Technische Universität Braunschweig

Institute of Aerospace Systems

Active Debris Removal of Multiple Priority Targets

V. Braun, A. Lüpken, S. Flegel, J. Gelhaus, M. Möckel, C. Kebschull, C. Wiedemann, P. Vörsmann

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Overview

- **Introduction**
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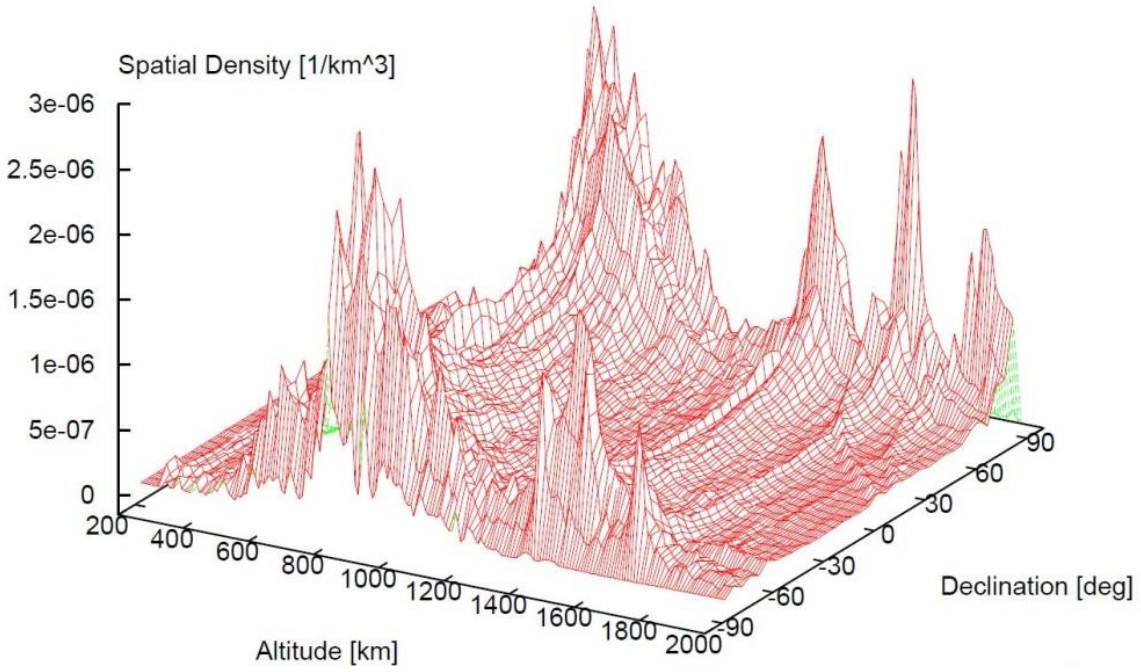
- **Scenario definition**
  - ➢ Chemical propulsion
  - ➢ Electric propulsion
- **Conclusion**

