SEP Trajectories and Mission Design

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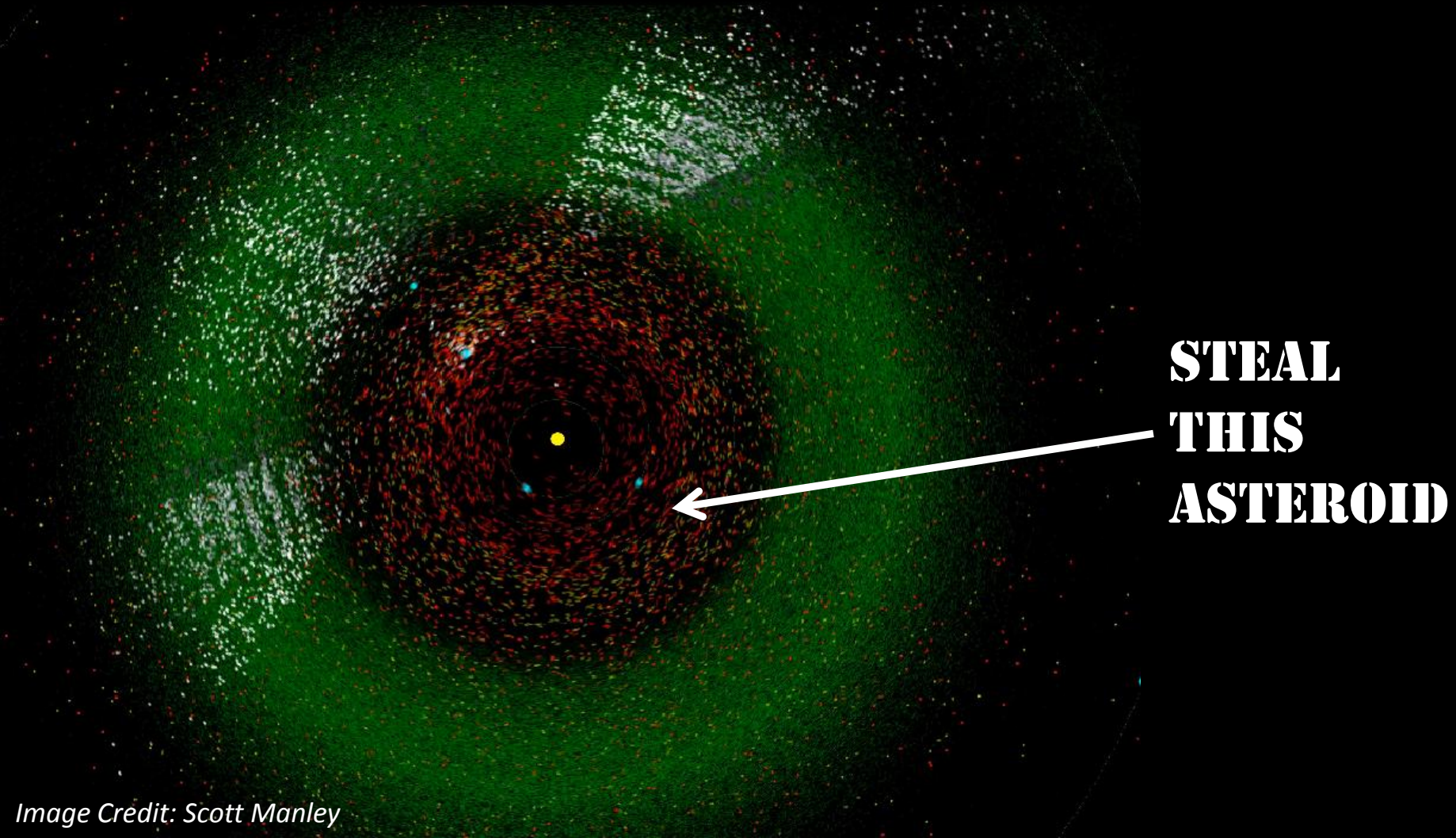
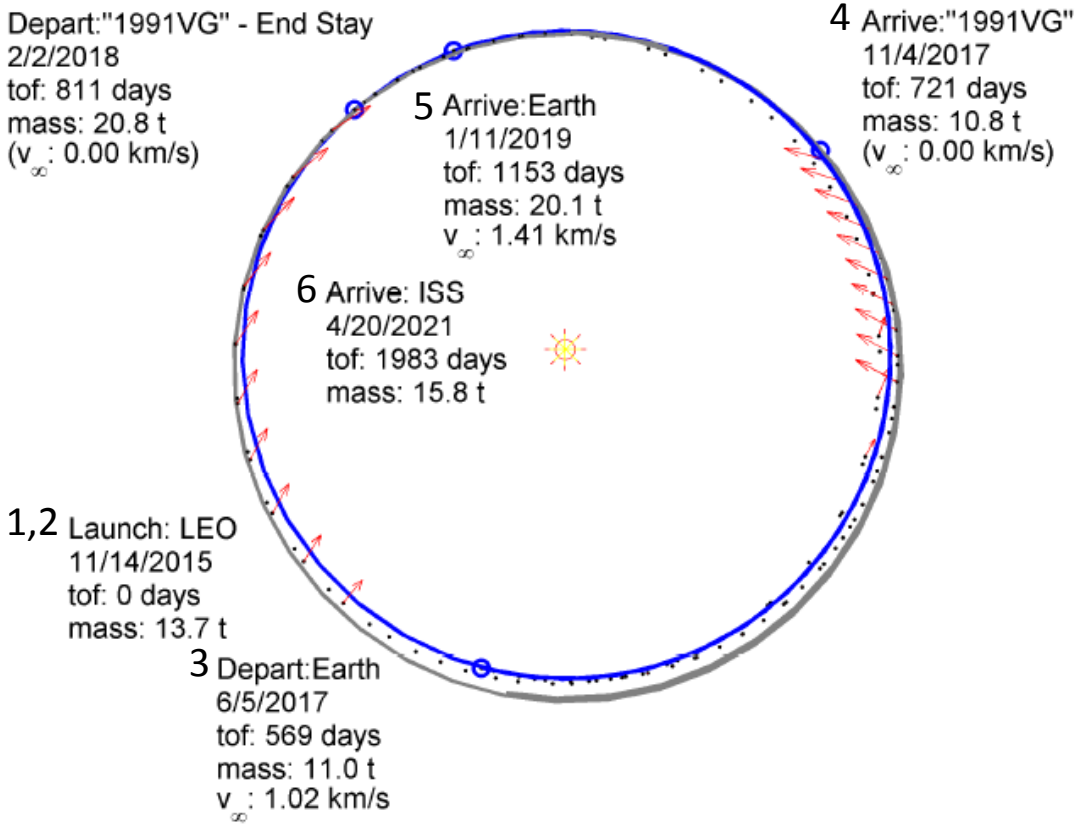


