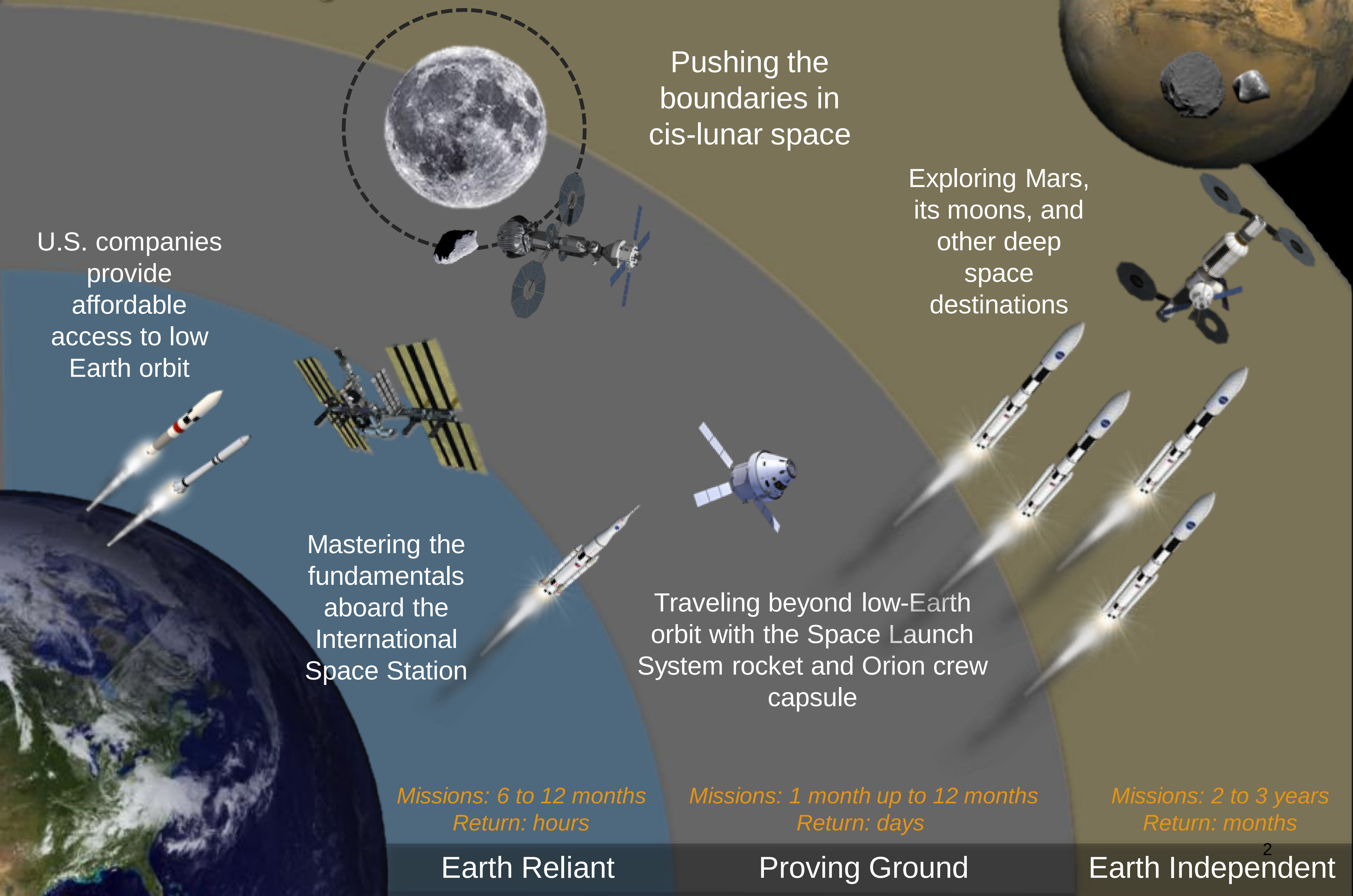
National Aeronautics and Space Administration

# Asteroid Redirect Mission Building Human Space Flight Exploration Capabilities

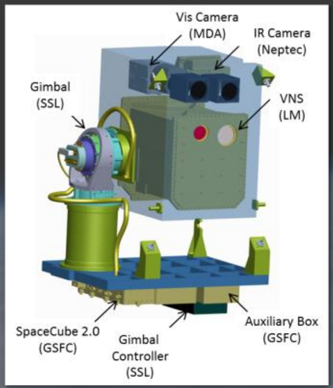
Steve Stich
Deputy Director, JSC Engineering
April 7, 2014

# The Future of Human Space Exploration

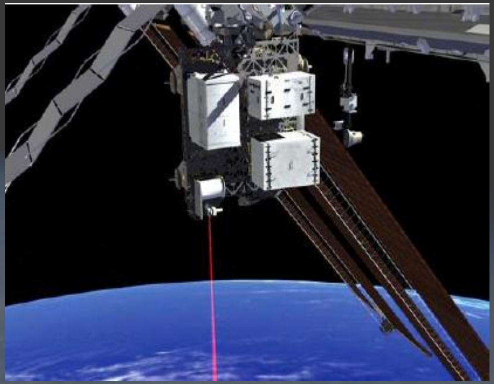
## *NASA's Building Blocks to Mars*



# ISS is Exploration- Extended to 2024



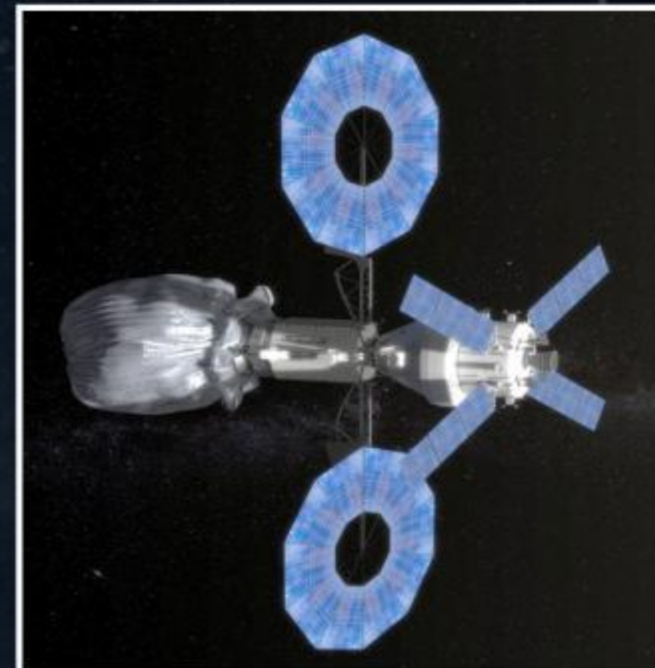


- Health and Human Performance
- Crew Habitability, Logistics, Maintenance
- High Reliability Closed Loop Life Support

# Asteroid Redirect Crewed Mission

Deliver crew on SLS/Orion

Orion Docks to Robotic Spacecraft

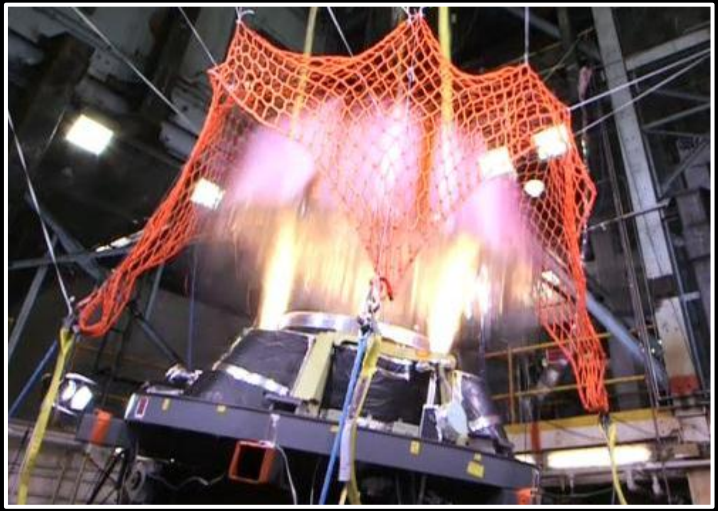


EVA from Orion to retrieve asteroid samples

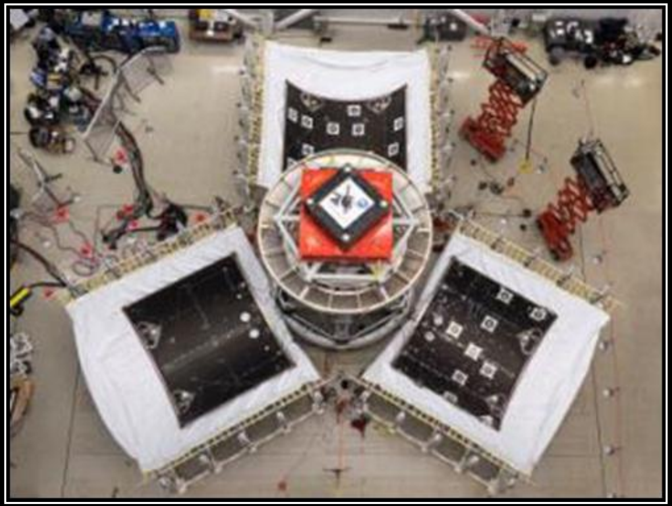
Return crew safely to Earth with asteroid samples in  Orion

