Asteroid Redirect Crewed Mission
Building Human Exploration Capabilities

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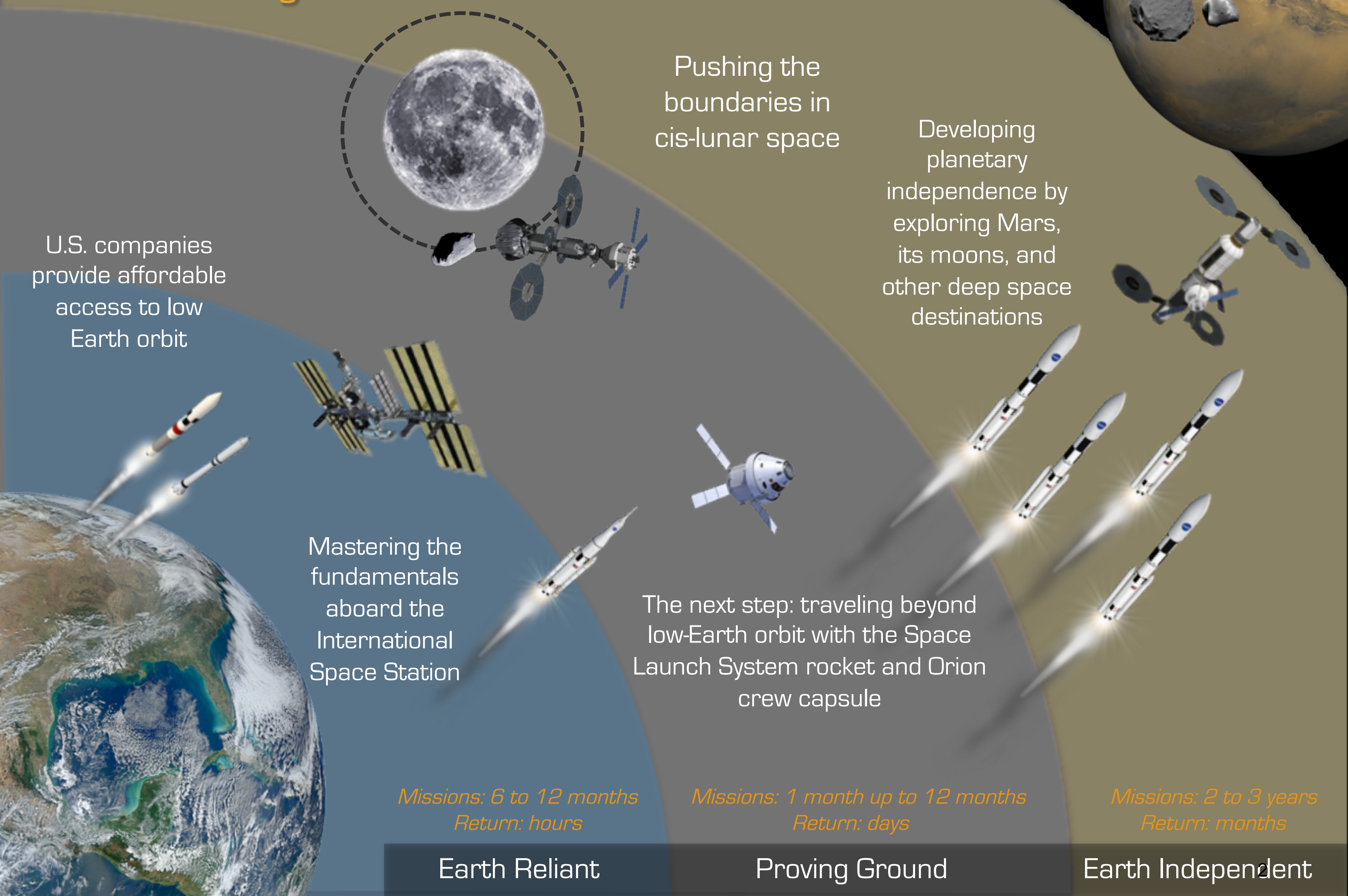
The Future of Human Space Exploration

