Round Trip Mars Mission Architecture via Propellantless Plasma Surfing

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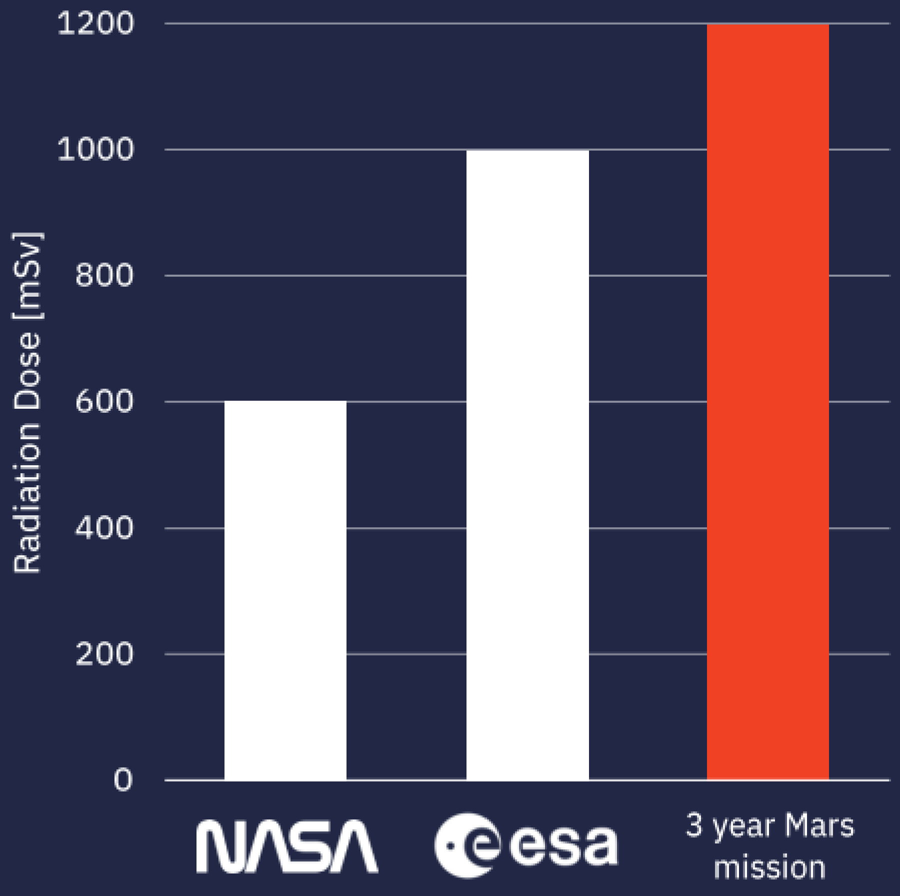
a: McGill University, b: Electric Sky

Why ?

» 3-year mission
  » 2% increase of cancer risk

» Harshest environment is interplanetary space [1]

» It is of interest to reduce time in space
  » Reduce consumables, spare parts, …
  » Increases abort possibilities

