

# International Space Exploration Coordination Group Science White Paper

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## ◆ ISECG is a non-political agency coordination forum of 14 space agencies

- Website: [www.globalspaceexploration.org](http://www.globalspaceexploration.org)

## ◆ 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
- Enable the multilateral or bilateral partnerships necessary to accomplish complex exploration missions
- Promote interest and engagement in space exploration among citizens and society

## ◆ ISECG operating principles

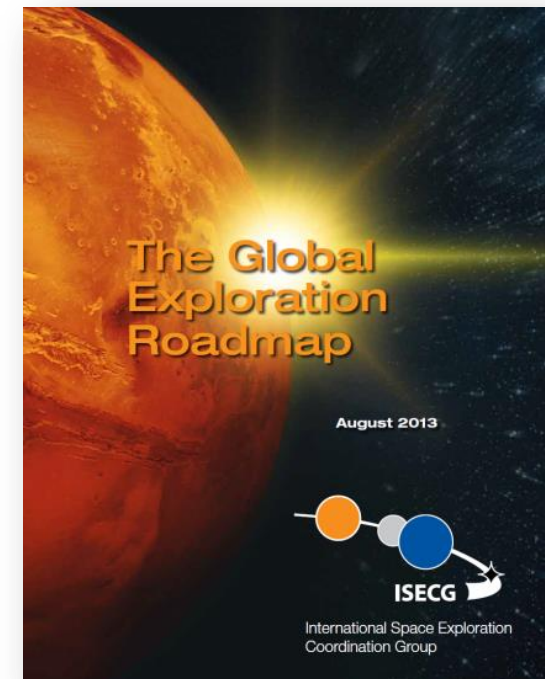
- Open and inclusive
- Flexible and evolutionary
- Effective
- Mutual interest



# About the Global Exploration Roadmap



- ◆ **The GER is a human space exploration roadmap, recognizing the criticality of increasing synergies with robotic missions while demonstrating the unique and important role humans play in realizing societal benefits**
- ◆ **The non-binding document reflects a framework for agency exploration discussions on:**
  - Common goals and objectives
  - Long-range mission scenarios and architectures
  - Opportunities for near-term coordination and cooperation on preparatory activities
- ◆ **Since release of updated GER in August 2013, participating agencies have continued discussions and joint work in several areas which are of mutual interest**
  - Increase understanding of design reference missions for early mission themes
- ◆ **Highlighting opportunities for the science community with a dedicated Science White Paper and within the GER itself is a priority**



# The Global Exploration Roadmap



2013

2020

2030

## International Space Station

General Research and Exploration  
Preparatory Activities

Note: ISS partner agencies have agreed to use the ISS until at least 2020.

