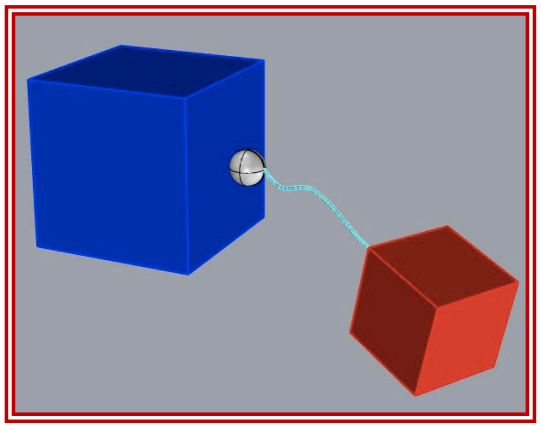

Tethered Electromagnetic Docking

CubeSat Mission Concept for Technology Demonstration

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A. Francesconi, E. C. Lorenzini

Outline

1. The Tethered Electromagnetic Docking Concept
2. TED Mission Objectives
3. Mission Overview
4. Mission Operations
5. Future Work

1. The Tethered Electromagnetic Docking Concept

TETHERED ELECTROMAGNETIC SOFT DOCKING:

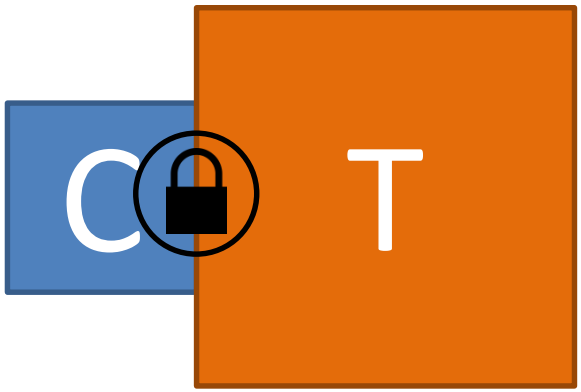
THE CONCEPT

Cooperative docking manoeuvre in two steps:

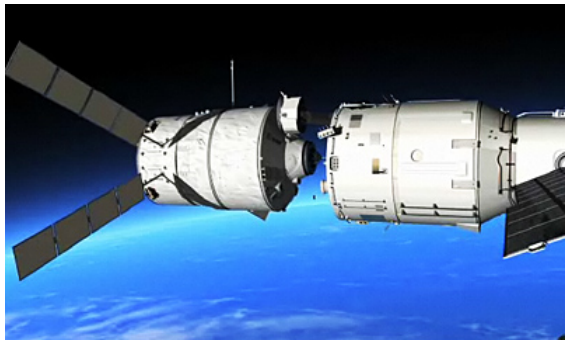
1. soft docking at distance taking advantage of **electromagnetic forces for self-alignment** using a **leashed probe** shot from the chaser
2. hard docking after the **tether** is **rewinded**

