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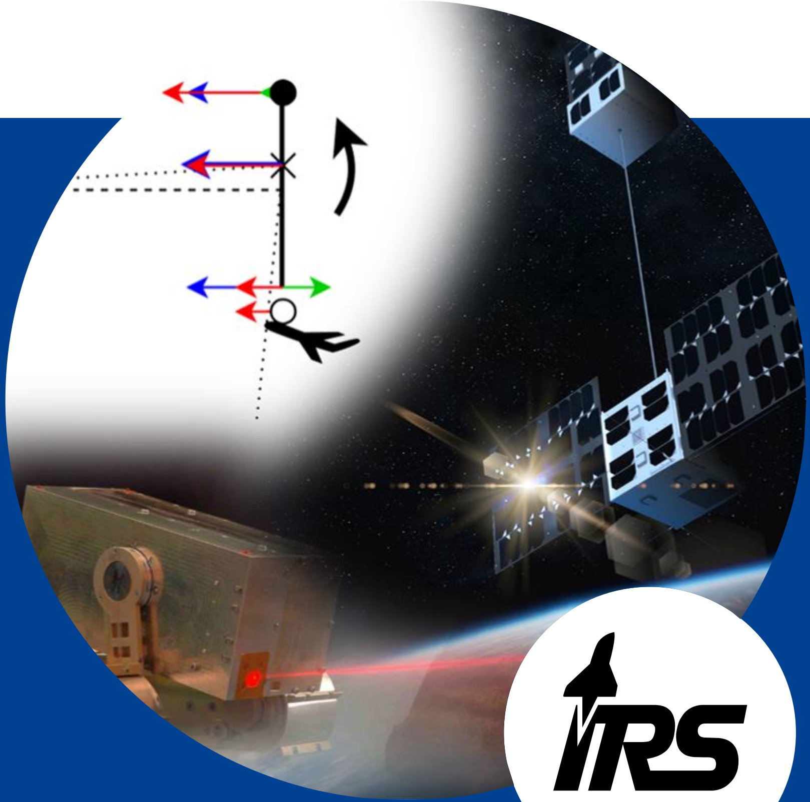


Space Tether Research at the University of Stuttgart

K. Waizenegger, M. Kanzow, M. Gewehr, P. H. Winterhalder, M. Lengowski, S. Klinkner

7th International Conference on Tethers in Space, June 2-5, 2024 in Toronto, Canada

Space Tether Research at the University of Stuttgart

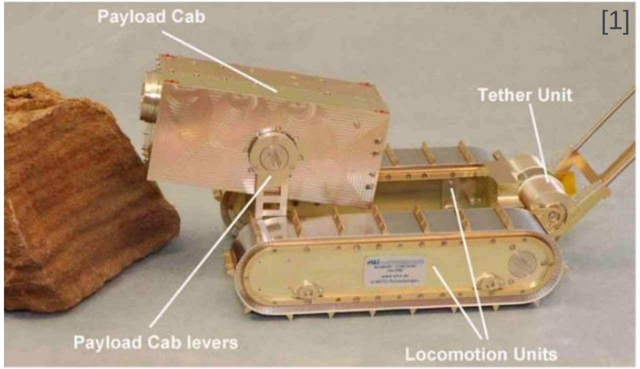
Areas of Investigation

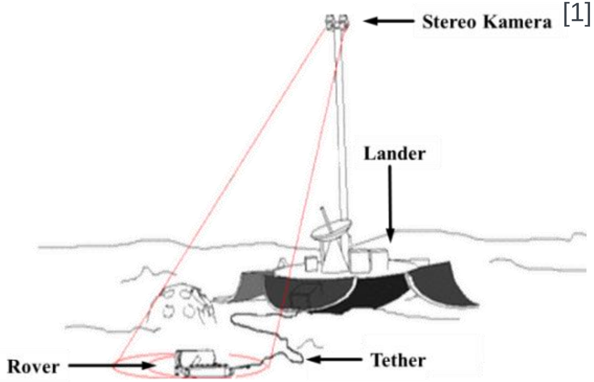
Tethered Rover Systems

- Micro-Rover Systems
- Miniaturisation of tether mechanism
- Remote Tether Detection and Tracking