Commercial or Government Low-Earth Orbit Platforms and Missions

## Robotic Missions to Discover and Prepare



Mars Sample  
Return and  
Precursor  
Opportunities

## Human Missions Beyond Low-Earth Orbit

Explore Near-Earth Asteroid

Extended Duration Crew  
Missions

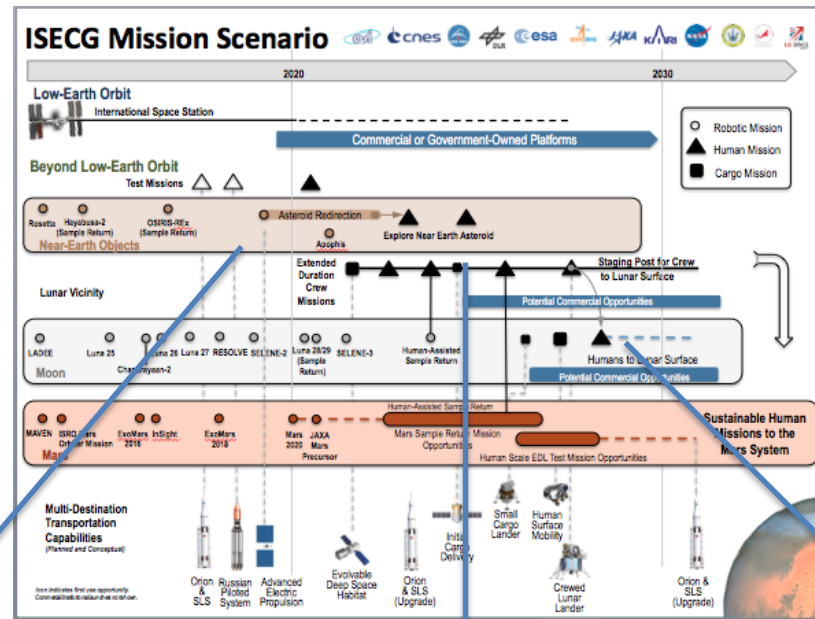
Humans to  
Lunar Surface

Missions to  
Deep Space and  
Mars System

Sustainable  
Human Missions  
to Mars Surface

Multiple Locations  
in the Lunar Vicinity

# GER Mission Themes



### Exploration of a Near Earth Asteroid

Human exploration of an asteroid which has been captured and redirected to lunar vicinity

**Enabling Capabilities**

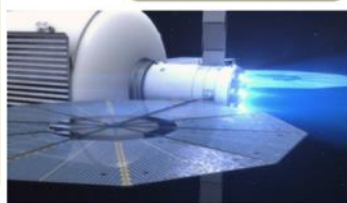
- NASA's SLS and Orion
- Advanced Electric Propulsion
- Extra Vehicular Activity

**Contributions to Mars Mission Readiness**

- Demonstration of the following core capabilities:
  - Space Launch System and Orion
  - 30-50kW Solar Electric Propulsion System
- Spacewalk, rendezvous, proximity operations, docking or grapple, deep space navigation and communications.

**Mission Activities**

- Characterize the composition of the asteroid
- Identify any resources and assess their potential for extraction
- Apply human evaluation capabilities to select samples for return to Earth laboratories
- Demonstrating sample acquisition, caching, storage operations, and crew transfer operations for future human-assisted sample return mission.



### Extended Duration Crew Missions

Visits to an evolvable Deep Space Habitat in the lunar vicinity

**Enabling Capabilities**


- NASA's SLS and Orion
- Russian Piloted System
- Evolvable Deep Space Habitat
- Cargo Delivery

**Contributions to Mars Mission Readiness**

- Demonstrate deep space exploration capabilities such as SLS, Orion, advanced Russian crew transportation capabilities and life support systems, achieving an acceptable level of risk prior to travel to destinations away from the relative safety of Earth's orbit
- Demonstrate autonomous crew operation capability
- Demonstrate operations with reduced supply chain
- Increase experience with complex deep space staging operations
- Advance core technologies and radiation protection strategies for long duration missions
- Demonstrate interactive human and robotic operations analogous to Mars operational concepts
- Gain experience with solar electric propulsion used on a crewed spacecraft

**Mission Activities**

- Advancing deep space human space flight operations and techniques, including staging operations
- Conducting high priority science benefiting from human presence, including human-assisted lunar sample return
- Testing technologies and subsystems benefiting from the deep space environment
- Characterizing human health and performance in a deep space environment



### Humans to the Lunar Surface

Using evolvable Deep Space Habitat as staging post

**Enabling Capabilities**


- NASA's SLS and Orion
- Russian Piloted System
- Evolvable Deep Space Habitat
- Lunar Lander
- Cargo Delivery

**Contributions to Mars Mission Readiness**

- Demonstrate staging operations with an Earth-return vehicle
- Demonstrate extended crew mobility and habitation systems
- Demonstrate advanced power systems
- Characterize human health and performance, combining deep space and partial gravity environment exposure
- Demonstrate operations concepts and enhanced crew autonomy for surface exploration
- Potentially provide the opportunity for advancing concepts related to the use of local resources

**Mission Activities**

- Test advanced surface power technologies
- Address high priority objectives of the science community which benefit from human surface presence
- Characterize human health and performance in a partial gravity environment
- Demonstrate long distance mobility concepts
- Explore concepts for human-robotic partnership in planetary surface exploration
- Utilize precision landing technologies demonstrated on robotic missions
- Explore landing sites of interest for extended durations





# GER Destination Themes Reference Missions



## ◆ Cislunar Deep Space Habitat

- Crew of four
- Initially annual missions lasting 30 days
- Increase both duration & frequency later in the decade.

