宇宙ダスト計測技術の研究

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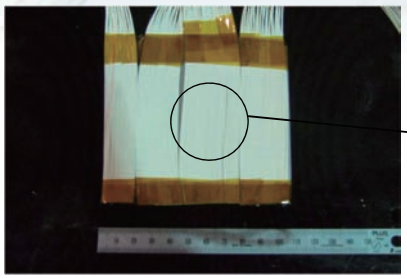
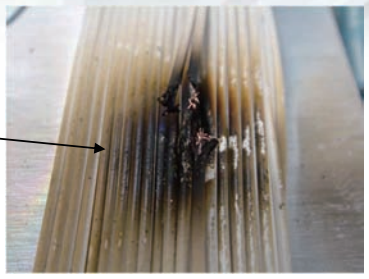
Background (1/4)

Examples of hypervelocity impact experiments on electric power harness of satellites

Power supply	Projectile material	Projectile diameter (μm)	Impact velocity (km/s)	Result
60V/2A	Al	600	3.97	sustained disruptive discharges
100V/3A	Glass	500	4.35	sustained disruptive discharges
100V/3A	stainless	300	4.01	sustained disruptive discharges



Before impact



After impact

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

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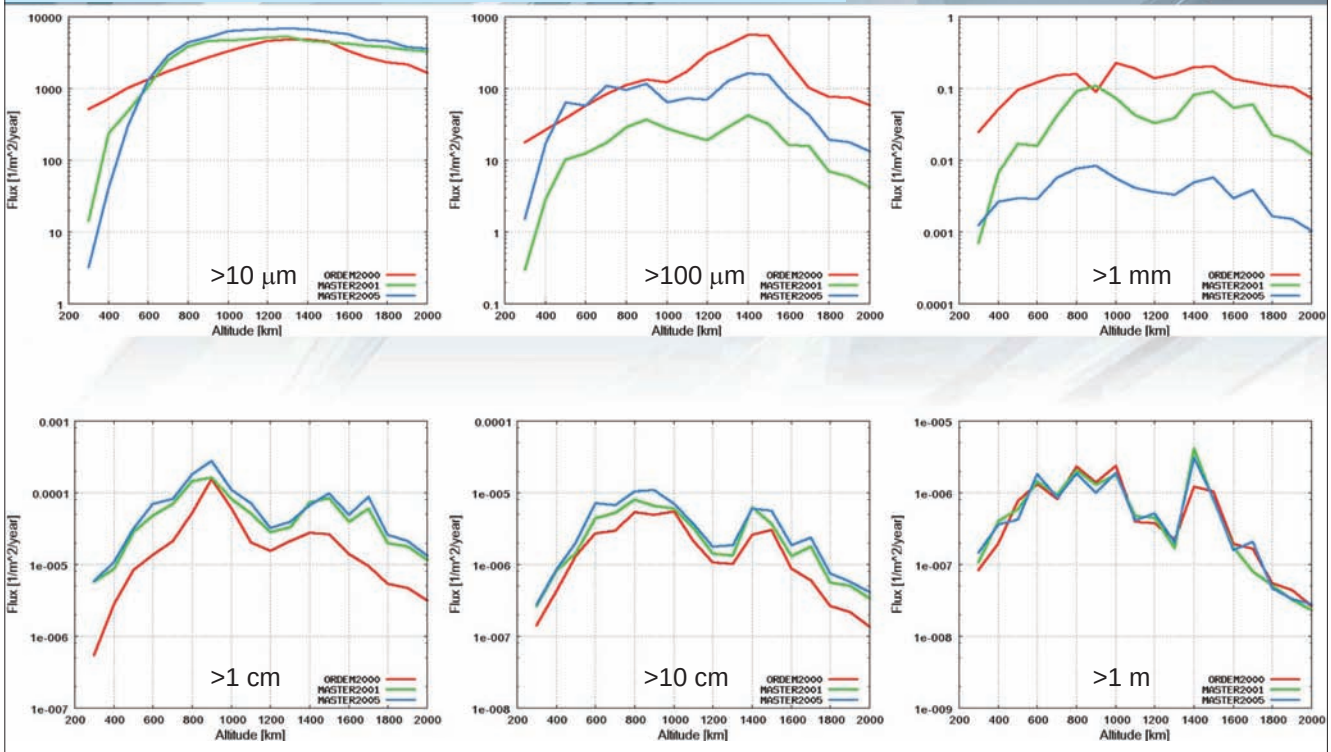
Background (2/4)

