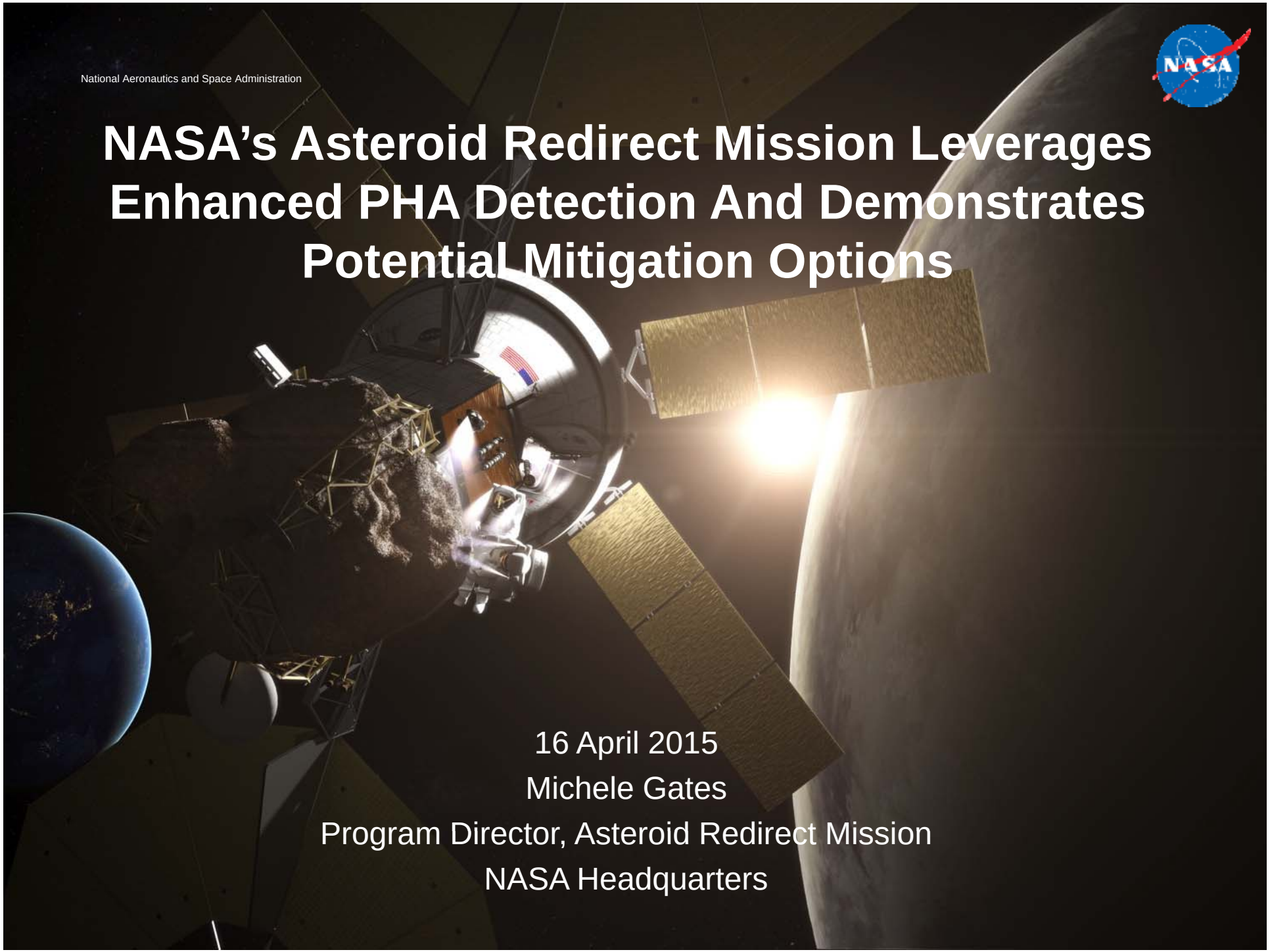
National Aeronautics and Space Administration

NASA's Asteroid Redirect Mission Leverages Enhanced PHA Detection And Demonstrates Potential Mitigation Options



16 April 2015

Michele Gates
Program Director, Asteroid Redirect Mission
NASA Headquarters

Asteroid Redirect Mission: Three Main Segments

IDENTIFY

Ground and space based assets detect and characterize potential target asteroids


Pan-STARRS


NEOWISE

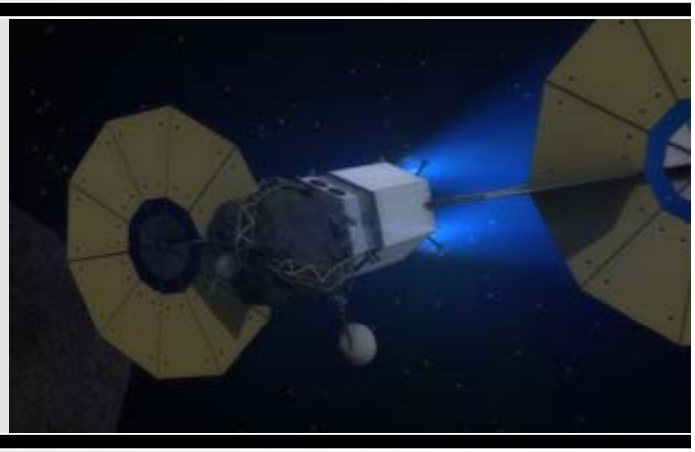

Goldstone


Arecibo


Infrared Telescope Facility

REDIRECT

Solar electric propulsion (SEP) based system redirects asteroid to cis-lunar space.