Image Credit: Scott Manley

Proof-of-Concept Mission

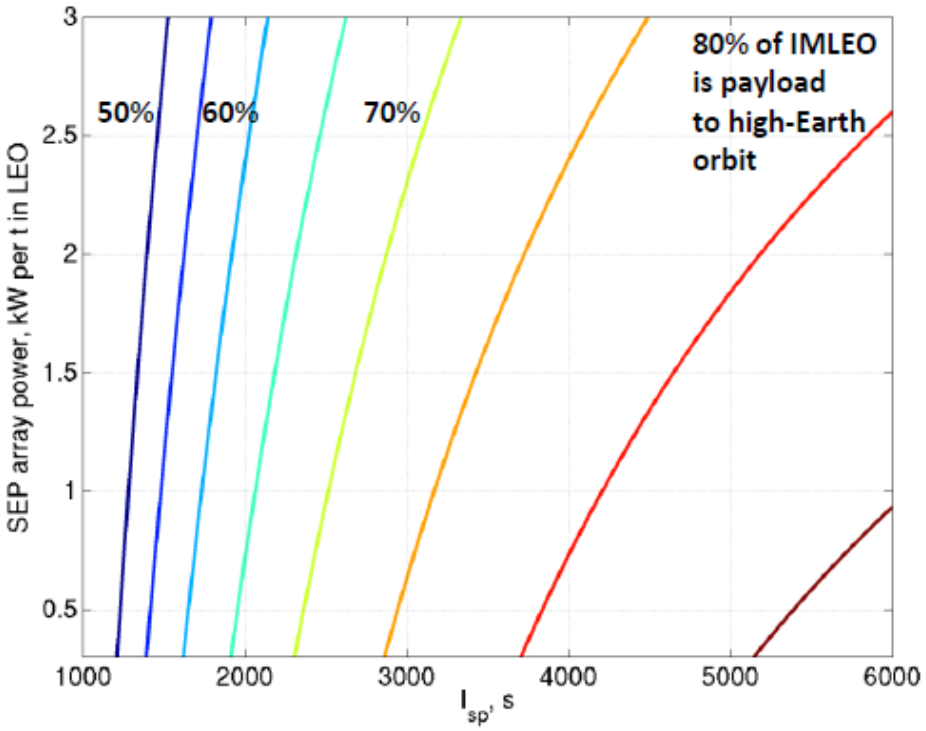
Return 10-t Asteroid to ISS

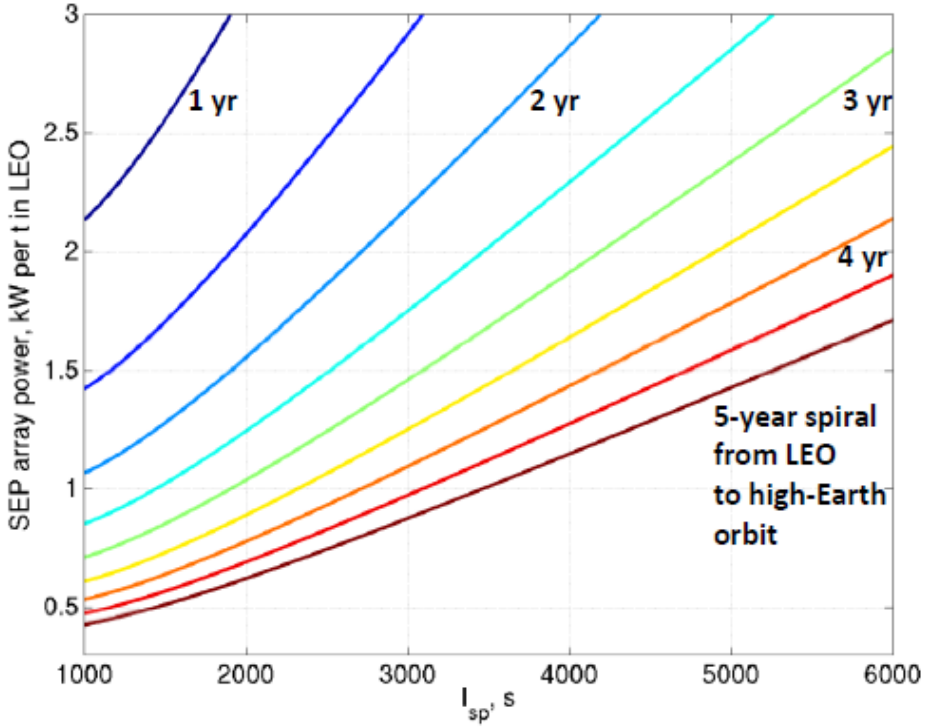


Mission Phases

1. Launch, 10–15 t s/c
   - Atlas 521 to LEO
   - Delta IV H to GTO
2. Departure spiral, 40 kW
   - 6.6 km/s, ~1.5 yr. from LEO
   - 3.0 km/s, ~0.6 yr. from GTO
3. Lunar flyby escape
   - 2–3 km/s for “free”
4. Interplanetary trajectory
   - 1–4 km/s, 1.5–3 yr.
5. Lunar flyby capture
   - 2–3 km/s for “free”
6. Capture spiral
   - 6.6 km/s, >2 yr. to ISS

SEP Spiral





Spiral Cheatsheet :

$$\eta_{jet/array} P_{array} = \frac{1}{2}\dot{m}\left(gI_{sp}\right)^2, \frac{m_0}{m_f} = e^{\Delta V / gI_{sp}}, \ \Delta V = V_{circ,1} - V_{circ,2}$$

$$m_{propellant} = m_0\left(1 - e^{-\Delta V / gI_{sp}}\right), \dot{m} = \frac{2\eta P_{array}}{\left(gI_{sp}\right)^2}, Time = m_{prop} / \dot{m}$$

