Title: IDEA (In-situ Debris Environmental Awareness)

Primary Point of Contact (POC): Akira Doi

Organization: Space Systems Dynamics Laboratory, Kyushu University

Point of Contact email: a_doi@aero.kyushu-u.ac.jp

Please check the box.

☑ **We apply to Student Prize.**

☐ **Please keep our idea confidential. We disagree to publish it on the website.**

Need

For future space exploration, it is necessary to aware the micro debris (≥100μm) environment, because its impact can be trigger of a critical damage to a spacecraft. However, conventional observation for micro debris, for example, scan of their impact scars on spacecraft's surfaces, can collect the actual data in only quite limited space and integrated debris population during the observation. That is why the actual data of micro debris environment is insufficient, and it is needed to construct the novel monitoring system by micro satellite's network.

Mission Objectives

The IDEA project intends to deploy a group of small satellites which measure debris impacts on their own, and transmit the information in real-time. The first satellite, IDEA-1 is supposed to fulfill the three missions as follows;

1) To demonstrate the technology for real-time measurement of micro debris impact
2) To measure micro debris flux continuously
3) To detect debris cluster which can be generated by breakup event

Mission 1 aims to succeed in keeping IDEA-1 on line to ground station, controlling the attitude to measure micro debris successfully, detecting the micro debris, and transmitting the mission data. This demonstration would activate the observation of micro debris environment.

Mission 2 aims to measure the micro debris flux from its number of impacts using eq. (1).

$$q = \frac{k}{At} \tag{1}$$

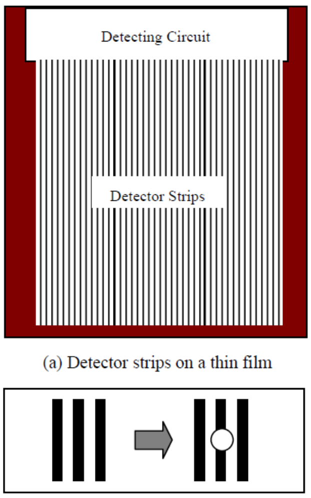
Here, k, q, A, and t are the number of impact, flux, sensor area, and measurement duration, respectively. By using some actual date of real orbital environment, the distributional population models of micro debris are constructed [1)2)]. Then, the modeled distribution is refined through the process of fitting the modeled debris flux to the actual flux. In this time, according to the fact that the actual flux value can be obtained statistically because the number of debris impact follows a Poisson distribution, this fitting process is proceeded by evaluations of the magnitudes of error [3)]. However, because the accuracy of micro debris environmental models partly depends on quantity of actual flux data, IDEA can contribute to improve them by acquiring a lot of flux data in orbits, especially > 600 km altitude region where exists particularly insufficient actual data. Moreover, differ from the conventional method estimating only accumulated impact rates, acquired time and position data of impacts are expected to build the novel method of modeling micro debris environment.

Mission 3 aims to detect the debris cluster. Major break-up events are predicted to occur about once every five years [4]. Generally, such events generate lots of micro debris, and most of them would be a cluster for a certain period. Thus, analyzing the multi-points information about the cluster is expected to enable the detection of breakup events.

Concept of Operations

The dust impact detector can detect micro debris impacts, and is under development at Japan Aerospace Exploration Agency [5]. As shown in Figure 1, a sheet of the impact detector consists of 350 conductive lines of width 50 μm spaced with 50 μm, forming a film on a nonconductive material. The size of debris can be estimated within ±100 μm error according to the number of changes of the on-off switch for each wire during an impact. The effective sensor area on a sheet is about 0.12 m^2 (0.35m ×0.35m).

IDEA-1 is supposed to be put into a sun-synchronous orbit with an altitude of 798 km, where the assessment of the micro debris is highly required. Figure 2 depicts the overview of system operation. The detector obtains the number and location of broken lines. In addition, the time and IDEA-1 position given by GPS are also obtained. Then, those data are transmitted to ground, and accumulated in database. This database is released to our project members and researchers who cooperate with our project.