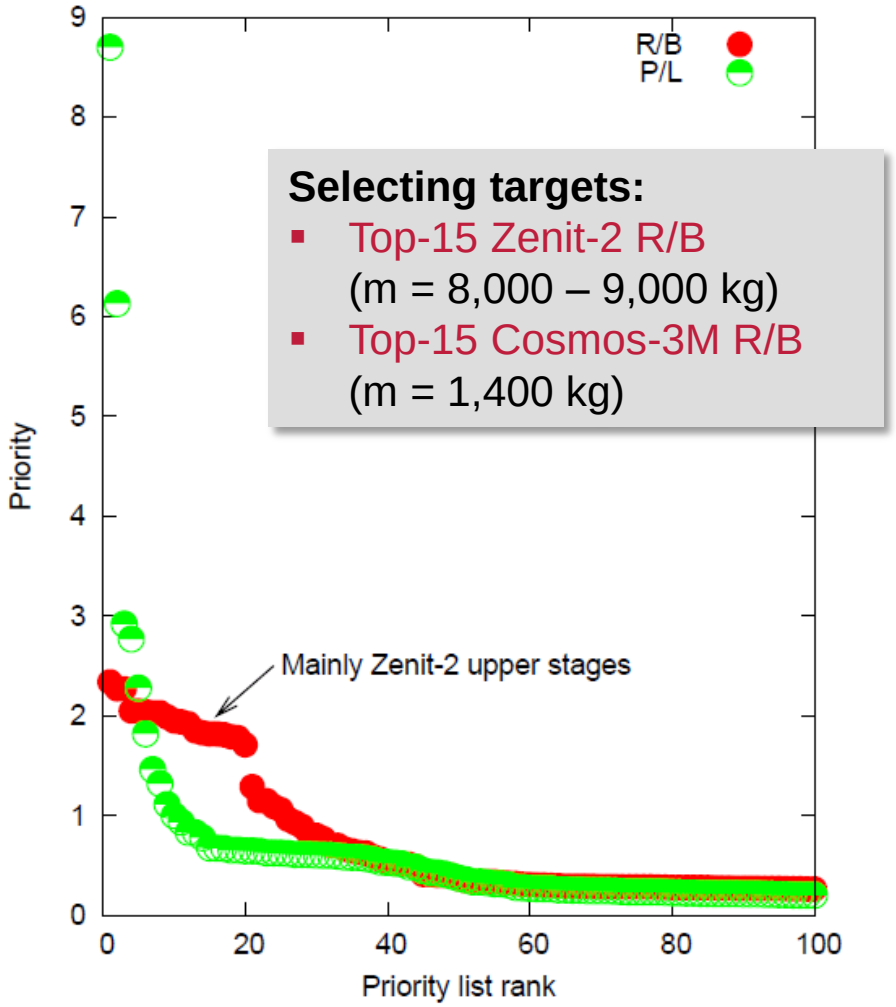


Priority targets

- Enhancing mission efficiency by **removing priority targets first**
- Definition of a **priority criterion *R*** wrt. collisional cascading:

$$R_i = P_{c,i} \cdot m_i$$

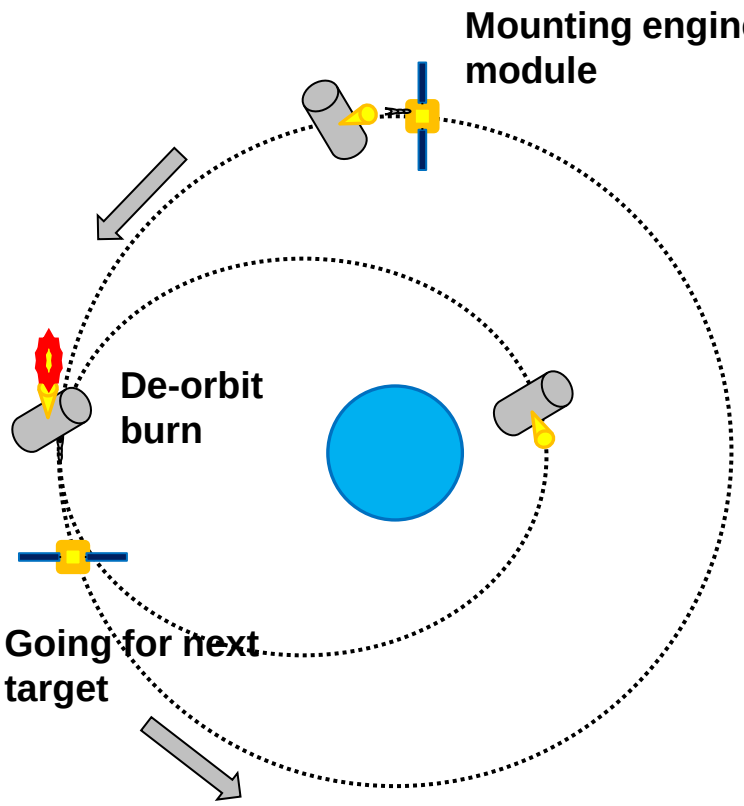
- Using MASTER-2009 to determine target orbit **catastrophic flux**
- Processing collision probability $P_{c,i}$ from **catastrophic flux** and **object's cross-section**



