National Aeronautics and Space Administration

Pioneering Space Through an Evolvable Mars Campaign

Pioneering Space - Goals

"Fifty years after the creation of NASA, our goal is no longer just a destination to reach. ***Our goal is the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time, ultimately in ways that are more sustainable and even indefinite.*** *And in fulfilling this task, we will not only extend humanity's reach in space -- we will strengthen America's leadership here on Earth."*

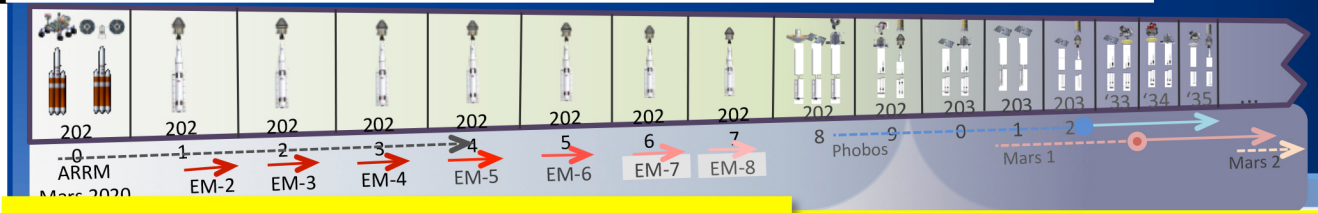
- President Obama - April, 2010

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.

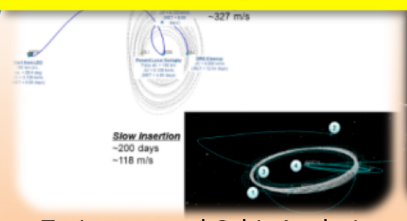
EMC Assessment Capability Requires Breadth and Depth……

Campaign Analysis, Timelines and Decision Needs



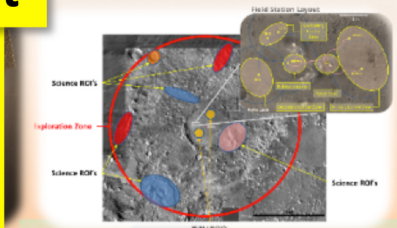
Congress
NAC
Int'l Partners
Industry
Public