add margin (10–30 %?) for radiation and shadowing

<u>SEP inert mass</u>

30 kg/kW array

15% Xe

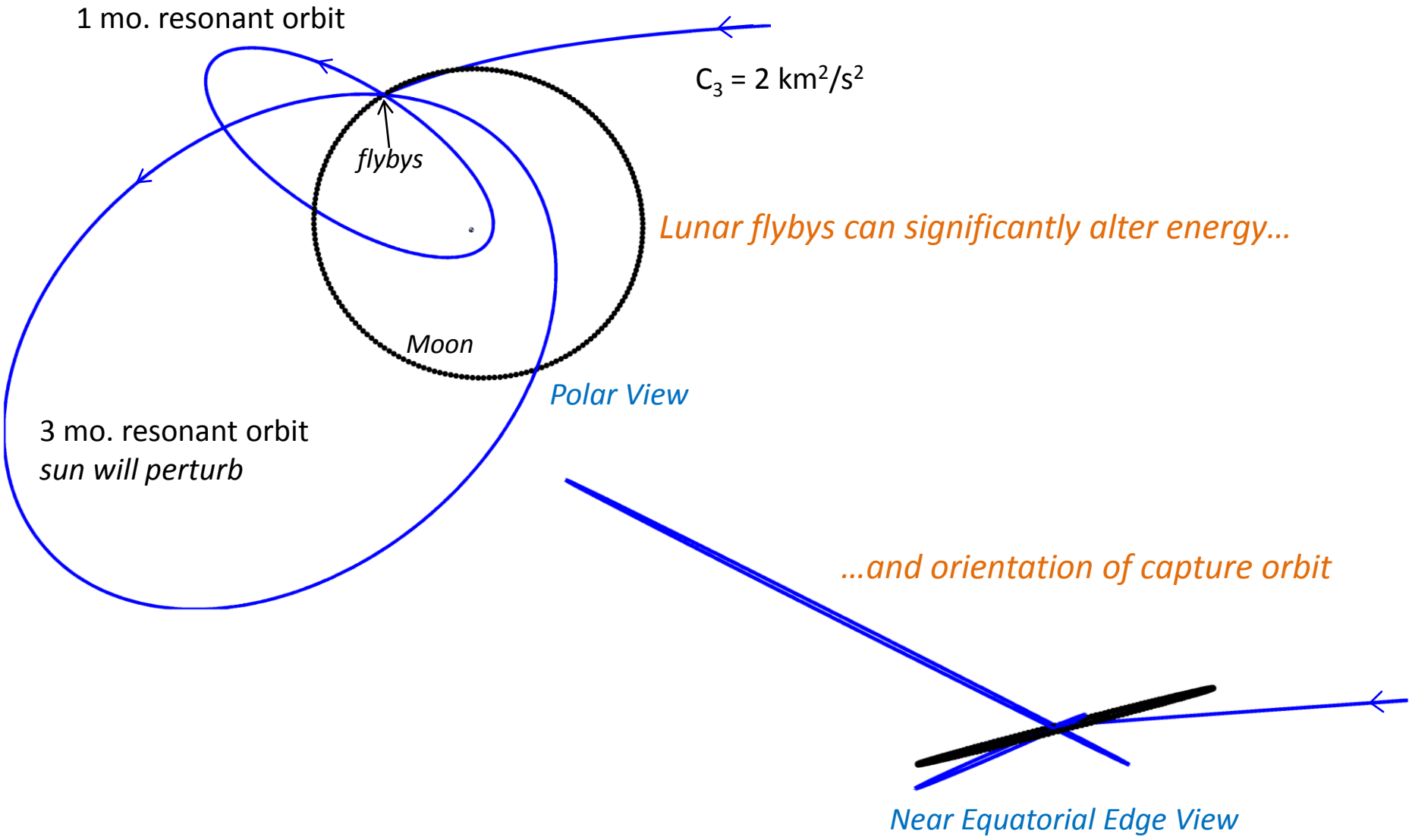
<u>Array to Jet efficiency</u>

50% @ 1600 s

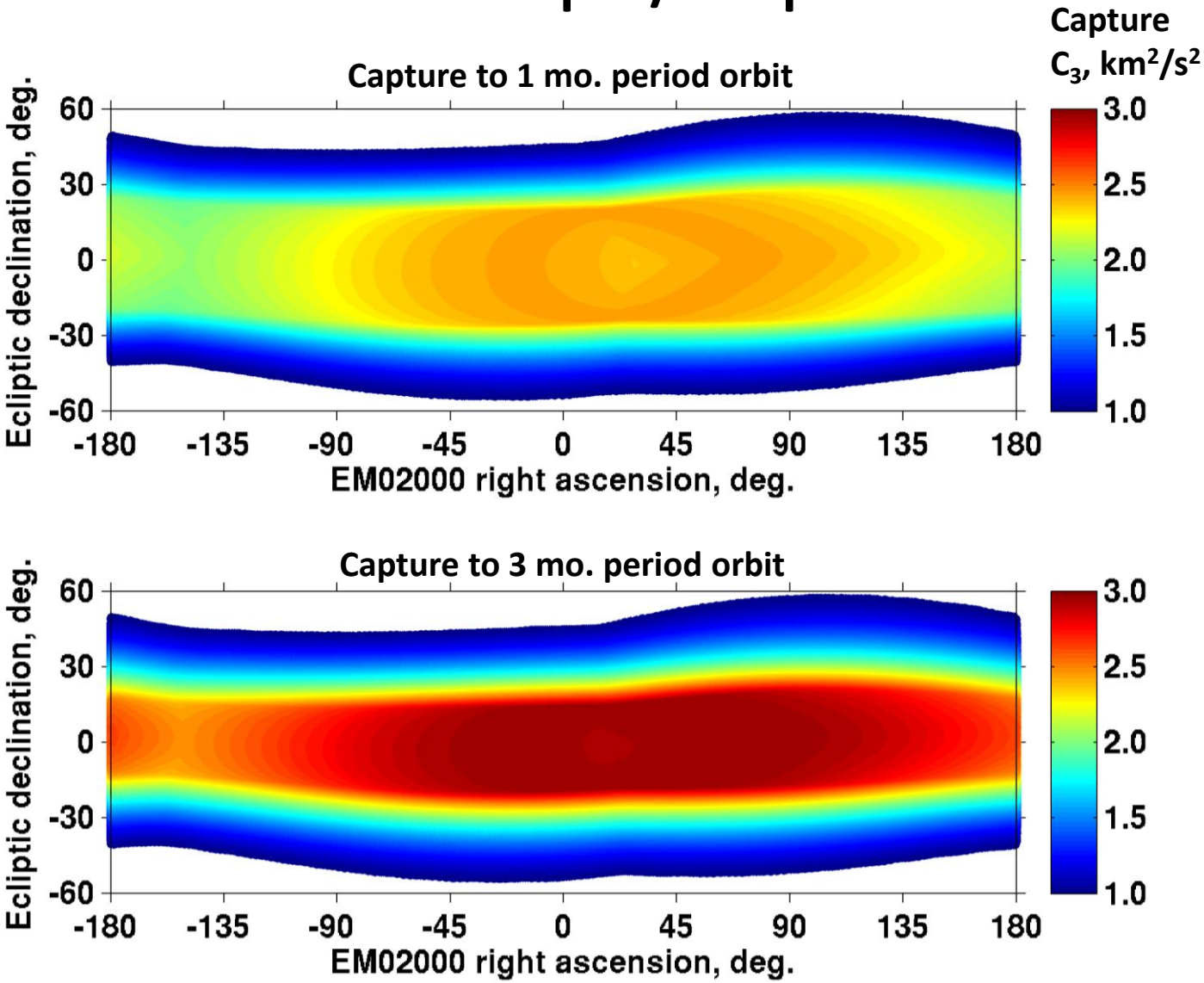