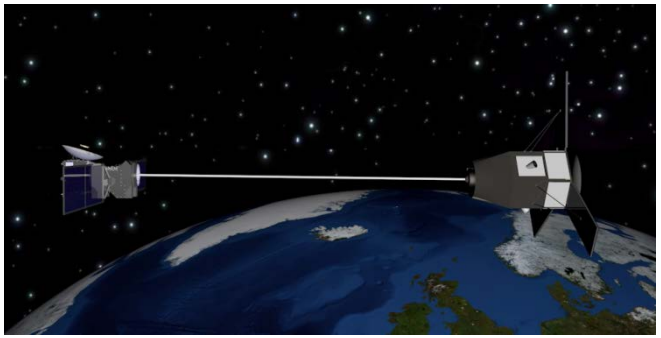
For example…

Hard docking



1. Introduction to TED (2/5)





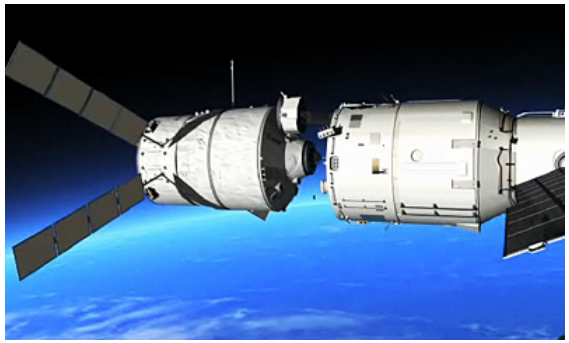
TRADITIONAL DOCKING SYSTEMS

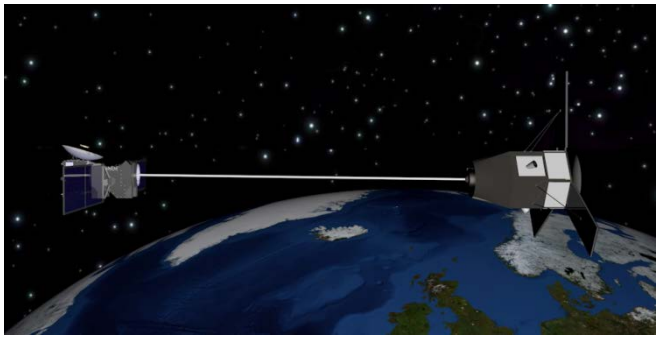
- High load transmission between target and chaser
- Very high precision during close navigation
- Strict alignment requirements

ELECTROMAGNETIC SOFT DOCKING

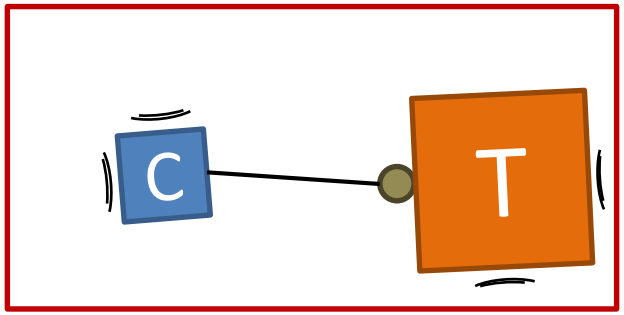
- Low impact forces: collision avoidance
- Looser attitude and navigation requirements (no close approach)
- Magnetic self-aligning

1. Introduction to TED (3/5)



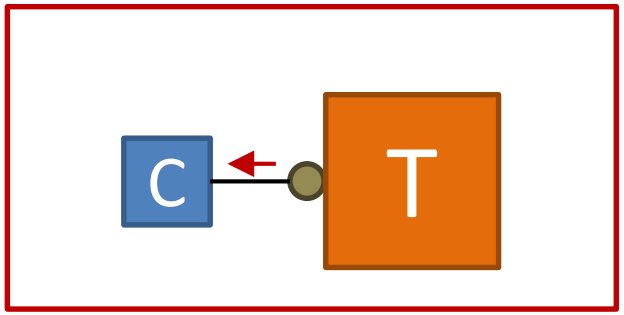


Very precise relative attitude control…

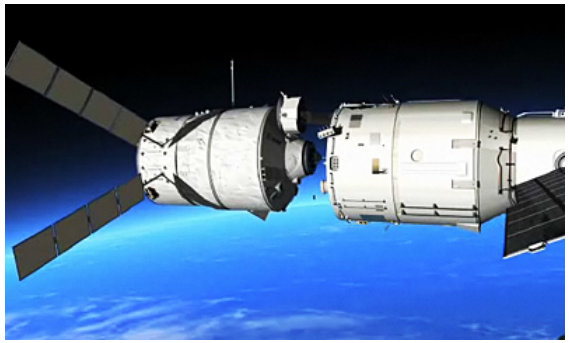


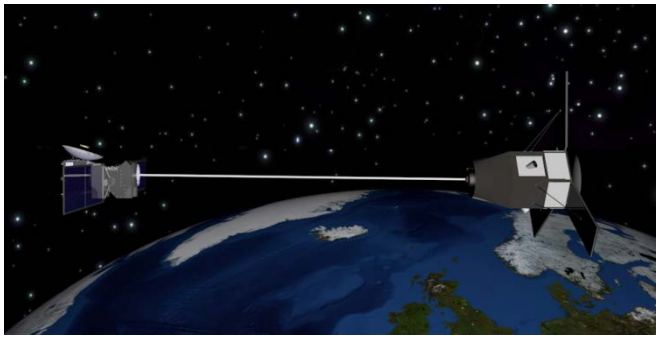
…only coarse relative attitude stabilization

Very precise relative navigation/alignment during close approach…



…no close approach: the tether do all the hard job!





