Membrane Deployment Deorbit System by Convex Tapes

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Outline

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2. Basic design
3. Detail design
4. Concluding remarks

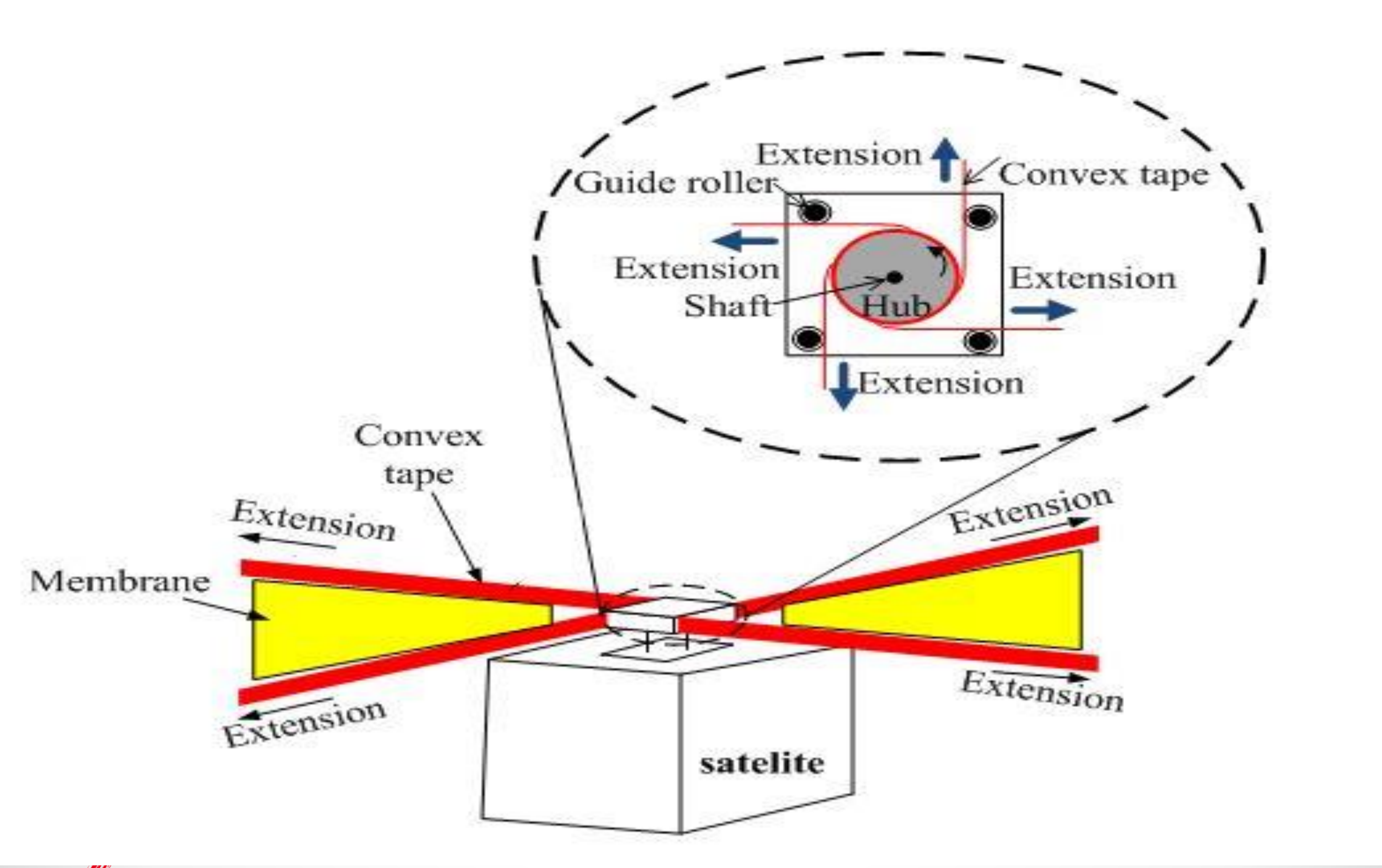
Requirements for Deorbit Device

1. Effectiveness
2. Mass and envelope at launch
3. Cost
4. Technical feasibility –Mechanical and electrical design
5. Impact on the satellite
6. Reliability
7. Safety
8. Maintenance before launch
9. User friendliness
10. Debris risk

