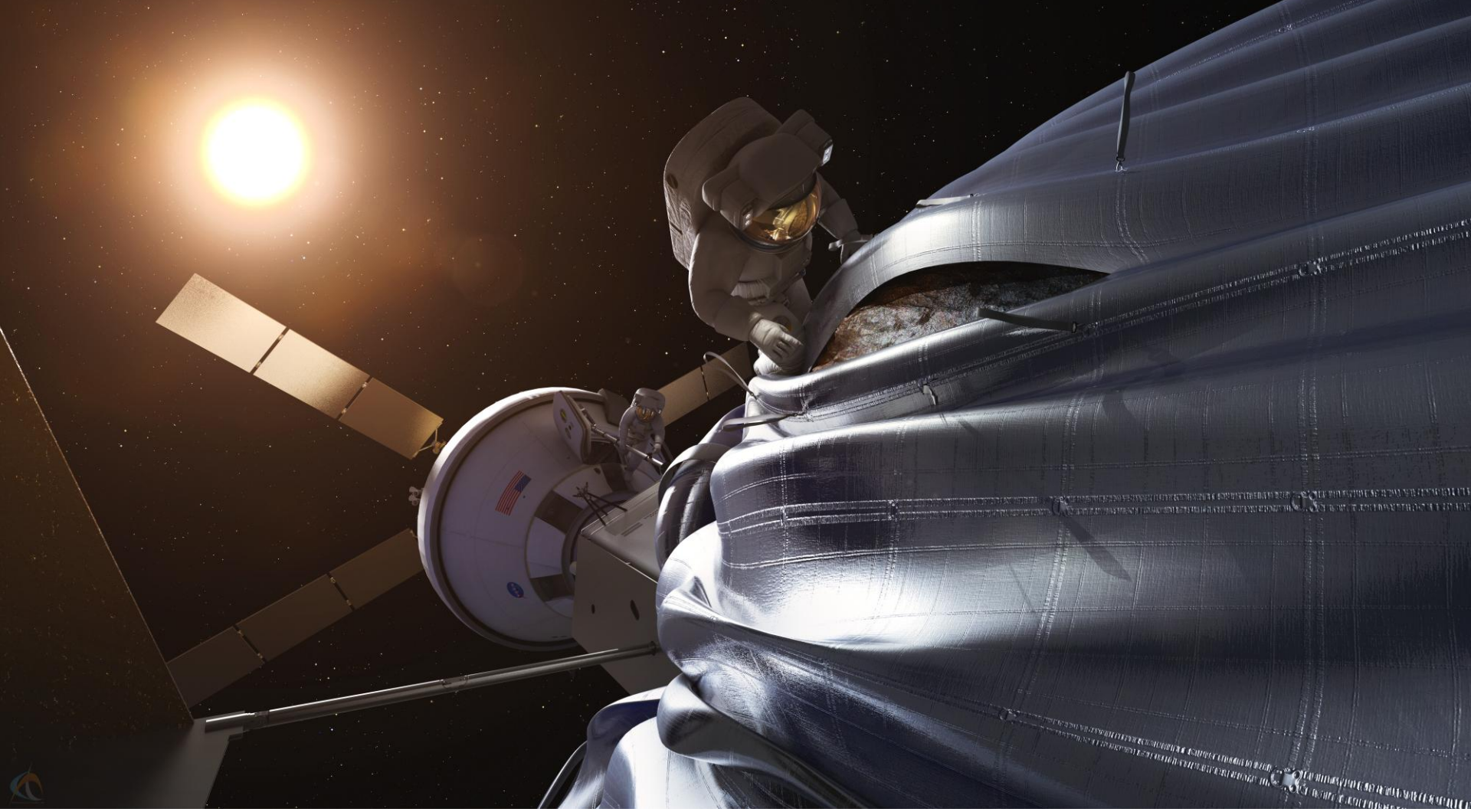


Asteroid Redirect Mission and Human Space Flight

Briefing to National Research Council

Committee for Study on Human Space Flight Technical Panel

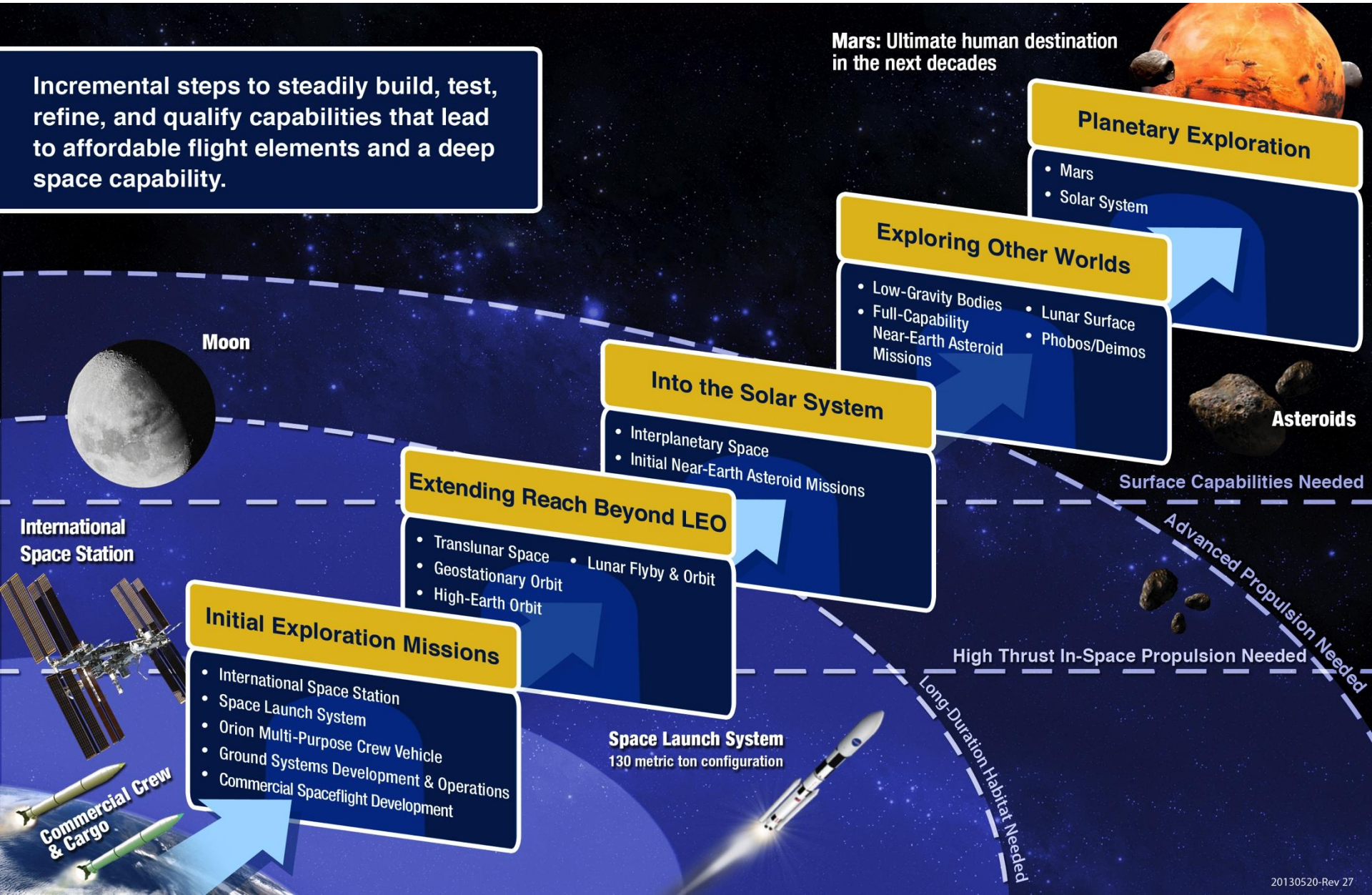
Steve Stich- Deputy Director JSC Engineering

