A03

Preventive Measure to Mitigate Debris by Using ElectroDynamic Tether System for Space Debris Prevention, Considering Sustainable Space Development

スペースデブリ発生防止用導電性テザーシステムを用いた、持続可能な宇宙開発を踏まえた予防的デブリ除去の取組み

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While the space industry is drastically expanding, there are not yet enough measures to maintain the environment on orbit which are critical to the industry. If we do not adequately address the disposals of space debris after missions, which may harm the future project, these debris could prevent the industry from developing properly. ALE and Japan Aerospace Exploration Agency (JAXA), as a part of the JAXA Space Innovation through Partnership and Co-creation (J-SPARC) project, are developing a PMD device using an Electrodynamic tether (EDT) to demonstrate the deorbit of satellites. In this project, we are planning to launch a satellite equipped with a PMD device. There are two approaches to mitigate space debris; ADR (dealing with space debris once after the mission of spacecrafts has ended, Active Debris Removal) and PMD (preventing spacecrafts from becoming space debris beforehand, Post Mission Disposal). Our developed EDT is categorized in PMD and able to significantly reduce the time required for the satellite to reenter the atmosphere. It can be utilized as a countermeasure for the prevention of space debris. This paper provides the impact of the developed PMD device for de-orbit and issues and current solutions about the coming mission.

宇宙産業が拡大する一方で、産業の基盤である軌道環境を維持・管理する活動は未だ途上である。ミッション後の宇宙機「スペースデブリ」の処理・破棄の履行が不徹底なまために将来の開発に悪影響が生じた場合、産業全体のボトルネックとなることが懸念される。ALE と JAXA では導電性テザー(EDT:Electrodynamic Tether)を用いた PMD デバイスによる軌道離脱の技術実証を目的とした事業協同実証(J-SPARC)を行っており、足元での当該技術の実証を計画している。当 EDT は、宇宙デブリに対処するアプローチである ADR（別機による事後的な処理）と PMD（自機へのデバイス搭載等による予防的な処理）のうち後者に属するものであり、軌道降下時間を大幅に短縮することが可能なため今後のスペースデブリ対策の一つとして効果的である。本講演では実証に向け開発を進める PMD デバイスの軌道降下への影響及びミッション実現に向けた課題とこの解決策についてこれまでの検討内容について紹介する。

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Company profile

Company name **ALE Co., Ltd**

Our Vision **Anchor space into our culture to empower humankind to new endeavors**

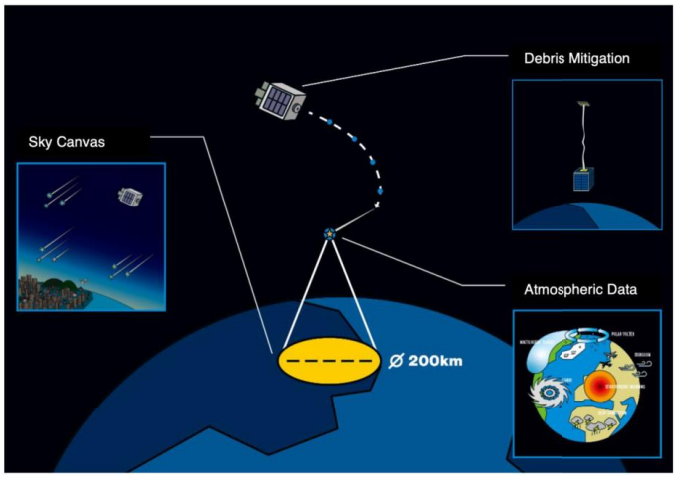
ALE aims to contribute to the sustainable development of humankind by expanding the area of human activity outside of Earth, to discover, collect, and apply the data mined from space.

