IDEA: In-situ Debris Environmental Awareness

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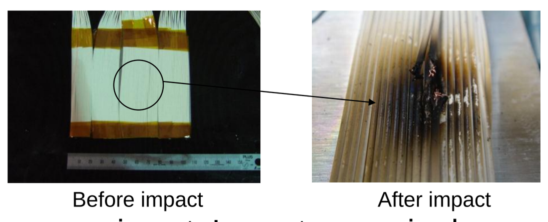
Background & Motivation

Dangerousness of Micro debris

Once micro debris collides with spacecraft, the impact would be a trigger of **critical damages** on spacecraft

- Radiator panels of STS (Endeavour and Atlantis)
- Window of the Cupola module of the International Space Station
- ADEOS-2
  - ✓ Micro debris is assumed a factor causing a solar panel failure

Micro object's impact on the window 2 of Cupola module (Ref: http://www.nasaspaceflight.com)



Collision experiment: Impact on a wire harness of satellite (Kitazawa et al., 2010)

Collisions of micro debris with spacecraft are recognized as not special events in space

➡ **Accurate comprehension of debris distribution is essential**

Debris Environment model

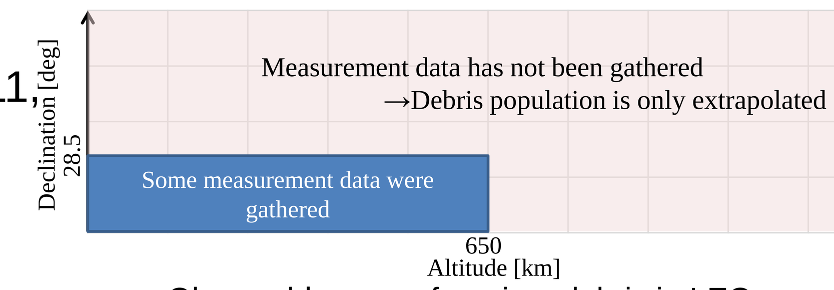
e.g.) MASTER (ESA), ORDEM (NASA)

Describe and characterize the current and future debris environment. However, those models still remain a lot of uncertainties in the micron-regime

➡ **Calibration with measurement data is fundamental**

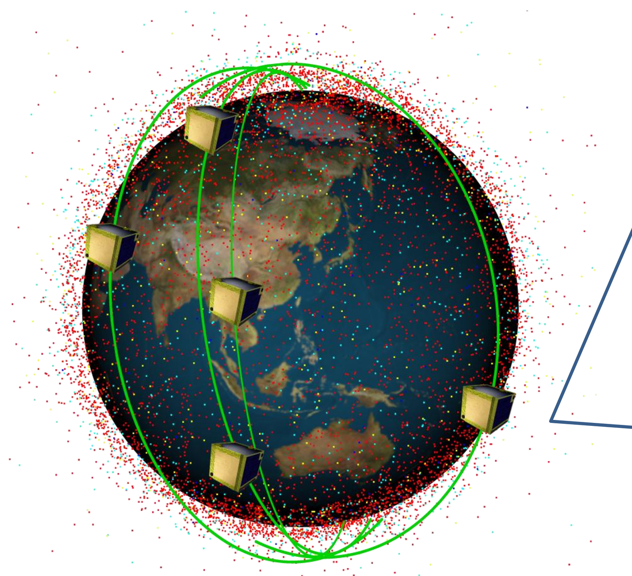
Micro debris Observation

- In-situ measurement is necessary for observation of micro debris
  - ✓ 100μm-1mm objects cannot be detected from ground
- The existing observation method for micro debris
  →Inspection of impact marks on surface on retrieval spacecraft only
  - ✓ Reveals only a time-integrated debris population during the observation
    - ◆ That means the collected data cannot tell the time and position of each debris impacts
  - ✓ Because retrieval spacecraft is captured by space shuttles, the observable space is limited in only the area that shuttle can achieve
    - ◆ The measurement data in the area > 650 km altitude and outside the 28.5° declination has not existed
  - ✓ Since space shuttles were retired in 2011, monitoring systems do not exist
  - ➢ **The accumulated data is insufficient in overall space**