Mission Operations Development

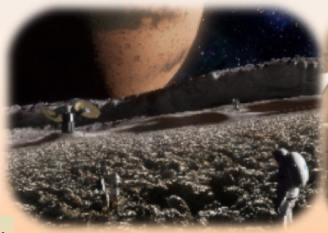


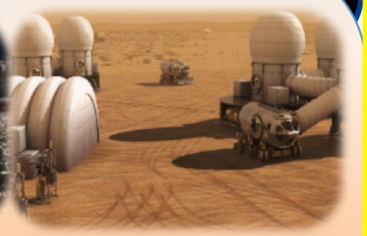
Trajectory and Orbit Analysis

Proving Ground Ops



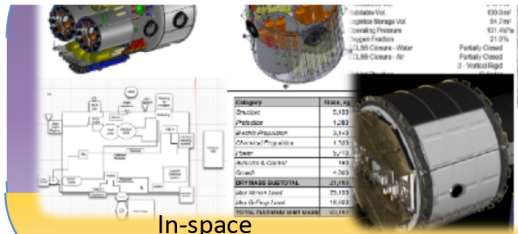
Landing Site Selection and Layout



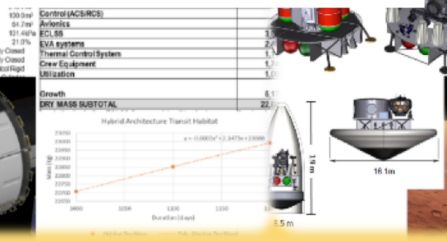


Destination Operations

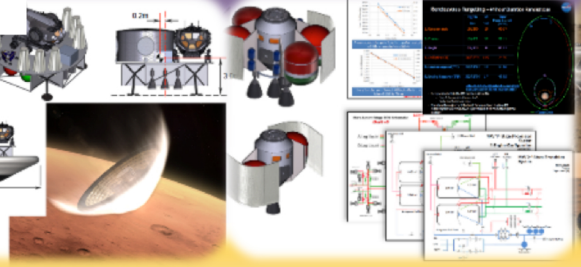
Element Conceptualization and Design



In-space Transportation Systems



Habitat Sizing



Lander

Mars Ascent Vehicle Design

Destination Systems

Capability Needs Analysis

Capability Gap Analysis and Roadmap Development

Pioneering Space Challenges

formance Parameter Definition

STMD
ISS
ESD
AES

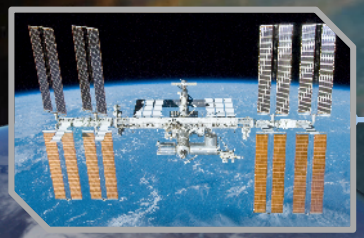
Strategic Planning

NASA Technology Roadmaps & Strategic Investment Plan

EARTH RELIANT: ISS

International Space Station: **Can humans live & operate independently for ~1000 days in micro-G?**

- Long-duration, Zero-g human factors research platform
- Highly reliable life support, advanced logistics, low maintenance systems
- Environmental monitoring
- Supportability & maintenance concepts



EARTH INDEPENDENT:

PHOBOS/DEIMOS/MARS ORBIT

Can humans travel to Mars orbit and safely return to Earth?

- Deep Space Proving Ground plus:
  - High power SEP
  - ~1000 day deep space habitat(s)
  - Deep space countermeasures
  - Mars vicinity propulsion

MARS SURFACE

Can humans break the supply train with Earth to enable long-term presence?

- Phobos/Deimos plus:
  - Mars entry & landing systems
  - Partial-gravity countermeasures
  - Long duration surface Systems (ISRU, fission power)

Continued Leveraging of Commercial & International Partnerships

PROVING GROUND: CIS-LUNAR & DEEP SPACE

Bridging from ISS, can human class systems operate in a deep space environment in a crew tended mode for long durations?

- Distant Retrograde Orbit:
- Heavy lift launch (SLS), Orion
- High-power In-Space Propulsion
- Initial beyond-Earth orbit habitation- Crew support for increasing duration
- Advanced EVA (Suit, Portable Life Support System)
- Deep space long duration systems and operations testing
- Aggregation of Mars Mission Vehicles