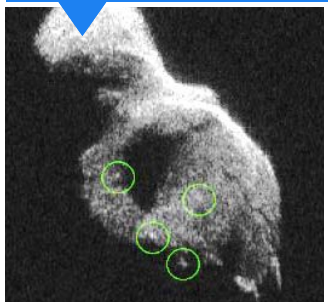


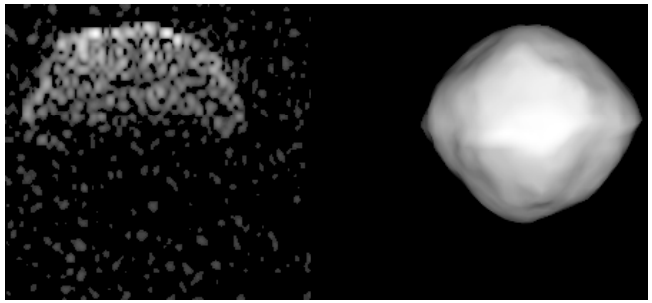
EXPLORE

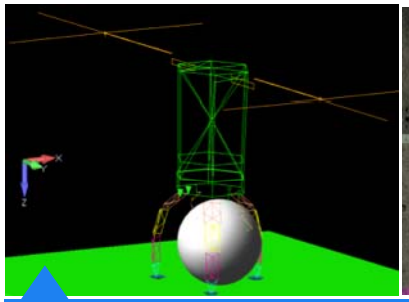
Crew launches aboard SLS rocket, travels to redirected asteroid in Orion spacecraft to rendezvous with redirected asteroid, studies and returns samples to Earth

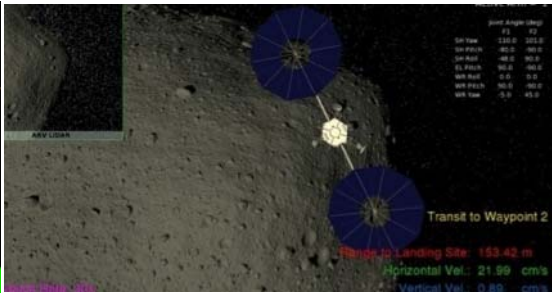
Asteroid Redirect Mission: 2014 Advancements

IDENTIFYING CANDIDATE ASTEROIDS



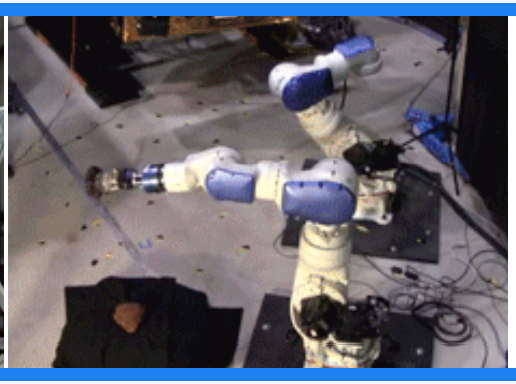






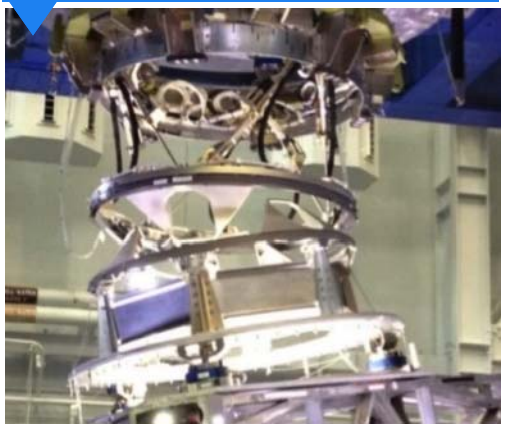
MISSION DESIGN AND SIMULATION OF CRITICAL MISSION OPERATIONS

PROTOTYPING AND TESTING CAPTURE OPTIONS



PROTOTYPING AND TESTING MODIFIED LAUNCH AND ENTRY SUIT

INTERNATIONAL DOCKING SYSTEM



SOLAR ELECTRIC PROPULSION

Objectives of Asteroid Redirect Mission

1. **Conduct a human exploration mission to an asteroid in the mid-2020's, providing systems and operational experience required for human exploration of Mars.**

2. **Demonstrate an advanced solar electric propulsion system, enabling future deep-space human and robotic exploration with applicability to the nation's public and private sector space needs.**

3. **Enhance detection, tracking and characterization of Near Earth Asteroids, enabling an overall strategy to defend our home planet.**

4. **Demonstrate basic planetary defense techniques that will inform impact threat mitigation strategies to defend our home planet.**

5. **Pursue a target of opportunity that benefits scientific and partnership interests, expanding our knowledge of small celestial bodies and enabling the mining of asteroid resources for commercial and exploration needs.**

PROVING GROUND OBJECTIVES

Enabling Human Missions to Mars

VALIDATE

- ✓Advanced Solar Electric Propulsion (SEP) systems to move large masses in interplanetary space
- ✓LDRO 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 SKG missions

Asteroid Redirect Mission

- ✓ SEP system moves up to 80 mt asteroid material to stable LDRO
- ✓ Astronauts visit asteroid aboard SLS/Orion, monitor crew health, conduct EVAs and other integrated human-robotic operations

