Prospects for Future Human Space Flight Missions to Near-Earth Asteroids

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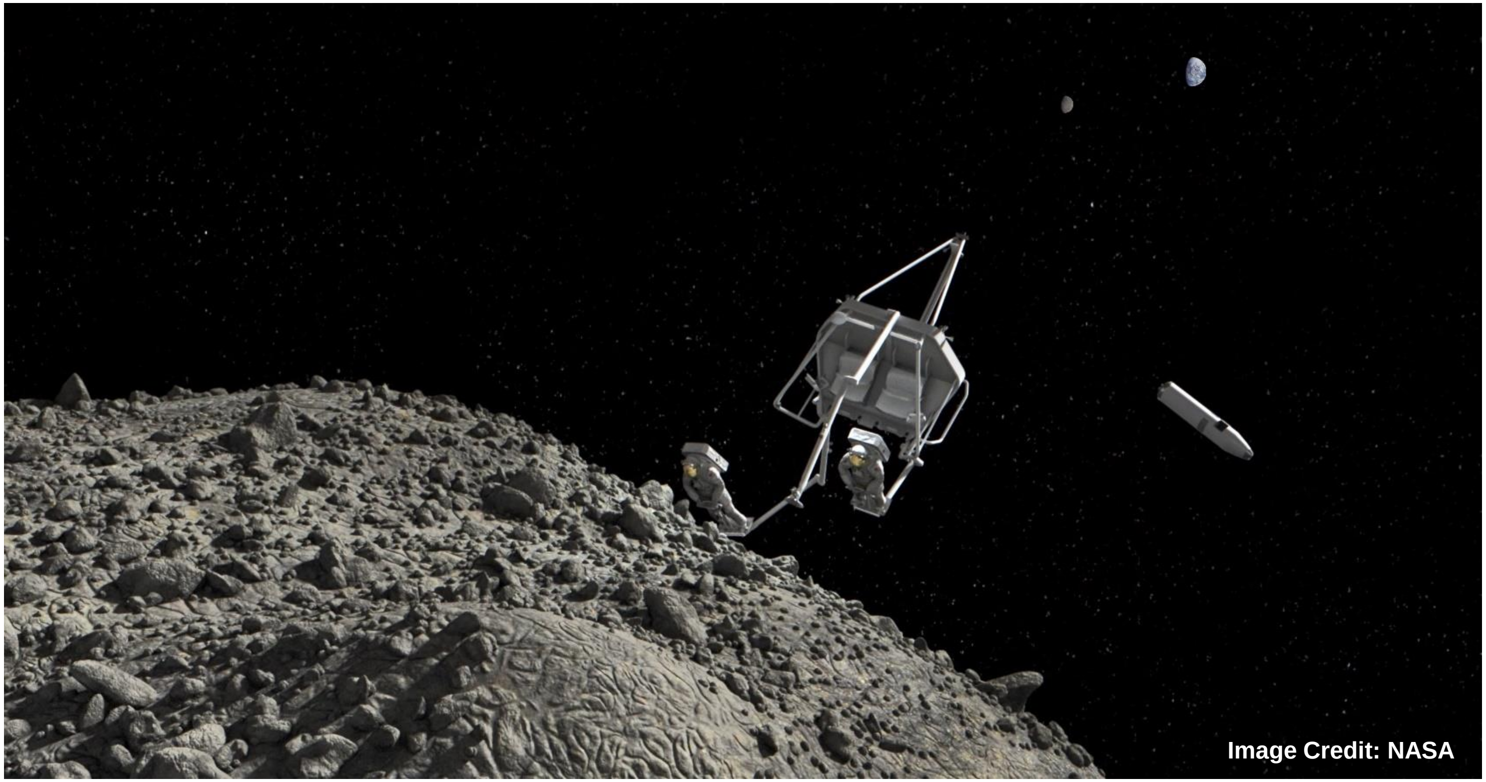
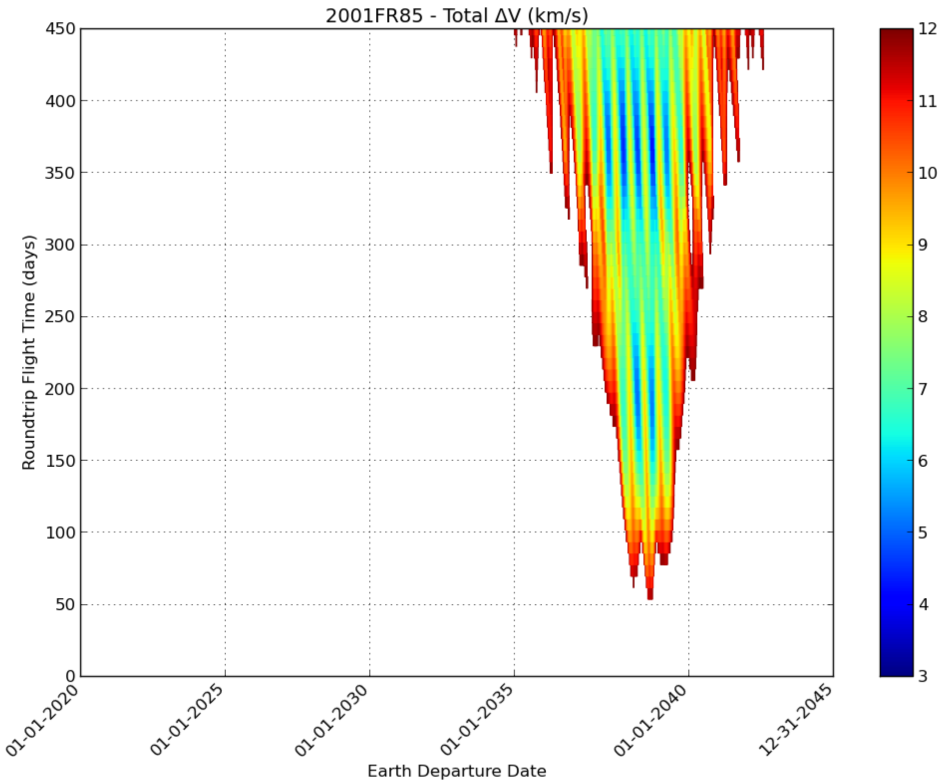
Introduction