Basic design

Basic design

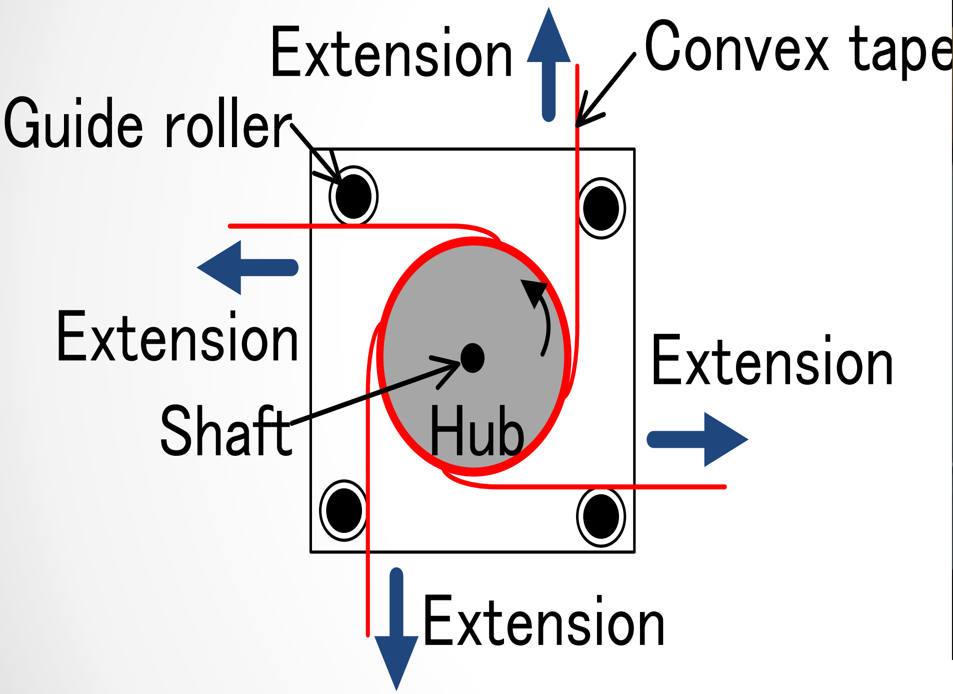
Basic design

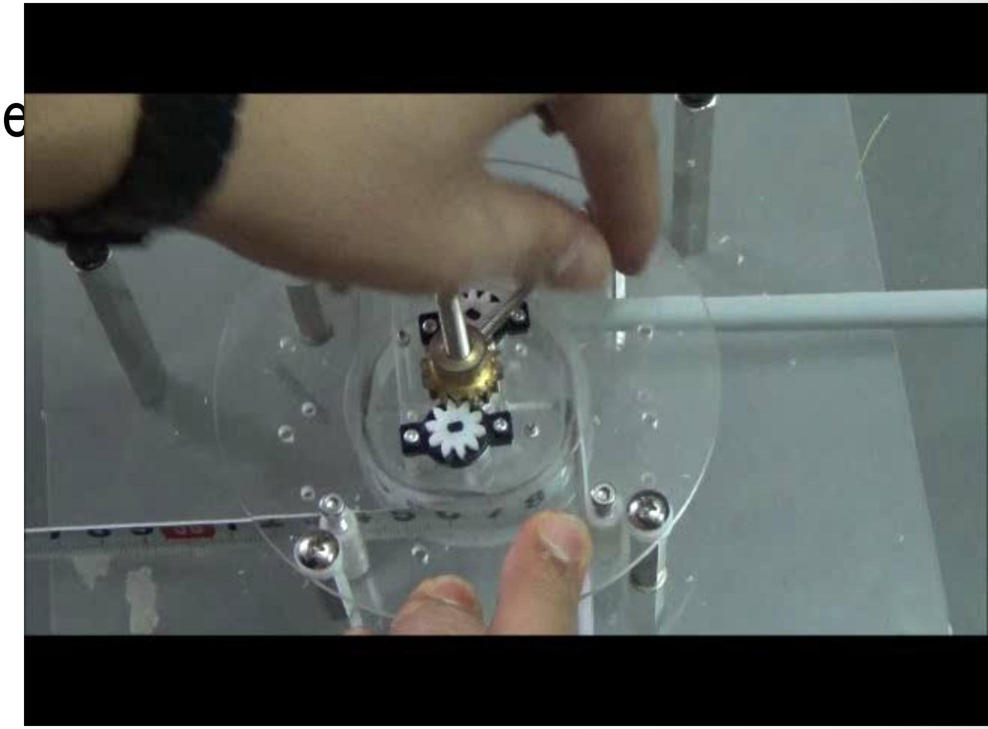


Simple model

Basic design

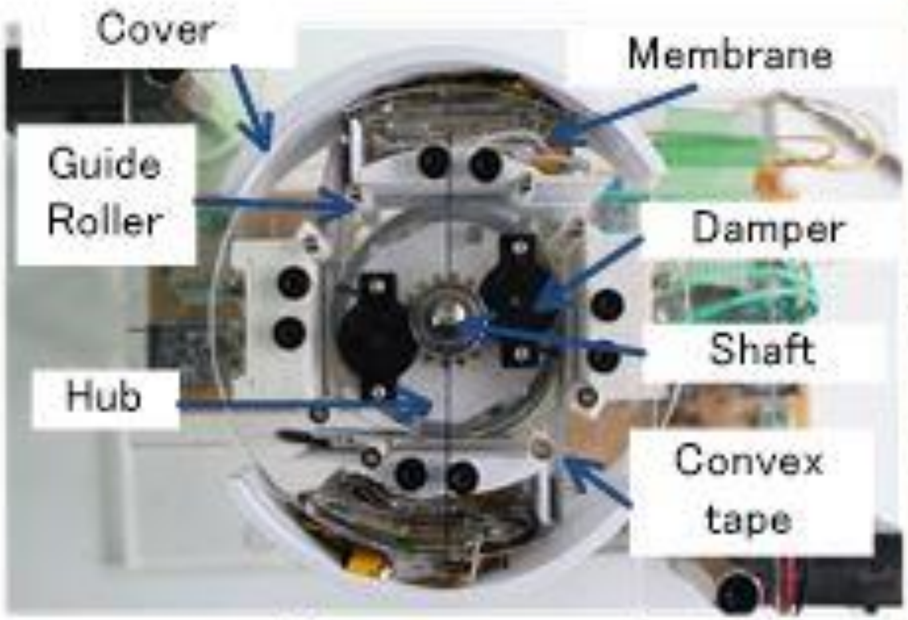
[Principal of deployment mechanism]



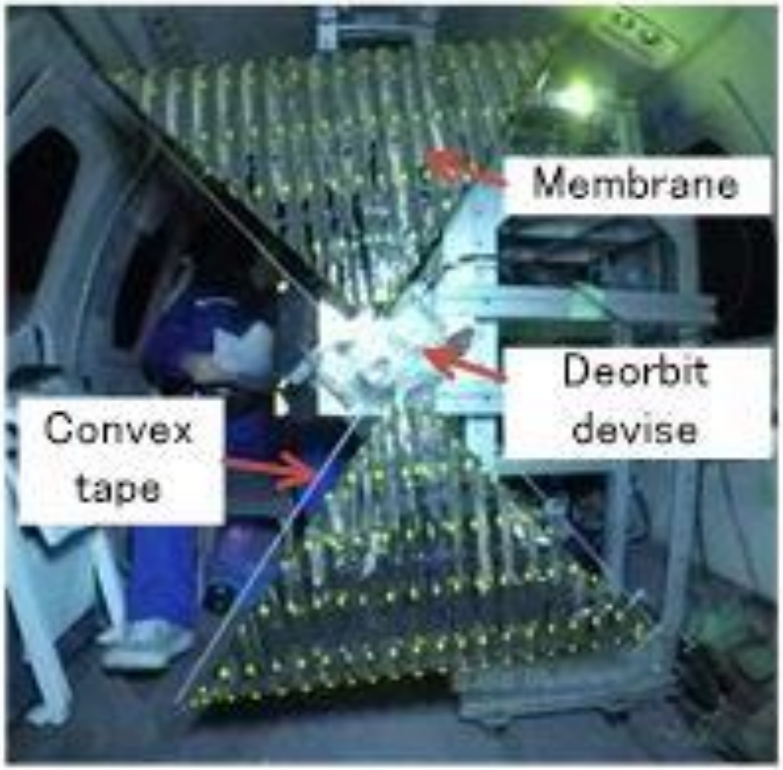


Basic design

[experiments under microgravity environment]



[Storage state]



[Deployed state]

