Between the Moon and Mars: The NEO Option

Marco Polo & Asteroid Sample Return Symposium

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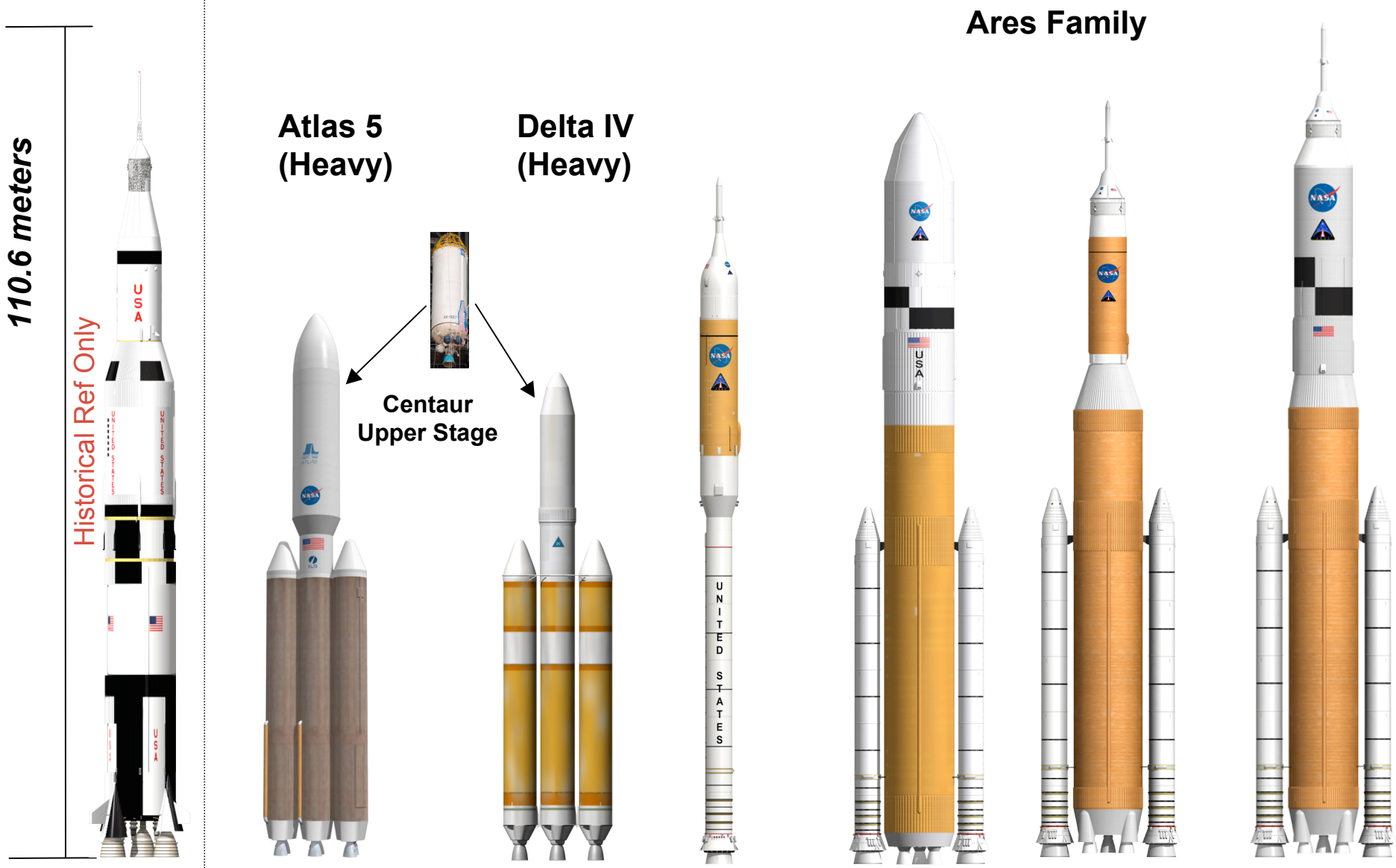
Important Disclaimer

- *This was only a Phase 1 technical feasibility study.*
- *NASA has not endorsed this mission concept yet.*
- *Work to date is based on a ~4 -month 'Phase 1' effort.*
- *Phase 2 study? TBD*

