#### 超小型衛星用の膜展開式軌道離脱装置 DOM の開発と宇宙実証 Development and Orbit Verification of De-Orbit Mechanism (DOM) for Microsatellites

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近年,超小型衛星による宇宙利用が増加している一方で,スペースデブリの低減のため運用が終了した衛星に ついては速やかに軌道離脱することが重要になってきている.そうした状況を受けて,2010年以来,東北大学と 中島田鉄工所は超小型衛星用の膜展開式軌道離脱装置 De-Orbit Mechanism (DOM)を開発してきた.DOM は地上であらかじめ衛星に取り付けられ,衛星とともに打ち上げられる装置である.衛星の運用が終了する際に 内部に搭載した薄膜を展開し,地球近傍の宇宙空間にわずかに存在する大気抵抗を増大させることにより,超 小型衛星を地球大気圏に再突入させる.2017年には1ユニットサイズの CubeSat, FREEDOM を用いて DOM の宇宙実証を行った.宇宙実証を通して DOM の動作と軌道離脱性能を確認できたことから,開発者らは, DOM に関する技術が実利用可能なレベルに到達したと判断している.発表では,DOM の動作原理,仕様を紹 介するとともに,FREEDOM を用いて実施した宇宙実証の結果について述べる.

In recent years, space utilization by microsatellites has been worldwide increasing. On the other hand, it is becoming important to remove a satellite from orbit after its operation phase is terminated. To tackle this situation, Tohoku University and Nakashimada Engineering Works, Ltd. developed De-Orbit Mechanism (DOM) for microsatellites. DOM is a device which is installed onto a satellite on the ground and then is launched together with the satellite. When the operation of the satellite is finished, a thin film stored in DOM is deployed and the satellite will re-enter the Earth atmosphere because of the atmospheric drag which extremely slightly exists in Low Earth Orbit and is increased by the film. In 2017, an orbit verification of DOM was carried out using "FREEDOM" which is a 1 unit size CubeSat. The development team evaluates that the technologies on DOM have reached a practical level because both the activation and the performance of DOM were confirmed through the orbit verification. This presentation includes the principle of motion of DOM, the specification, and the orbit verification results conducted by FREEDOM.



DOM の外観(左:打ち上げ時,右:展開時)

## 超小型衛星用の膜展開式軌道離脱装置 DOMの開発と宇宙実証

Development and Orbit Verification of De-Orbit Mechanism (DOM) for Microsatellites

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8<sup>th</sup> Space Debris Workshop



- Background
- De-Orbit Mechanism "DOM"
- Orbit verification of DOM
- Future outlook
- Conclusion



Appearance of DOM

This document is provided by JAXA.

## Background

- In recent years, space utilization by microsatellites has been worldwide increasing.
- On the other hand, it is becoming important to remove a satellite from orbit after its operation phase is closed.
- An international agreement is that a satellite in Low Earth Orbit should de-orbit in 25 years.



Image of space debris around Earth

## De-Orbit Mechanism "DOM"

 Tohoku University and Nakashimada Engineering Works, Ltd. have been developing De-orbit Mechanism (DOM) since 2010.



Launch configuration



Deployed configuration Appearance of DOM

4

3



## Motion principle of DOM

2. Joule heat cuts wires made of polyethylene.



- 1. Electric voltage of 5 V is supplied.



4. Convex tapes extend and film is deployed.

3. Coil spring ejects convex tapes and thin film.

## **Deployment action of DOM**



Serial photographs of deployment action of DOM

## **DOMs of various sizes**

 DOMs with various film sizes were developed for various satellite masses and initial altitudes.



#### DOM500

- Dimensions  $\phi$  80×50 mm
- Film size 500×500 mm
- Mass 250 g



#### DOM1500

- Film size 1500×1500 mm
- Mass 1000 g



#### DOM2500

- Film size
   2500×2500 mm
- Mass 1600 g

8

7

## Installation image of DOM



DOM500 installed onto a CubeSat



DOM2500 installed onto a 50 kg class satellite





DOM1500 installed onto a 50 kg class satellite

9

## Satellites where DOMs were installed



#### CubeSat RAIKO

- DOM500
- Released in 2012
- RISING-2
  DOM1500
  Launched in 2014

Photographs are provided by Tohoku University

#### RISESAT

- DOM2500
- Scheduled to be Launched

\*There are the other two satellites where DOMs were installed.

## **CubeSat FREEDOM**

- FREEDOM is a 1 unit size CubeSat.
- Its only mission is an orbit verification of DOM.
- FREEDOM was released into orbit from Japan Experimental Module "Kibo" in 2017.



Launch configuration



Deployed configuration

Appearance of FREEDOM

11

## **Orbit verification of DOM by FREEDOM**



**Mission of FREEDOM** 

12

## How to operate FREEDOM

- How to obtain orbital information
  - Joint Space Operations Center (JSpOC) puts orbital information on a website "Space-Track".
  - The orbital information is provided in the format of Two-Line Element set (TLE).
- How to evaluate the performance of DOM
  - Orbit altitude of the satellite was calculated from TLE.
  - Numerical simulations on orbital transition were run.
  - Both of them were compared in order to evaluated the deorbiting capability of DOM.

## **Comparison of TLEs with simulations**

- TLEs agree with case of "B" at altitudes above 350 km very well.
- The difference between TLEs and the case of "B" appears below 350 km.

Numerical simulation results of orbit of FREEDOM



- FREEDOM TLE
- A Simulation (S =  $1.25 \text{ m}^2$ )
- B Simulation (S = 0.64 m<sup>2</sup>) The case in which the film ideally deploys and functions averagely
- C Simulation (S =  $0.33 \text{ m}^2$ )
- S: Cross-sectional area of satellite

# Evaluation of de-orbiting capability of DOM

- Above 350 km, TLEs agree with the case in which the film ideally deploys and functions averagely.
  - The film was fully deployed.
  - FREEDOM was freely rotating relative to the velocity vector.



Fully deployed and free rotating FREEDOM

- Below 350 km, satellites de-orbit very rapidly due to the dense atmosphere.
  - DOM has successfully demonstrated its capability of deorbiting LEO (Low Earth Orbit) satellites.

#### 15

## **Future outlook**

- Practical use of DOM
  - The technologies on DOM have reached a practical level.
  - DOM is expected to be used as a de-orbit device for various microsatellites.



Installation image of DOM

### Upgrade of function and capability

- Reduction in weight, upsizing of film, and film deployment devices for other purposes are being addressed.

## Conclusion

- De-orbit Mechanism (DOM) is a device which deploys a film and makes a microsatellite de-orbit.
- In 2017, an orbit verification of DOM was carried out using "FREEDOM" which is a 1 unit size CubeSat.
- DOM has the capability of de-orbiting LEO (Low Earth Orbit) microsatellites according to the results of the orbit verification.
  Numerical simulation results of orbit of FREEDOM







Pictures representing this presentation

## Thank you very much.