National Aeronautics and Space Administration

Architectures for Human Exploration of Near Earth Asteroids

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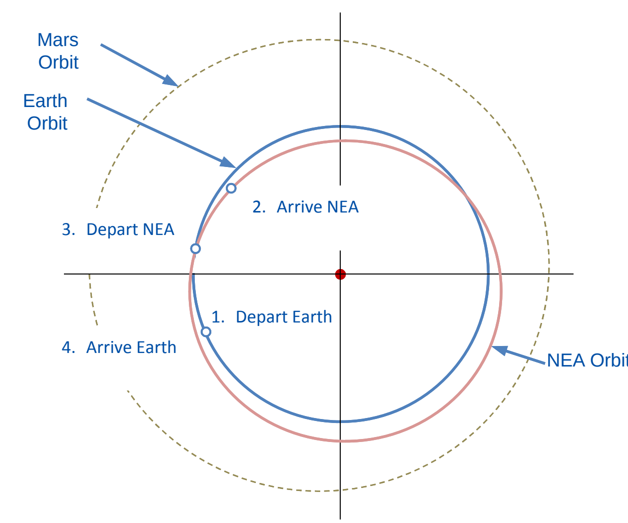
Human Exploration of NEAs Key Factors

- **Challenges of supporting humans for long-durations in deep-space**
  - How short can the trip times be reduced in order to reduce crew exposure to the deep-space radiation and micro-gravity environment?
- **Incorporation of advanced technologies**
  - Are there options to conduct easy, early missions?
  - What is the affect of infusion of advanced propulsion technologies on target availability
- **Mission design constraints:**
  - When do the departure opportunities open up?
  - How frequent are they?
  - How long is the departure window
- **How many launches are required to conduct a round trip human mission to a NEA**



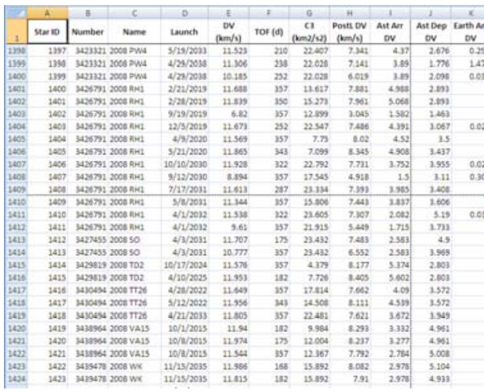
Overview

- **NHATS [Near-Earth Asteroid (NEA) Human Space Flight (HSF) Accessible Targets Study] trajectory scans by both the GSFC and JPL teams produced millions of potential trajectories to thousands targets**
- **Of those millions of trajectories, thousands may represent “good” candidate mission opportunities**
- **Several different transportation technologies considered, including**
  - All chemical propulsion
  - Nuclear Thermal Propulsion (NTR)
  - Electric Propulsion (Solar Electric) for the deep space portion of the mission
  - Hybrid Propulsion as characterized by chemical boost + Solar Electric
- **Architecture mass estimated for each unique trajectory to help facilitate the strategic planning process**

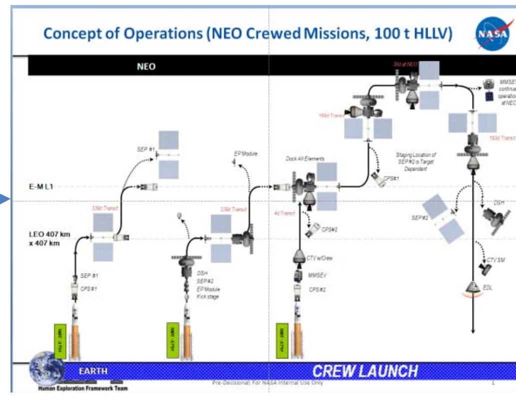
CAUTION **Due to time limitations and the sheer magnitude of number of simulations to be run, only parametric mass sizing was implemented. Although the parametric results have been validated with results from more detailed assessments, the results contained herein should be used for comparative assessments only**

Applied Methodology

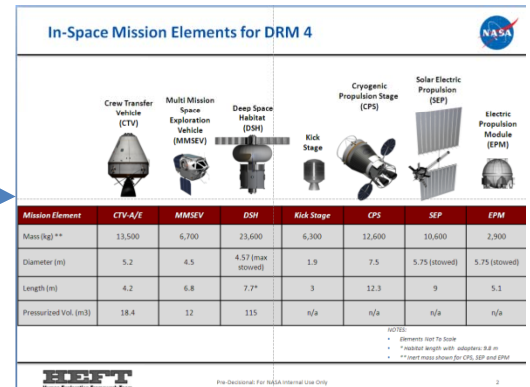
Trajectory Scans



Operational Concept



Mission Payload Definition



Propulsion System Parametric Sizing

$$R = e^{\frac{\Delta V}{g * I_{sp}}}$$

$$Mass_{prop} = Mass_{payload} * (R - 1) * \frac{(1 - f_{inert})}{1 - R * f_{inert}}$$