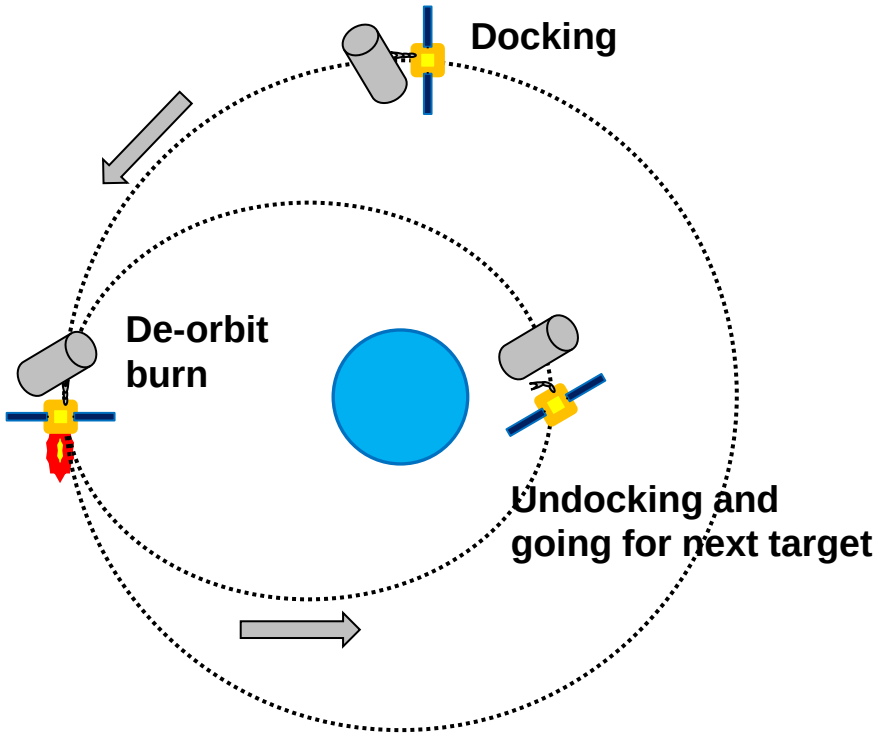
Selecting targets:
- Top-15 Zenit-2 R/B (m = 8,000 – 9,000 kg)
- Top-15 Cosmos-3M R/B (m = 1,400 kg)

Scenario definition – Chemical propulsion (1)

Scenario 1:

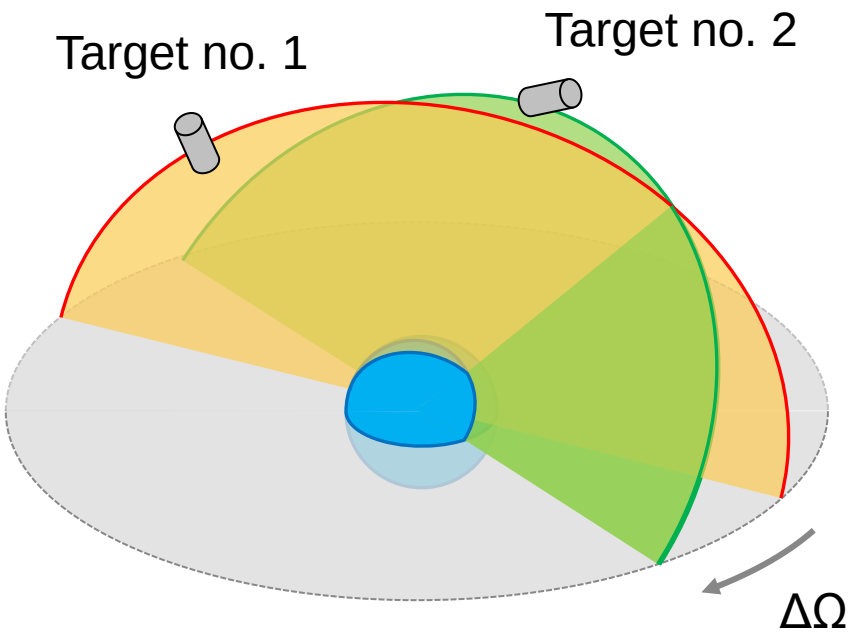


Scenario 2:



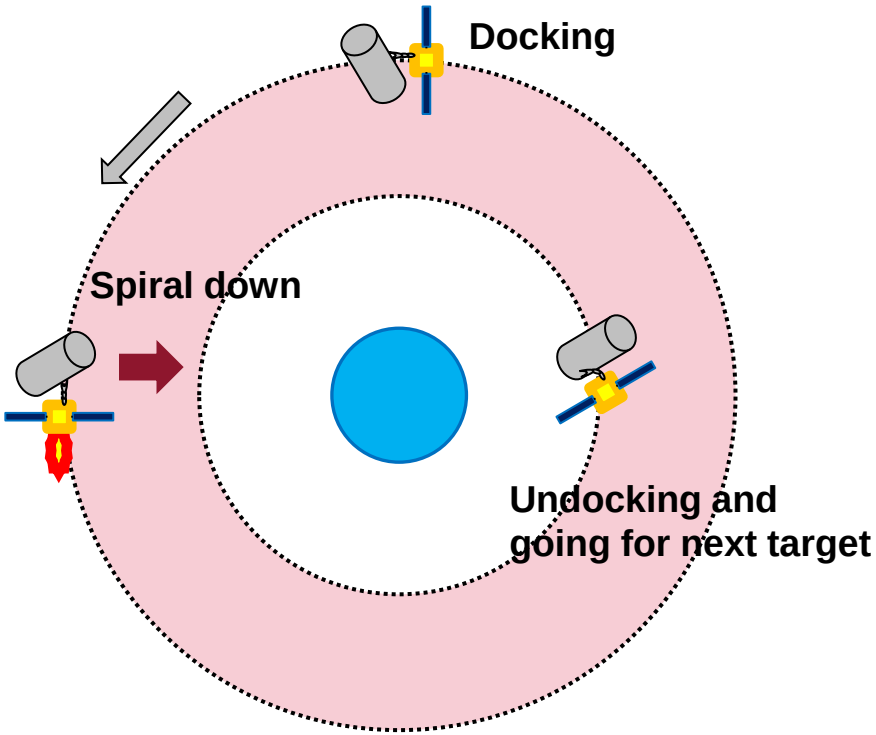
Scenario definition – Chemical propulsion (2)

- Main problem in multi-target mission: **Orbital plane change maneuvers**
- Two possible solutions:
  - Take advantage of **natural differential nodal precession** (Scenario 2)
  - Perform **orbital plane change maneuver** (Scenario 1)



Scenario definition – Electric propulsion (1)

Scenario 3:



Scenario 4:

- Similar to Scenario 3
- Additional thruster to provide **thrust normal to orbital plane**
- Providing plane change capability

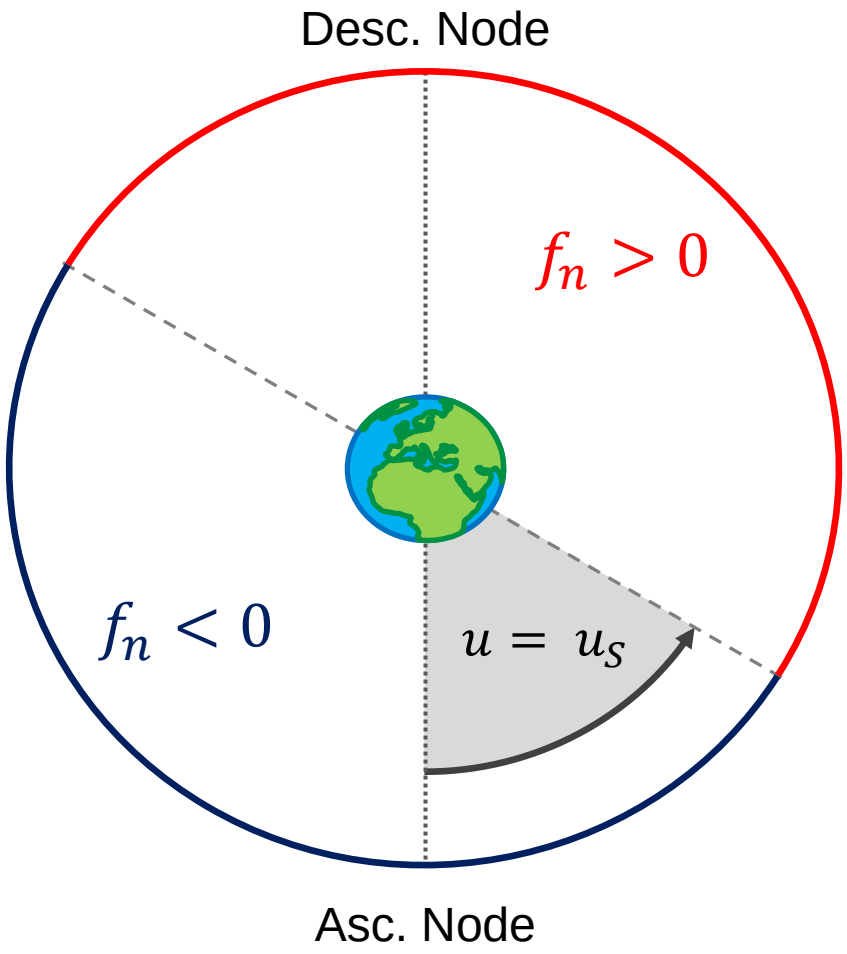
Scenario definition – Electric propulsion (2)