PROVING GROUND OBJECTIVES

Enabling Human Missions to Mars

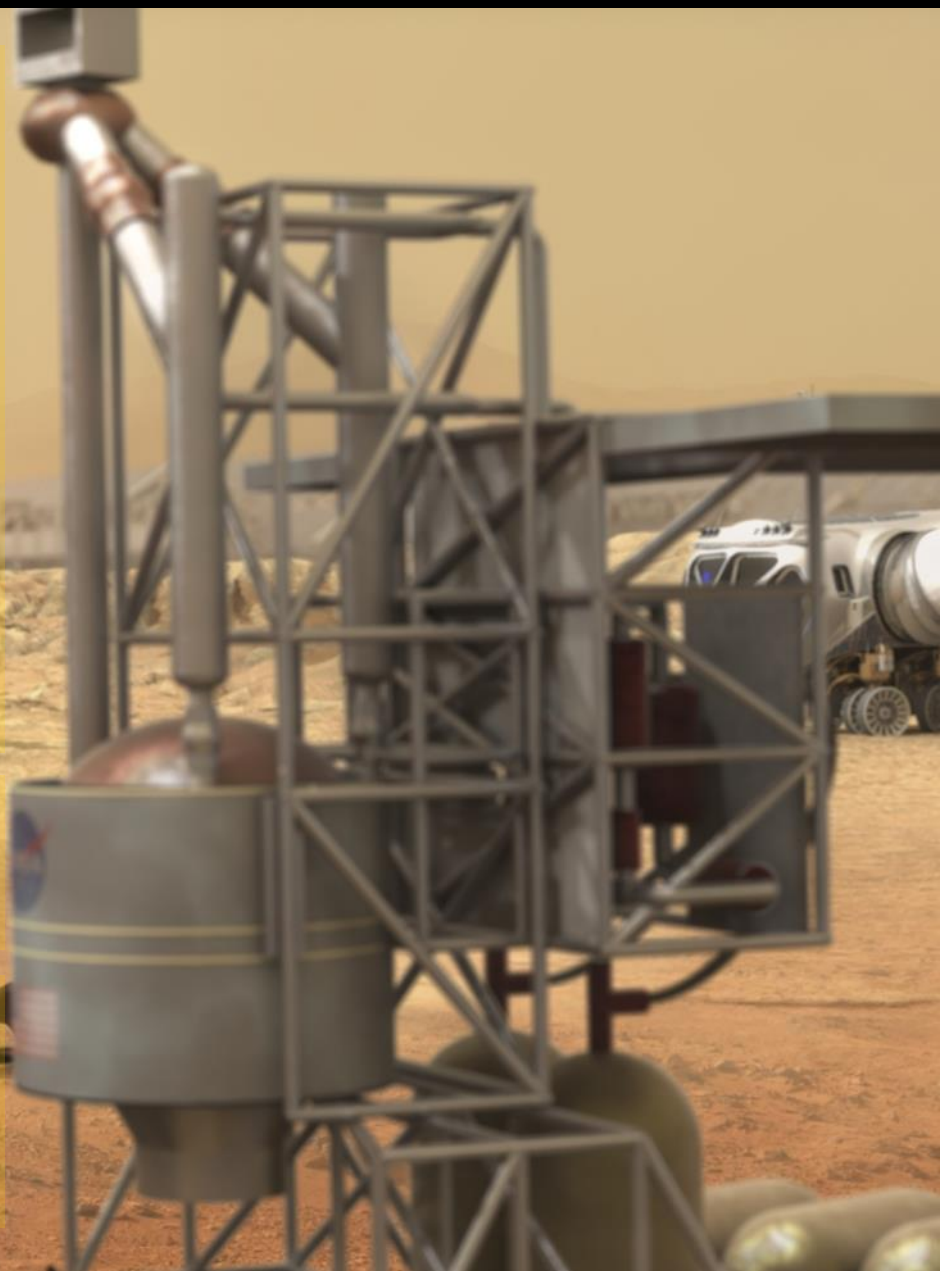
VALIDATE through analysis and flights

- Advanced Solar Electric Propulsion (SEP) systems to move large masses in interplanetary space
- Lunar Distant Retrograde Orbit as a staging point for large cargo masses en route to Mars
- SLS and Orion in deep space
- Long duration, deep space habitation systems
- Crew health and performance in a deep space environment
- In-Situ Resource Utilization in micro-g
- Operations with reduced logistics capability
- Structures and mechanisms

- **CONDUCT**
- EVAs in deep space with sample handling in micro-g
- Integrated human and robotic mission operations
- Capability Pathfinder and Strategic Knowledge Gap missions

Mars Surface Mission: Becoming Earth Independent

- **Initial Human Mission Include Tech Demos for:**
  - **ISRU (Water, other resources extracted from regolith)**
  - **Building infrastructure**
  - **Manufacturing systems in-situ**
  - **Growing food**
  - **Human/Social "Engineering"**
- **Humans Perform Mars Science**
- **Humans return and reuse infrastructure at a single Mars site.**