# Orion Spacecraft

**Orion is the first spacecraft in history capable of taking humans to multiple destinations in deep space.**



Forward Bay Cover Jettison Test Denver, CO



Fairing separation test at Lockheed Martin, Sunnyvale, CA

Heat shield completed and delivered to O&C for final processing

Service Module / Spacecraft Adaptor mate complete at O&C

# Orion Fully Powered at KSC

# Space Launch System

**SLS is the rocket and launch system capable of transporting humans, habitats and support systems directly to deep space.**

Completed MSA Shell

Vertical weld tool complete at Michoud Assembly Facility

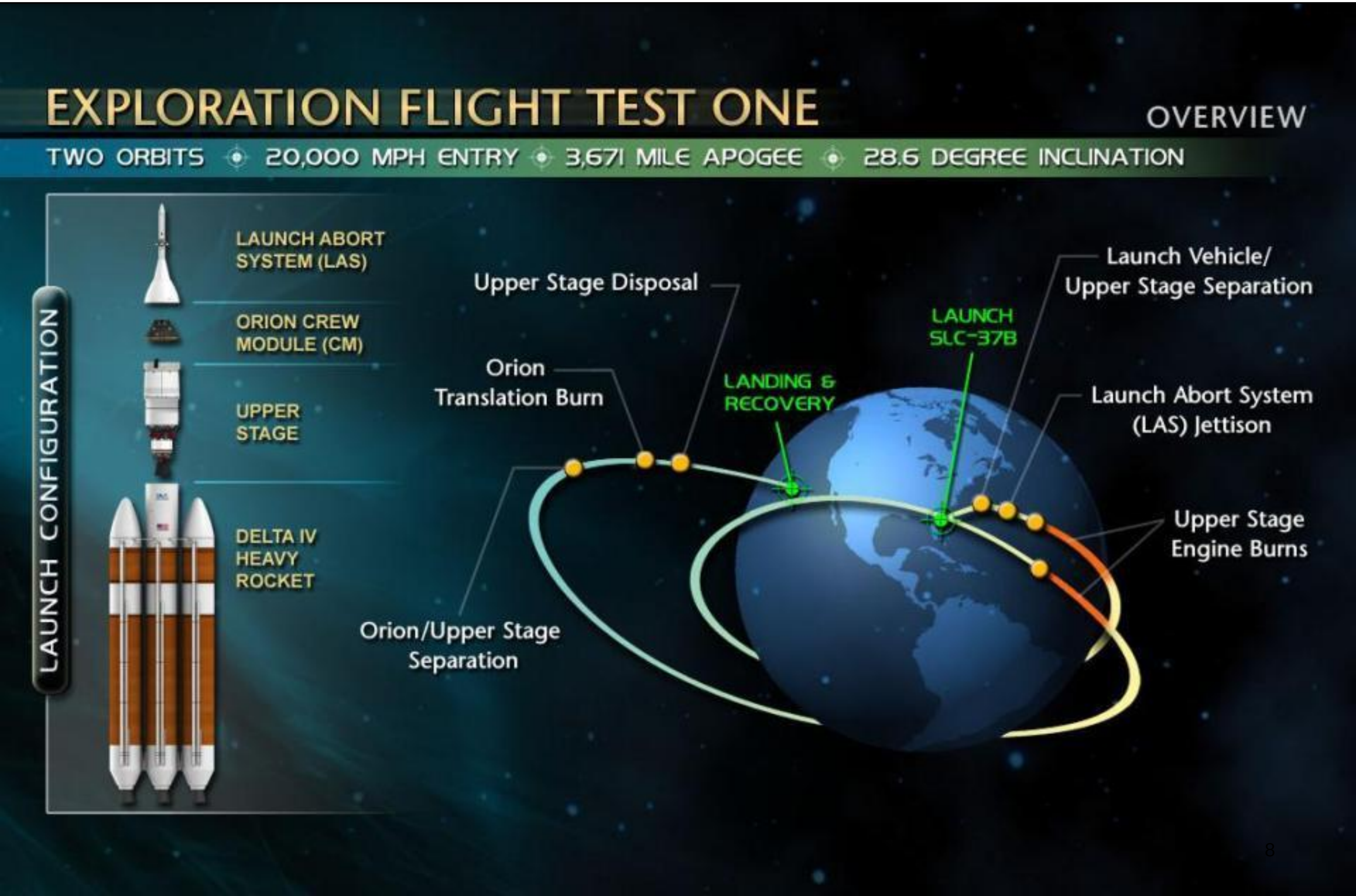
1:100 scale model of SLS Core Stage B-2 test stand completed wind tunnel testing

Center segment for QM-1 delivered to its test bay at ATK's facility in Utah

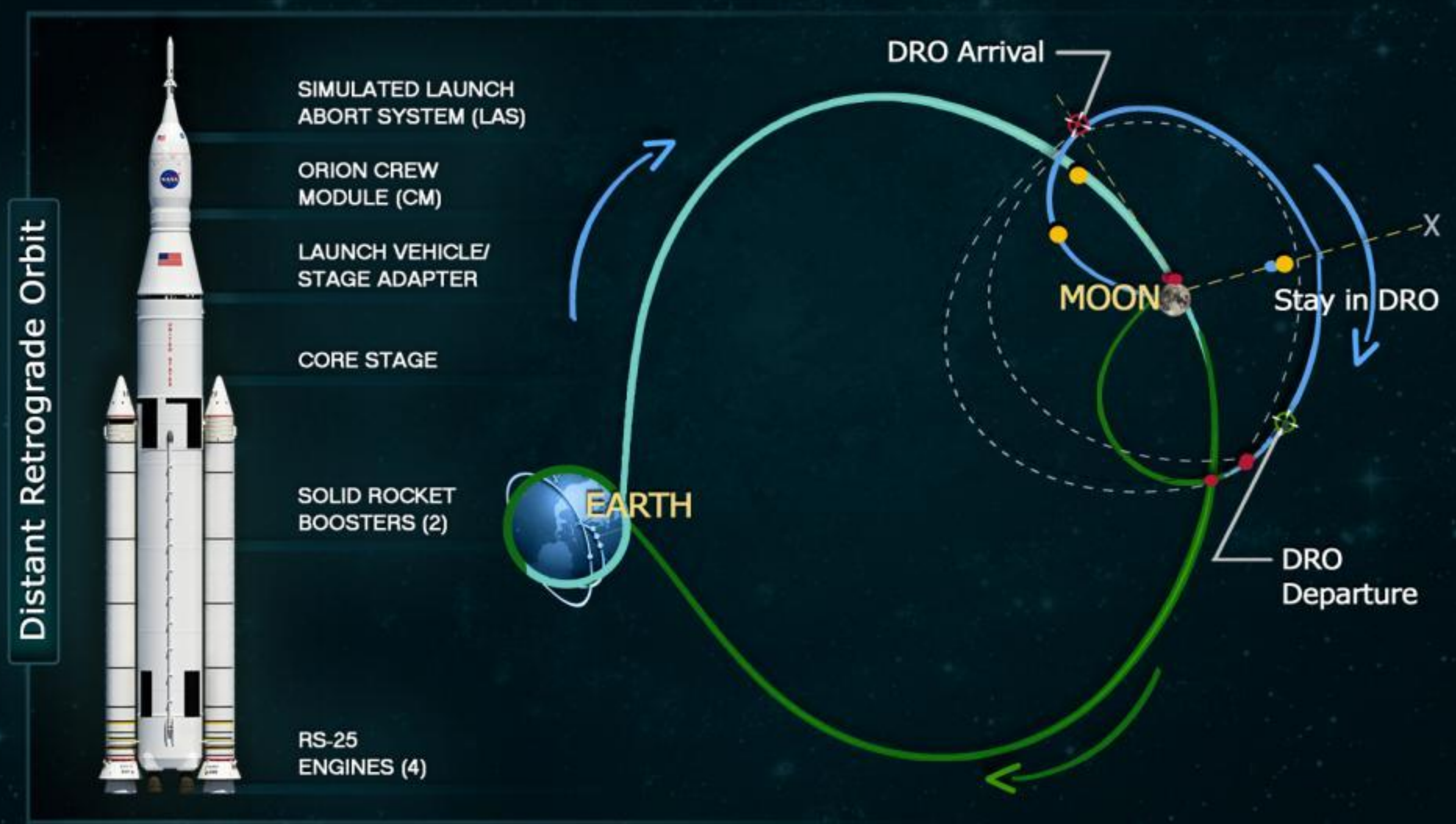
Diaphragm installed and tested on MSA in support of EFT-1