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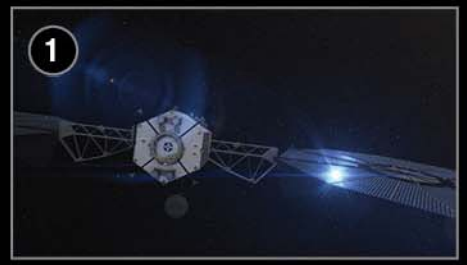
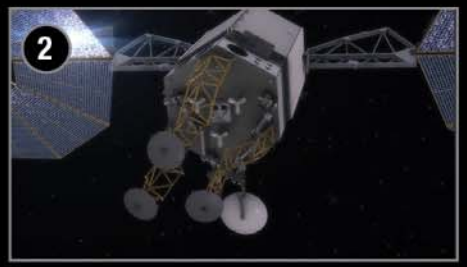
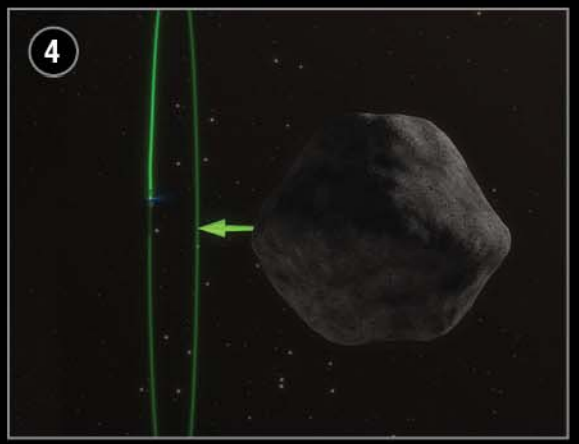
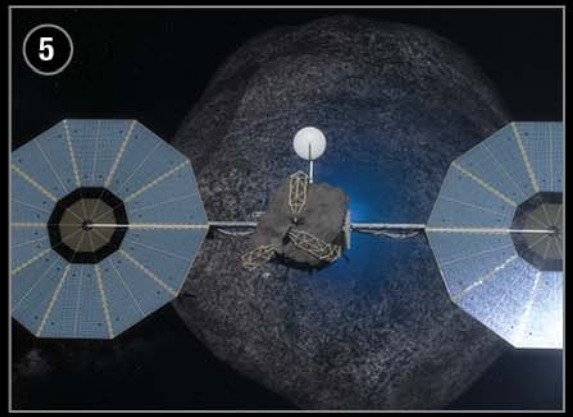
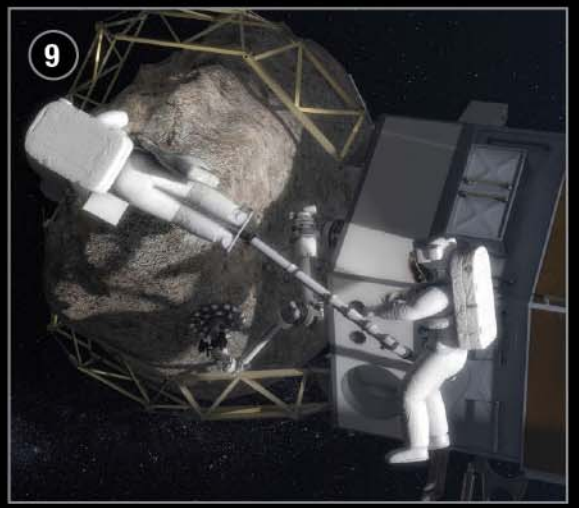
ASTEROID REDIRECT MISSION HIGHLIGHTS









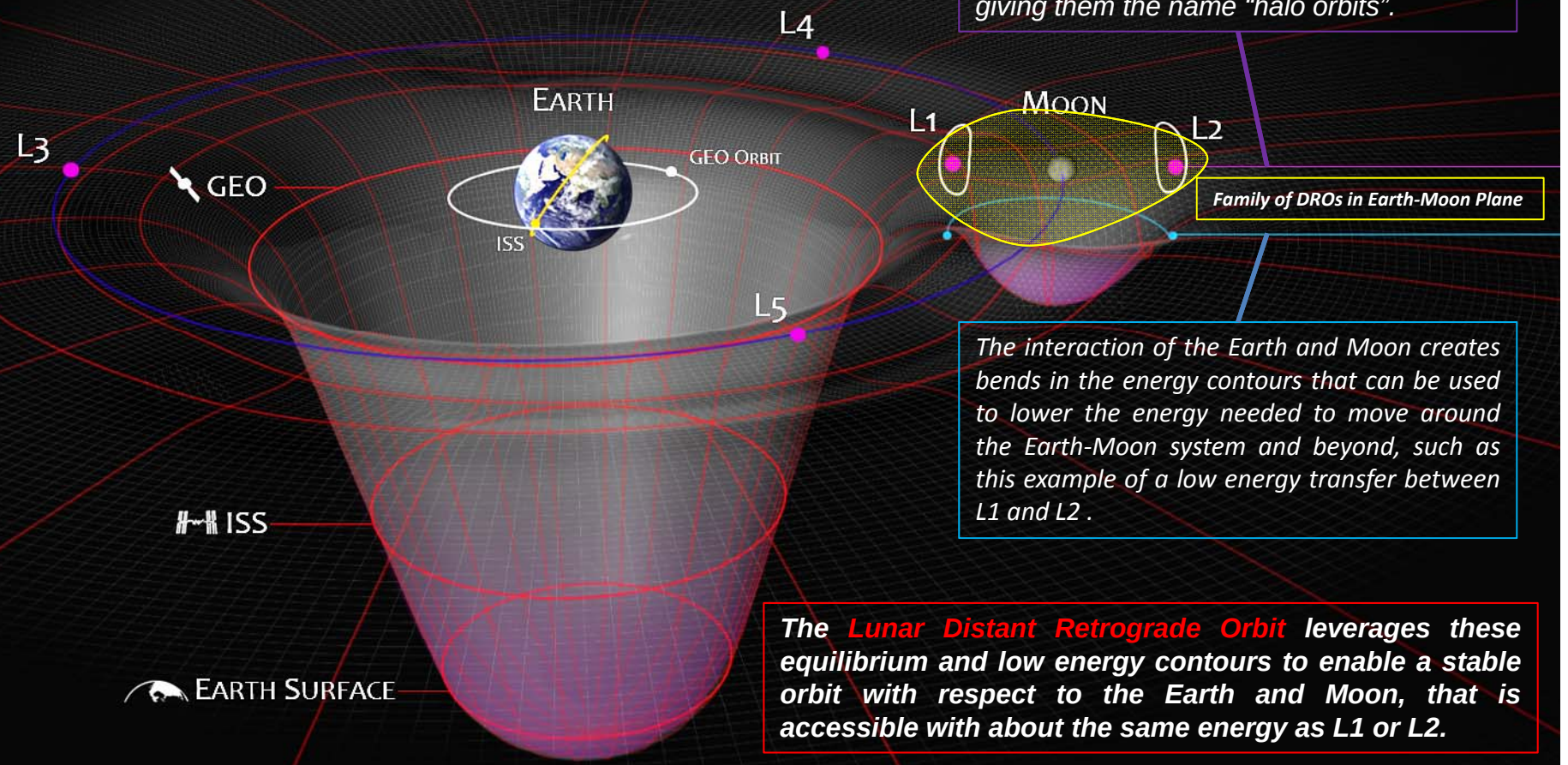


(1) The Asteroid Redirect Vehicle (ARV), powered by advanced Solar Electric Propulsion, is deployed to rendevous with a large asteroid. (2) The ARV prepares to descend to the asteroid surface. (3) The ARV captures a boulder from the asteroid's surface. (4) The ARV demonstrates planetary defense on a hazardous-size asteroid before it (5) begins its transit toward a stable orbit around the moon. (6) The powerful Space Launch System rocket leaves Earth (7) with two crew members (8) aboard the Orion spacecraft. (9) The astronauts conduct spacewalks to investigate the asteroid boulder before returning to Earth with samples.