## ◆ Near Earth Asteroid in Cislunar space

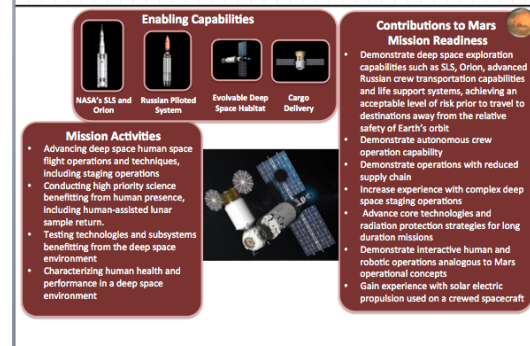
- Boulder collected using SEP-based s/c
- Crew of two visits asteroid boulder in lunar DRO

## ◆ Lunar Surface

- Five 28-day missions with a crew of four
- One mission per year
- Reuse pressurized rover for each mission
- Rover is moved to next landing site in between crewed visits

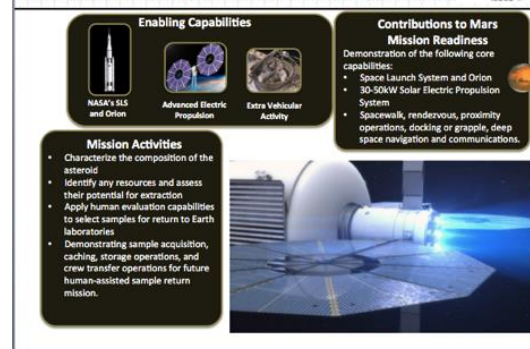
### Extended Duration Crew Missions

Visits to an evolvable Deep Space Habitat in the lunar vicinity



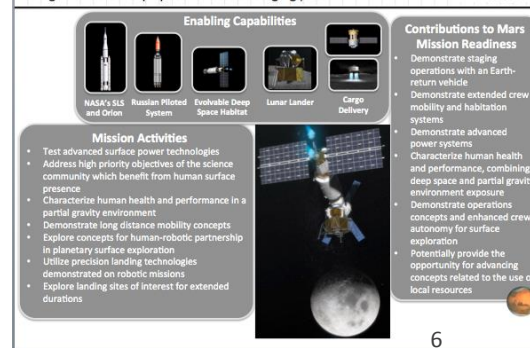
### Exploration of a Near Earth Asteroid

Human exploration of an asteroid which has been captured and redirected to lunar vicinity



### Humans to the Lunar Surface

Using evolvable Deep Space Habitat as staging post



- ◆ **ISECG agencies acknowledge science communities as major stakeholders and scientific knowledge gain as important benefit of exploration activities.**
  - Scientists in general support GER and want to engage in the discussion.
- ◆ **Several agencies agreed in winter 2014/15 to facilitate interaction**
  - ASI, CNES, CNSA, CSA, DLR, ESA, JAXA, NASA, SSAU, UKSA (+ESF, SSERVI)
- ◆ **Objectives**
  - Coordinate interaction with the science communities on exploration planning and activities as required for the generation of ISECG products
  - Advance the development of a Science White Paper for the articulation of science opportunities in the GER in conjunction with the science communities

## ◆ Describe an international view of the science that could be enabled by human missions in the GER

- Engage the scientific communities in identifying these opportunities
- Target the same stakeholder community as the GER
- Focus on human missions and human/robotic concepts
- Incorporate activities that have feed-forward benefits to Mars exploration

## ◆ Incorporate interdisciplinary scientific topics that

- Encompass all relevant science communities and disciplines: planetary science, space science, life sciences, astrobiology, astronomy, physical sciences, etc.
- Span all destinations (LEO, cis-lunar space, Moon, asteroids, Mars)
- Incorporate input from the international science communities