F-1B gas generator – tech demo for advanced booster concept

# Coming This Fall…

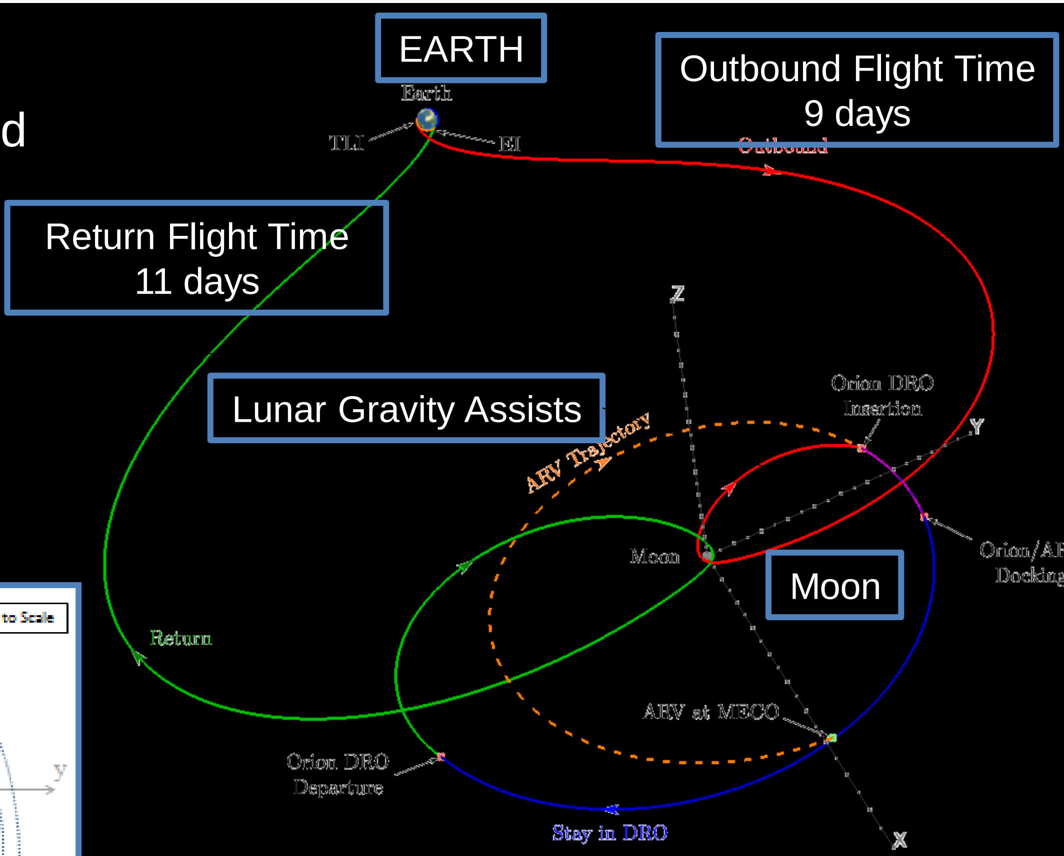


# Exploration Mission One (EM–1)



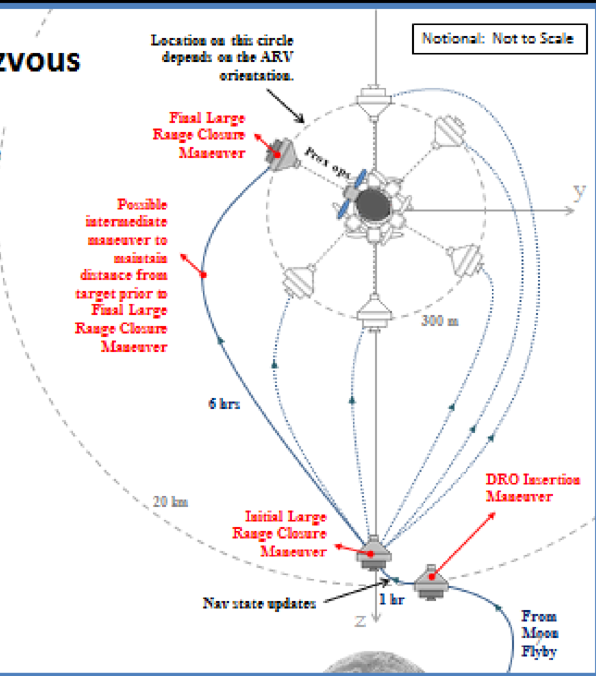
# Leveraging Existing Investments:
# Deep Space Trajectory and Rendezvous

- Rendezvous/prox-ops sensors derived from Space Shuttle Detailed Tests
- Trajectory launch constraints, rendezvous techniques, navigation enable Mars
- Lunar gravity assist is learning environment for Mars cargo pre-deployment or human Venus fly-by

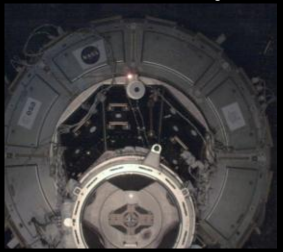



## Far-Field Rendezvous Strategy

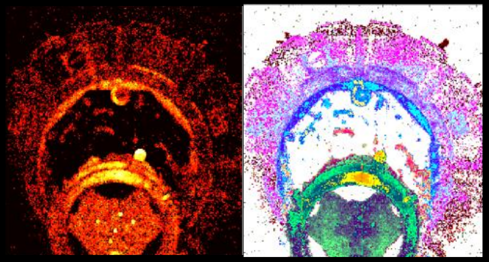
- A large (~20 km) range closure (2-burn) maneuver sequence places the Orion 300 m range from ARV/Asteroid
- The near rectilinear motion in the DRO allows for many possible transfer approaches to the 300 m ARV/Asteroid offset
- The path can be selected to provide desirable collision avoidance and final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