60% @ 2500 s

68% @ 6000 s

Lunar Capture

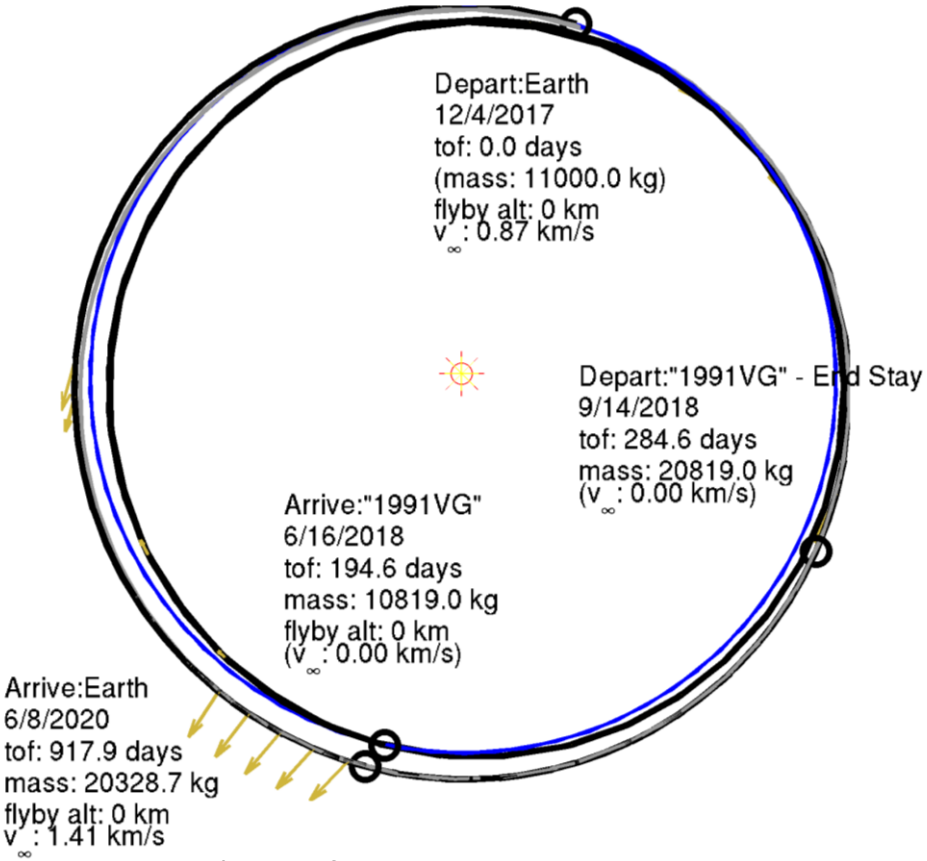


Lunar Escape/Capture

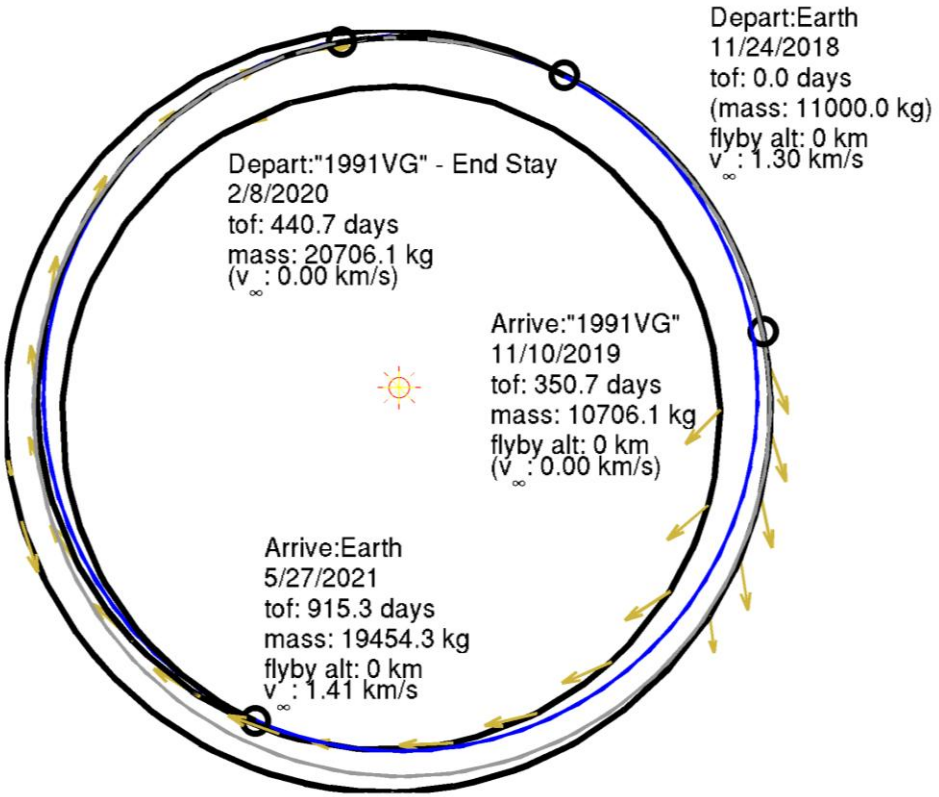


Interplanetary Trajectories
Launch Year Variation