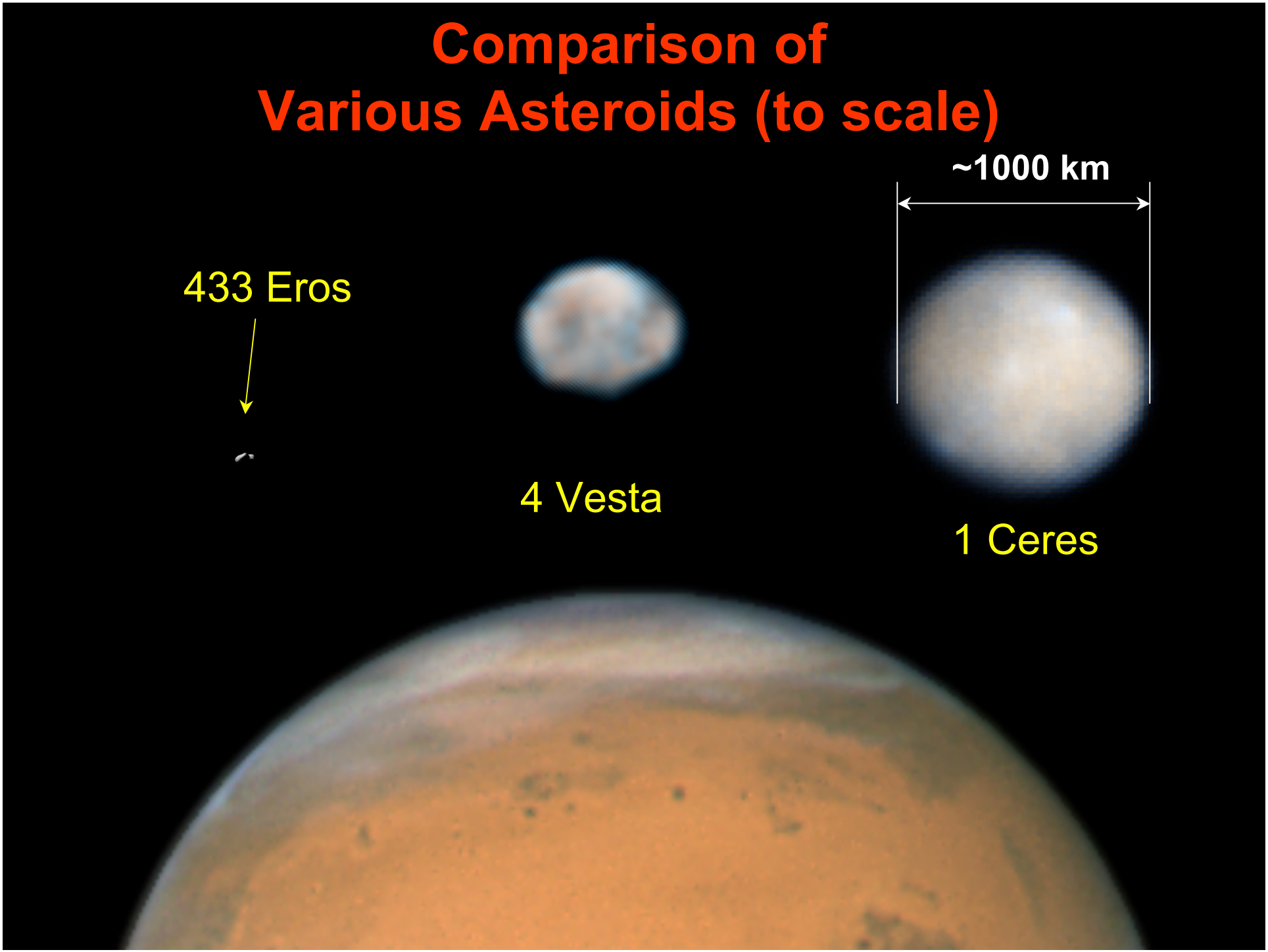
Past NEO Exploration Studies

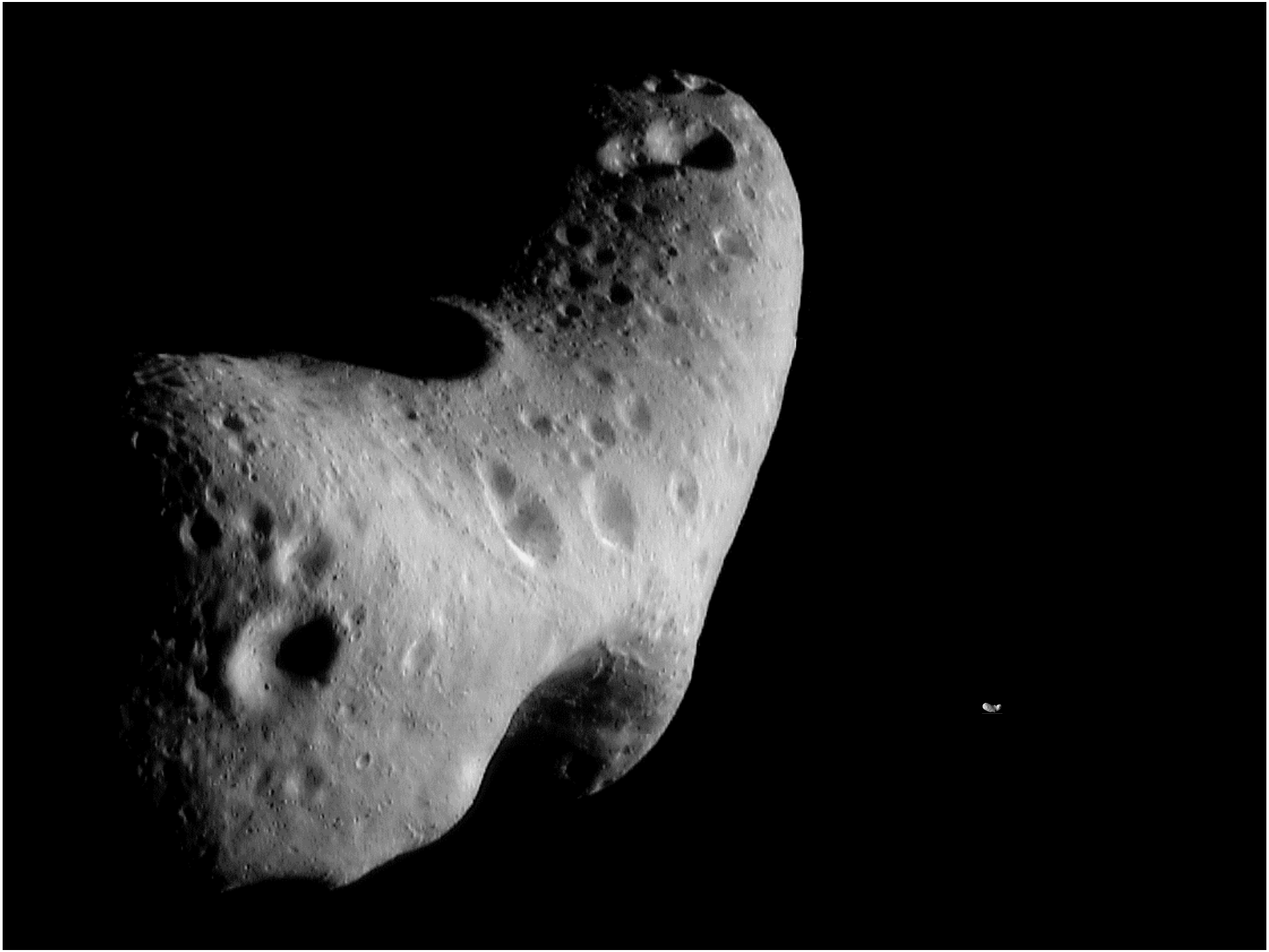
- **Eugene Smith (1966)** "A Manned Flyby Mission to Eros", Northrop Space Labs, World Space Congress
- **Douglas Nash *et al*., (1989)** *Science Exploration Opportunities for Manned Missions to the Moon, Mars, Phobos and an Asteroid*, NASA Office of Exploration Doc No. Z-1.3-001/JPL Publication 89-29.
- **Donald Davis *et al*., (1990)** *The Role of Near-Earth Asteroids in the Space Exploration Initiative*, SAIC-90/1464, Study No. 1-12-232-S28.
- **Michael Griffin, Owen Garriott *et al*., (2004)** *Extending Human Presence into the Solar System: An Independent Study on the Proposed U.S. Space Exploration Policy*
- **Thomas Jones *et al*., (1994)** "Human Exploration of Near-Earth Asteroids", *Earth Hazards Due to Comets and Asteroids*, University of Arizona Press, Tucson, Arizona, pp. 683-708.
- **Thomas Jones *et al*., (2002)** "The Next Giant Leap: Human Exploration and Utilization of Near-Earth Objects", *The Future of Solar System Exploration 2003-2013 ASP Conference Series*, **272**:141-154.
- **Daniel Mazanek *et al*., (2005)** "Near-Earth Object Crew Mission Concept Status", NASA Internal Study.