Tethered Rover Systems
Nanokhod Micro-Rover

- Developed for ESA‘s BepiColombo
- Mission scenario
  - 14 days
  - 50 m tether
  - 3.2 kg, thereof 1 kg payload
- Adapted for future (lunar) missions
  - Polar regions
  - Crater rims
  - Lava tube skylights

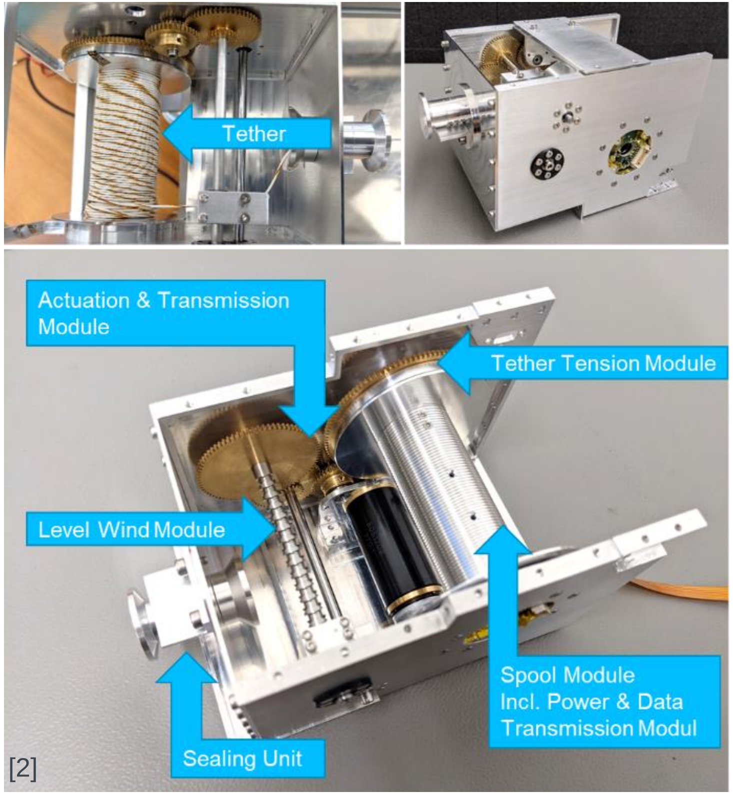




Tethered Rover Systems

Nanokhod Tether Mechanism (NTM) and Dust Simulant Testing

- Length increased to 100 m
- Contactless power and data interface
- Recoil capabilities
- Seals against lunar regolith



[2]

Tethered Rover Systems

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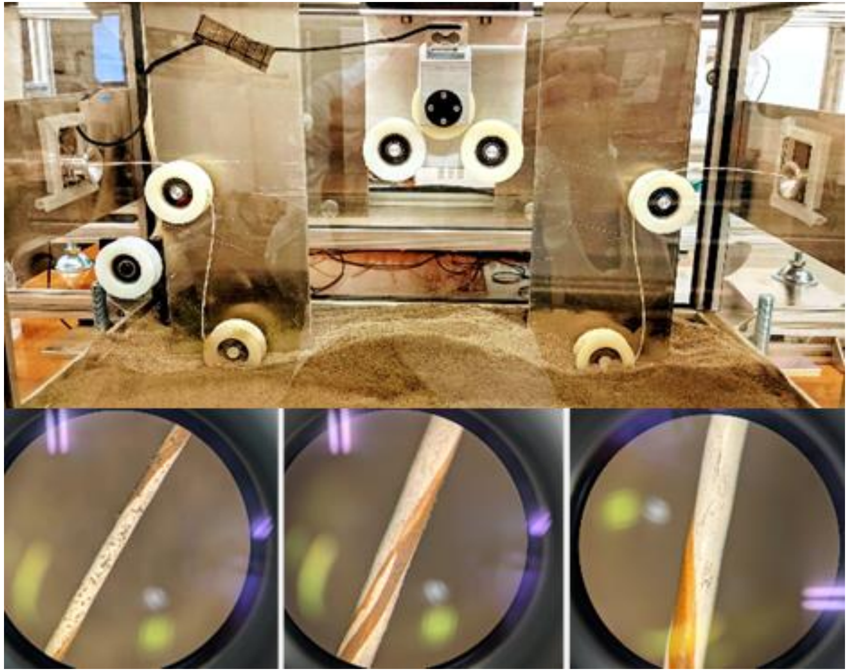