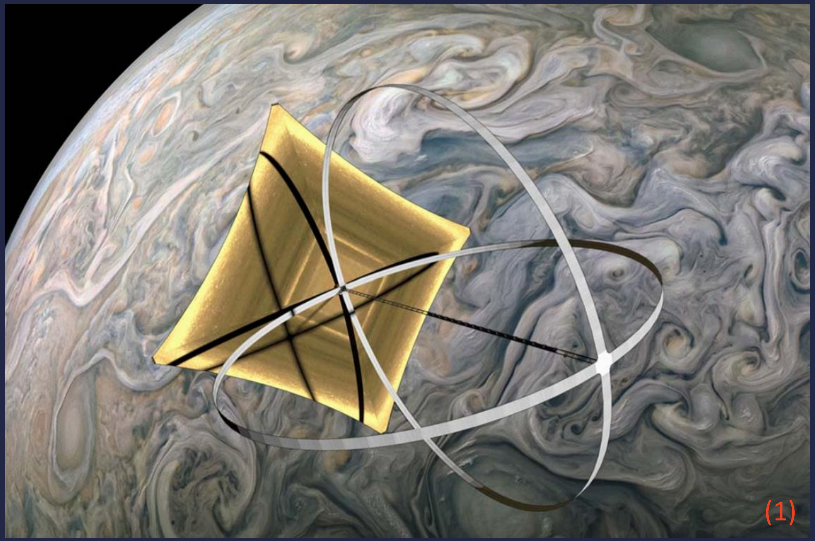


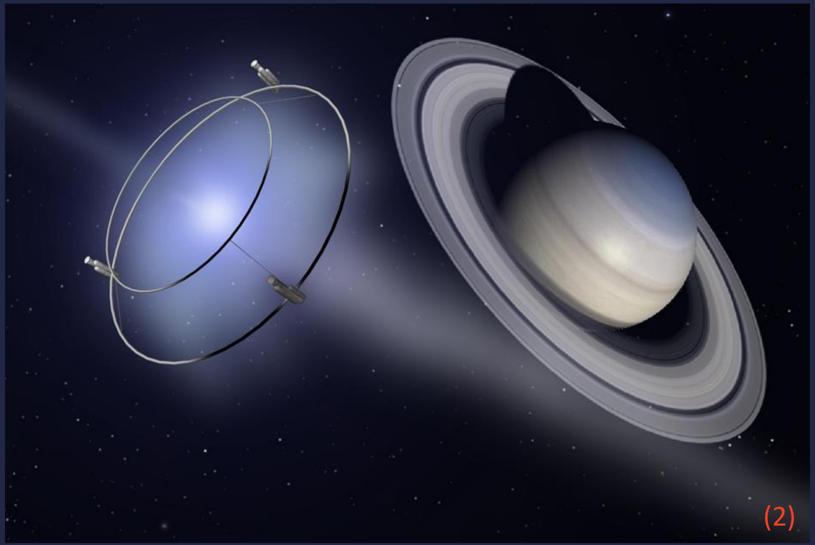
(1) Berger, Thomas et al. "Long Term Variations of Galactic Cosmic Radiation on Board the International Space Station, on the Moon and on the Surface of Mars." *Journal of Space Weather and Space Climate* 10 (2020): 34. https://doi.org/10.1051/swsc/2020028.

Background

- Externally powered propulsion systems
  - MagSail, Plasma Magnet

- Drag only
  - $a_D = 0.1\ \mathrm{m/s^2}$





(1) Brent Freeze *et al* 2022 *PASP* **134** 023001 DOI:10.1088/1538-3873/ac4812

(2) Magnetic sails , Image from Steve Bowers, https://www.orionsarm.com

Background

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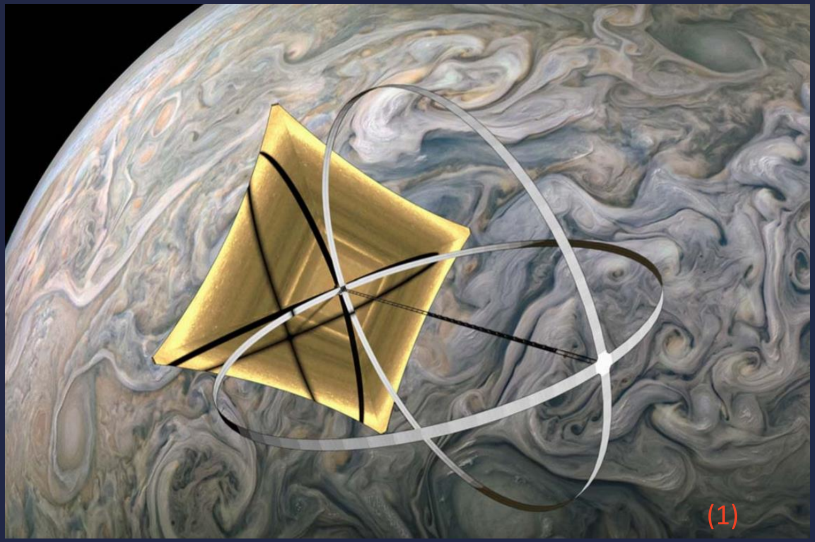
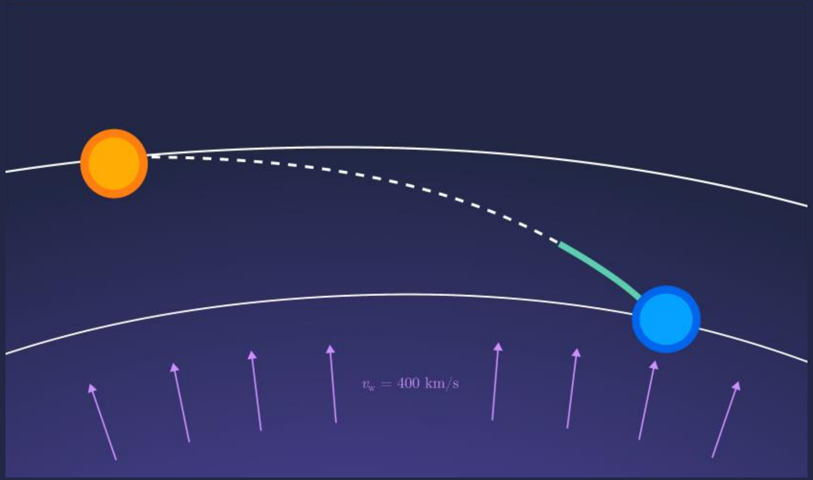