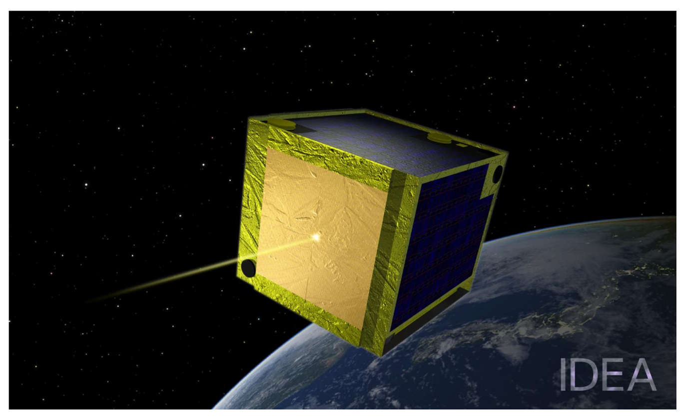
Observable space for micro debris in LEO

Mission Objectives



Objectives of IDEA project

To construct the monitoring network by a group of micro satellites(IDEA satellites)



Missions of IDEA-1

1) To demonstrate the technology for real-time measurement of micro debris impact

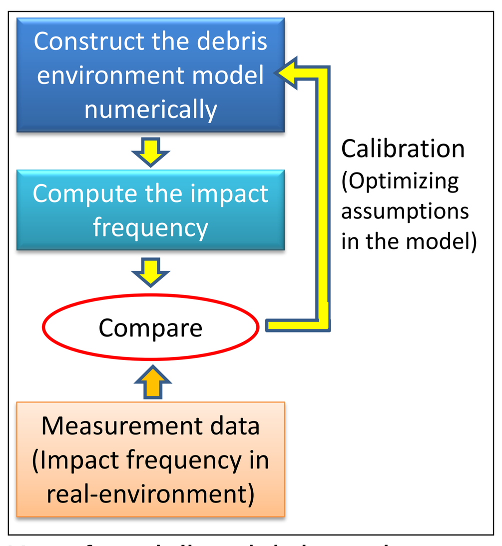
2) To detect micro debris impact, measure its debris size, record the time and location of impacts, and transmit the data in an instant

Data utilizations

Collected data by IDEA-1 contributes following utilizations

1. To validate the existing debris environment models
   - With the Poisson distribution, the collision frequency is estimated by the measurement error of population
   - Even if measurement data is only few, those data are useful to define the population threshold in the environment

2. To develop the up-to-date debris environment model
   - Debris environment model is constructed numerically
   - The model is calibrated by comparing the impact frequency between our model and measurement data
     - ➢ Optimizing assumptions in our model is continued to approach the real debris environment



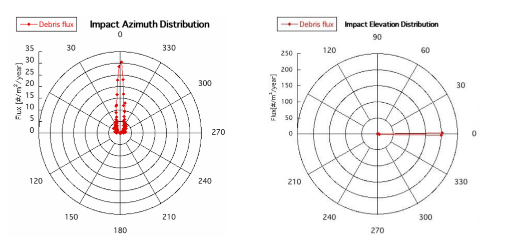
Way of modeling debris environment

3. To detect breakup events
   - Analyzing the multi-points **cluster** information makes estimating several specifications of breakup events possible
     - ✓ Breakup events generate lots of micro debris, and most micro debris grows in a **cluster** during certain period
     - ✓ Cluster can be detected only when the specific time information of impacts are clear
   - IDEA satellites can catch and transmit measurement data, so we can **immediately** recognize the fluctuation of debris environment caused by breakup events

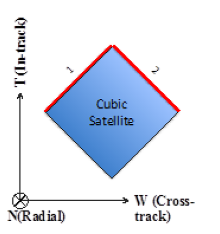
Development of IDEA-1

Orbit

- Sun-synchronous orbit, alt: 798 km
  - ✓ Debris flux is relatively high because of major breakup events:
    - the intentional destruction of the FY-1C in 2007
    - the collision of the Cosmos 2251 and the Iridium 33 in 2009
  - ✓ **65** hits (≥100μm) are estimated by MASTER-2009