[2]

- Dust simulant test environment
- Dust adhesion
- Long-term abrasion
- High fidelity facility planned for lunar environment

Tethered Satellite Systems

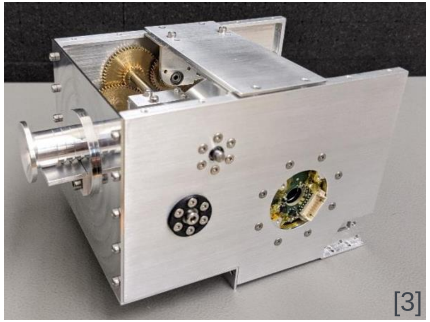
CubeSat Mission Study – Phase 0/A

Educational Mission Objective:

Design a tethered CubeSat Mission with a Perception Payload

Image Credit: DALL-E [3]

- 12U CubeSat launch configuration
- Adapted Nanokhod Tether Mechanism for power and data
  - 100 m, Ø 1 mm, 15 W, < 1 Mbit/s
- Perception payload < 1U



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Tethered Satellite Systems

AETHER (Academic Experiment for TetHers in End-of-life Removal) and C-MOON

- In-orbit rendezvous for space debris removal
- Secondary satellite is deployed via tether
  - Includes grappling system
- Main CubeSat hosts
  - Perception system
  - Tether spooling
  - Communication system

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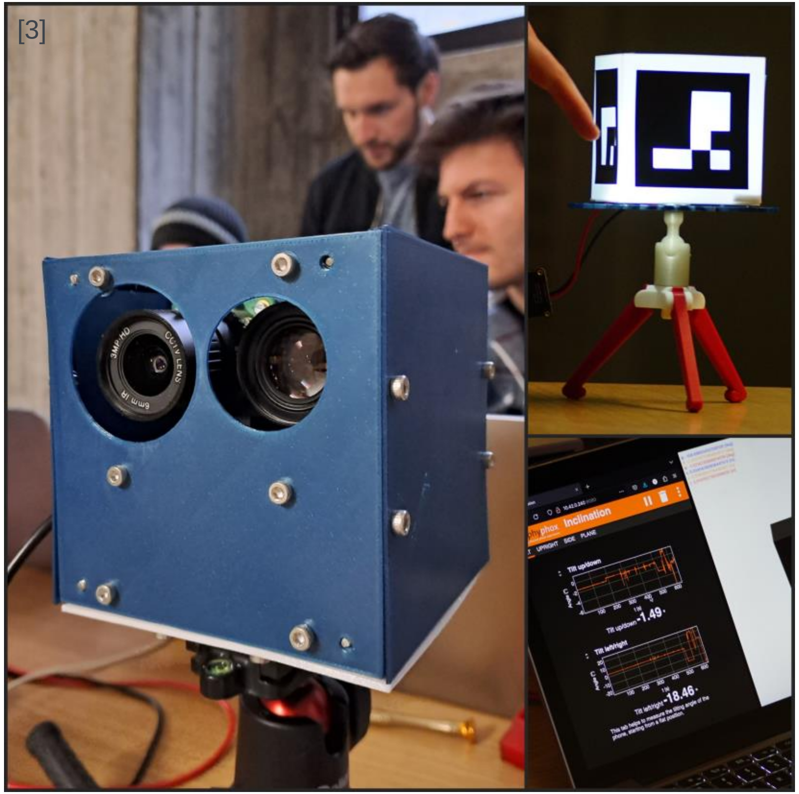
Tethered Satellite Systems

AETHER and C-MOON (CubeSat Mapping using Optical Orientation for Navigation)



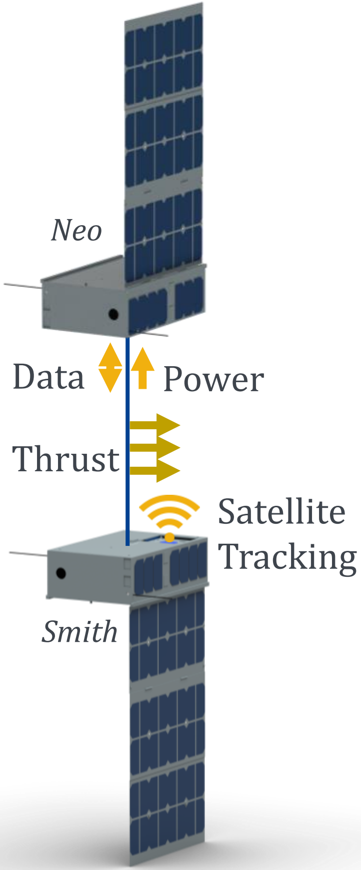
[3]

