

Rapid Mission Design to Enable Asteroid Mining



ASTRO
FORGE

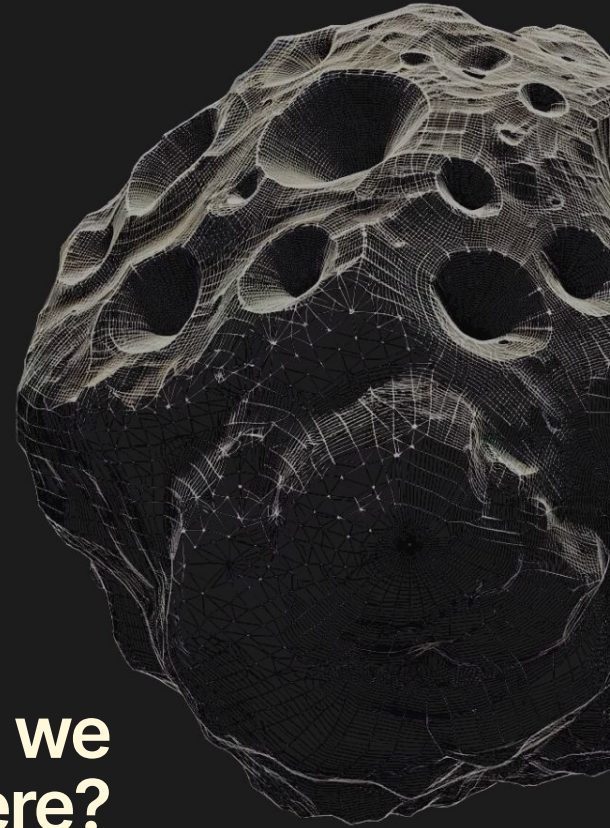
Demyan Lantukh
Colin Helms

Space Resources Roundtable
June 7, 2024

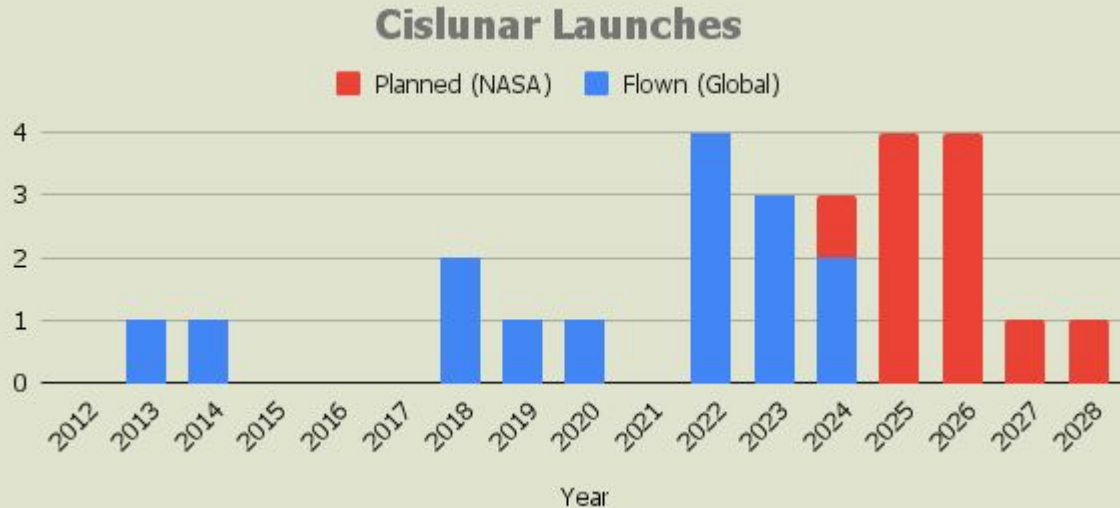
A wealth of resources
is out there



**How do we
get there?**

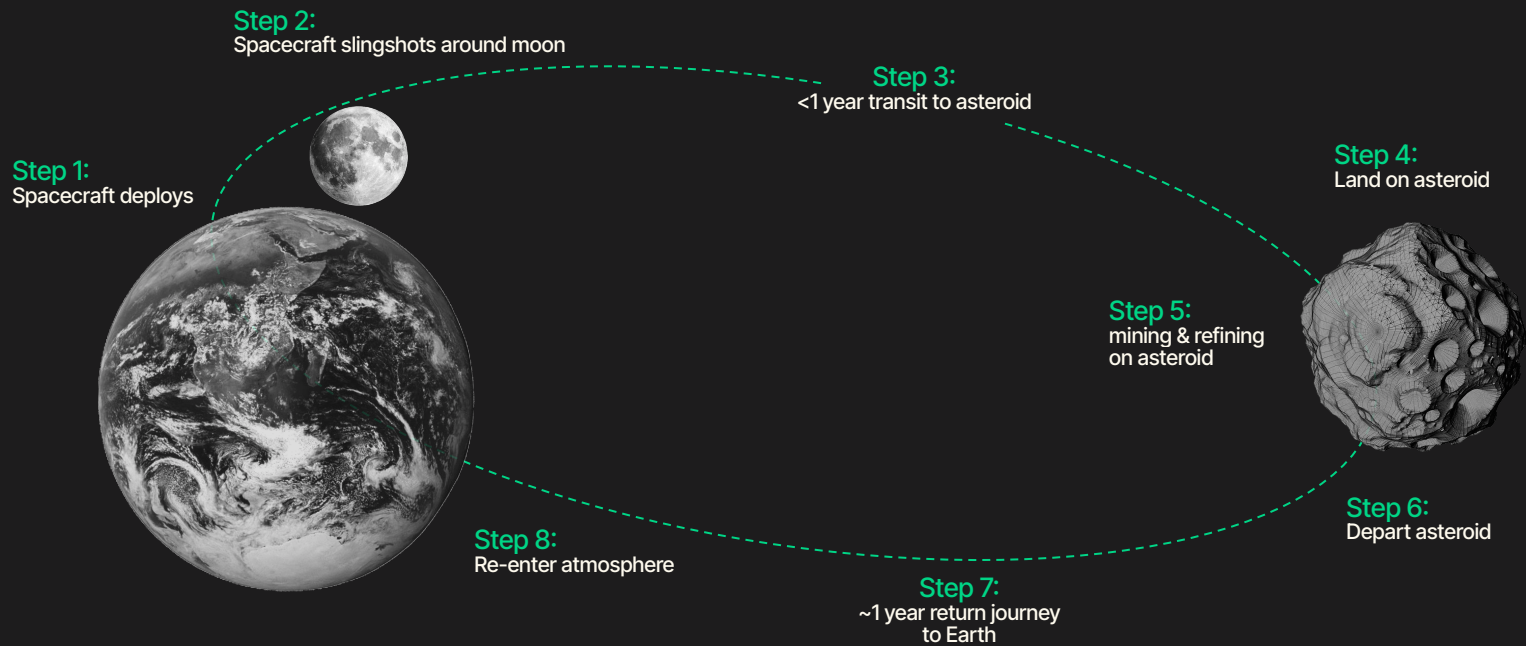


The world is going to the moon



Can we use these launches to go farther?