NASA's Building Blocks to Mars

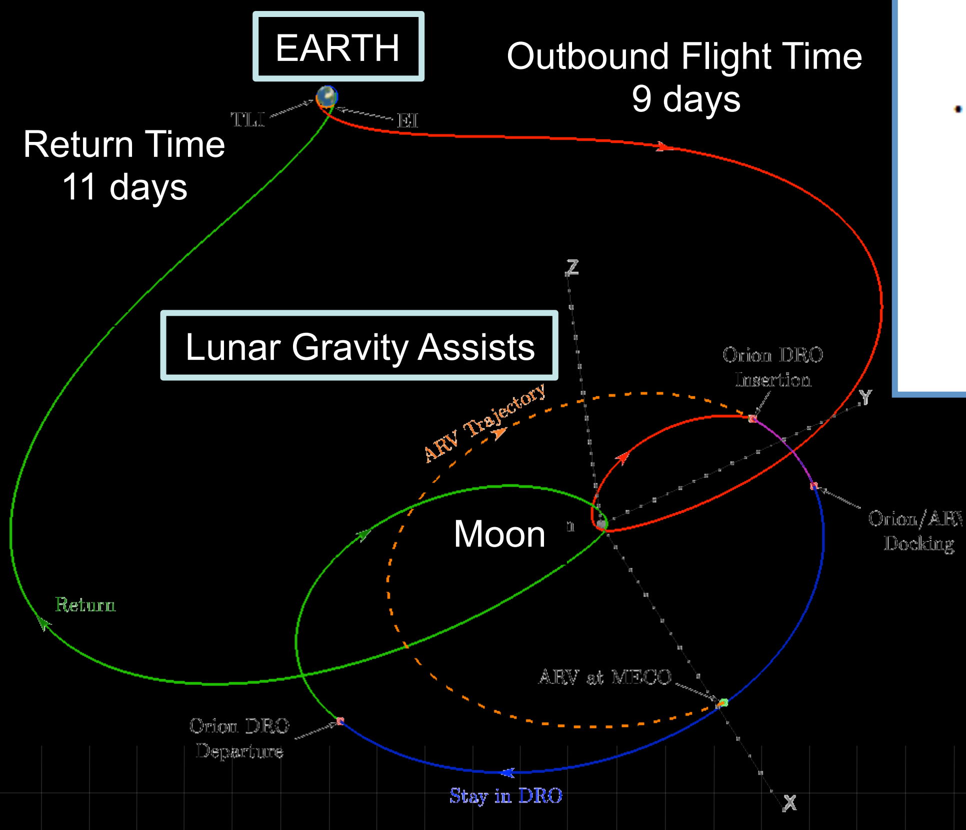


ISS and ARM Provides First Steps to Mars

	Mission / Sequence	Earth Reliant	Proving Ground		Earth Independent		
		Current ISS Mission	Asteroid Redirect Mission	Deep Space Long Stay	Mars Orbit	Mars Surface Short Stay	Mars Surface Long Stay
Mars Destination Capabilities	In Situ Resource Utilization & Surface Power						X
	Surface Habitat						X
	Entry Descent Landing, Human Lander					X	X
	Advanced Propulsion Stage				X	X	X
Initial Exploration Capabilities	Deep Space Habitat			X	X	X	X
	Exploration EVA		X	X	X	X	X
	Solar Electric Propulsion for Cargo		X	X	X	X	X
	Deep Space Guidance Navigation and Control/Automated Rendezvous		X	X	X	X	X
	Crew Operations Beyond LEO – High Speed Entry (Orion)		X	X	X	X	X
	Heavy Lift Beyond LEO (SLS)		X	X	X	X	X
ISS Derived Capabilities	Deep Space Habitat Systems	*		X	X	X	X
	High Reliability Life Support	*		X	X	X	X
	Autonomous Assembly	*		X	X	X	X

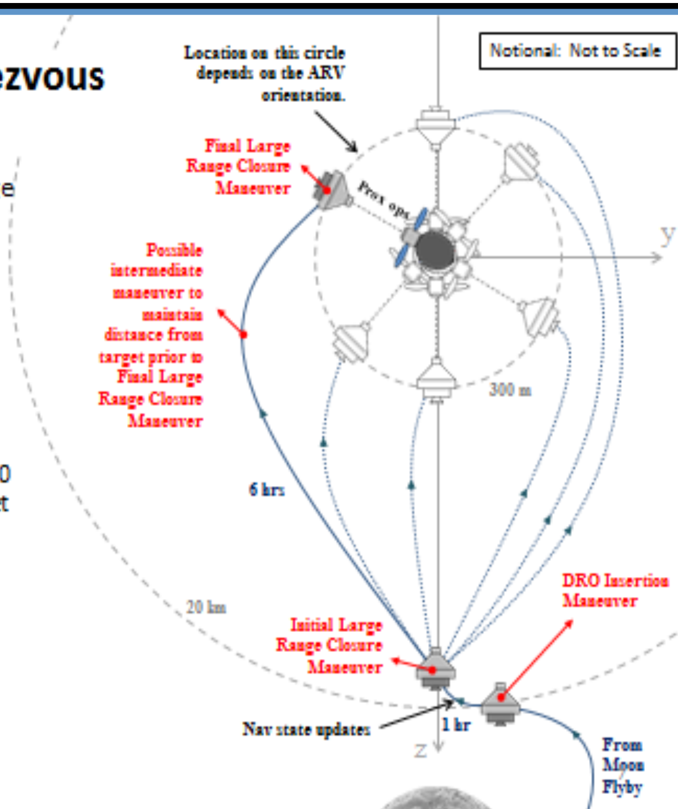
Trajectory, Rendezvous, and Proximity Operations

- Common Rendezvous/prox-ops sensors leveraging Space Shuttle Detailed Tests
- Rendezvous /proximity operations maneuvers result largely in rectilinear motion
- Trajectory, launch window, rendezvous, and navigation techniques enable Mars



Far-Field Rendezvous Strategy

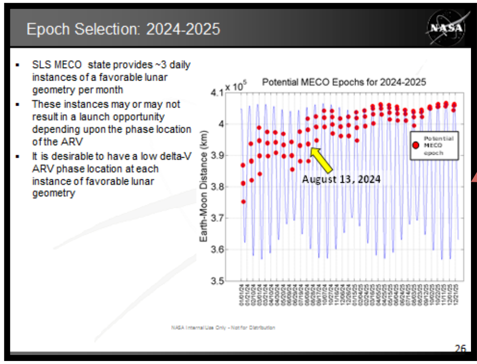
- A large (~20 km) range closure (2-burn) maneuver sequence places the Orion 300 m range from ARV/Asteroid
- The near rectilinear motion in the DRO allows for many possible transfer approaches to the 300 m ARV/Asteroid offset
- The path can be selected to provide desirable collision avoidance and final prox-ops approach geometry (e.g., Sun behind Orion on approach)



