National Aeronautics and Space Administration

HEOMD Update

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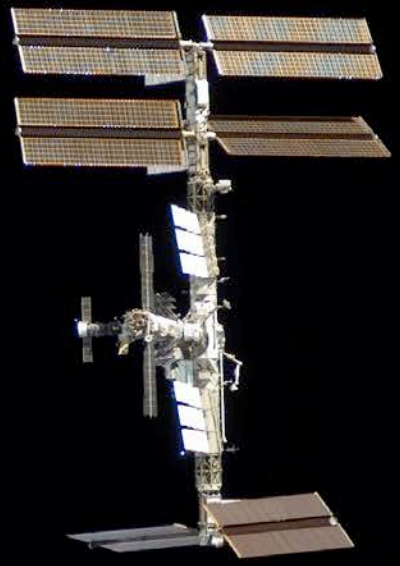
Earth Reliant

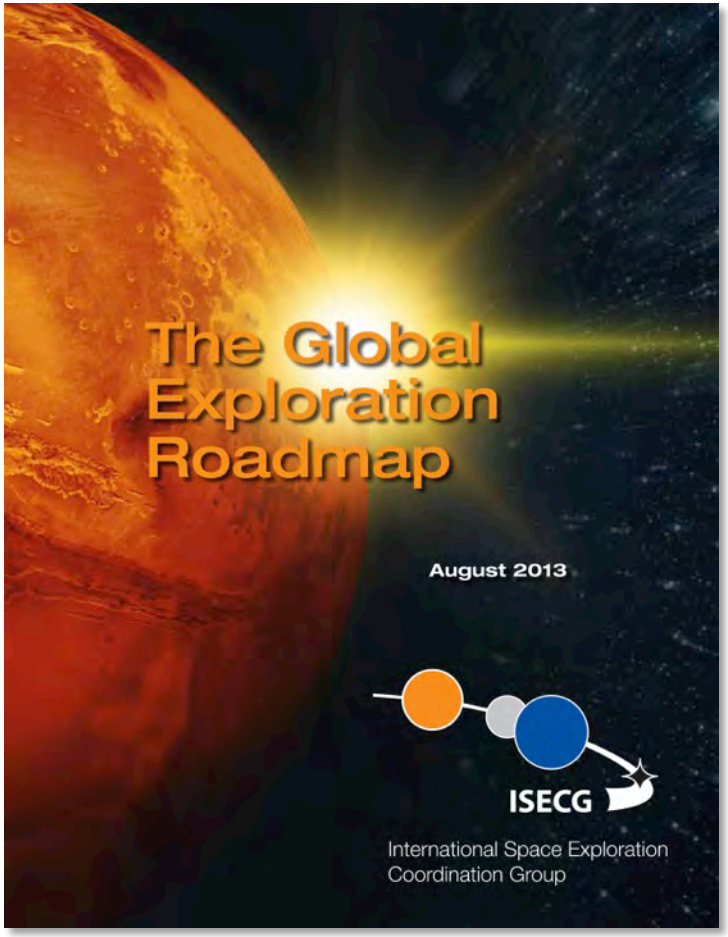


Strategic Principles for Sustainable Exploration

- Implementable in the ***near-term with the buying power of current budgets*** and in the longer term with budgets commensurate with economic growth*;*
- ***Exploration enables science*** **and science enables exploration***, leveraging robotic expertise for human exploration of the solar system*
- Application of ***high Technology Readiness Level*** (TRL) technologies for near term missions, while focusing sustained investments on ***technologies and capabilities*** to address challenges of future missions;
- ***Near-term mission opportunities*** with a defined cadence of compelling and integrated human and robotic missions providing for an incremental buildup of capabilities for more complex missions over time;
- Opportunities for ***U.S. commercial business*** to further enhance the experience and business base;
- ***Resilient architecture featuring multi-use, evolvable space infrastructure*****,** minimizing unique major developments, with each mission leaving something behind to support subsequent missions; and
- Substantial ***new international and commercial partnerships***, leveraging the current International Space Station partnership while building new cooperative ventures.