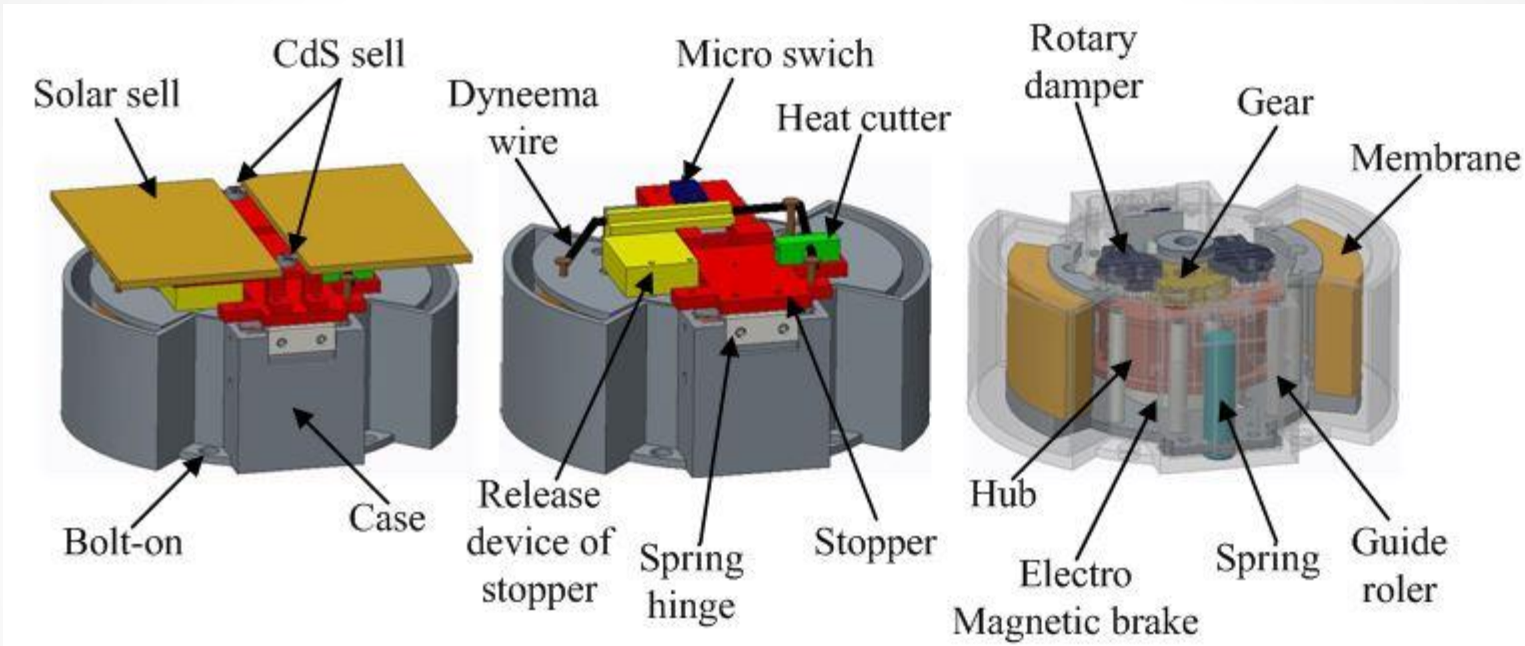
Basic design

[experiments under microgravity environment]

Detail design

Detail design

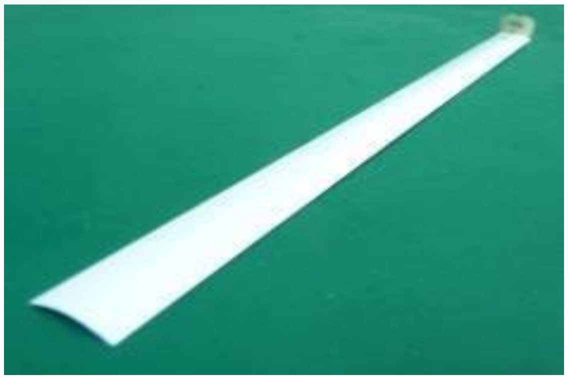
[Summary of proposed deorbit device]

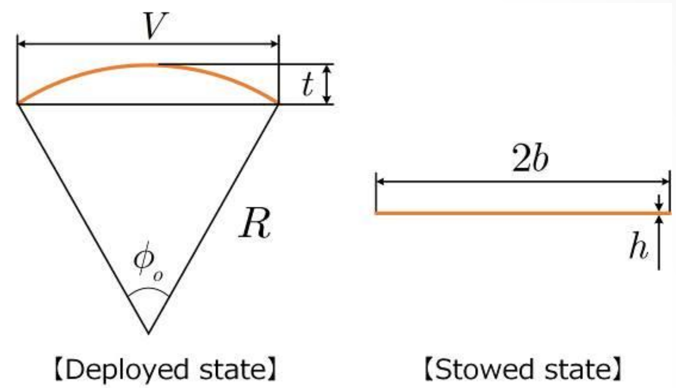


Width	90[mm]	Weight	0.246[kg]
depth	76[mm]	Membrane area	0.3[m]
height	46[mm]	Effective sectional area	0.0137[m]

Detail design

[Convex tape]

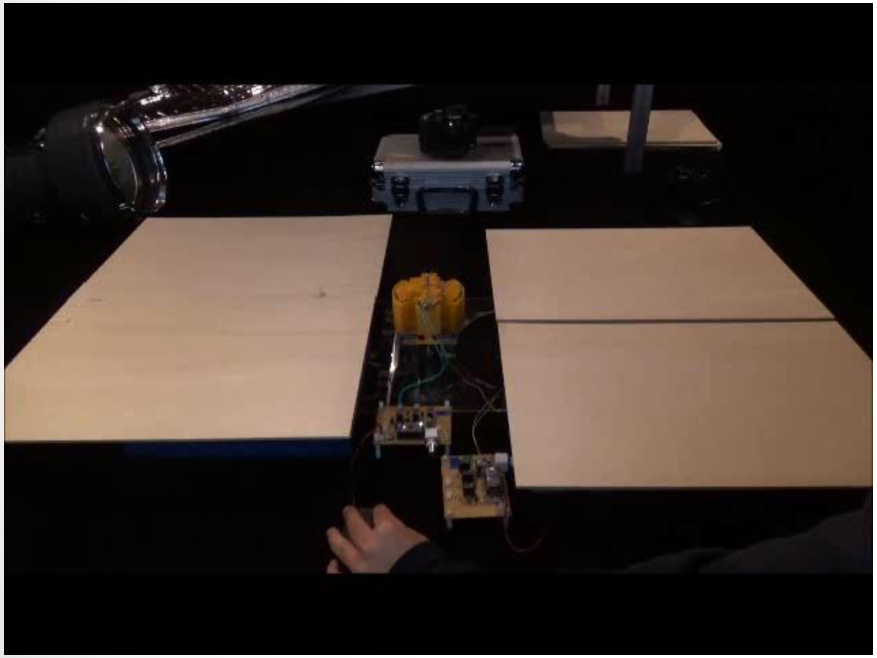




Length	L	590[mm]	Height in deployed state	t	1.4[mm]
Young's modulus	E	127[GPa]	Width in deployed state	V	11.8[mm]
Poisson's ratio	n	0.3	Arc-angle	f_o	52.2[rad]
Thickness	h	0.1[mm]	Radius of curvature	R	14.2[mm]
Half width	b	6.5[mm]			