Rapid missions for rapid results

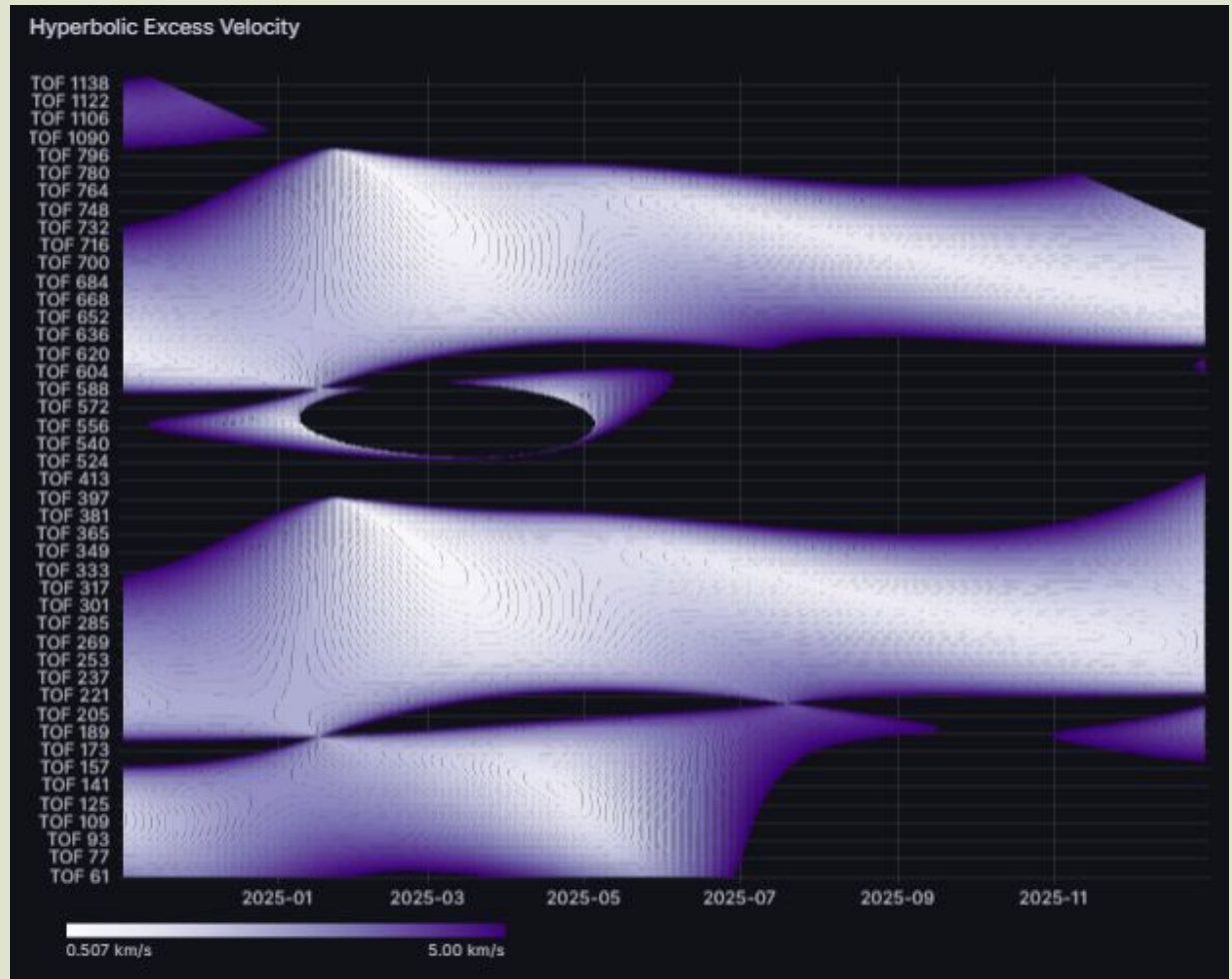


Dedicated launch

Start from a trade space of time of flight (TOF), launch date, and launch energy (hyperbolic excess velocity)

Each point in this trade space gives a **departure asymptote** that the launch vehicle targets