Head office **Tokyo, Japan**

Founder & CEO **Dr. Lena Okajima**

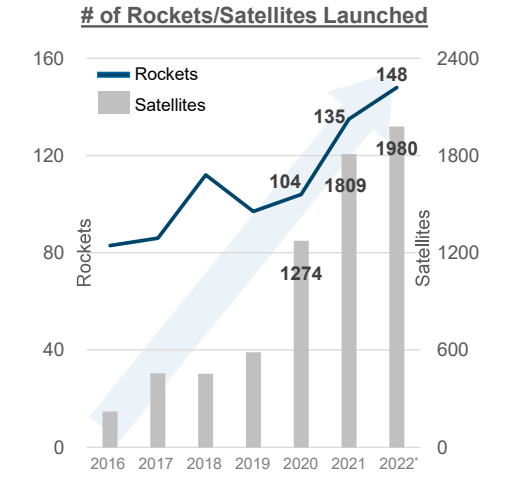
Employees **About 40**

Nature of business
- -Sky Canvas
- -Debris Mitigation
- -Atmospheric Data



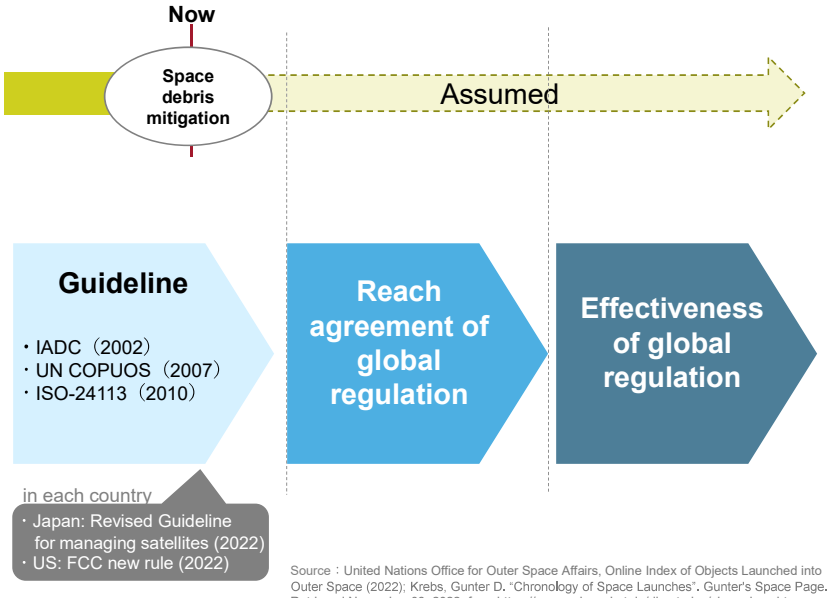
Global trends about space debris

Given the deterioration in orbit, regulation on space debris is about to be embodied.