Possible Launch Vehicles for NEO Missions



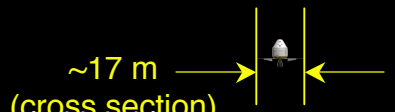
Comparison of Various Asteroids (to scale)

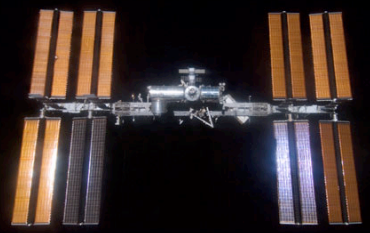




Asteroid Itokawa, ISS, and CEV Orion

CEV Orion





540 meters

~120 meters
(ISS at 15A Stage)

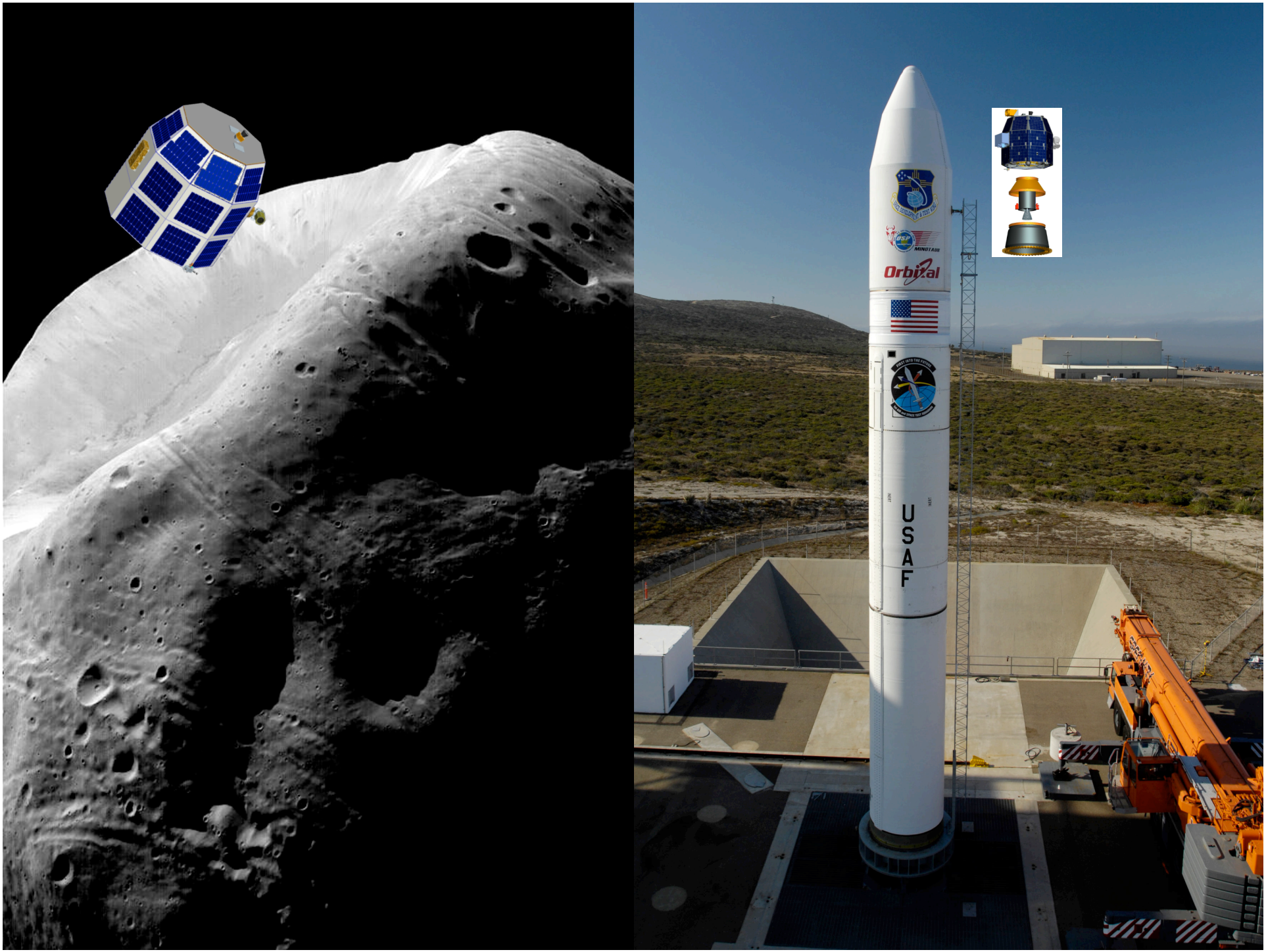
JAXA, NASA

NEO Program's Next Generation Search

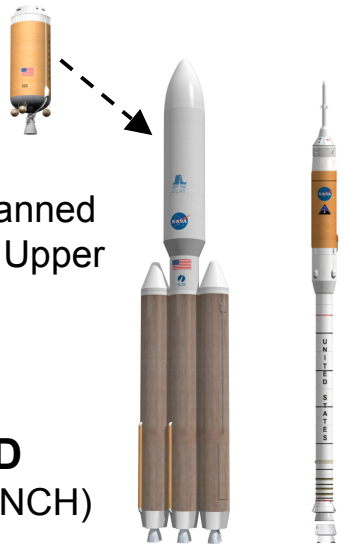
- **NEO Next Gen Search (2010 – 2021) will be at 100 times the current discovery rate**
  - First month of PanSTARRS-4 operation is estimated to discover more asteroids than are currently known
  - ~500,000 new asteroids
  - ~100,000 near-Earth objects (D > 140m)
  - ~20,000 PHOs 140 m and larger by 2021
- **Many PHOs could be possible candidates for Crewed NEO Mission**
  - Viability depends on orbital phasing and on Δv to rendezvous