STORRM Camera Image

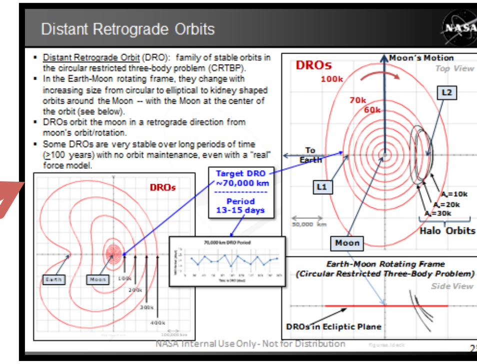
STORRM LIDAR Images

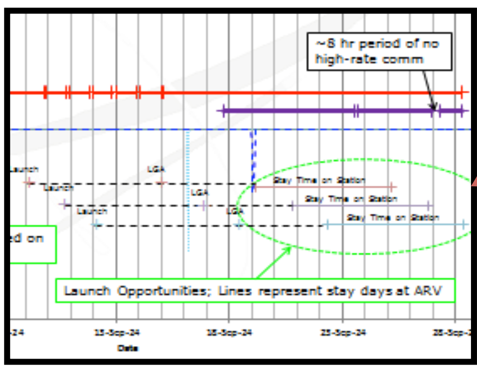
Mission Design Considerations



Launch Availability ~2-3 opportunities per month

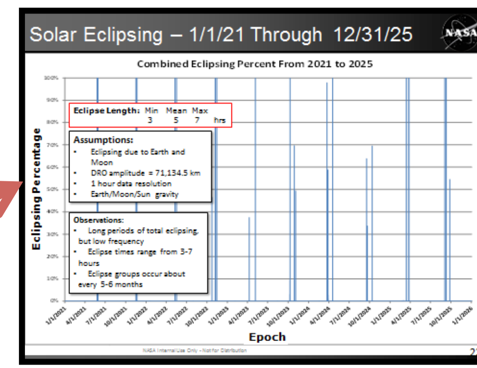
71433km DRO improves launch availability by syncing with Lunar period

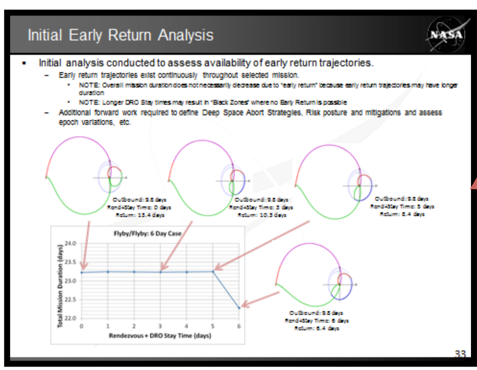




Acceptable Communications Coverage for Orion/ARRV

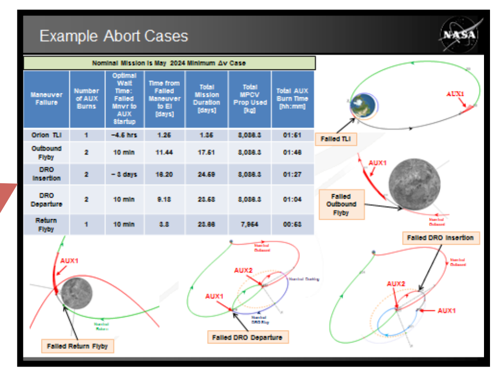
Long Solar Eclipse Periods Manageable for launch availability





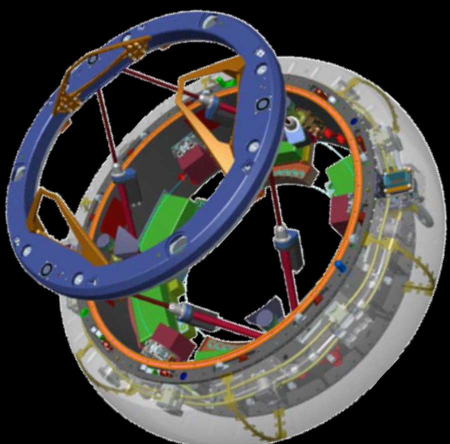
Orion Propellant Available for Early Return Throughout Mission

Orion Propellant Allows Auxiliary Thruster Contingency Return

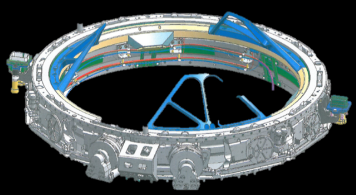


Docking System

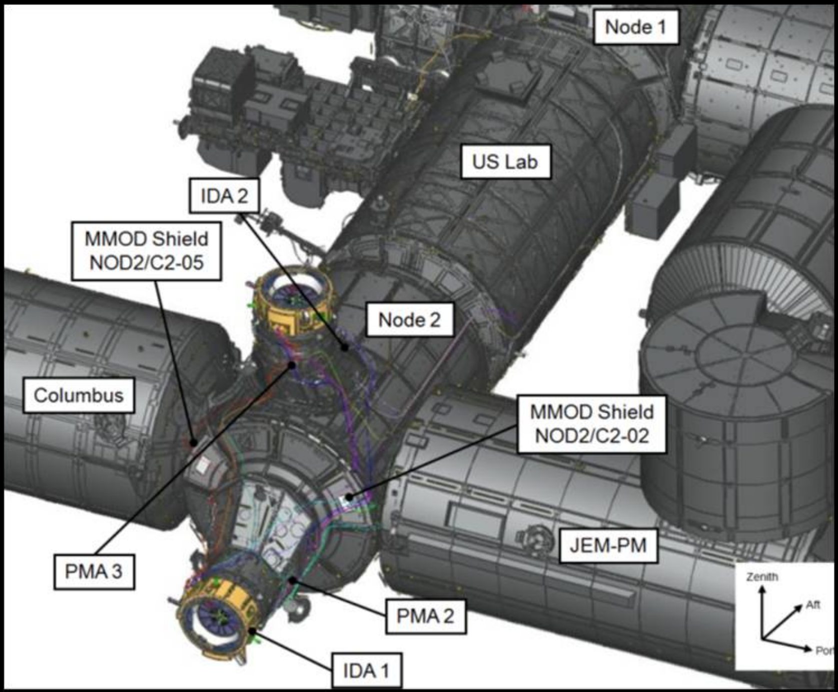
- **Docking System for Orion and Robotic Spacecraft leverages development of International Docking System Block 1**
- **All Mars/Deep Space Architectures will require some form of autonomous docking**