- Deterioration of orbital environment
- Discussion about strict regulation

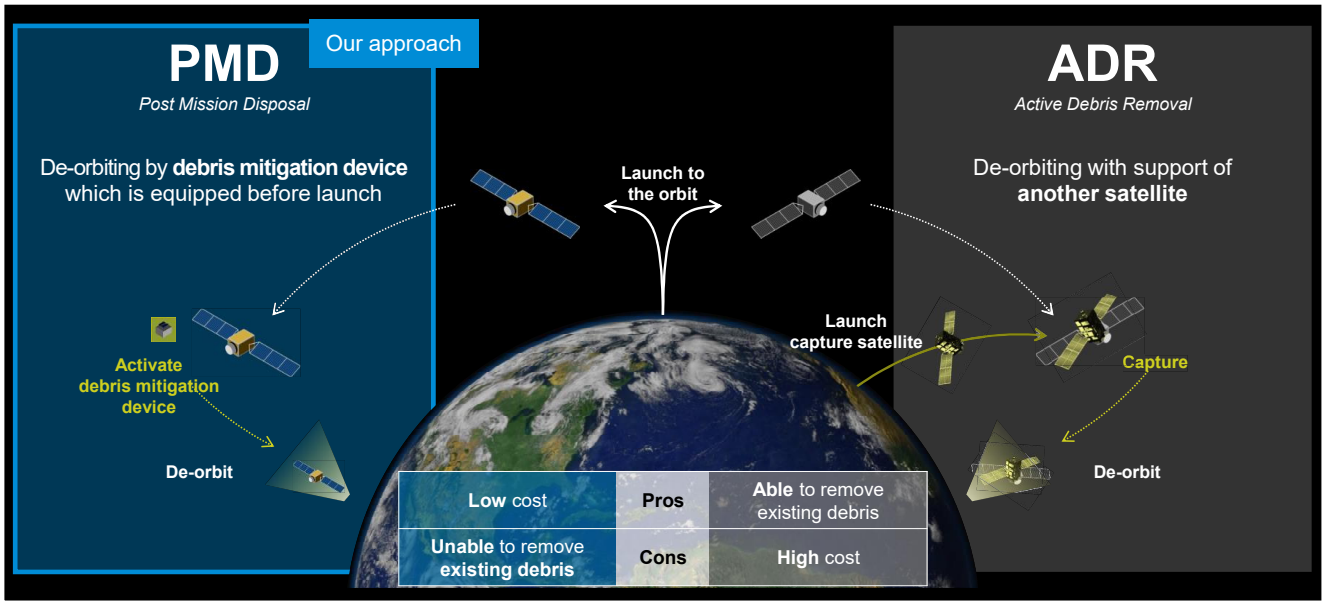
* As of November, 2022



Source：United Nations Office for Outer Space Affairs, Online Index of Objects Launched into Outer Space (2022); Krebs, Gunter D. 'Chronology of Space Launches'. Gunter's Space Page. Retrieved November 06, 2022, from https://space.skyrocket.de/directories/chronology.htm

Approaches to mitigate space debris

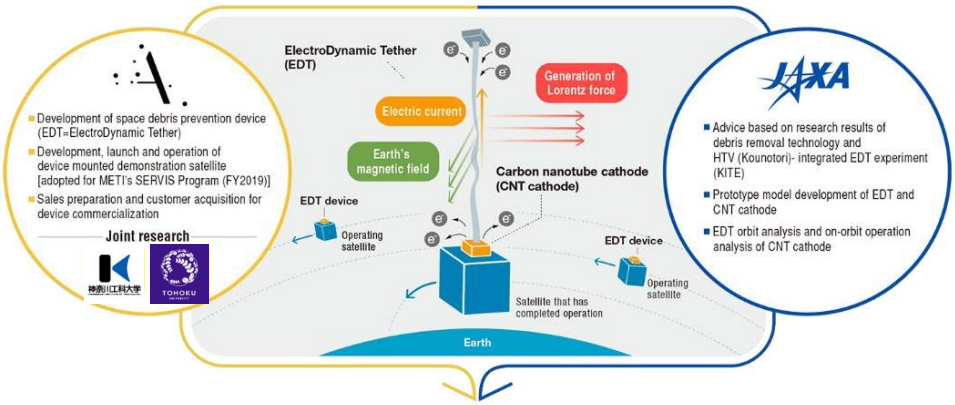
Human-kind needs both of PMD and ADR since they have each Pros-Cons.



Collaboration with JAXA

Maximizing the probability of success on first on-orbit demonstration through collaboration with JAXA, which has knowledge and technique of EDT.

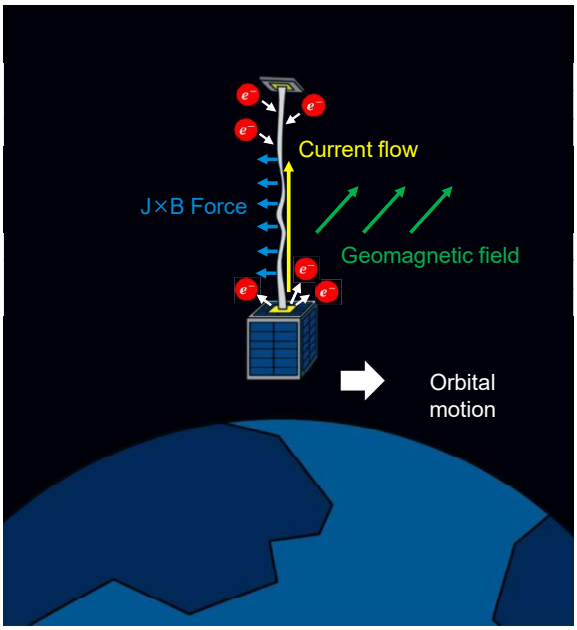
The project members are collaborating with us, and we will utilize their knowledge and experience to further enhance the technology.