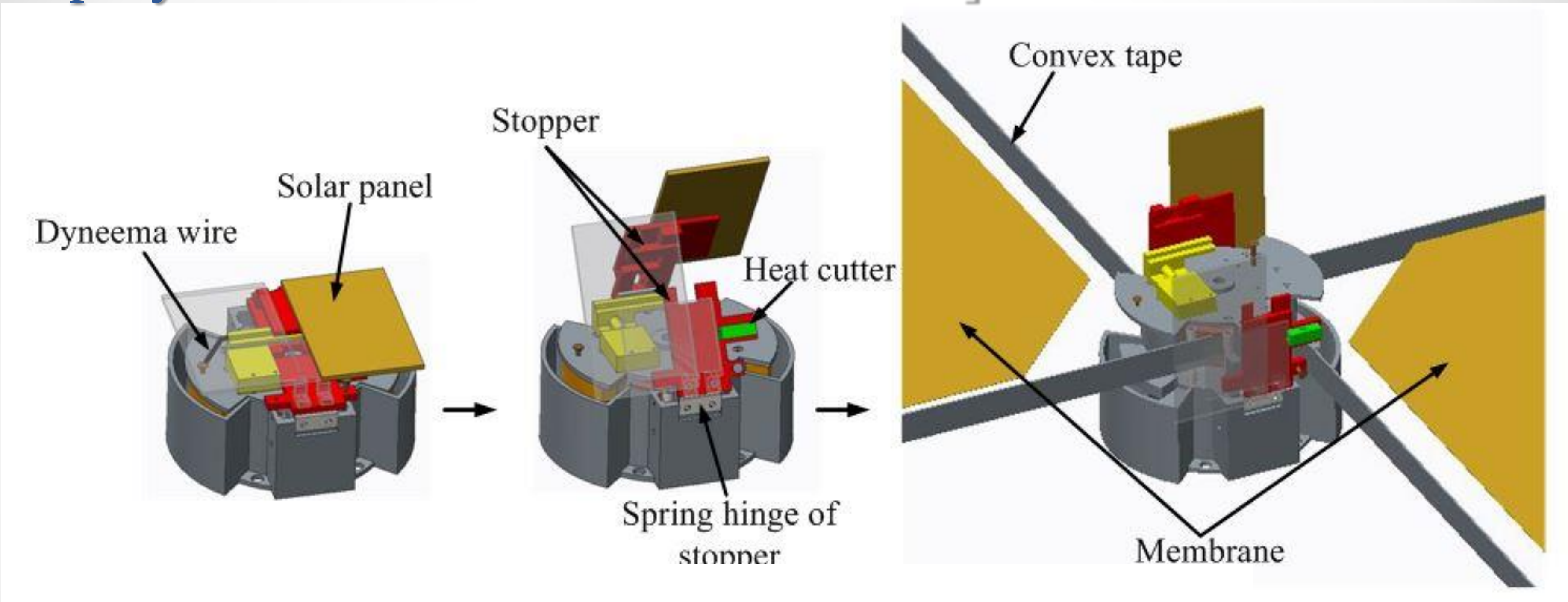
Detail design

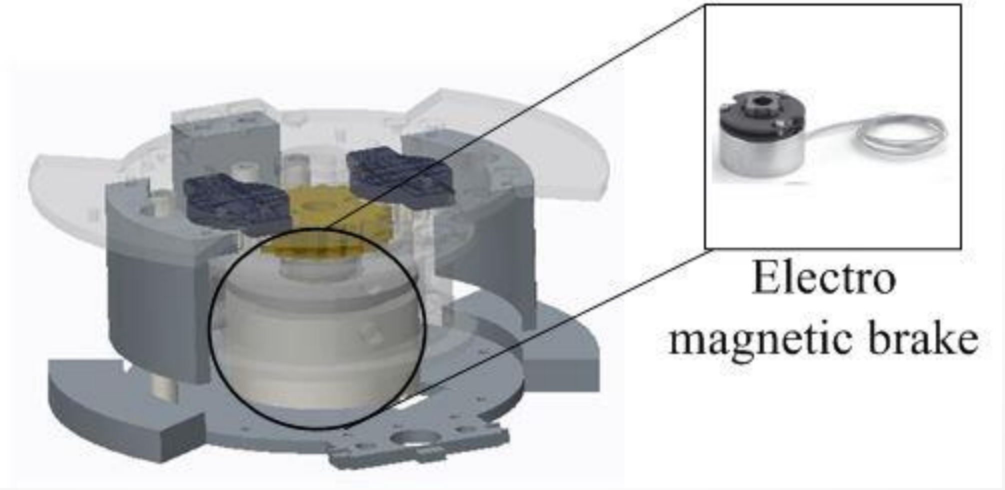
[Deployment mechanism of the device]



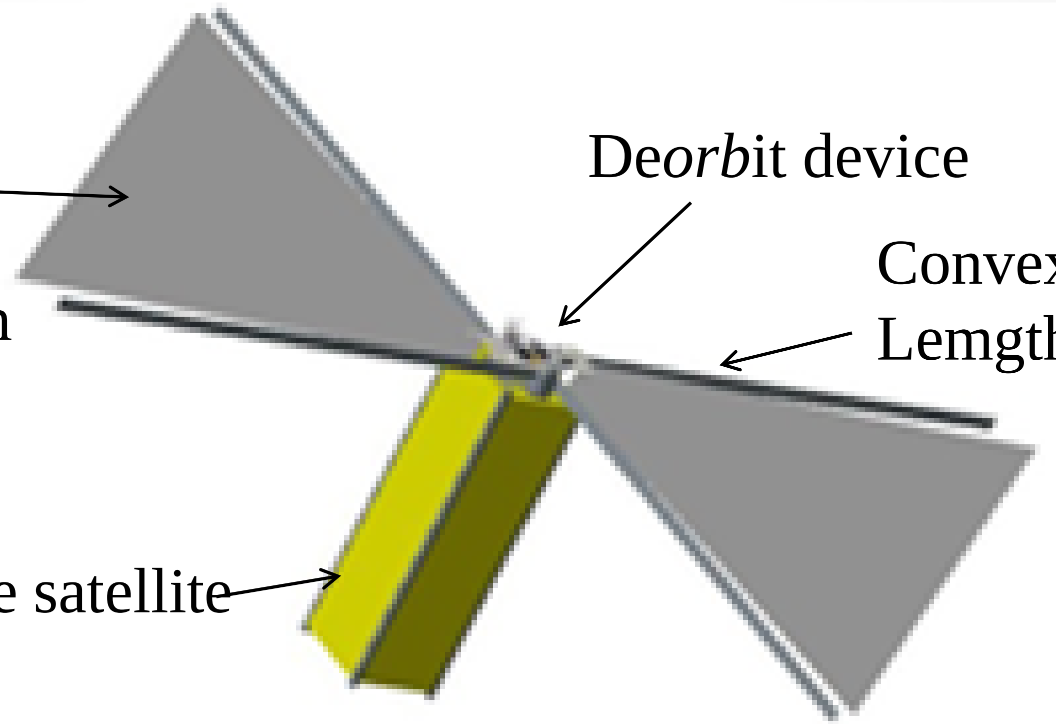
Detail design

[Deployment mechanism of the device]





Detail design
[Effectiveness]

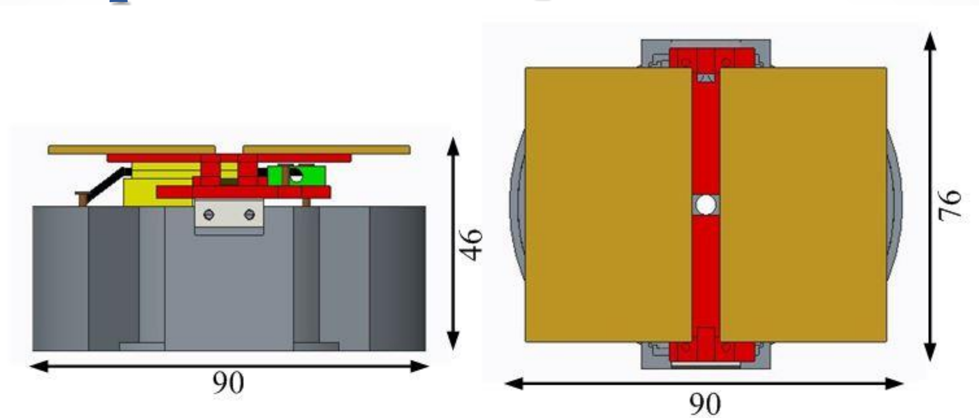


[Deployed configuration of proposed deorbit device with 3U CubeSat]

- The orbit lifetime of the satellite is about 3.68 years
(The orbit calculation software DAS)

Detail design

[Mass and envelope at launch]



[Cost]

Estimated price of parts of proposed device (exchange rate：1USD＝113.09JPY)