Orion Active Docking Mechanism

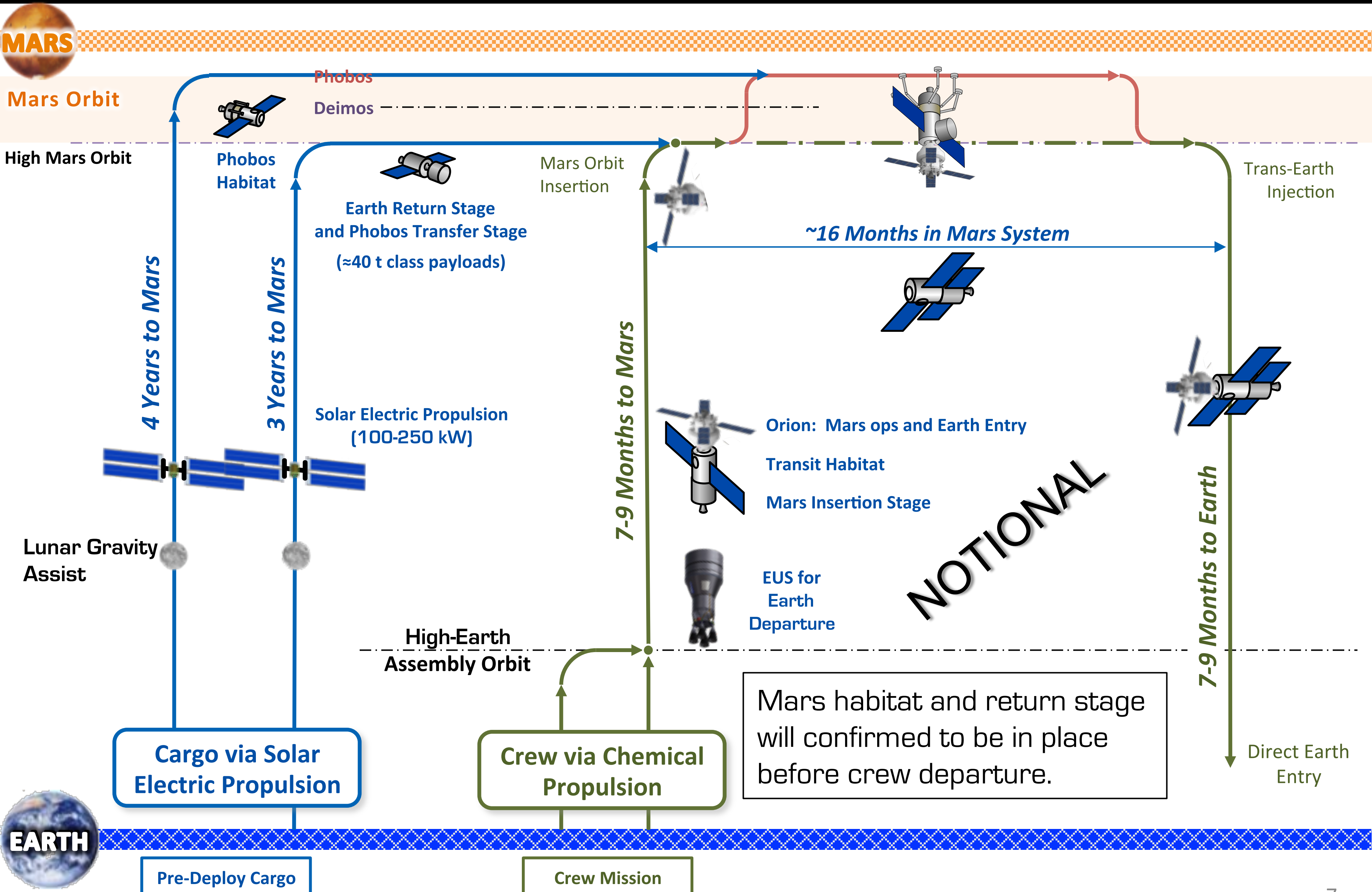


Robotic Spacecraft Passive Docking Mechanism



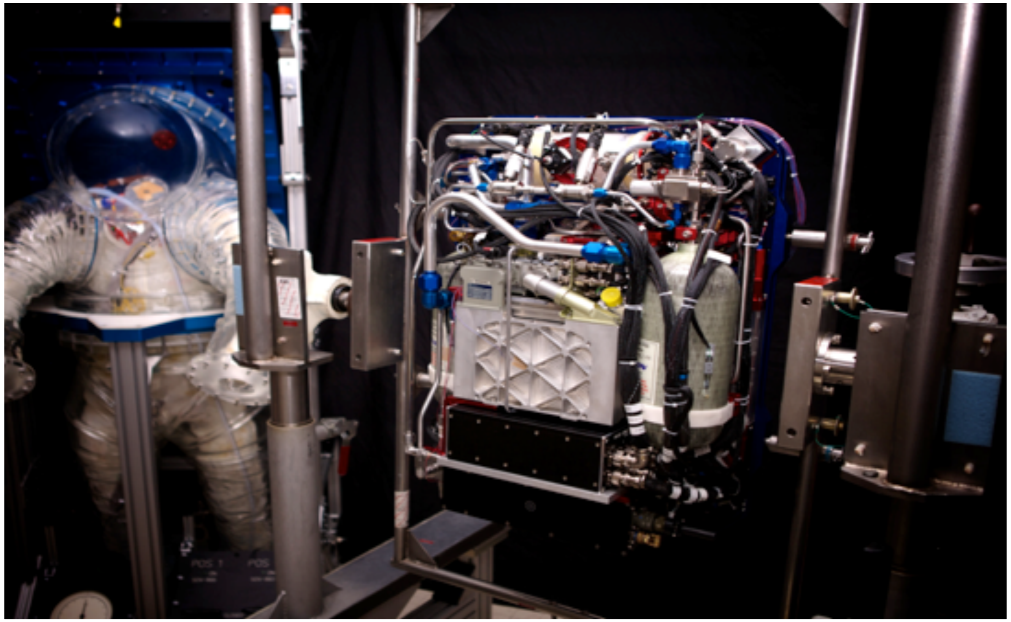
- International Docking Adapter will create a docking port on ISS to provide power and data utility connections to visiting vehicles
- Beginning FY14 study with ISS Program to evaluate Block I to Block II:
    - Voltage and avionics
    - Deep space environment
    - Mass reduction opportunities
    - Overall system design efficiency

