H1

HTV-5 における微小デブリセンサ実証実験の計画

Demonstration Experiment of Space Debris Sensor on HTV-5

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Yukihito Kitazawa (IHI)

HTV 5 号機には宇宙環境観測装置 KASPER（Kounotori Advanced SPace Environment Research equipment）が搭載される。KASPER では HTV 電位・プラズマ電流計測とともに微小デブリセンサの軌道上実証を行なう。本センサは、JAXA で開発を進めてきたフィルム貫通型デブリ計測装置で、0.1～数 mm サイズのデブリ検出を目的としている。これまでの微小デブリセンサと比較し、有感面積が大きい割に軽量コンパクト、また回収の必要がないアクティブセンサという特長がある。これまでミリ、サブミリサイズのデブリは、宇宙機への影響が懸念されながらもほとんど観測データのない領域であった。本センサはこのような微小デブリを直接観測する手段を提供し、広く観測を進めることで宇宙機に対する適切なリスク評価・防御設計に貢献することを目標にしている。本センサの特徴および HTV-5 における実証実験について報告する。

HTV-5における微小デブリセンサ実証実験の計画

DEMONSTRATION EXPERIMENT OF SPACE DEBRIS SENSOR ON HTV-5

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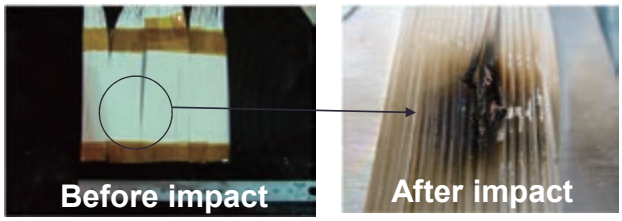
Yuki Kobayasi (JAXA), Yukihito Kitazawa (IHI)

Background

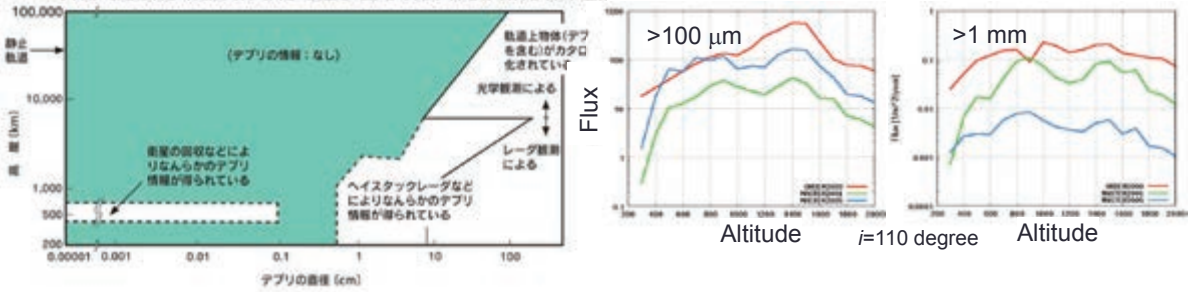
- Meteoroid and space debris of approximately 100 micro-meters to several millimeters in size
  - An impact damages the wire harness and other equipment on board.



An example of experiment results.
- Diameter of projectile : 0.3 mm
- Impact velocity : 4 km/s

(JERG-2-144-HB001 'JAXA Space Debris Protection Design Manual Appendix 2 ', 2008)

  - The debris flux in the size are not well known in LEO



➡ To measure flux of debris from 100 micrometer to several millimeters.

Measurement Methods of Small Particles

- Target: the flux and size of debris from a hundred micrometer to several millimeters in size.

- Ground observation

It is difficult to measure the flux of the size range.