Cis-Lunar Space:
How the Earth and the Moon Interact

The contours on the plot depict energy states in the Earth-Moon System and the relative difficulty of moving from one place to another.

A spacecraft at L2 is actually orbiting Earth at a distance just past the Moon, however if you look at it from the Moon, the orbit will look like an ellipse around a point in space giving them the name "halo orbits".



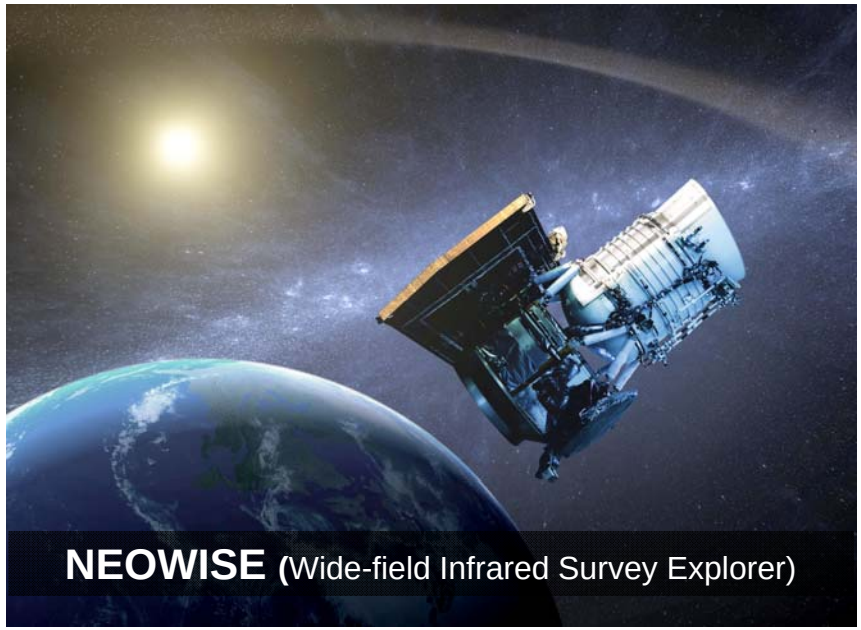
The interaction of the Earth and Moon creates bends in the energy contours that can be used to lower the energy needed to move around the Earth-Moon system and beyond, such as this example of a low energy transfer between L1 and L2 .

The Lunar Distant Retrograde Orbit leverages these equilibrium and low energy contours to enable a stable orbit with respect to the Earth and Moon, that is accessible with about the same energy as L1 or L2.

Asteroid Target Identification and Characterization

Pan-STARRS

Goldstone 70 m

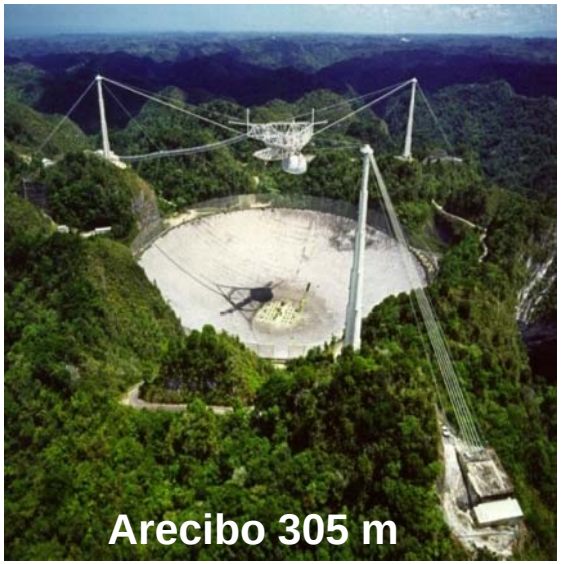


NEOWISE (Wide-field Infrared Survey Explorer)

