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UNIVERSITÀ DEGLI STUDI DI PADOVA

Green in-space transportation with tether technology

Alice Brunello - 36th Cycle

Supervisor: to be defined

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1. Introduction: *what is a Tethered Satellite?*

A Tethered Satellite is coupled by a long cable to another mass or spacecraft.
Tethered satellites provide propellant-free propulsion.
Tethers can be Inert (e.g., used to redistribute momentum from one body to another) or Electrodynamic (with additional capability to interact with the magnetic and electrical force fields).

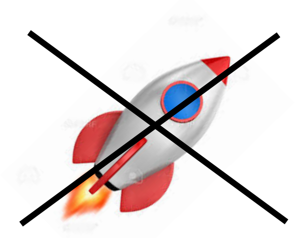
What does the sustainability of Near Earth Orbits require?

- ✓ External contamination must be minimized
- ✓ The number of orbital debris must be reduced

The project of a tethered vehicle can lead to a new technological solution for generating propulsion in space that is:

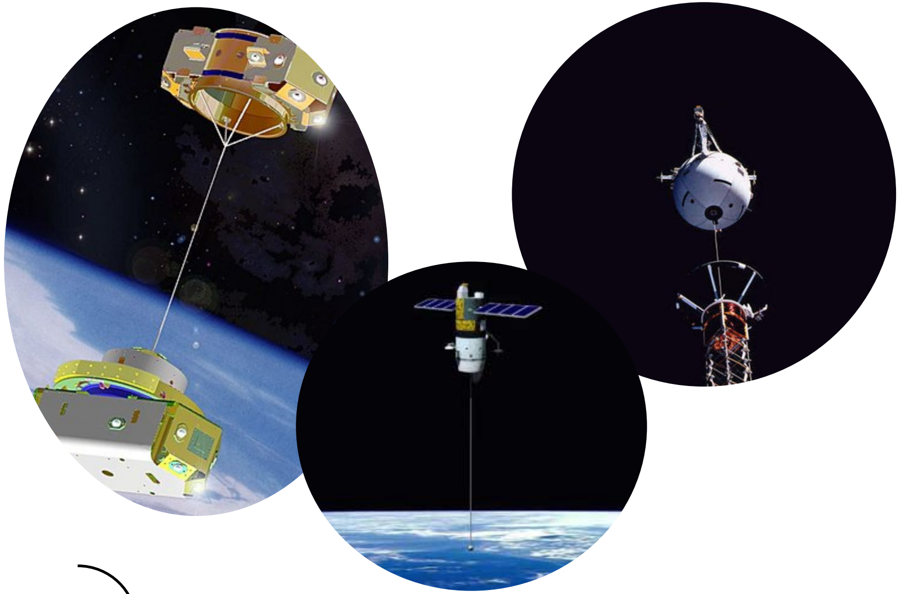
- ➢ Safe

- ➢ Free of pollution



- ➢ Propellant-free

2. Motivation: *why I chose Tether Systems?*



- 2019 Research Activity

«Technological Development for Auxiliary Deorbiting System from the ISS»

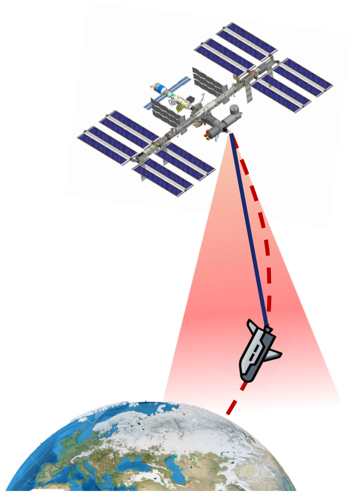
- Tether System main features:

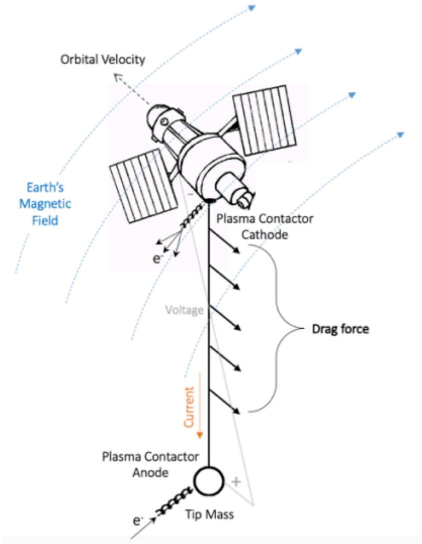
✓ Versatile
✓ Adaptatable to many different mission requirements
✓ Effective for propulsion
✓ *Enable long-term operations (propellant-free)*
✓ *«Ecological Spirit»*

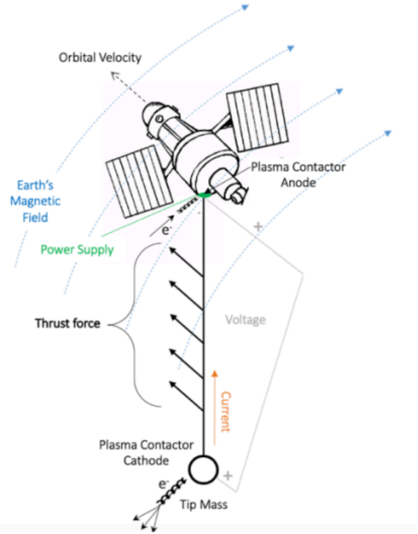
An important advancement for future Space Missions

3. Tether System Applications

What kind of missions a Tether System can be used for?







- Re-entering payload from space
  Preserving cleanliness of space environment
- De-orbiting end-of-life satellites
  Space debris mitigation
- Reboost LEO satellites
  Avoid propellant resupply

4. Tether System Benefits

A Tether System is able to provide adequate thrust or drag without the complications of combustions and with a minimal impact on the space environment:

1. **PRESERVING THE CLEANLINESS OF EXTERNAL ENVIRONMENT**

   The use of a classical chemical propulsion system near sensitive and inhabited space areas can cause contamination due to the fuel ejection

   - Exhaust on external system and optics
   - Chemical deposists
   - Exhausted launcher stages
   - Danger of starting rocket motors

   → Safe and Pullution free

2. **DEBRIS MITIGATION**

   End-of-life payloads and satellites disposal need to follow the guidelines of many agencies on debris mitigation. The 25 years recommendation for satellites deorbit leads all major spacecraft providers to install disposal systems on board of their vehicles, save propellant for deorbiting, or to arrange dedicated interfaces for on orbit servicing and deorbit operations at end of life.

   - Propellant onbord the satellite for a long period → NO propellant leakage and degradation

3. **PROPELLANT RESUPPLY**

   To maintain chemical satellites at their design altitude, a continuous propellant resupply is required.

   - Need a continuous supply → Satellite self-indipendent from Earth

5. Research Project Goal

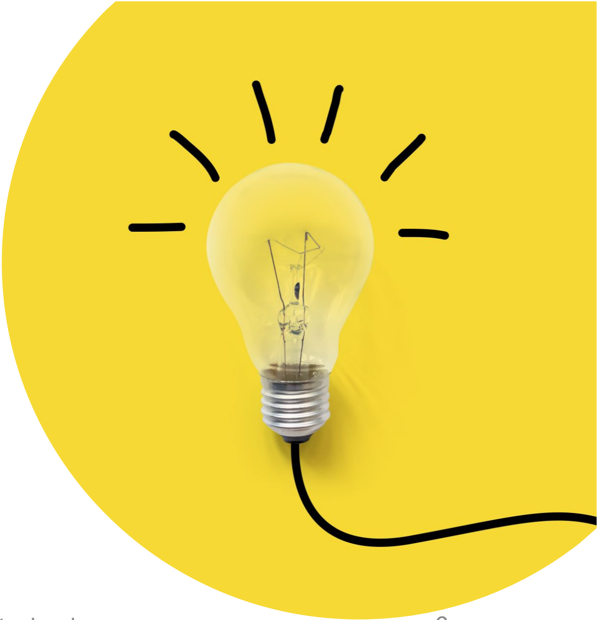
Past Missions (SEDS-I, SEDS-II, YES2, PMG, TSS, TSS-1R and several shorter-tether missions):