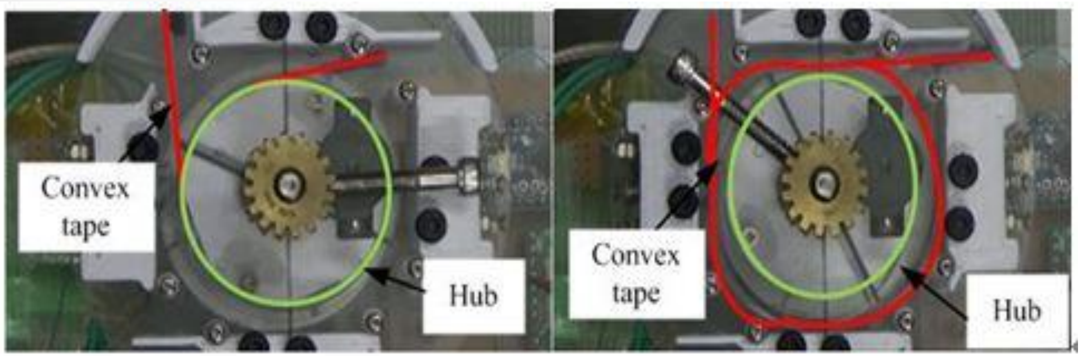
parts	Price(USD)	parts	Price(USD)
Convex tape	0.88	spring	5.08
Spring hinge	5.08	Rotation axis	1.77
gear	3.54	Electro magnetic brake	20.7
Rotary damper	2.65	Aluminum pleat	44.2
Roller	3.54	Processing cost	630
Bearing	2.84	Margin	80.1
			Total 800

Detail design

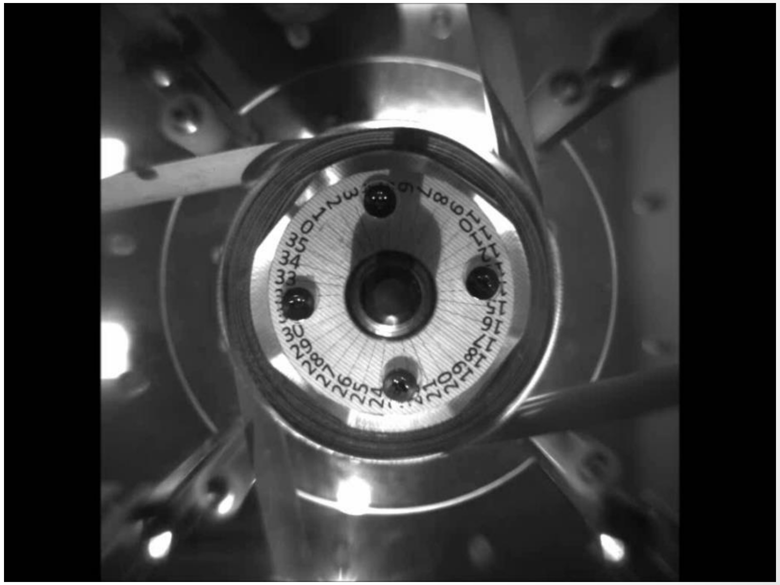
[Technical feasibility-Mechanical design-]

~Angular velocity of rotating hub~

We observed that the convex tape begins to separate from the rotating hub under a certain condition, which results in the jam of the tape in the device and the failure of the deployment



Not separation separation

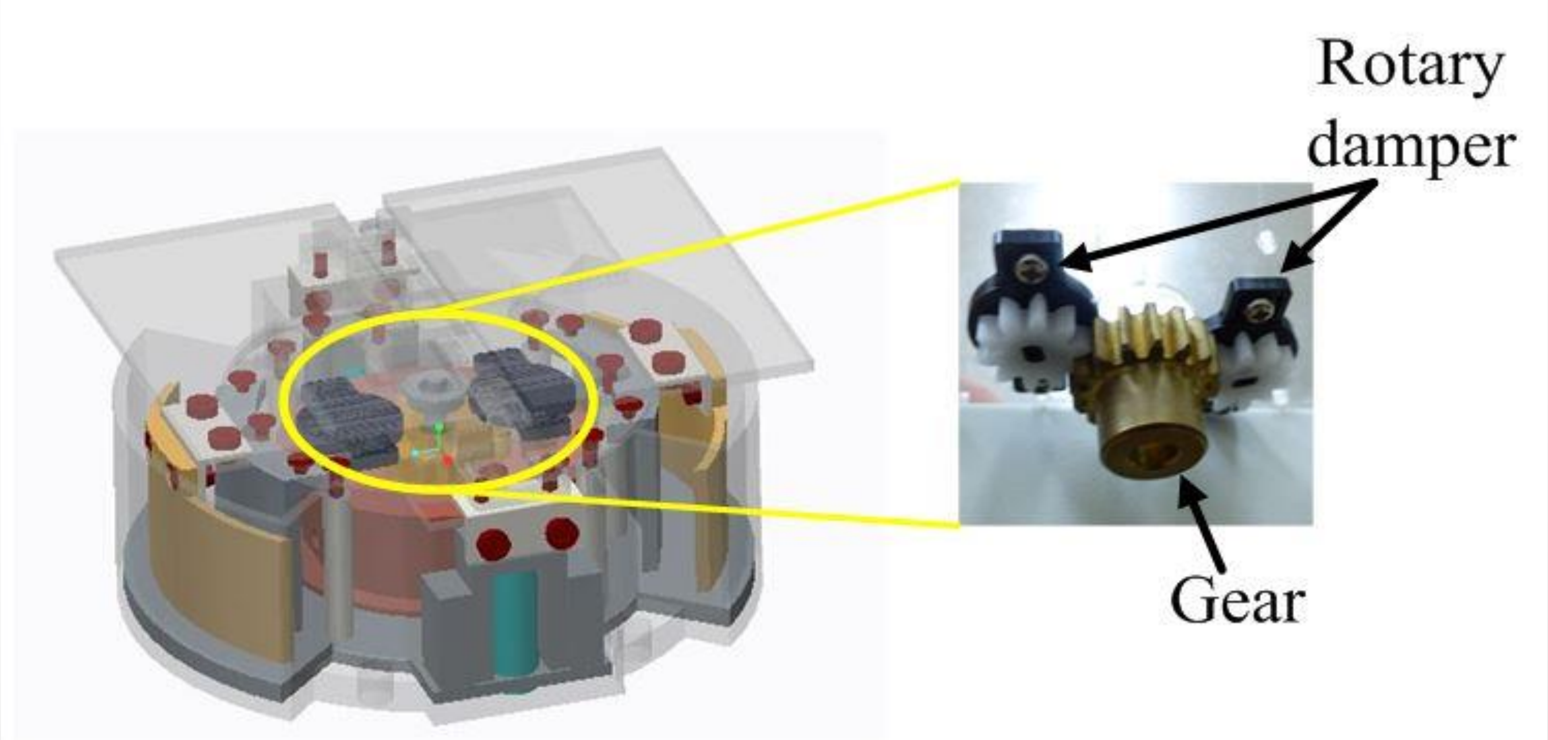


Detail design

[Technical feasibility-Mechanical design-]