STORRM Camera Image

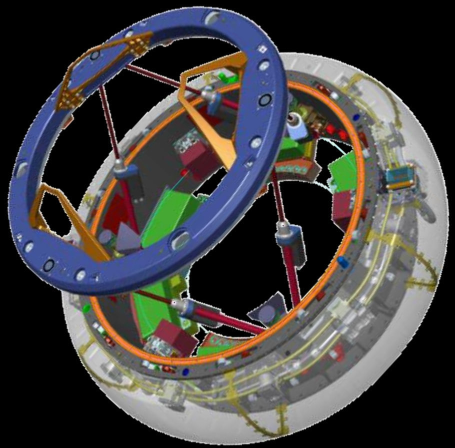


STORRM LIDAR Images

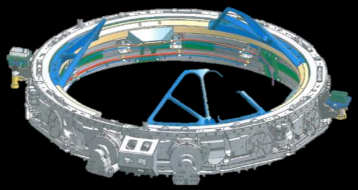


# Docking System

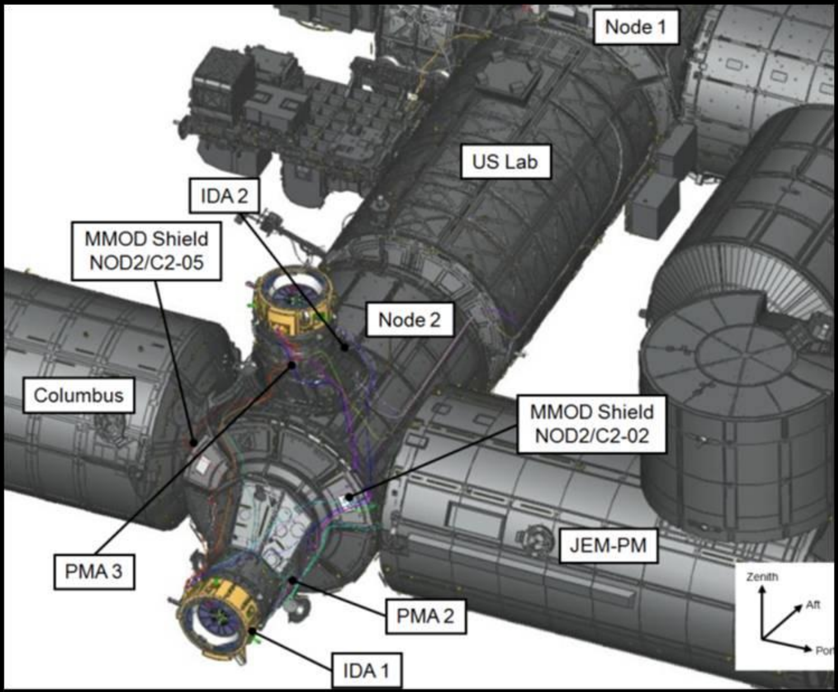
- **Docking System for Orion and Robotic Spacecraft leverages development of International Docking System Block 1**
- **All Mars/Deep Space Architectures will require some form of autonomous docking**



Orion Active Docking Mechanism



Robotic Spacecraft Passive Docking Mechanism



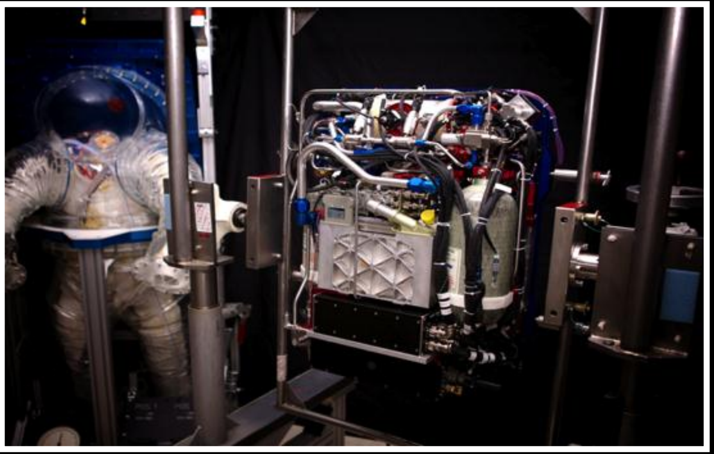

- International Docking Adapter will create a docking port on ISS to provide power and data utility connections to visiting vehicles
- FY14 study with ISS Program to evaluate Block I to Block II:
  - Voltage and avionics
  - Deep space environment
  - Mass reduction opportunities
  - Overall system design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

Leveraging Existing Investments:

# EVA Suit and Primary Life Support System (PLSS)

- Exploration PLSS- capable with small modifications of ISS EVA demonstration, Exploration Suit, or Modified Advanced Crew Escape Suit (MACES) via an architecture that is Mars capable
  - Initial PLSS prototype completed in FY13
  - WSTF Variable Oxygen Regulator flammability testing
  - Integrated metabolic and functional testing in FY14
- Exploration Suit - Architecture support mission requirements, represented in a Mars mission, that is applicable to any surface, and adaptable for micro-gravity

Completed PLSS 2.0 Test Article



MACES with PLSS and EVA Suit Kit

Z-2 Exploration Suit

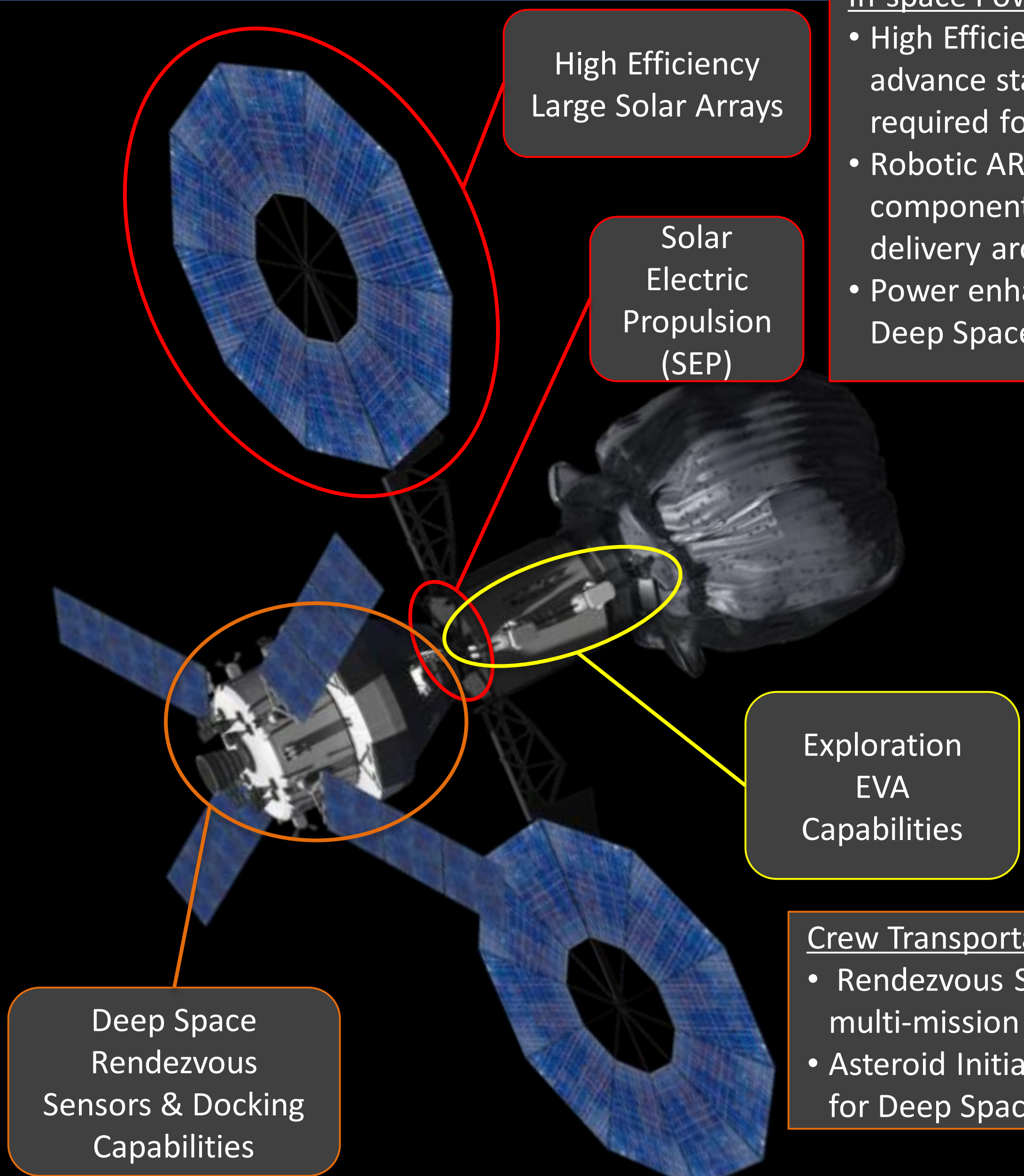
# Modified ACES EVA Testing in NBL

- February 2014 testing focused on first portion of spacewalk (egress, translation, worksite prep):
  - 2 Crew Capability
  - Enhanced Suits with arm bearing and positioning
  - EMU Boots
  - Portable Foot Restraint
- April test series will emphasize sample capture and worksite stability