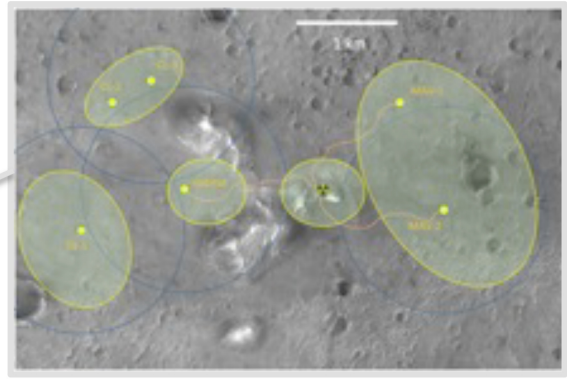


Architecture Approach within the EMC – Mars Surface

Emplacement

(Threshold Goal) 12-18 month stay enabled Earth independent for that time period

1



Mars Surface Field Station

Mars Surface Proving Ground

2

(Ultimate Goal) Indefinite stay enabled Earth independent

Utilization

A <u>two-major-milestone</u>, <u>three-phase</u> surface architecture approach is used to achieve the Ultimate Goal (i.e., Earth Independence), and would include a "Mars Surface Proving Ground" during Phase 2

Phase 1 | **Phase 2** | **Phase 3**

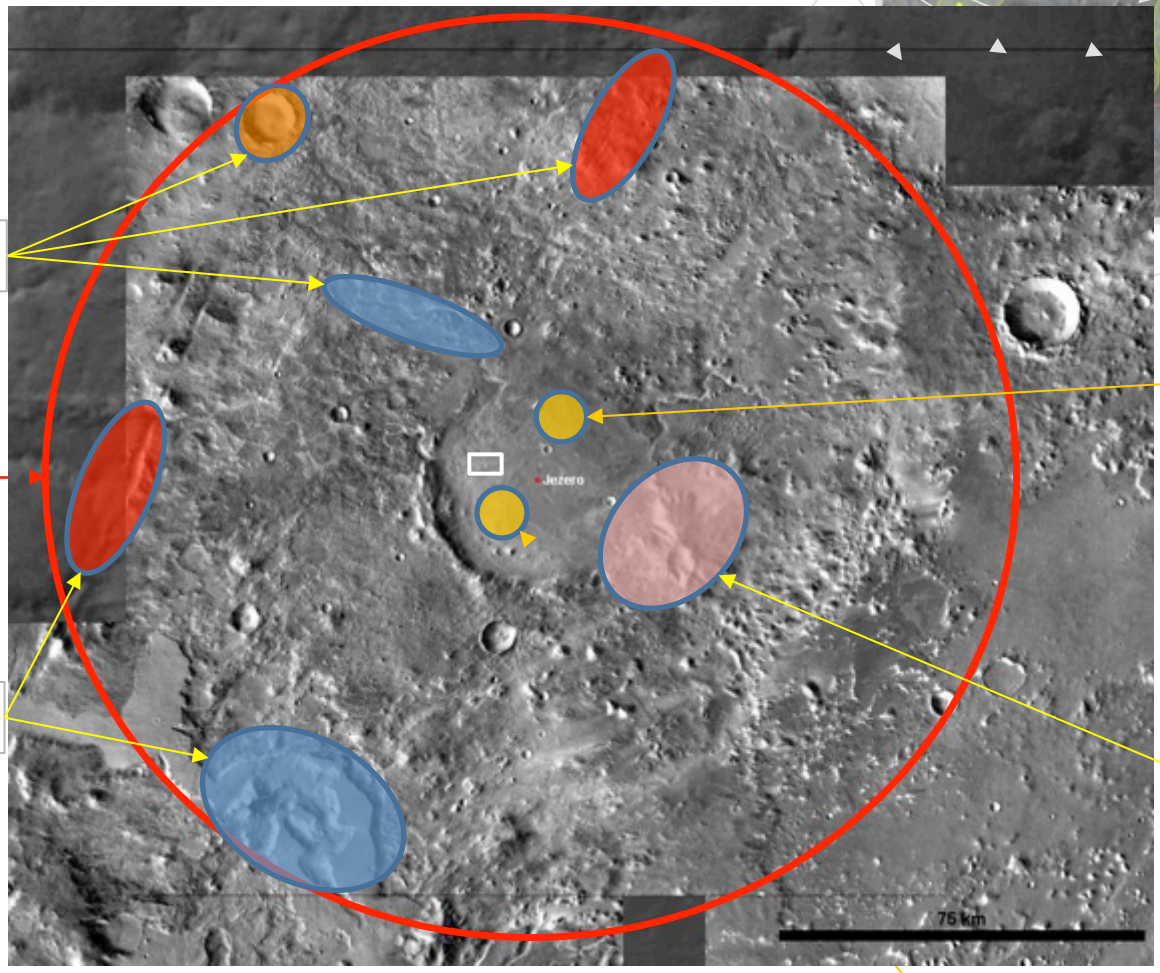
Bridging the Gap: A Mars Surface Field Station