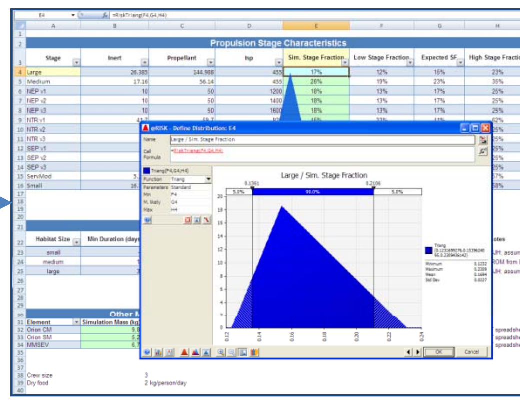
$$Mass_{inert} = Mass_{prop} * \frac{f_{inert}}{1 - f_{inert}}$$

$$Mass_{stage} = Mass_{prop} + Mass_{inert}$$

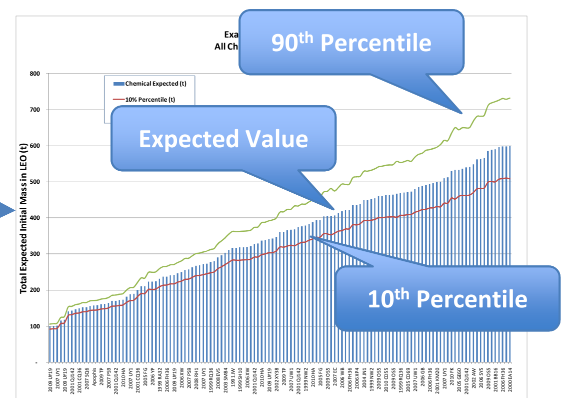
$$Mass_{phase} = Mass_{stage} + Mass_{payload}$$