TED ADVANTAGES

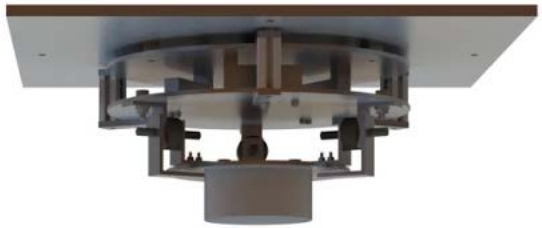
1) Disruptive decrease of docking <u>maneuver time</u>

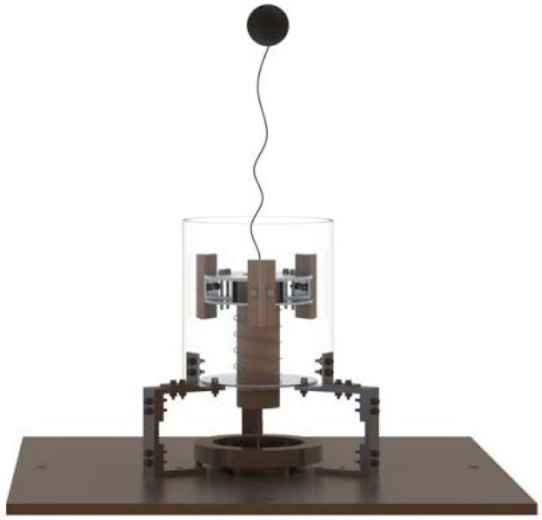
2) <u>Safety</u>

3) Lower demand of <u>resources</u> (power, GNC, ADCS)

4) Enabling docking in <u>MicroSat class</u>

1. Introduction to TED (4/5)





FELDs Experiment:

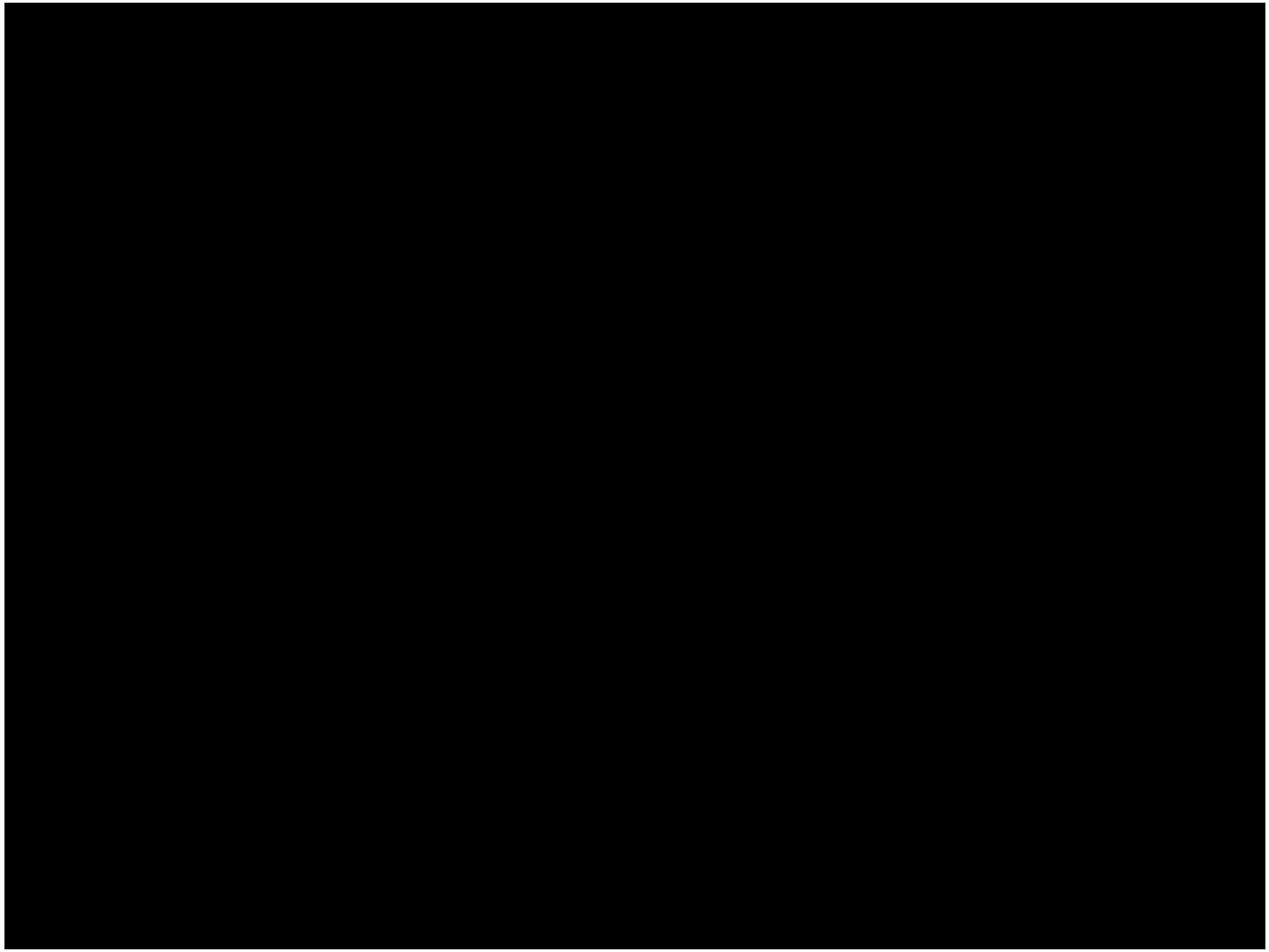
Flexible
Electromagnetic
Leash
Docking
system