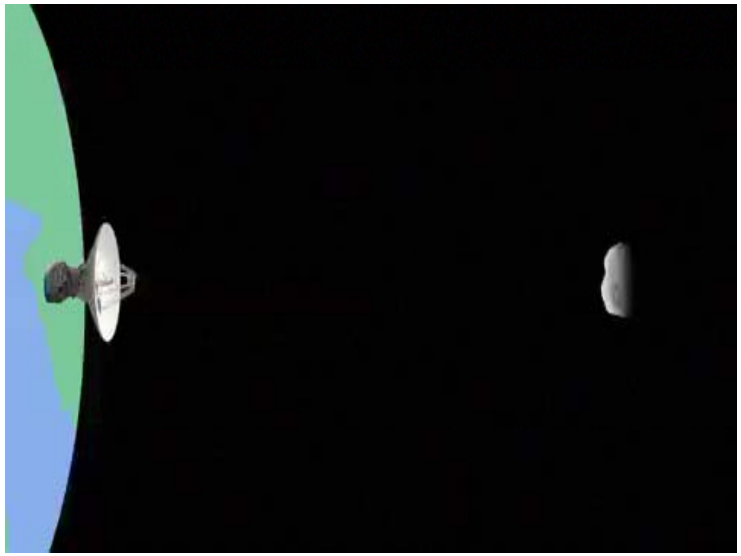
Spitzer Space Telescope

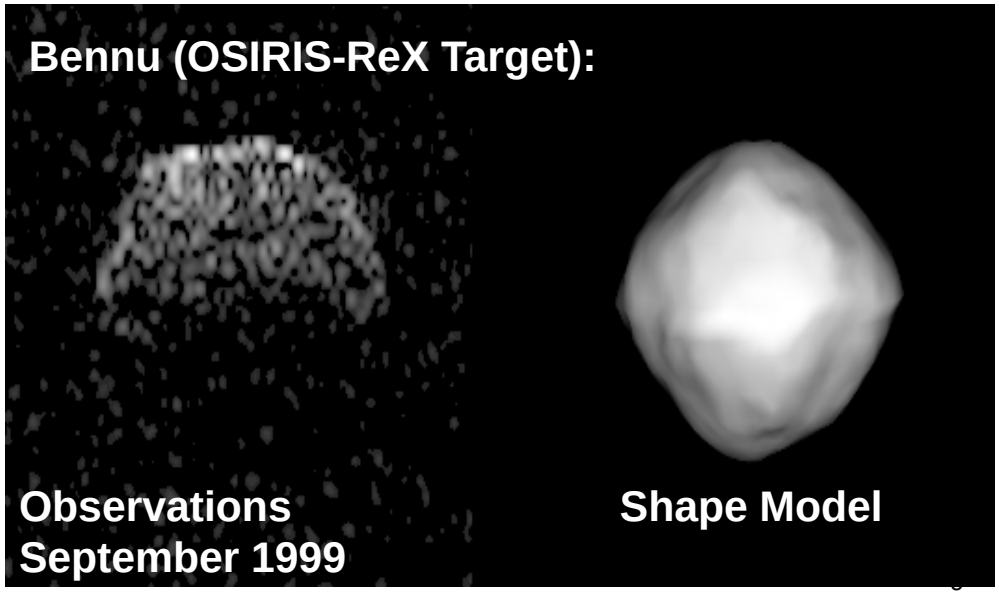
Radar Observations of NEOs


Goldstone 70 m


Arecibo 305 m

Currently, 70-80 NEOs are observed every year.



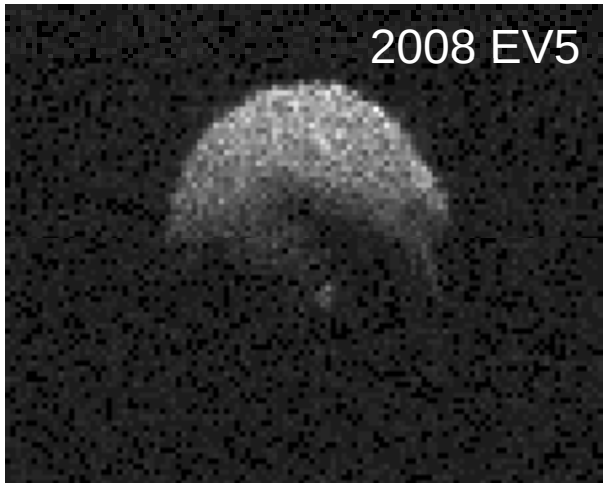


Valid ARRM Candidate Asteroid Targets