- Combined change of inclination and RAAN by **changing thruster orientation** at specific location

$$\frac{di}{dt} = \frac{r \cdot \cos u}{n \cdot a^2 \cdot \sqrt{1 - e^2}} \cdot f_n$$

$$\frac{d\Omega}{dt} = \frac{r \cdot \sin u}{n \cdot a^2 \cdot \sqrt{1 - e^2} \cdot \sin i} \cdot f_n$$

- Tuning of **arbitrary ratio of inclination to RAAN change** possible



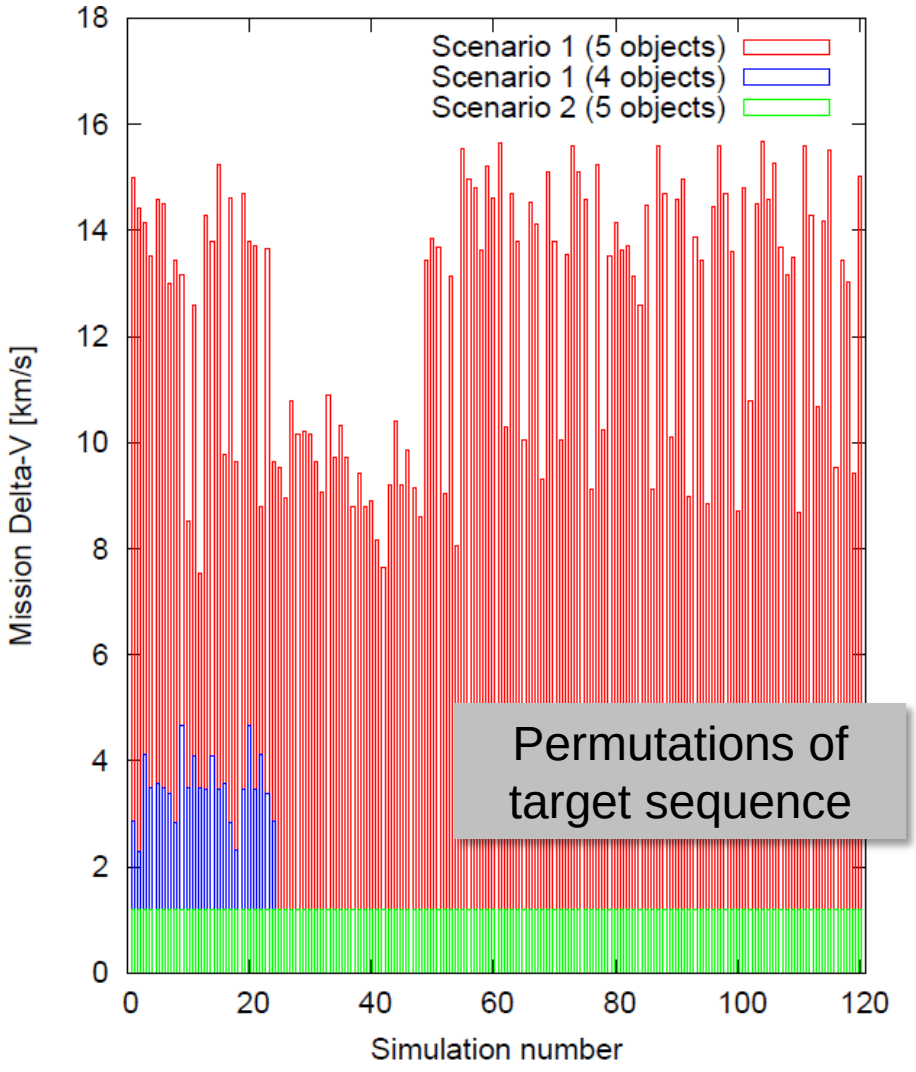
Chemical propulsion – Results (1)