Student team selected for
Drop Your Thesis! 2014 Campaign

Primary Objective:

*«To study the dynamics of an innovative **magnetic self-aligning tethered soft docking system**»*

1. Introduction to TED (5/5)

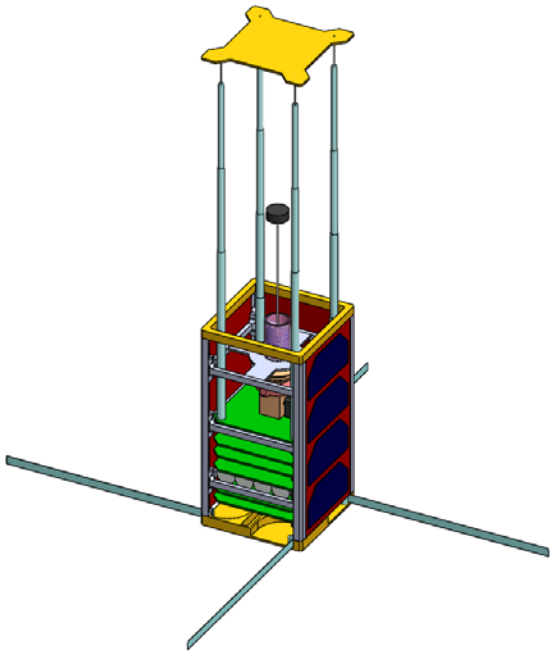


2. TED Mission Objectives

2. TED Mission Objective

MISSION STATEMENT

"To demonstrate the feasibility and the effectiveness of tethered soft docking concept in space"



OBJECTIVES

- To demonstrate the novel **joining technology** in space.
- To validate **launch system** and **Retrievable Reel System**.

2U CUBESAT: DEMONSTRATION PROCEDURE

(1) **Deployment of an iron plate** outside the satellite bus.

(2) **Soft docking** between a tethered probe (electromagnet) and the iron plate.