Extend conductive tether from EDT device mounted on microsatellite and de-orbit.
Mitigate the generation of space debris thereby contributing to sustainable space development.

EDT De-orbit Mechanism (1/2)

EDT accelerates spacecrafts' deorbiting by two drags.



The bare tether utilize interactions with space environment to accelerate the de-orbit of spacecraft through **atmospheric drag** and **electromagnetic force**.

Mechanism of electromagnetic drag

1. During the conductive tether orbiting, it across the geomagnetic field and electromotive force on the bare tether is generated.
2. The biased tether attract electrons from ambient plasma. Then, current flows in the tether.
3. Due to the interaction between the current and the geomagnetic field, Lorentz (electromagnetic) force is induced to opposite direction of orbital motion.

* Electron emitter increases the current and Lorentz force can be enhanced.
* Compared with another PMD device, such as Dragsail, EDT works well in the high altitude because of Lorentz (electromagnetic) force.

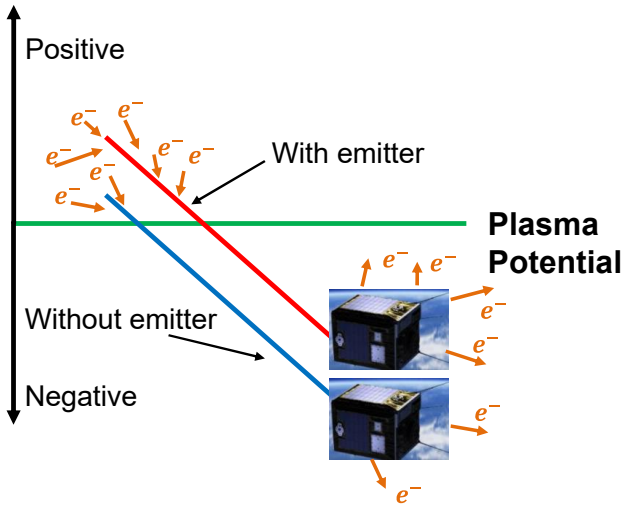
EDT De-orbit Mechanism (2/2)

Electron emitter

- Apparatus for emitting electrons into space.
- Installed on the end of the tether where the potential is negative.

More electrons can be collected from the tether surface, thereby increasing the current flowing.

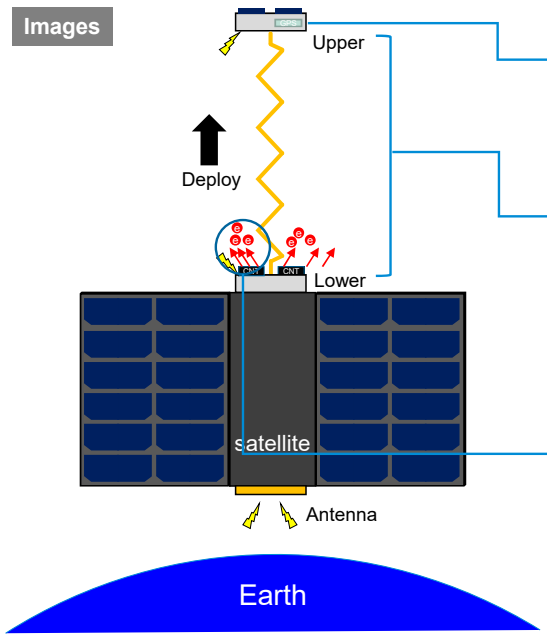
- ✓ Can shorten the time required for deorbiting.
- ✓ Reduce the risk of debris collision during PMD device operation.
- ✓ Collision avoidance maneuver may be possible.