Scenario 2

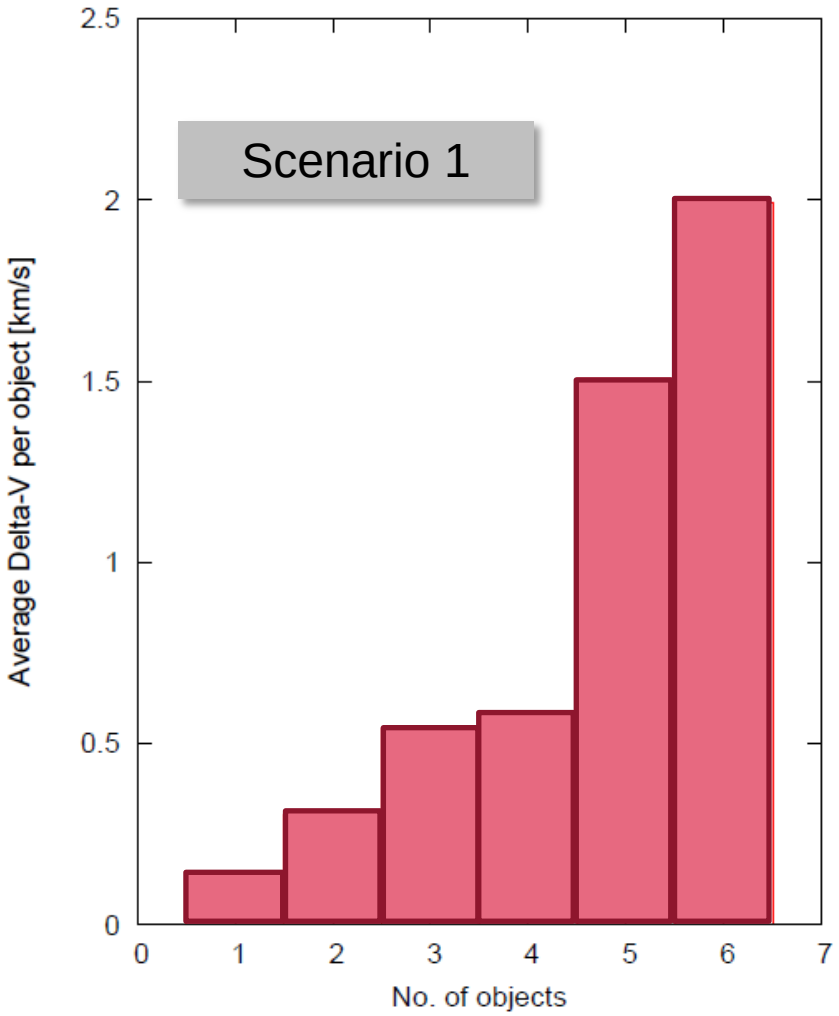
- Nearly constant ΔV of 1.2 km/s
- Mission duration of about 200 days