# Science Advisory Group Membership



## ◆ Co-chairs:

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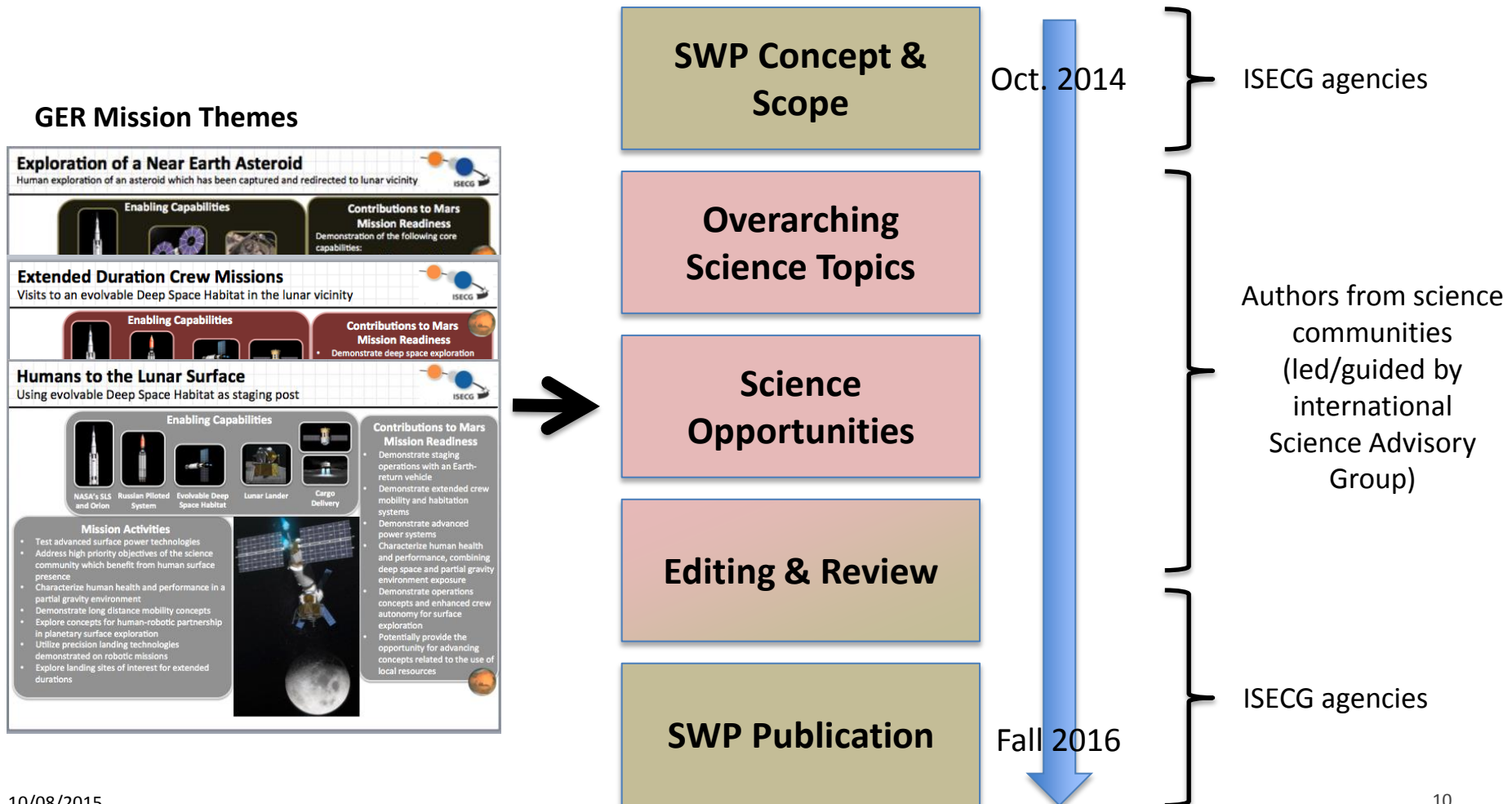
## ◆ Executive Secretary

- Greg Schmidt (SSERVI, USA)

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# Science White Paper – Development Process

- ◆ Apply a transparent, interactive process that stimulates discussion on science opportunities in preparation of GER3



## *Table of Contents (as of 10/2015) – total ~20 pages*

### ◆ **Scope & Purpose**

- Broad interaction between science communities and ISECG agencies

### ◆ **Exec. Summary (2)**

### ◆ **1. Linkage to GER (2)**

- GER approach
  - Connect to Goals & Objectives
  - Long-term horizon goal (Mars)
  - Near-term destination focus
- Human-robotic partnership / Value of human presence

### ◆ **2. Science Topics (2)**

- Introduce topics
- Spans all destinations
- Incl. many scientific disciplines

### ◆ **3. Cislunar Deep Space Habitat (4)**

### ◆ **4. NEA in Cislunar Space (4)**

### ◆ **5. Lunar Surface (4)**

- Each chapter 3-5 to highlight
  - Short summary of the mission theme including DRMs
  - Scientific opportunities structured by science topics
  - Science findings

### ◆ **Conclusion (1)**

### ◆ **References (1)**

- E.g. GER2, COSPAR PEX, Decadal Surveys, MEPAG report, ILEWG, others, ...