- NEAs offer unique opportunities for the most ambitious human voyages ever undertaken.
- The Apollo program forever changed humanity's perspective by showing us Earthrise from our Moon through human eyes. Crewed missions to NEAs will forever change our perspective again by showing us Earth as a distant point of light in the heavens as seen from an asteroid by astronauts.



Introduction

- **In 2010, NASA performed the Near-Earth Object (NEO) Human Space Flight (HSF) Accessible Targets Study (NHATS), creating an automated online system monitoring mission accessibility of NEAs that continues to operate.**
  - Thus far 4790 NHATS-compliant NEAs have been discovered (as of 2023-03-20), and more are discovered regularly.
  - https://cneos.jpl.nasa.gov/nhats/
- **Herein we describe a notional mission to a NHATS-compliant NEA, 2001 FR85, that would test and demonstrate potential Mars mission architecture elements with less risk to the crew.**



https://cneos.jpl.nasa.gov/nhats/details.html#?des=2001%20FR85&dv=12&dur=450&stay=8&launch=2020-2045

The plot above shows total mission delta-V as a function of Earth departure date and total round-trip flight time (mission duration). It summarizes the many potential mission scenarios by plotting, for each case, the total round-trip delta-V values (color-coded) required for each launch date and round trip flight time considered. Note that these trajectories span a range of possible stay times at the NEA.

Background

- **NASA's forthcoming Near-Earth Object (NEO) Surveyor space telescope is a foundational asset designed to complete NASA's congressionally-mandated goal of cataloging ≥90% of NEOs ≥140 meters in size as soon as practical, and to discover Earth impactors far in advance.**
- **NEO Surveyor is also critical to near-Earth asteroid (NEA) exploration because it will find suitable accessible NEAs for robotic and human missions, often on Earth-like orbits with long synodic periods.**

For more information about NEO Surveyor, see the following from Session 2:

- Mainzer, A. The Near-Earth Object Surveyor Mission
- Masiero, J. Validation of the Survey Simulator Tool for the NEO Surveyor Mission Using NEOWISE Data

Image Credit: NASA

Background

- **NEAs pose Earth-impact hazards, but are also scientifically important and contain resources, such as water (OH), that could be utilized off-Earth.**
- **Planetary defense endeavors to understand asteroid and comet impact risks and to develop mitigation capabilities.**
- **NEA missions are synergistic in multiple ways.**
  - Science – understanding Solar System formation and evolution
  - Exploration – enabling human exploration beyond cislunar space
  - Resources – developing capabilities for in situ resource utilization (ISRU)
  - Planetary Defense – mitigating impact hazards

Example Starship-Based Piloted Near-Earth Asteroid (NEA) Mission Concept

Conceptual Initial Mass Sizing Estimate Summary

- **Assumptions:**
  - Crew size = 3 (mass allocation per crew member = 200 kg)
  - High-Earth Orbit (HEO) departure and return (~7,800 x 113,300 km to minimize mission ΔV and radiation exposure)
  - Mission duration = 152 days + 30 days of HEO crewed loiter after Earth return and 30 days uncrewed before mission
  - Cargo and consumables/logistics:
    - NEA unpressurized ops craft = 2,500 kg (left at NEA before crew departure)
    - Utilization and spares delivered to NEA = 1,000 kg
    - Utilization returned from NEA (samples, containers, experiments, etc.) = 200 kg
    - Crew consumables = average of 18.5 kg/crew/day + additional 10% tare mass (18 kg/crew for 142 days and 25 kg/crew for 10 days of EVAs with an additional 30 days for maximum post-mission loiter – note: consumable rates include margin of ~10%)
  - Liquid oxygen/methane (LOX/LCH4) propulsion system specific impulses: main propulsion = 363 s; secondary propulsion = 327 s; reaction control system (RCS) = 295 s
  - Passive boiloff strategy with venting (300 kg/day in HEO and 115 kg/day during remainder of the mission)
  - Total mission Δv = 7.051 km/s + 400 m/s of RCS