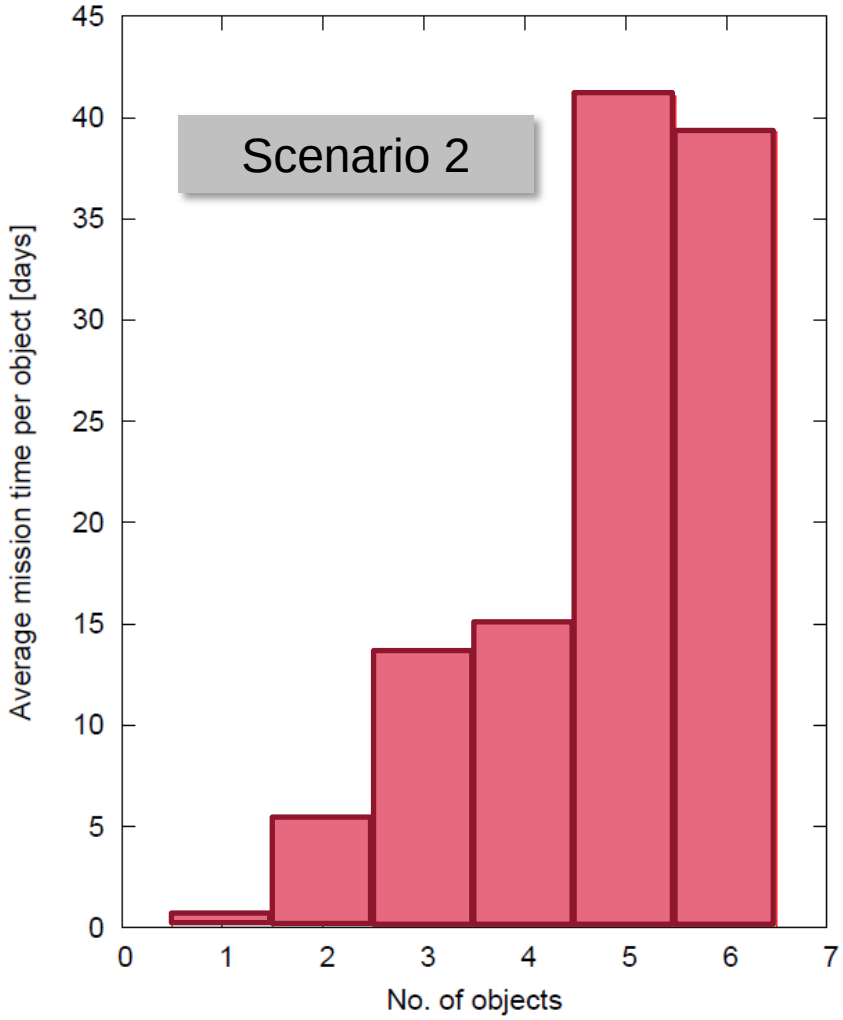
Scenario 1

- Five-target mission (Zenit-2):
  - Minimum ΔV of 7.5 km/s
  - About 5,500 kg system mass
- Four-target mission (Zenit-2):
  - Acceptable ΔV of 2.3 km/s
  - System mass at 2,400 kg



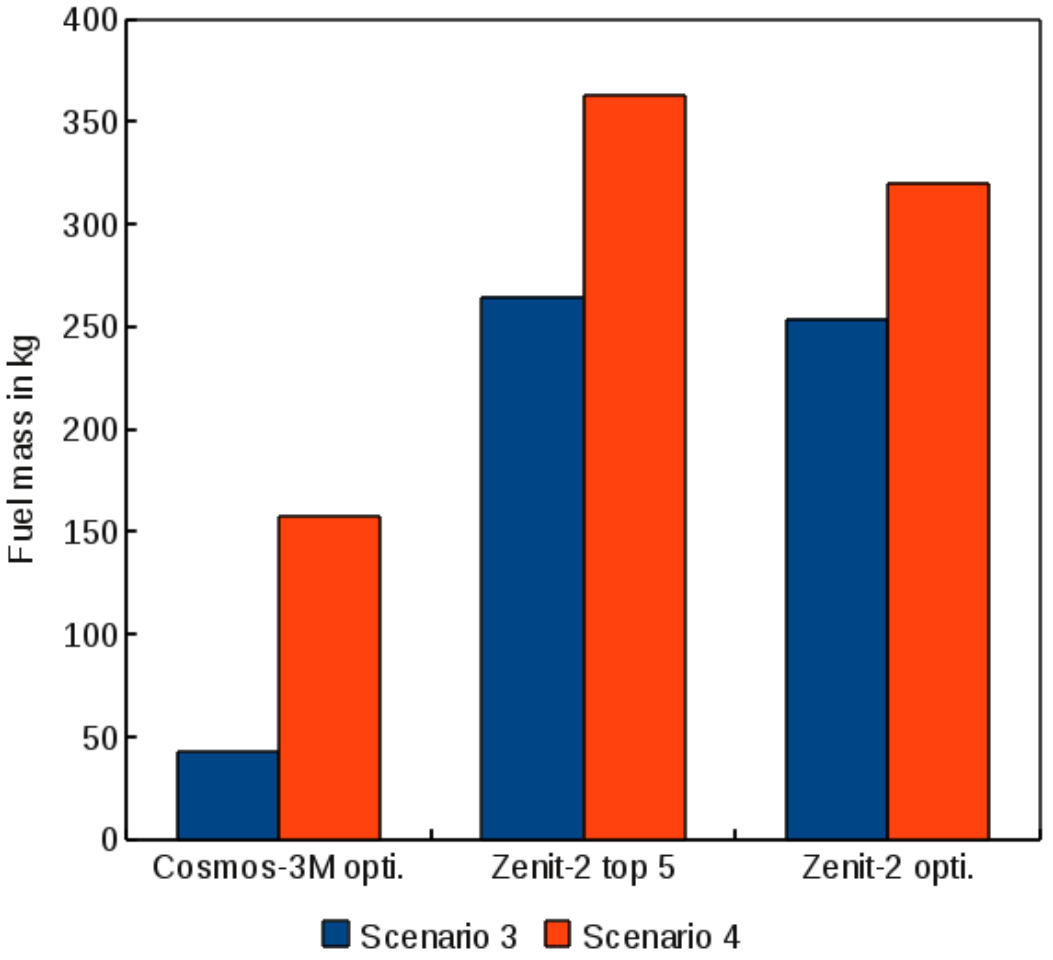
Chemical propulsion – Results (2)