Precursor Mission Instruments

- **High resolution optical camera system**
  - Surface identification, navigation, characterization, and optical mapping
- **LIDAR**
  - Topographical mapping, gravitational field survey, and shape modeling
- **Visible and near-IR spectrometer**
  - General compositional investigation
- **Small lander package**
  - APXS, micrometeorite counter, dust collector, solar wind/particle collector, imager, radiometer, *etc.*


Orbital
MINOTAUR
USAF

NEO Mission Launch Concepts



EELV
Used to loft unmanned Centaur Upper Stage

ARES I
Used to loft Orion and Crew

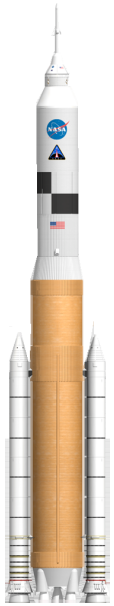
LOWER BOOKEND
(DUAL LAUNCH)

ARES I US

ARES V Core + Boosters

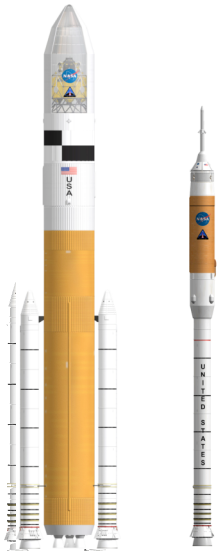
ARES IV
used to loft Orion

MID-VOLUME IV
(SINGLE LAUNCH)



ARES V
used to loft Orion

MID-VOLUME V
(SINGLE LAUNCH)



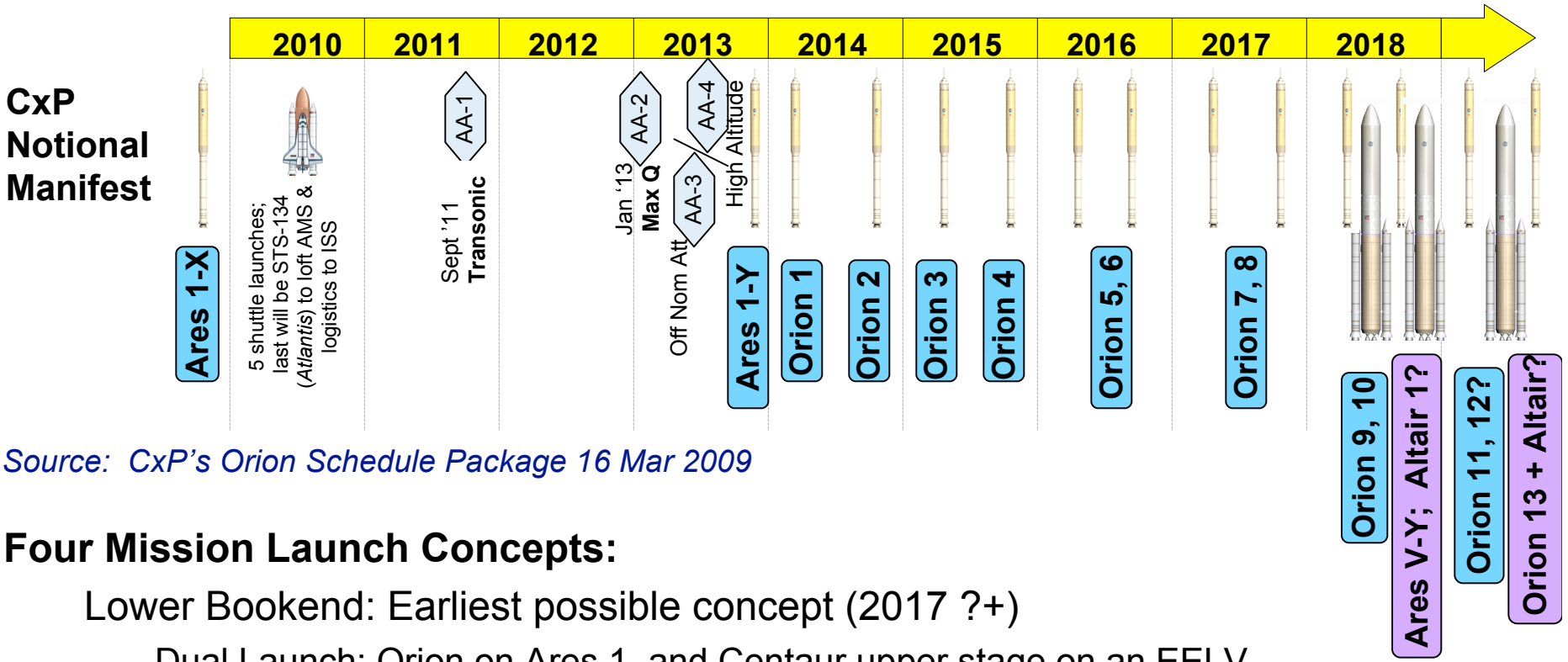
ARES V
Used to loft EDS + LSAM

ARES I
Used to loft Orion

UPPER BOOKEND
(DUAL LAUNCH)

Vehicles are not to scale.