Model description ~ Inclination 100 degrees ~



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Background (4/4)

Technical issues regarding dust particles (meteoroids & space debris) of approx. 100 micrometers to several millimeters in size

1. Depending on the size, impact may damage the wire harness and other equipment
2. Space debris flux (number) for the size range not well known

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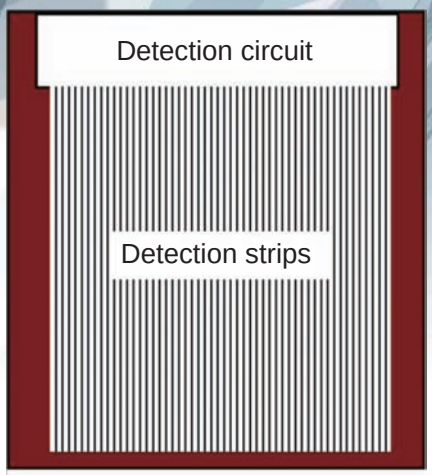
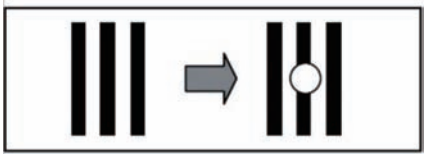
Detection principle for new type of active dust sensor (QPS dust sensor)*



(a)Detector Strips on thin film



(b) Strips severed by debris particle

Fig.1 Detector concept

Objective: To measure the dust flux for dust ranging in size from 100 micrometers to several millimeters.

QPS dust sensor**: a thin layer (film) of nonconductive material on which multiple thin, conductive strips with a fine pitch are formed.

A dust particle impact is detected when one or more strips are severed by an impact (perforation) hole.

*** QPS: Institute for Q-shu Pioneers of Space, Inc.**

*** * Patent pending**

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Study results for FY2008/09

1) Prototype models successfully manufactured.
   Strip line width: 50 μm; Pitch: 100 μm; Material: Aluminum
   Film thickness: 12.5 & 25 μm; Material: Polyimide (PI)
2) Hypervelocity impact experiments conducted on the prototypes
   Breakup signals detected.

Technical issues remaining from FY2008/09 study:
- Problems concerning design and manufacturing
- Parametric survey not performed.

Objectives for FY2009/10 study

- Improve of stability of sensor performance
- Evaluate sensor performance by hypervelocity impact experiments

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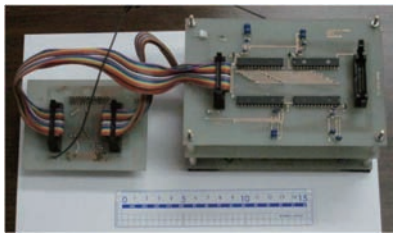
Sensor prototype (FY2008/09)

Sensor film (10 cm x10 cm)



Detection circuit unit

- **Stability during sensor performance evaluation**
  - Loss of film's terminal area progressed with time
- **Yield rates for sensor's conductive strips**
  - Up to 50 %
- **Uncertainty regarding data (severed signal) discernment**
  - Caused by use of analog circuit
- **Mass of data acquisition circuit**
  - Total mass: 470 g (without wire-harness)

Summary of improvements for FY2009/10

- Small, fine-pitch connecters are used for terminal area
- The film was divided in accordance with the width of the connecter.
- Cu coating adopted for strip line material
- Digital circuit using MUX adopted for data acquisition circuit

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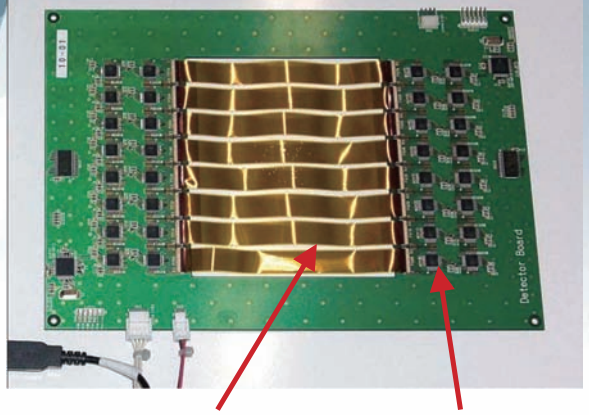
Improved prototype sensor (FY2009/10)

Sensor unit (sensor area:10cm × 10cm)



Sensor films　　Detection Circuit units

Total mass: 160g

Sensor material: Cu-coated polyimide film（t=25 μm)

Stability during sensor performance evaluation

No loss of terminal area.