June 19, 2013

Leveraging Capabilities for an Asteroid Mission

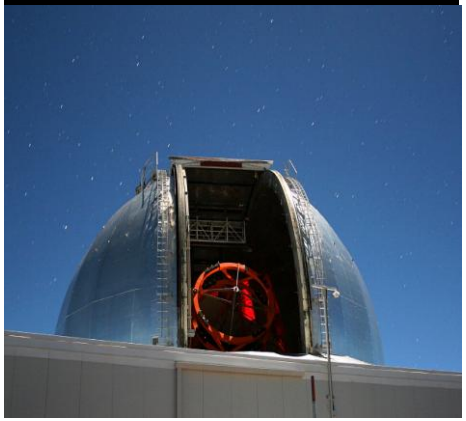
- **NASA is aligning key activities in Science, Space Technology, and Human Exploration and Operations Mission Directorates**
  - Asteroid Identification and Characterization efforts for target selection
  - Solar Electric Propulsion for transport to and return of the target asteroid
  - Autonomous guidance and control for proximity operations and capture
  - SLS and MPCV missions for asteroid rendezvous
  - EVA technologies
- **Each individual activity provides an important capability in its own right for human and robotic exploration**
- **We are working to utilize all of these activities to**
  - Identify, capture and redirect a small NEA; and
  - Investigate and return samples with our astronauts using the Orion and Space Launch System assets.
- **The FY14 budget supports continued advancement of the important individual elements and furthers the definition of the overall potential mission.**

Capability Driven Framework



Overall Mission Consists of Three Main Segments

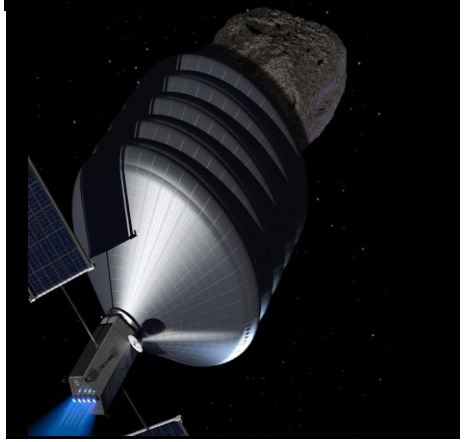
Identify



Asteroid Identification Segment:

Ground and space based NEA target detection, characterization and selection

Redirect



Asteroid Redirection Segment:

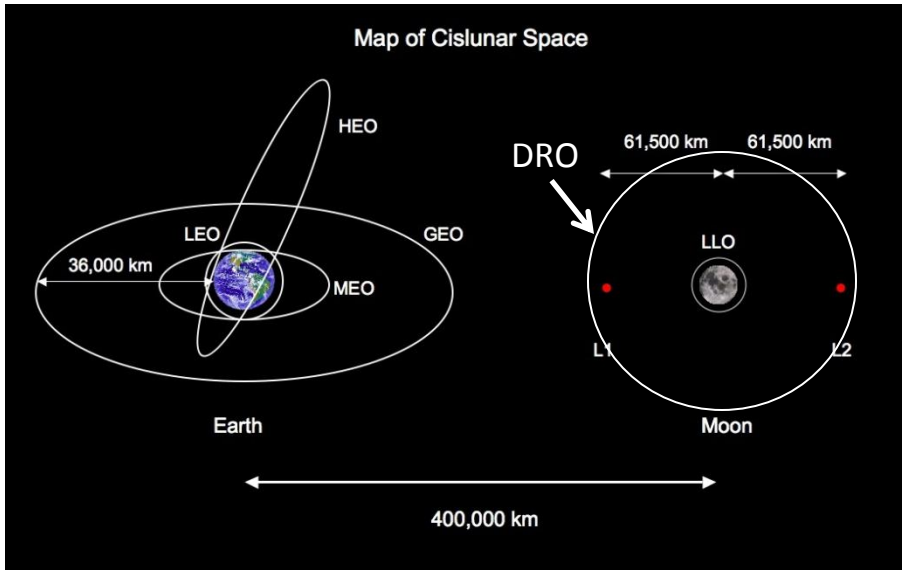
Solar electric propulsion (SEP) based robotic asteroid redirect to trans-lunar space