Repeat for each potential asteroid target

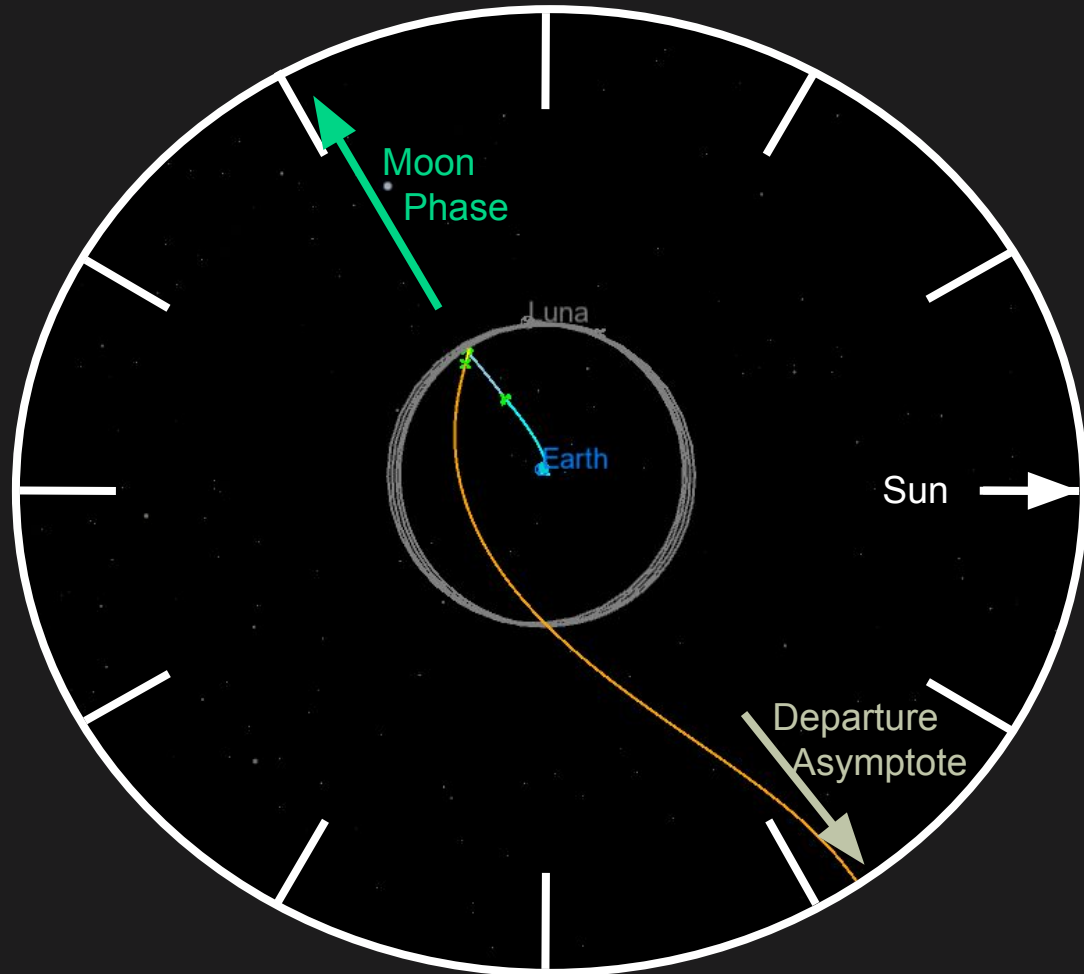


Being a rideshare

Primary payload sets launch date and moon phase we are going to get

We need to figure out how to get from there to the right departure asymptote

This changes each time launch slips / changes





Data pipeline approach to mission design

Enabling quick iteration and incorporating new asteroid observations as long as possible

1-3 years before launch Target Prioritization & Feasibility

- Low-fidelity models
- Thousands of asteroids