- Tracking of Target CubeSat with ArUco markers
- 80 x 80 mm ArUco markers with backlight
- Dual camera setup (0..1.5m & 1.5..100m)
- Distances up to 80 m (75 m in low-illuminance conditions)

Tethered Satellite Systems

AGENTS (Atmosphere Gradient ElectrodyNamic Tether Satellites) and TOAST

- Two nearly identical 6U CubeSats
- Electrodynamics for experimental orbit raising
- Atmospheric measurement suite
  - Plasma
  - electron density and temperature
  - Chemical composition



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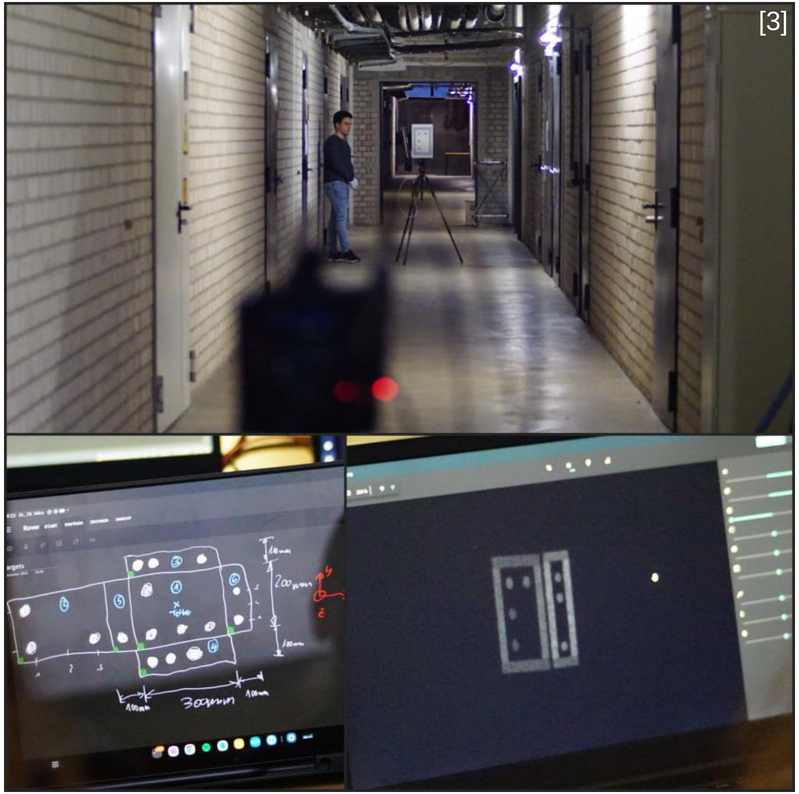
Tethered Satellite Systems

AGENTS and TOAST (Tethered in-Orbit Active Satellite Tracking)

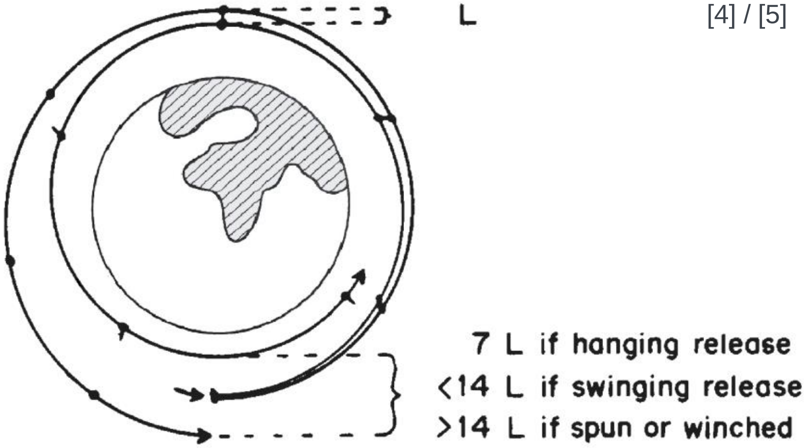


- Tracking of secondary CubeSat with self-designed markers made of retro reflector tape
- Laser module for narrow bandwidth illumination
- Dual camera setup with filter
- Laser range finder
- Distance 50 – 80 m in low-illuminance
    - Difficulties in sun-lit conditions