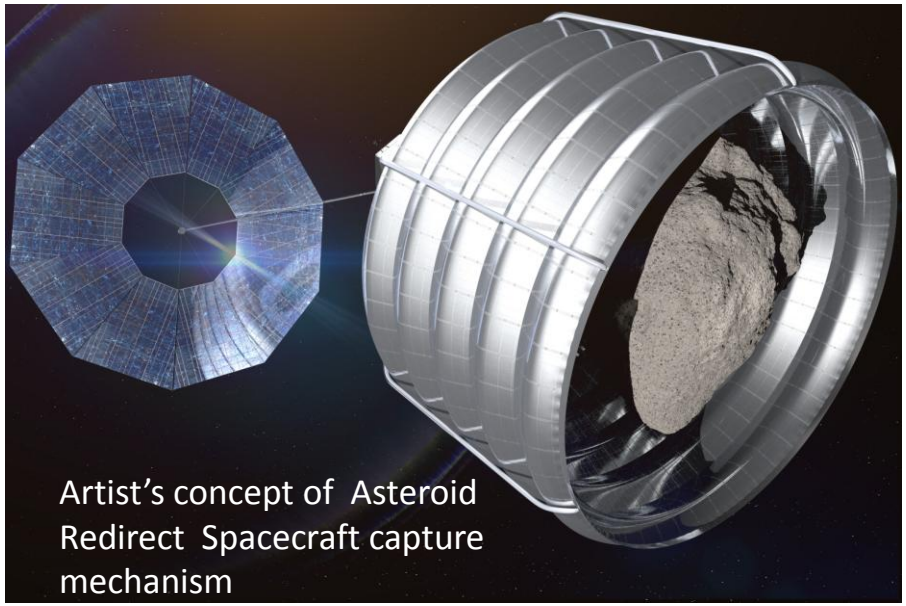
Explore

Asteroid Crewed Exploration Segment:

Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid

Asteroid Capture & Redirect Reference Mission Concept



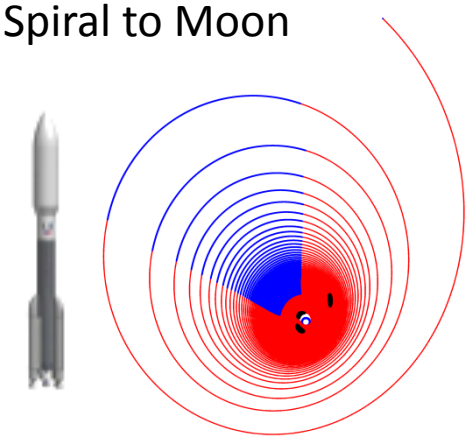


- **Capture and redirect a 7-10 meter diameter, ~500 ton near-Earth asteroid (NEA) to a stable orbit in trans-lunar space known as a Distant Retrograde Orbit (DRO)**
- **Enable astronaut missions to the asteroid using Orion as early as 2021**
- **Parallel and forward-leaning development approach**

Reference Mission Design Executive Summary

1. Launch (2 Options)

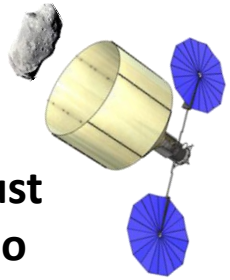
1a. *Atlas V* – Low Thrust Spiral to Moon



1b. *SLS or Falcon Heavy* – Direct Launch to Moon or to Asteroid

2. Lunar Flyby to Escape
(If Needed)

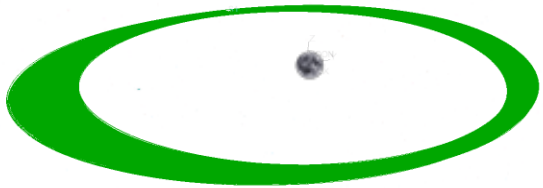
3. Low Thrust Trajectory to Asteroid

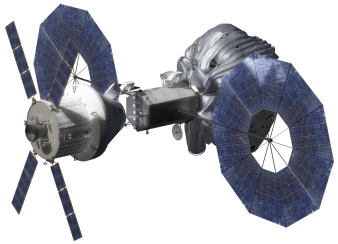


4. Low Thrust Trajectory with Asteroid to Earth-Moon System

5. Lunar Flyby to Capture

6. Low Thrust Trajectory to Storage Orbit





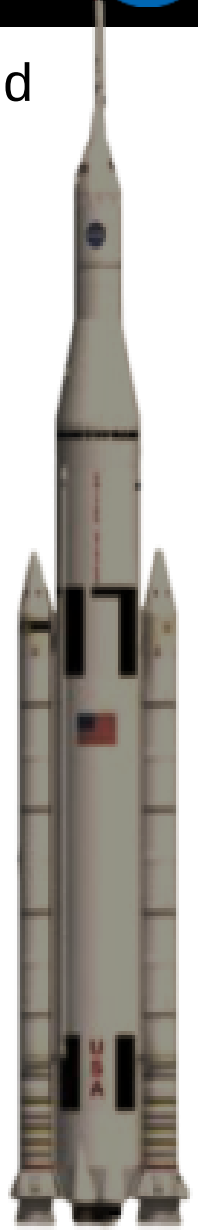
7. MPCV Rendezvous

Reference Mission Feasibility Study Initial Results

- **A short list of candidate asteroids that potentially meet target requirements (size, mass, spin-state and know orbits with return dates in the early 2020's) have been identified. All require further observation.**
- **Very small asteroids (<10m) are difficult to detect, track and characterize.**
  - NASA's Near Earth Object Observation Program plans to enhance ground-based observation capabilities for potential near-term detection rate increase to several/year
  - Assured target detection and characterization of such small asteroids may require space-based capabilities
- **SEP technologies currently under development for future exploration are enabling for the robotic redirect mission.**
- **Among options for asteroid locations within the earth-moon system, we have established the lunar Distant Retrograde Orbit (DRO) as a reference**
  - Long-term stability (> 100 years) and SLS – Orion accessible
  - 22-25 day nominal Orion mission
- **The addition of mission "kits" for the Orion vehicle appear to enable asteroid exploration and sampling.**
- **No show stoppers for mission feasibility have emerged.**

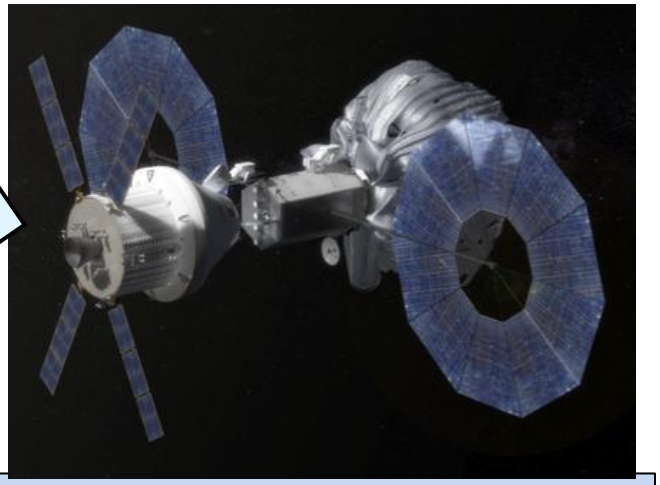
Asteroid Redirect Human Mission Design Philosophy

