C04

# 次世代型宇宙用デブリモニタ BBM の開発

## Development of JAXA Space Debris Monitor BBM

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宇宙デブリセンサ SDM は、JAXA 研究開発部門で開発を行っている軌道上直接観測用のデブリセンサである。ターゲットである高度 600-1000km 上のサブミリサイズのデブリは、大きいものに比べて圧倒的に数が多く、今後も急増することが予測されている。その一方で、十分なデータが取得できておらず、データ取得は世界的に急務の課題となっている。この SDM の特徴は、シンプルな機構を持ち、特別な校正が必要ないという点である。この利点を活かして他のセンサーと組み合わせて利用することも可能であり、現在 NASA ODPO と協力の下、軌道上運用を目的としたデブリセンサの開発を行っている。SDM は検出エリアと回路部からなっており、検出エリアは極薄のポリイミドフィルム上に、数千本の 50 μm 幅の導線を細線加工したものである。ここにデブリが衝突することにより、100 μm~数 mm のデブリの直径が取得できる。本講演では、BBM の開発状況と今後の計画を紹介する。

The space debris monitor (SDM) is a flight experienced in-situ debris sensor focusing on micro to mill sized debris on 600 – 1000 km orbit. A continuous in-situ observation of those small debris at 600 to 1000 km has never been conducted. However, this information is essential to properly understand the current situation of vast amount of small debris orbiting near our earth because they are becoming a dominant risk factor on orbit. The unique point of the SDM is its simple detection system which does not need any special calibrations. Thanks to this advantage, the SDM has the potential to collaborate easily with other debris sensors. The SDM consists of a debris-detection area and circuit areas. The debris-detection area is made of very thin polyimide film and there are thousands of 50 μm-wide conductive grid lines capable of detecting the diameter of collided debris sized from 100 μm to millimeters. On this presentation, the current status of developing the SDM BBM and our future plan will be shared with audiences.

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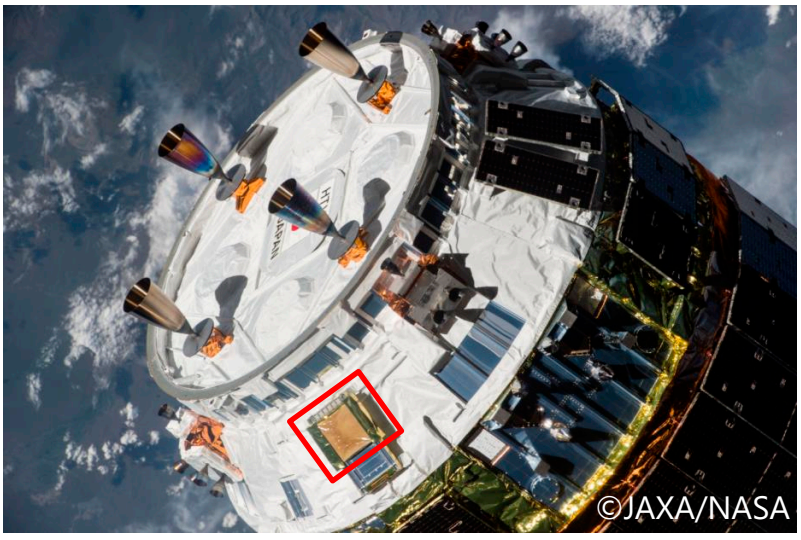
(JAXA R&D)

## Space Debris Monitor (SDM)

- ✓ In-situ debris detector
- ✓ Focusing on submillimeter-size debris under 1000km

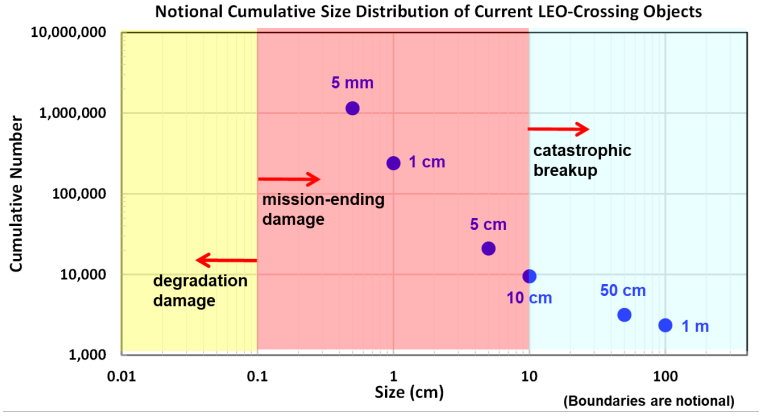



SDM on HTV-5

# Background

## Why focusing on submillimeter-size debris?

- Smaller debris is much more dominant on total number of orbital debris
- Small debris (mm to cm) is the main risk of mission-ending damage