NEO Mission Launch Concepts



Source: CxP's Orion Schedule Package 16 Mar 2009

Four Mission Launch Concepts:

Lower Bookend: Earliest possible concept (2017 ?+)

Dual Launch: Orion on Ares 1, and Centaur upper stage on an EELV

Upper Bookend: Most like a lunar mission (2020+)

Dual Launch: Orion on Ares 1, and Altair prototype on Ares V (atop an EDS)

Mid Volume (two versions): Alternate launch concepts at CxPO request

a) Single launch: Orion on Ares 4

(Where Ares 4 = Ares 5 core / boosters with Ares 1 upper stage)

b) Single launch, Orion on Ares 5 and EDS

"Mid Volume V" Near-Earth Object (NEO) Crewed Mission - Ares V

EDS / Orion SM provides Earth Departure, NEO Arrival, and Earth Return δV

Assumes 2 Crew w/ Telerobotic Exploration and EVA;

NEO

EDS & Orion SM Performs NEO Rendezvous

Orion SM performs Earth Return burn

NEO Heliocentric Orbit

EDS Expended

7-14 Day NEO Visit

~1 - 45 Day Inbound Segment

~20-75 Day Outbound Segment

Management of δV across mission is important trade

EDS performs Trans NEO Injection with a large margin

Service Module Expended

Low Earth Orbit

EDS2, CEV

Direct Entry (<12 km/s) Land Landing

Note - Ares V and Orion modifications:
- **Ares V man rating**
- **Orion long duration life support**

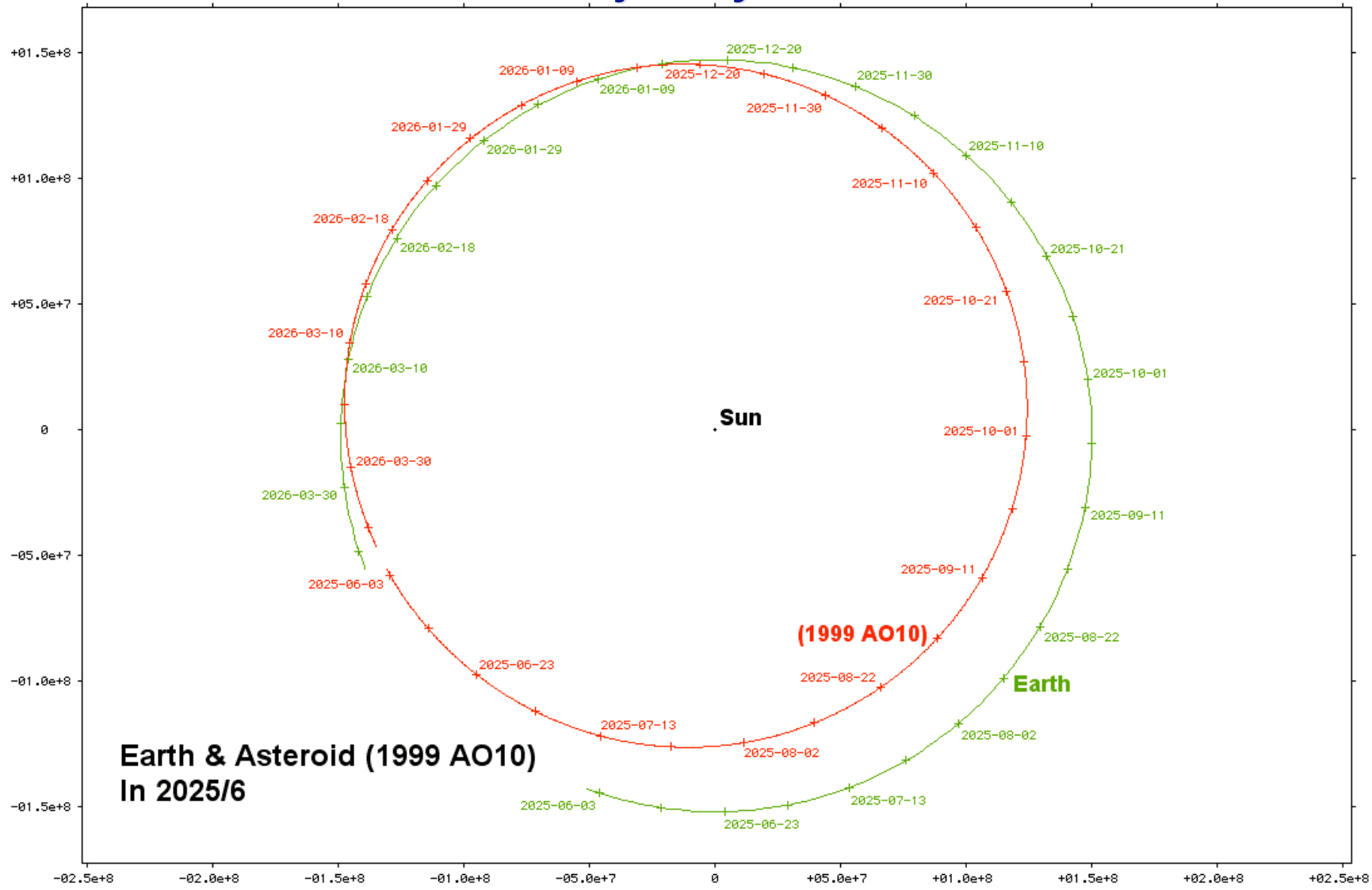
Vehicles are not to scale.

EARTH

Mid-Volume (Ares 5 – Single Launch)