(a) Detector strips on a thin film

(b) A strip is severed by a debris

Figure 1 The concept of the dust impact detector [3]

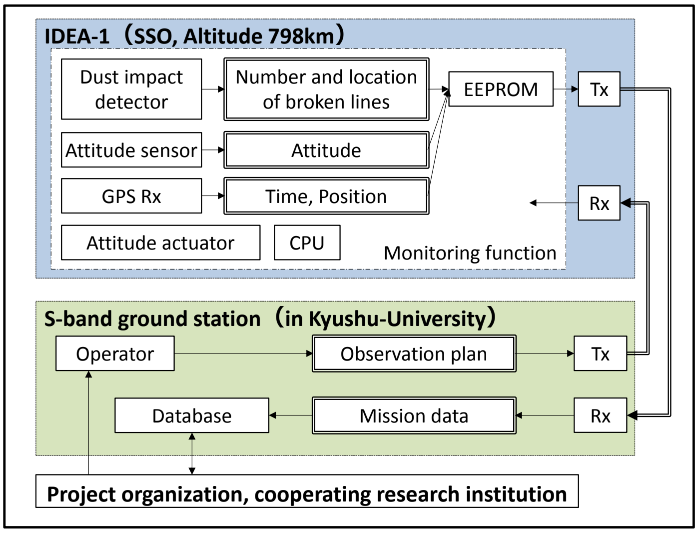


Figure 2 Overview of system operation diagram

Key Performance Parameters

Figure 3 depicts the predicted flux distributions in the planning mission orbit by MASTER-2009, which is the debris flux model developed by European Space Agency. Figure 3 shows an intensive flux distribution along the ram direction. Therefore, we design IDEA-1 installed with two sheets of impact detectors on neighboring side surfaces, and keeping on exposing the detectors to the ram direction as Figure 4 depicts.

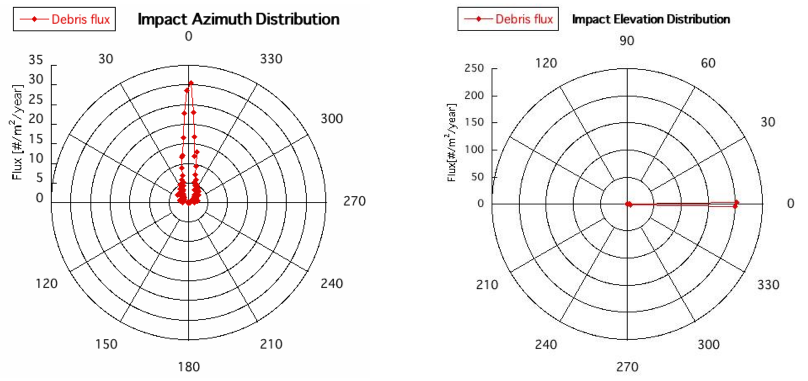


Figure 3 Flux distributions (≥ 100μm) in terms of: (left) azimuth, and (right) elevation

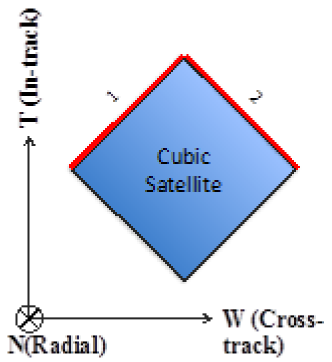


Figure 4 Satellite orientations relative to the ram direction

The number of debris impact depends on the entry angle of debris to the each surface. In order not to change the impact number a year, it is required to control the attitude within ±6°. The big feature of our project is to observe the debris environment in real-time. Thus, it is defined to transmit mission data within 24 hours since measuring debris impact.

Space Segment Description

The concept of IDEA-1 is a simple design dedicated to monitor the micro debris environment, so well-demonstrated technology or equipment is applied preferentially. The IDEA-1 is 50 cm^3 size and 24.3 kg weight micro satellite, and its outer and inner structures are shown in Figure 5. The specifications of IDEA-1 are listed in Table 1, and these components are installed inside the windmill structure depicted in the right illustration of Figure 5. Next, Figure 6 describes the system diagram of IDEA-1. The command and data handling subsystem is working in the integrated process architecture. IDEA-1 is equipped with deployment sail to comply with the so-called 25-year rule, which recommends that a satellite in the LEO region should decay into atmosphere within 25 years after the end of operation.

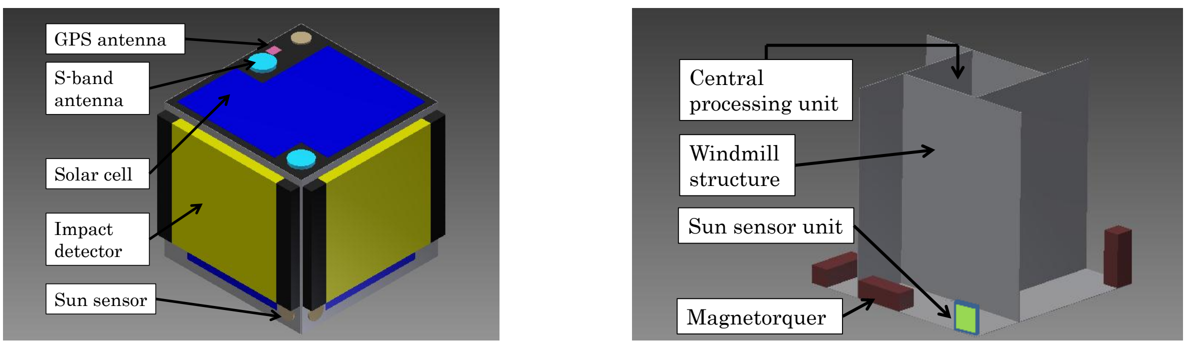


Figure 5 Structure of the IDEA-1 (Left: Outer, Right: Inner)