Candidate Option B Targets	Type	Mass, Diameter	Spin Period	V_∞ (km/s)	*Perihelion (AU)*	Absolute Magnitude *H*
2008 EV5	C	7.0×10^7t, 400m	3.73 hrs	4.41	1.04	20.0
Bennu	C	7.8×10^7t, 490m	4.30 hrs	6.36	1.36	20.8
1999 JU3	C	6.9×10^8t, 870m	7.63 hrs	5.08	1.42	19.2
Itokawa	S	3.5×10^7t, 320m	12.1 hrs	5.68	1.70	19.2

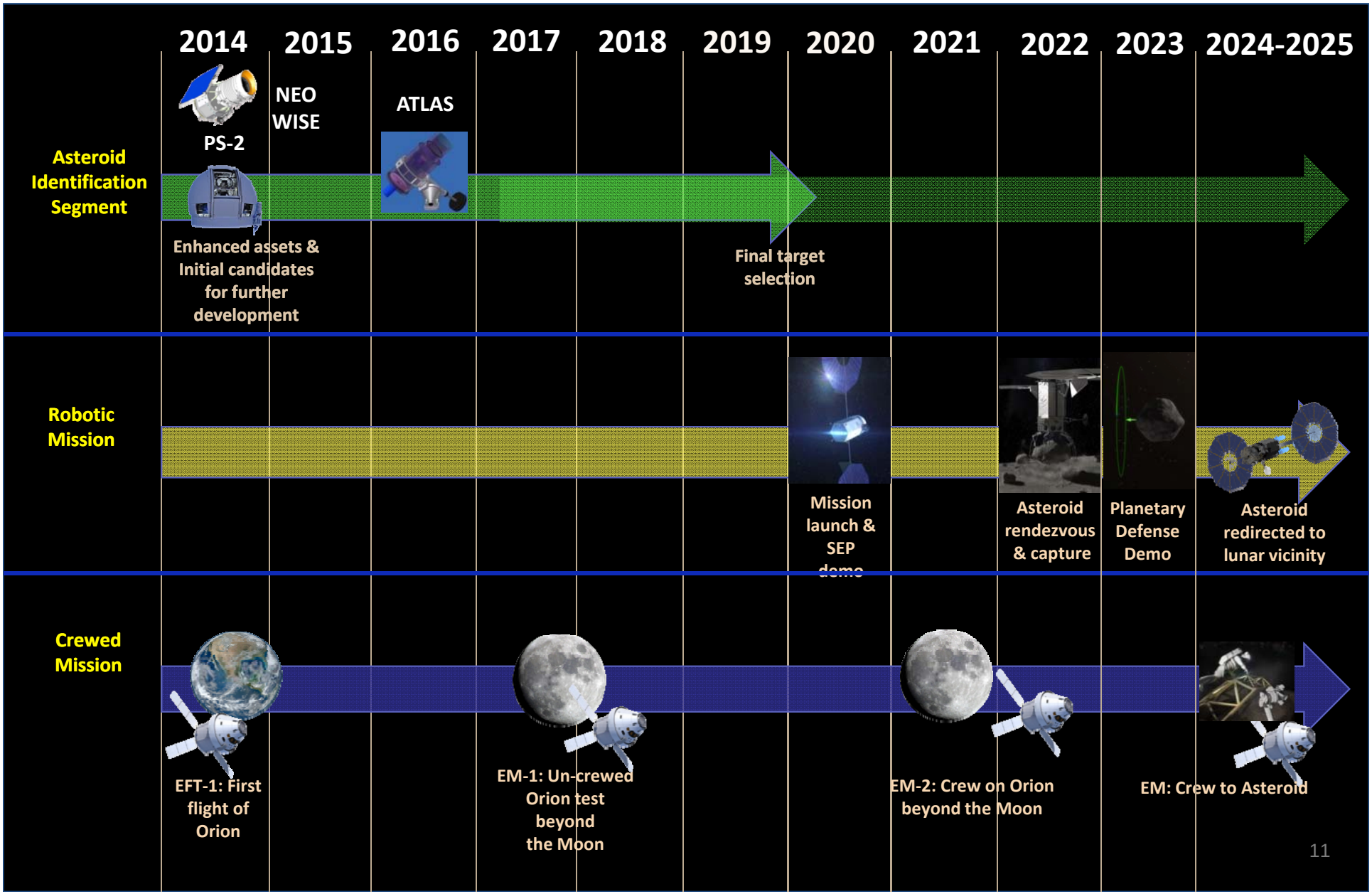
Precursors:

- Itokawa: Hayabusa (visited 2005)
- 1999 JU3: Hayabusa 2 (scheduled 2018)
- Bennu: OSIRIS-REx (scheduled 2018)
- 2008 EV5: No precursor, but radar detected boulders in 2008

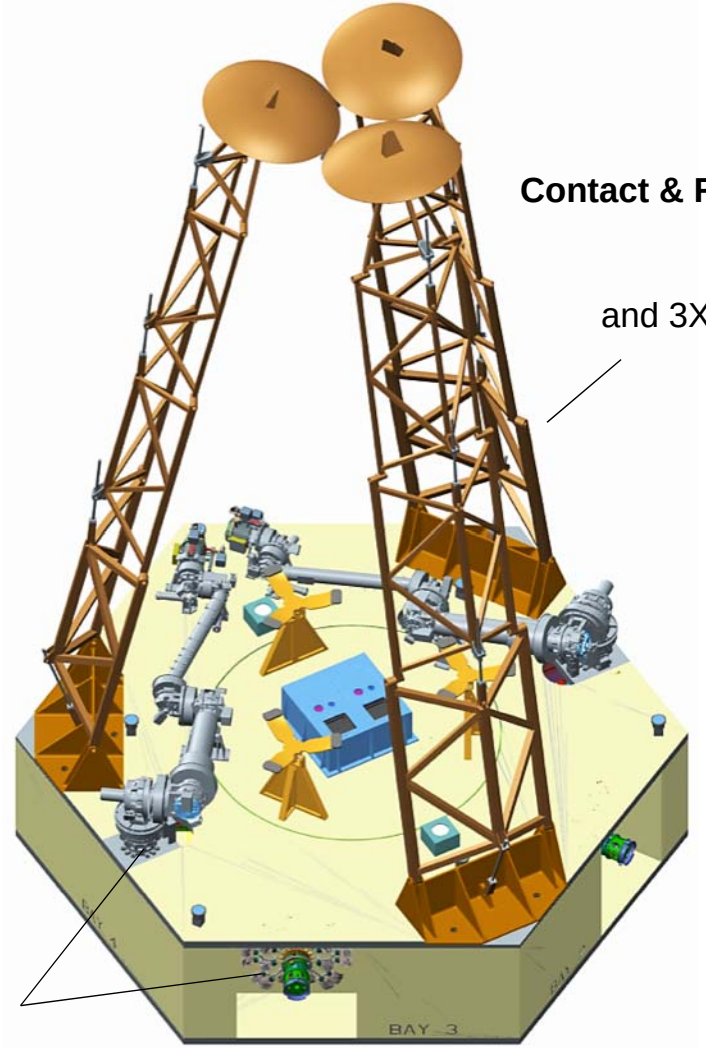


Reference ARRM Target

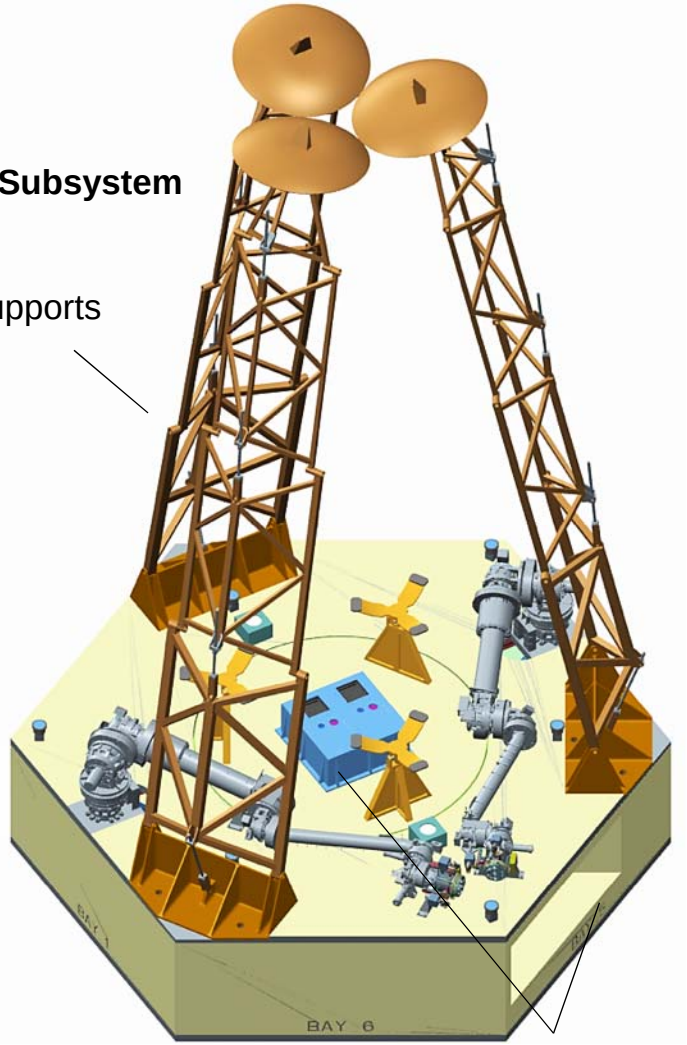
ARM Schedule



ARM Robotic Capture Module



Contact & Restraint Subsystem (CRS)
3X “legs”
and 3X cradle supports



Robot Subsystem
Capture arms (2X)
and tool stowage (2X)

3 SpaceCube computers, VDSU
w/ 128 Gigabytes storage

Relative Navigation Subsystem (RNS)
Deck sensor assembly and
gimbal sensor suite (shown stowed)

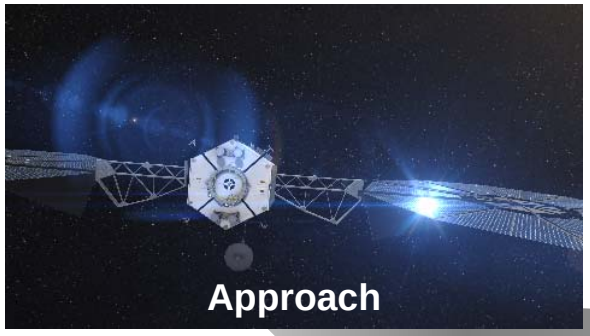
ARRM Capture Phase Overview

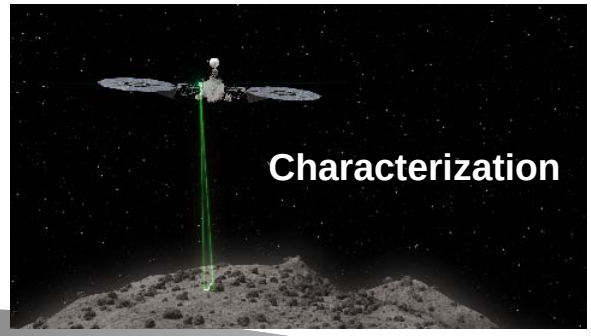
Approach
14 days

Characterization
72 days

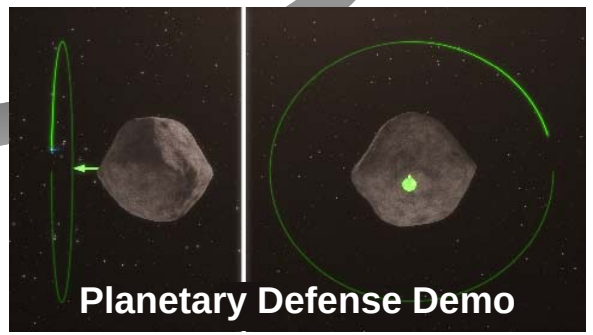
Boulder Collection
69 days

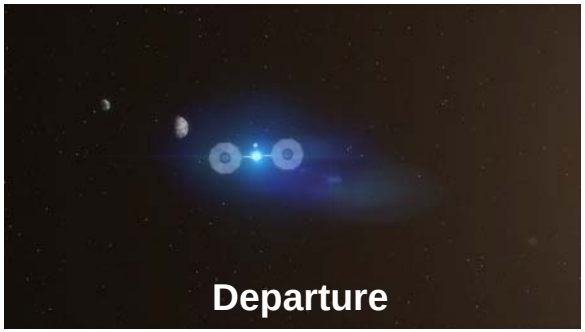
Planetary Defense Demo
150 days (30 deflection + 120 hold & verify)