(3) **Tether rewinding** to pull the iron plate back to its stored configuration

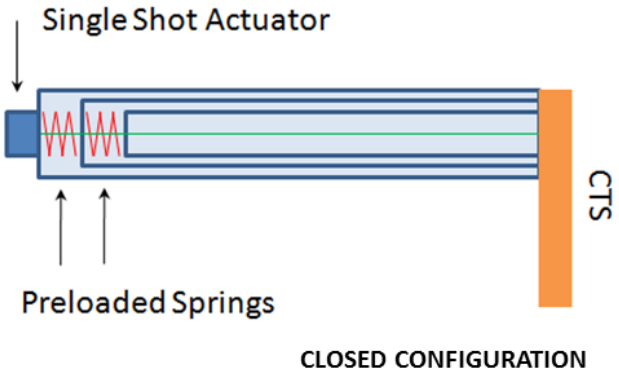
(4) **Replicate the procedure automatically** as many times as possible.

3. Mission Overview

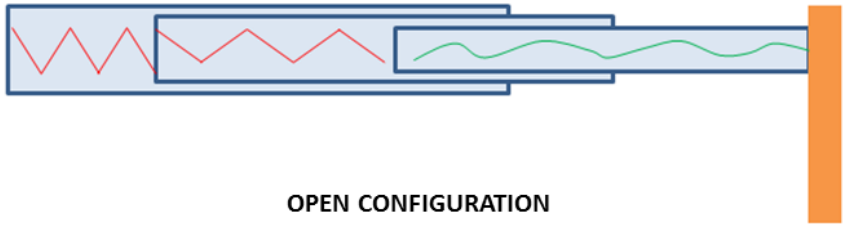
3. Mission Overview (1/4)

CUBESAT TARGET SURFACE DEPLOYMENT SYSTEM

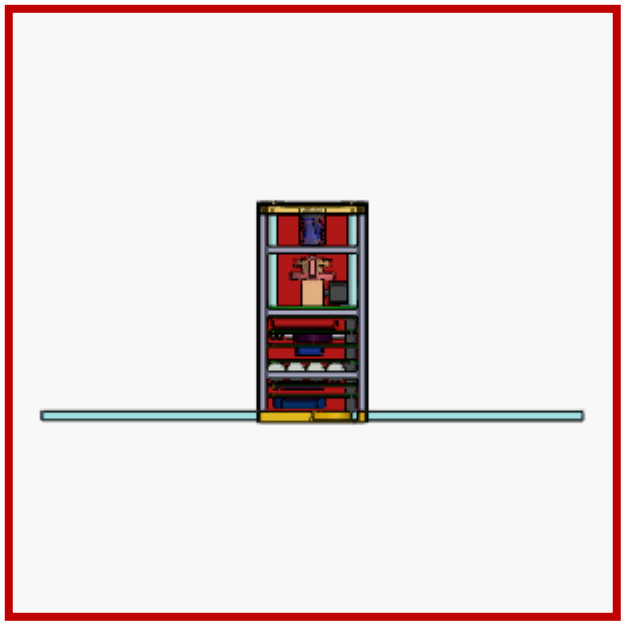
(1) to **deploy the CTS** at a distance of at least 0.2 m
(2) to keep **disturbances low** during deployment
(3) to **allow refolding** during tether rewind



CLOSED CONFIGURATION



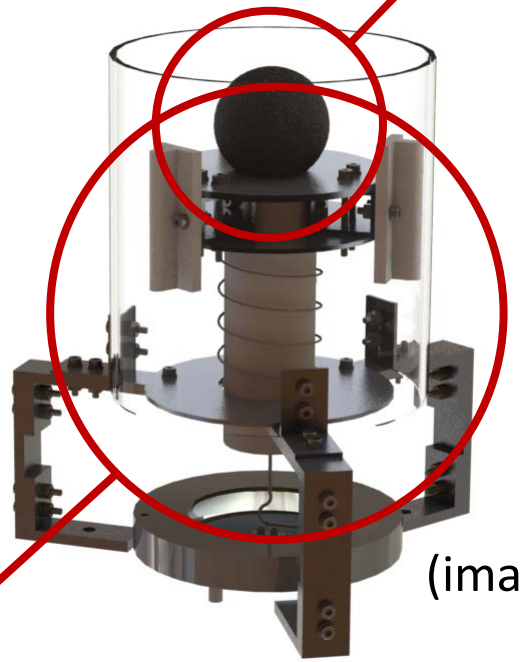
OPEN CONFIGURATION



3. Mission Overview (2/4)

EM PROBE…

- A leashed electromagnet to be launched
- Powered through the tether



(image: FELDs Experiment)