- Surface inspection of retrieved spacecraft

Only applicable to retrievable spacecraft

- Restricted orbit - Restricted flight opportunity - Not able to get real time data
- Difficult calibration

- Passive Sensor (sample return of small debris)

Only applicable to retrievable spacecraft

- Restricted orbit - Restricted flight opportunity - Not able to get real time data

- In-situ measurement by active sensors

Applicable to all spacecraft

But

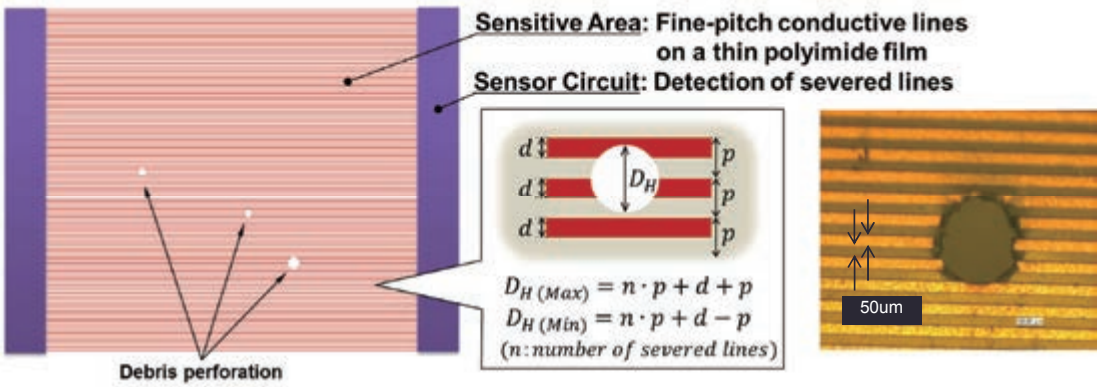
- Conventional sensors are not necessarily suitable for the measurement of the size range
- Many hypervelocity impact tests are required for the calibration

→ **Development of a sensor suitable to measure the debris in such size**

Principle of the Micro-Debris Sensor

Sensor concept (Sakurai, 2008)

- New type active sensor
  - A multitude of thin and conductive strips is formed with fine pitch on a thin nonconductive film.
  - An debris impact is detected when one or more strips are severed by the perforation.

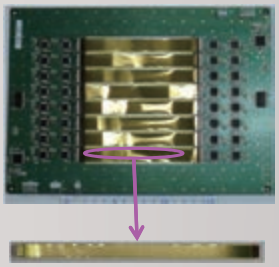


US patent registered

Principle of the Micro-Debris Sensor

- Features
  1. Simple mechanism and high reliability (sensing precision)
  2. Free of hypervelocity impact experiments (calibration shots)
  3. Flexible configuration (size and shape)
  4. Sensitive area is able to be monitored.
  5. Low weight, low power and low cost (ex. < 200g and < 1W per 1m^2 [sensing area])
  6. Additional parameters (velocity and incident direction) by minor expansions.

Development of Sensors

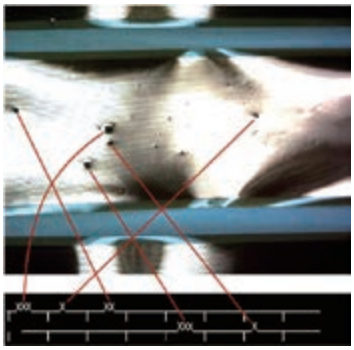
2008-2009	2010	2011-2012
Laboratory model	Breadboard model (BBM)	Engineering model (EM)
		
✓ Consists of small 8 unit. ✓ one unit size is 1.2 × 10 cm	✓ Large area unit was developed. ✓ 1 unit size is 40 × 30 cm. ✓ One large FCP board as a sensor	✓ Circuits to detect severing were equipped. ✓ No mechanical connector to the film and to reduce the number of parts

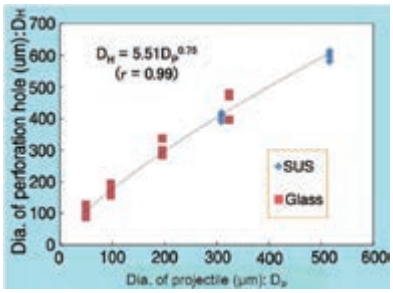
Sensitive area specification	
Thickness	< 20 um
Width of a conductive line	50 um
Gap between conductive lines	50 um

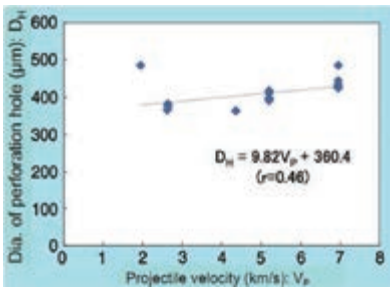
Hypervelocity Impact Experiments

Two-stage light gas gun
(JAXA/ISAS)