- **One well-established concept that is used to handle "unknowns" is the *field station* or *experiment station***

  - **Field Stations bring the basic tools of research—from electricity to communication to community—to the places where research needs to be done**
    - They provide access to the environment.
    - They provide logistical support for a wide range of activities including individual research projects; networking of research on larger scales; science, technology, engineering, and mathematics (STEM) training; and public outreach.
    - Through time they become environmental and operational models in which the steady accumulation of knowledge becomes a platform for future research.
  - ***Field Stations* create a bridge between natural environments and [Earth-based] research laboratories.** *Research laboratories* offer considerable power to conduct analyses in a predictable environment and to infer cause and effect from manipulative experiments, but they may miss factors that turn out to be critical in a natural environment. Field studies can encompass the full range of relevant interactions and scales, but they are not as tightly controlled. By offering access to both laboratories and field environments, Field Stations combine the best of both worlds.

Note: Adapted from Billick, I., et.al. 2013. Field Stations and Marine Laboratories of the Future: A Strategic Vision. National Association of Marine Laboratories and Organization of Biological Field Stations.

Example Mars Surface Field Station and Surrounding Regions of Interest (ROI's)



Summary: EMC Major Results to Date

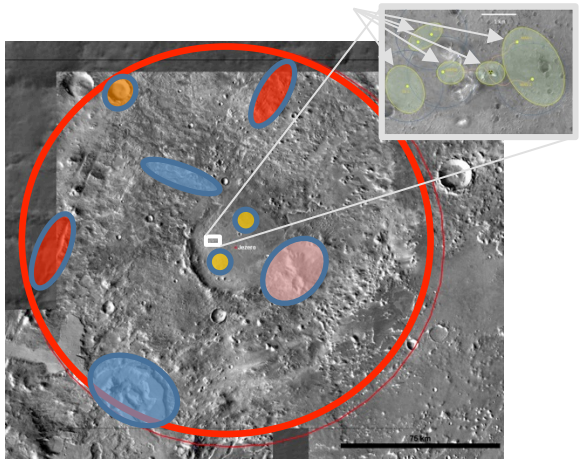
- **Regardless of Mars vicinity destination, common capability developments are required**
  - Mars vicinity missions selection not required before 2020
- **ISS provides critical Mars mission capability development platform**
- **Lunar DRO is efficient for aggregation and potential refurbishment due to stable environment**
  - Use of gravity assist trajectories enable use of DRO
- **Orion Block 1 is sufficient for Mars architectures with reusable habitats**
- **SLS co-manifested cargo capability increases value of crewed missions and improves cadence**
- **Deep-space habitation serves as initial starting point regardless of implementation or destination**
- **ARV derived SEP vehicle can serve as an effective tool for human Mars missions**
  - Reusability can enable follow-on use in cis-lunar space
  - Refuelability under study to enable Mars system follow-on use
  - Current SEP evolvability enables Mars system human missions
- **Mars Phobos /Deimos as initial Mars vicinity mission spread out development costs and meets policy objectives of Mars vicinity in 2030's**
  - Common crew transportation between Mars Phobos / Deimos and Mars Surface staging
  - Phobos provides 35% reduction of radiation exposure compared to other Mars orbit missions
  - Provides ability to address both exploration and science objectives
  - ARM returned asteroid at Lunar DRO serves as good location for testing Mars moon's operations