Define Simulation Variables

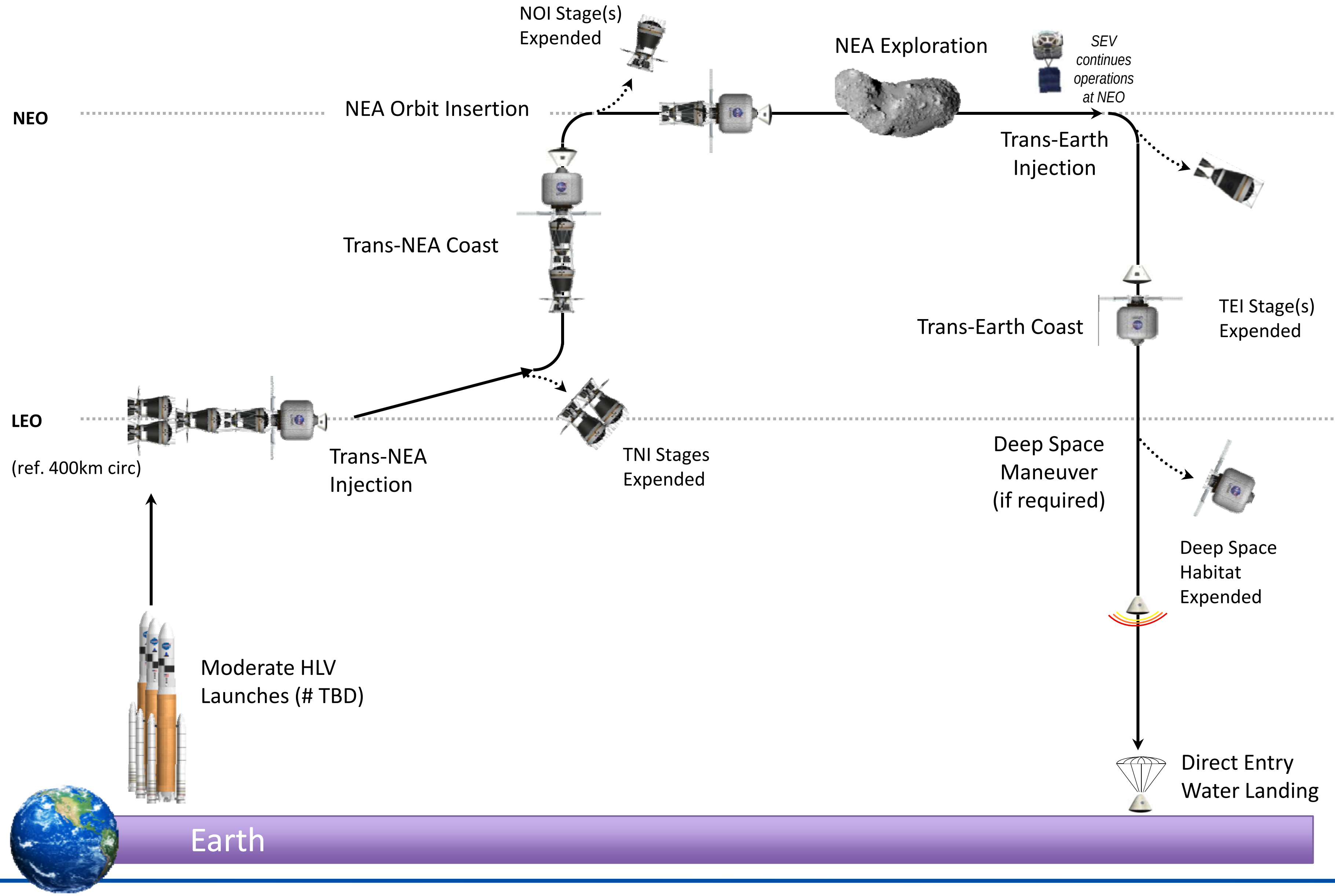
To account for early conceptual designs



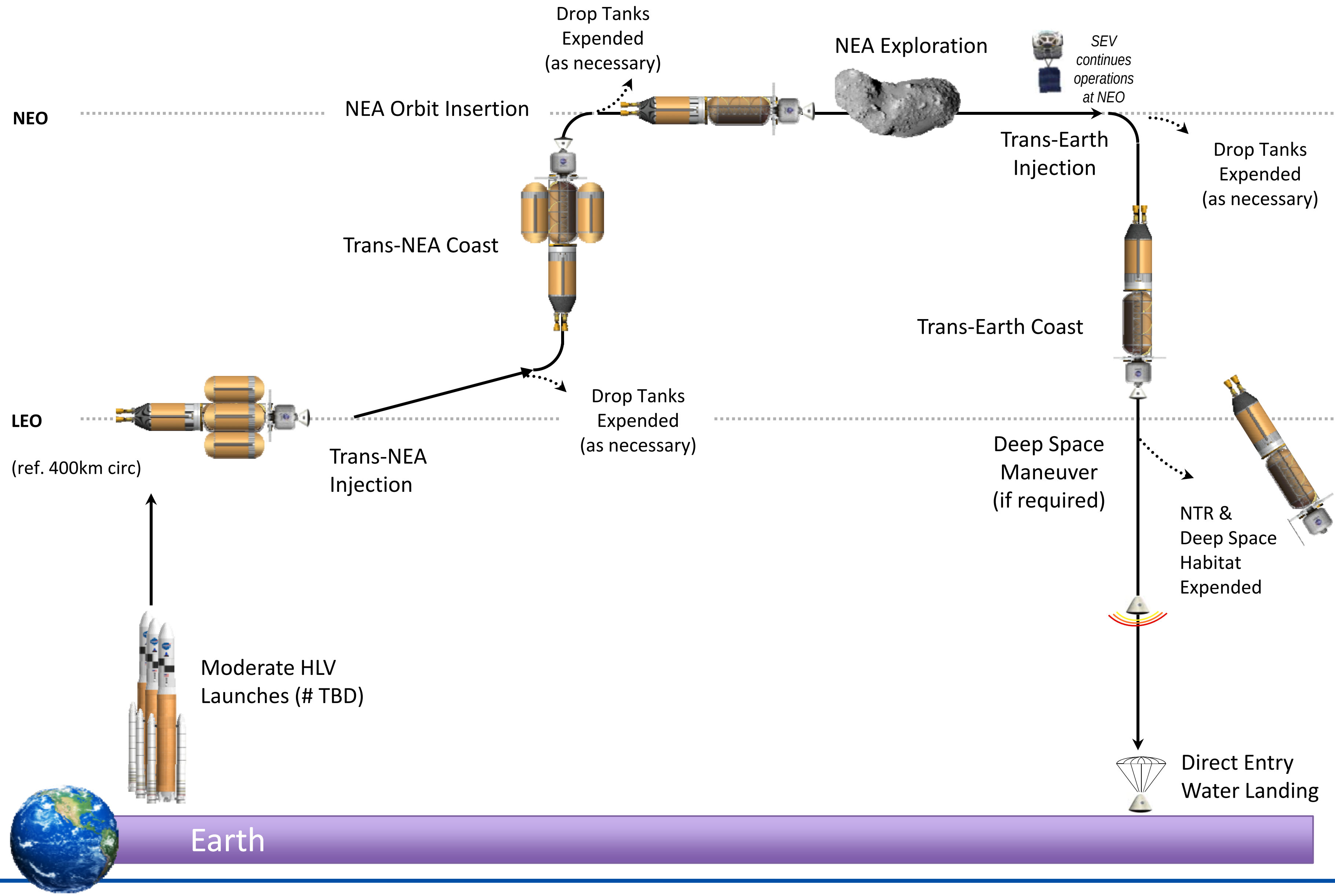