# 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

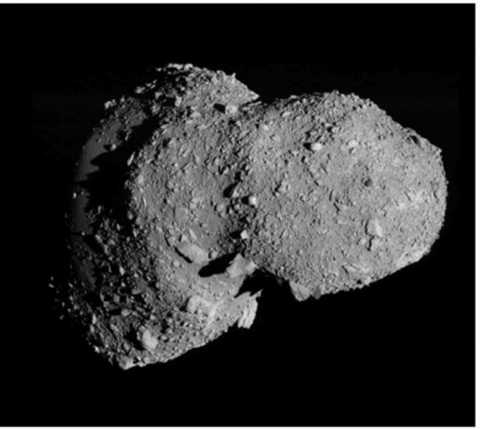
EVA:
- Build capability for future exploration through Primary Life Support System Design which accommodates Mars
- Test sample collection and containment techniques including planetary protection
- Follow-on missions in DRO can provide more capable exploration suit and tools

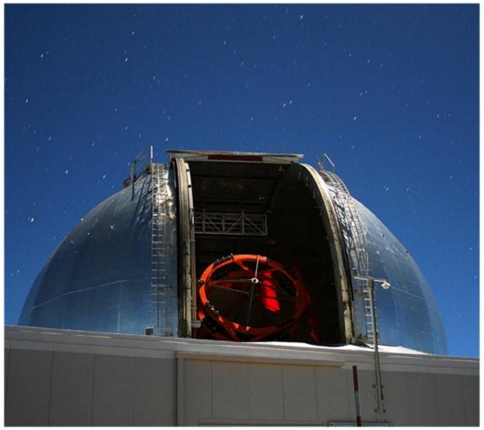
Crew Transportation and Operations:
- Rendezvous Sensors and Docking Systems provide a multi-mission capability needed for Deep Space and Mars
- Asteroid Initiative in cis-lunar space is a proving ground for Deep Space operations, trajectory, and navigation.

National Aeronautics and Space Administration

# Future Extensibility for the Asteroid Redirect Crewed Mission

Mark McDonald, JSC



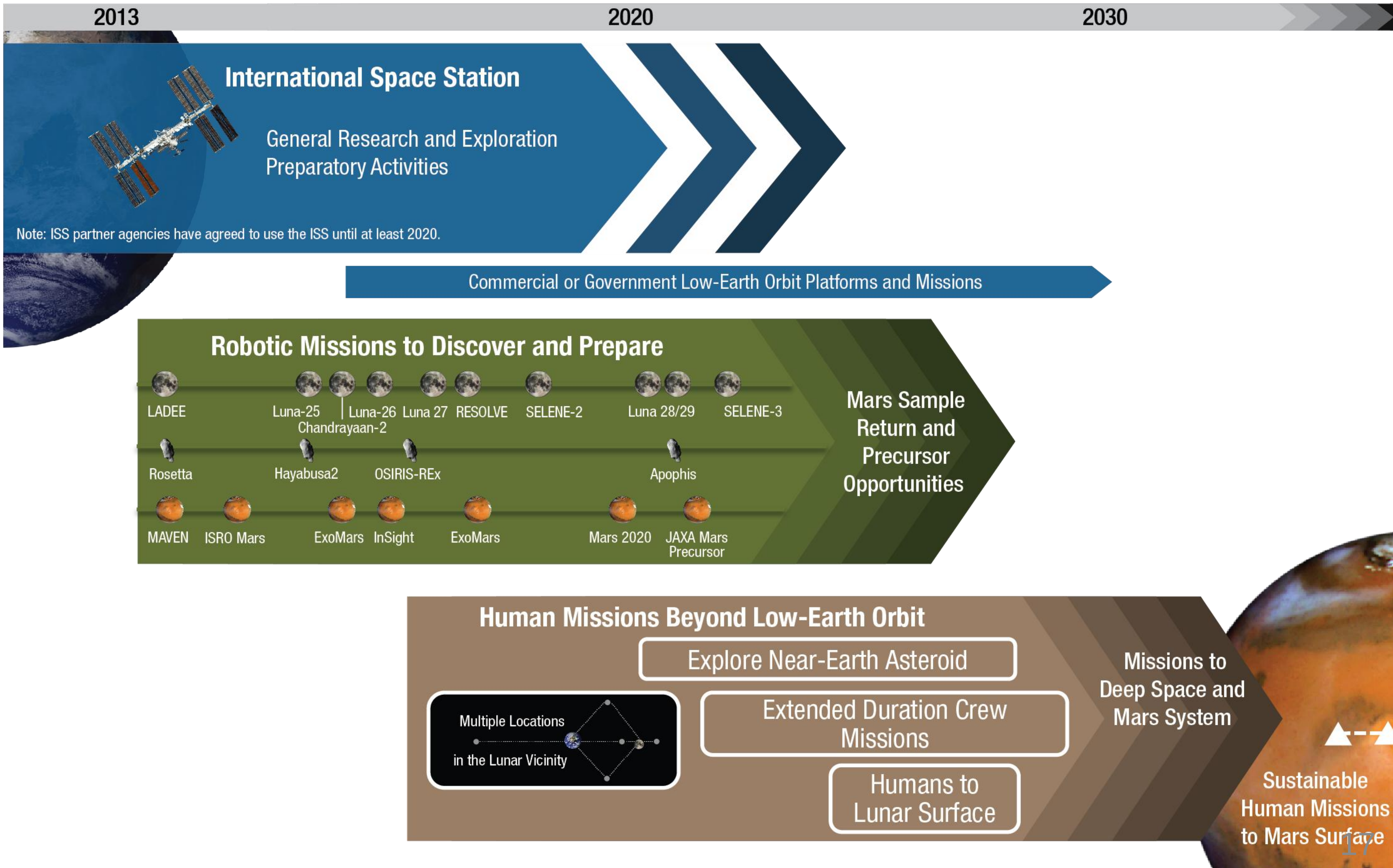


# Principles for Incrementally Building Capabilities

**Six key strategic principles to provide a sustainable program:**

1. Executable with current *budget with modest increases*
2. Application of *high Technology Readiness Level* (TRL) technologies for near term, while focusing research on technologies to address challenges of future missions
3. *Near-term mission* opportunities with a defined cadence of compelling missions providing for an incremental buildup of capabilities for more complex missions over time
4. Opportunities for *US commercial business* to further enhance the experience and business base learned from the ISS logistics and crew market
5. *Multi-use* space infrastructure
6. Significant *international and commercial participation*, leveraging current International Space Station partnerships and commercial companies

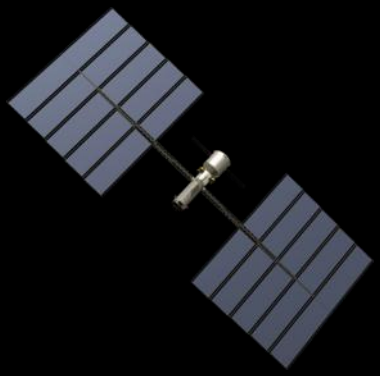
# Global Exploration Roadmap 2.0



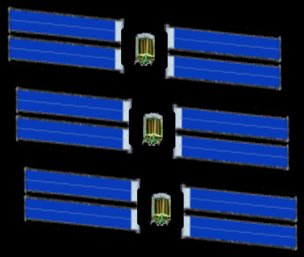
# Use of ARM Solar Electric Propulsion (SEP)

- Previous assessments have shown that human Mars missions utilizing a single round-trip monolithic habitat requires very high power SEP (approximately **1 MW total power)**
- As part of going analysis related to Mars architectures we are developing scenarios that have evolvable ARM SEP supporting cargo delivery for human missions into deep space and the Mars Surface.
  - Pre-deploy crew mission assets to Mars utilizing high efficient SEP, such as
    - Orbit habitats: Supports crew while at Mars
    - Return Propulsion Stages or return habitats
    - Exploration equipment: Unique systems required for exploration at Mars.
  - High thrust chemical propulsion for crew
    - Low-thrust SEP too slow for crew missions
    - Crew travels on faster-transit, minimum energy missions: 1000-day class round-trip (all zero-g)