Summary: EMC Mars Surface Operations Options

- **Integrate and incorporate inputs from this workshop into overall EMC Mars Surface Operations options into FY16 tasks**

- **Mars Exploration Zones (EZ)**
  - Review results of the workshop
  - Revise EMC list of EZ engineering constraints & considerations to use in deeper EZ analyses, based on examples from the workshop
  - Identify data needed to analyze & select a Mars EZ

- **EMC to use these reports for deeper analysis**
  - MEPAG HSO-SAG final report
  - ICEWG final report



Pioneering Next Steps in Space Exploration

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NASA Releases Plan Outlining Next Steps in the Journey to Mars

NASA is leading our nation and the world on a journey to Mars, and Thursday the agency released a detailed outline of that plan in its report, "NASA's Journey to Mars: Pioneering Next Steps in Space Exploration."

"NASA is closer to sending American astronauts to Mars than at any point in our history," said NASA Administrator Charles Bolden. "Today, we are publishing additional details about our journey to Mars plan and how we are aligning all of our work in support of this goal. In the coming weeks, I look forward to continuing to discuss the details of our plan with members of Congress, as well as our commercial and our international and partners, many of whom will be attending the International Astronautical Congress next week."

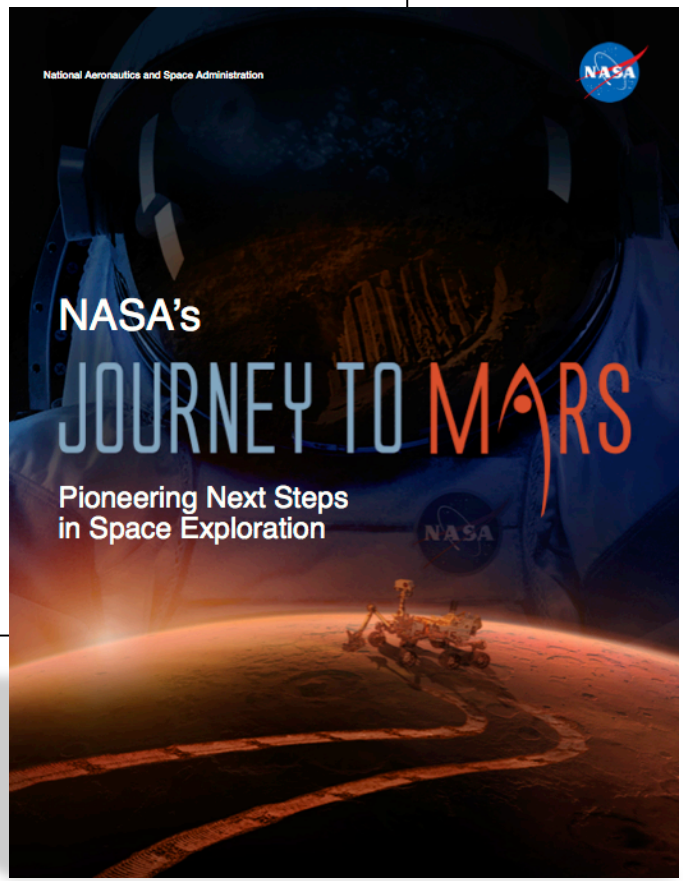
The plan can be read online at:

http://go.nasa.gov/1VHDXxg

The journey to Mars crosses three thresholds, each with increasing challenges as humans move farther from Earth. NASA is managing these challenges by developing and demonstrating capabilities in incremental steps:

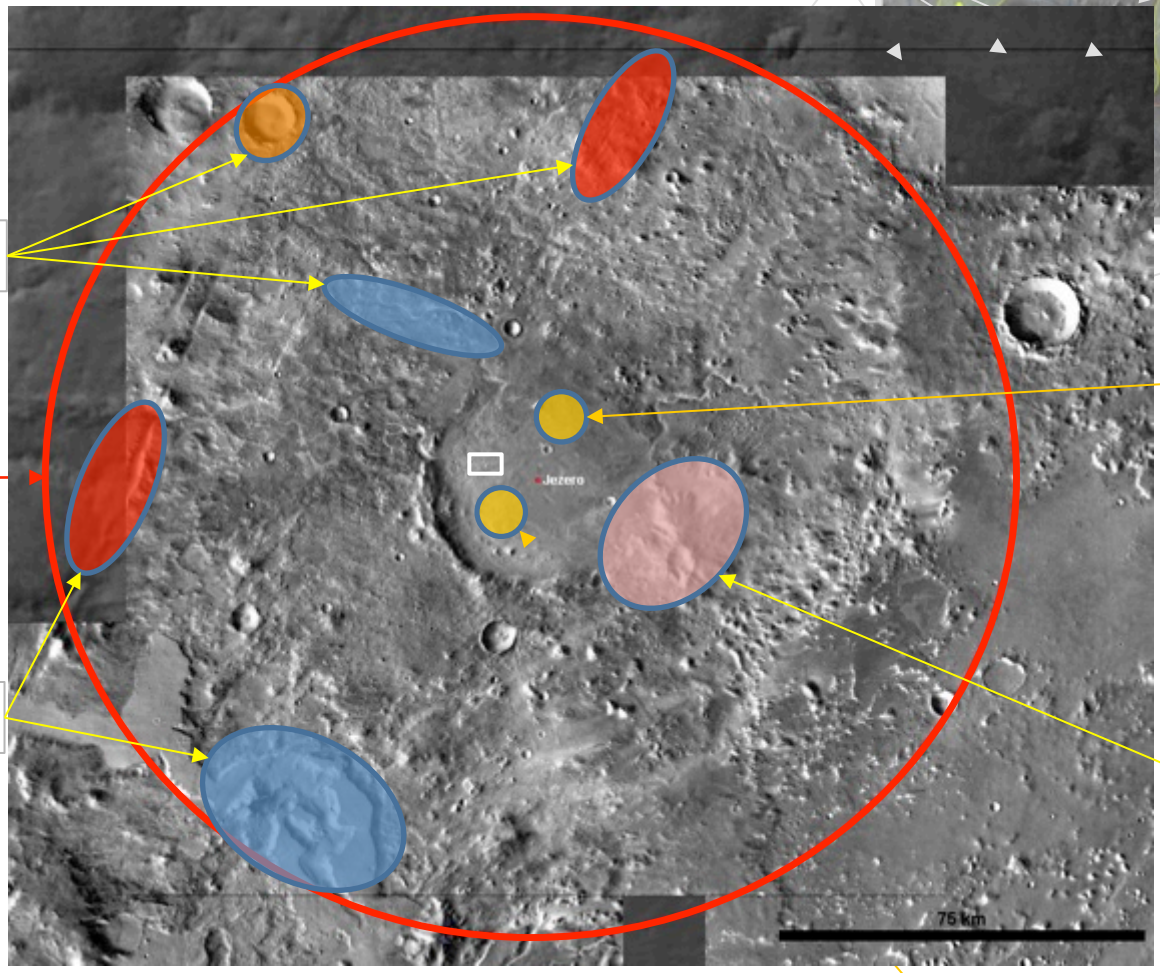
Earth Reliant exploration is focused on research aboard the International Space Station. From this world-class microgravity laboratory, we are testing technologies and advancing human health and performance research that will enable deep space, long duration missions.

In the **Proving Ground**, NASA will learn to conduct complex operations in a deep space environment that allows crews to return to Earth in a matter of days. Primarily operating in cislunar space—the volume of space around the moon featuring multiple possible stable staging orbits for future deep space missions—NASA will advance and validate capabilities required for humans to live and work at



http://www.nasa.gov/press-release/nasa-releases-plan-outlining-next-steps-in-the-journey-to-mars

Example Exploration Zone with Mars Surface Field Station and Surrounding Regions of Interest (ROI's)



Example Exploration Zone with Mars Surface Field Station and Surrounding Regions of Interest (ROI's)