- Stable tether deployment
- Proven feasibility of propellant free propulsion: SEDS-I (momentum exchange), PMG (Electrodynamic)

- measure tether boost
- Payload re-entry or deorbiting mission
- Thrust forces for satellite reboost

Demonstrate different configurations of Tether Systems to:

- ➢ overcome the limitations of rocket propulsions
- ➢ enable new classes of missions currently unaffordable or unfeasible
- ➢ significantly advance the tether technology to an operational level



6. International Research Programs

- Tether system as a Re-entry Device
  - ✓ Re-entry a capsule from the ISS: **IPERDRONE.1** (https://www.cira.it/it)

- Tether System as a De-orbiting Device
  - ✓ Debris mitigation with electrodynamic tether: **E.T.PACK** (https://etpack.eu/)

- Tether system as a Reboost Device
  - ✓ Compensation of the aerodynamic drag of LEO satellites: **IN-SPACE TRANSPORTATION**

6.1 IPERDRONE.1

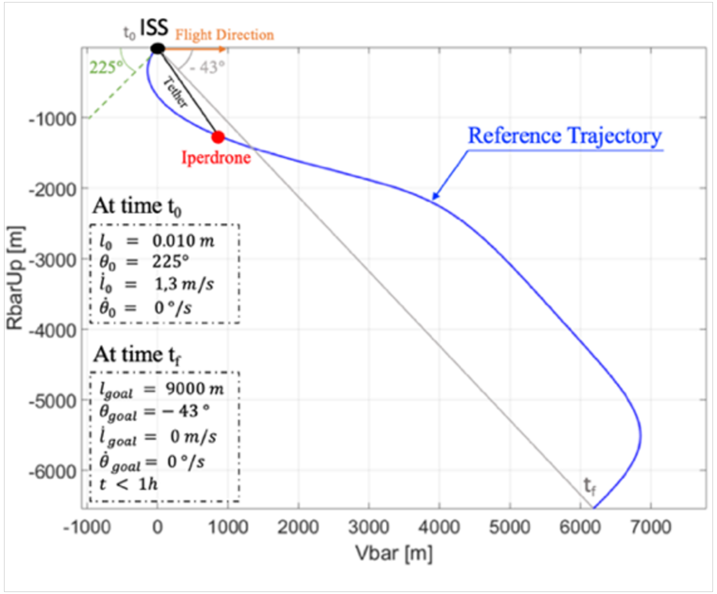
Investigation: the University of Padova design and develop a Small Space Deployment Tether System for de-orbiting a space drone with a minimum impact on the space environment

Motivation: demonstrate the feasibility of unwinding a payload (small sat) with a feedback control law

Implementation: arrive at a solution that is effective for deorbiting and efficient from the point of view of mass and operation of the whole re-entry system

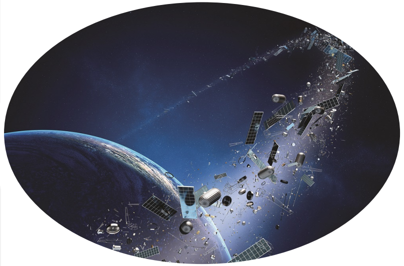
Agenzia Spaziale Italiana

Centro Italiano Ricerche Aerospaziali

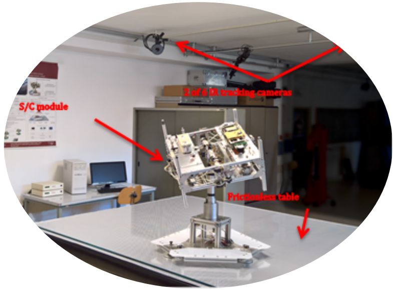


6.2 E.T.PACK

Motivation: I plan to work towards a future with a safe and clean space using pollution-free systems for debris mitigation, reducing the impact on the environment.



Investigation: Contributions to analyses of a propellant-free Electrodynamic Tether Kit to be mounted on satellites prior to launch and to be deployed at the end of the satellite operational life for deorbiting



Implementation: Contributions to the development of a prototype tether deployer that will lead to an in-orbit demonstration mission of the technology in the future: internal dynamics of the deployer, optimization of mechanisms and sensors and testing the functionality of the deployer.