150-Day Mission to 1999 AO_{10}

Heliocentric Trajectory Plot for Mission



Km Units View From Y= 0.0°, P= 0.0°, R= 0.0°

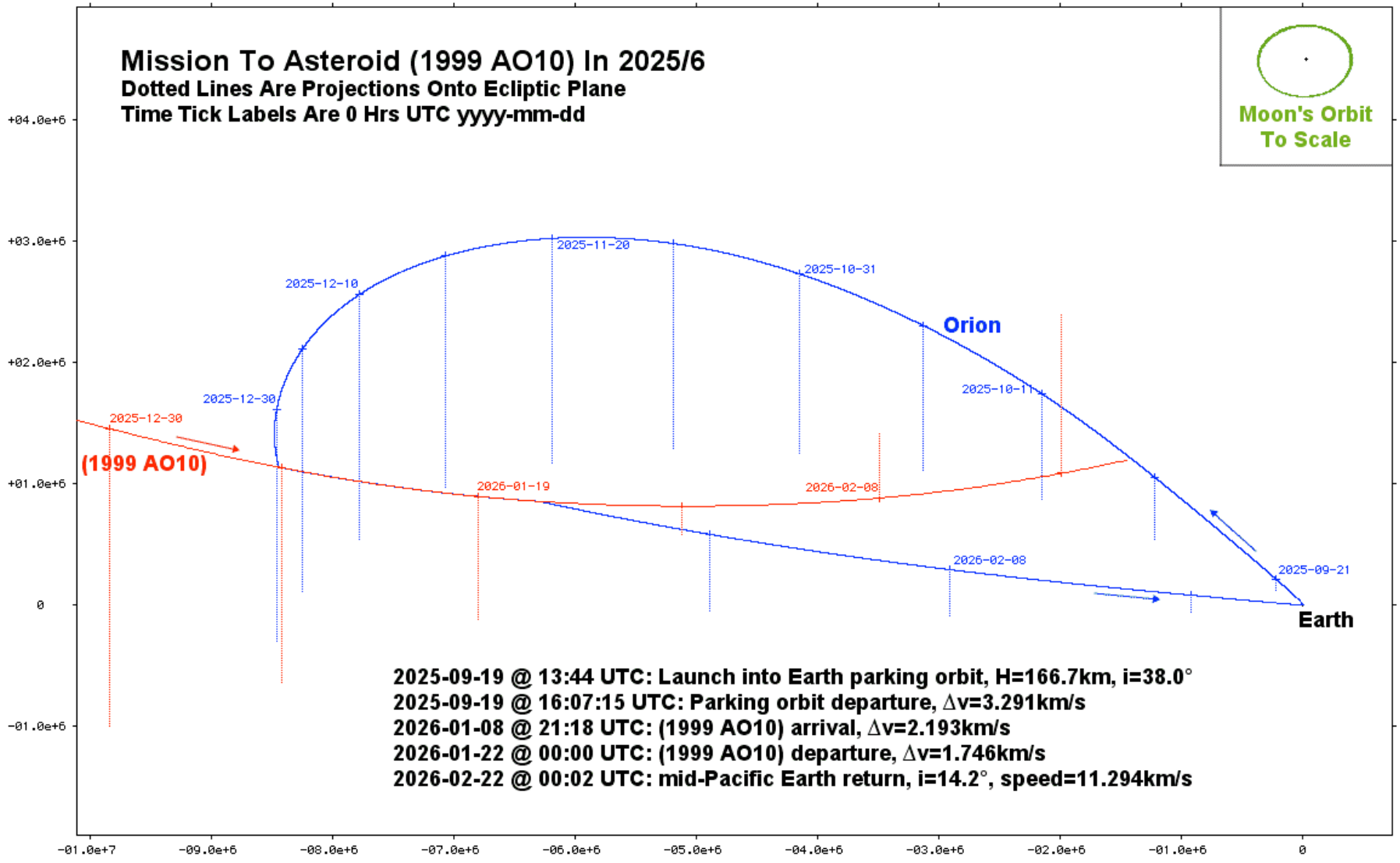
Sun-Centered J2KE Coordinate System

Visit to (1999 A01O)

Mid-Volume (Ares 5 Single Launch)

150-Day Mission to 1999 AO_{10}

Earth-fixed Trajectory Plot for Mission



Km Units View From Y= 0.0°, P= 0.0°, R= 45.0°

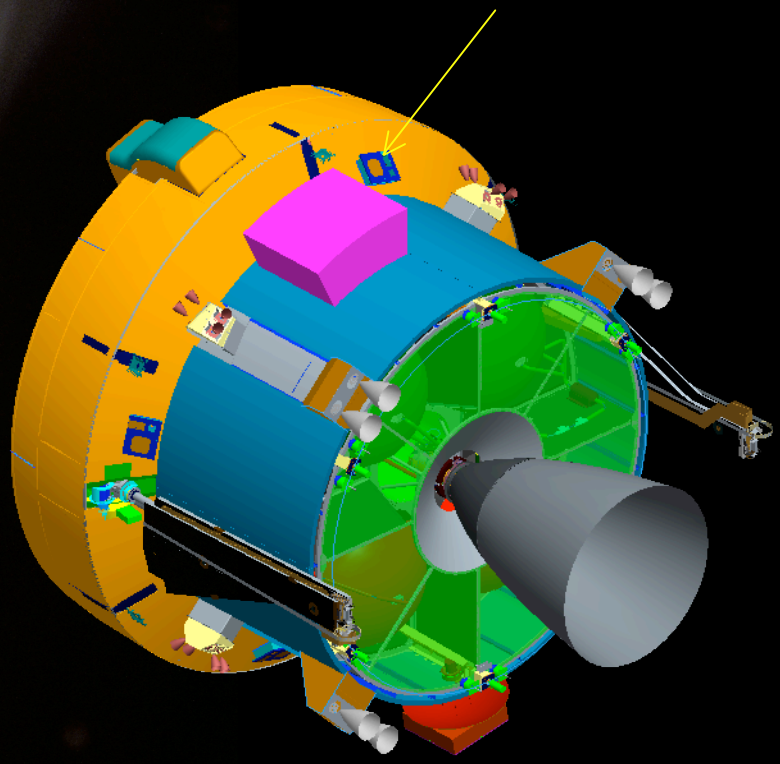
Earth-Centered J2KE Coordinate System

Visit to (1999 AO10)

SIM Bay

Added to J-series
(*Apollo 15, 16, 17*)

SIM Bay for Orion



Orion Mission Instruments

- **Teleoperated robotic rover/hopper**
  - Multiple trips to/from surface
  - Supplemental collection from other/difficult to reach areas on the NEO
  - Collection of ultra-pristine samples
- **Multi-wavelength radar system**
  - Radar tomography of the NEO to obtain internal structure
- **Small instrument packages for precision deployment by the crew**
  - Deployed by crew during EVA or by the robotic rover system
  - Science payloads, engineering structures, EVA equipment, *etc*.
- **Human crew**
  - Have the adaptability and ingenuity to deal with complex issues in real time
  - Direct interaction with the surface via a variety of methods
  - Hand-held high-definition camera for E/PO events

CEV Mission Objectives

- **Sample Return**
  - Several macroscopic samples (10s to 100s of kg) from the surface
  - Collected in geological context from different locations by astronaut EVAs
  - Supplemental robotic collection enhances sample return
  - Collection of different or unusual samples from the surface (*e.g.,* black boulders on Itokawa)

- **Investigate NEO interior characteristics**
  - Determination of internal structure (size scale & distribution of components)
  - Measurement of density and macroporosity of the NEO

- **Test/Attach payloads to surface for operation and subsequent retrieval**
  - Microgravity regime
  - Possible rubble pile nature with high porosity