- Drag only
  - $a_D = 0.1 m/s^2$
  - 3 month flight
  - Need to aerobrake 5km/s



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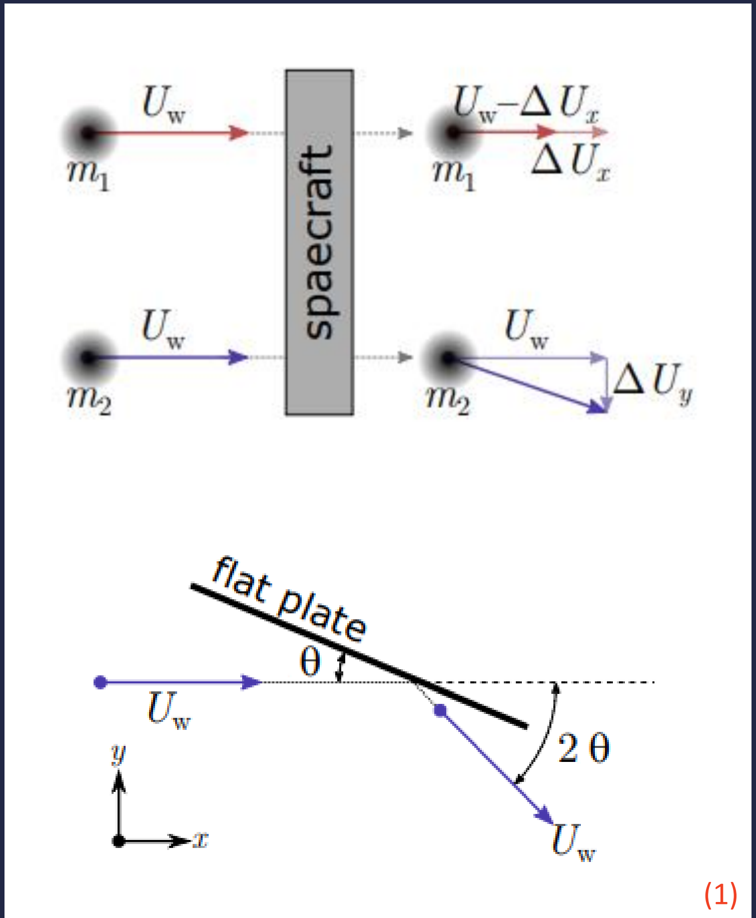
The Spacecraft

- Stroke solar wind to extract energy
  - Produce drag
- Accelerate flow perpendicularly
  - Generate Lift

$$\frac{L}{D} = \frac{2U_w}{\Delta U_y}$$

- Hypersonic flat plate model
- 2 rotors operating perpendicularly

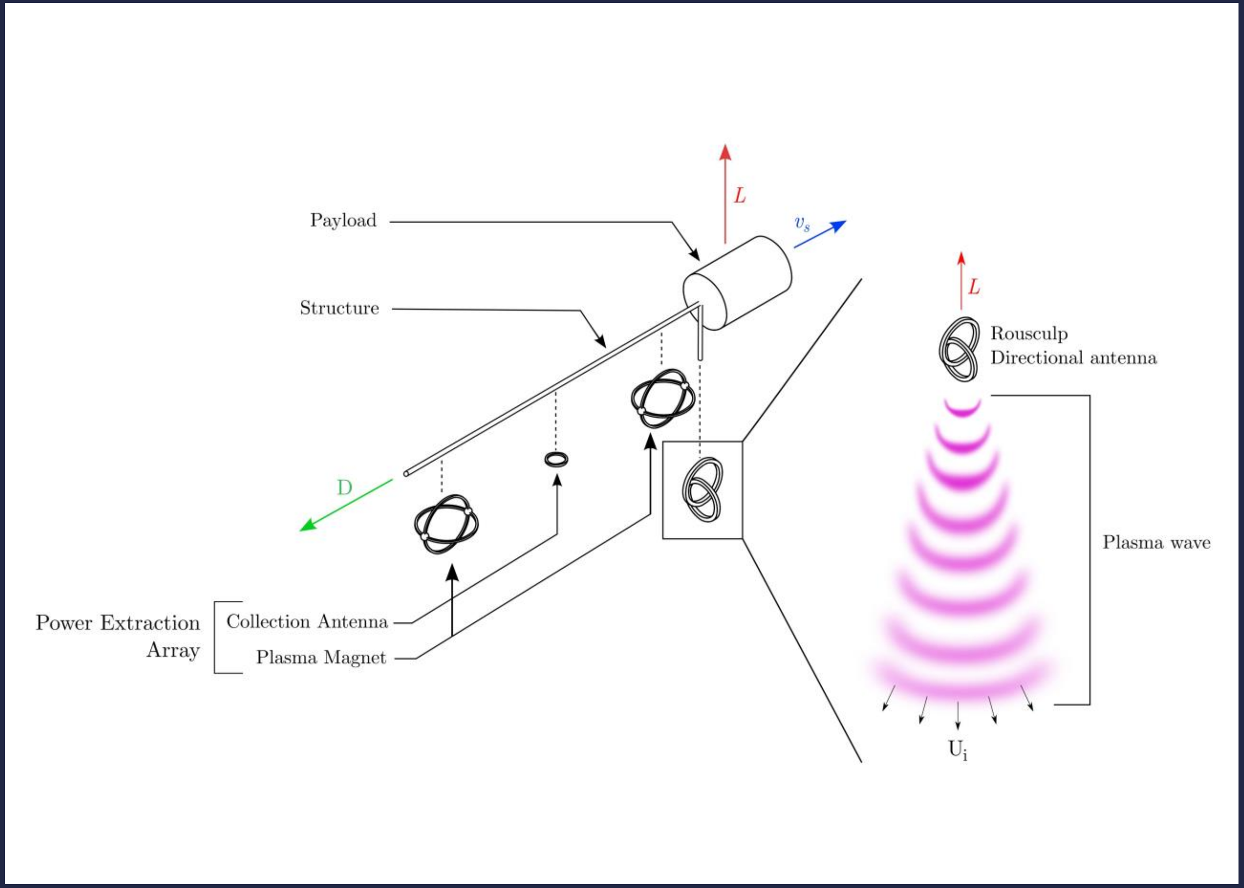


(1) Larrouturou, Higgins, Greason (Frontiers 2022) : "Dynamic Soaring as a Mean to Exceed Solar Wind Speed"