- Perform sample return mission in two launches: Asteroid Redirect Robotic Spacecraft and Orion/SLS with Crew
- Minimize changes to Orion design for EM-2 Mission
- No changes to SLS Block 1 Design
- Affordability key consideration in every design trade
- Develop additional Orion mission hardware in add on kits
  - Lightweight EVA Suit/Primary Life Support System
  - EVA Tools & Translation Aids
  - Sample Container
  - EVA Communications
  - Relative Navigation Sensor System
  - Grapple Arm or Docking Kit (Option Under Assessment)
- Utilize robotic spacecraft for Extra-Vehicular Activity (EVA) augmentation (e.g. tool stowage, handholds)
- Provide capabilities that enhance future exploration goals



Explore: Orion Mission Overview

Deliver Crew in Orion

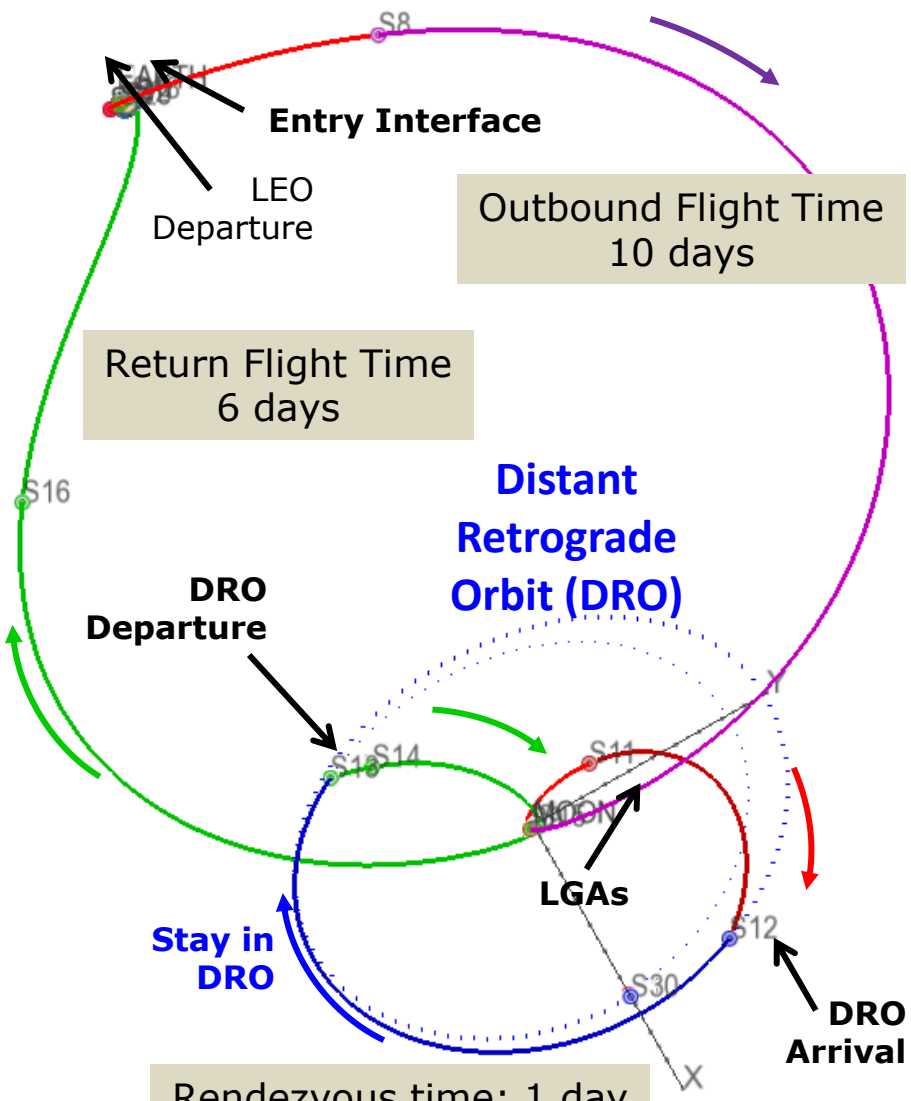


Attach Orion to robotic spacecraft

Perform Extra- Vehicular Activity (EVA) to retrieve asteroid samples

Return crew safely to Earth with asteroid samples in Orion

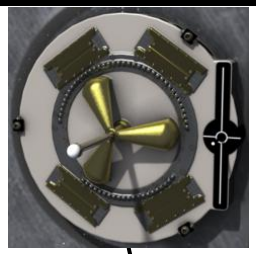
Nominal Orion Mission Summary



- **Outbound**
  - **Flight Day 1 – Launch/Trans Lunar Injection**
  - **FD 2-FD 5 – Outbound Trans-Lunar Cruise**
  - **FD 6 – Lunar Gravity Assist (LGA)**
  - **FD 7-FD 9 – LGA to DRO Cruise**
- **Joint Operations**
  - **FD 10 – Rendezvous**
  - **FD 11 – EVA #1**
  - **FD 12 – Suit Refurbishment, EVA #2 Prep**
  - **FD 13 – EVA #2**
  - **FD 14 – Contingency/Departure Prep**
  - **FD 15 – Departure**
- **Inbound**
  - **FD 16 – DRO to Lunar Cruise**
  - **FD 17 – Lunar Gravity Assist (LGA)**
  - **FD 18-FD21 – Inbound Trans-Lunar Cruise**
  - **FD22 – Earth Entry and Recovery**