**Hyper Velocity Shock Test**


- Particle size : 0.3 mm
- Collision Speed: 4 km/s

Orbital Debris Mitigation in Support of Space Situational Awareness and Space Traffic Management, J.C. Liou, International Symposium on Ensuring Stable Use of Outer Space http://www.jsforum.or.jp/stableuse/2019/pdf/2%20OD%20Mitigation,%20SSA,%20and%20STM%20rev%202%20(Liou).pdf

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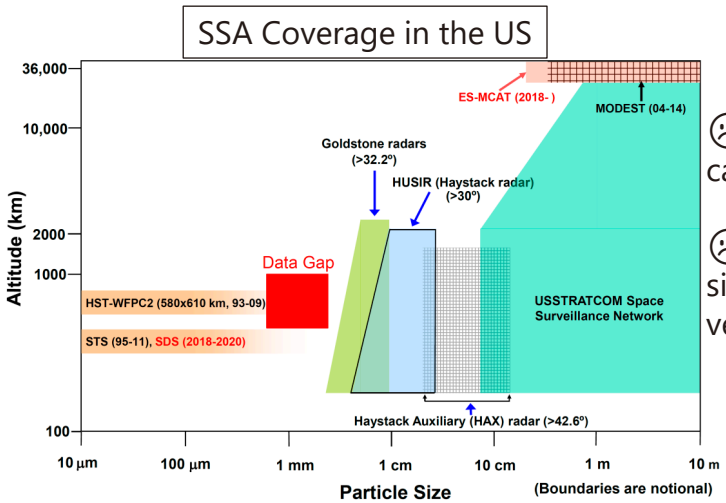
# Background

- Space debris problem is getting worse
- Data gap still exists on distribution map of space debris → 600 to 1000km




☹Submillimeter-sized debris(<3 mm) can't be detected from the ground

☹Available data of submillimeter-sized debris at 600 -1000 km orbit is very limited.

U.S. Space Debris Environment, Operations, and Research Updates
J.-C. Liou, https://www.unoosa.org/documents/pdf/copuos/stsc/2018/tech-14E.pdf

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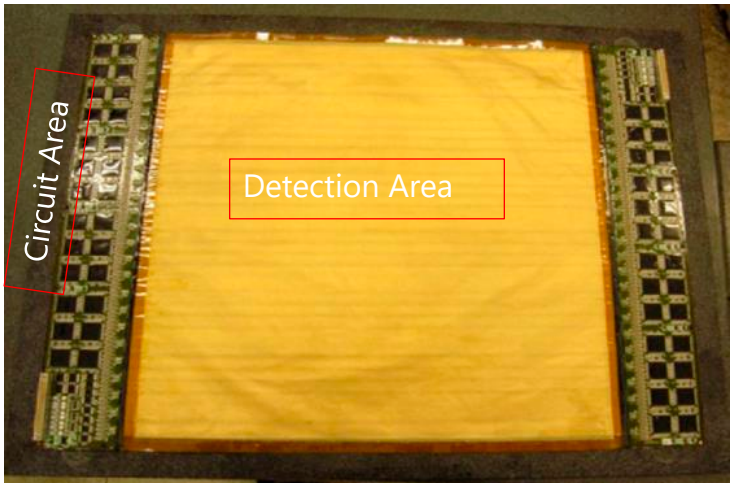
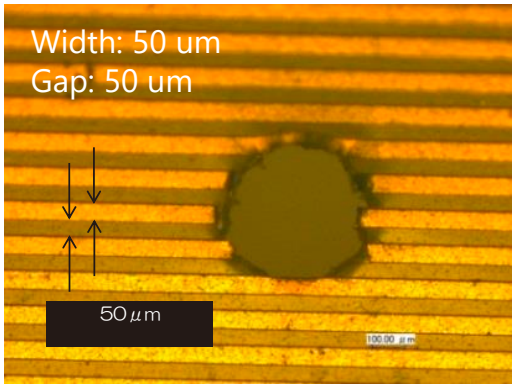
# Development SDM So Far

