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Customer-driven deorbit kit based on bare electrodynamic tether technology

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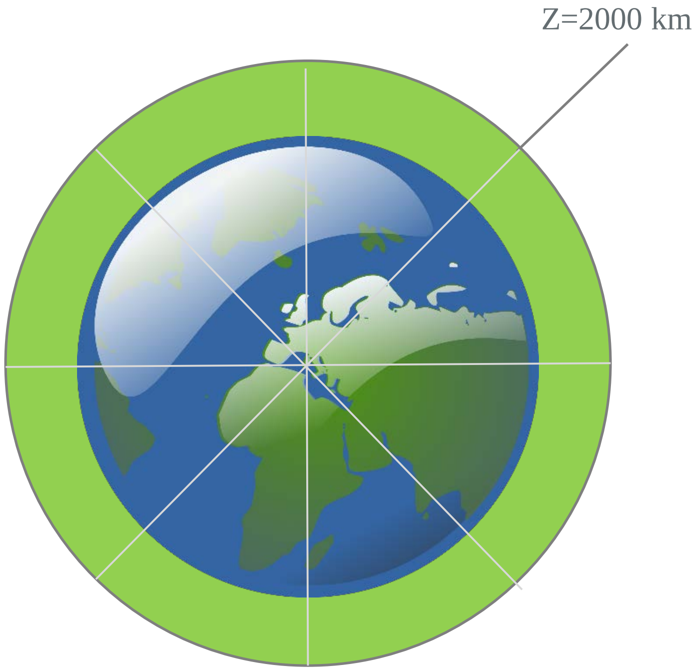
1. Motivation - Keep LEO Clean

The **European Code of Conduct for Space Debris Mitigation** indicates:

- SD-OP-03: The operator of a space system should **perform disposal manoeuvres** at the end of the operational phase to limit the permanent or periodic presence of its space system in the protected regions to a maximum of 25 years.
- SD-DE-09: […] **de-orbiting measures should be taken into account** in the design of the space system.

The **French Space Operation Act (LOS)** formalizes as mandatory requirements the respect of the protected regions.



Protected regions: The low Earth orbit region (LEO region) is the spherical shell region that extends from the Earth's surface up to an altitude (Z) of 2000 km.

1. Motivation - Keep LEO Clean

- **Five key facts on space debris**

1. Space debris population is now under the Kessler syndrome.
2. New launches and megaconstellations will make the problem worse.
3. The legal framework (guidelines and regulations) is changing towards a more strict scenario (IADC, ESA, CNES).
4. New commercial opportunities and technologies will appear.
5. Deorbiting satellites at the end-of-life will play a central role because it is probably the only long-term solution.

- **The space debris problem = a business opportunity**

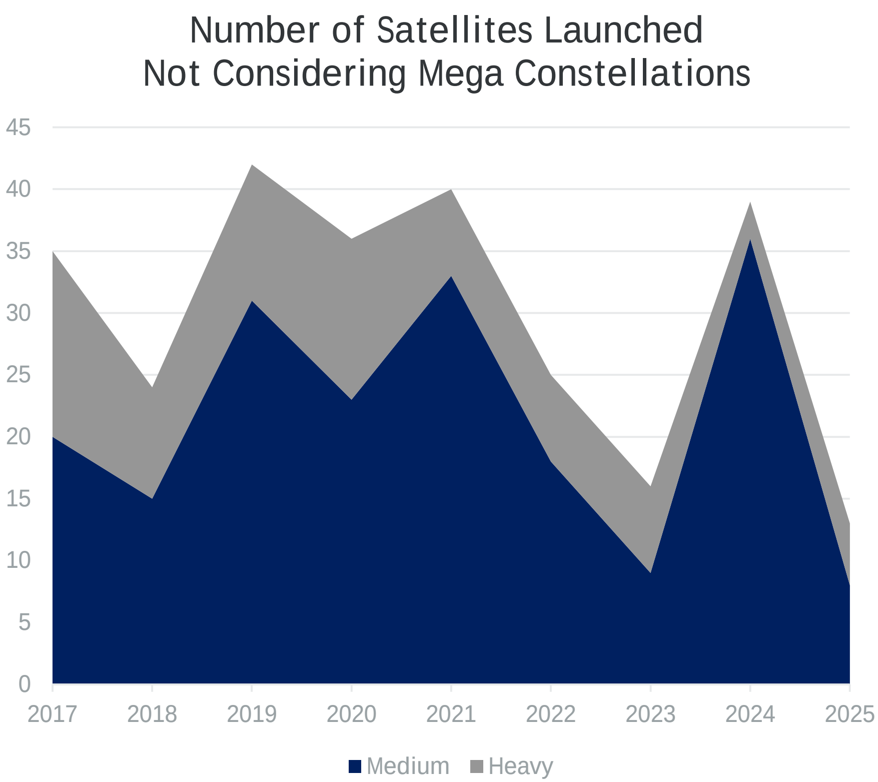
1. There are technologies that can deorbit, but they present drawbacks (see next slide).
2. Today, the deorbit cost > branding benefits → currently, companies do not deorbit.
3. At some point, deorbiting will be mandatory.
4. In the next years, the company owning the right technology will dominate the market.