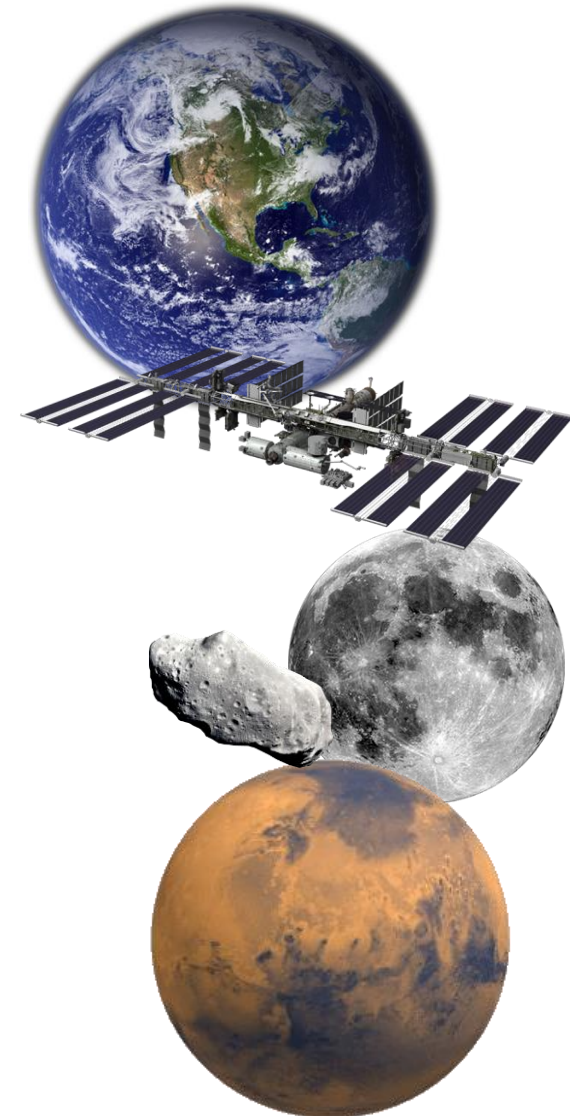
- ◆ **Each destination chapter has 2 SAG co-leads**
  - Science Opportunities of a Cislunar Deep Space Habitat
    - » Co-Leads: Giles Clement & Gordon Osinski
  - Science Opportunities at a NEA in Cislunar space
    - » Co-Leads: Masaki Fujimoto & Tim McCoy
  - Science Opportunities on the Lunar Surface
    - » Co-Leads: Ian Crawford & Clive Neal
  - Other SAG members may choose to support one or more chapters
  
- ◆ **Chapter co-leads solicit input from subject experts in the community**
  
- ◆ **Additional community 2-way interaction and feedback by presenting initial science ideas at major meetings**
  - European Lunar Symposium, Small Bodies Assessment Group (SBAG), Lunar Exploration Analysis Group (LEAG), ESA Moon 2020-2030 Workshop, Exploration Science Forum
  - SWP COSPAR/SWG workshop planned for February 2015 in Paris

## ◆ Living and working in space

- Overarching questions:
  - How do we become a spacefaring species?
  - How do we sustain life outside Earth?
- Disciplines involved, e.g.
  - Human physiology, life sciences and life support
  - Prospecting and utilising local resources