Flux distributions (≥ 100μm) in terms of: (left) azimuth, and (right) elevation



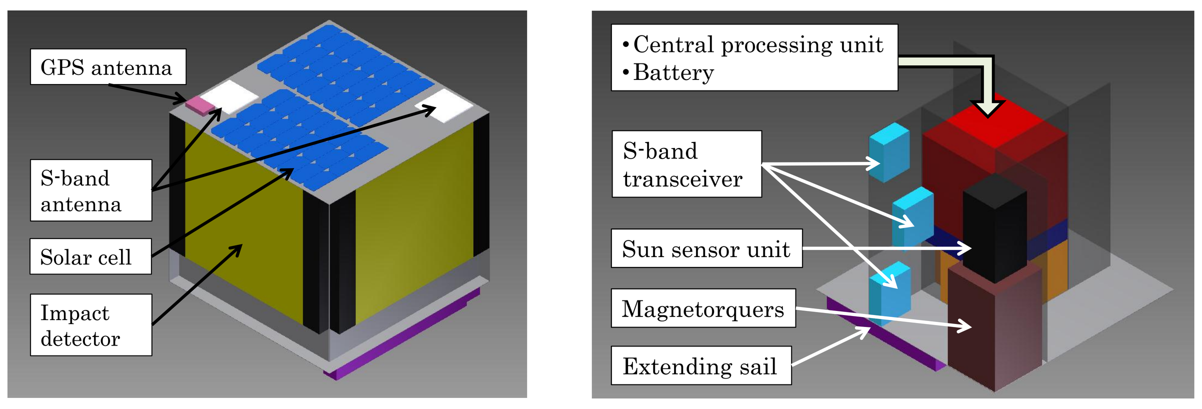
Satellite orientations relative to the ram direction

Requirement

- Installing two sheets of Dust impact detectors on neighboring side surfaces
- Keeping on exposing the detectors to the ram direction
  - ✓ According to an analysis by MASTER-2009, there is an intensive flux distribution along the ram direction in the planning orbit

Concept

- Simple design focused on the micro debris detections
- Applied well-verified technology and devices preferentially



Exterior Interior

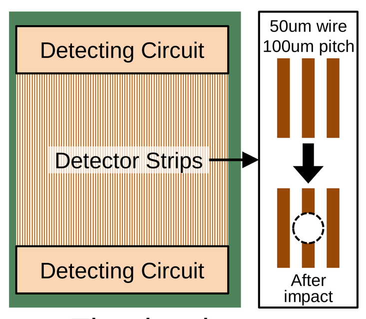
Specifications of IDEA-1

Size, Mass	50cm×50cm×50cm, 25 kg
Mission instrument	Dust impact detector
	Measuring size range: 100μm-1mm, Sensor area: 0.12 m^2/sheet × 2 sheets
Bus functions	
Command and data handling	Integrated task process architecture, Health monitoring and administration part EEPROM, GPS receiver
Attitude determination	Angular sensor: PSD sun sensor, Magnetometer Angular rate sensor: MEMS gyro
Attitude control	3-axis Magnetorquer
Power	GaAs solar cell, NiMH battery, 31.5 W (average generation), 35.8 W (peak consumption)
Communications	S-band transceiver, Patch antenna Receiver: PCM-PSK/PM, 50 W(transmission power), 2.10 GHz, 20kbps Transmitter: BPSK, 0.5 W(transmission power), 2.25 GHz, 30 kbps
De-orbit	Extending sail (35cm×4m)
Structure and thermal control	Skin-Frame structure (A5052-H32), PAF239M separation mechanism, Passive thermal control

Dust impact detector

(Mission instrument)

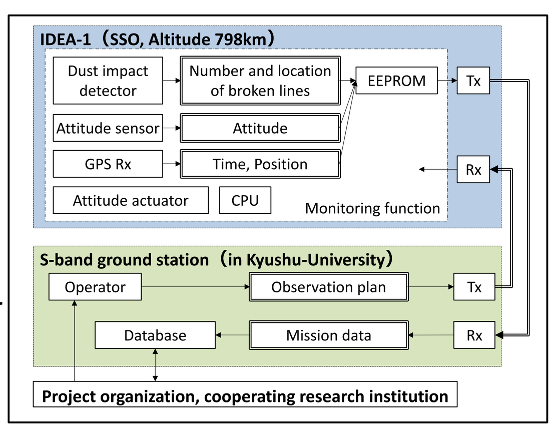
- Under developing at Japan Aerospace Exploration Agency (JAXA)
- Consisting of 350 conductive stripes being spaced on non-conductive thin film
- Detecting debris (≥100μm) impact and measuring its size within ±100 μm error
- 0.12 m^2 detective area