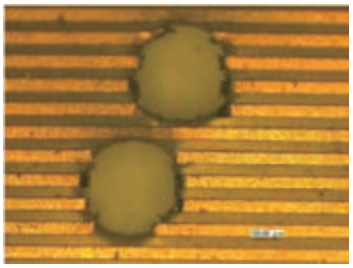
Vacuum	<5 [Pa]
Temperature	Room temperature
Projectile material	SUS304 and Glass
Projectile diameter	50 - 516 [um]
Impact velocity	1.9 - 17.0 [km/s]
Impact angle	90, 60, 30, 15 [deg]







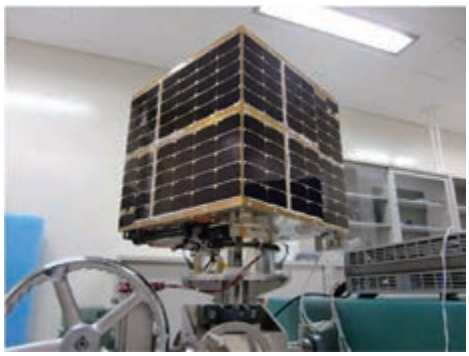
$$D_p = 1.39 \times 10^{-1} {D_H}^{1.28}, \quad D_H = n \cdot p + d \pm p$$

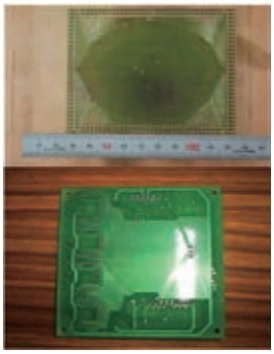


Example of perforation hole
- Projectile: SUS 309 μm
- Impact velocity: 4.65 km/s

Preliminary Flight Experiments

- Educational mode is onboard a small satellite Horyu-II built at KIT (Kyushu Institute of Technology) and launched on 18 May 2012
- Laboratory model on a small satellite QSAT-EOS by Kyushu Univ. was launched in 6 Nov. 2014.