Simulation Results



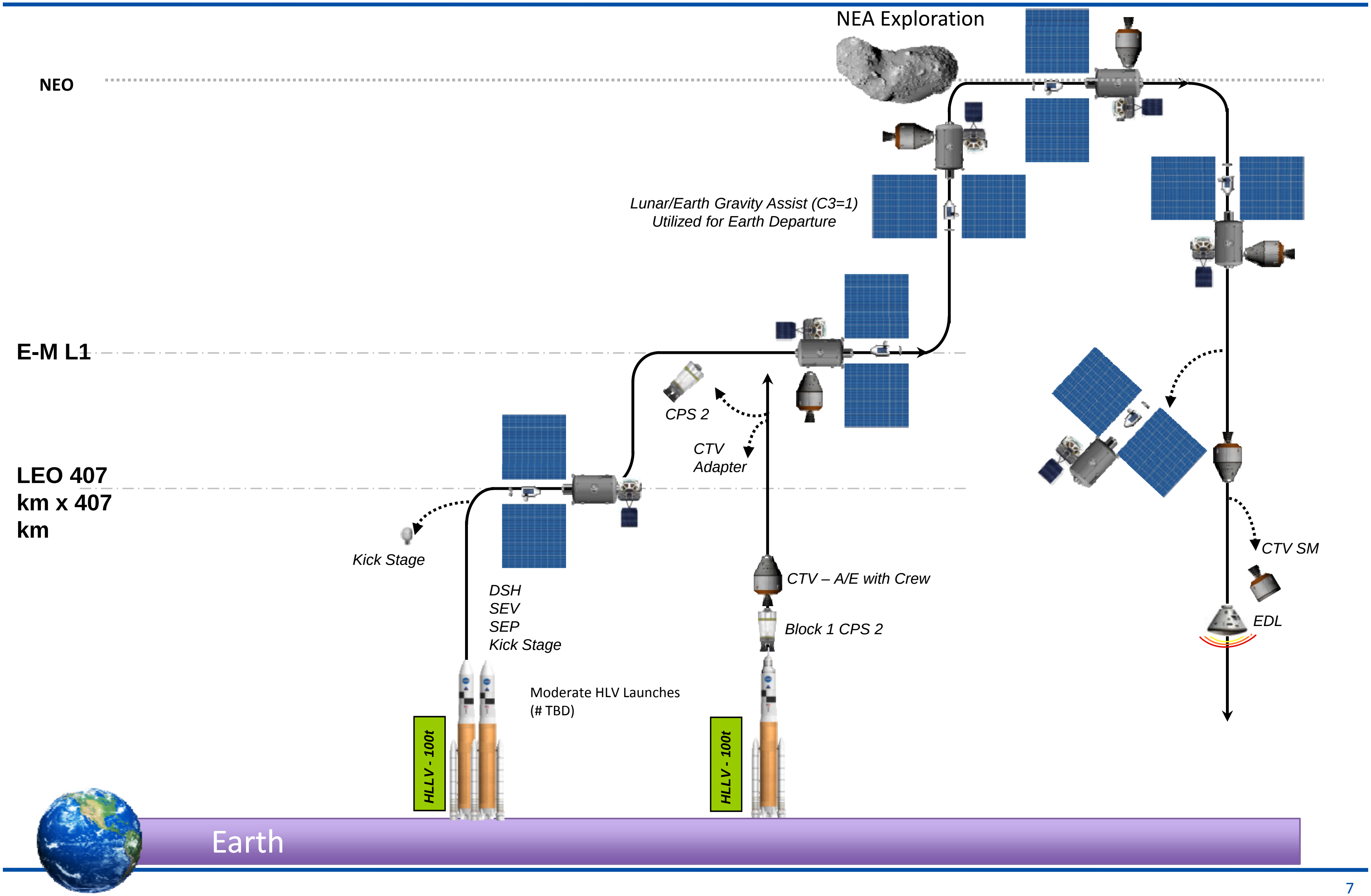
All Chemical NEA Mission Operations



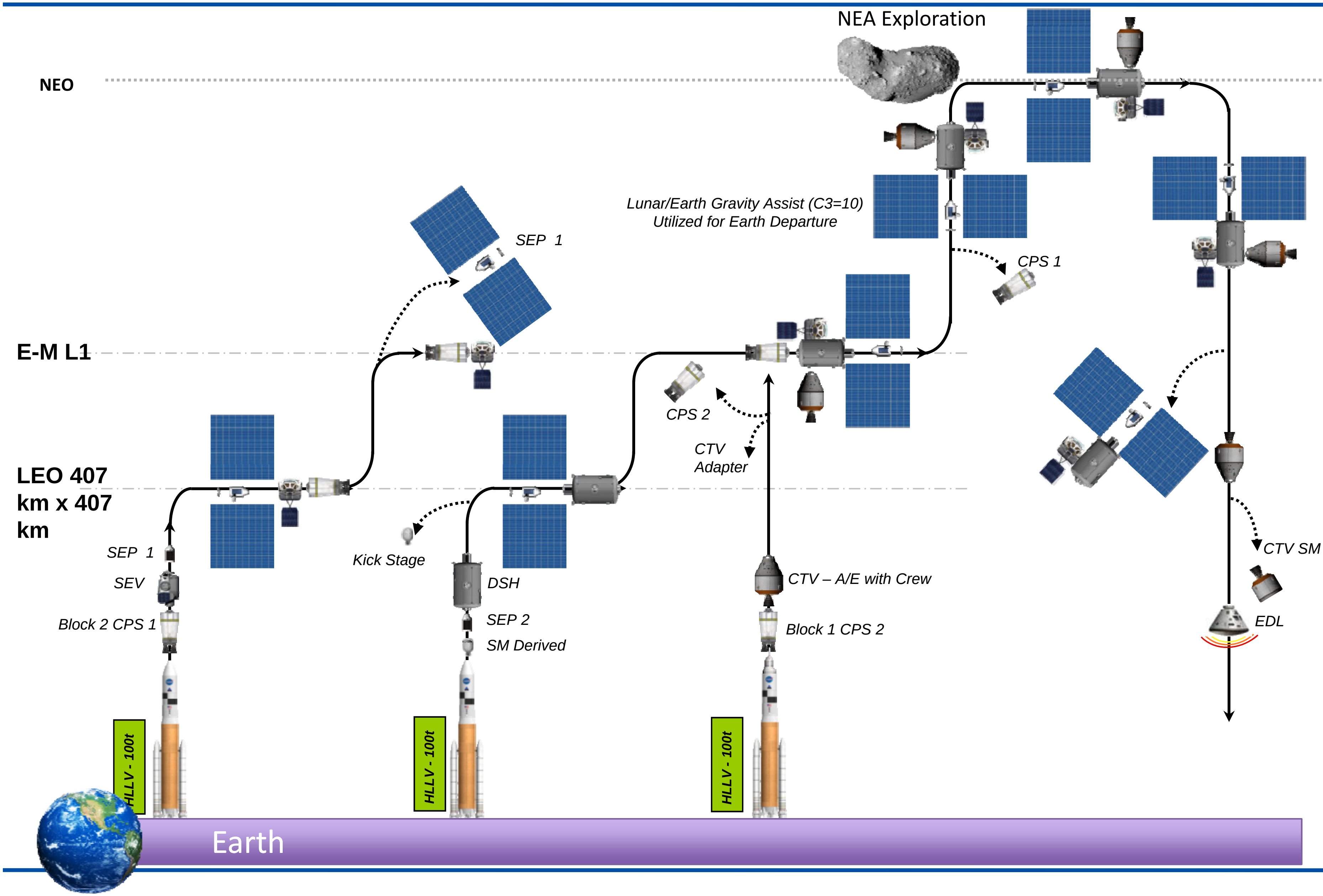
All Nuclear Thermal Propulsion