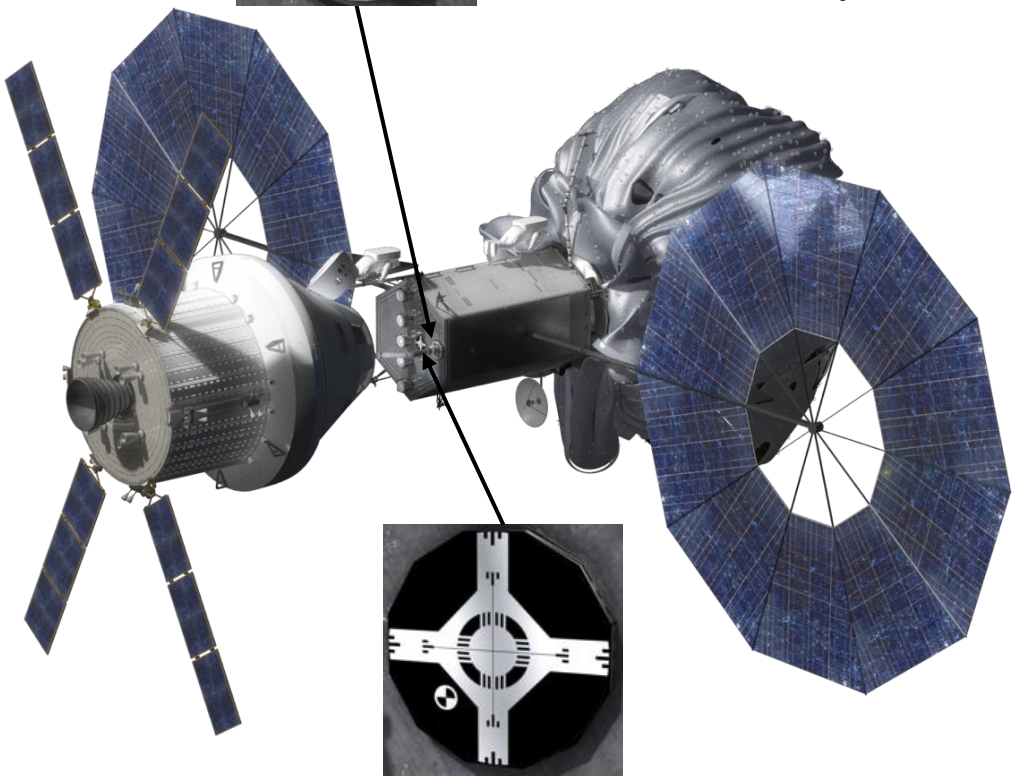
Mission Duration and timing of specific event will varying slightly based on launch date.

Notional Design For Grapple: Robotic Spacecraft



Grapple Fixture

- Orion approaches to berthing box,
- Orion grapple arm aligns to grapple fixture and captures the robotic spacecraft



Docking Target

- Augmented with features for relative navigation sensors
- Visual cues for crew monitoring

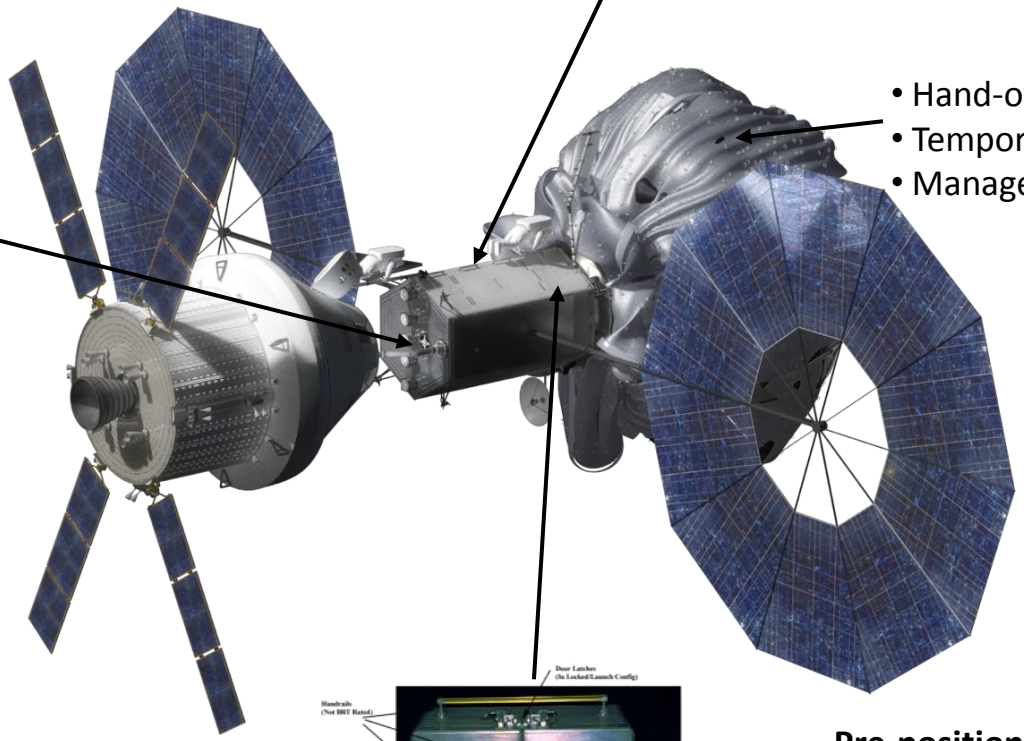
Notional Design for EVA: Robotic Spacecraft

Translation Boom and Attach Hardware

- Translation from Orion to spacecraft
- Translation from spacecraft to capture device bag for asteroid access

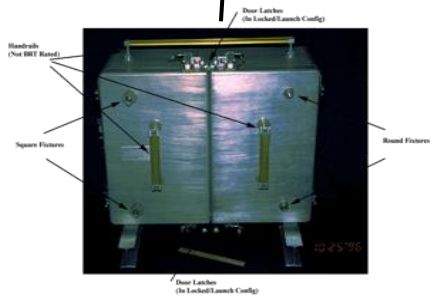
Hand Rails

- Translation path from aft end of spacecraft to capture device
- Ring of hand rails around spacecraft near capture device