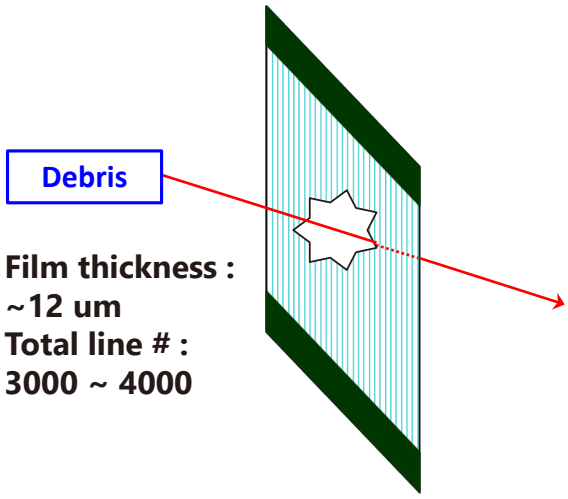



- Flight Experiences: 2 (1 successful, 1 launch failure)
- Detection method: by 50um-wide conductive grids
- Detection area per sheet: ~40 x 40 cm
- Disconnection Detector: FPGA
- Material: Polyimide based (FPC manufacturing method used)



# Basic Specification on SDM




- Detectable from 100 um size debris
- Debris diameter and detection time can be determined from the information of disconnecting conducive grids
- No need for calibration → very simple detection system

# New SDM: FPC Type

Data Measurement Equipment (DME)

| Specification of FPC Type | |
|---|---|
| Size | ~50 x 50 cm |
| Weight | ~ 100 g |
| Cu laminated film thickness | 21 um |
| Line width | 50 um |
| Line gap | 50 um |
| No of total lines | 4096 / sheet |

## Basic design does not change from old one, but…

- ✓ 52 FPGAs are replaced with one CPU and small diodes + α.
- ✓ Diodes are mounted on the outer space side. (the other hand of adhesive type)
- ✓ I/F can be integrated in one place by attaching DME.

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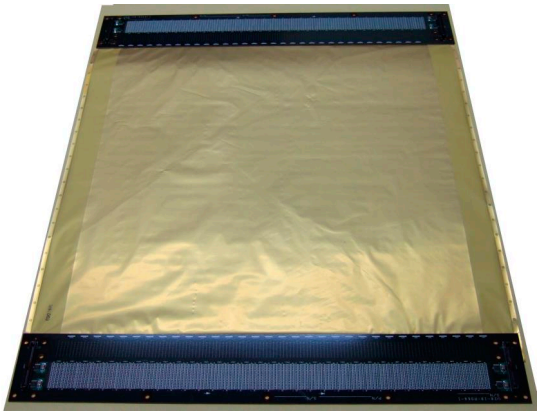
# New SDM: Adhesive Type



DME 

| Specification of Adhesive Type | |
|---|---|
| Size | 57 x 48 cm |
| Weight | ~ 200 g |
| Cu laminated film thickness | 18.5 um |
| Line width | 50 um |
| Line gap | 50 um |
| No of total lines | 4096 / sheet |

## There are two big changes on the adhesive type SDM

- ✓ 52 FPGA are replaced with one CPU and small diodes + α.
- ✓ I/F can be integrated in one place by attaching DME.
- ✓ The Self Assembly Paste is applied to connect components with different materials (PCB and polyimide film)

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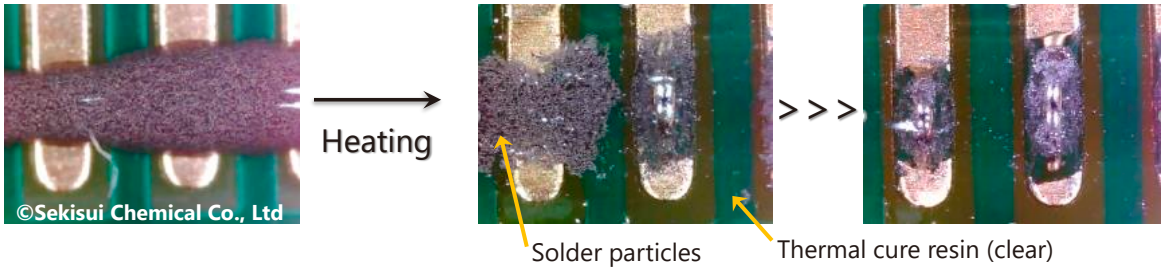
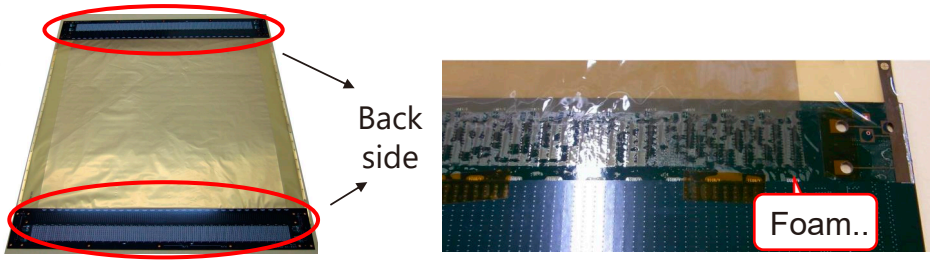
# Changes on the Adhesive Type