Notional ARM Derived Phobos Mission



EVA Suit and Primary Life Support System (PLSS)

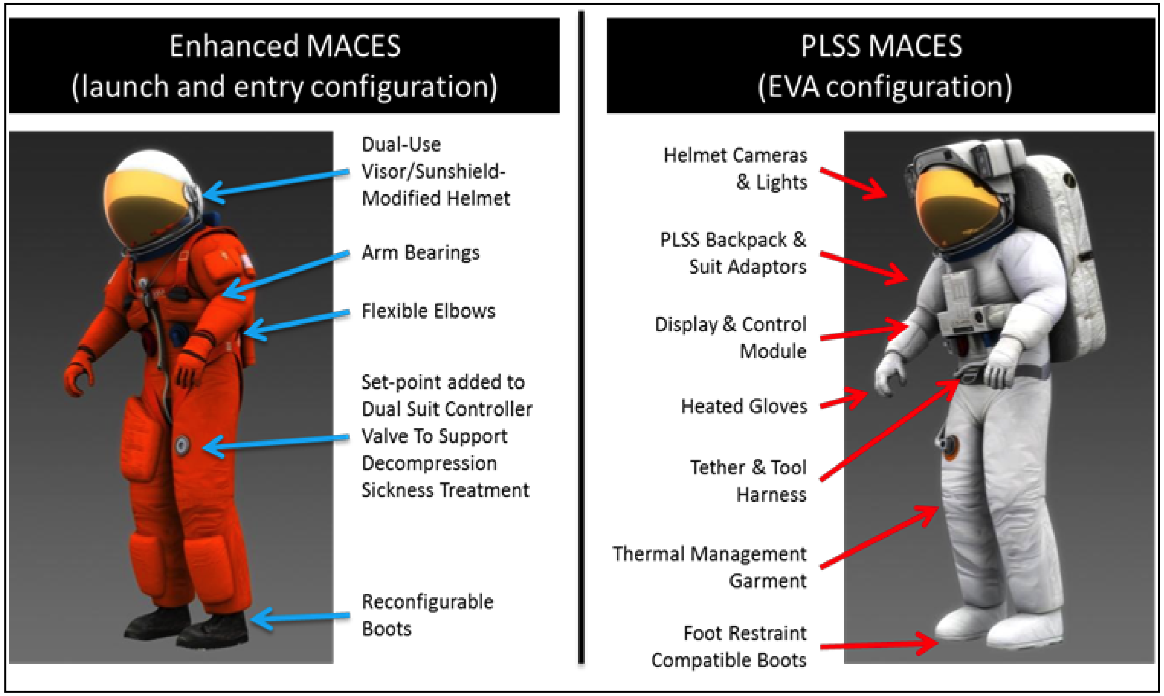
- **Exploration PLSS- capable with small modifications of ISS EMU, Exploration Suit, or MACES with architecture that is Mars capable**
  - PLSS 2.0 prototype completed in FY13
  - Variable Oxygen Regulator flammability testing completed at White Sands Test Facility
  - FY14 work includes integrated metabolic and functional testing and fabrication of a PLSS/MACES integration kit



Variable Oxygen Regulator Testing at WSTF

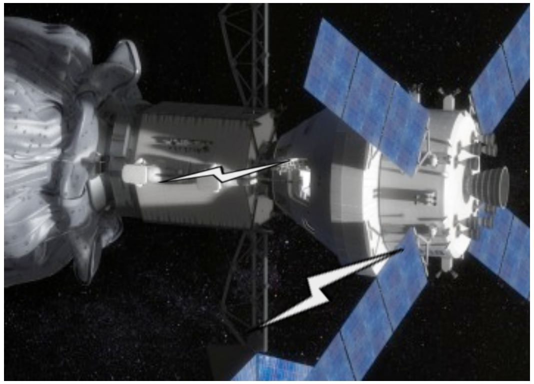
MACES with PLSS and EVA Suit Kit

Mission Kit Concept Enables Affordable Crewed Mission

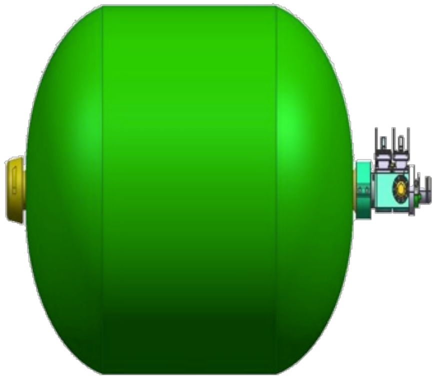


Tools & Translation Aids

Sample Container Kit



EVA Communications Kit



Repress Kit

Much of the EVA hardware can be utilized for other future exploration missions

Modified ACES Testing Summary

Lab, Zero G, ARGOS tests

MACES EVAs are demonstrated as feasible and neutrally buoyant testing is warranted

NBL Series #2 – 5 tests (2, 3 and 4 hours long)

Task complexity increases while improvements are made to the suit including EMU gloves, drink bag, etc.

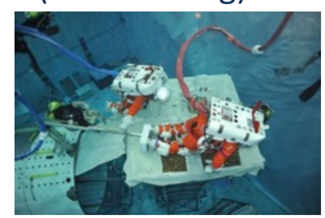
Need for improved stability and work envelope

May | June | July | August | Sept | Oct – Jan | February | March | April | May

NBL Series #1 – 3 tests (2 hours long)

Established NBL Interface, ability to weigh-out the suit, and the subject's ability to use the suit underwater.