～Angular velocity of rotating hub～

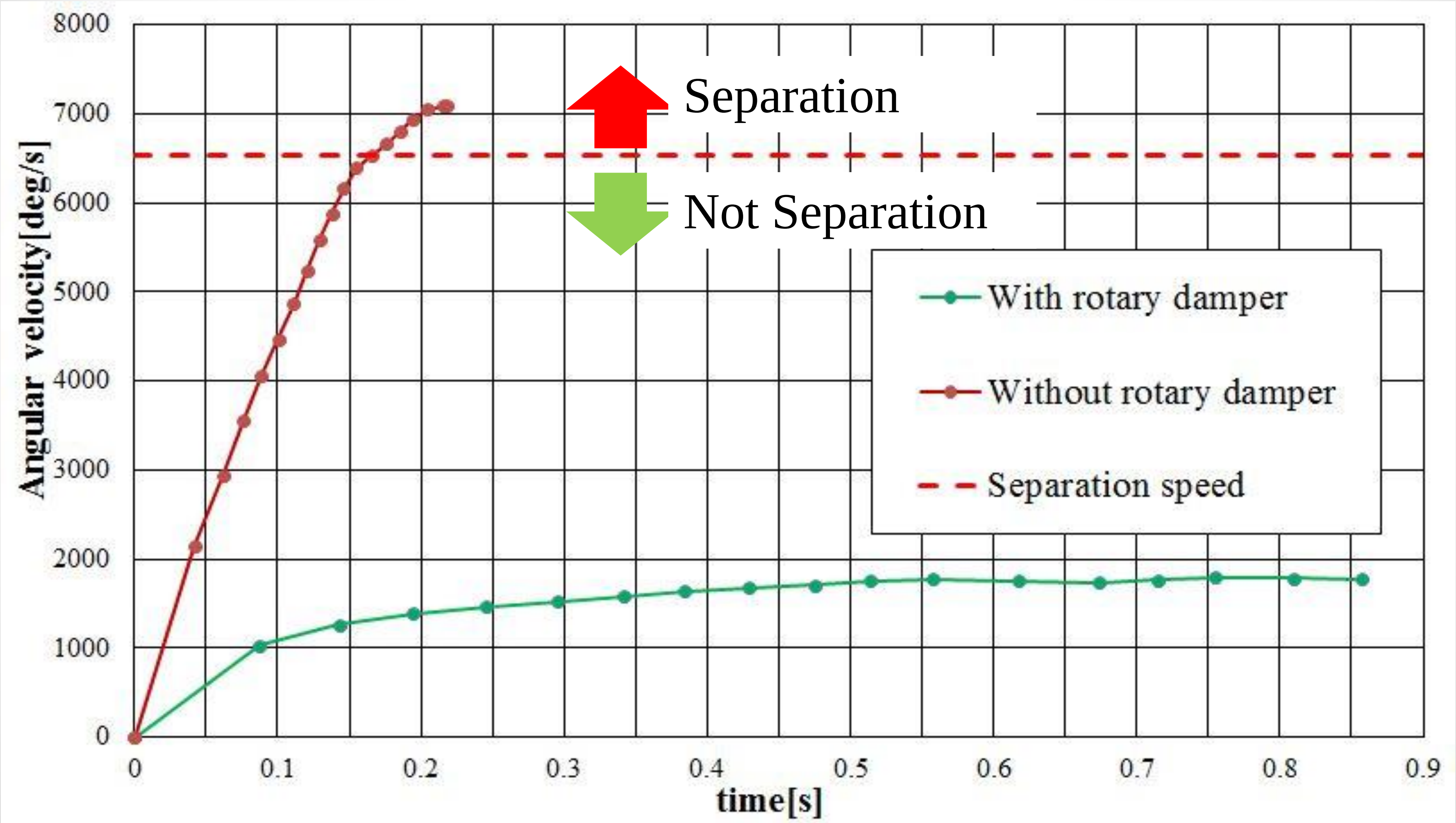
the separation occurs if the angular velocity of the hub exceeds a certain value. Therefore we introduced the rotary damper that gives the constant negative torque to the angular velocity to the hub in order to reduce the angular velocity of the hub.



Detail design

[Technical feasibility-Mechanical design-]

～Angular velocity of rotating hub～

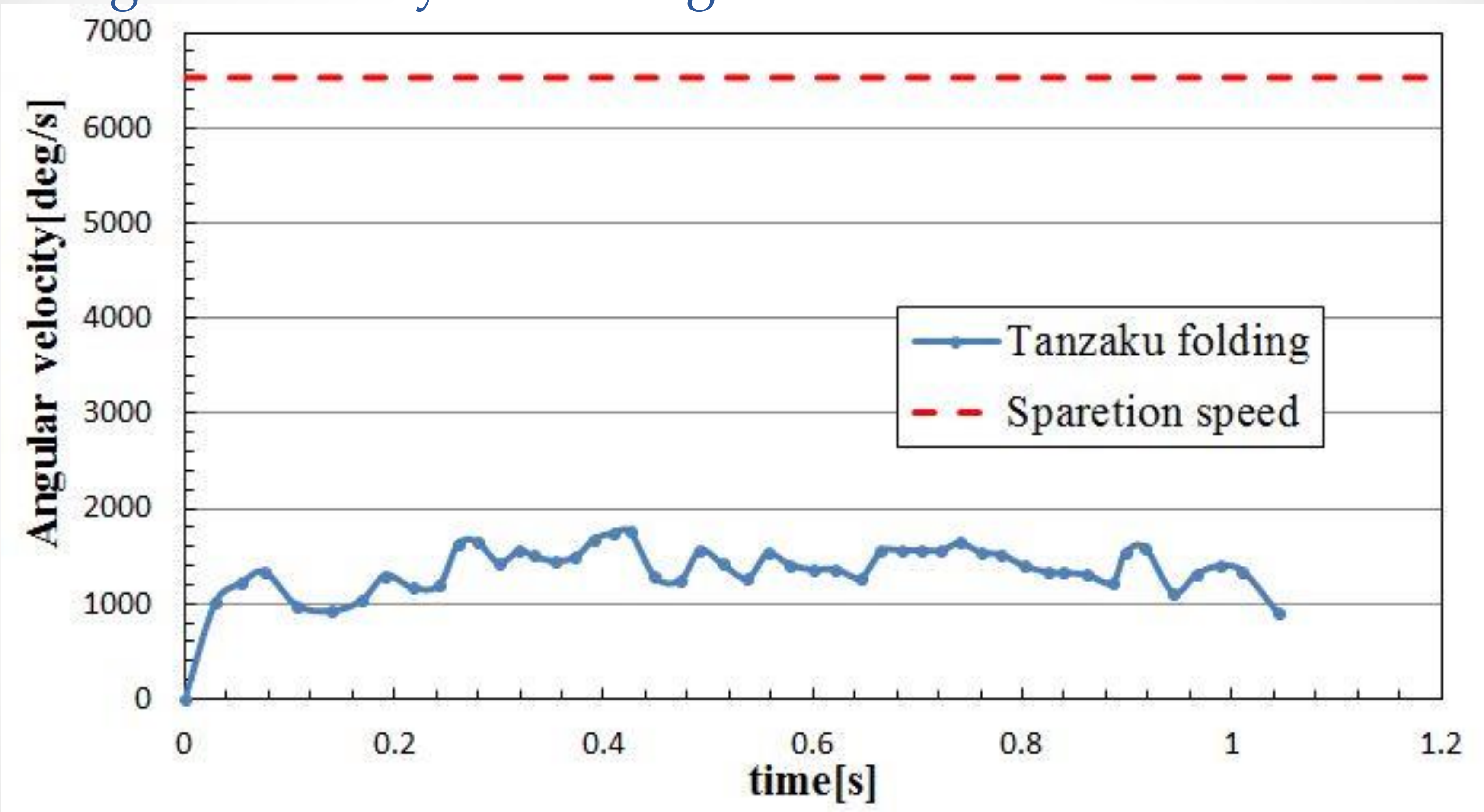


time history of angular velocity under 1G environment.