The Spacecraft

- Power extraction :
  - Plasma Magnet Array
- Lift generation:
  - Plasma waves

- Based on the previous work:
  - Greason (JBIS 2019): 72(5):146 (2019) “A Reaction Drive Powered by External Dynamic Pressure” ***q-drive***
  - Larrouturou, Higgins, Greason (Front. Space Technol., 2022): Dynamic Soaring as a Means to Exceed Solar Wind Speed doi: 10.3389/frspt.2022.1017442

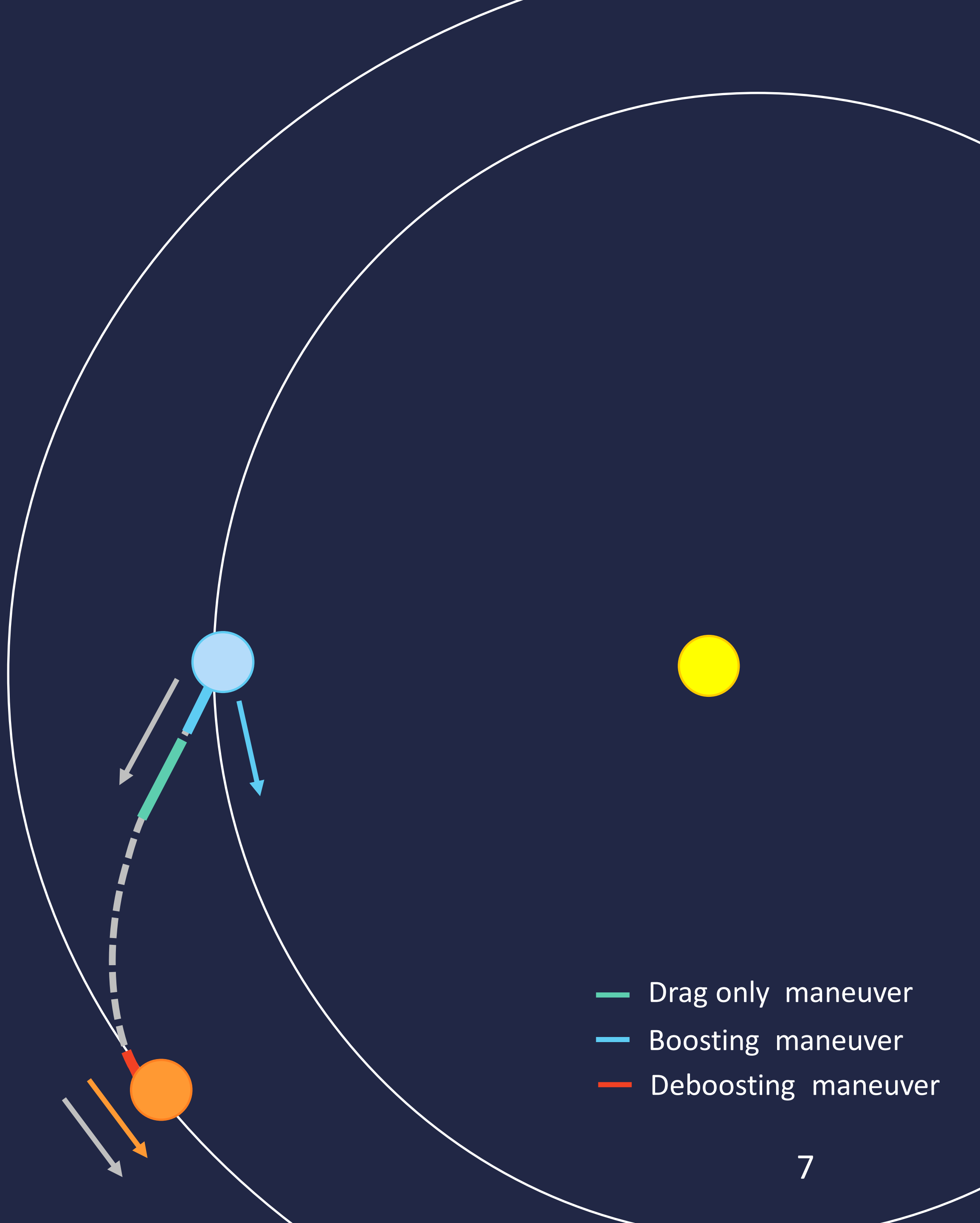


Trajectory

- $\frac{L}{D} = 5, a_D = 0.1\ \mathrm{m/s^2}$

- Earth to Mars:
  - 75 days with no aerobraking
  - 49 days with 10km/s aerobraking