Yield rates for sensor's conductive strips

100 %

Data (severed signal) discernment

Signal discernment certainly possible.

The mass of the data acquisition circuit

Total mass of sensor unit: 160 g
cf.　FY2008/09 model: 470 g
(without wire-harness)

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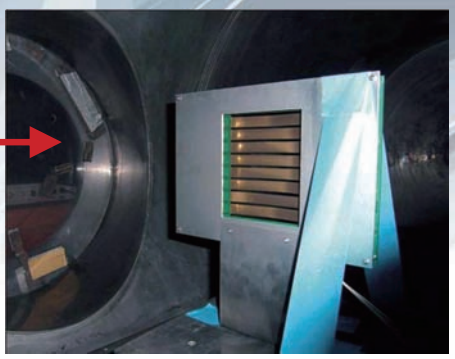
Hypervelocity impact experiments on sensor (February 2010)

Two-stage light gas gun (ISAS/JAXA)



Prototype dust sensor

Vacuum level: <5 Pa

Temperature: Room temperature

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Experimental conditions

Environmental conditions	Vacuum level (Pa)	<5
	Temperature	Room temperature
Impact conditions	Projectile material	SUS304, Glass
	Projectile diameter (μm)	50 – 516
	Impact velocity (km/s)	1.9 – 7.0
	Impact angle (°)	90 (vertical to sensor surface)

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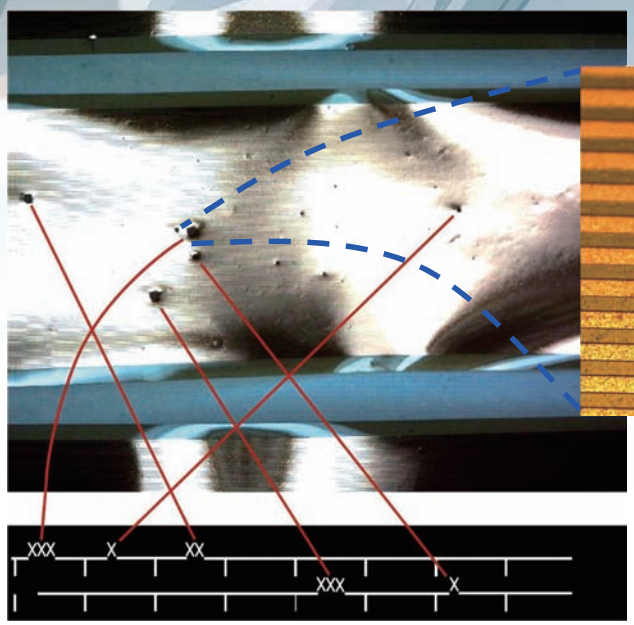
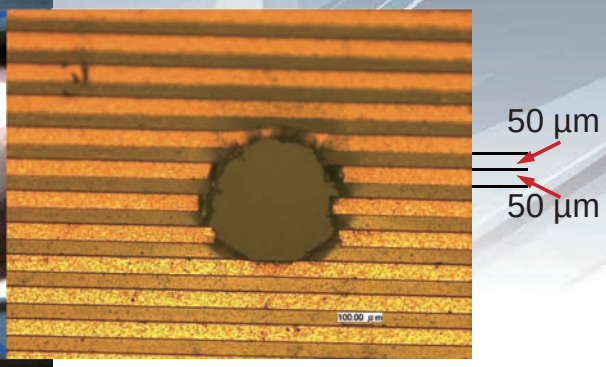
Example correspondence between signal and perforation hole