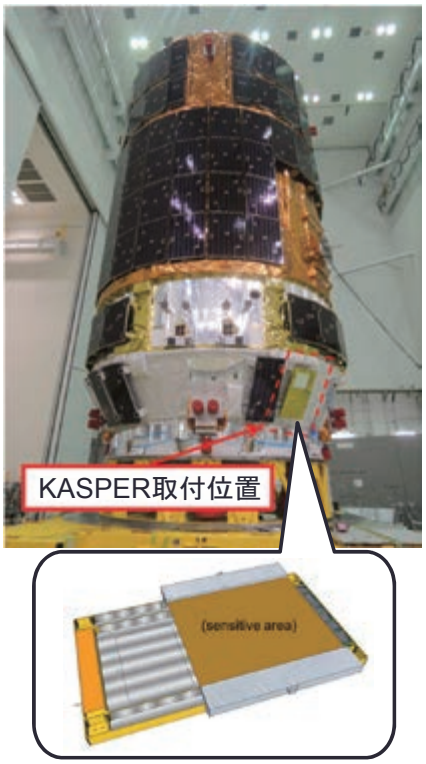




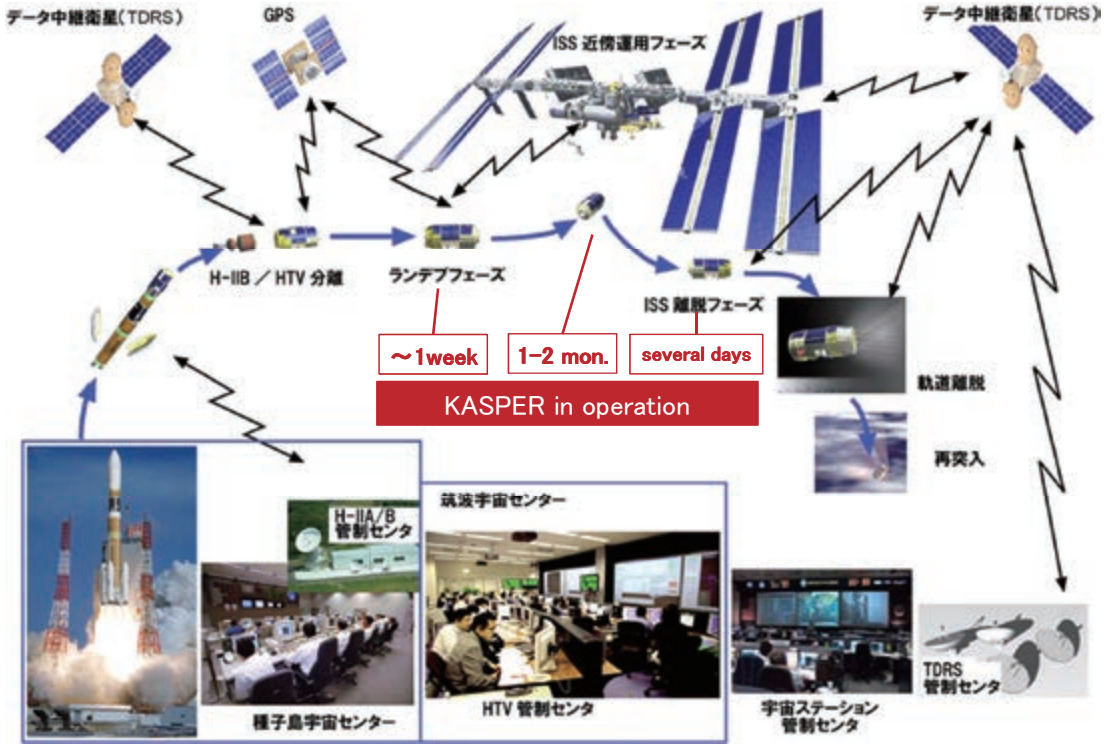
Faure *et al.*, 2012

Flight Experiment on HTV

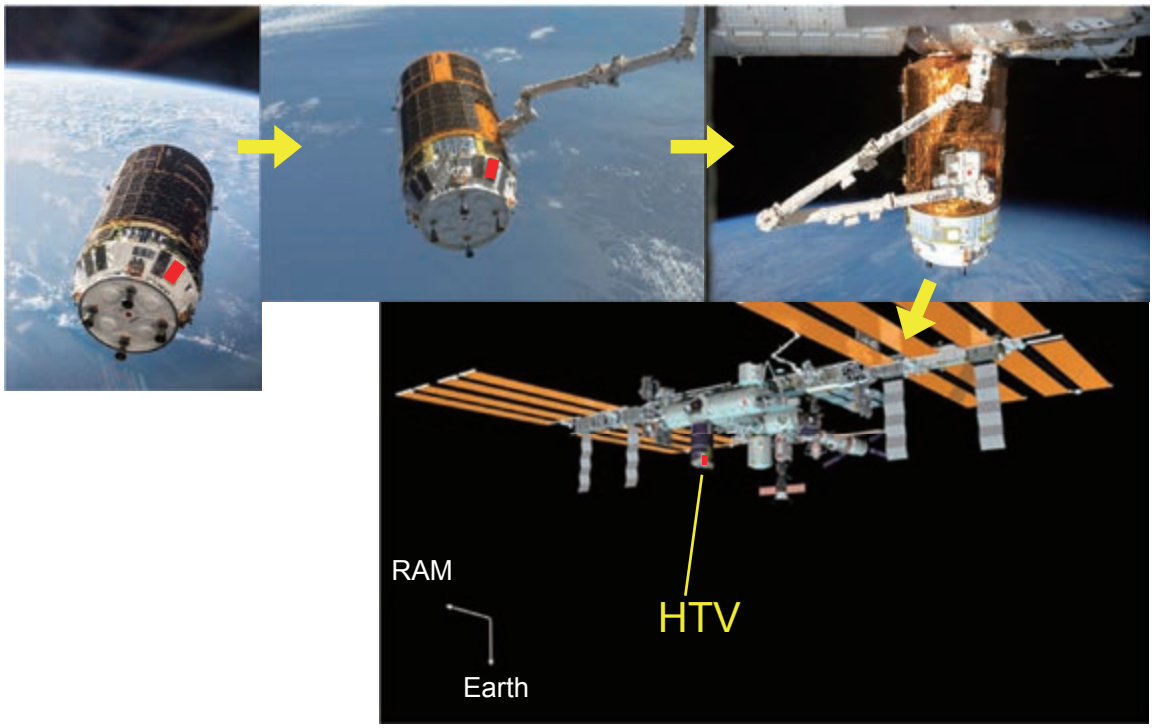
- HTV (H-II Transfer Vehicle) "KOUNOTORI"
  - JAXA's unmanned cargo transfer spacecraft which delivers supplies to the International Space Station (ISS).
- KASPER (KOUNOTORI Advanced Space Environment Research Equipment)
  - Space Debris Monitor + Charging Monitor
  - On the propulsion module of HTV-5
  - To be launched in 2015
  - Mission duration: 1-2 months
- To demonstrate the sensor's functional capability in space environment.