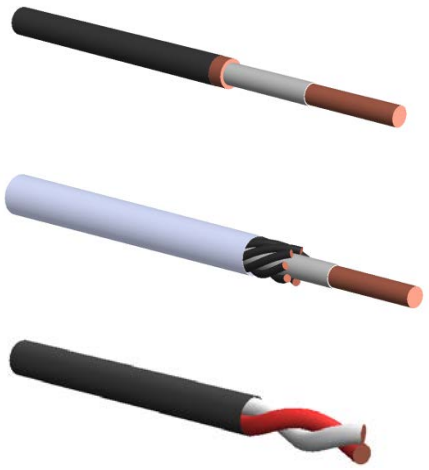
…AND LAUNCH SYSTEM

- A rechargeable spring-based device
- Proper guides to allow several cycles

3. Mission Overview (3/4)

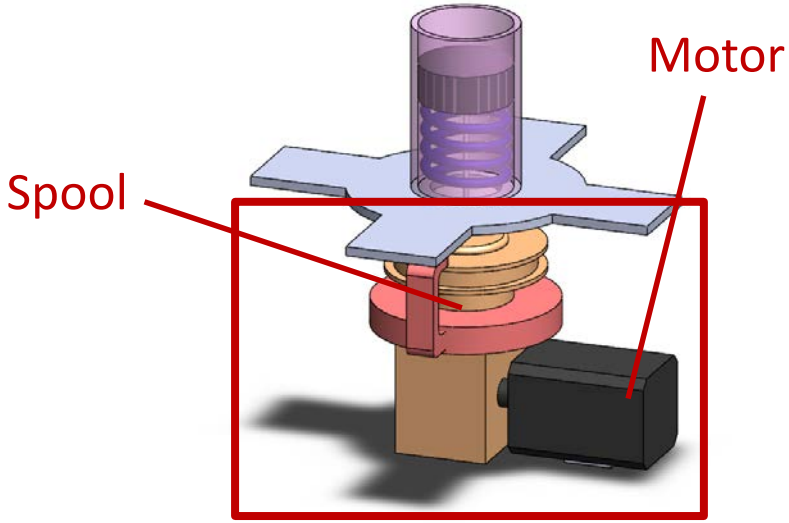
NEW TECHNOLOGIES TO BE DEVELOPED?

TETHER…



- No space inheritage for bipolar wires
- Provides electrical power to the probe
- Sufficient longitudinal ***E*** and σ_s
- Low lateral ***E***
- Proper α/ε ratio
- Isolation properties (thermal, electrical)