- Prograde Δv
  - Boost Maneuver
- Retrograde Δv
  - Deboost Maneuver



Trajectory

» $\frac{L}{D} = 5, a_D = 0.1 \text{ m/s}^2$

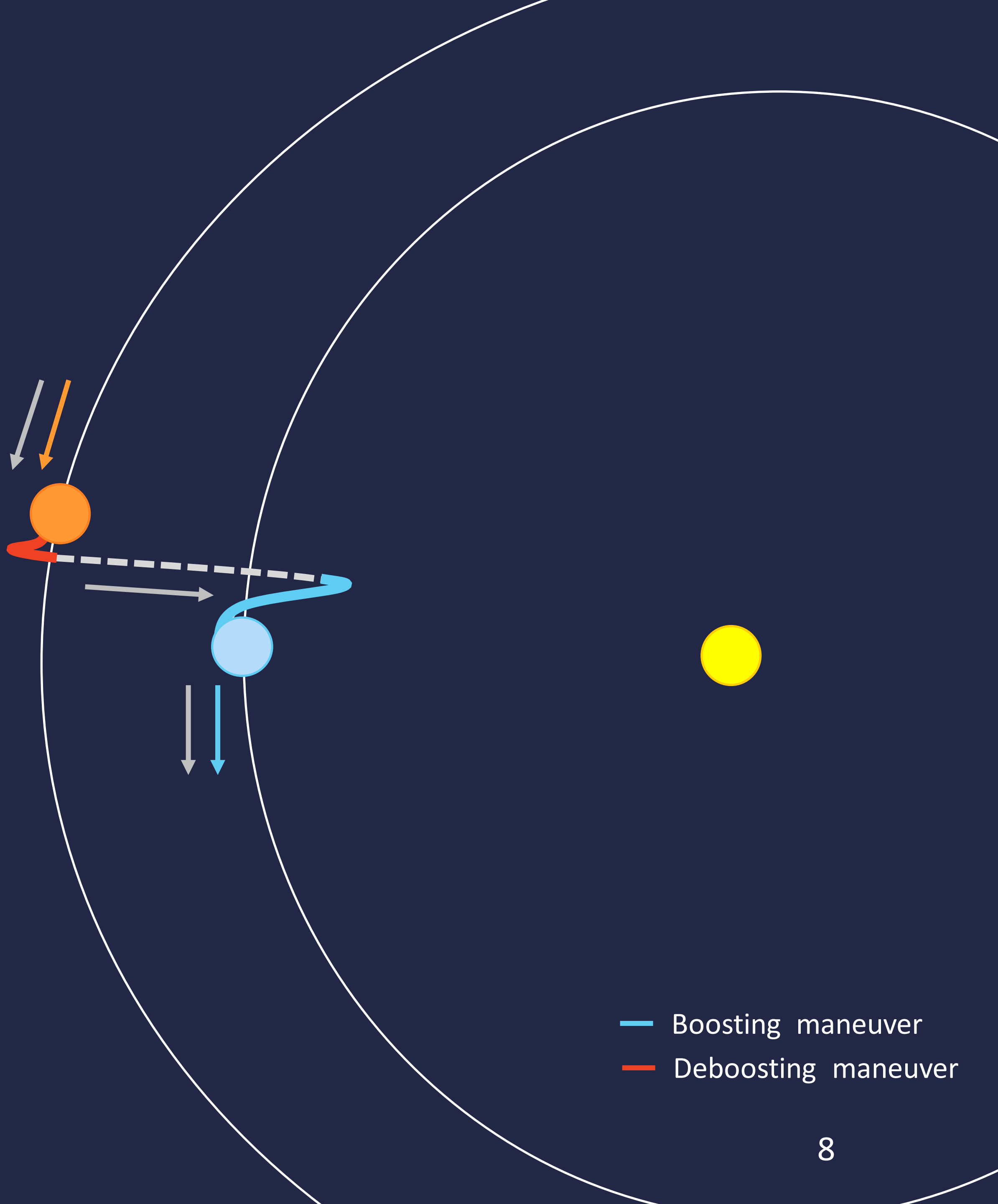
» Mars to Earth:

  » 80 days with no aerobraking

  » 68 days with 10km/s aerobraking

» Minimum $\frac{L}{D} = 0.2$ trip in 1 year

  » Precursor mission, technology demonstrator or cargo mission

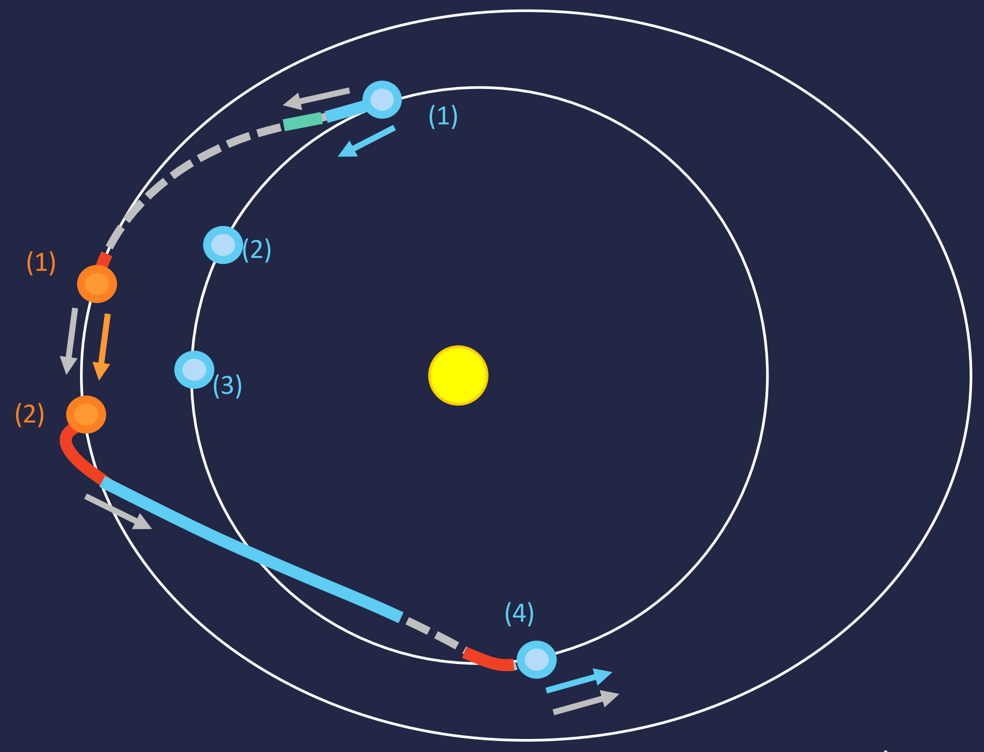


Round Trip Trajectory

- Orbits don't allow for 2 fast maneuvers

- Earth to Mars: 49 days
- Mars stay: 30 days
- Mars to Earth: 120 days