Depart 12/2017, 2.5 yr., 0.7 t Xe*



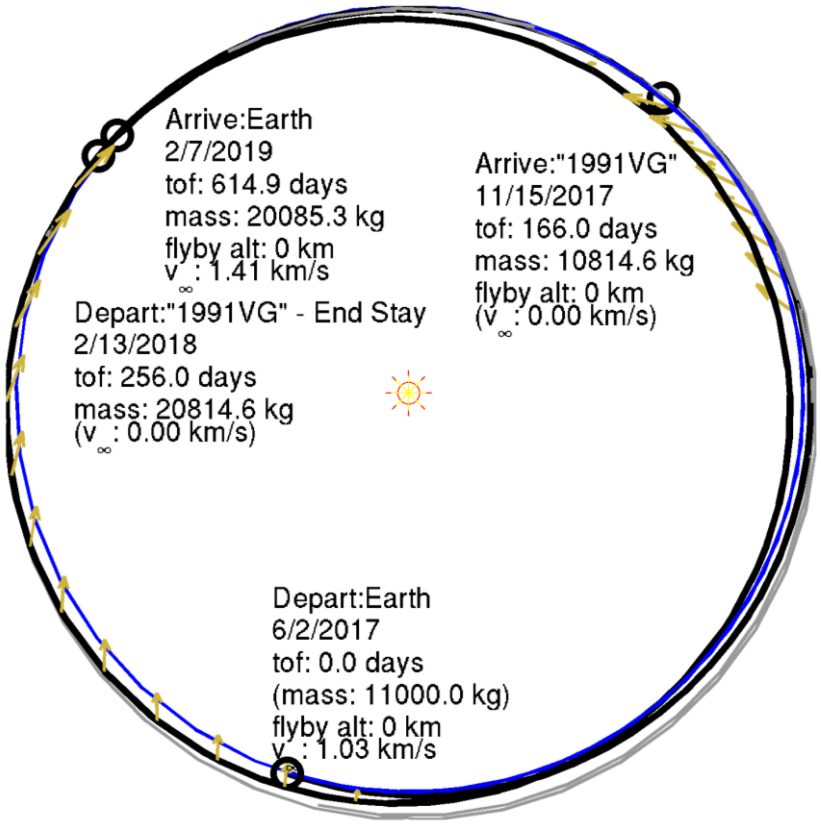
Depart 11/2018, 2.5 yr., 1.5 t Xe



*Data for interplanetary phase only, excluding spirals

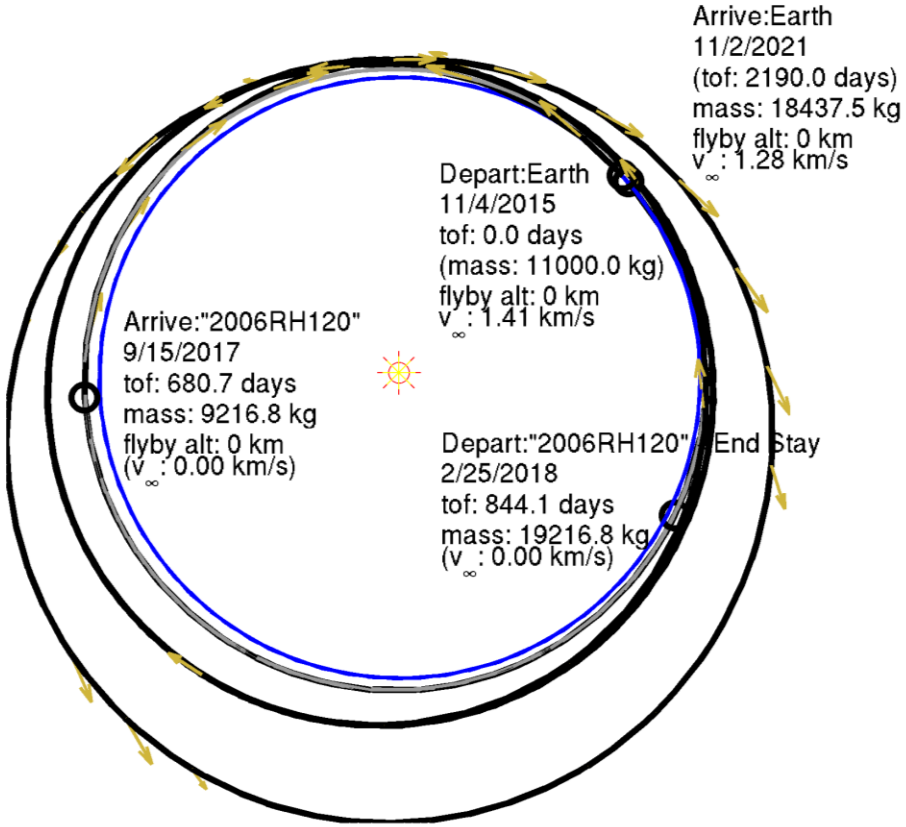