Advantages of EDT

Even if main spacecrafts break down, EDT can independently work securely as a back-up.

Images



1. Lightness of Tether

Deploying light tether suggests **a bigger projected area** rather than other existing structures, utilizing **stronger atmospheric drag.**

2. Gravity Gradient

Gravity gradient from an altitude difference works at both ends of tether and **keeps tether fully extended between the center of the earth and the zenith**. As a result, tether will utilize stable aerodynamic drag on the running direction. The system passively works and **does not need an attitude control.**

3. Current Flows

With the fully extended position, electric current flows in the tether from induced electromotive force and cosmic plasma, which system **works as a break force** to the spacecrafts. Installing Field Emission Cathodes (**FECs**) **on both sides of EDT**, we can **enforce the force** and does not need to care positions of a parent and a child mass.

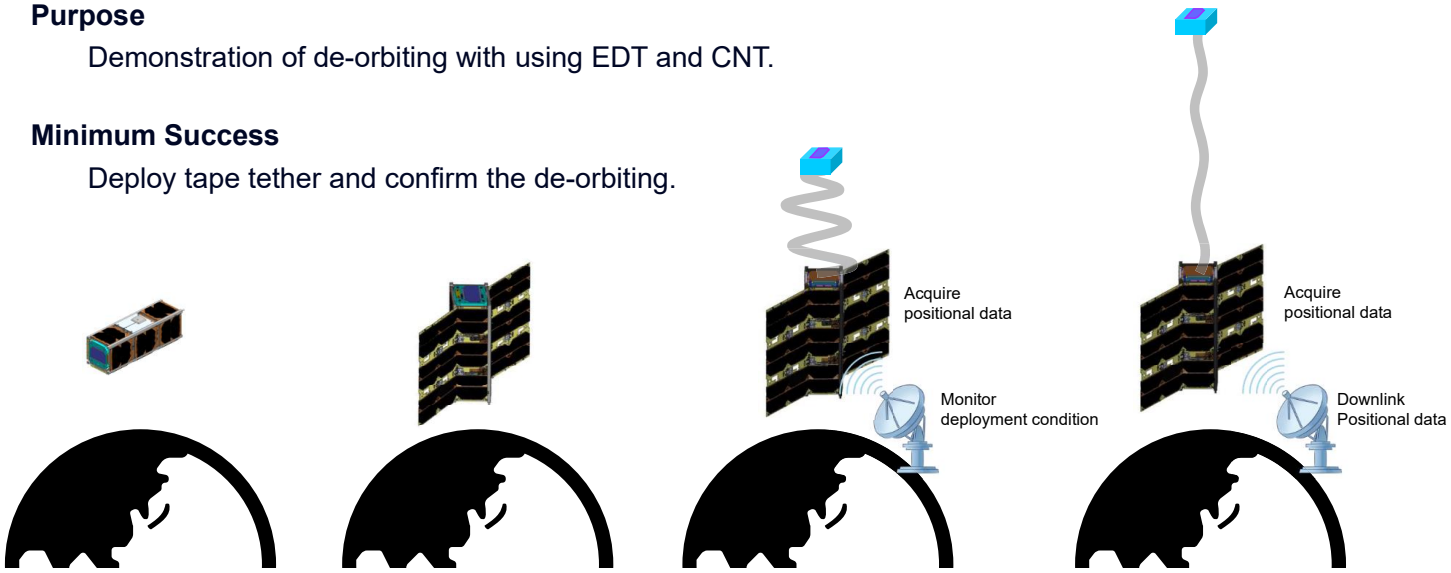
EDT-sat Project

Purpose

Demonstration of de-orbiting with using EDT and CNT.