Signals of perforation holes



Example perforation hole on sensor surface

Projectile: SUS 309 μm
Impact velocity: 4.65 km/s

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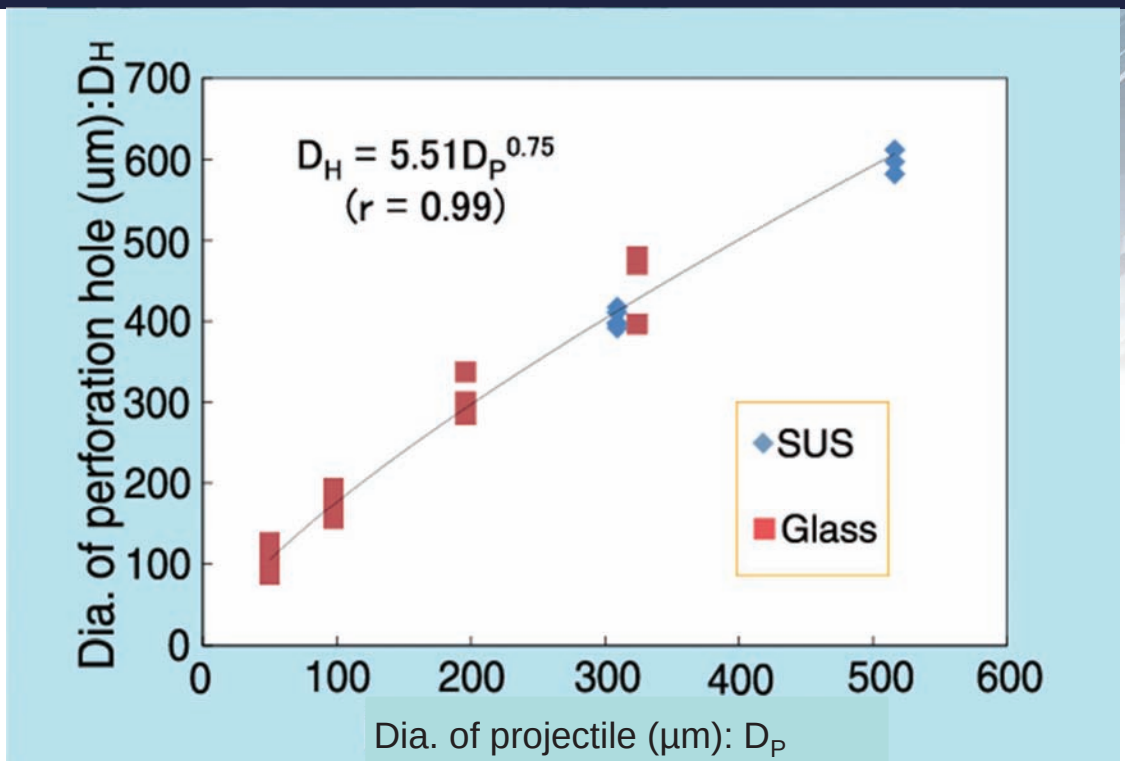
Experimental results - Projectile dia. vs. Perforation dia. -



SUS and glass projectiles travelling at 5.2–5.3 km/s

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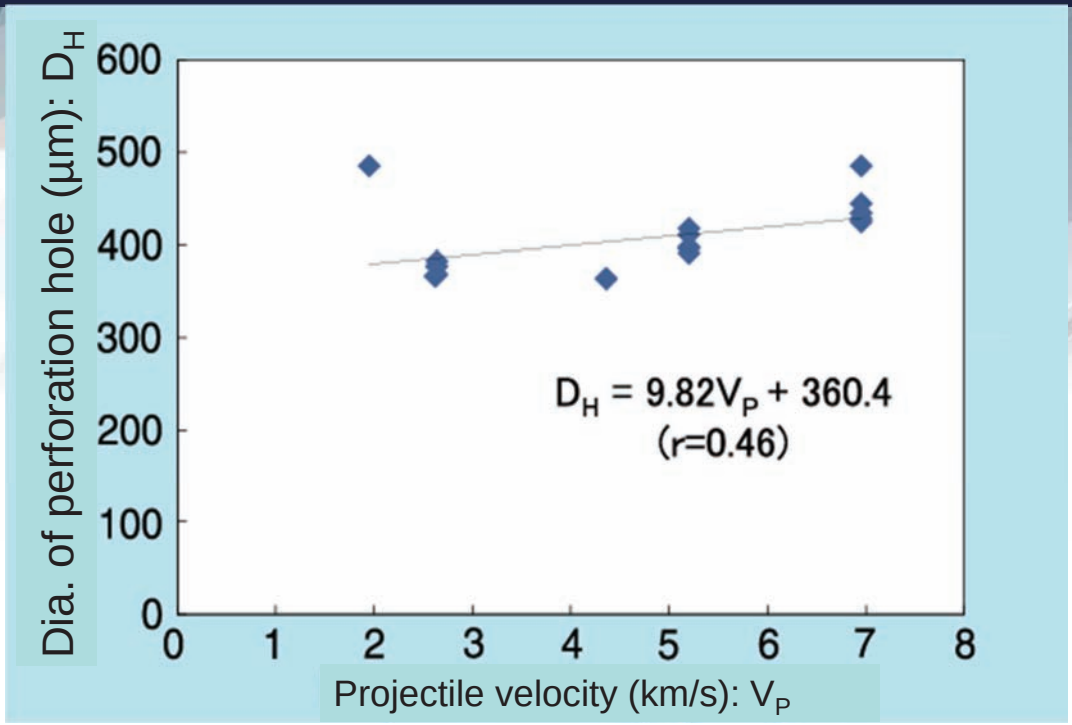
Experimental results
- Projectile velocity. vs. Perforation dia. -