Detail design

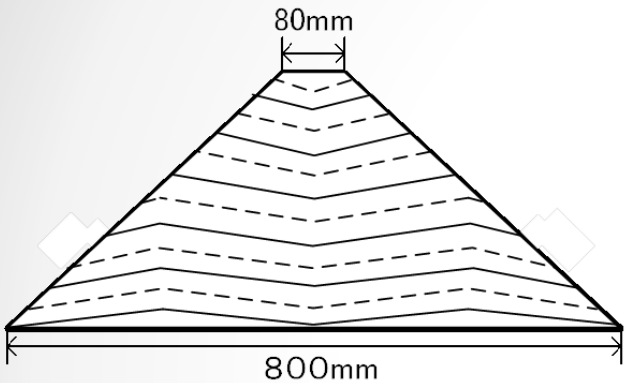
[Technical feasibility-Mechanical design-]

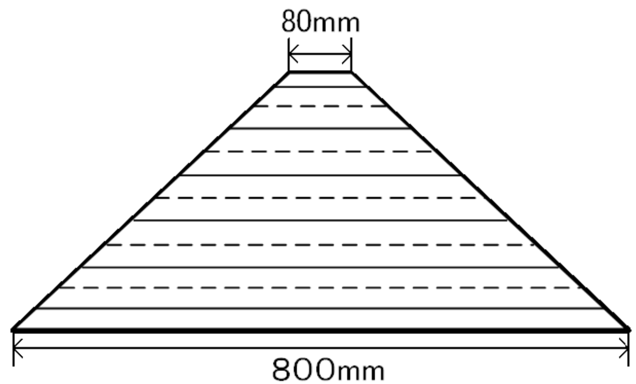
～Angular velocity of rotating hub～

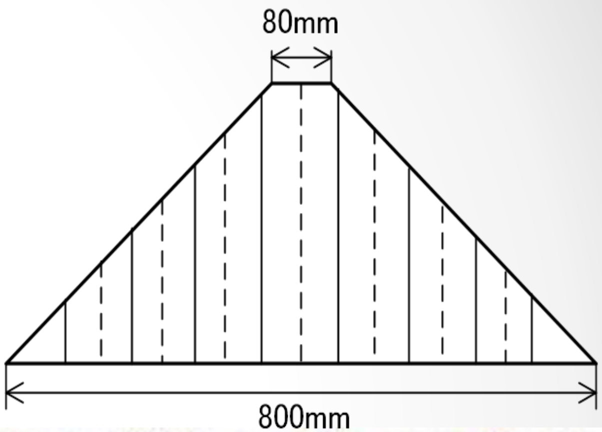


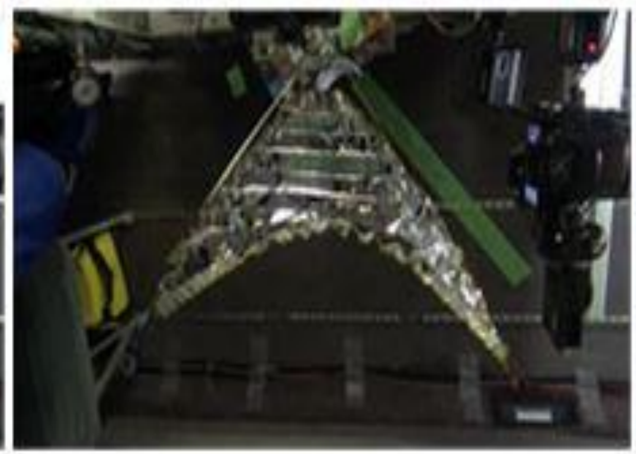
Comparison of time history of angular velocity under micro-gravity

Detail design
[Technical feasibility-Mechanical design-]
～Folding-pattern of membrane～







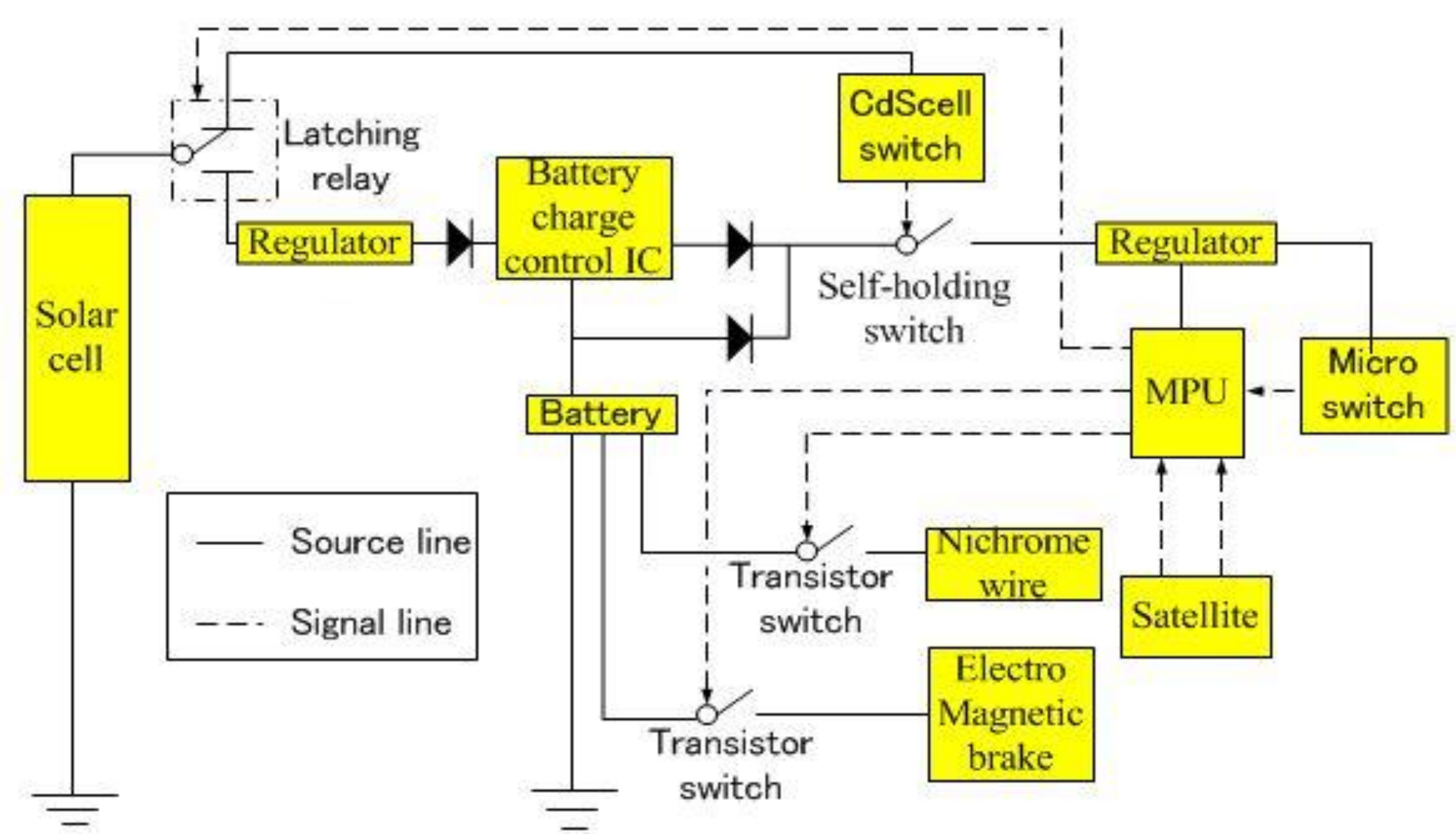


Miura-folding

Bellows-folding

Strip-folding

Detail design
[Technical feasibility-electrical design-]



Detail design
[Impact on the satellite]

1)The device can be put on the top surface of a CubeSat.

