-HRP-4) & cell culture response to deep space (EST-HRP-5) • Crew behavioral health & performance (EST-HRP-6) • Instrumented "Crash dummies" (EST-HRP-7)	• Microbial growth & interaction in hypo-g (EST-HRP-8, -9) • Hypo-g & variable-g effects (e.g., plant growth, systems, countermeasures, EVA, habitation) (EST-HRP-10, -11, -12, -13, -14, -15, -16, -17, -18, -19) • Deep space effects on crew (e.g., muscle & bone strength; exercise; orthostatic tolerance; medications) (EST-HRP-20, -21) • Food stability in GCR (EST-HRP-22)
Space Biology	10	• Plant & seed-to-seed growth in deep space radiation (EST-SB-1, -7) • Stability of microbial communities in deep space (EST-SB-2) • Survival of bacteria & lichens in deep space (EST-SB-3, -4)	• Biological-based life support (EST-SB-5) • Higher life in deep space (EST-SB-6) • Biosentinels: life in deep space (EST-SB-8) • Small specimens in AG (EST-SB-9) • Radiation effects on living systems (EST-SB-10)
Spacecraft Materials & Environments	7	• Materials Experiments @L1/L2 (MEL) (EST-SMS-1) • Debris evaluator (EST-SMS-2) • Solar Wind Field Turbulence (EST-SWS-3)	• Lunar L1/L2 charged particles (EST-SWS-4) • Lunar impact monitoring (EST-SWS-5) • GCR & Avionics (EST-SWS-6) • EM environment (EST-SWS-7)

GCR = Galactic Cosmic Radiation EM = Electromagnetic

Summary of Exploration Science & Technology (EST) Opportunities at Earth-Moon L1/L2 Waypoint

Discipline	Total	Types of Opportunities	
Advanced Exploration Systems (AES)	8	• ECLSS/PLSS (EST-AES-1) • EVA (EST-AES-2) • MMSEV (EST-AES-3) • Radiation Sensors (EST-AES-4)	• Autonomous Mission Ops (EST-AES-5) • Lunar Lander (EST-AES-6) • ISRU (EST-AES-7) • NEA precursors (EST-AES-8)
OCT Technologies	17	• ISRU & lunar sample return (EST-OCT-1, -2, -3) • Active radiation shielding (EST-OCT-4) • Deep Space Comm (optical, atomic clock, DTN) (EST-OCT-5, -6, -7) • Solar Sail Demo (EST-OCT-8) • Universal Space Transponder Demo (EST-OCT-9)	• GCR Avionics test bed (EST-OCT-10) • AEDL Demos (4) (aerocapture, hypersonic inflatable, Mid L/D Entry, TPS Validation) (EST-OCT-11, -12, -13, -14) • Synthetic biology/Gene behavior (EST-OCT-15) • Cryogenic propellant storage & transfer (EST-OCT-16) • Solar Electric Tug to L2 (EST-OCT-17)
Fundamental Physics	3	• Optical Test of Equivalence Principle (EST-FP-1) • Microarcsecond Telescope (EST-FP-2)	• Relativistic Gravity Expt (EST-FP-3)

ECLSS = Environmental Control & Life Support System PLSS = Portable Life Support System EVA = Extravehicular Activity MMSEV=Multi-Mission Space Exploration Vehicle ISRU = In-Situ Resource Utilization NEA = Near-Earth Asteroid DTN = Disruption-Tolerant Networking GCR = Galactic Cosmic Radiation AEDL = Aerocapture, Entry, Descent, & Landing

Conclusion

- **The purpose of the presentation is to encourage innovative ideas to support ISECG road-mapping work**
- **Concepts/ideas can be brought to the attention of any ISECG participating agency**