## Self Assembly Anisotropic Conductive Paste (SAP)



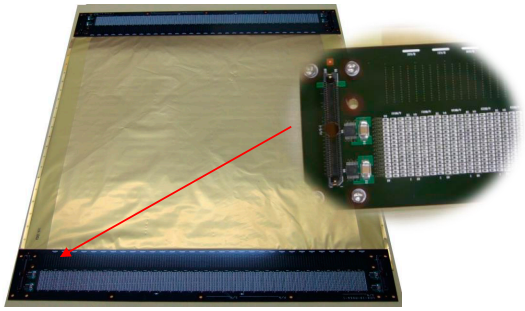




☺ PCB and polyimide film can be adhered with SAP
☹ Foams came out at the connecting area because resin was too little



# Changes on the Adhesive Type

## Many FPGAs were replaced by a CPU and diodes

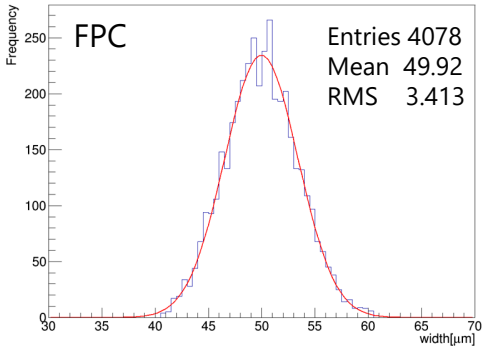


| FPC (old) | **SDM Type** | Adhesive |
|---|---|---|
| 52 custom-made FPGA | **Processor** | 1 CPU |
| - | **Additional Electronics** | 4096 diodes, capacitors, analog multiplexers |

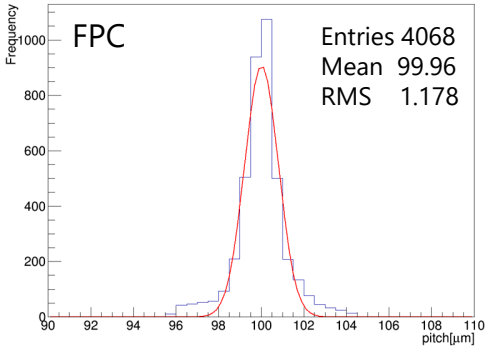
☺ The cost of electronics can be reduced on the adhesive type
☹ Issues remain in selection and mounting method of diodes

# Sensor Pattern L/S measurement

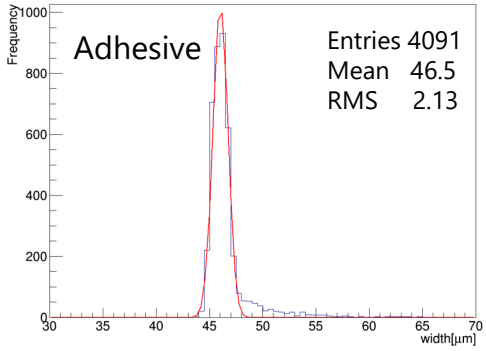
## L/S are measured by video measuring system (Nikon NEXIV)

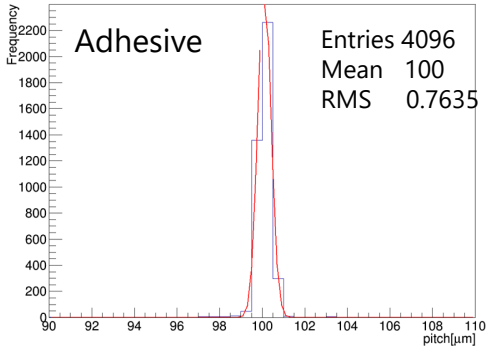



Cu line width




Pitch width (L+S)