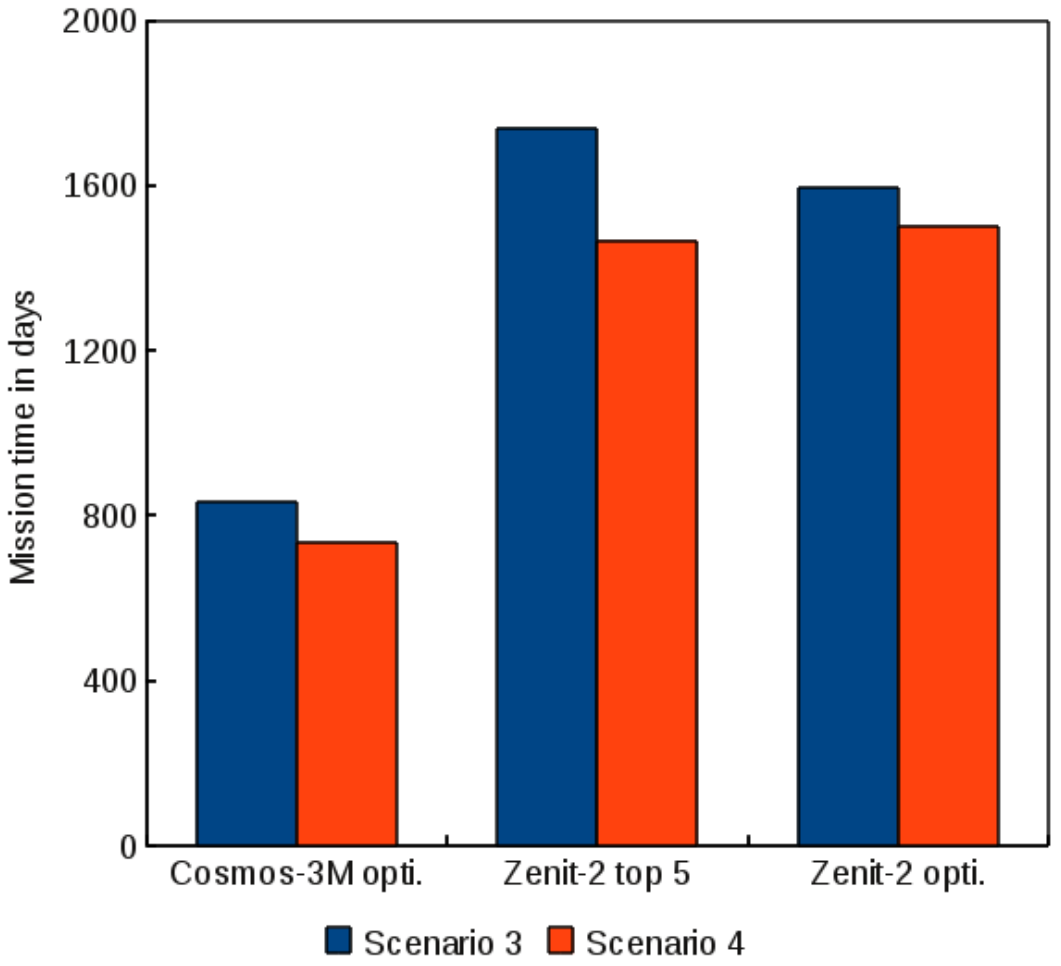
Electric propulsion – Results (1)

- Higher fuel mass for Scenario 4 (as expected)
- Additional fuel needs acceptable, especially for heavy targets



Electric propulsion – Results (2)

- Very high mission time
- Depends on thruster used
  - ➢ F = 75 mN in this case



Conclusion

- Active debris removal essential for stabilisation of LEO debris environment
- Identification of priority targets to enhance mission efficiency
- Orbital plane change maneuvers required due to RAAN / inclination distribution
- **Chemical propulsion:**
  - trade-off between Scenario 1 and 2 would result in acceptable values for ΔV and mission duration
- **Electric propulsion:**
  - Additional thrust normal to plane during transfer looks promising
  - More powerful thruster would allow for reduction of mission duration

Thank you very much for your attention!