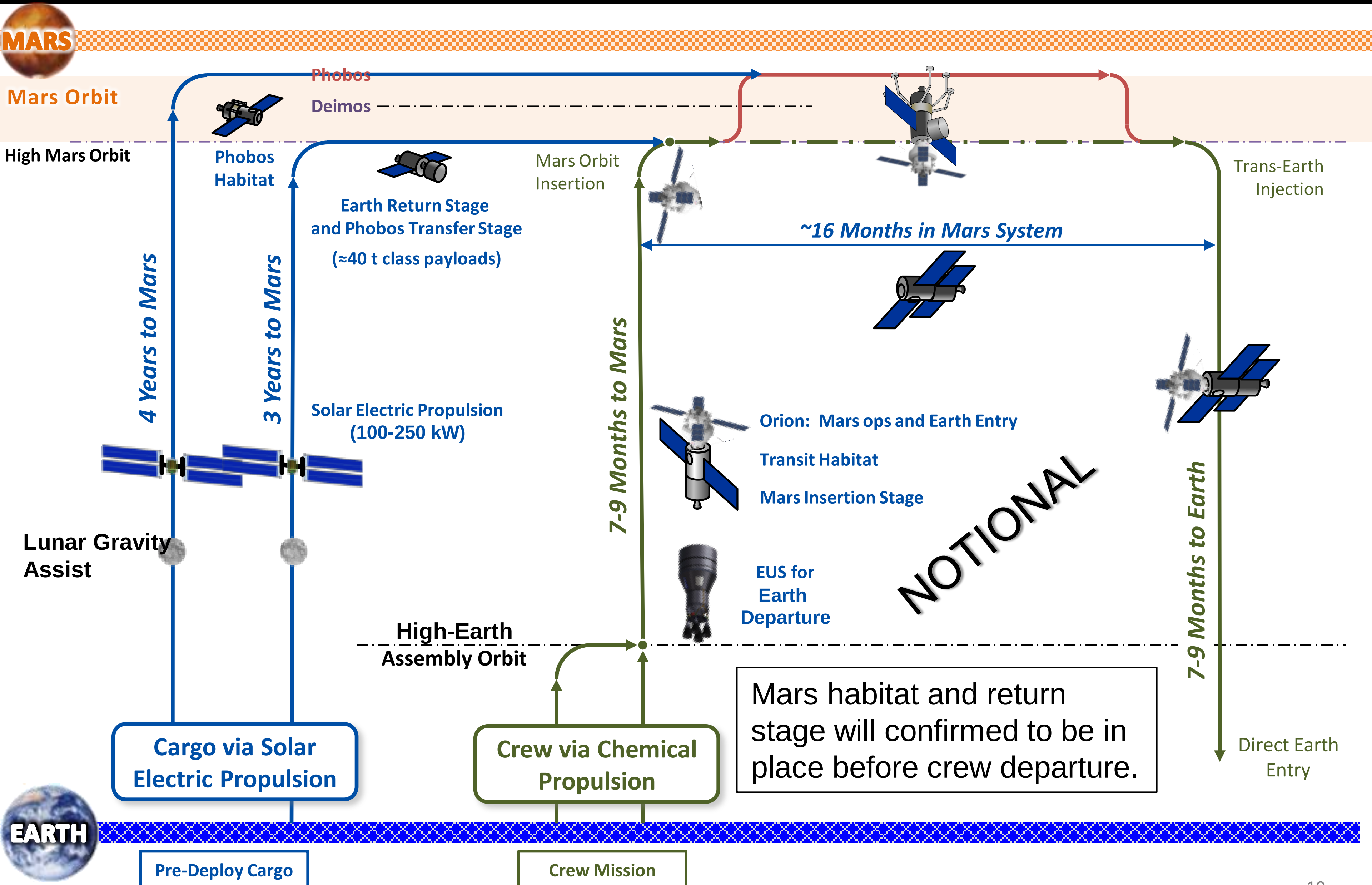
**One Very Large SEP**



**Multiple ARM derived SEPs (100-250 Kw Class)**

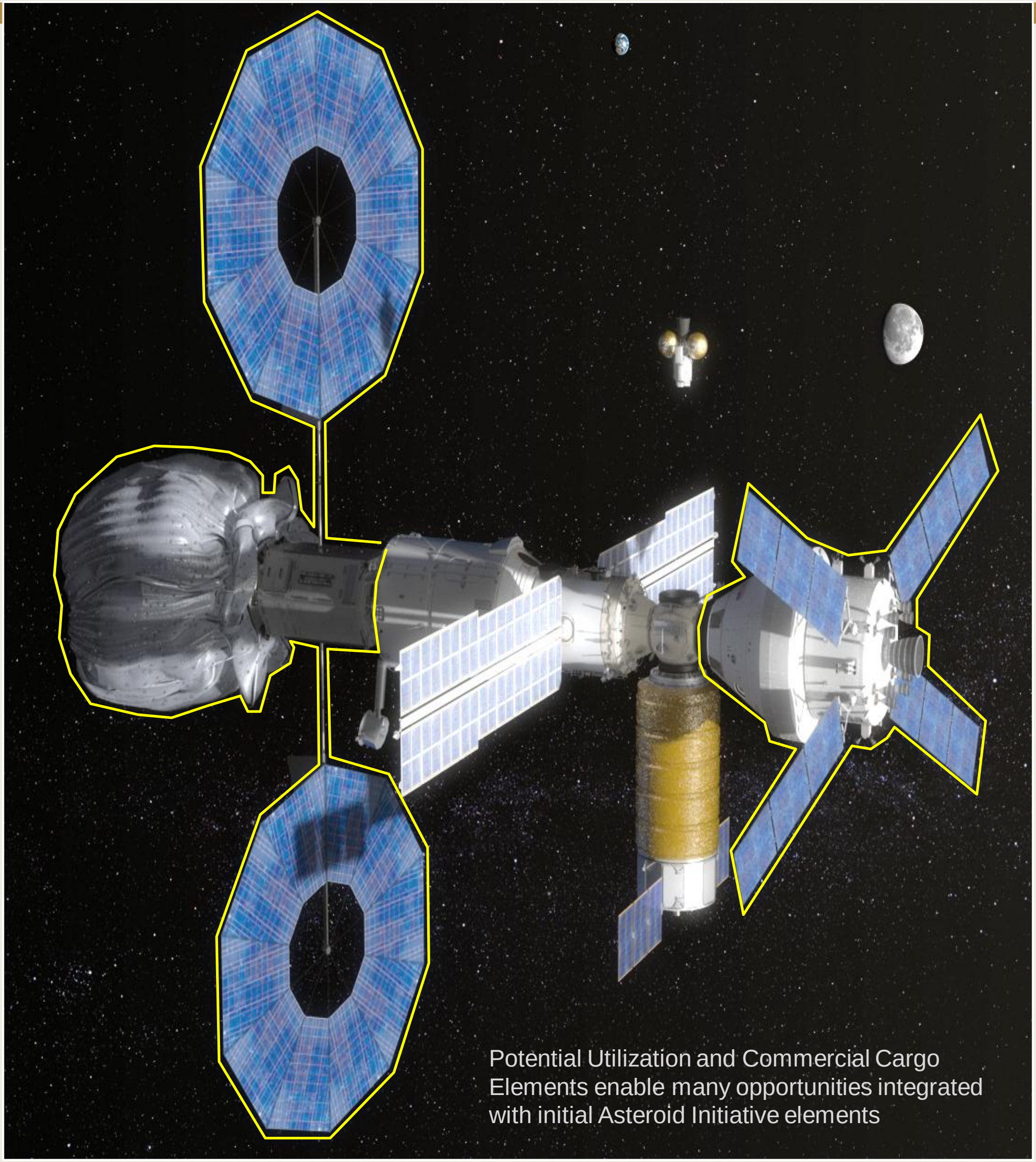


# Notional ARM Derived Phobos Mission



# Further Utilization Enables Broader Participation to Achieve Exploration Goals

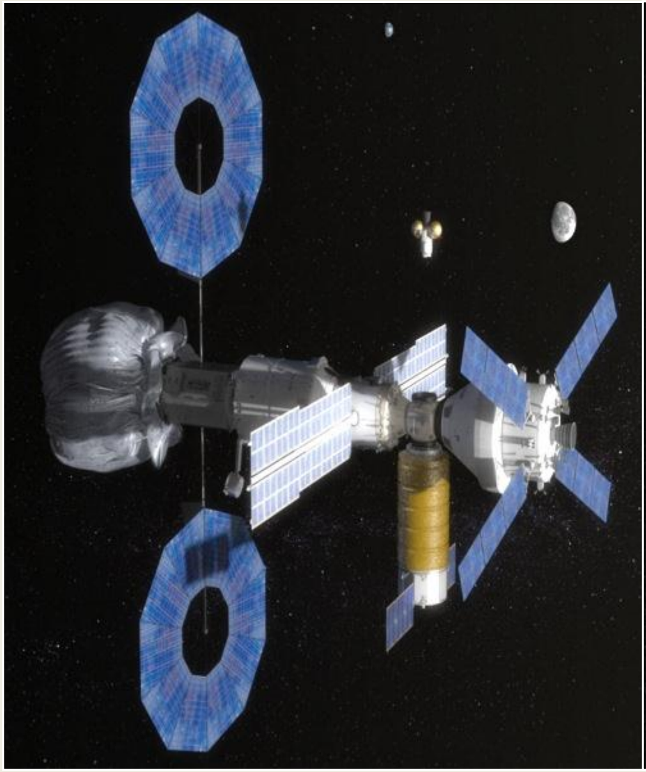
- Many possible opportunities for further utilization of the Asteroid
  - Testing of anchoring techniques
  - In-situ Resource Utilization (ISRU) Demonstration
  - Additional Asteroid Sample Collection
  - Lunar and Mars sample return
  - Scientific Experiments
  - Many other possibilities
- Realization of these opportunities requires additional payload delivery resources
  - Extending Commercial opportunities beyond low Earth orbit
  - Opportunity for International Partner Contributions
- Addition of utilization elements provide:
  - Extended crewed mission duration and additional EVA capability
  - Enhance crew safety with more robust systems and infrastructure