- 6-month mission
- Can scale to 2-month stay

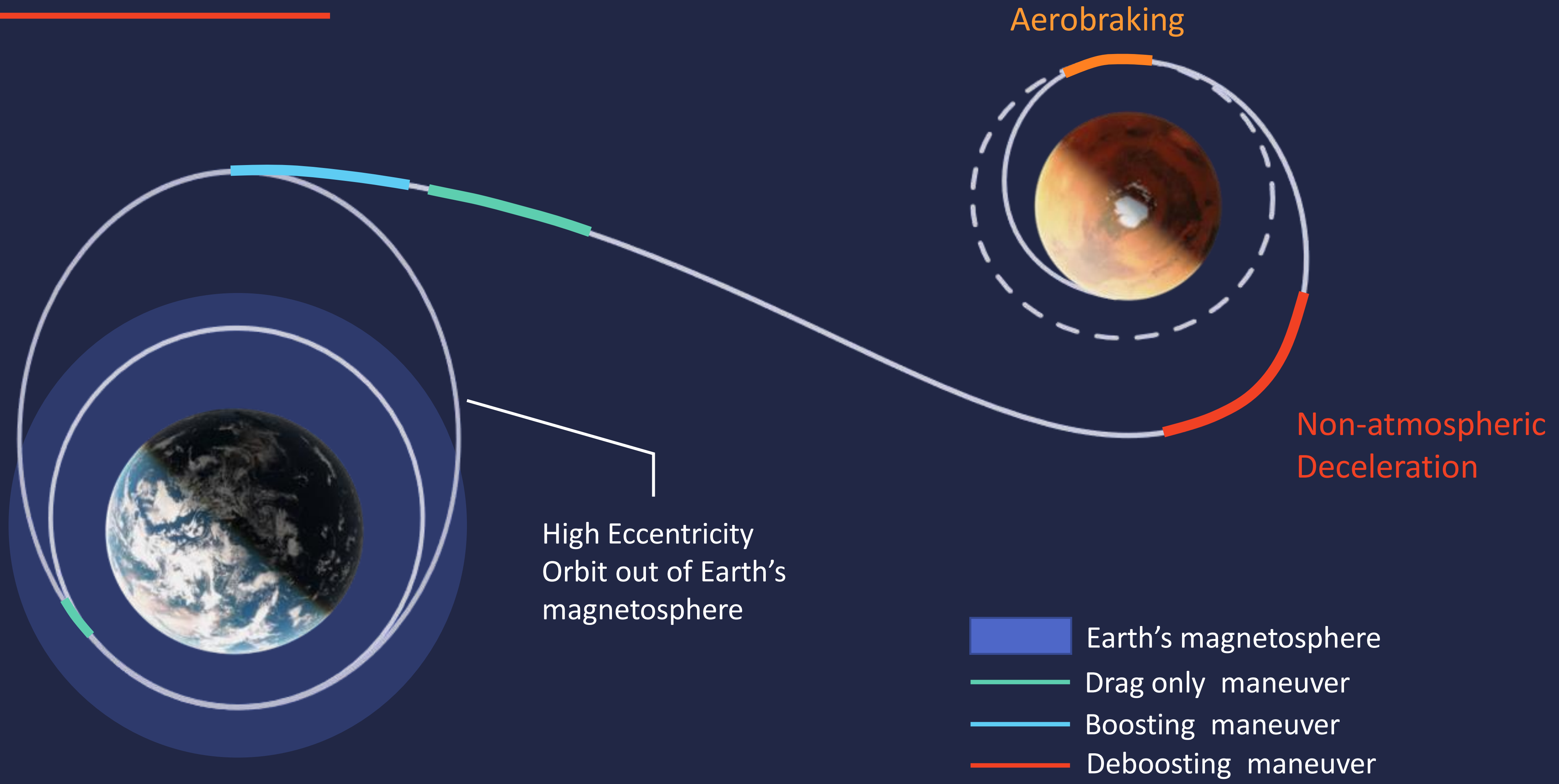


(1) Arrival on Mars
(2) Departure from Mars

(1) Departure from Earth
(2) Position at Arrival on Mars
(3) Position at Mars Departure
(4) Arrival at Earth

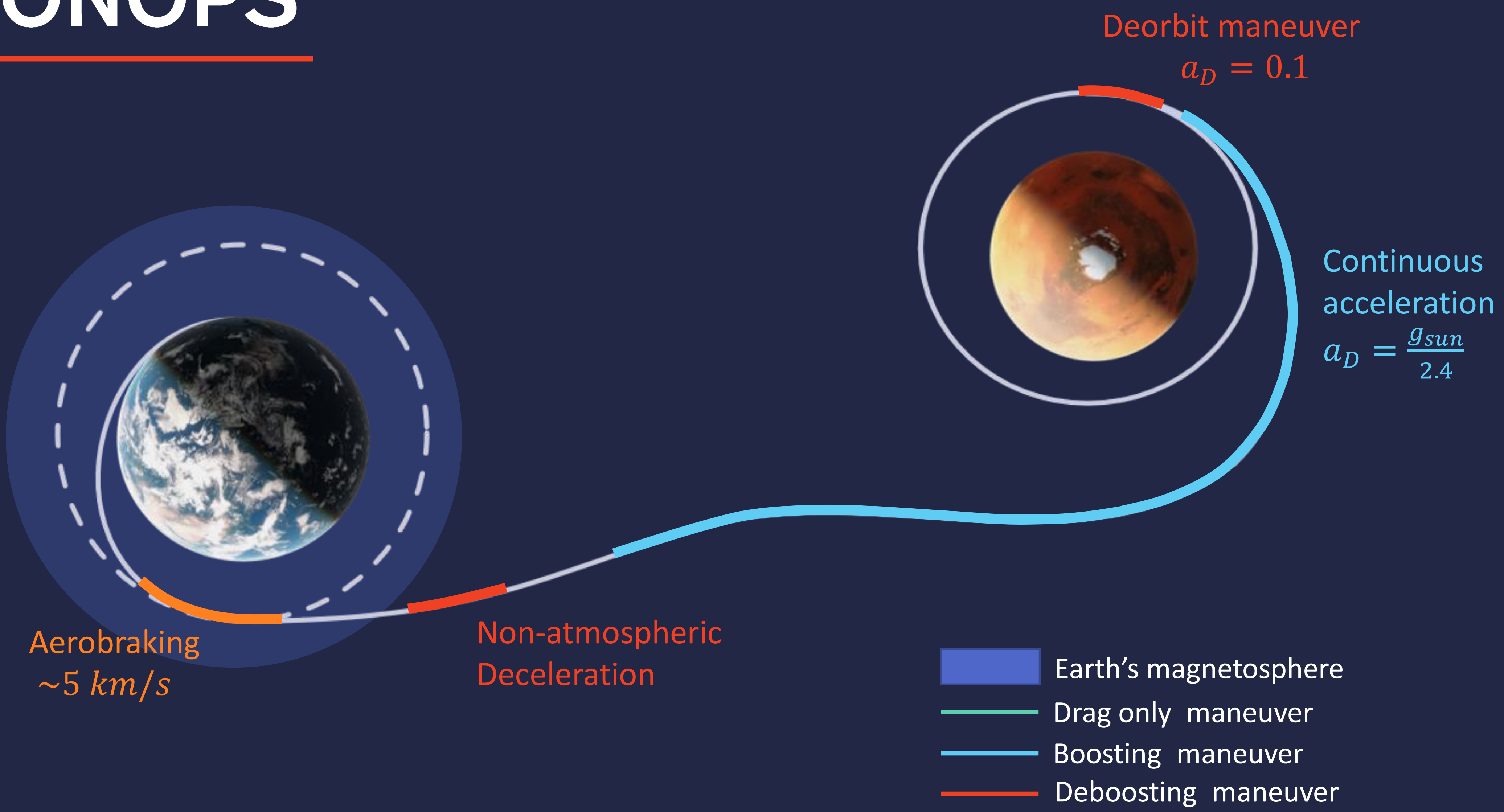
Drag only maneuver
Boosting maneuver
Deboosting maneuver