- Thousands of launch and arrival dates
- Handle chemical and electric propulsion.
- Generate requests to astronomical observatories to gather data on the most promising asteroids

6 months before launch Launch Window & Uncertainty

- Detailed design at flight fidelity
- Couple months of potential launch dates
- Monte Carlo and sensitivity analysis
- Generate operations products for tests and rehearsals.
- Multiple target asteroids in consideration

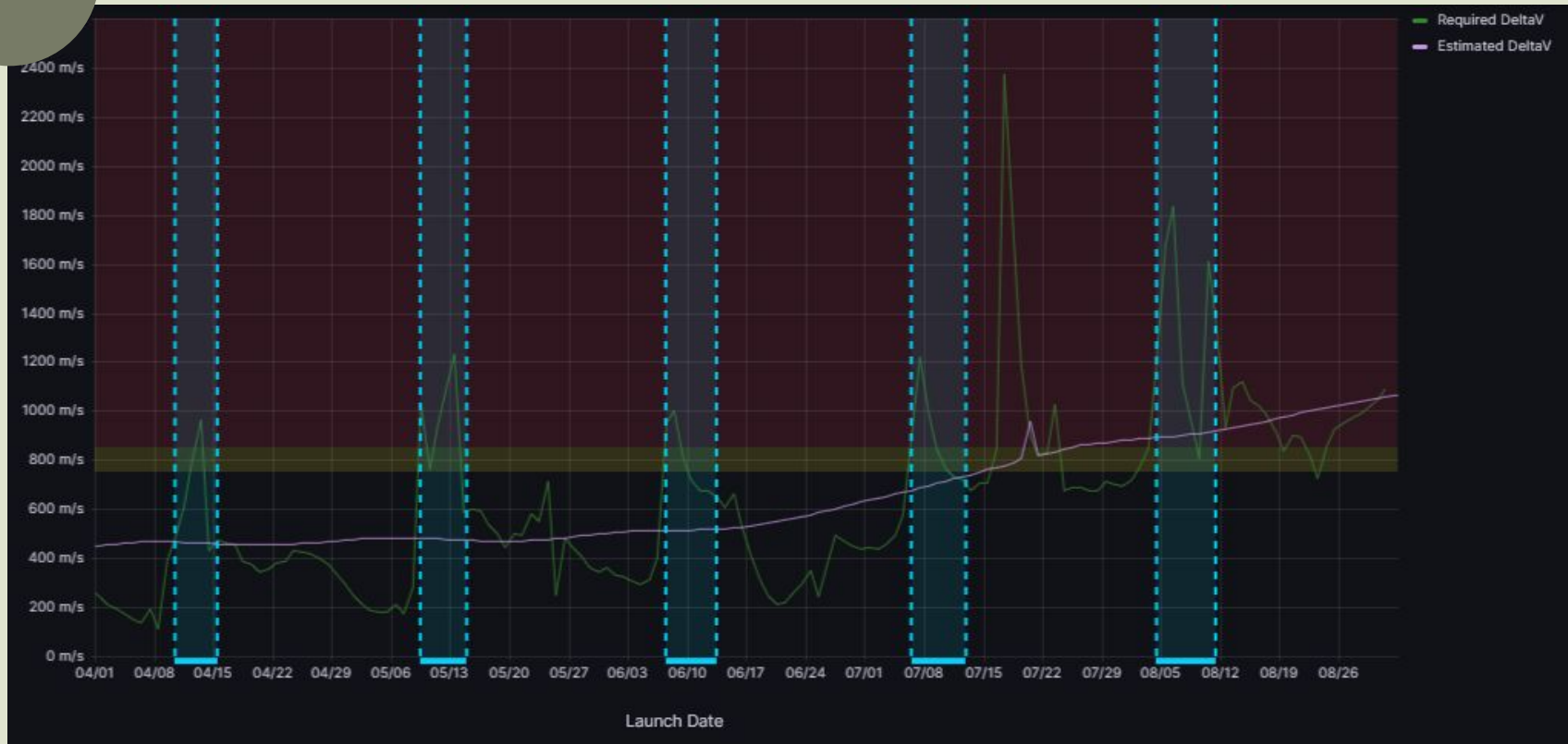
1 month before launch Target Selection & Flight