Momentum Exchange Tether

MISSION SCENARIO

- 30t of mass
- 30d turnaround
- 10 missions per year
- Minimise
  - Earth dependence
  - Interference with other orbits, tether length < 1000km
- > TRL3



[4] / [5]

Momentum Exchange Tether

MISSION SCENARIO

- 30t of mass
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    - Earth dependence
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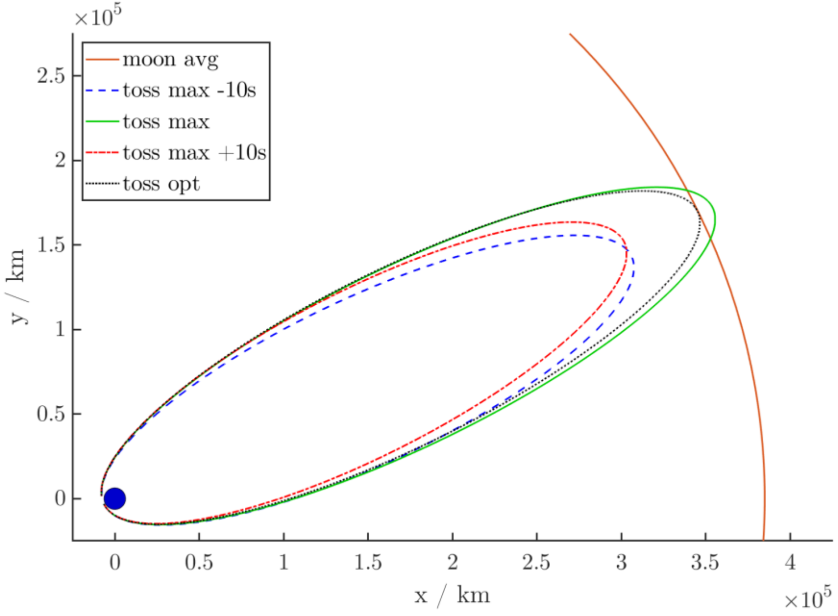
STUDY SYSTEM PARAMETERS

Parameter	Unit	#1	#2	Comment
h_{min}	km	300	1000	Minimum tip altitude
Δv_{max}	km s^{-1}	3.000	2.856	Max. imparted Δv
$m_{sys,mod}$	t	1616	1337	System mass
P_{ED}	kW	11040	9066	Electrodynamic power
a_{PL}	ms^{-2}	26.68	24.86	Payload static acceleration

Momentum Exchange Tether

Mission Challenges

- Precise timing and positional requirements for rendezvous and tossing
- The relation between the target operational orbit and risk of collisions
- The relation between Δv, angular velocity, length and orbital synchronisation after rendezvous and tossing
- Evenly distributed acceleration for sustained operations with electrodynamics



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Thank you! Questions?

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Title and Slide 2, Nanokhod: courtesy of vH&S GmbH