EVA Tether Points

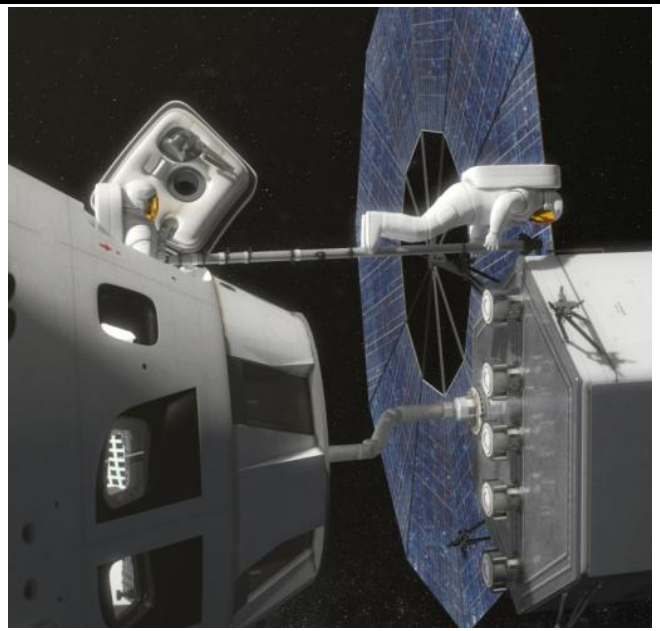
- Hand-over-hand translation
- Temporary restraint of tools
- Management of loose fabric folds

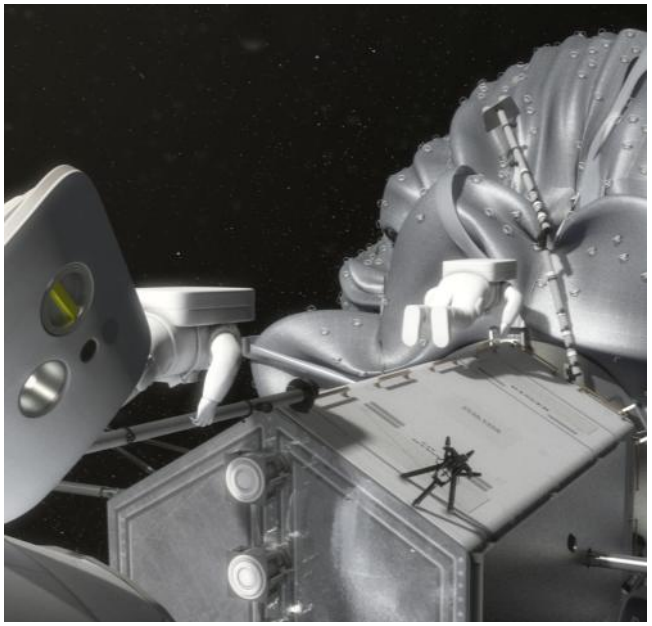


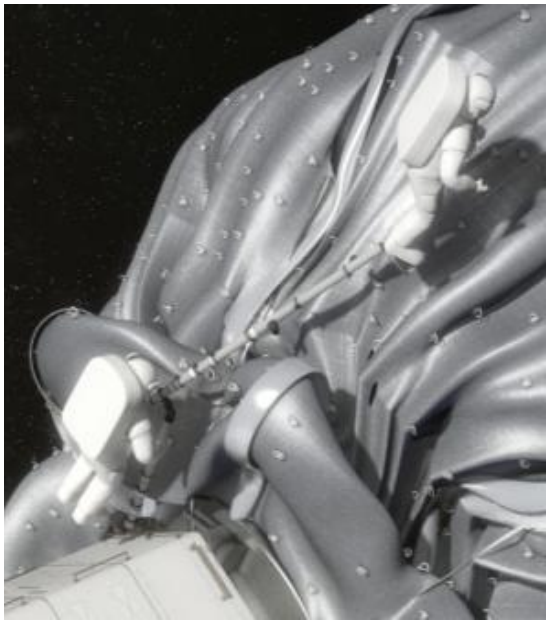
Pre-positioned EVA Items

- Tool box to offset mass in Orion
- Two additional translation booms

Notional EVA Operations From Orion







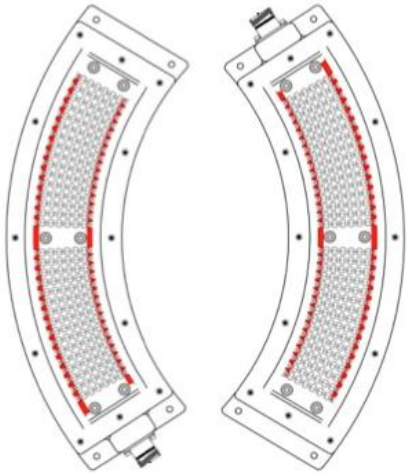
- Two EVAs executed from Orion
- Crew translates from Orion to robotic spacecraft
- EVA Tool box prepositioned on spacecraft
- Telescoping booms pre-stowed on spacecraft
- Crewmember stabilized on Portable Foot Restraint for Worksite
- Loops available on Capture Mechanism Bag for additional stabilization

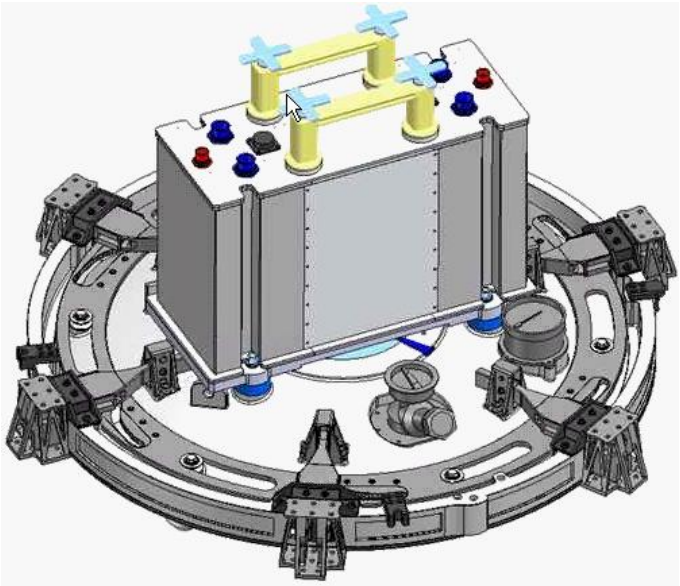
Notional Rendezvous/Prox Ops Sensor Kit

- Rendezvous, proximity operations and capture sensor consists of the Vision Navigation Sensor (VNS) and Docking Camera (DC) rolled into a single package called Laser Optical Camera Instrument (LOCI)
  - Mounted to the interior side of docking hatch by crew prior to AR&D operations
  - VNS and DC tested on STS-134 Space Shuttle Mission in STORRM DTO
- Docking Lights
  - Mounted to exterior of docking hatch, encompassing docking hatch window perimeter