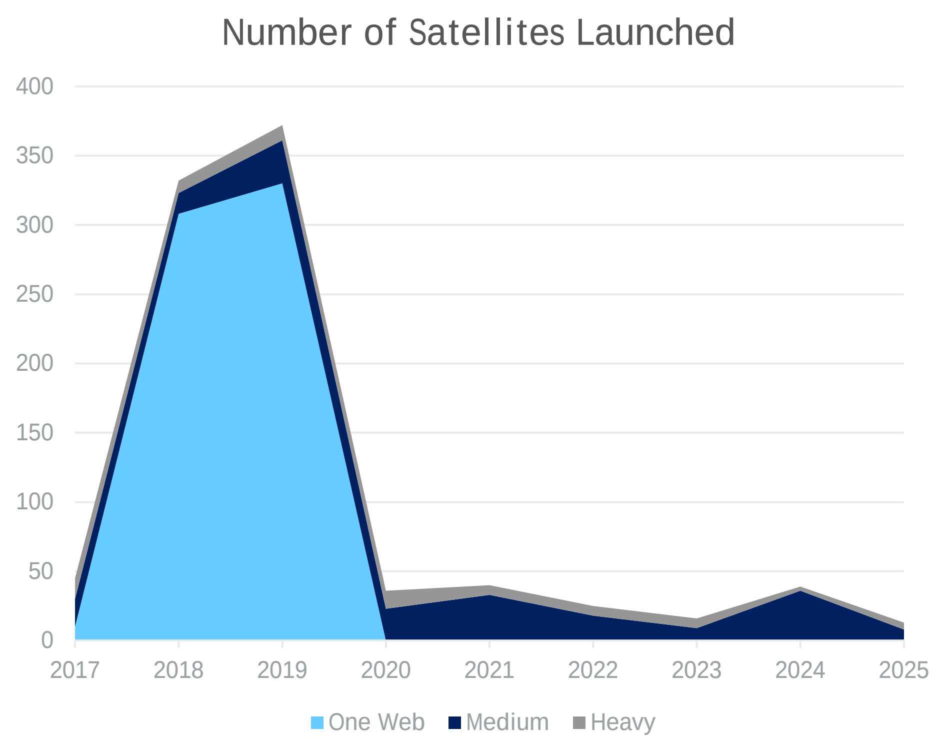
1. Motivation - Huge increase in satellites launch

From 2017 to 2025 a total of 918 small satellites will be launched with the following mass distribution:

- 50-250 kg: 841
- 251-500 kg: 77

These data considers only One Web Mega Constellation (648 satellites)