NEA Mission Operations



SEP Only for Deep Space Mission Operations



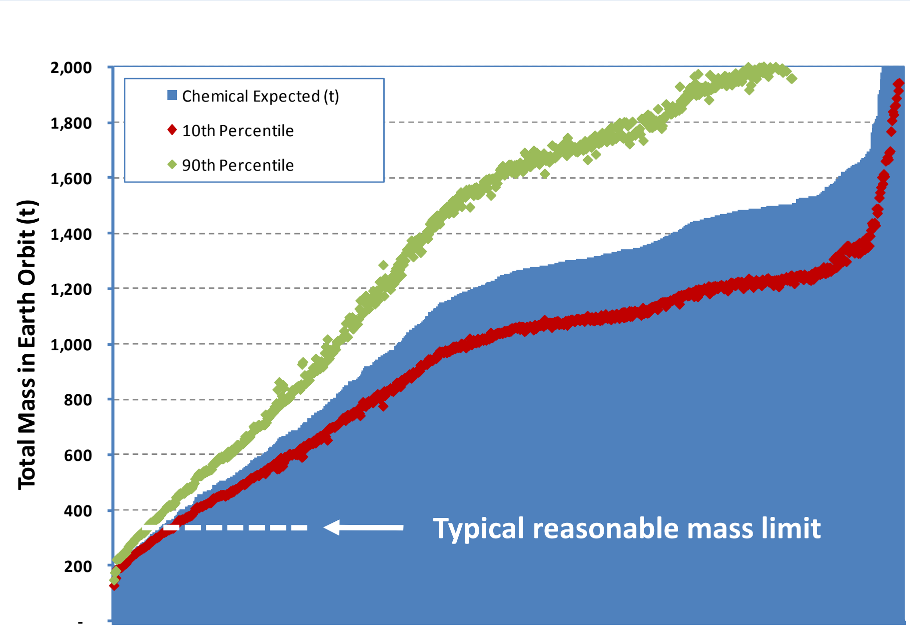
SEP/Chemical Hybrid NEA Mission Operations