… AND RETRIEVABLE REEL SYSTEM

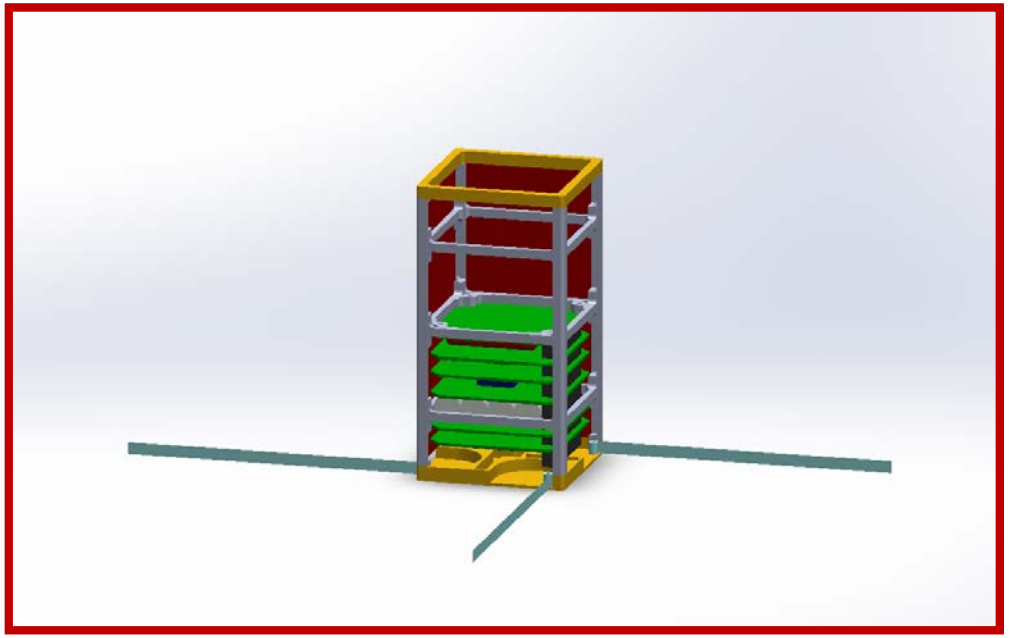


- Insufficient experience in space for retrievable tether deployer
- Frictionless
- Low inertia
- Retrieval capability (multi-shot)
- High reliability

3. Mission Overview (4/4)

BUS

- Structure
- Power
- Communication
- Command & data handling
- Attitude control (passive)