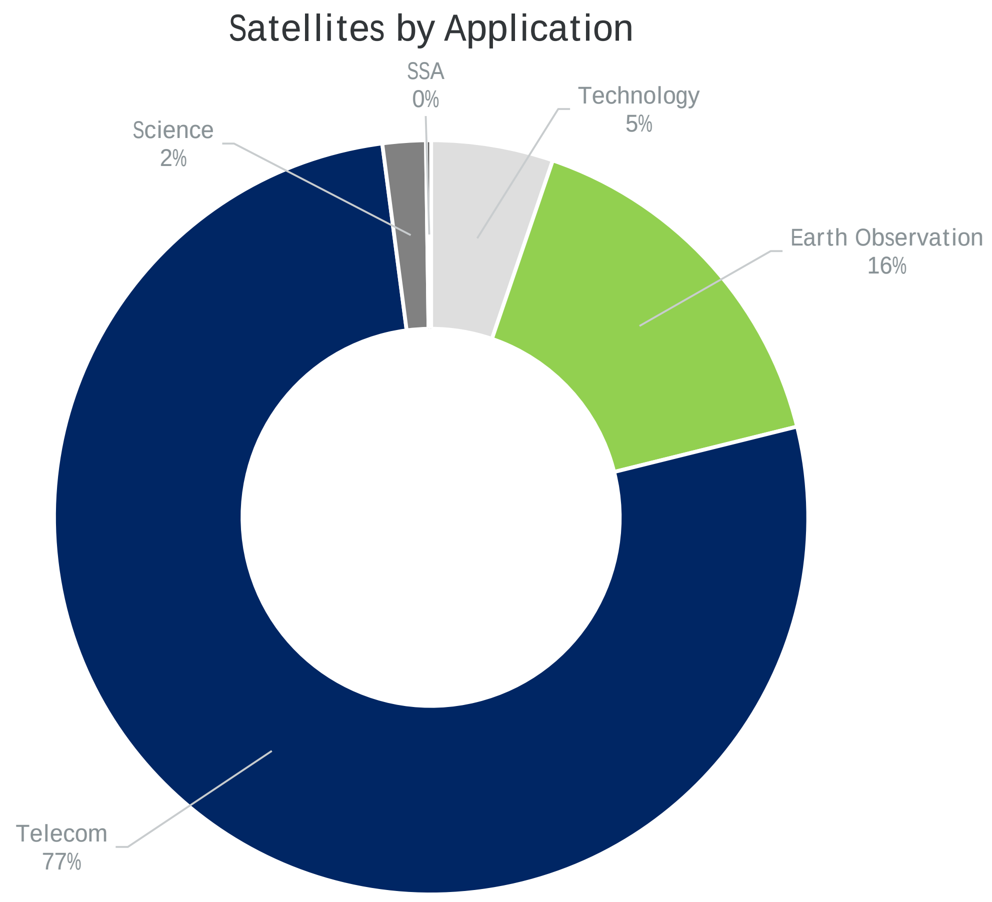




1. Motivation – Telecom Satellites main Applications

SmallSat Application share is:

- Telecom 77%
- Earth Observation 16%
- Technology 5%
- Science 2%
- SSA <1%

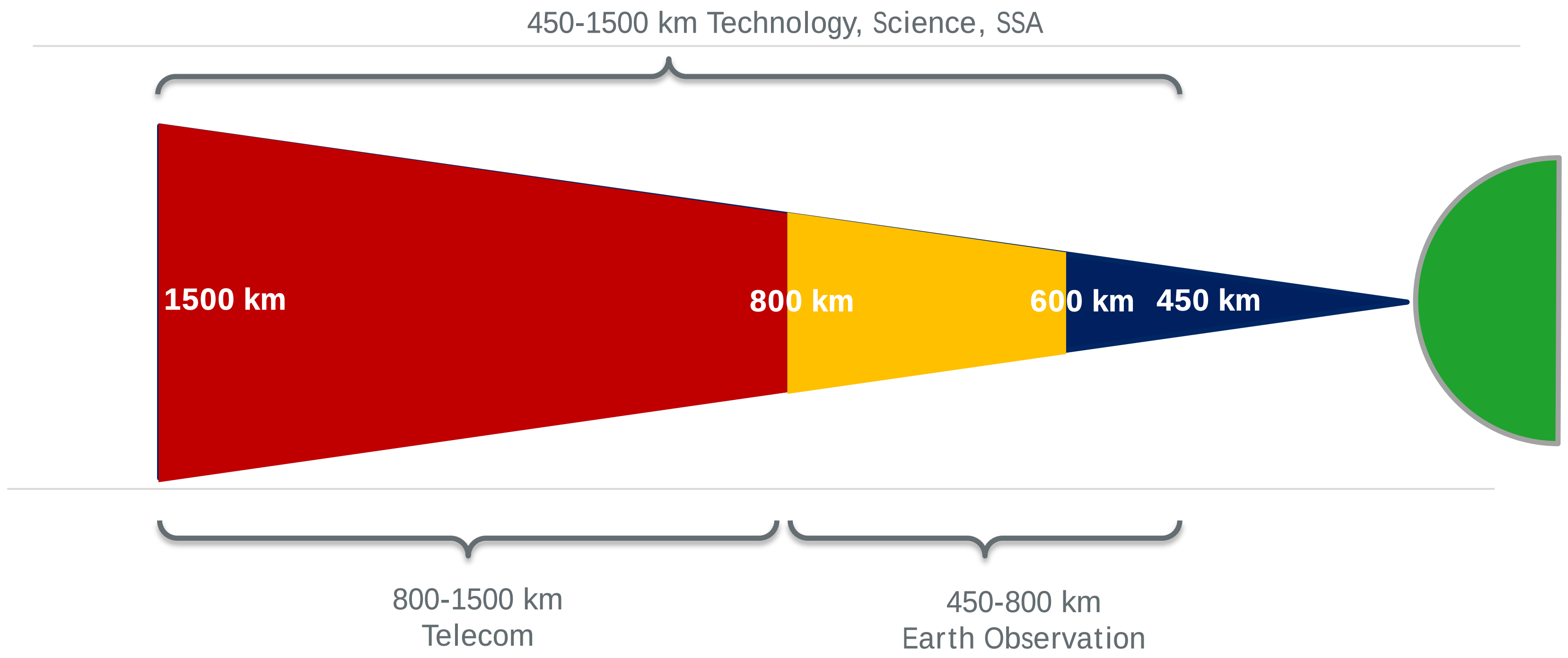


Application	Medium	Heavy
Technology	45	3
Earth Observation	96	50
Telecom	705 (648 OneWeb)	13
Science	6	11
SSA	2	0