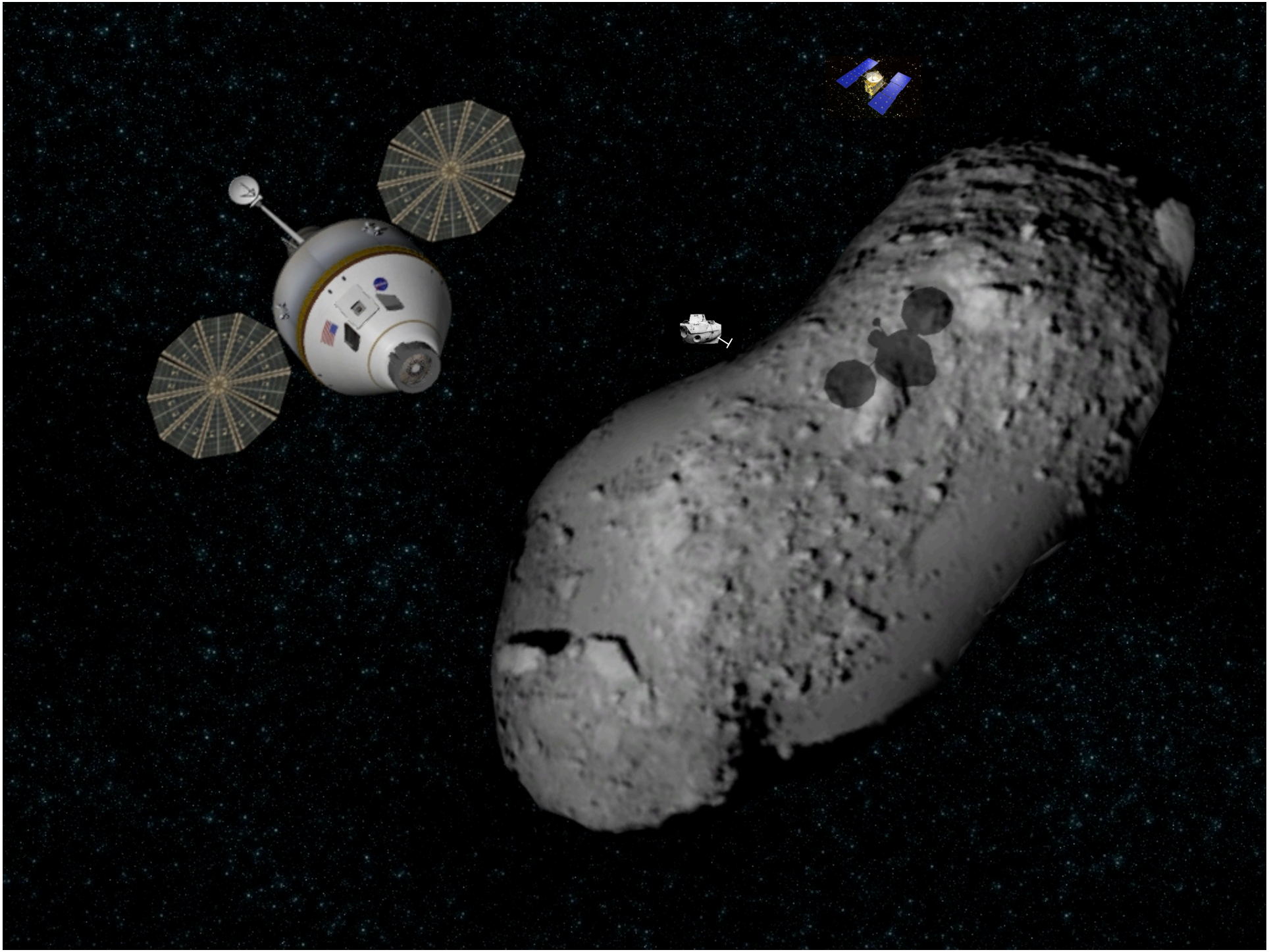
- **Emplace and operate a resource extraction device**
  - IRSU applications for water production or metal extraction
  - Demonstrate capability even in token quantities