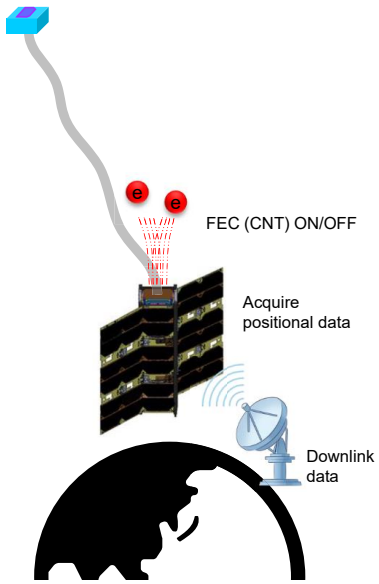
Minimum Success

Deploy tape tether and confirm the de-orbiting.



0: Earth orbit 1: Attitude control 2: Start to deploy tether 3: Complete tether deployment

EDT-sat Project



Full Success

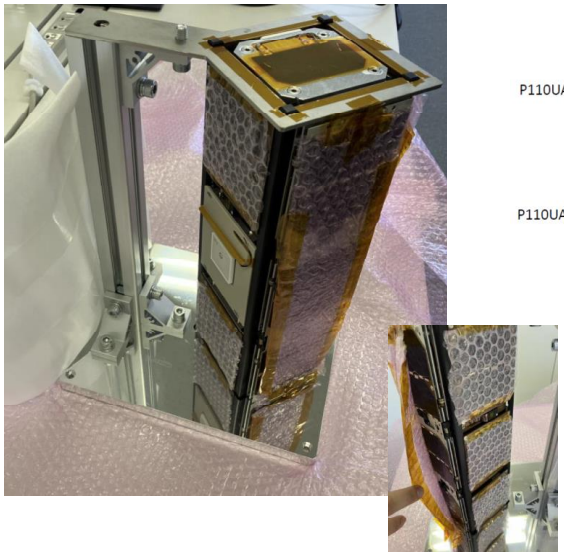
Confirm the change of de-orbiting performance by ON/OFF of CNT electron emitter.

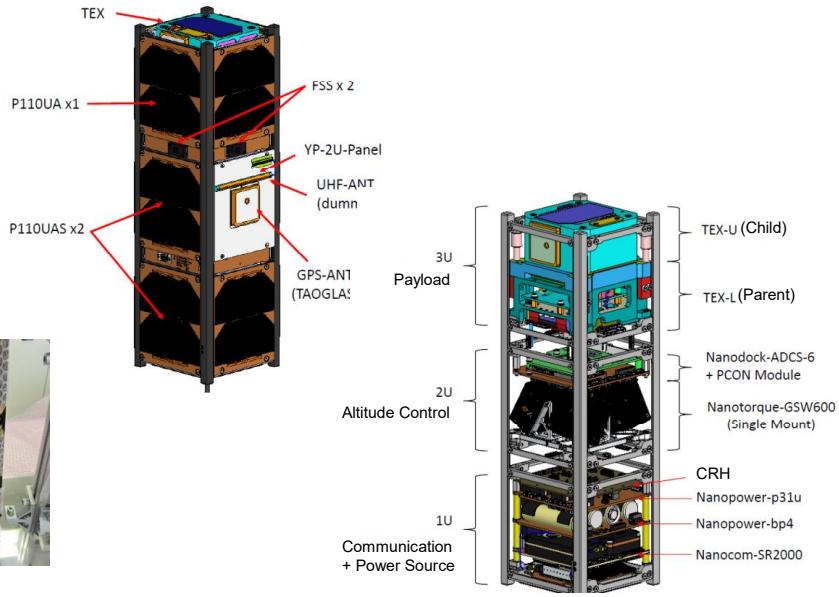
Extra Success

Measure the tether position and confirm the effect of Lorentz force.