CONOPS



Aerobraking
Non-atmospheric
Deceleration
High Eccentricity
Orbit out of Earth's
magnetosphere
Earth's magnetosphere
Drag only maneuver
Boosting maneuver
Deboosting maneuver

CONOPS



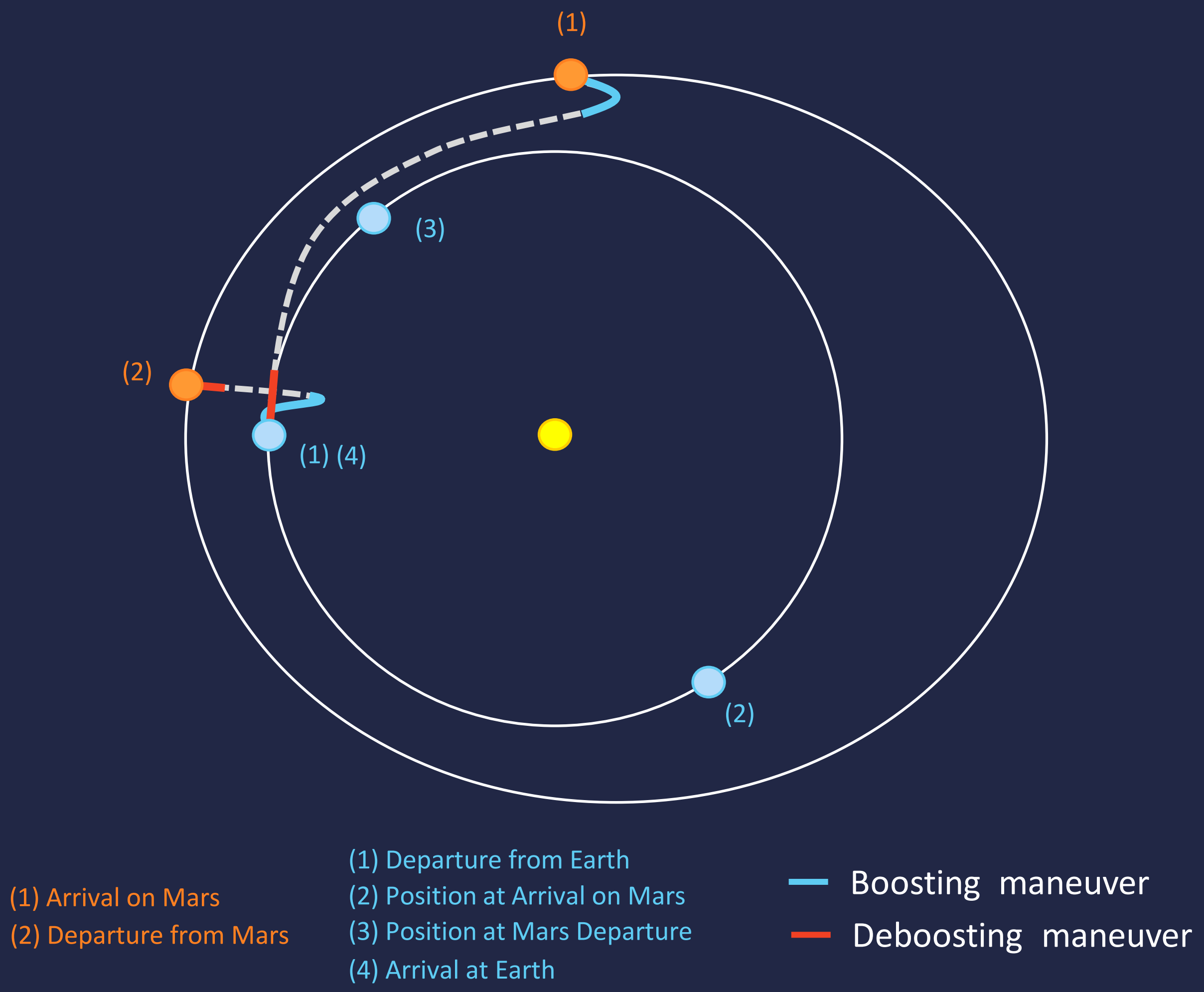
Deorbit maneuver
$a_D = 0.1$
Continuous
acceleration
$a_D = \frac{g_{sun}}{2.4}$
Aerobraking
$\sim 5\ km/s$
Non-atmospheric
Deceleration
Earth's magnetosphere
Drag only maneuver
Boosting maneuver
Deboosting maneuver

Long stay mission

- Earth to Mars: 120 days
- Mars stay: 7 months
- Mars to Earth: 70 days

- Earth to Mars: 75 days
- Mars stay: 9 months
- Mars to Earth: 70 days

- Capable of reaching mars and Earth in between synodic periods



Conclusion

- One way trip:
  - 49 days to Mars
  - 75 days to Earth
  - Minimum L/D of 0.2 for return trip in 1 year
  - With no propellant expanded
- 6 month round trip possible
  - Can scale to 2 month stay on mars
  - Minimum L/D of 5
- For Longer stay
  - Retrograde Architecture