Global Exploration Roadmap:
Common Goals and Objectives

- **Develop Exploration Technologies and Capabilities**
- **Enhance Earth Safety**
- **Extend Human Presence**
- **Perform Science to Enable Human Exploration**
- **Perform Space, Earth, and Applied Science**
- **Search for Life**
- **Stimulate Economic Expansion**

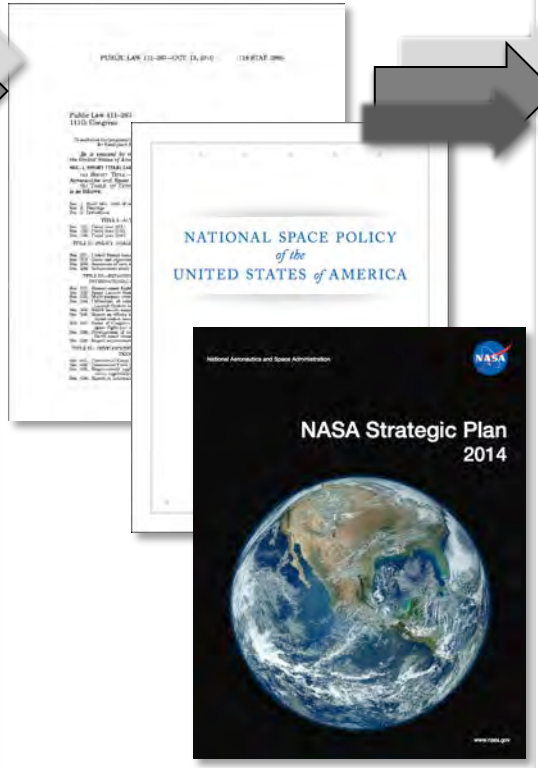


Evolvable Mars Campaign – Study Activity

Body of Previous Architectures, Design Reference Missions, Emerging Studies and New Discoveries

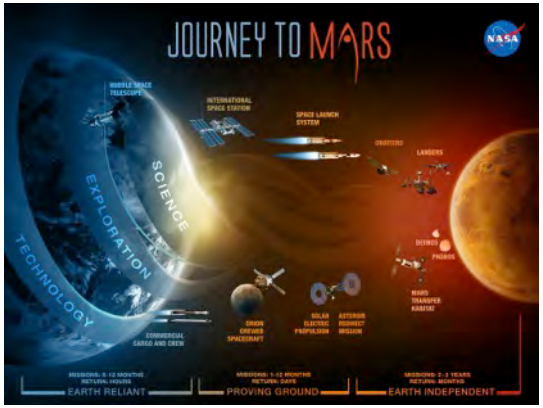
- Internal NASA and other Government
- International Partners
- Commercial and Industrial
- Academic
- Technology developments
- Science discoveries

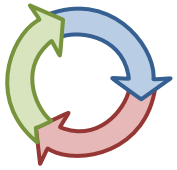
2010 Authorization Act, National Space Policy, NASA Strategic Plan



- Establish capacity for people to live and work in space indefinitely
- Expand human presence into the solar system and to the surface of Mars