1 Motivation - Satellites Orbit By Applications

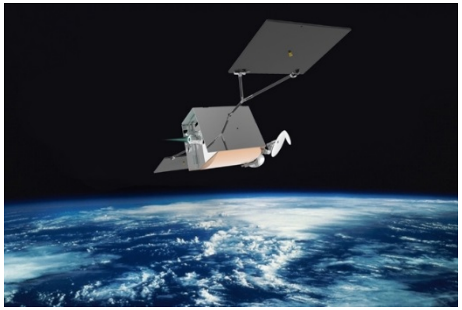
Smallsat Orbit is mainly driven by the required Application share is:

- Telecom is operating in 800-1500 km
- Earth Observation in 450-800 km
- Technology, Science, SSA in any orbit from 450 to 1500 km

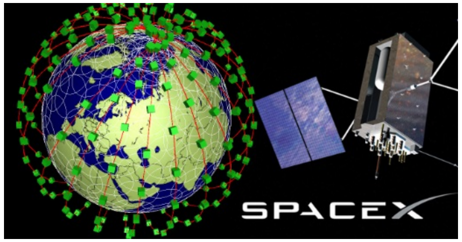


1. Motivation - Telecom Constellations Threat

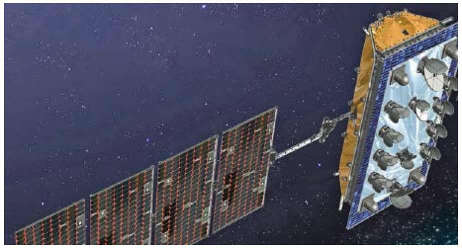
- OneWeb Constellation (648 satellites)
  Mass 200kg, orbit 1200km, launch 2017-2019



- SpaceX Constellation (4425+ satellites)
  Mass 380kg, orbit 1100km, launch 2019



- LeoSat Constellation (108 satellites)
  Mass TBCkg, orbit ~900km, launch 2019-2022