Out of Phase with Earth

Depart 6/2017, 1.7 yr., 0.9 t Xe
Close approach in 2017



in phase

Depart 11/2015, 6.0 yr., 2.6 t Xe
Close approach isn't until 2028

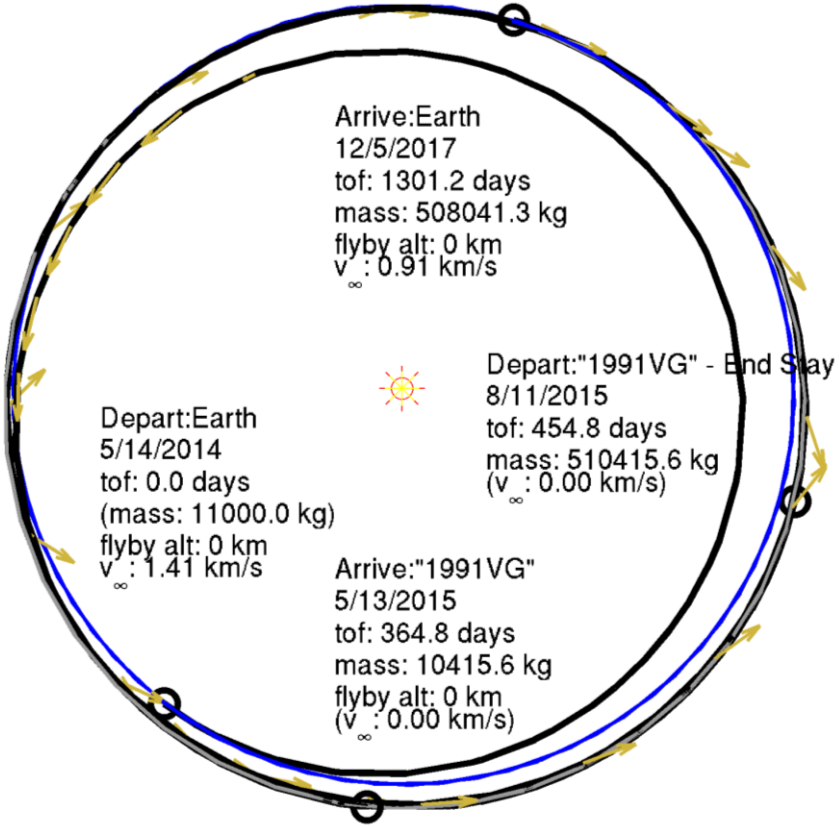