2) The height of the device is 46 mm

3) The weight is only 0.276kg.

4) The device does not require the power from the satellite.

5) Only four M3 bolt holes and two signal line is required to attach the device on the satellite.

Detail design
[Reliability]

1)The deployment method has been already proved in space

2) We has already clarified the failure mode.

3) The hold-release mechanism using the heat-cut system has been already proved in space by various CubeSat.

4) The two signals are sent from the satellite by the different lines to avoid the malfunction.

5) device works without the power supply from the satellite, and even without the signal from the satellite

Detail design
[Safety]

1)The proposed device does not have any propulsion system, so that no gas/liquid will exhaust.

2) The system of the device is turned off when it is launched.

3) The hold-release mechanism using the heat-cut system has two inhibits to avoid the unexpected deployment.

Detail design
[Maintenance and testability]

1) The terminal pin for the battery charge is exposed at the side of the device

2) The folding-pattern is quite simple (strip-folding).

3) The wrapping of the convex tapes around the hub is completed.

Detail design

[User friendliness]

1) The device does not require the power from the satellite.

2) Only four M3 bolt holes and two signal line is required to attach the device on the satellite.

[Debris risk]

1) The proposed device functions even if the satellite system is failed or the electrical interface between the proposed device and the satellite has trouble.

2) The proposed device does not generate any objects.

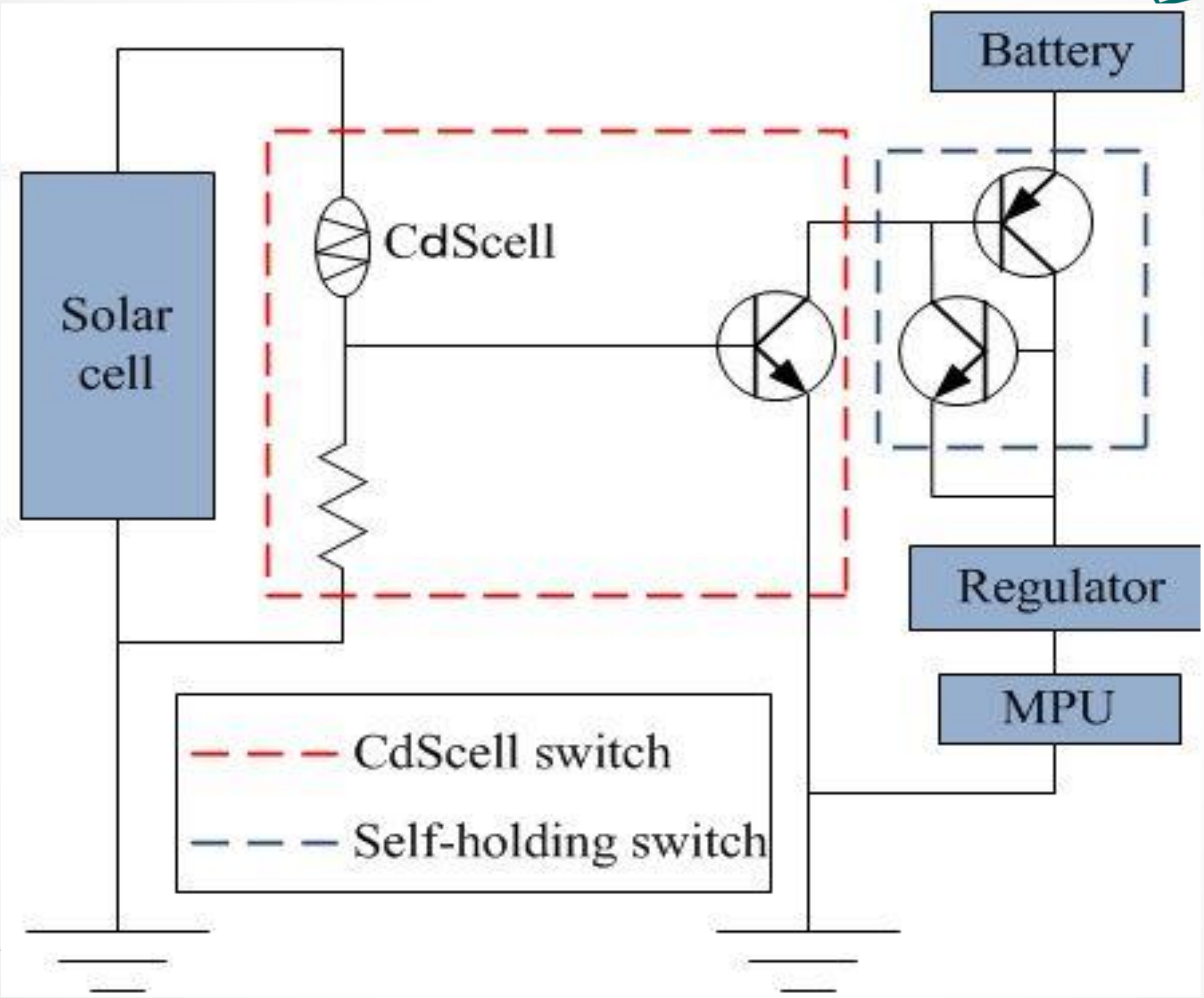
Concluding remarks

- The prototype of the device was already verified by experiments including the deployment experiment under micro-gravity environment.
- The reliability, safety and the reduction of the debris risk is considered in the design of the device as well as the mass and the envelope.

We are ready for developing
the flight model of the device!!

Thank you

CdS cell switch and Self-holding switch



研究背景

✓ 膜面展開の有用性

- 前述のデオービット機構とは，推進機器(スラスター)や展開物による空気抵抗の増加によって衛星を減速，降下させる機構の総称である。
- 推進機器は燃料及び酸化剤を含み，サイズ・重量が共に大きいため，小型衛星に軌道降下用として搭載するには適さない。
- より軽量かつ収納力のあるパネルや膜を用いた展開物が有用であると考えられる。

研究背景

✓ コンベックステープを用いた膜面展開

- 膜を用いた展開物の展開方法には，スピン展開や伸展部材を用いた展開が挙げられる。その中でもコンベックステープを伸展部材とした膜面展開方法は，必要とする機器が少ないため軽量，コンパクト，安価なデオービット機構が実現できる。