- Telesat LEO (100TBC satellites)
  Mass 80TBCkg, orbit 1000TBCkm, launch 2021

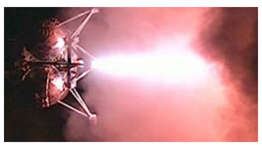
2. De-Orbit Kit Requirements

De-orbit Technologies

Active

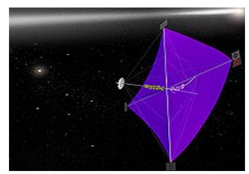
Passive

Chemical Propulsion

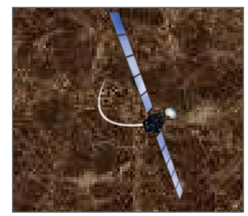


Electrical Propulsion

Sails



Tethers



Newton's Third law

Newton's Third law

Air Drag

Magnetic drag

They will always need propellant

Weak at h>800km
$A \times T_D$= cte

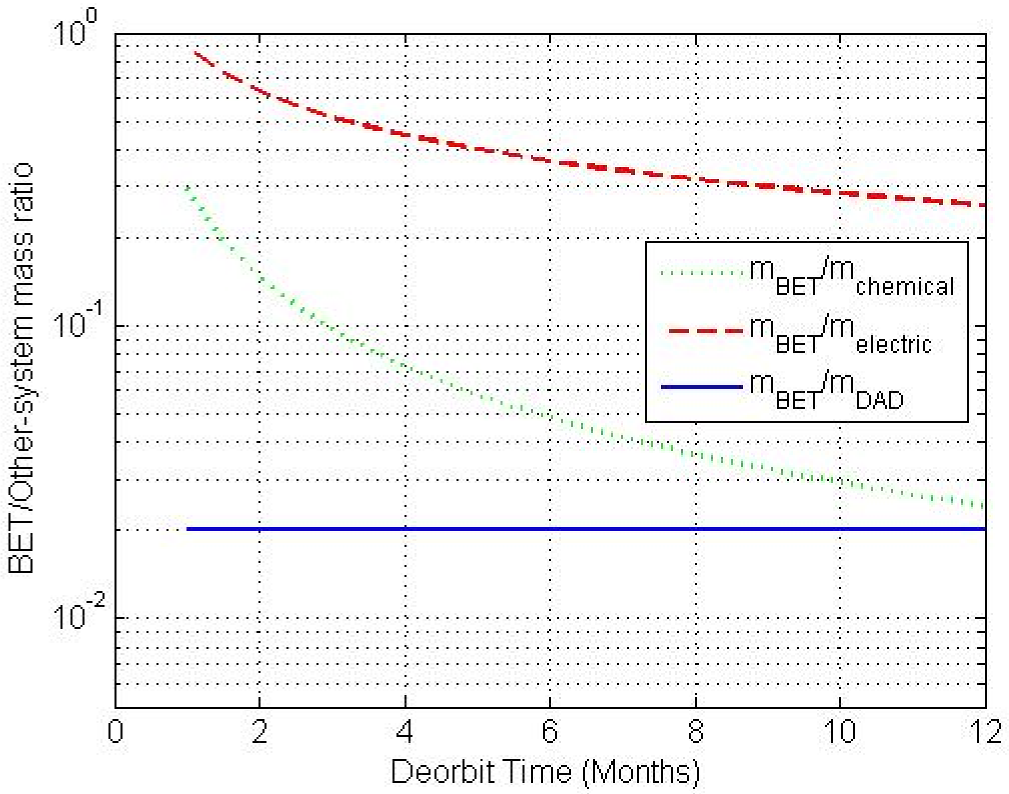
The wish list

1. Bring deorbit time below 25 years
2. Cheap.
3. Light.
4. Passive (no power, no attitude control)
5. Efficient at h > 800km
6. Decrease $A \times T_D$
7. Allow maneuver.
8. Simple and reliable.
9. Allow scalable design.
10. High TRL.

Electrodynamic tether technology does not satisfy now the wish list, but it is the only one that could do it in the future.

3. EDT KIT - Performances

Bare electrodynamic tether (BET)-to-other technologies mass ratio versus deorbit time (initial altitude 850km, middle inclination).

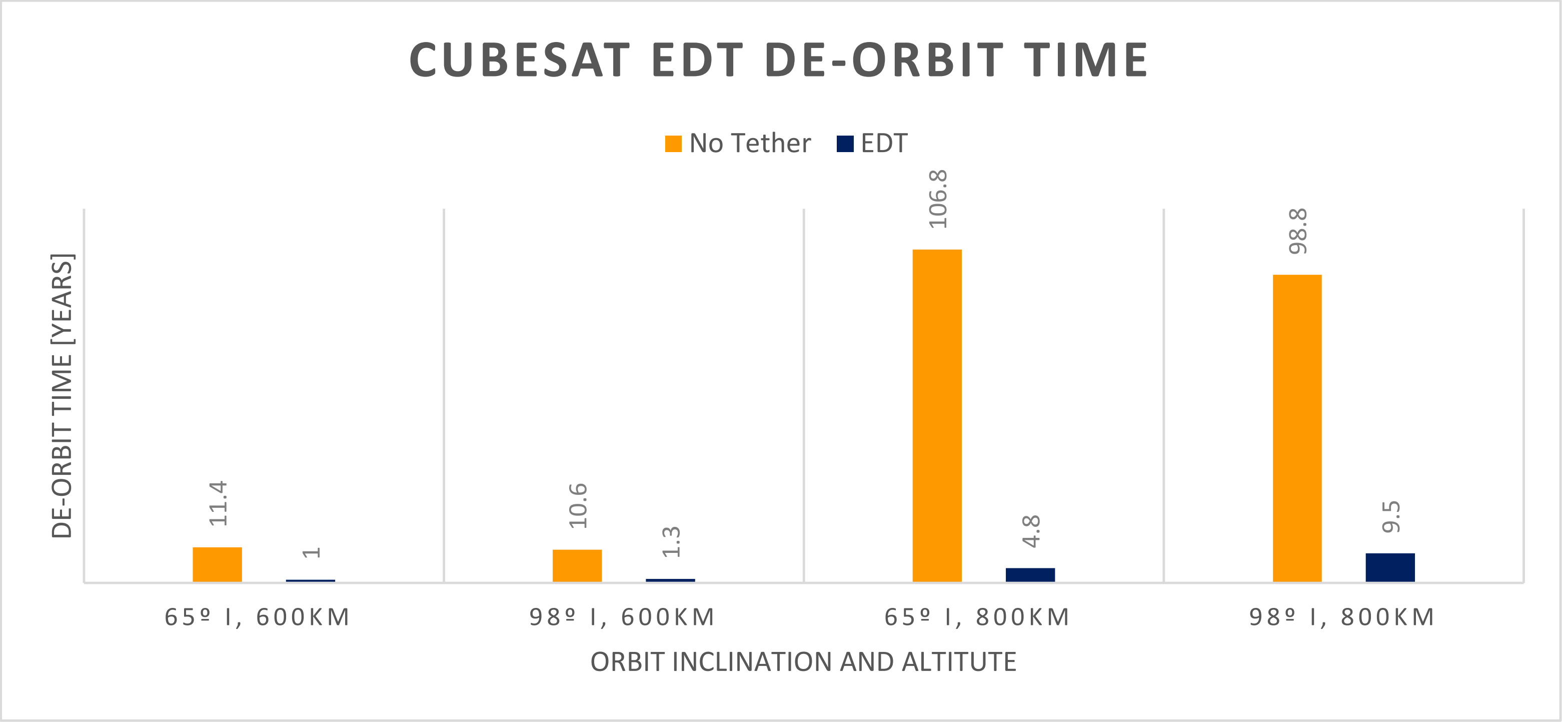


See the details of the models and the numerical values used in G. Sánchez-Arriaga, J.R. Sanmartín, and E.C. Lorenzini, Comparison of technologies for deorbiting spacecraft from Low-Earth-Orbit at the end of mission, Acta Astronautica, Vol 138, 536-542, 2017.