## ◆ Our place in the universe

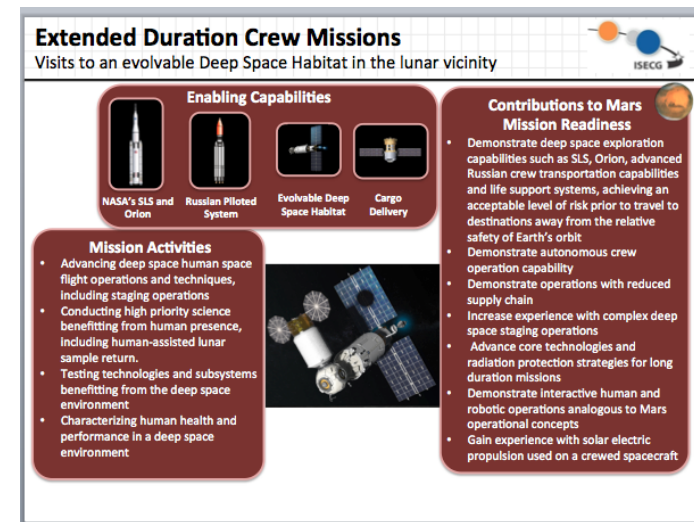
- Overarching question:
  - How do terrestrial planets form and evolve?
  - How does life evolve in the planetary environment?
- Disciplines involved, e.g.
  - Astronomy
  - Planetary geology
  - Solar physics, space physics
  - Astrobiology (understanding the building blocks of life)



# Science Enabled by Humans to a Cislunar Habitat



- ◆ **Human-assisted lunar sample return**
  - Increased return through more and improved selection of lunar samples
- ◆ **Construct and/or service large space telescopes**
- ◆ **Understand combined effects of radiation/reduced-gravity/isolation on humans**
- ◆ **Monitor Earth's climate to help design exoplanet observing instrument**
- ◆ **Facilitate access to challenging regions by low-latency telerobotics (e.g. permanently shadowed crater floors)**
  - Telerobotics experience useful for Mars exploration





## ◆ Sample return provides key science

- Humans permit careful selection of samples for high sample quality
- Larger sample return mass compared to robotic missions
- Increase the value of the current meteorite collections
- Provide an archive of samples for analyses that must be done on Earth

## ◆ Increased surface access

- Multiple drilling sites
- Exposure ages at different depths

## ◆ Instrument deployment

- Placing instruments on the surface enabled by humans
- Long-term instrument deployment



# Science Enabled by Humans to the Lunar Surface



## ◆ Sample return provides key science

- Humans best at identifying scientifically important samples
- Improve our understanding of impact cratering
- Provide insight into the evolution of the terrestrial planets
- Study the history of the Sun

## ◆ Understand lunar volatiles

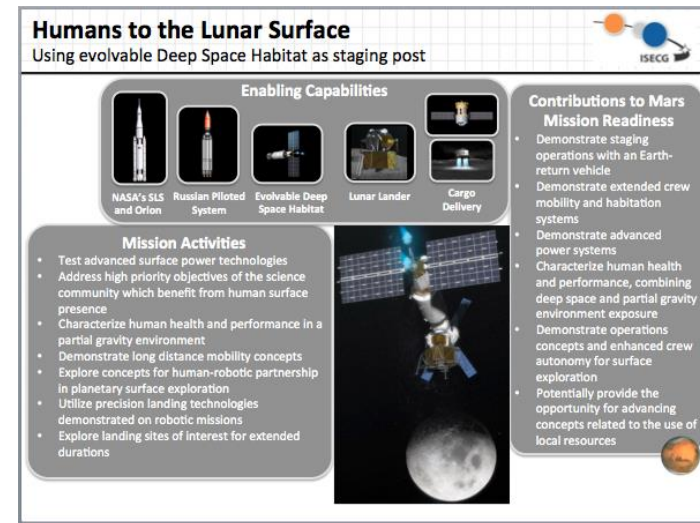
- Record of the flux and composition of volatiles
- Help answer astrobiological questions
- Install and maintain resource utilization equipment (i.e. generate water)

## ◆ Emplacement of delicate or large astronomical instruments

## ◆ Understand the physiological effects of the lunar environment on human health, contributing to medical benefits on Earth

## ◆ Understand how plants and other non-human forms of life adapt to, or can be protected from, the conditions on hostile planetary surfaces

## ◆ Feed-forward activities (using the Moon as a gateway to the Solar System)



*SSERVI is a virtual institute established to advance basic and applied lunar and planetary science research and to advance human exploration of the solar system through scientific discovery.*

SSERVI ***builds bridges*** between:

- SMD and HEOMD
- Destinations (comparative planetology)
- Teams (rapid inter-team collaborations)
- Teams and the wider scientific community
- Disciplines
- International and domestic partners
- Government and commercial partners
- Generations of researchers