- Use launch window analysis and any data from ground-based observations to select specific target.
- Detailed design at flight fidelity using design reference mission (DRM) from launch provider.
- Generate operations products and apply before flight (ABF) settings

Target prioritization & feasibility



Launch window computation



Uncertainty analysis - Lunar flyby

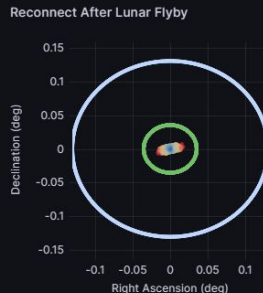
Targeting Maneuver After 1 day

Targeting Maneuver After 2 days

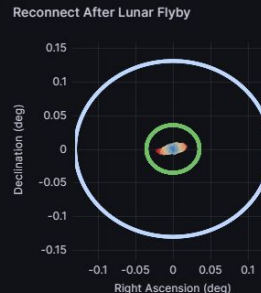
Targeting Maneuver After 3 days

Achieve Target
Orbit
Determination
Accuracy: $4 \times 2 \times 2$
km

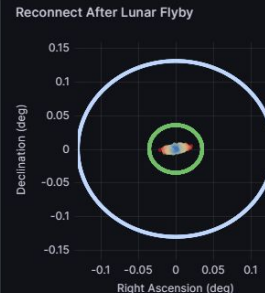
Impact the Moon
0%
Targeting ΔV_{99}
39.2 m/s



Impact the Moon
0%
Targeting ΔV_{99}
62.4 m/s

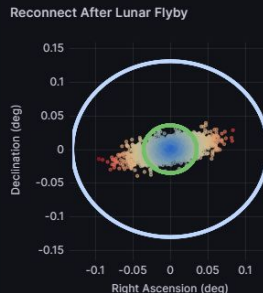


Impact the Moon
0.23%
Targeting ΔV_{99}
111.8 m/s

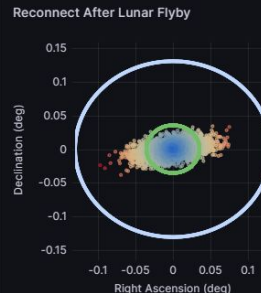


Achieve Standard
Orbit
Determination
Accuracy: $20 \times 10 \times 10$
km

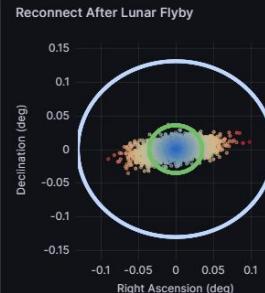
Impact the Moon
0.53%
Targeting ΔV_{99}
39.1 m/s