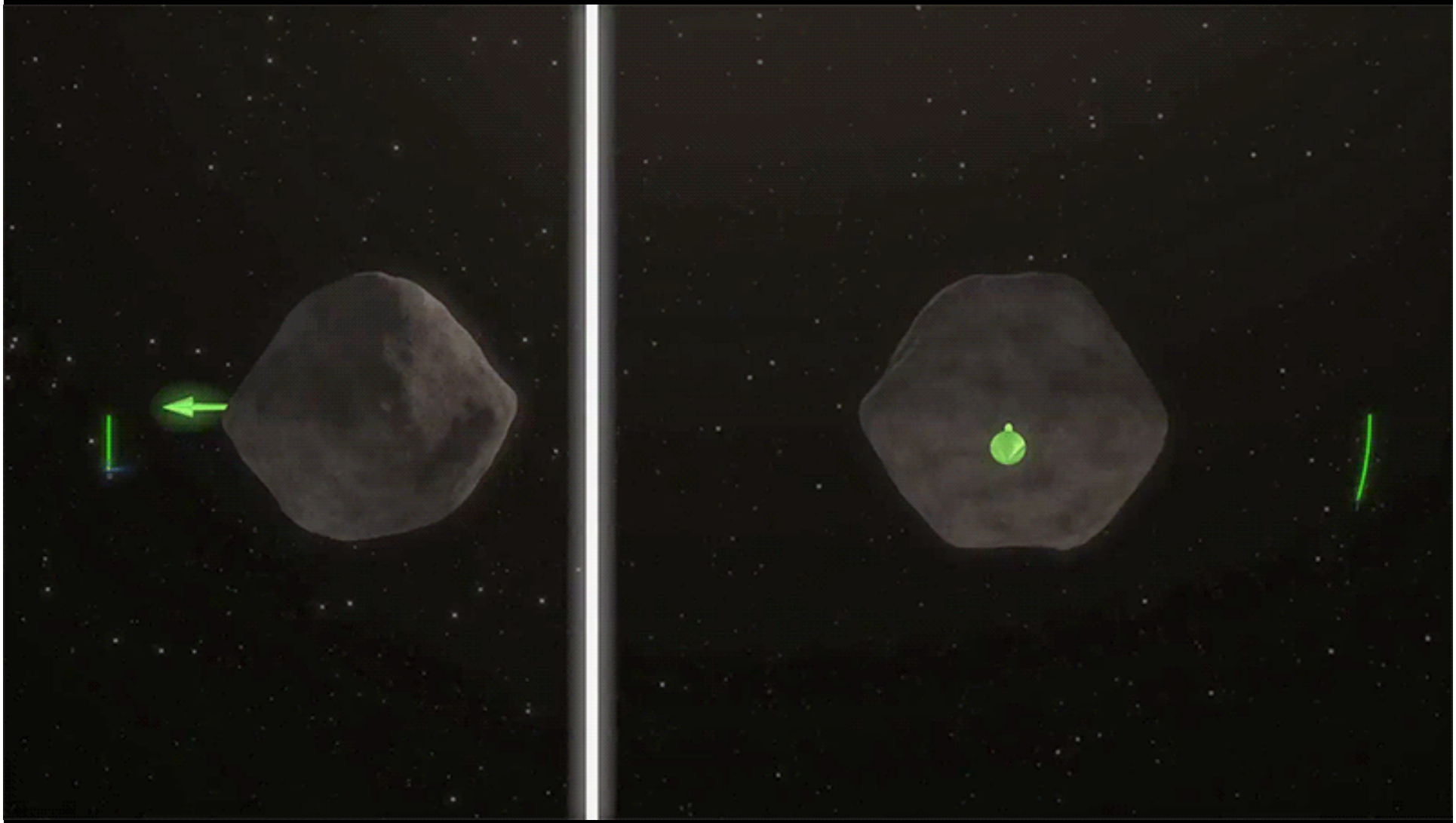


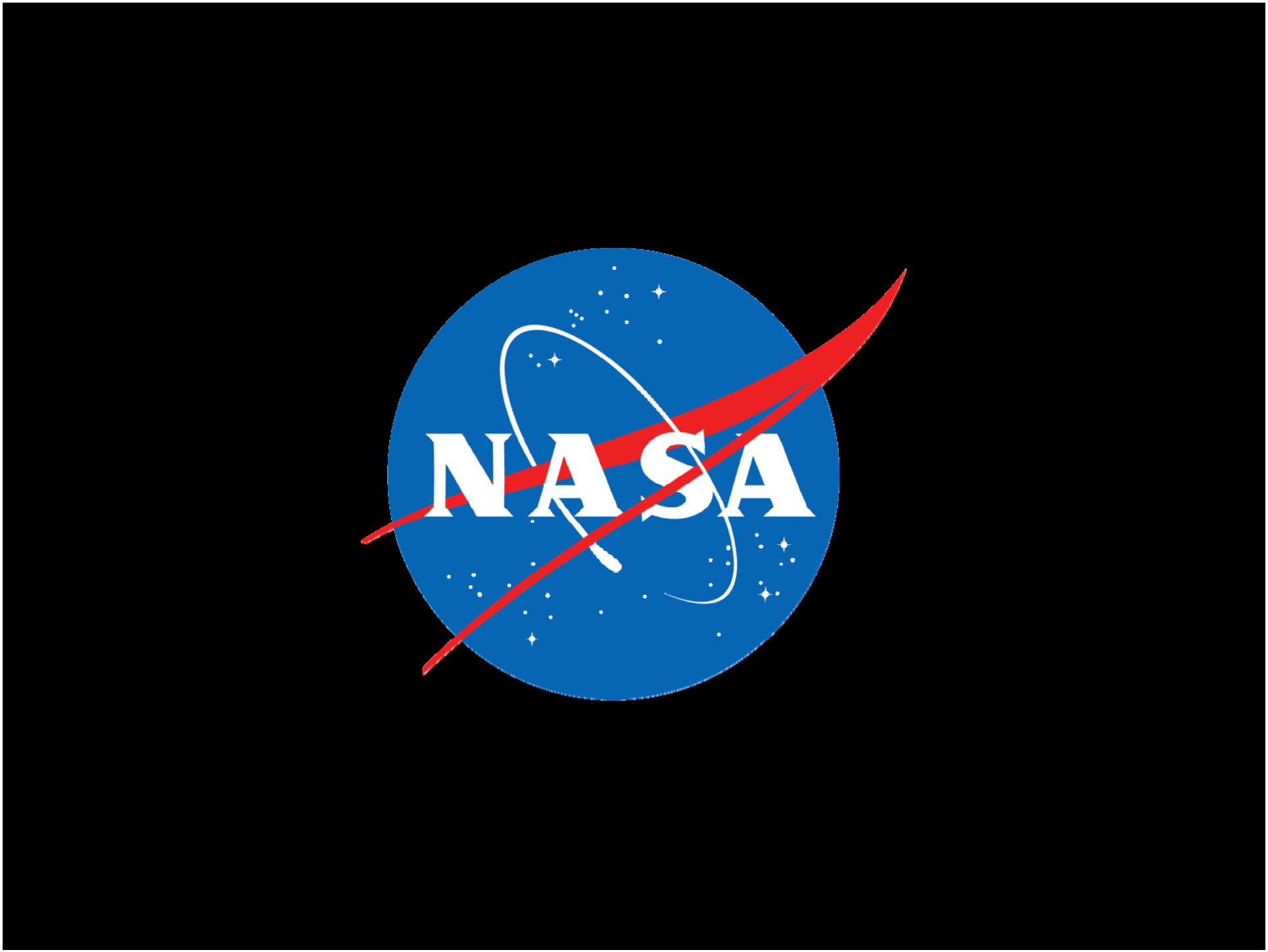
Note: Asteroid operations timeline varies depending on target asteroid. Times shown are for 2008 EV_5: total stay time of 305 days with 95 days of margin.





Enhanced Gravity Tractor –
Planetary Defense Demonstration




NASA