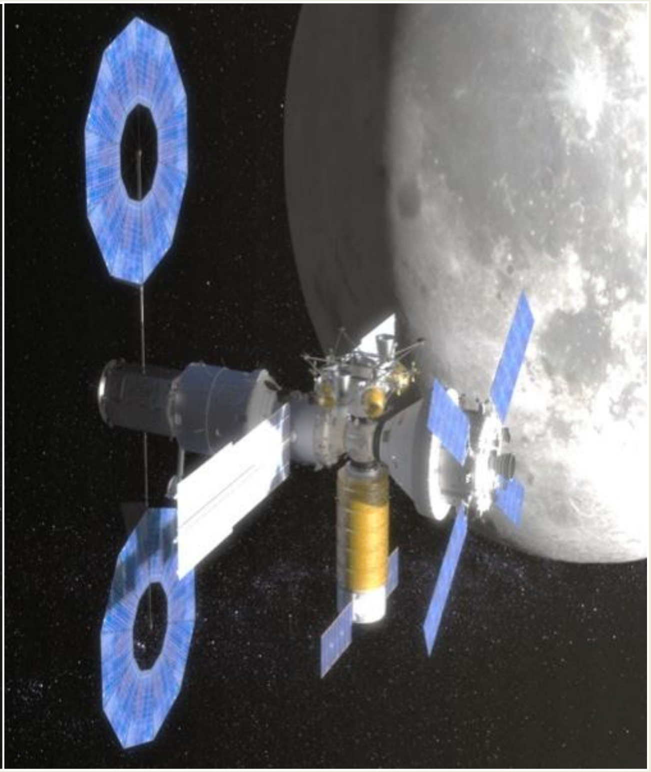

Moon size in image not to scale

Initial Asteroid Initiative Elements

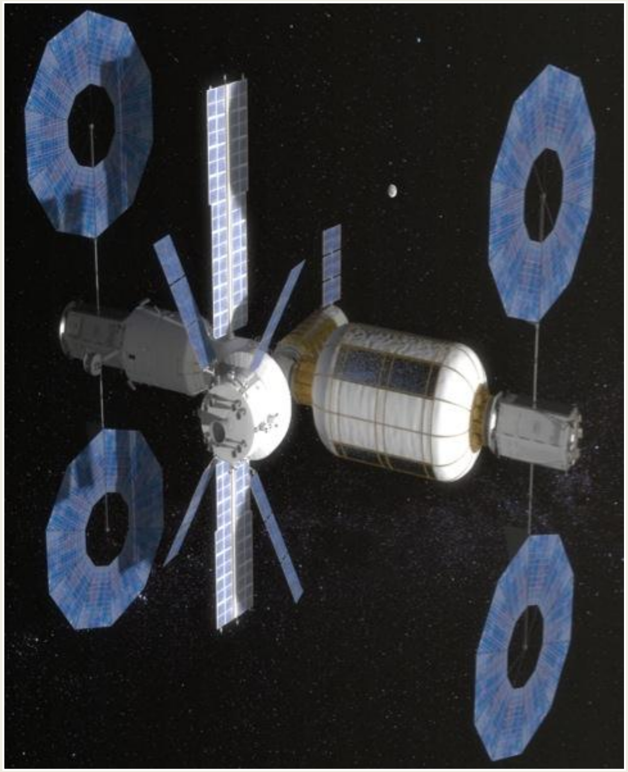
# Asteroid Redirect Mission Builds upon Orion/SLS to enable Global Exploration Roadmap



**Asteroid Exploitation Missions**



**Lunar Vicinity Missions**



**Deep Space Missions**

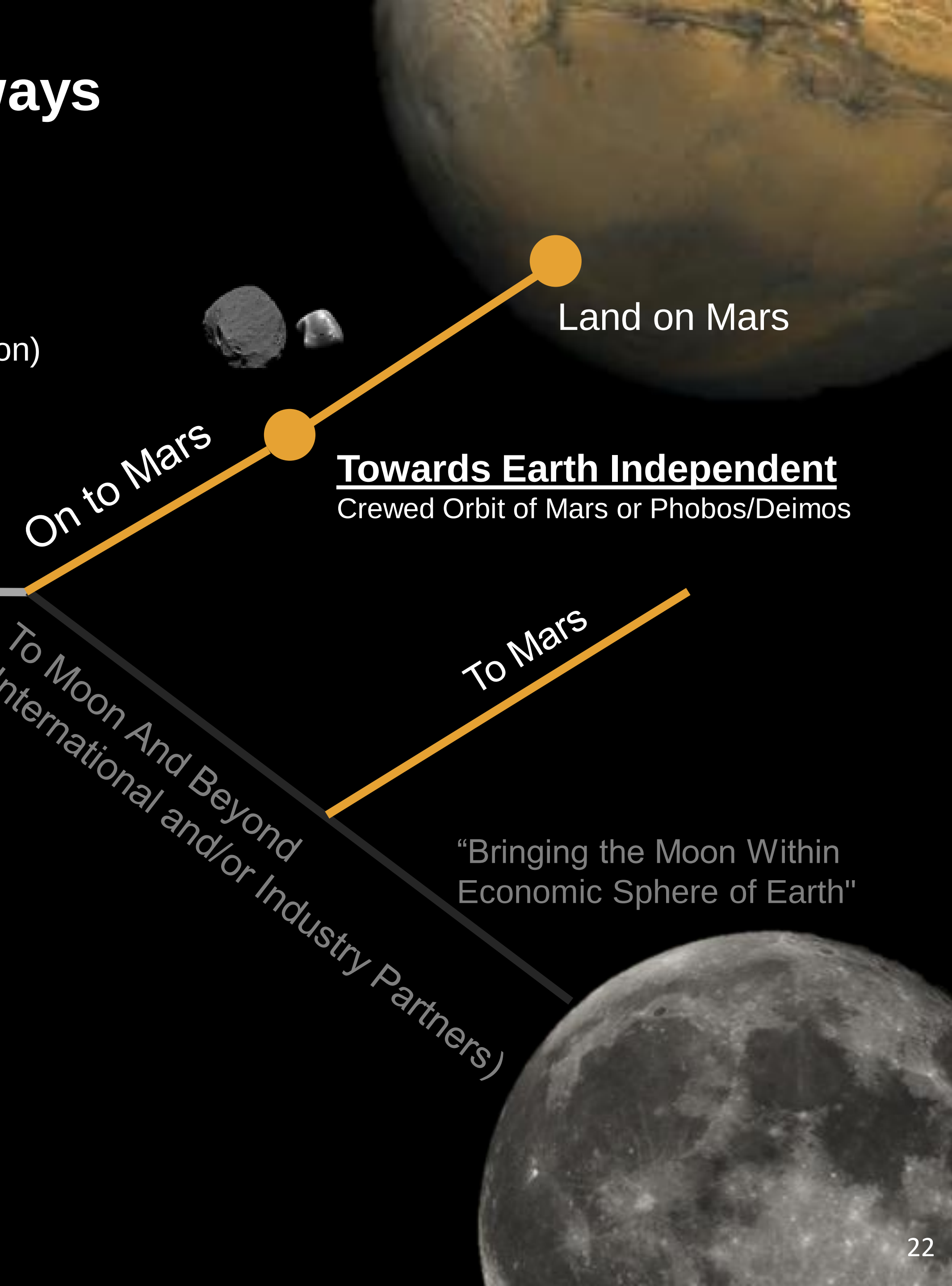
# Human Exploration Pathways

## Mastering the Fundamentals

- Extended Habitation Capability (ISS)
  - High Reliability Life Support
- Deep-space Transportation (SLS and Orion)
- Exploration EVA
- Automated Rendezvous & Docking
- Docking System