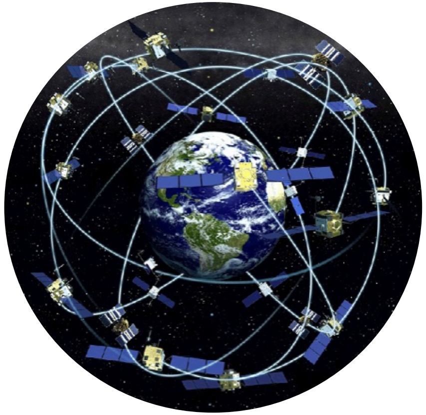
6.3 In-Space Transportation

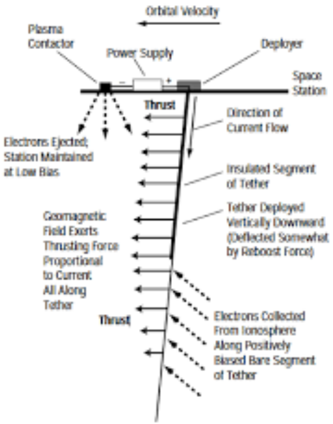
Investigation: development of a new technology based on the use of an Electrodynamic Tether System for reboost satellites in LEO orbits.

Motivation: compensation of the Aerodynamic Drag

Implementation: development of current control strategies and therefore thrust for navigation and guidance of satellites maintained in their original orbit by propellant-less electrodynamic tether propulsion;

Analysis/development of a mass-efficient system that can generate the desired thrust for applications of great future interest such as LEO satellite constellations





7. Gantt Chart

			FIRST YEAR												SECOND YEAR												THIRD YEAR											
			T1			T2			T3			T4			T1			T2			T3			T4			T1			T2			T3			T4		
WBS NUMBER	TASK TITLE	% OF TASK COMPLETE	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
ET PACK																																						
1	**Study of the program state of art**	30%																																				
1.1	Requirements and goals	100%	125																																			
1.2	Deployment Kit design	0%		125																																		
1.2.1	Deplyment Mechanism Module	0%		31,3																																		
1.2.2	Electron Emitter Module	0%		31,3																																		
1.2.3	Tether longitudinal Structure	0%		62,5																																		
1.3	Performance of the Deplyment Kit demonstration	0%			125																																	
1.3.1	Initial stabilization	0%			31,3																																	
1.3.2	Controlled deplyment	0%			62,5																																	
1.3.3	Deorbit Perfomance	0%			31,3																																	
2	**Detailled design and Manufacturing**																																					
2.1	Deployer Design	0%				62,5	62,5	62,5	62,5	62,5	62,5	31,3	31,3																									
2.2	Deployer Cold Gas System	0%				62,5	62,5	62,5	31,3																													
2.3	Breadboarding and Prototype	0%							31,3	62,5	31,3	31,3	62,5																									
3	**Subsystem Test**																																					
3.1	Deployer Functional Test	0%												62,5	62,5	62,5																						
IPERDRONE.1																																						
4	**Feseability and Analysis**	0%									31,3	62,5	31,3				62,5	62,5	62,5																			
5	**System Design**	0%															62,5	62,5	62,5	62,5	62,5	62,5	62,5	62,5	62,5	31,3												
6	**Software Development**	0%																		62,5	62,5	62,5	62,5	62,5	31,3	31,3												
IN SPACE-TRANSPORTATION																																						
7	**Study and resarch of feseability**	0%												31,3	62,5	62,5									31,3	31,3	125	62,5	62,5	62,5	62,5	62,5	31,3	62,5	31,3	62,5	31,3	31,3
8	**Current control strategies and thrust for navation and guidan**	0%																										62,5	62,5	62,5	62,5	62,5	31,3	31,3	62,5			
9	**Conceptual Design**	0%																															62,5	31,3	31,3	31,3	31,3	31,3
THESIS AND REPORT																																						
10	Report	0%												31,3												31,3												31,3
11	Thesis	0%																																		31,3	62,5	31,3
Educational Activities																																						
12	Educational Activities (250 hours/year)	0%																																				

Thanks for the attention!

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