LOCI mockup

Relative Navigation		Qty	Rate (kg)	Subtotal
LOCI	Vision Navigation System	2	13	26.0
	Docking Camera	2	1	2.0
	Sensor cabling/connectors	1	10	10.0
Lights	Docking light	2	2	4.0
	Docking light power cable	1	2	2.0
	Total Loading			**44.0** kg


Docking Lights assembly


LOCI mounted to docking hatch

Orion Stowed EVA Tools Kit

- EVA tools launched on Orion
  - Required for contingency EVA
  - Needed for Orion egress
  - Sensitive hardware which might not survive long duration
  - Unique geological tools designed and added to manifest after asteroid capture
- All other EVA tools launched on robotic spacecraft

Safety Tether, Waist Tether, Retractable, Adjustable

Boom and ORU bag

Description	Mass (kg)
Suit-Worn EVA Tools (Unit x 2 Suits)	
85' Safety Tether	7.2
2 Waist Tethers	4.0
Equipment Tethers	3.6
Mission EVA Tools (Stowed In Orion)	
Boom mounting bracket	2.0
Boom	13.6
Geological Tools Allocation	13.6
ORU Bags	6.8
Misc. support Equipment (Stowage, battery chargers, PLSS Checkout, Drink Bags, Etc.)	39.2
Total	**90.0**

Asteroid Redirect Mission Alignment with Human Spaceflight Strategic Principles

1. Executable with current *budget with modest increases.*
2. Application of *high Technology Readiness Level* components and systems for near term missions
3. *Near-term mission* opportunities with a defined cadence of compelling missions

   -Build incremental capabilities for more complex missions over time

4. Opportunities for *US Commercial Business* to further enhance experience and business base
5. *Multi-use* Space Infrastructure when possible
6. Significant *International participation*, leveraging current International Space Station partnerships

Elements Required By Potential Destination

Phase	Capability	Potential Required Element	For Potential Destinations			
			Translunar	Asteroid	Mars Orbit / Moons	Mars Surface
Getting There	BEO Access	**Space Launch System (SLS)**	X	X	X	X
	Crew	**Orion**	X	X	X	X
	High Thrust/Near Earth	**Cryo Propulsion Stage (CPS)**	X	X	Option	Option
	Low Thrust/Near Earth	**Solar Electric Propulsion (SEP)**	Option	Option	Option	Option
	High Thrust/Beyond LEO	**Nuclear Thermal Propulsion (NTP)**	Option	Option	Option	Option
	Low Thrust/Beyond LEO	**Nuclear Electric Propulsion (NEP)**	Option	Option	Option	Option
	Habitation	**Habitat**	Option	Option	X	X
	Descent	**EDL / Landers**				X
Working There	Habitation	**Habitat**				X
	Micro-g Sortie and Surface Mobility	**Robotics and Mobility**		X	Option	X
	In Situ Resource Utilization	**In-Situ Resource Utilization (ISRU)**				X
	Surface Power	**Fission Surface Power System**				X
	EVA (nominal)	**EVA Suits**	X	X	X	X
Coming Home	Ascent	**Ascent Vehicle**				X
	Crew Return	**Orion**	X	X	X	X

Note:

X – Required Elements/Capabilities for these potential destinations

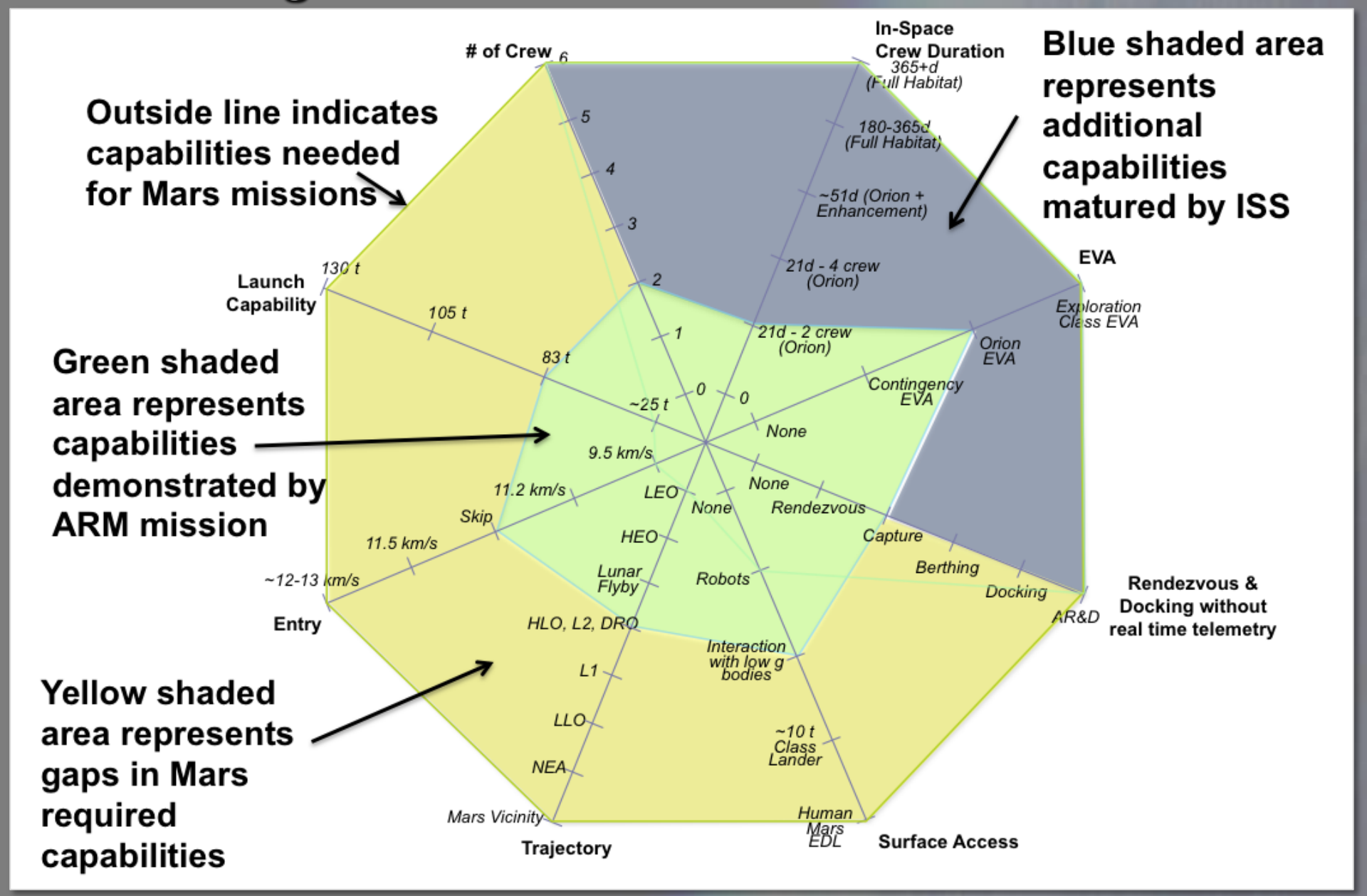
Option – Element/Capability may be needed or multiple options could exist to enable missions for that specific potential destination or could be for verification for future needs.