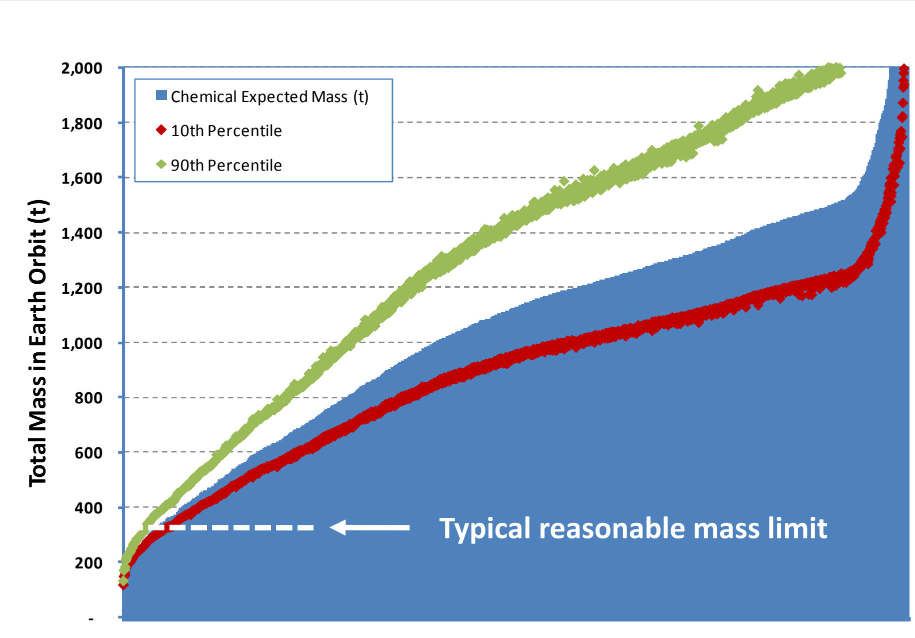
Example Mass Trends Between Datasets

All Chemical Propulsion Architecture

GSFC Dataset

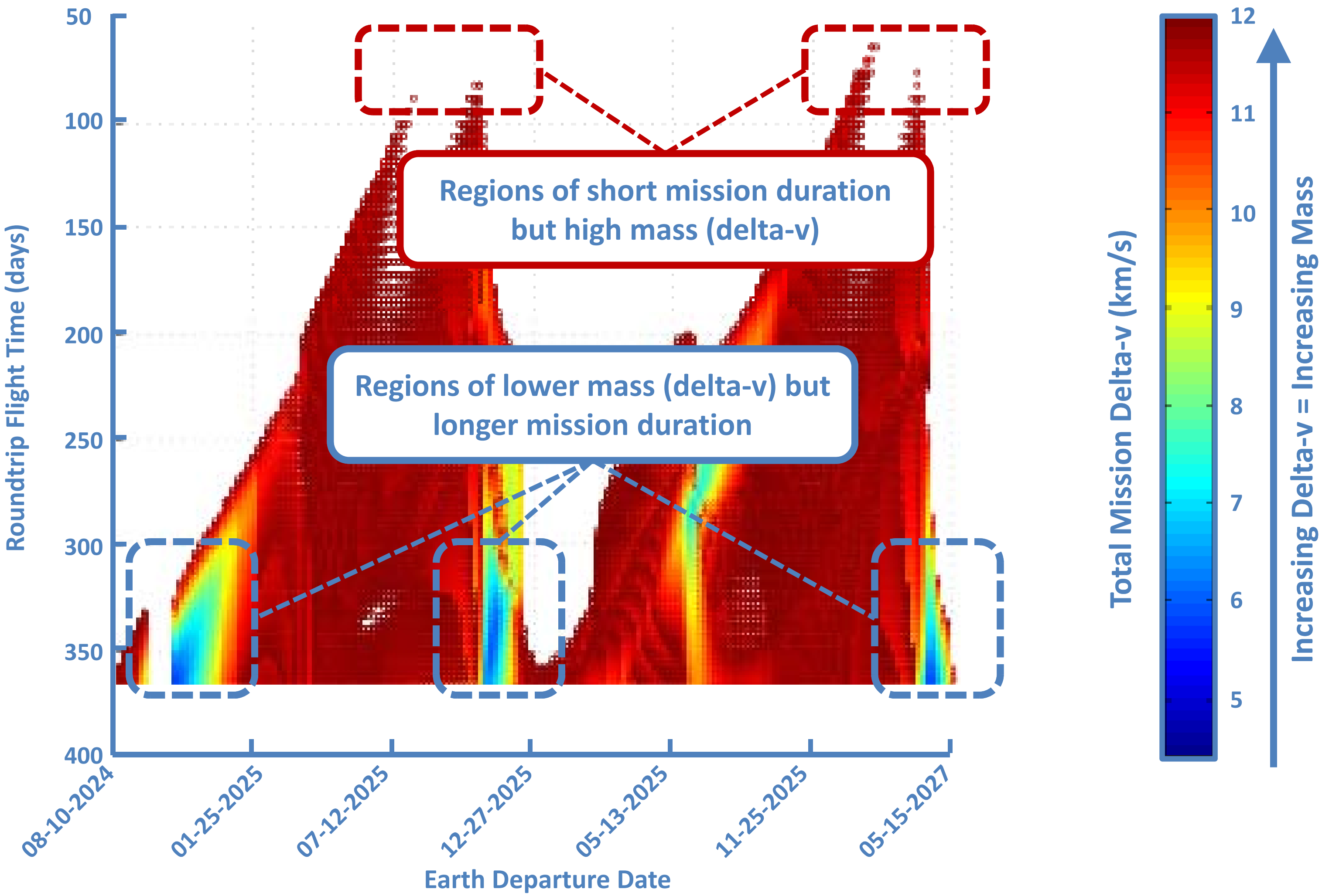


JPL Dataset



Example Sensitivity of Delta-v and Trip Time

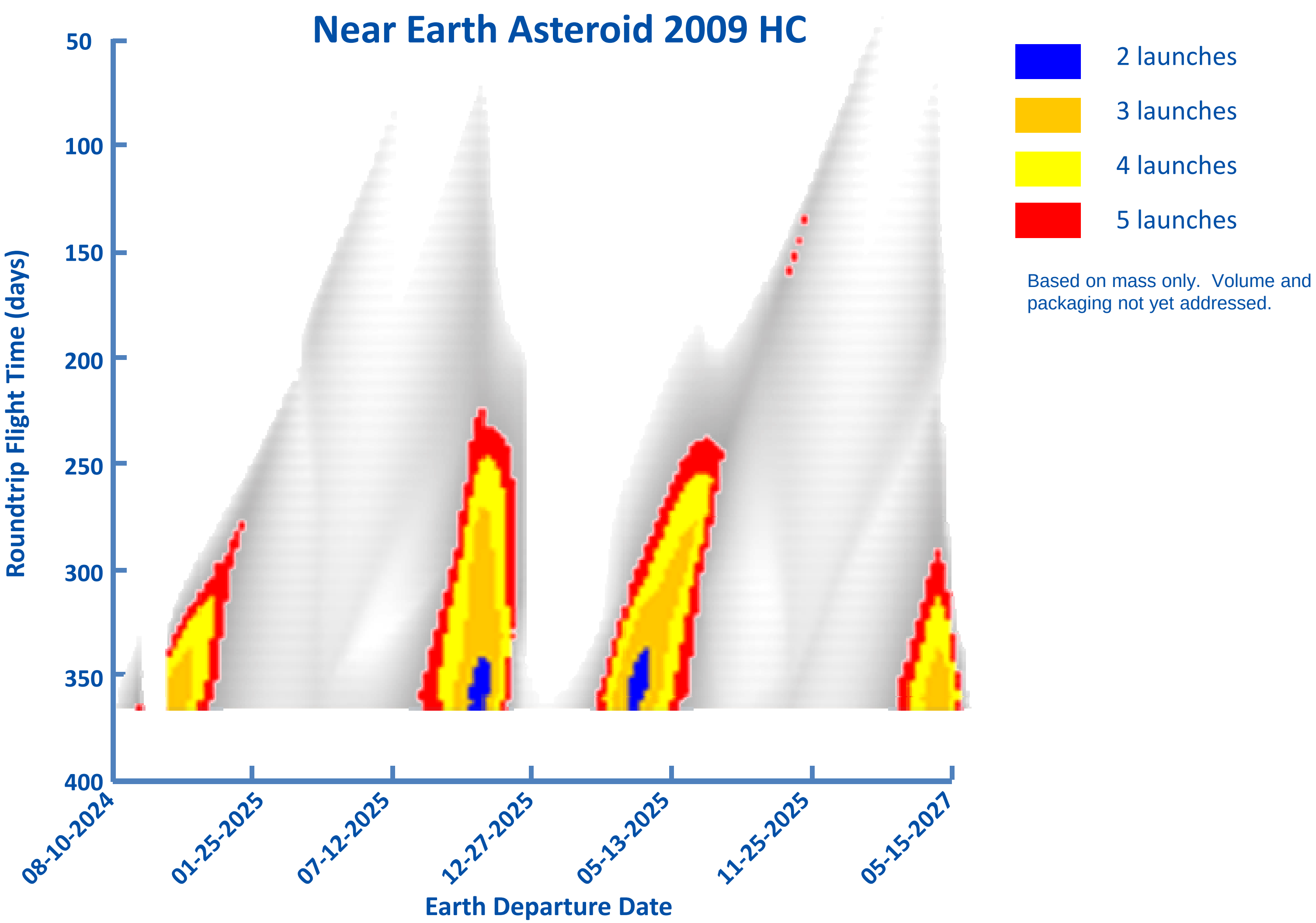
Near Earth Asteroid 2009 HC



Courtesy GSFC

Example Sensitivity of Number of Launches and Trip Time

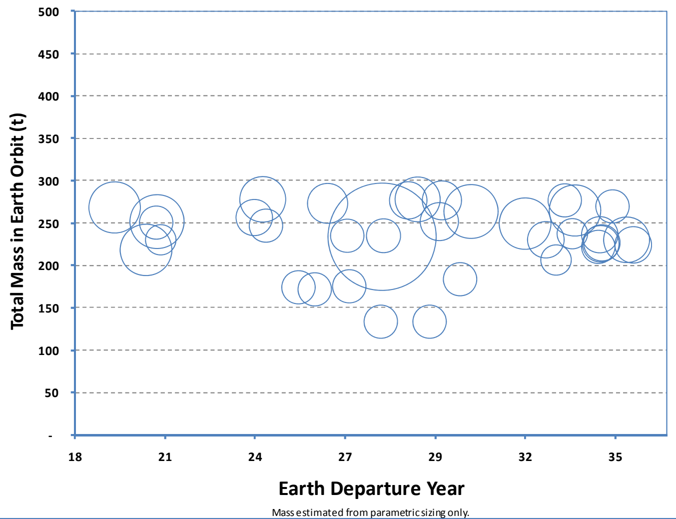