out of phase

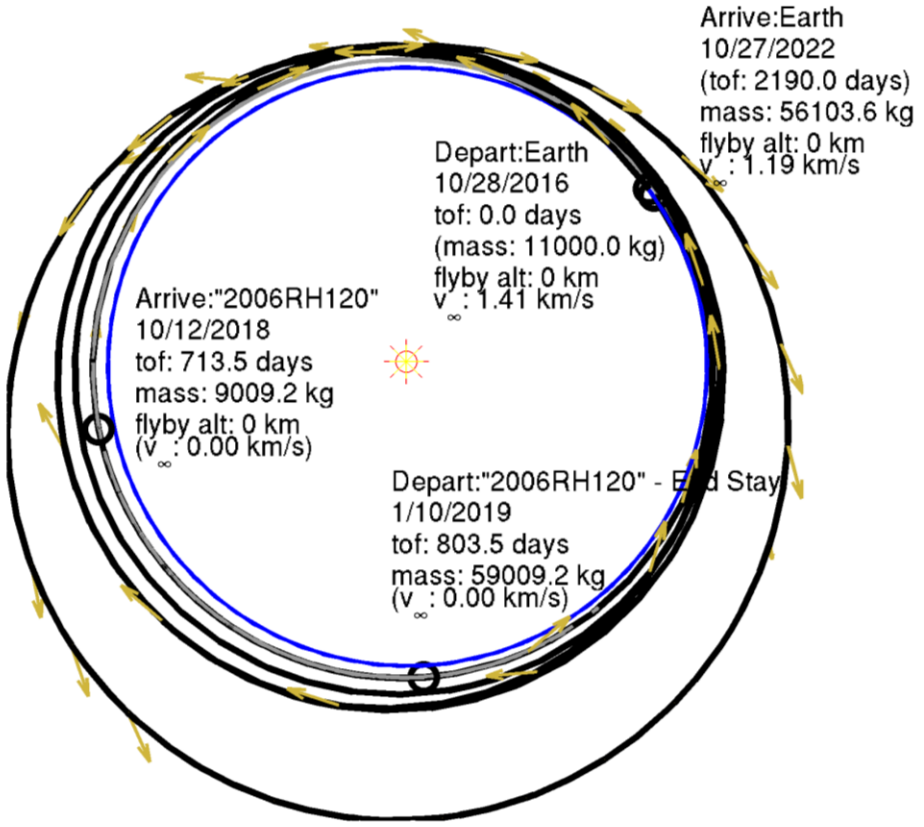
Capture to Loose Orbit

Forgo 2 yr., 4.2 t Spiral to ISS

Depart 4/2014, 3.6 yr., 3.0 t Xe
H = 28.4, D ~ 8 m, OCC = 2
Returns 500 t to Earth!