HTV Flight Plan

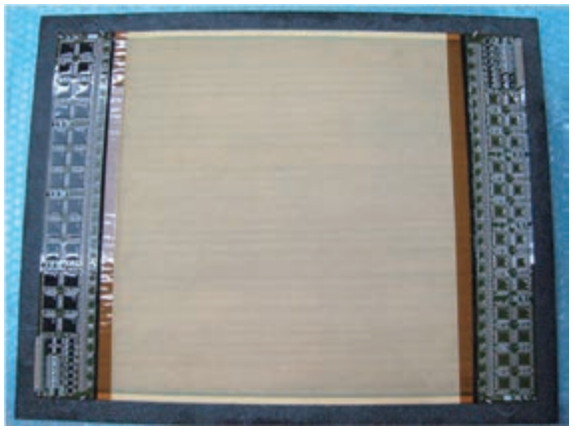


HTV Flight Plan



SDM（KASPER Model）

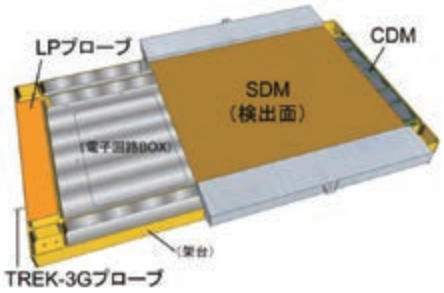
- A flight model sensor is reinforced mechanically with wide patterns and cover lays.
- There were less faulty wires produced in fine-structure processing
- Protective coat against atomic oxygen (AO)
  （developed by JAXA, a few micrometers in thickness）



Space debris sensor on HTV-5	
Thickness of sensitive area	< 20 um
Width of a conductive line	50 um
Gap b/w conductive lines	50 um
Sensitive area	30 x 35 cm
Number of lines	3300
Weight (incl. outer box)	1.5 kg
Size (incl. outer box)	50 x 39 x 4 cm
Power	～2W (max.)

Features of KASPER

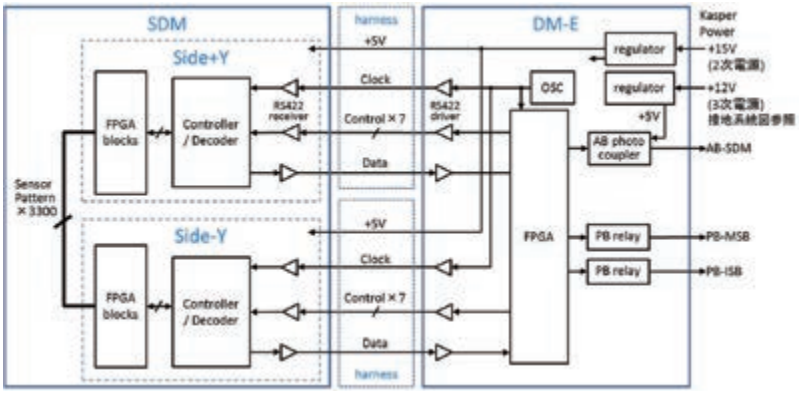
KASPER	
Sensor	2 charging sensors + 2 debris sensors
Size	75×50×12 cm
Weight	～ 8kg
Power	30W (including 16.8W for heaters)
Telemetry	PA×2、PB×4、AB×2
Telecommand	6