SUS projectiles with diameter of 309 μm

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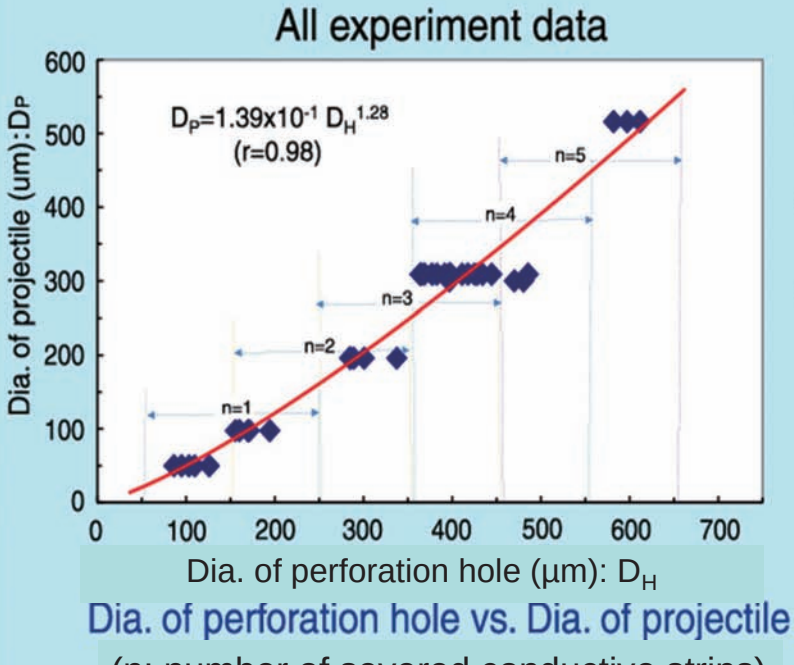
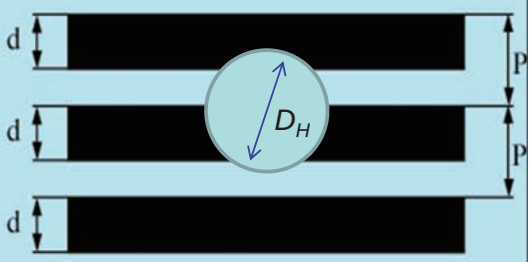
Experimental results
- All data -



Dia. of perforation hole vs. Dia. of projectile
(n: number of severed conductive strips)



$$D_{H(Maximum)} = np + d + p$$
$$D_{H(Minimum)} = np + d - p$$

D_H: dia. of perforation hole
n: number of severed strips
d: width of conductive strips
p: pitch of conductive strips