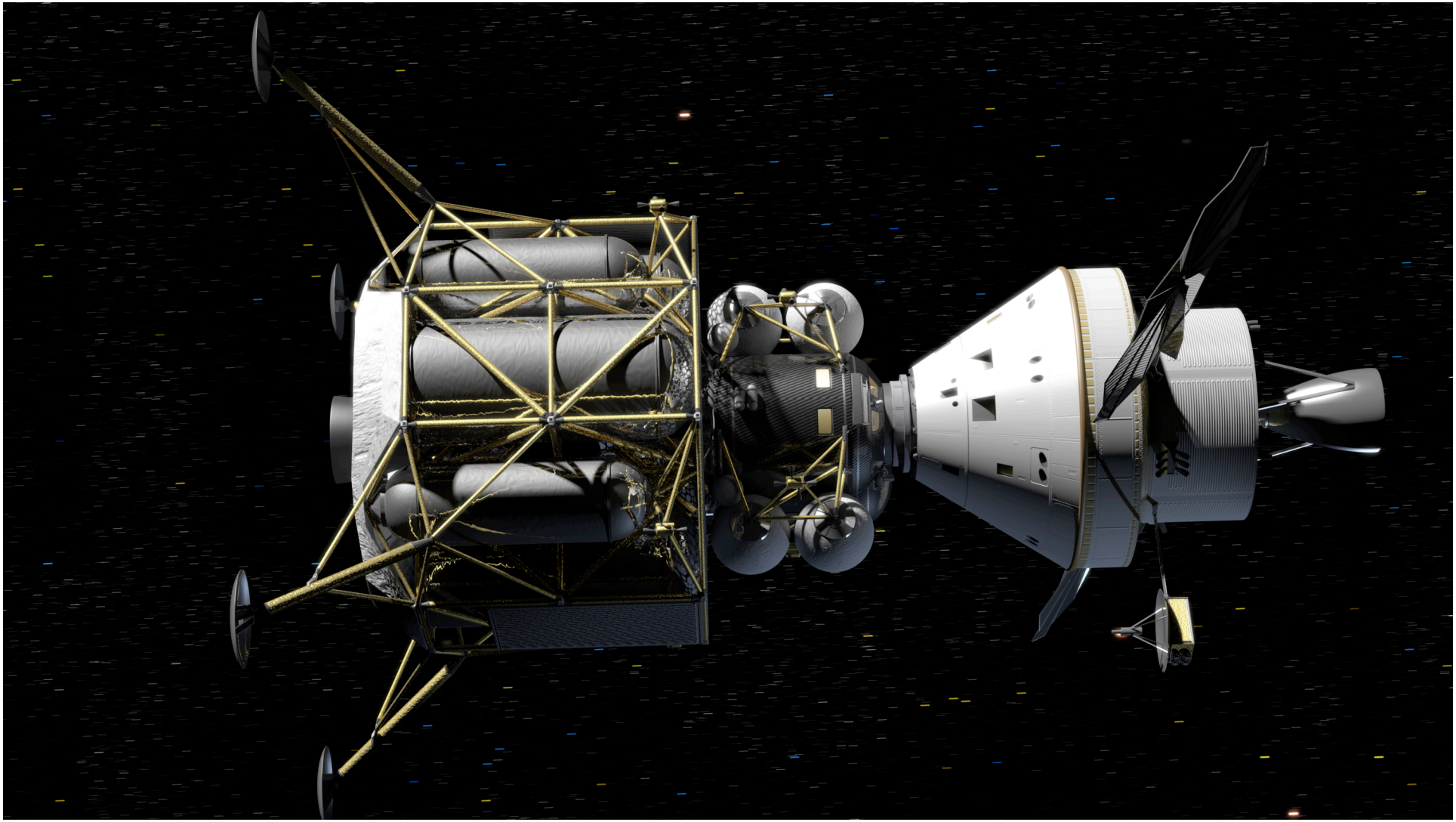
Value of Human Exploration of NEOs

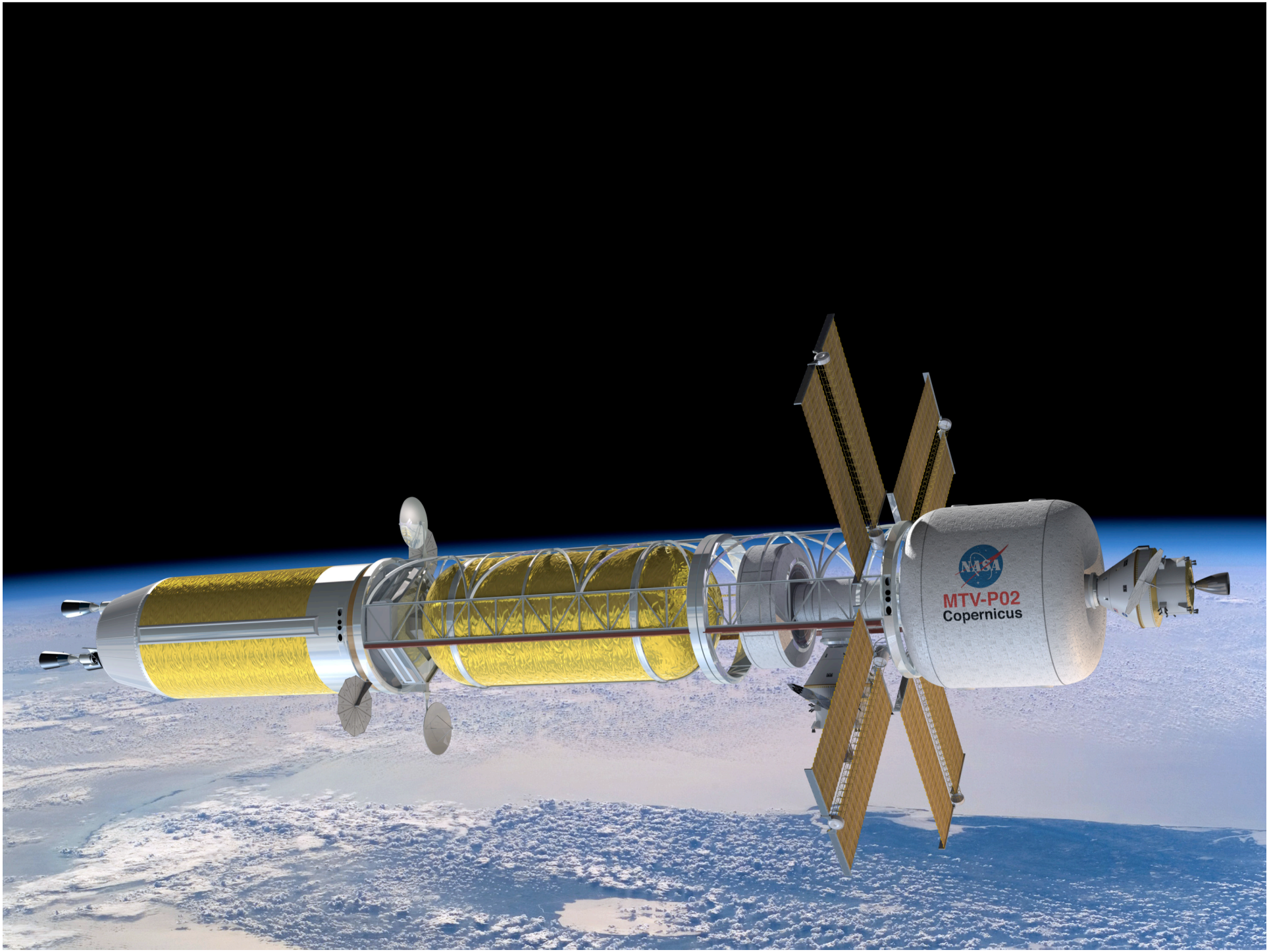
- Expand human capability to operate beyond low-Earth orbit and ***the Earth-Moon system***
- Verify physiological impacts outside the earth's magnetosphere and in the interplanetary radiation environment
- Assess the psychology of crew autonomy; ground/crew interactions at 7 to 10 sec (OWLT) delay for deep space operations
- Assess resource potential of NEOs for exploration and commercial use
- Demonstrates the utilitarian nature of the Constellation Program

Summary Findings for Lower Bookend Mission Analysis

- **In general, mission ΔV can be reduced by**
  - Longer mission duration
  - Shorter stay times (second order)
  - Lunar gravity assist (second order)
- **NEO Launch Windows**
  - Two ~equal launch opportunities to NEOs - each several days long
- **A NEO must be in the right place in its orbit at the right time to have a really close approach to Earth, thus allowing a low-ΔV fast mission**
- **Can we do it? Yes.**






NASA
MTV-P02
Copernicus

NEO Human Mission Opportunities