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
  – Orion and Space Launch System (SLS) missions for asteroid rendezvous
  – Technologies for astronaut extra-vehicular activities

• 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 and redirect a small asteroid to a stable orbit in the lunar vicinity; and
  – Investigate and return samples with our astronauts using the Orion and SLS assets.

• The FY14 budget supports continued advancement of the important individual elements and furthers the definition of the overall potential mission.
Overall Mission Consists of Three Main Segments

Asteroid Identification Segment:
Ground and space based NEA target detection, characterization and selection

Asteroid Redirection Segment:
Solar electric propulsion (SEP) based robotic asteroid redirect to trans-lunar space

Asteroid Crewed Exploration Segment:
Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid
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. Orion Rendezvous
Explore: Orion Mission Overview

Deliver Crew in Orion

Attach Orion to robotic spacecraft

Return crew safely to Earth with asteroid samples in Orion

Perform Extra-Vehicular Activity (EVA) to retrieve asteroid samples
Nominal Orion Mission Summary

- **Outbound**
  - Flight Day 1 – Launch/Trans Lunar Injection
  - FD2-FD5 – Outbound Trans-Lunar Cruise
  - Flight Day 6 – Lunar Gravity Assist (LGA)
  - FD7-FD9 – Post LGA to DRO Cruise

- **Joint Operations with Robotic Spacecraft**
  - Flight Day 10 – Rendezvous/Grapple
  - Flight Day 11 – EVA #1
  - Flight Day 12 – Suit Refurbishment, EVA #2 Prep
  - Flight Day 13 – EVA #2
  - Flight Day 14 – Contingency Day/Departure Prep
  - Flight Day 15 – Departure from DRO

- **Inbound**
  - Flight Day 16 – DRO to Lunar Cruise
  - Flight Day 17 – Lunar Gravity Assist
  - FD18-FD21 – Inbound Trans-Lunar Cruise
  - Flight Day 22 – Earth Entry and Recovery

Note: Mission Duration Varies From 22-25 Days
Notional EVA Operations From Orion

- Two EVAs executed from Orion
- Crew translates from Orion to robotic spacecraft
- EVA Tool box prepositioned on robotic spacecraft
- Telescoping booms pre-stowed on robotic spacecraft
- Crewmember stabilized on portable foot restraint for worksite
- Loops available on capture mechanism for additional stabilization
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
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
Incremental steps to steadily build, test, refine, and qualify capabilities that lead to affordable flight elements and a deep space capability.
Mars Exploration Capability Build-Up Using Asteroid Redirect Mission and ISS

Outside line indicates capabilities needed for Mars missions.

Green shaded area represents capabilities demonstrated by ARM mission.

Yellow shaded area represents gaps in Mars required capabilities.

Blue shaded area represents additional capabilities matured by ISS.

Launch Capability

In-Space Crew Duration
- 365+d (Full Habitat)
- 180-365d (Full Habitat)
- ~51d (Orion + Enhancement)

# of Crew
- 6

Entry

11.5 km/s

11.2 km/s

105 t

83 t

9.5 km/s

~25 t

None

None

Rendezvous

Capture

Berthing

Docking

AR&D

130 t

105 t

Interaction with low g bodies

HLO, L2, DRO

L1

LLO

NEA

Mars Vicinity

Surface Access

Human Mars EDL

~10 t Class Lander

~10 t

21d - 2 crew (Orion)

21d - 4 crew (Orion)

Contingency EVA

Orion EVA

Exploration Class EVA

EVA

Rendezvous & Docking without real time telemetry