NBL Series #3 – 5 tests (4 hours long)

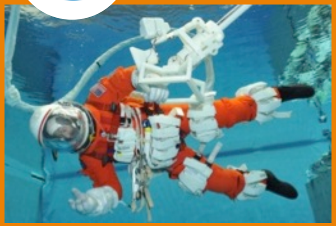
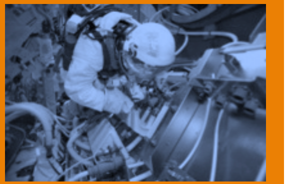
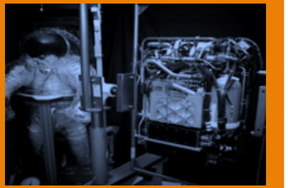
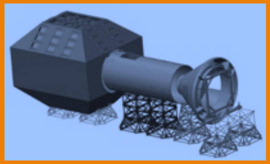


Evaluation of mobility enhancements, improved worksite stability, and testing on higher fidelity capsule mockups with tools culminating in a full ARCM EVA timeline.

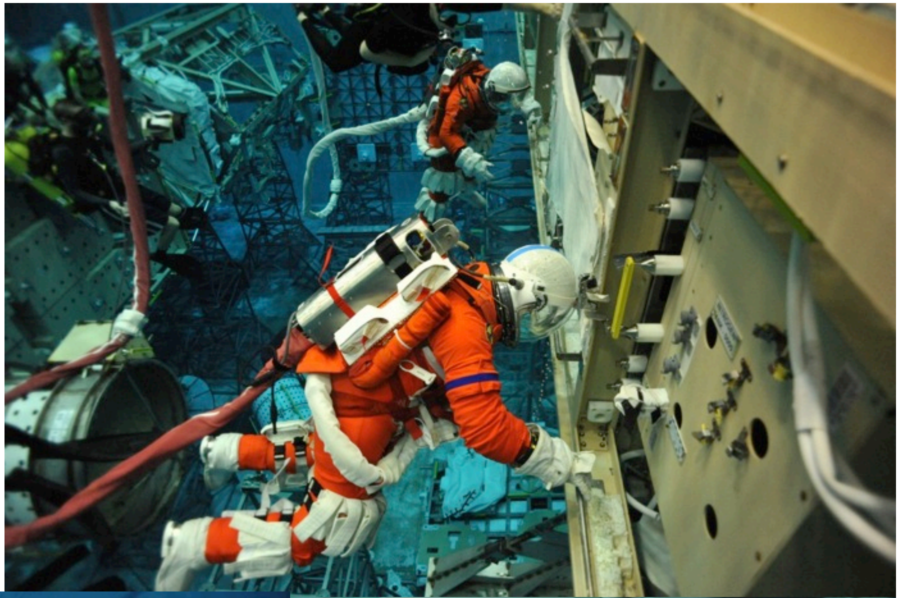
Hardware and Procedure Improvements

- Improved weights
- EMU Gloves
- Added tool harness
- Drink bag included
- New liquid cooling garment
- Mobility Enhancements
- Dual Suit Ops
- EMU Boots
- PLSS Mockup
- Body Restraint Tether

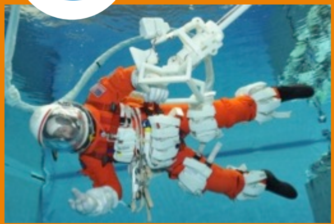
NBL Testing – Basic Mobility

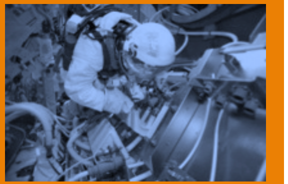





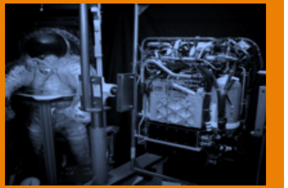

- The crew was able to complete translation, body positioning, and hatch ingress tasks.
- Successfully completed ISS Global Position Satellite and Main Bus Switching Unit Replacement Tasks.

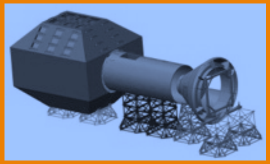


Test Results – Capsule Ingress/Egress



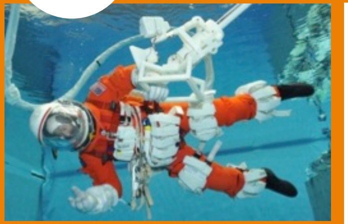


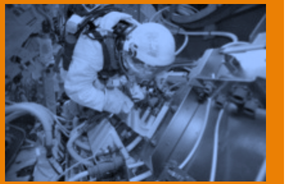


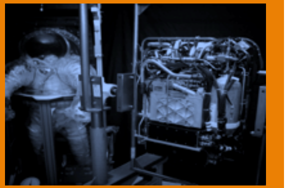


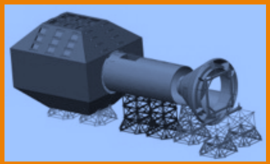
- Ingress and egress from Orion mockup was demonstrated
- Crew was also able to manipulate translation boom that links Orion to ARV