## Pushing the Boundaries

- Deep Space Operations
  - Deep Space Trajectories
  - Deep Space Radiation Environment
  - Integrated Human/Robotic Vehicle
- Advanced In-Space Propulsion (SEP)
  - Moving Large Objects
- Exploration of Solar System Bodies



# ISS and ARM Provides First Steps to Mars

| | Sequence \ Mission | Current ISS Mission | Asteroid Redirect Mission | Long Stay In Deep Space | 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 Cryogenic Upper 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 | * → | → | X | X | X | X |
| | High Reliability Life Support | * → | → | X | X | X | X |
| | Autonomous Assembly | * → | → | X | X | X | X |

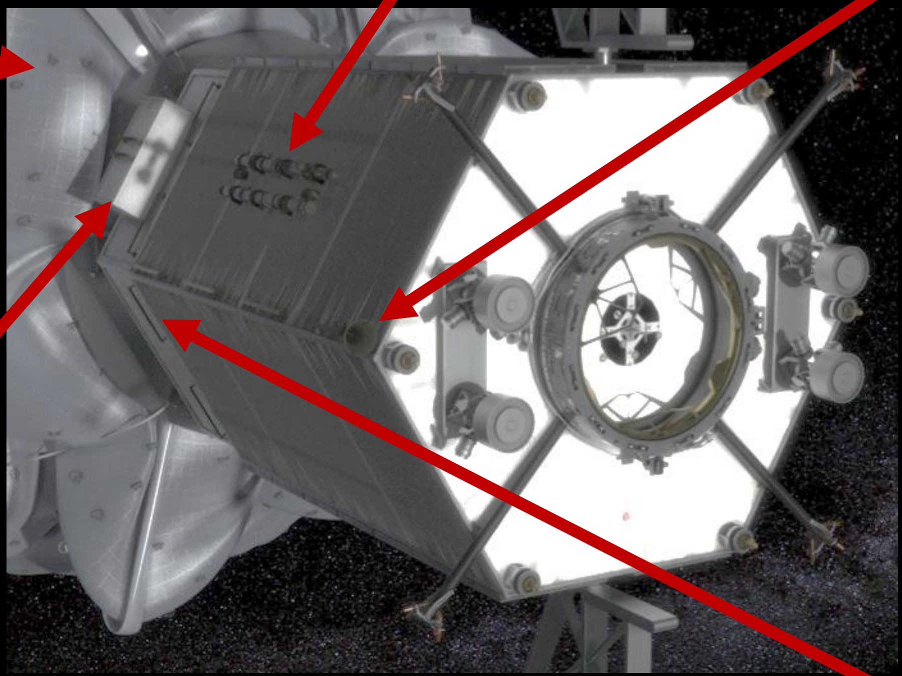
# Back-Up

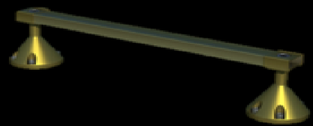
# EVA Accommodations for Crewed Mission

**EVA Tether Points**
- Hand-over-hand translation
- Temporary restraint of tools
- Management of loose fabric folds

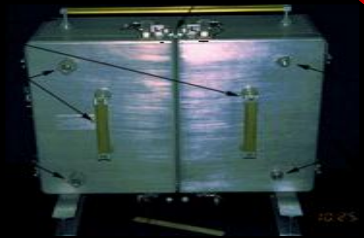
**EVA Translation Booms**
- Translation Booms for Asteroid EVA

**EVA Translation Attach Hardware**
- Circumference of Mission Module at base of Capture System and ARRV-Orion Interface



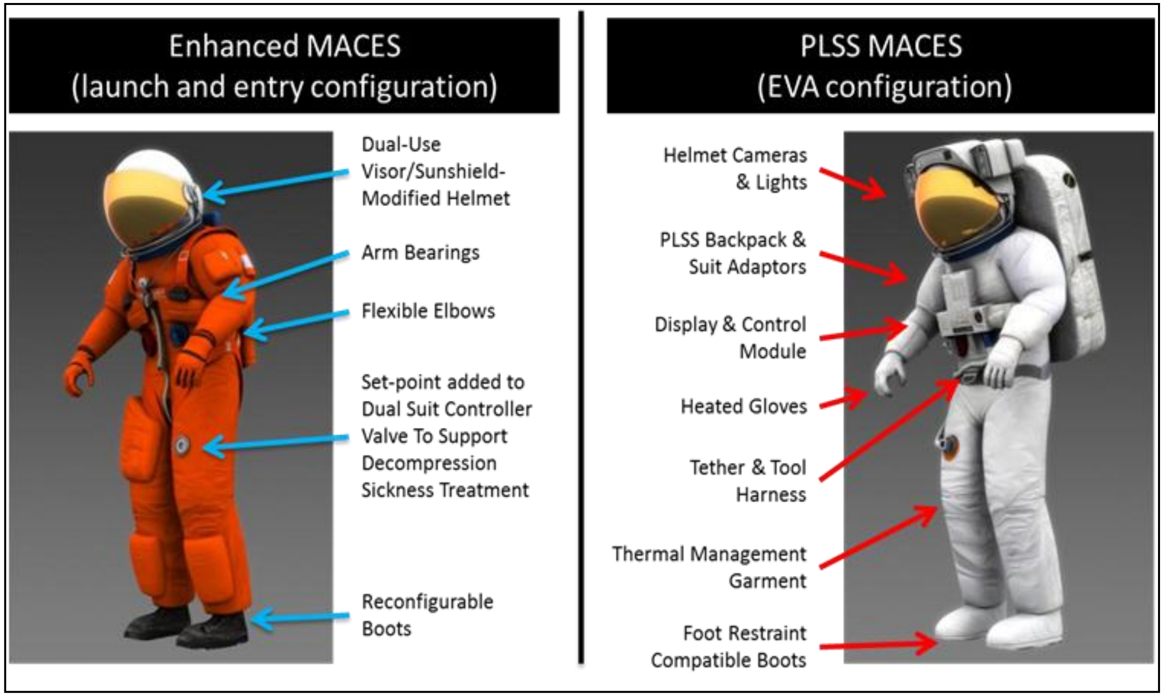


**Pre-positioned EVA Tool Box**
- Tool box to offset Orion mass (85kg tools)



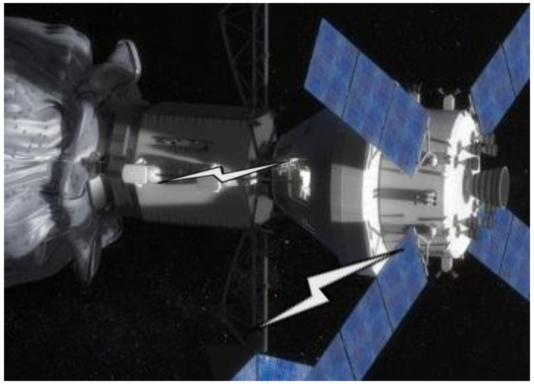
**Hand Rails**
- Translation path from aft end of ARRV to capture bag
- Ring of hand rails around ARRV near capture bag

# Mission Kit Concept Enables Affordable Crewed Mission

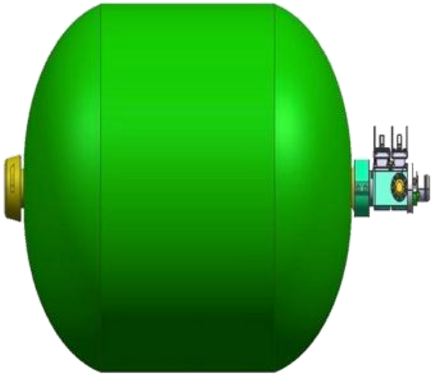



**Tools & Translation Aids**


**Sample Container Kit**



**EVA Communications Kit**



**Repress Kit**