All Chemical Propulsion Architecture



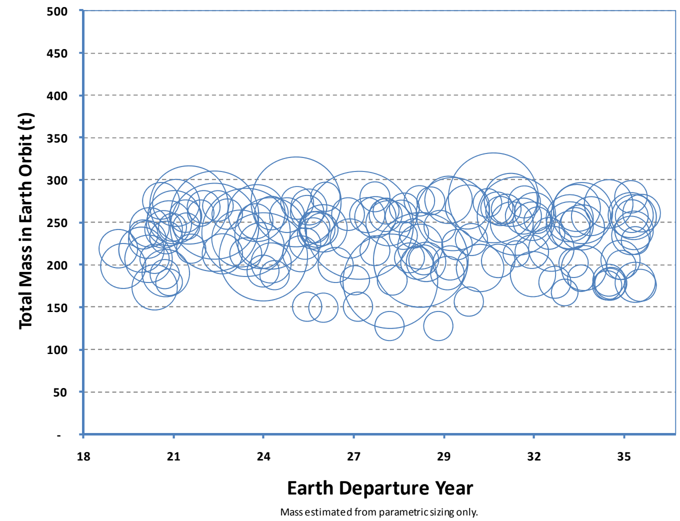
Example # of Expected Targets for Various Transportation Architectures

Circa 2020-2035, Asteroids > 30m, Approximately 3 Launches, < 1 Year Duration

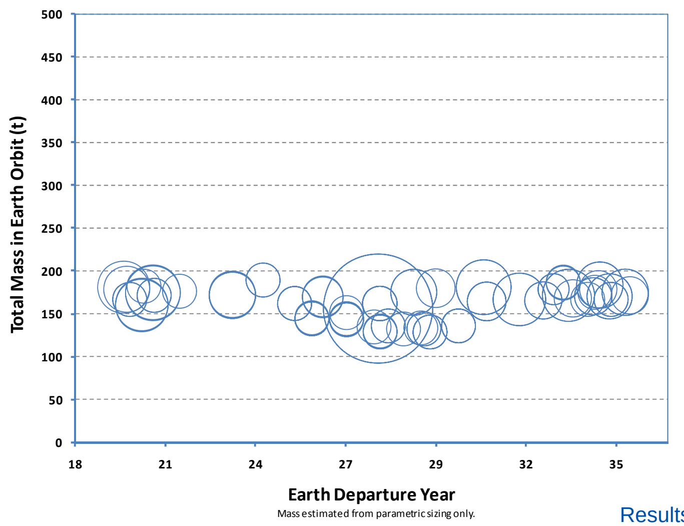
All Chemical Architecture



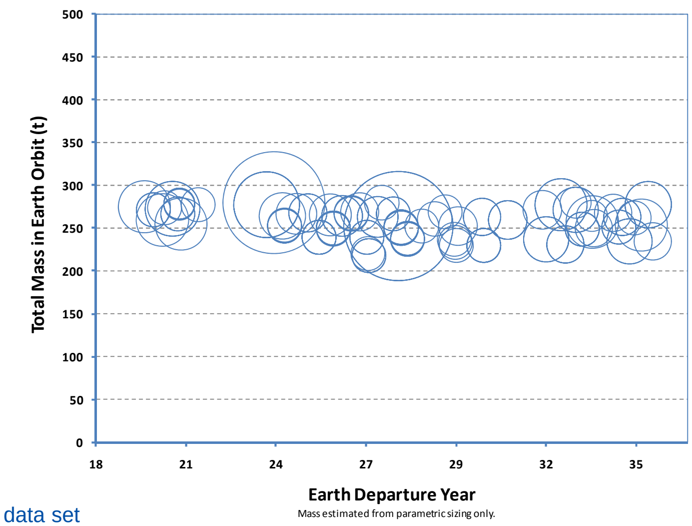
All NTR Architecture



All SEP for Deep Space



SEP/Chemical Architecture



Results associated with the JPL data set

Summary

- Mission design and architectural assessments still under way
- No firm decisions yet on specific technologies or NEA targets have been made
- Key focus is on understanding the key capabilities and technologies required for a broad range of exploration architectures including human exploration of NEAs

Contributors

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