Evolvable Mars Campaign



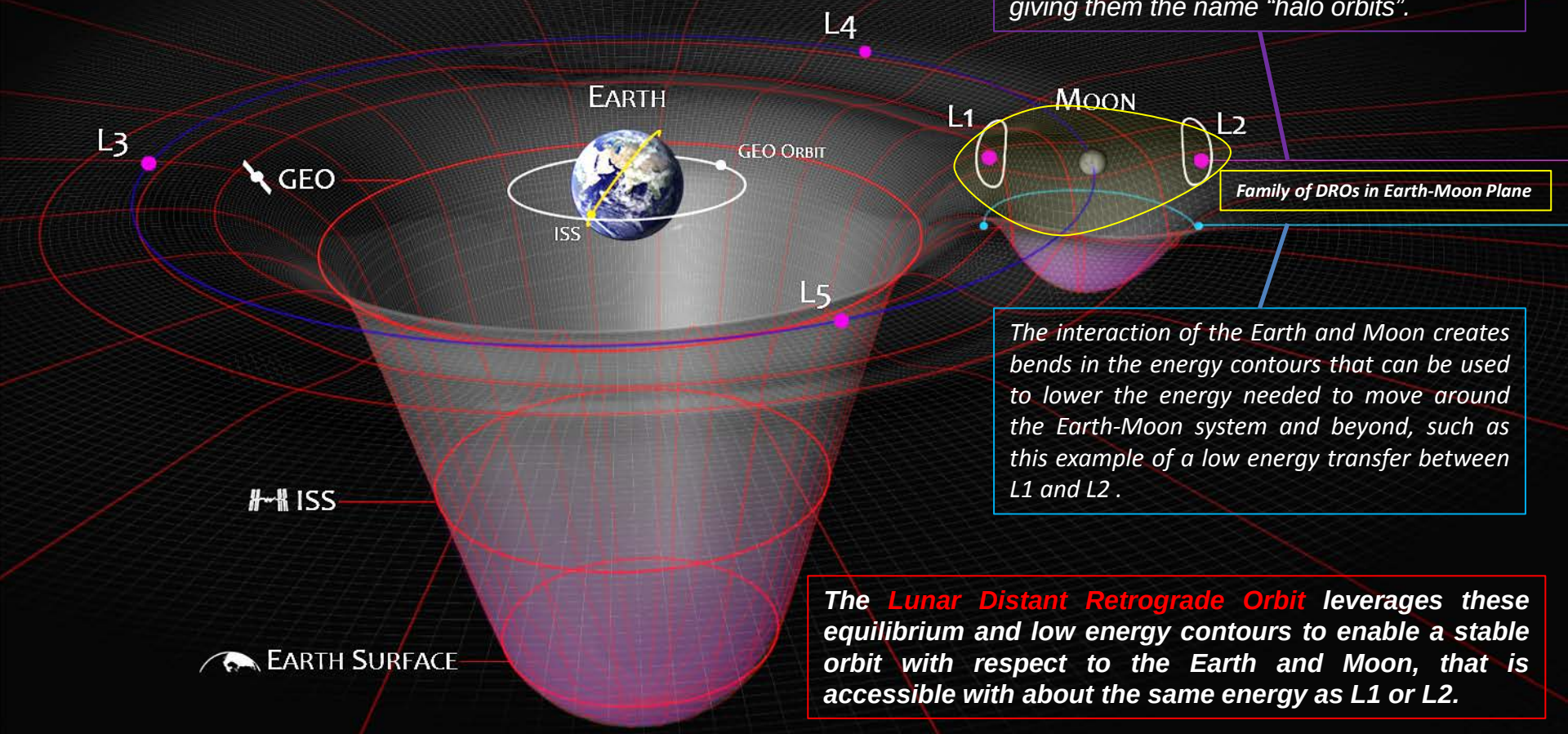


- An ongoing series of architectural trade analyses to define the capabilities and elements needed for a sustainable human presence on Mars
- Builds off of previous studies and ongoing assessments
- Provides clear linkage of current investments (SLS, Orion, etc.) to future capability needs

Cis-Lunar Space:
How the Earth and the Moon Interact

The contours on the plot depict energy states in the Earth-Moon System and the relative difficulty of moving from one place to another.

A spacecraft at L2 is actually orbiting Earth at a distance just past the Moon, however if you look at it from the Moon, the orbit will look like an ellipse around a point in space giving them the name "halo orbits".



The interaction of the Earth and Moon creates bends in the energy contours that can be used to lower the energy needed to move around the Earth-Moon system and beyond, such as this example of a low energy transfer between L1 and L2 .

The Lunar Distant Retrograde Orbit leverages these equilibrium and low energy contours to enable a stable orbit with respect to the Earth and Moon, that is accessible with about the same energy as L1 or L2.