- Early builds of circled elements utilized in Asteroid Redirect Mission

Asteroid Mission Supports Long-Term Human Mars Exploration Strategy

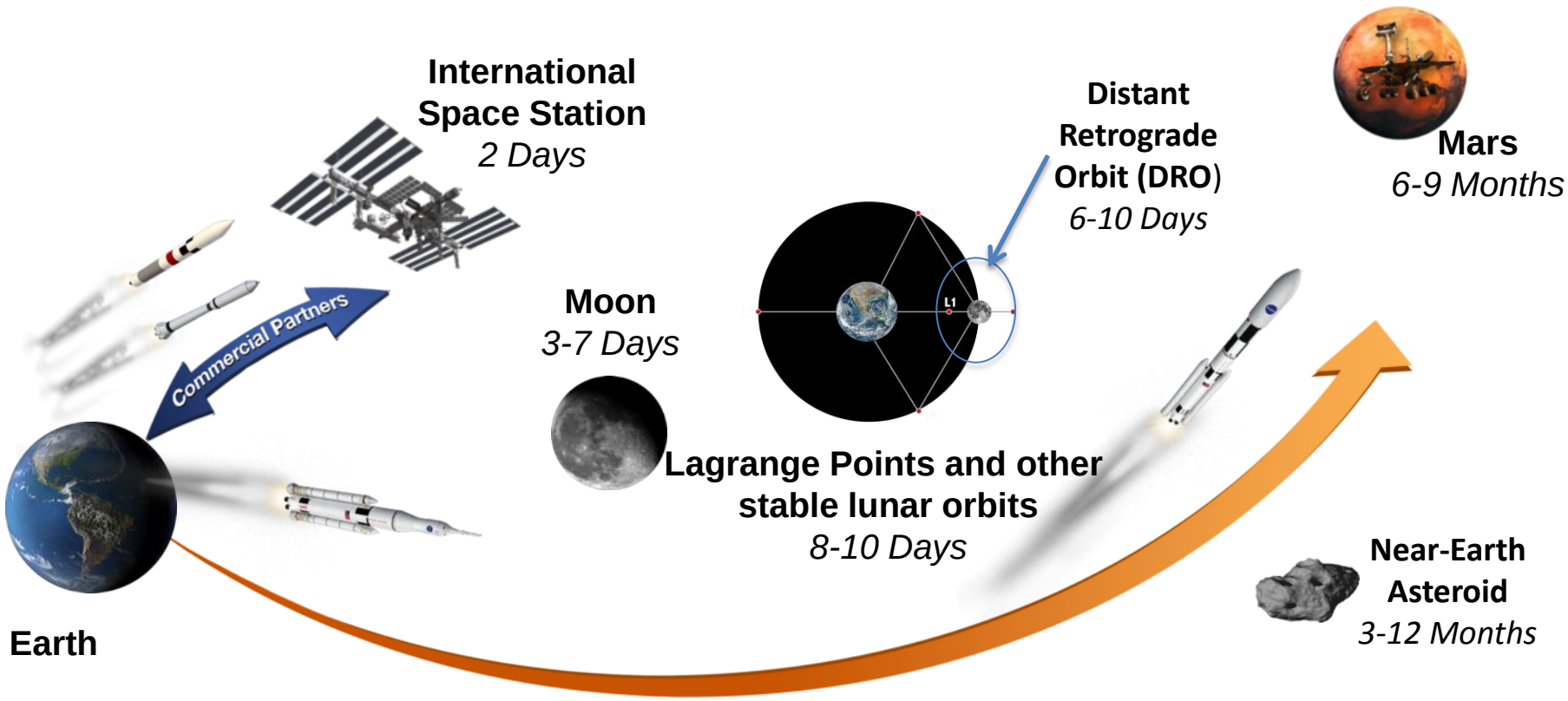
- Demonstration of Core Capabilities for deep space missions:
  - Block 1 SLS, Orion
  - 40kW Solar Electric Propulsion System
  - EVA, rendezvous, proximity operations, docking or grapple, deep space navigation and communications
  - Human operations and risk management beyond low earth orbit
  - Sample acquisition, caching, storage operations, and crew transfer operations for future Lunar/Mars sample return missions
- Demonstrates ability to work and interact with a small planetary body:
  - Systems for instrument placement, sample acquisition, material handling, and testing
  - Understanding of mechanical properties, environment, and mitigation of hazards

Mars Exploration Capability Build-Up Using Asteroid Redirect Mission and ISS



The Future of Human Space Exploration

Exploration Destinations and One-Way Transit Times



Asteroid Redirect Mission benefits near term exploration objectives for carrying humans further into space than ever before while providing the building blocks for even more ambitious future missions to Mars

Recent and Next Steps

- **June 18: Asteroid Initiative Industry and Partner Day**
  - Open invitation, including international
  - Communication of what we are doing, discussion, and engagement plans
- **June 18: Request for Information Release**
- **July 9: Target NEO 2 Workshop**
  - Workshop sponsored by SBAG and others in planetary science community to assess the challenges with very small asteroid detection, characterization and science
- **July 18: RFI Response Date**
- **July 30: Mission Formulation Review**
  - Continued pursuit of overall mission
  - Planning content for budget process
  - Decisions on path forward: content, structure, Center assignments, supporting Center assignments, make-or-buy planning, impact on the workforce
- **Sept TBD: Mission Open Ideas Event/Workshop**
  - RFI Input Synthesis
  - Input to Mission Planning