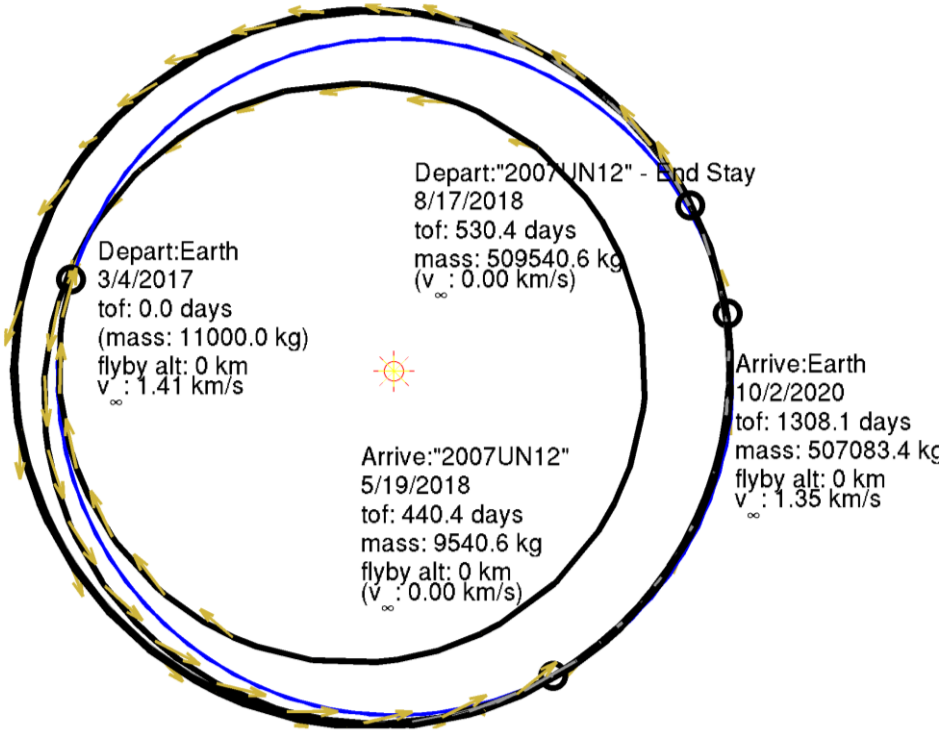


Depart 10/2016, 6.0 yr., 5.0 t Xe
H = 29.5, D ~ 4 m, OCC = 1
Returns "only" 50 t to Earth

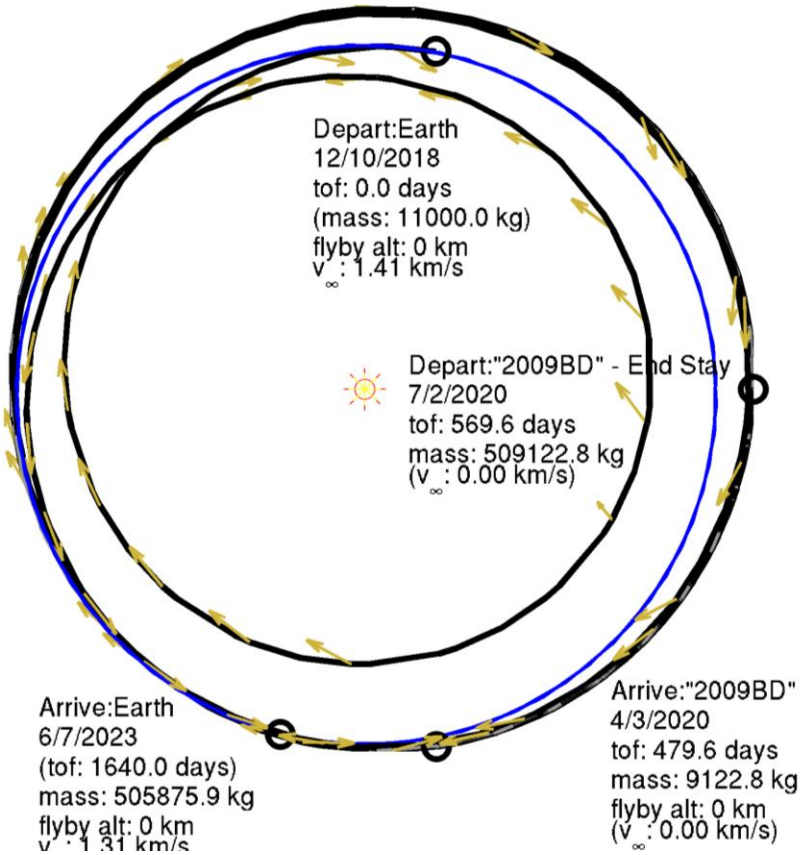


Return 500 t to Loose Orbit

Depart 3/2017, 3.5 yr., 3.9 t Xe
H = 28.7, D ~ 6 m, OCC = 4



Depart 12/2018, 4.5 yr., 5.1 t Xe
H = 28.3, D ~ 7 m, OCC = 1



Remarks

- 6 years, 8 t of Xe, & 40 kW SEP system returns:
  - 10 t asteroid to ISS
  - 500 t asteroid to Earth capture orbit
- For fixed flight time, power and s/c mass scale with asteroid mass
- Earth spiral time is inversely proportional to power
- Interplanetary trajectories tend to change in 1-year increments
- Best time to return asteroid is when it naturally has a close approach to Earth
- Adjusting arrival time with a big rock can be expensive