3. EDT KIT - Performances

Analysis showed that 100m x 50 mm x 50µm of conductive EDT, can deorbit 50kg satellite

- orbiting at 600 km with i= 65º in about 1 year (being the natural de-orbit time 11.4 years)
- orbiting at 600 km with i= 98º in about 1.3 years (being the natural de-orbit time 10.6 years)
- orbiting at 800 km with i= 65º in about 4.8 years (being the natural de-orbit time 106.8 years)
- orbiting at 800 km with i= 98º in about 9.5 years (being the natural de-orbit time 98.8 years)



4. EDT KIT for satellites- components

EDT system main components are:

Tethers, made up of a Bare part and an Inert part.

- Bare part is a conductive tape that exchanges momentum with the planet magnetosphere.
- Inert part is used to stabilize the system tether system.

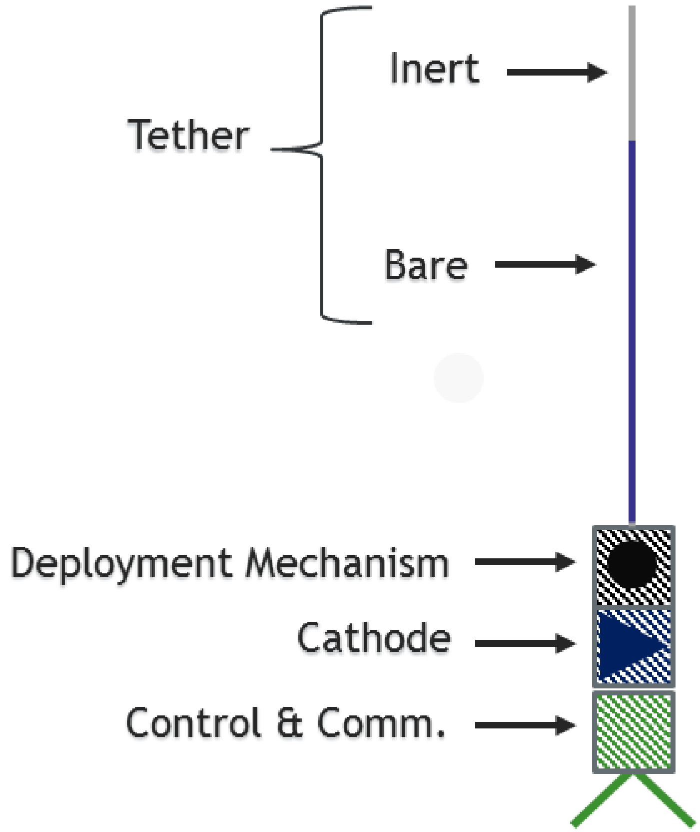
Deployment system providing two functions:

- Extraction of the tether from the coiled configuration.
- Provide separation force between the two elements connected with the tether to get the required straightness.

Cathode is required to eject electrons to close the electric circuit with the plasma.

Control and Communication elements are required to provide authonomy for:

- Communication (autonomous command)
- Stabilization prior to deployment
- Avionics, power



4. EDT KIT - Configurations

The tether attitude stability during the de-orbiting depends on the carefull design of the system. Tether instability may result in odd dynamics and eventually in significant reduction of de-orbit performance.

Two configurations are possible:

Integrated

This configuration consists of a module to be integrated with the spacecraft. No autonomy is implemented. The host spacectaft is in charge of providing power and data to the EDT-KIT. Upon command from the host spacecraft the tether is deployed. A tip mass of is used to stabilize the tether.