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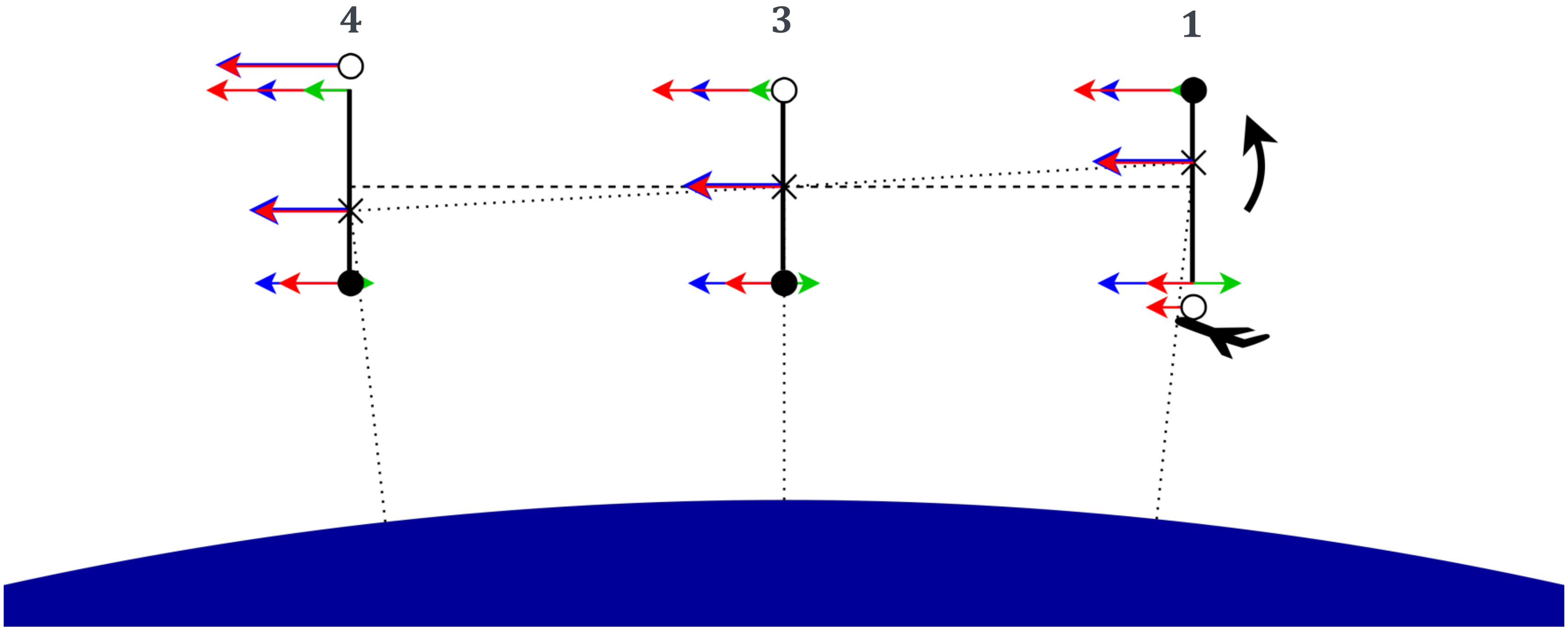
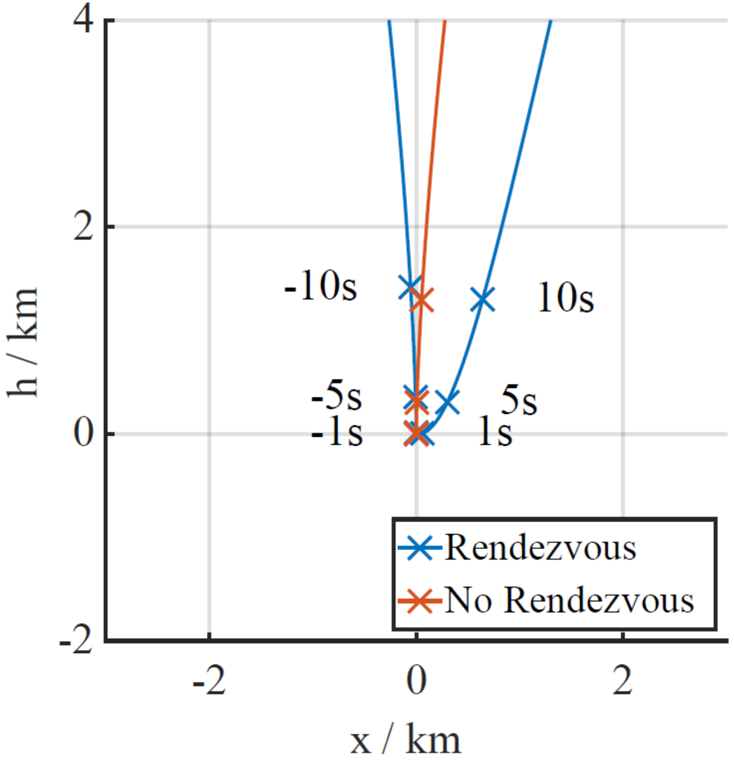
Momentum Exchange Tether
Rendezvous and Tossing



Momentum Exchange Tether
Tether Movement – Rendezvous Window



Momentum Exchange Tether

Electrodynamics