NBL Test Results – Worksite Stabilization

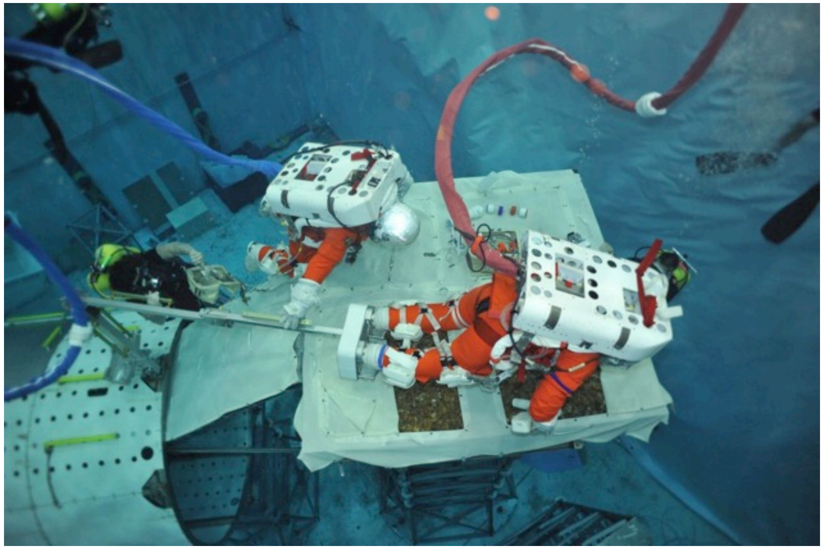




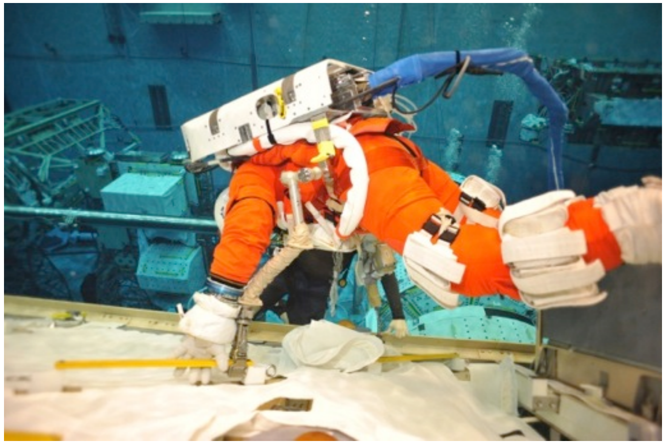




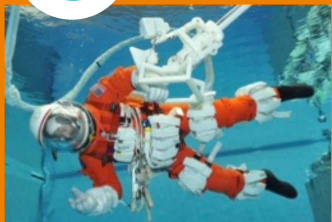
- Adjustable Portable Foot Restraint operations were tested and execution is very similar to the ISS Extravehicular Mobility Unit.

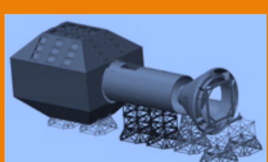


- Body Restraint Tether allowed the crew to perform two handed tasks

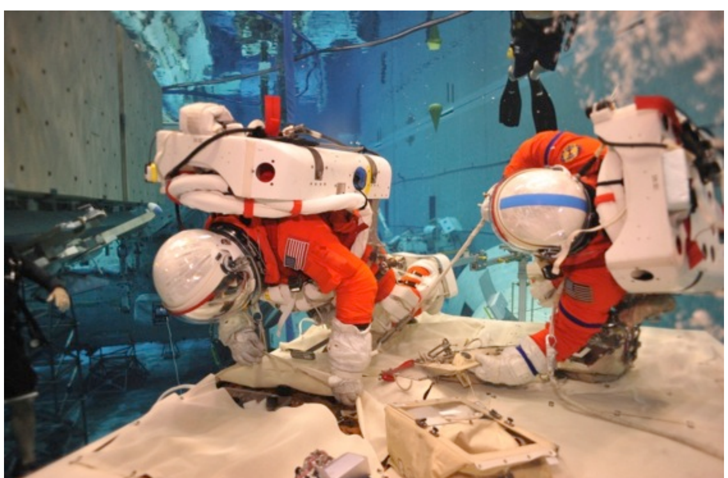


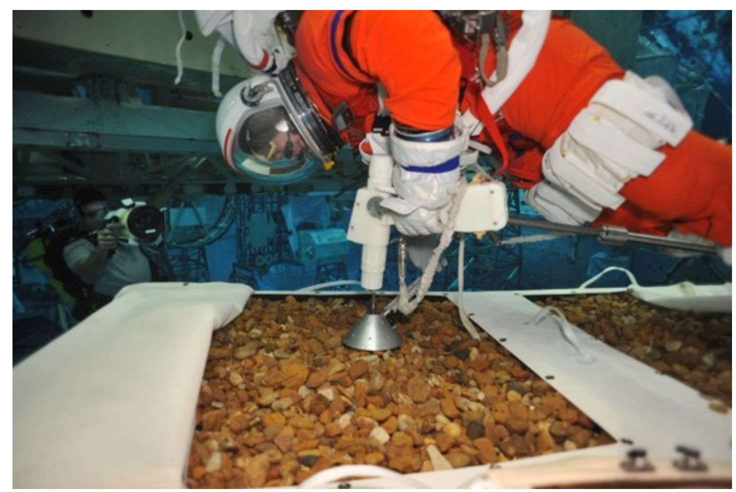
Test Results – Sampling Tasks





- Crew was able to perform several sampling tasks including worksite imaging, float sample collection, hammer chiseling and pneumatic chiseling.