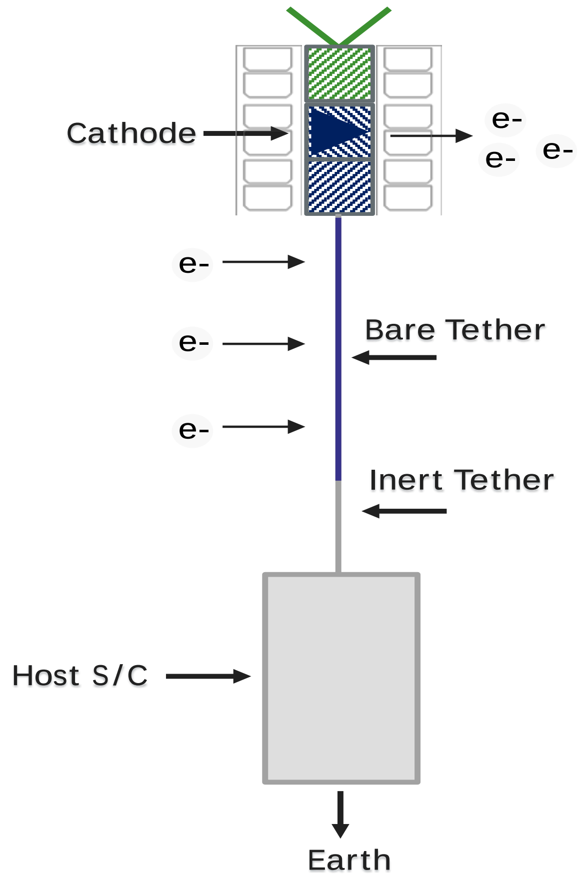
Autonomous

This configuration consists on a fully autonomous system to be connected with the spacecraft. The EDT-KIT is deployed from the host spacecraft and used as tip mass.

The Control and Communication element provides the correct orientation of the host S/C at beginning of deployment (when still attached to the S/C) and communication with the ground during deorbiting.

Power is autonomously generated by solar panels and batteries.

AUTONOMOUS EDT SYSTEM
Host S/C is required to provide nothing



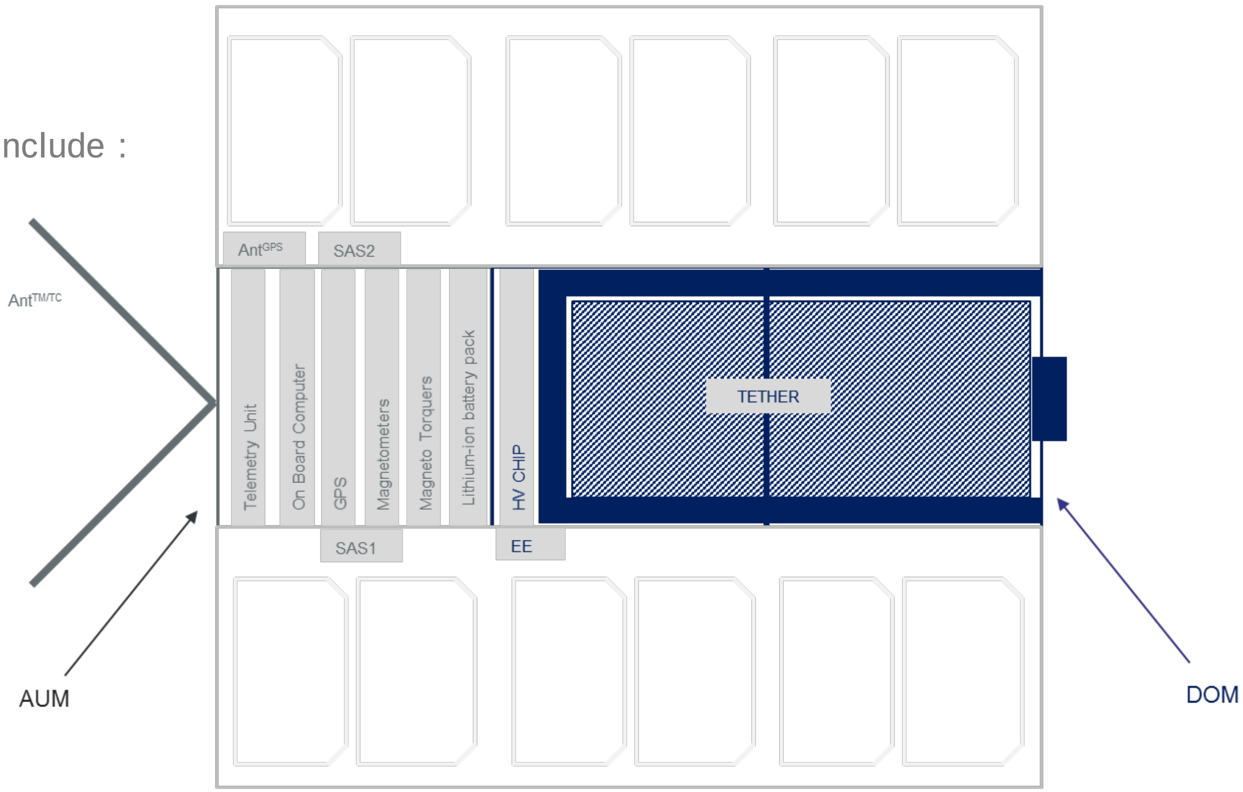
4. EDT KIT - Cubesat based Design

The 2U Deorbiting Module (DOM) will include:

- Tether
- Tether deployment mechanism
- HV Chip
- Electron Emitter
- Power and data interfaces