KASPER デブリセンサ			
SDM	フィルム貫通型微小デブリ計測装置。薄膜を貫通した100μm～数mmのデブリの大きさを計測する。	測定デブリサイズ	100μm以上
		測定精度	100μm
		時間分解能	>900秒
		テレメトリレート	0.2 bps (1bit/10秒)
CDM	圧電素子型デブリ計測装置。数μm以上のマイクロデブリが衝突した際の電圧を計測する。(千葉工大)	測定範囲	100pg・km/sec以上
		時間分解能	1秒
		テレメトリレート	0.2 bps (1bit/10秒)

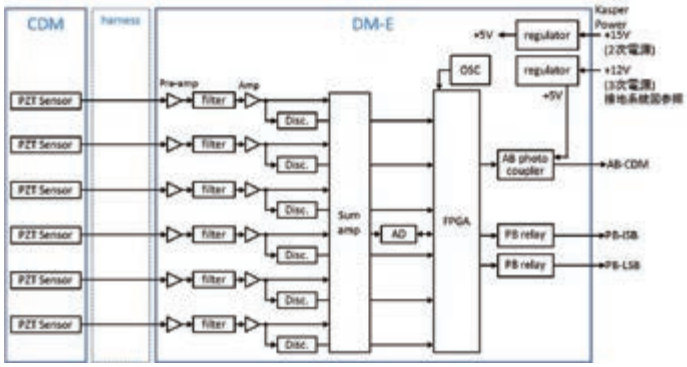
SDM : フィルム貫通型デブリ計測装置

- 100μm～数mmのデブリが衝突した時刻と大きさを計測
  - センサ部と回路部(DME)から構成される。
  - 回路部は900秒ごとにセンサ部を起動し、断線計測とデータ取り込みを行う。
  - センサ部は、電圧印加により1本ずつ断線を検査する。
  - 3300本の結果を回路部にて整理、パケット化し、テレメトリする。
  - 計測時刻とデブリ貫通孔をリスト化した情報がテレメトリされる。



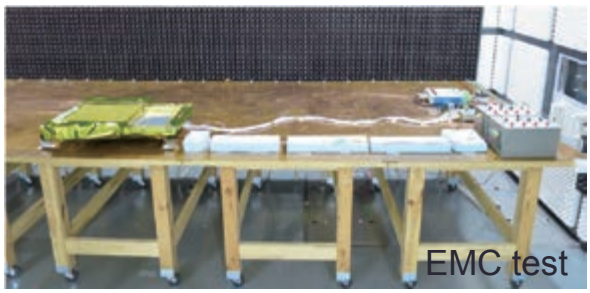
CDM : 圧電素子型デブリ計測装置

- 100μm以下のサイズのデブリ・メテオロイドのその場計測
  - 千葉工業大学　惑星探査研究センターとの共同研究
  - センサには4×4cmの圧電性素子PZT（チタン酸ジルコン酸鉛）を6枚用いており、そのいずれかにデブリが衝突した際に発生する電圧を検知する。
  - 回路部では6枚のPZTからの信号はサムされてAD変換される。
  - 設計上は10pg・km/sec以上を検出できるが、実際の下限は軌道上でのノイズレベルに依存。そのため、常時ノイズレベルをモニタし、トリガレベルを自動決定する。
  - イベントとして取り込んだAD値に時刻、トリガー条件、温度を付加してパケット化し、テレメトリする。



Development of KASPER

SDM (KASPER)	
2013	Design Review
	Initial performance test
	EMC test
2014	Shock test
	Thermal vacuum test
	Vibration test
	Final performance test
2015	PQR/PSR
	Launch & Observation



Summary

- JAXA is developing a new-type active sensor to detect particles ranging in size from a hundred micrometers to several millimeters
- This sensor has a simple mechanism and requires almost no calibration as it is essentially a digital system.
- The latest sensor model will be onboard HTV-5 and launched by H2B next year.