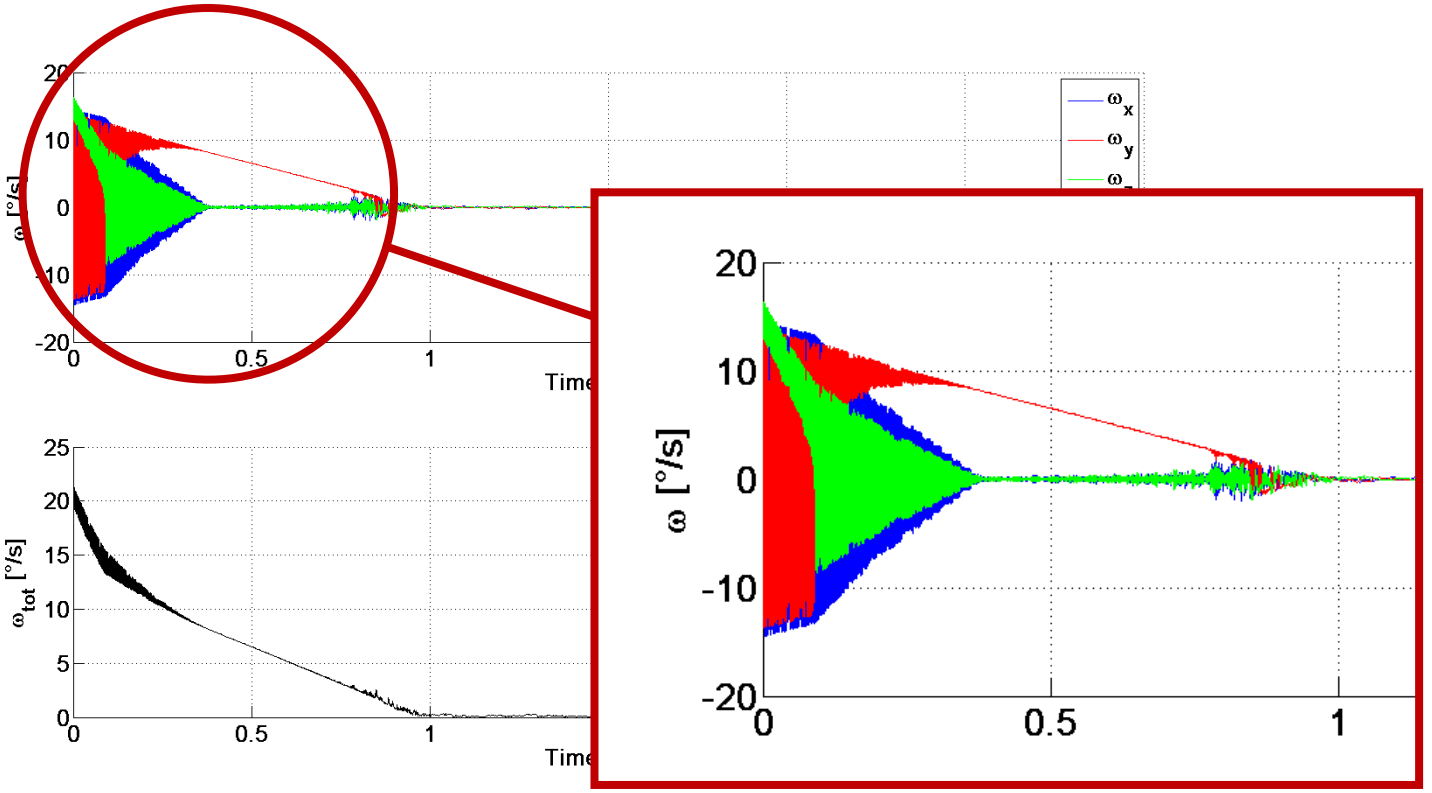


4. Mission Operations

4. Mission Operations (1/2)

ORBIT

- Expected LEO orbit with $i > 70°$
- **3 hysteresis rods** to passively damp angular velocity (1 along each axis)
- With $\boldsymbol{\omega_0}$ **= (10,-10,15) °/s** angular velocity is **damped in one day** (|ω|=0,15 °/s)



5. Mission Operations (2/2)

MISSION ACTIVITIES

After initial tumbling is damped:

(1) Target deployment

(2) Probe launch

(3) Magnetic attraction

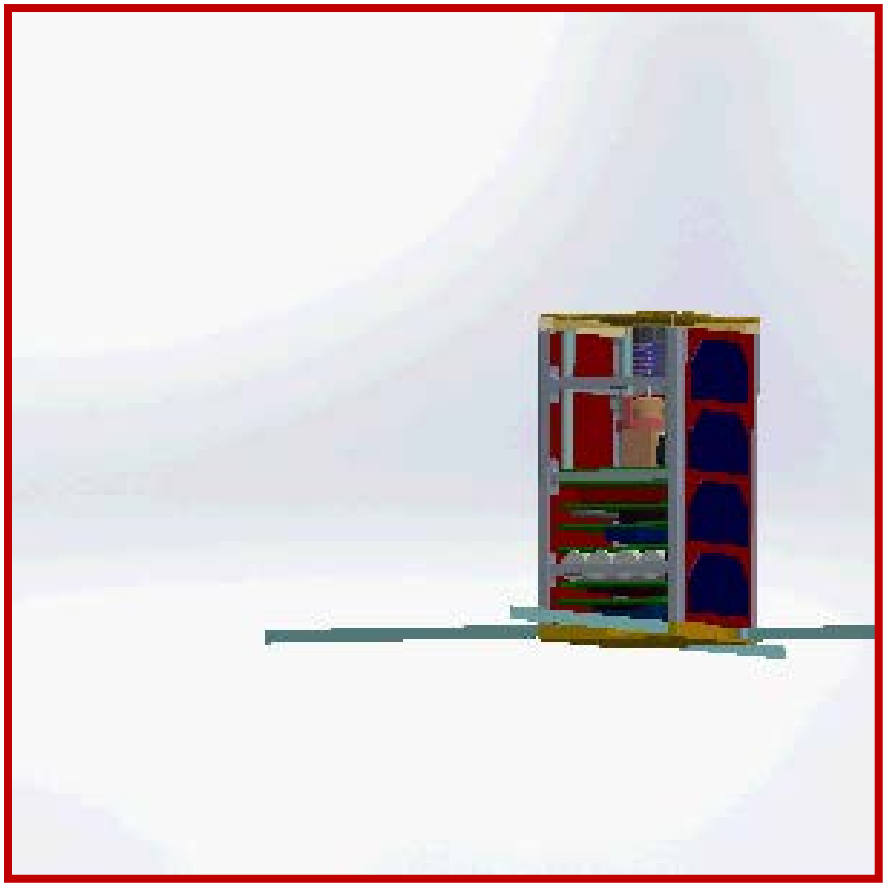
(4) Soft docking

(5) Tether rewinding

(6) Launch system recharging

(7) Initial position restored

(8) New cycle…



5. Future Work

5. Know-How at University of Padova

MAGNETIC SELF-ALIGNMENT

TETHER CLOSE LOOP CONTROL

(Almost…)

Know-how from *SEDS I-II* and *BETs*

FELDs Experiment at ZARM drop tower

What do we need?

RETRIEAVABLE REEL SYSTEM

Retrievable Reel System on REXUS 19/20?

COMING SOON!

HARD DOCKING

ARCADE on BEXUS 16/17

THE END!