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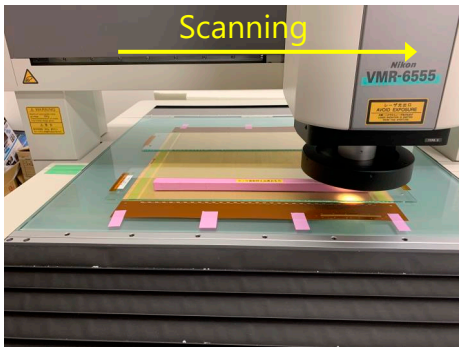
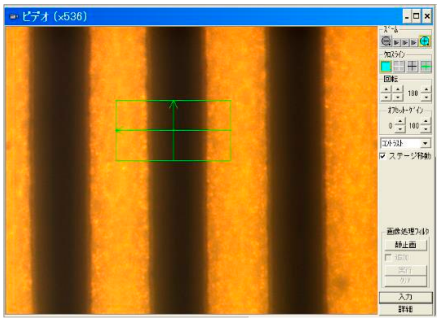


- ✓ Line width and spacing of the Adhesive type are better controlled.
- ✓ The film of the FPC type looked little wavy and it caused scanning error.
- ✓ Controlling of pitch (=line width + spacing) is more important than controlling of line width.

# Thermal Shock Test Results

Number of disconnection lines

| | Before | After |
|---|---|---|
| Adhesive | 0 | 122 |
| FPC (new) | 7 | approx. 3000 |

| Test condition | |
|---|---|
| Temp. | -30 /+100 ℃ |
| Hold time/cycle | 30 min |
| Cycle | 500 |

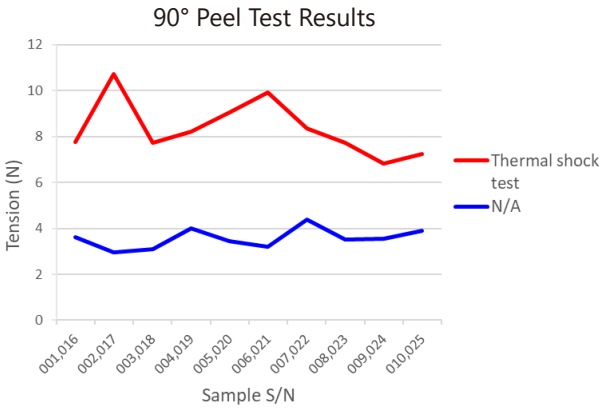
**Adhesive type seems to show good durability for thermal shock !**
**However, there is doubt about the results…**

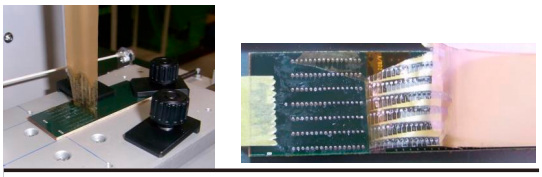
- ✓ Thermal wind was too strong (30~40km/h) and might damage the samples.
- ✓ Lots of diodes fell out from the circuit board after the test, especially on the FPC type because this type has diodes on the back (shelf) side.
- ✓ Circuit board of FPC type is thinner than Adhesive type.
- ✓ Corrosion was founded on the electrode of diodes. It possibly caused soldering defects.

→Need for thermal shock test again with a no-air-type equipment



# Tensile test on Adhesive type



| Sample preprocess | No of samples | Design value | Ave. value |
|---|---|---|---|
| N/A | 10 | 3.84 N | 3.56 N |
| Thermal shock test | 10 | - | 8.35 N |

- ✓ Strength of the adhesion is sufficient (it is same as the design value)
- ✓ The sample after thermal shock test shows more strength because of baking of the thermal cure resin.
- ✓ Strength of SAP's adhesion does not deteriorate and get to be strong by heat.
- ✓ Ratio of resin in the SAP should be increased.

# Conclusion & Future Plan

- ✓Adhesive type shows good performance.
- ✓The blending ratio of SAP needs to be changed. (ratio of solder and resin)
- ✓Connecting method of film and PCB on the Adhesive type needs improvement.
- ✓Need for reselection of diode.

## Collaboration with NASA ODPO

- ✓JAXA and NASA ODPO now work together for a new in-situ debris monitor targeted submillimeter size debris.
- ✓Our BBM is ready for hyper velocity test in the US.



# Our New BBM