- **NEA Starship Mass Summary**
  - Inert mass = 105,000 kg
  - Total propellant mass = 1,100,000 kg
  - Total initial mass in HEO = 1,220,000 kg

Example Starship-Based Piloted Near-Earth Asteroid (NEA) Mission Concept:

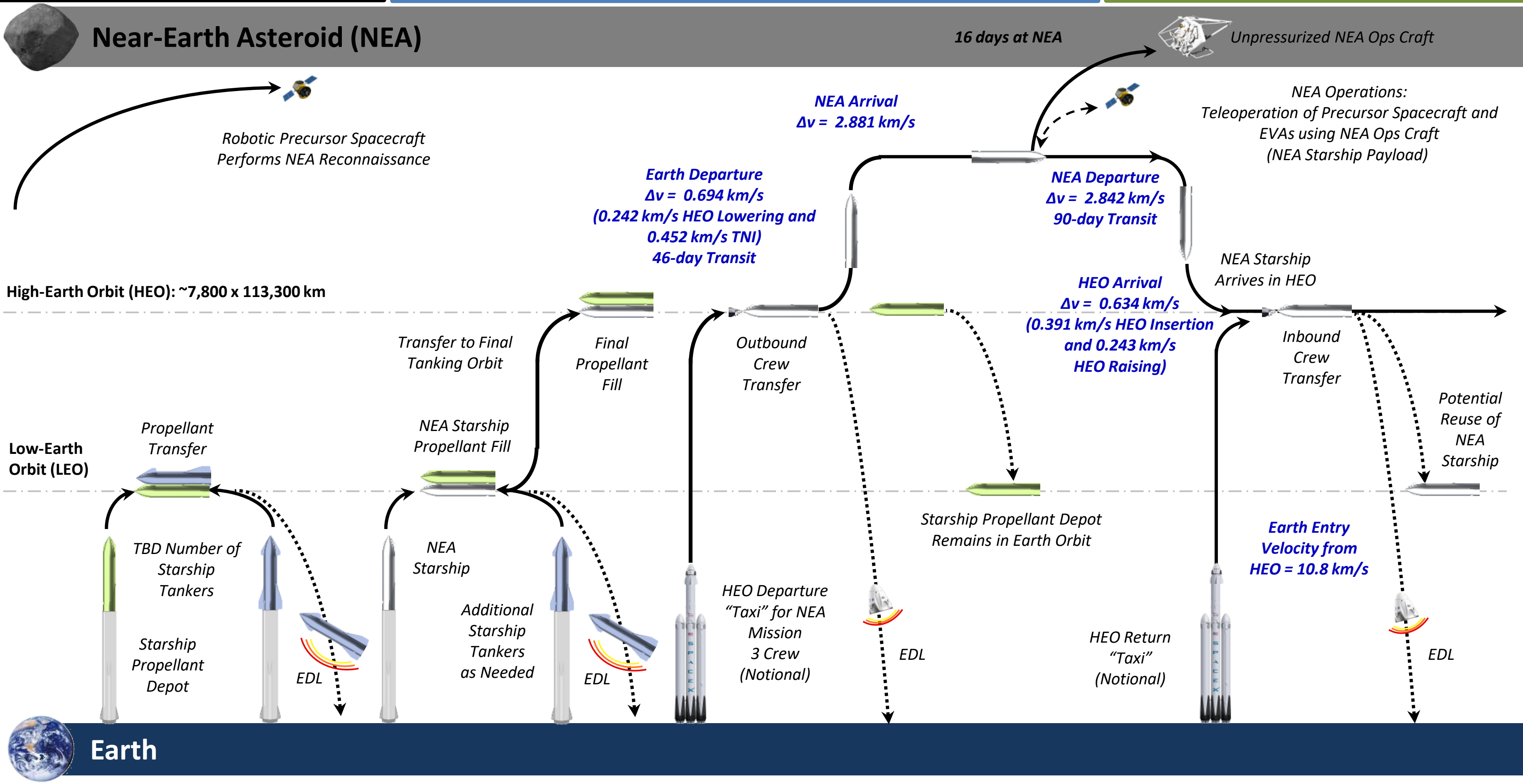
High-Earth Orbit (HEO) Departure and Return with NEA Teleoperated Operations and Crew EVAs