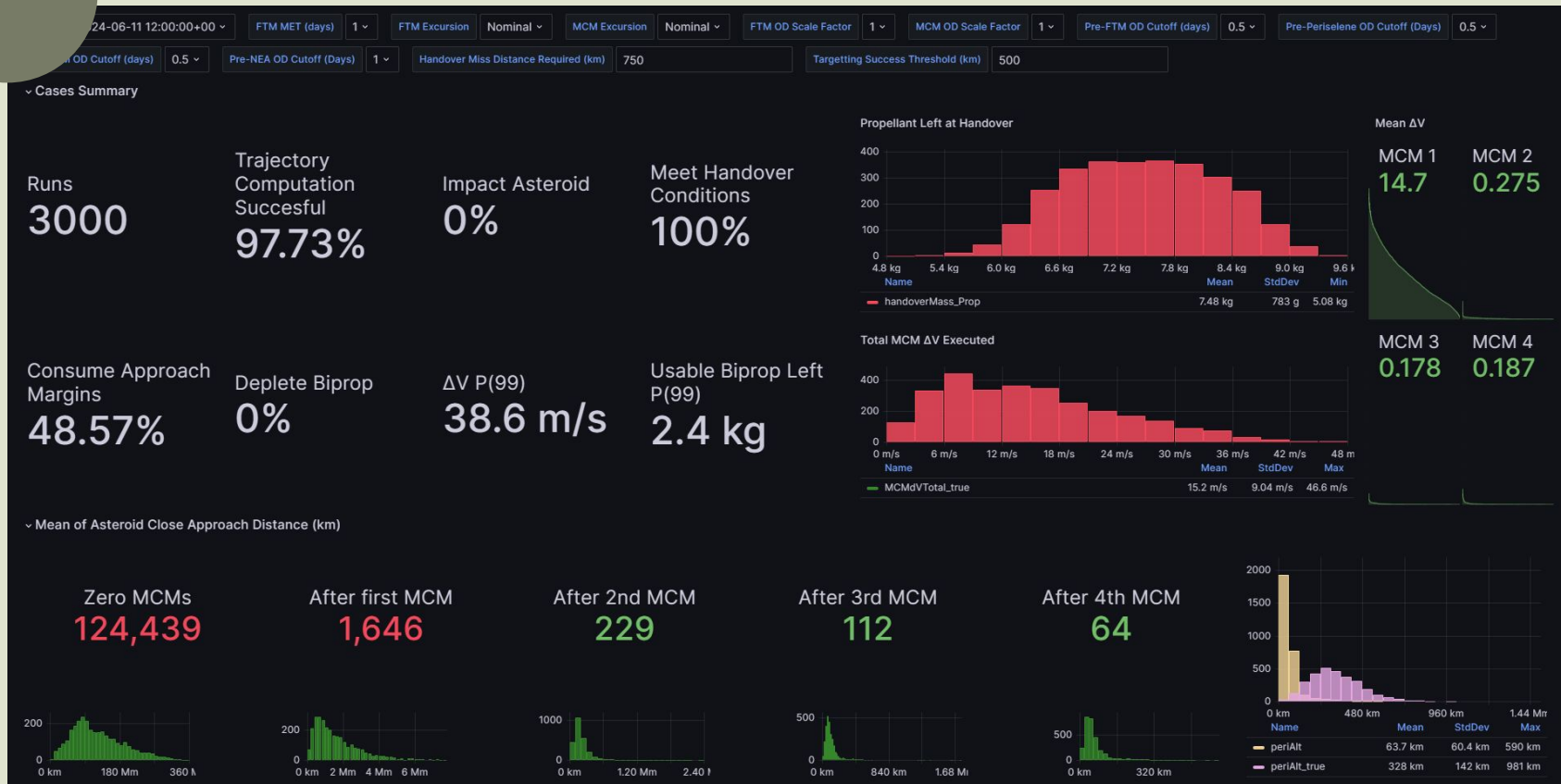
Impact the Moon
0.2%
Targeting ΔV_{99}
62.4 m/s



Impact the Moon
0.3%
Targeting ΔV_{99}
112.1 m/s



Uncertainty analysis - setting up for asteroid approach

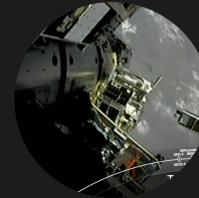


The time for asteroid mining is now



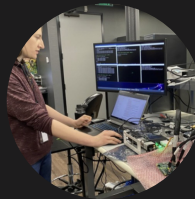
Decrease in launch costs

Rideshare deals for cislunar launches and cheaper dedicated launches



Industry Expansion

New space economy enables affordable components for spacecraft assembly



Greater Asteroid Data

Significant data on NEAs coming in annually and we have devised a process to reach them

Thank you.