Proving Ground

PROVING GROUND OBJECTIVES

Enabling Human Missions to Mars

TRANSPORTATION

- **Heavy Launch Capability**: beyond low-Earth orbit launch capabilities for crew, co-manifested payloads, large cargo
- **Crew**: transport at least four crew to cislunar space
- **In-Space Propulsion**: send crew and cargo on Mars-class mission durations and distances

WORKING IN SPACE

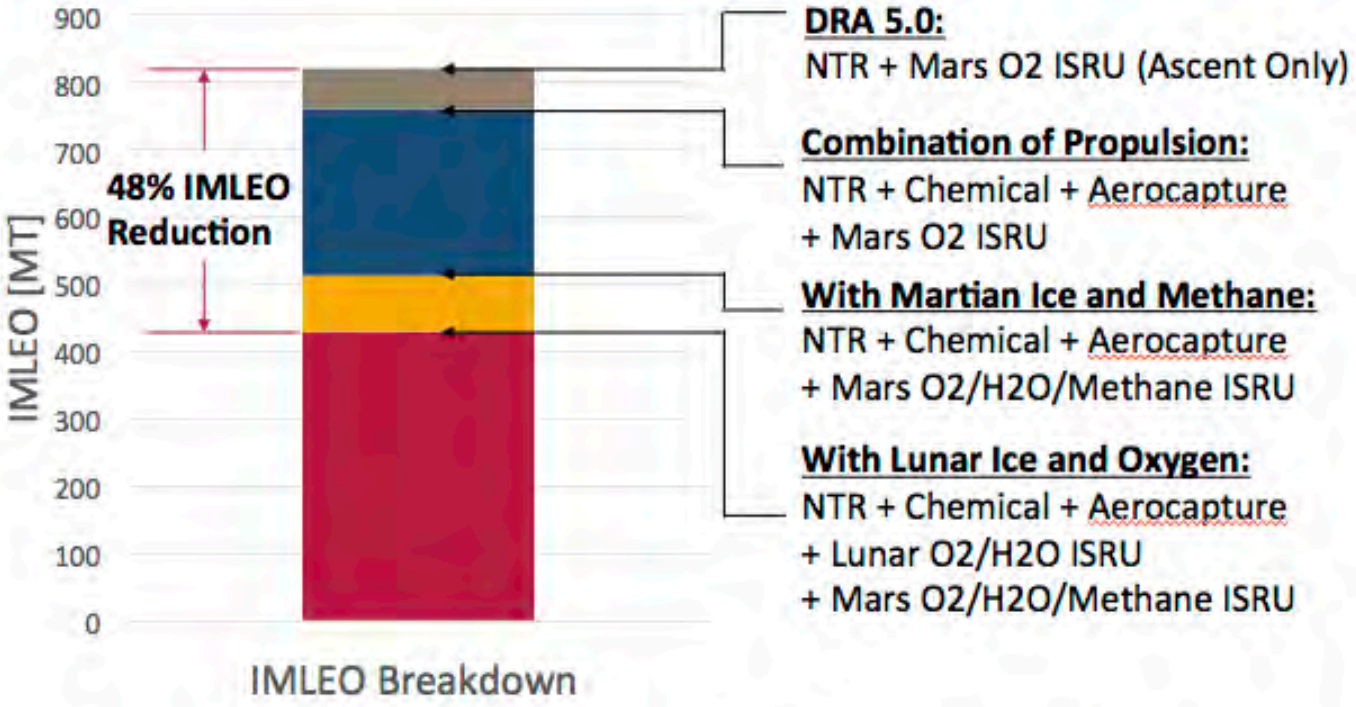
- **ISRU**: Understand the nature and distribution of volatiles and extraction techniques and decide on their potential use in human exploration architecture.
- **Deep-space operations capabilities**: EVA, Staging, Logistics, Human-robotic integration, Autonomous operations
- **Science**: enable science community objectives

STAYING HEALTHY

- **Deep-Space Habitation**: beyond low-Earth orbit habitation systems sufficient to support at least four crew on Mars-class mission durations and dormancy
- **Crew Health**: Validate crew health, performance and mitigation protocols for Mars-class missions

Volatiles: Why We care!

Dynamic GMCNF 1: Human Mars Exploration Initial Mass to LEO (IMLEO) Improvement



- **Importance of combination of propulsion system and ISRU system**

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Schreiner, et al., Development of a Molten Regolith Electrolysis Reactor Model for Lunar In-Situ Resource Utilization. 8th Symposium on Space Resource Utilization

Questions?