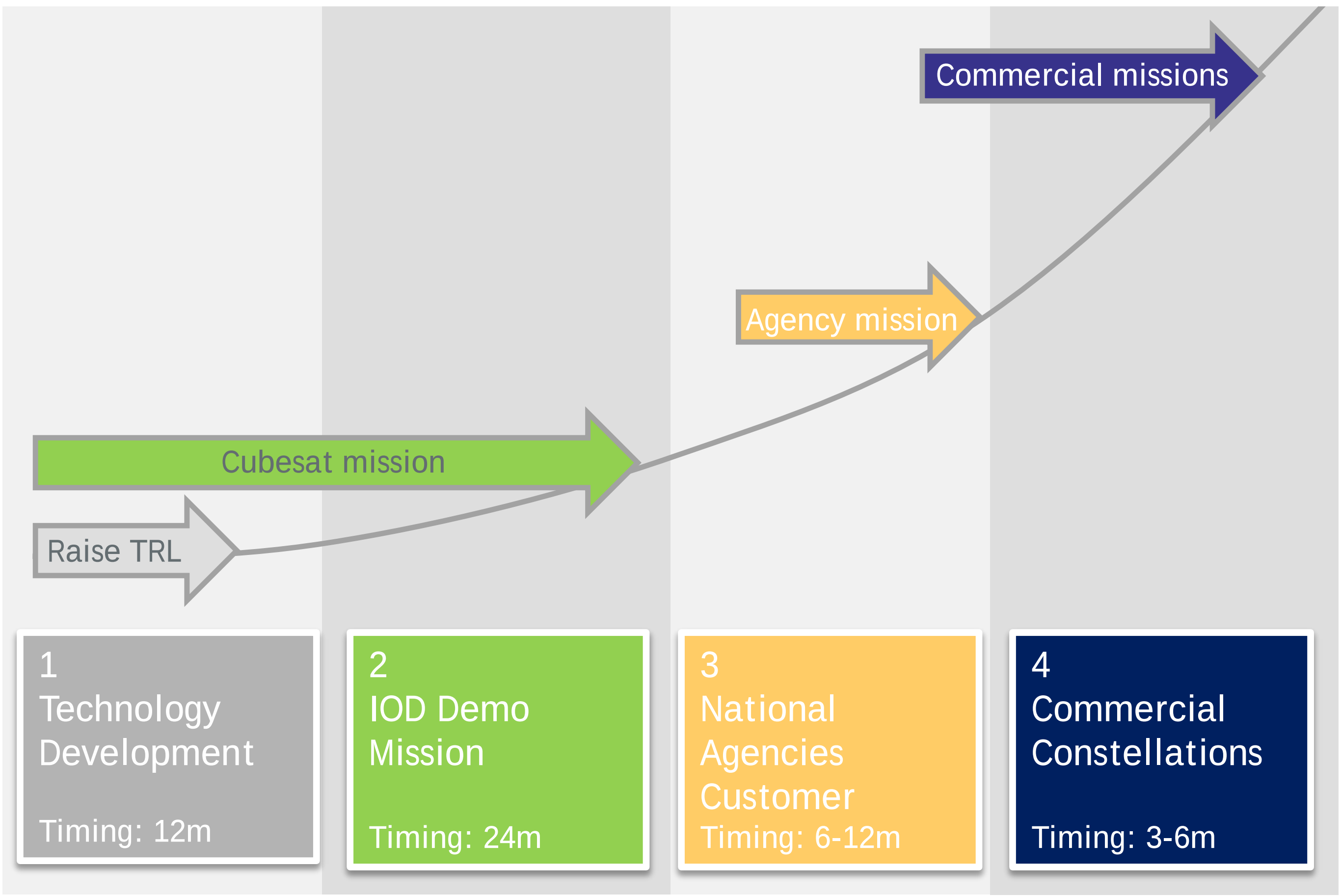
The 1U Autonomy Module (AUM) will include :

- Antennas
  - Deployable TM/TC antenna
  - GPS pacth antenna
- Telemetry board
- On Board computer
- Sensors
  - GPS,
  - 2x Sun Sensors
  - 3-axis Magnetometer
- Magneto torquers
- Battery pack
- Solar panels



5. Roadmap and preliminary programmatic

EDT-KIT roadmap phases



6. Conclusions

- Small satellite launch forecast indicates that 900+ satellites will be launched in the next decade. Most of them in high orbit >800 km
- There is a need for a light de-orbit kit to maintain LEO environment clean reducing de-orbit time.
- EDT is a very promising de-orbit technology.
- EDT KIT is currently being developed by a consortium led by SENER.
- Consortium partners controls all critical technologies.
- First EDT KIT version can fit a 3U cubesat and is targeted to deorbit 50kg satellites.
- EDT KIT evolution will be able to de-orbit larger satellites.
- EDT-KIT will reduce the de-orbit time simplifying satellite design for passivation and EOL operations.

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