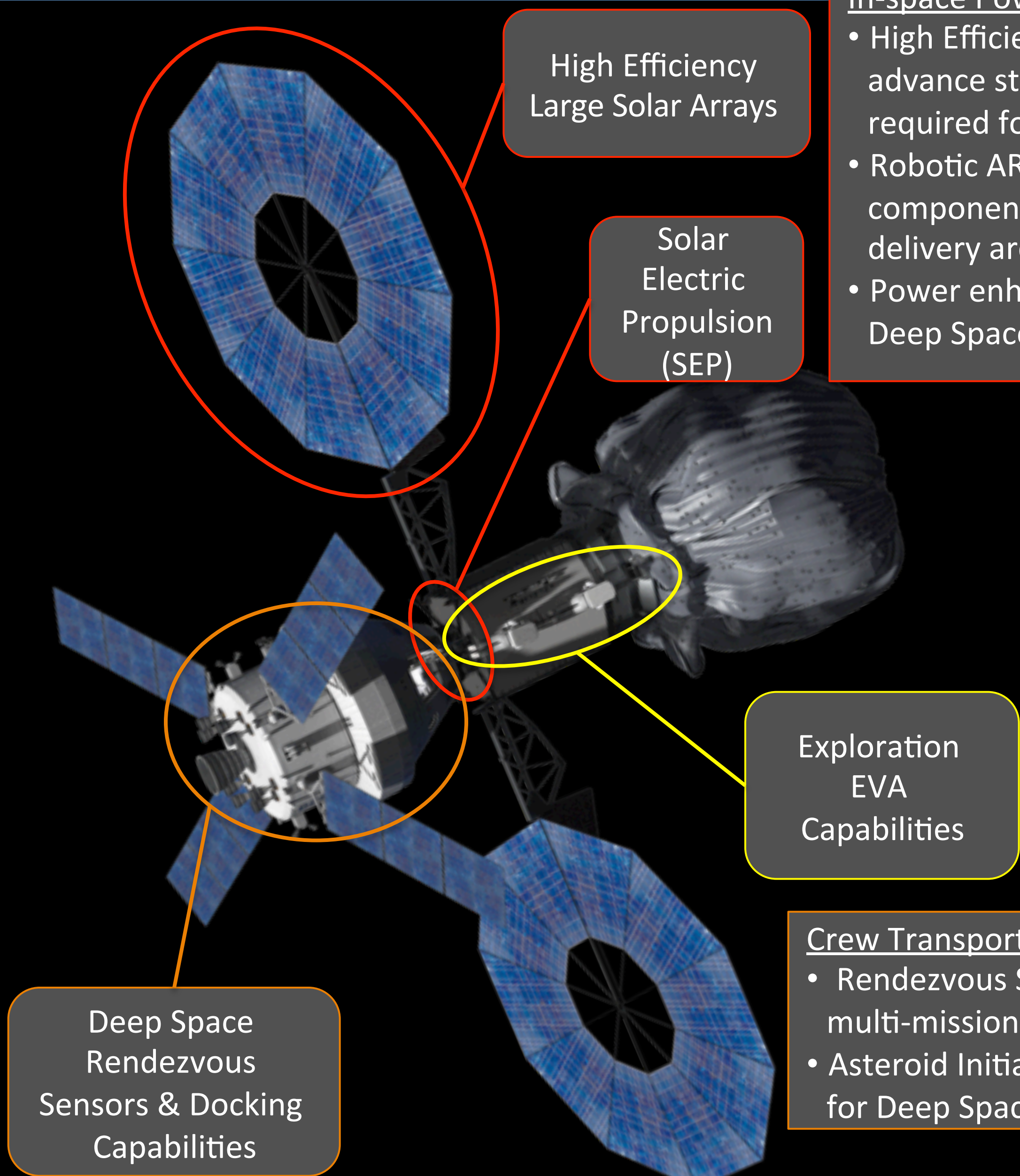
Continued Work with Curation and Planning Team for Extraterrestrial Materials (CAPTEM)

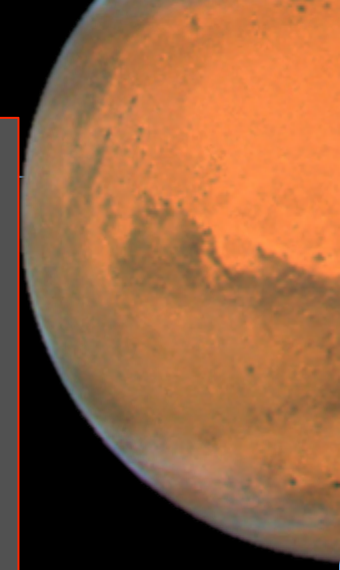
- CAPTEM recommendations were provided for :
  - Activities that would be conducted during EVAs that are relevant for characterization, selection, collection, stowage, and transport of multiple samples to Earth.
  - Protocols for tools and instruments relevant for sample collection/characterization.
  - High level objectives that would be required to maximize the scientific usefulness of the EVAs and ensure the scientific integrity of the returned samples.

- Crewed Mission Team Looks Forward to Increased Dialogue for the Ten CAPTEM Recommendations in preparation for MCR :

1. Asteroid needs to be multi-spectrally imaged prior to crew flight for site selection.
2. Communication with ground-based Science Team is critically important.
3. Photo-documentation of the samples before and after collection is vital
4. Contamination Control of both the samples and the crew areas is vitally important.
5. At least two diverse sites with 1000 g of material from each.
6. At least one 5-cm diameter, 4 cm deep (100 cm depth desirable) core sample of regolith from each of the two sites.
7. Preservation of volatiles is desirable, particularly if sampled asteroid is of type C, P, or D.
8. A measurement of porosity and internal structure of body using an acoustic survey is desirable.
9. A placement of instruments (e.g., retroreflectors) to measure deformation of the body during the mission is desirable.
10. Optical albedo measurements and measurements of Yarkovsky effect are not of high priority.

Asteroid Redirect Mission Provides Capabilities For Deep Space/Mars Missions





In-space Power and Propulsion :

- High Efficiency Solar Arrays and SEP advance state of art toward capability required for Mars
- Robotic ARM mission 40kW vehicle components prepare for Mars cargo delivery architectures
- Power enhancements feed forward to Deep Space Habitats and Transit Vehicles

EVA:

- Build capability for future exploration through Primary Life Support System Design which accommodates Mars
- Test sample collection and containment techniques including planetary protection
- Follow-on missions in DRO can provide more capable exploration suit and tools

Crew Transportation and Operations:

- Rendezvous Sensors and Docking Systems provide a multi-mission capability needed for Deep Space and Mars
- Asteroid Initiative in cis-lunar space is a proving ground for Deep Space operations, trajectory, and navigation.

Back-Up

EVA Concept Enables Mars Surface Missions

- EVA assumptions:
  - Long duration (up to 8 hours)
  - Complex tasks that require significant lower torso mobility
  - 100 EVA system life
  - Low pressure CO2 atmosphere
- Mars mission through technology development and testing
  - Thermal Micrometeoroid Dust Garment (TMDG) which requires new technology, as well as walking boots and dust resistant visor
  - Specific mission needs will be TMDG with a specialized Aerogel insulation
- Current PLSS schematic is Mars forward. Some modifications will be required to the baseline for partial atmosphere use
  - CO2 scrubbing modifications
  - Heat rejection modifications

Aerogel TMG glove for use in Martian environment

Spacesuit Evaporator Absorber Radiator (SEAR) for Martian atmospheric operation of PLSS

Suit Water Membrane Evaporator (SWME) being tested at Mars atmospheric pressure