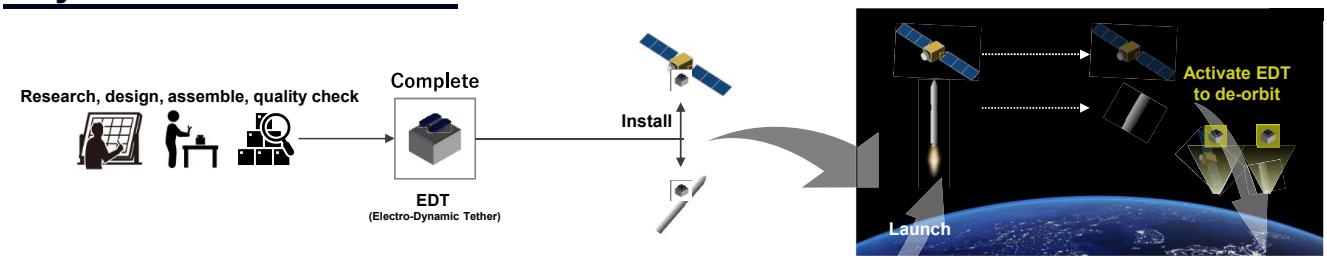
Development of EDTsat

We have almost completed FM of EDTsat, waiting for an adequate launch opportunity.

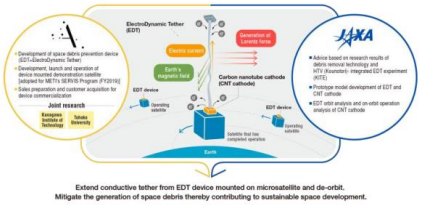




Key Features of EDT



R&D + Manufacturing	BEFORE launching	After launching
High reliability	**High efficiency**	**Low burden**
✓ **Collaboration with Japan Aerospace Exploration Agency, JAXA** in the joint demonstration	✓ **Quite small and light device** for de-orbiting to spacecrafts ✓ **Minimum interfaces** needed ✓ **No other satellite** required for de-orbiting	✓ **No additional operations** needed from ground ✓ **Secured redundant design** installed ✓ **Telecommunication** may be available, if needed ✓ **Works securely as a back-up** even if the main spacecrafts break down



Key Notes

Broad and practical acknowledgement of space debris are needed.

The problem of space debris…

- Imposes **a comprehensive topic** not only on space industry but also on humankind
- Shows **a long-term issue** that we need to continuously empower practical activities
- Needs **practical approaches for "not increasing"** (which is NOT "decreasing")

Acknowledgment

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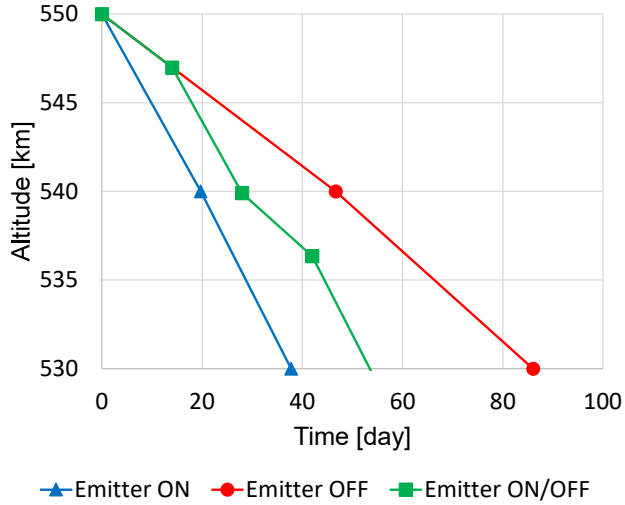
- Demonstration of EDT-sat is partly funded by Space Environment Reliability Verification Integrated System (SERVIS) project.

Appendix: Case Study



※ OML available ratio: about 50%
※ The solar activity was assumed to minimal.
※ FEC(CNT) ON/OFF：
The case of assuming electron emitter was turned on/off every two weeks.

In this case, clearly, orbital descent ratio is differed between with and without an electron emitter.

The effect of EDT can be confirmed by orbital descent ratio.

- The performance obtained varies depending on the tether dimensions, orbital parameters, and other factors.
- By making such evaluations, the specifications of the tether and electron emitter can be determined for such electrodynamic tether requirements as orbital conditions, weight, and deorbit time.

ALE Co., Ltd.