The dust impact detector (Kitazawa et al., 2011)

Concept of Operation

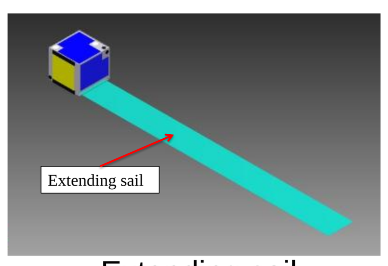
- Collecting mission data
  - ✓ Debris size, time, location of IDEA-1, attitude
- Accumulating data from IDEA-1 in database server
- ➢ This database is released to our project members and researchers who cooperate with our project



System operation diagram

De-orbit

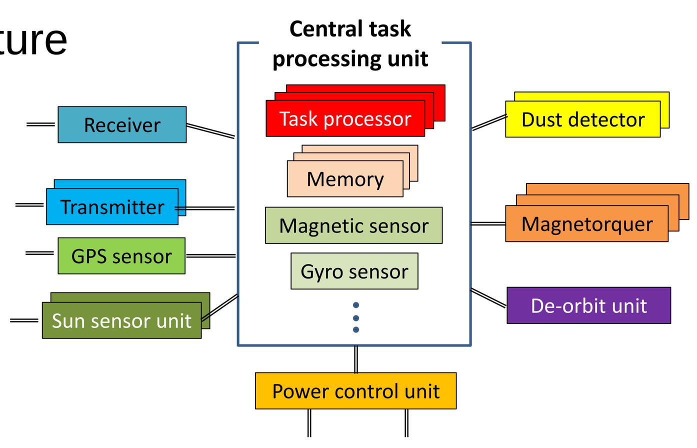
- Equipping a extending sail, in order to decay into atmosphere within 25 years after the end of operation.
- The sail enlarges own surface area at the end of mission to increase atmospheric drag
- Dimension: 0.35 m (width) × 4 m (length)



Extending sail

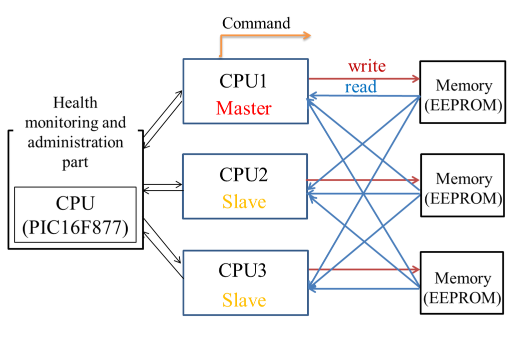
Command & Data Handling

- Integrated task process architecture
- Triple redundancy system
  - ✓ Transmitting mission data triply, and selects a data by majority voting
  - ➢ Tolerating one bit invert by Single Event Upset (SEU) on one CPU and at most two troubles of onboard CPUs for data processing



Systems diagram of IDEA-1 (Integrated task process architecture)

- Health monitoring and administration part
  - ✓ Monitoring a latch-up current in task processors
  - ✓ Transferring the authority of Master to other one Slave CPU, when some troubles occurred in Master CPU
  - ✓ Using PIC16F877, which has excellent durability for Single Event



Structure of data handling system

Implementation Plan

- Aiming to develop the other IDEA satellites every two years
- Developing a Bread Board Model (BBM) at present
- Going to accomplish FM of IDEA-1 on March, 2014

Year	2012			2013												2014		
Month	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
IDEA-1																		
Design	Detailed Design																	
Hardware	Bread Board Model						Engineering Model						Flight Model					
		Structure Thermal Model																
Software	System Design							System Testing										
			Component Testing															
Ground Station	System Design																	
	Component Testing											System Design						
Milestone						PDR						CDR						
IDEA-2																		
Design																Conceptual Design		

Top-level project schedule