Transportation:
- Target: 2001 FR85 (19-85 m est. size)
- Departure Date: 2039-02-14
- Crew size: 3
- Total Crewed Mission Duration: 152 days
- Total Mission Δv: 7.051 km/s
- Earth Entry Velocity (via HEO taxi): 10.8 km/s

Destination:
- Time at 2001 FR85: 16 days
- Delivered Cargo: 3,500 kg
- Resources at NEA: Teleoperated Robotic Precursor Spacecraft; NEA Ops Craft (2,500 kg); utilization & spares (1,000 kg)
- Samples/Cargo Returned to Earth: 200 kg

Sensitivities:
- Total duration and NEA stay time
- Cargo (delivered and returned)
- Propellant Boiloff

Chart Notes:
- Spacecraft icons are not to scale
- Additional acronyms:
  - TNI = Trans-NEA Injection
  - EVA = Extravehicular Activity
  - EDL = Entry, Descent, and Landing



Mission Concept Animation

Play Video

Conclusions

- **We have presented an exemplar piloted mission to a known NEA that utilizes potential Mars mission architecture elements, but with relatively low requirements for total round-trip mission duration, total mission mass, and total mission Δv.**
- **Such a mission tests and demonstrates the elements and capabilities needed for missions to more demanding destinations such as Mars and other NEAs, but only requires the crew to handle five months in deep space.**
  - Moving outward into the solar system beyond the Earth-Moon system in a way that manages risk.
- **The exemplar mission shown herein to a known ~50 m NEA requires only ~7 km/s Δv (approximately the same as a round-trip mission to the lunar surface) and only a 5-month round-trip mission duration for the crew.**

Conclusions

- **Future NEO survey assets, such as NASA's forthcoming NEO Surveyor IR space telescope, will discover many NEAs that are larger in size and require even less round-trip mission duration / Δv during programmatically advantageous time frames in the 2030s.**
- **These "stepping stones" will pave the path for humanity to expand into the solar system while garnering knowledge about solar system history and evolution, planetary defense, and highly accessible in-space resources.**

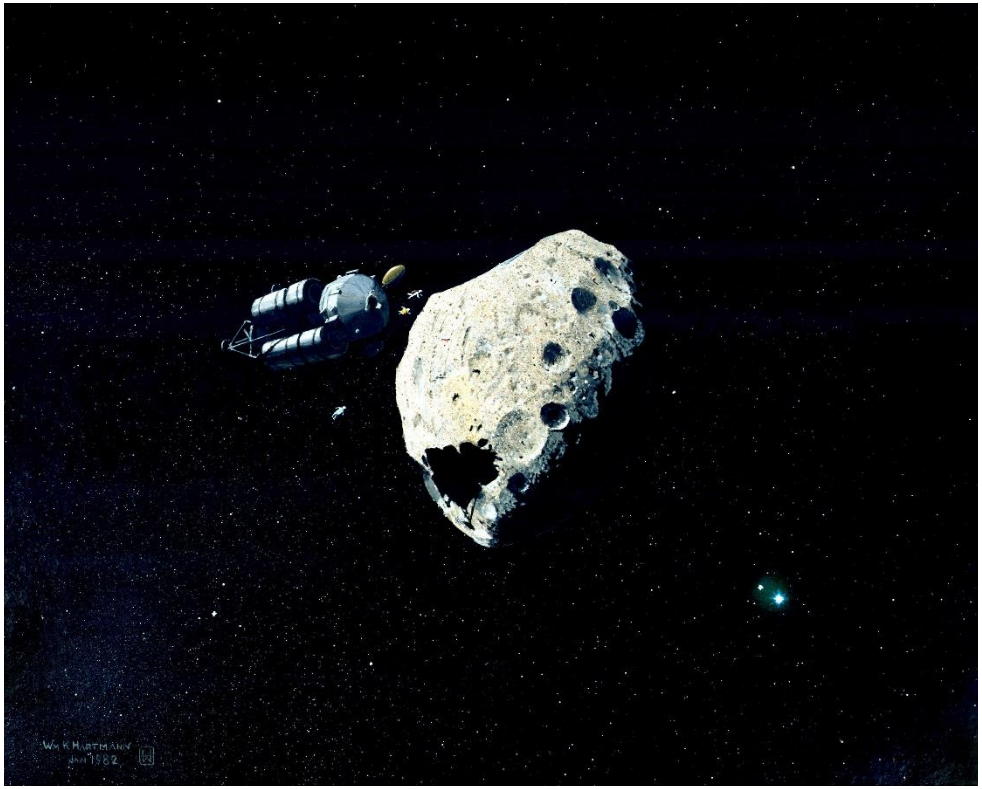


Image Credit: Bill Hartmann