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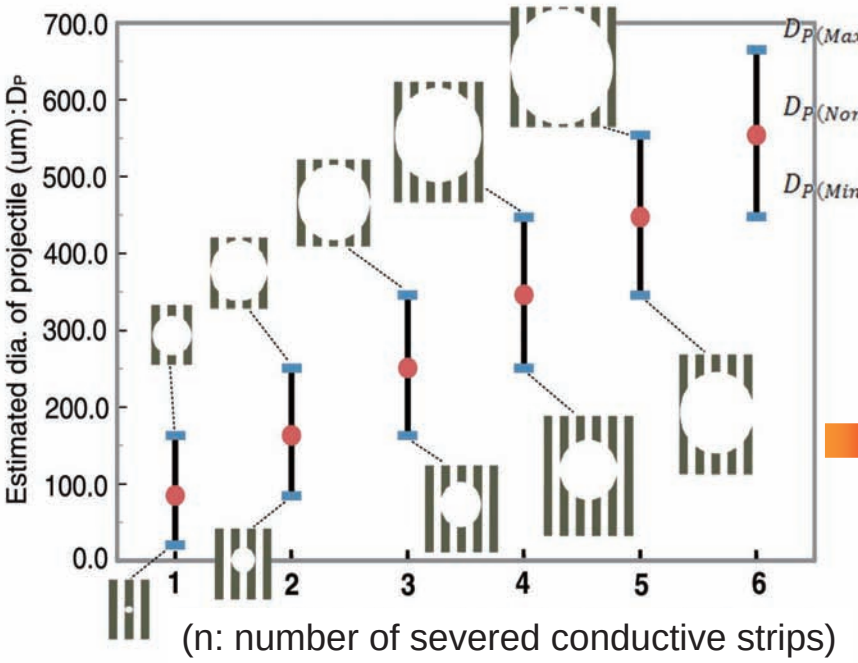
Experimental results
- All data -



(n: number of severed conductive strips)

Detection of debris size and measurement error accurately estimated.

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Study plan for FY2010/11

1. Design & manufacture a BBM model

- 1 unit are: 35 cm x 35 cm
- Space proven manufacturfe methods and parts

2. Envirment tests on a BBM model

- Thermal-strain tests

3. Conduct hypervelocity impact experiments on sensor

- Oblique impacts

4. Mission planning (case study)

- Effective measurements using small satellites

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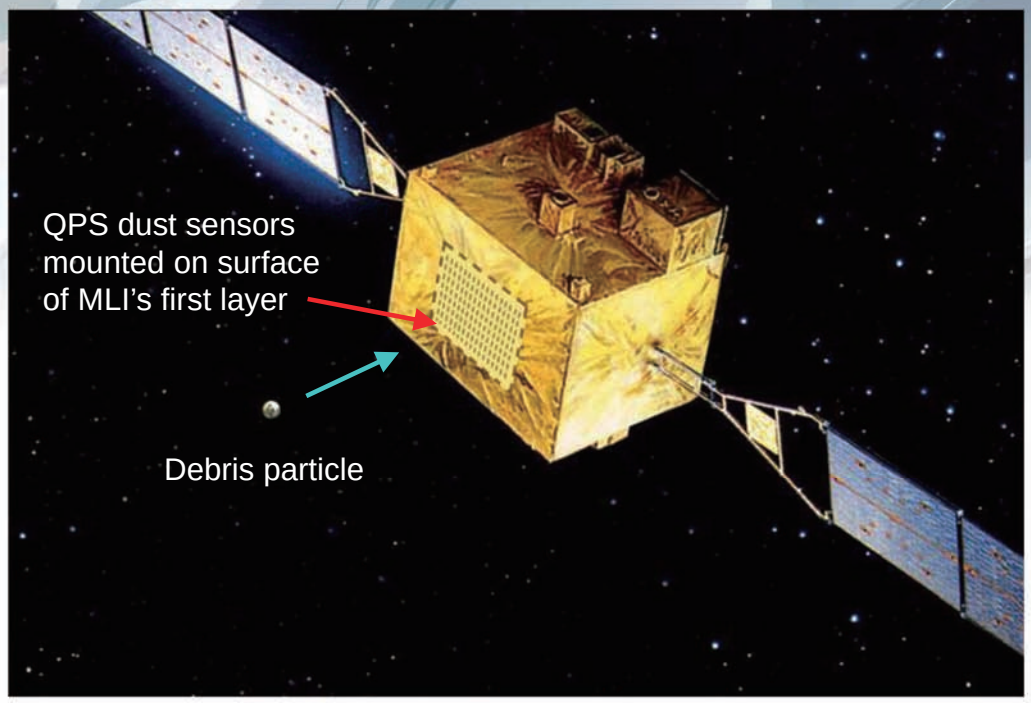
Example application on satellite



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Summary

1 Improved prototype model of QPS dust sensor successfully manufactured.

- Stability during sensor performance evaluation: Stable
- Yield rates for sensor's conductive strips: 100%
- Data (severed signal) discernment: Certainly possible
- Total mass of sensor unit: 160 g (Sensing area: 10cm x10cm)

  cf. FY2008/09 model: 470 g without wire-harness

2 QPS dust sensor performance evaluated by hypervelocity impact experiments

- Projectile diameter estimated from number of signals from severed strips .

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