P11

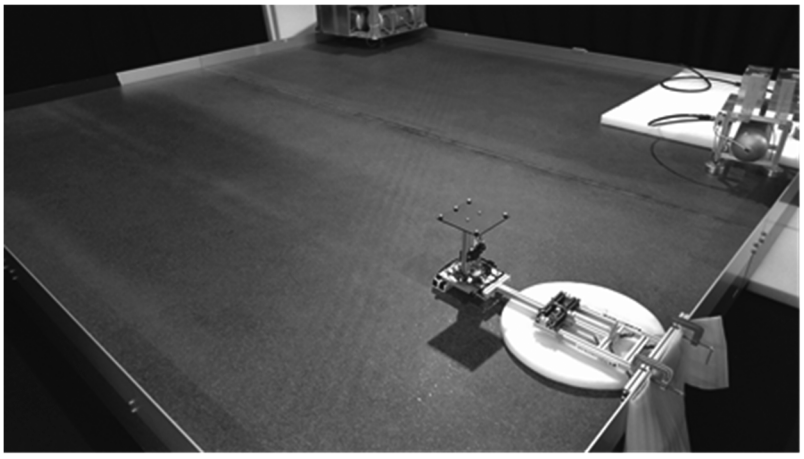
# テープテザー展開機構の分離展開に関する実験的研究

## Experimental Study on Separation of Tape Tether Deployment Module for PMD

坂元洋輝, 荒井賢人, 梅津賢太, 藤田崇司, 佐藤強, 渡部武夫（KAIT）,
河本聡美（JAXA）, 蒲池康, 及川祐, 岡島礼奈（ALE）
Hiroki Sakamoto, Kento Arai, Kenta Umetsu, Takashi Fujita, Tsuyoshi Sato,
Takeo Watanabe (KAIT), Satomi Kawamoto (JAXA), Koh Kamachi,
Yu Oikawa and Lena Okajima (ALE)

大気抵抗と導電テザー推進によるローレンツ力を併用した超小型衛星用の PMD（Post Mission Disposal）デバイスとして、折りたたみ型再突入支援テザー展開モジュールの開発を進めている。
このデバイスは、母衛星のミッション終了後にエンドマスを分離放出し、折りたたまれた導電テープテザーを展開、軌道離脱の支援を行う。その分離展開機構として、エンドマスを保持するクランプを金属ワイヤーで拘束した状態から、ピンプラーを用いて解放する機構を有する。
現在、分離機構 BBM（Bread Board Model ）等の開発・試作を進めており、JAXA の保有する、石定盤と空気浮上装置から構成される二次元微小重力模擬実験システムを用いた分離展開試験を計画している。本発表では、分離展開試験の速報を紹介する。

The authors are study on post mission disposal (PMD) device for microsatellites using electrodynamic tether (EDT). This PMD device includes tether deployment system (FORTE: FOldaway Re-entry assist TEther deployment module). A PMD device with electrodynamic tether is expected to have high deorbiting performance even in high orbit by using both the Lorentz force and atmospheric drag. After the main satellite's mission, the folded bare tape tether is stretched by releasing an end mass. This deployment system has clamps and metal wire which holds end mass, and is released by pin-pullers.
We are planning deployment test on a two-dimensional micro-gravity using a breadboard model (BBM) of deployment system.
This presentation introduces the updates on the deployment tests.



# Experimental Study on Separation of Tape Tether Deployment Module for PMD

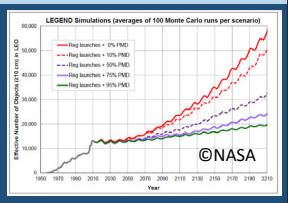
Hiroki Sakamoto, Kento Arai, Kenta Umetsu, Takashi Fujita,
Tsuyoshi Sato, Takeo Watanabe (KAIT)
Satomi Kawamoto (JAXA)
Koh Kamachi, Yu Oikawa and Lena Okajima (ALE)

## 1. Background

The growth of Micro-satellite Business and Concept of Micro-satellite Mega Constellation plan

Concern about mass production of space debris from the post mission satellites

The needs for development of Space Debris prevention (PMD) technology




Space Debris increases on LEO.
Space Environmental Problem

## 2. PMD Device "FORTE" Concept Overview

**FORTE フォルテ**
Foldaway Re-entry assist Tether deployment module

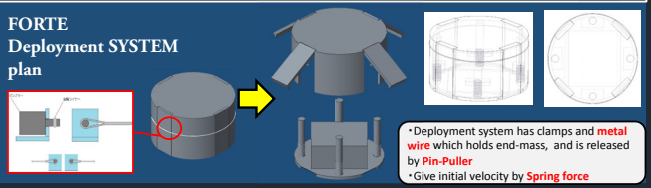
- Supports re-entry of satellites by Atmospheric drag and Electrodynamic Tether propulsion (Lorentz force)
- Post Mission Disposal (PMD) Device

① Install "FORTE" at pre launch

②After the mission, release an end-mass and deploy the tape tether

③Deorbit


FORTE Deployment SYSTEM plan



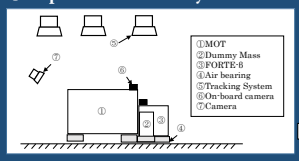
- Deployment system has clamps and metal wire which holds end-mass, and is released by Pin-Puller
- Give initial velocity by Spring force

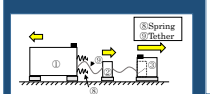
## 3. Purpose of "Ground Experiment"

- To confirm the effectiveness of the Wire Pin-Puller type development system
- BBM test in the two-dimensional micro gravity experiment system

## 4. Experimental Setup

**O Experiment devices layout**



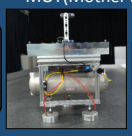

Device layout from the horizontal direction


Device layout from the y direction

- Micro Gravity Simulate System

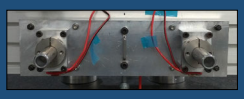
- Two-dimensional micro gravity by Air bearings and Precision stone surface plate
- Tracking system
Resolutions: 0.424 mm, 120Hz

- MOT(Mother Satellite Model)

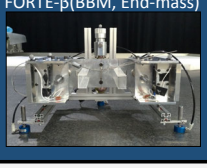


- Size: 450 × 300 × 250[mm]
- Weight: 50[kg]

- FORTE-α (BBM, MOT side)



FORTE-β(BBM, End-mass)



- Tape Tether (ALPET)

- FORTE-α and FORTE-β are held by a pair of clamps
- Clamp fixed with metal wire
- The metal wire is held with two Pin-Pullers
（In this experiment, we used solenoids.）
- When the pin plug is activated, the wire loosens, the fixation of the clamp is released, and the springs push and release FORTE-β
- It is a device of double redundancy

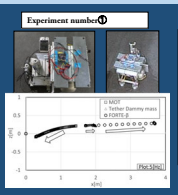
| Experiment Number | ① | ② | ③ | ④ | ⑤ | ⑥ | ⑦ |
|---|---|---|---|---|---|---|---|
| Tether length | 2[m]×2 | 2[m]×2 | None | None | 1[m]×1 | 1[m]×1 | 1[m]×1 |

## 5. Experimental Conditions

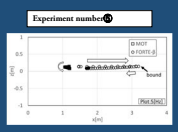
| Initial Speed | 1.0[m/s] | | | |
|---|---|---|---|---|
| Tether Dummy mass | Include | Not Include | | |
| Tether | Include | Not Include | Include(Short) | Include(Short/With Damper) |
| ①Two side of the Pin-Puller | ①～② | | ⑤ | ⑥～⑦ |
| ②One side of the Pin-Puller | | ③～④ | | |

- Weight ratio of MOT, Dummy Mass, FORTE-β was fixed at 50: 2: 4
- The initial speed of deployment :1.0 m/s (The reference initial speed)
- Comparing their influence : Dummy Mass and Presence of tether, Bounding with short tether or brake device
- Make one side of the Pin-Puller inactive and check system redundancy

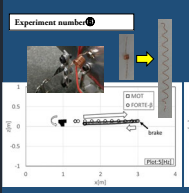
## 6. Experimental Results

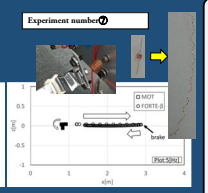



- The theoretical initial speed of MOT was 0.14[m/s], but the result was 0.06[m/s]
→ Possible causes: air resistance, friction, mechanical loss.
- Tether Dummy mass should be almost stationary, but in fact fine motion was shown
→ Possible causes: touch with FORTE-β, and tether tension
- The theoretical initial speed of FORTE-β was 0.86[m/s], and the result was 0.8[m/s] , as a separation rate approximate to the theory




- Bounced due to the elasticity of the tether at full-length deployment
- Risk of closing and collision to MOT with speed due to the tension at the bound
- Necessity of simple brake system




**Plastic Deformation Coil Brake**

- Coil type plastic deformation brakes were tested: length 300[mm], ϕ1.2and and ϕ0.9[mm] of copper wire
- At ϕ1.2[mm], the elastic range was wide, and it is considered that it entered the elastic region before absorbing kinetic energy sufficiently
- At ϕ0.9[mm], it is considered that the plastic deformation brake was completely extended, and it was not able to sufficiently absorb the kinetic energy

## 7. Conclusions

We demonstrated about the development behaviors of FORTE BBM as follows

1 Confirmation of redundancy of the Wire Pin-Puller type as a deployment system
2. Effect of short tether's bouncing on separation behavior of FORTE-β
3. Damping characteristics by plastic deformation coil brake

神奈川工科大学 KANAGAWA INSTITUTE OF TECHNOLOGY