Table 1 Specification of the IDEA-1

Size, Mass	50cm×50cm×50cm, 24.3 kg

	Space Systems Dynamics Laboratory, Kyushu University
Mission instrument	Impact detector Measuring size range: 100um-1mm, Sensor area: 0.12 m^2/sheet × 2 sheets
Bus functions	
Command and data handling	Integrated task process architecture, Health monitoring and administration unit EEPROM, GPS receiver
Attitude determination	Angular sensor: PSD sun sensor, Magnetometer Angular rate sensor: MEMS gyro
Attitude control	3-axis controller: Magnetorquer
Power	GaAs solar cell, NiMH secondary battery, 31.5 W (average generation), 35.8 W (peak consumption)
Communications	S-band transceiver, Patch antenna
De-orbit	Deployment sail (35cm×4m)
Structure and thermal control	Skin-Frame structure (A5052-H32), PAF239M separation mechanism, Passive thermal control

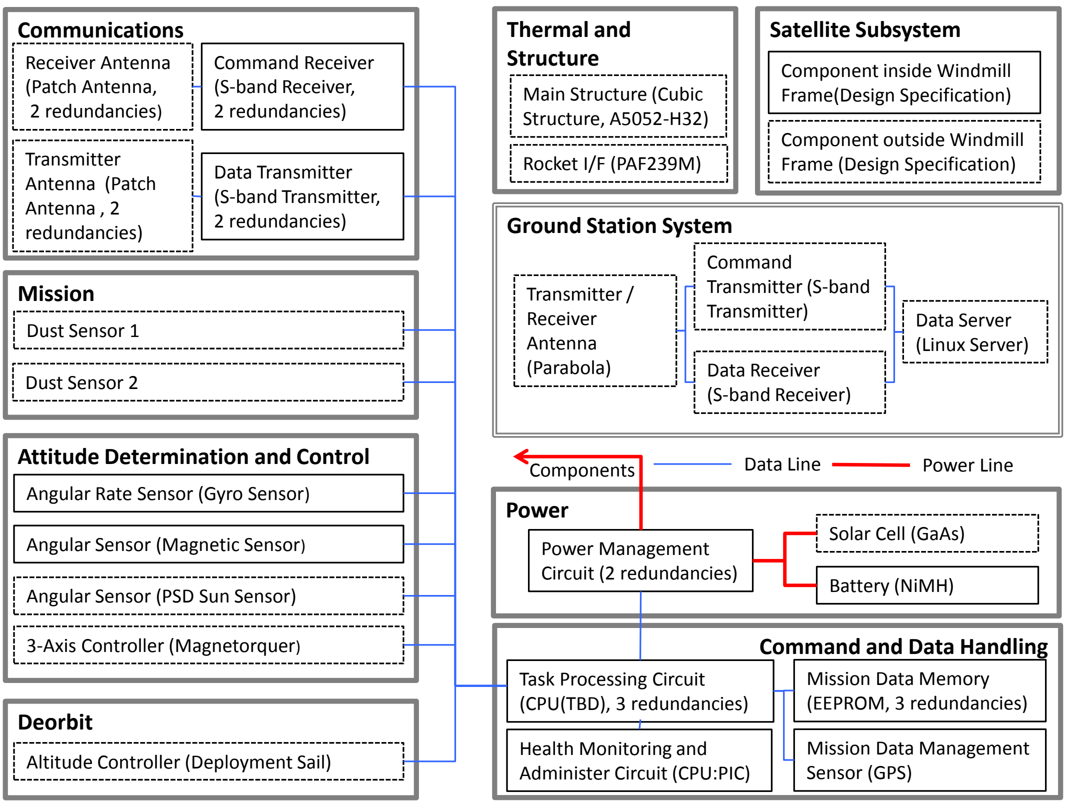


Figure 6 System diagram of IDEA-1

Orbit/Constellation Description

For IDEA satellites, including IDEA-1, planning orbits and flux values analyzed by MASTER-2009 are described in Table 2. In these orbits, the actual data is insufficient, and debris flux is relatively high because major breakup events occurred near their regions in 2007 and 2009. Moreover, we have some opportunities shown in Table 2 of piggy-back launching with JAXA's GCOM or ALOS satellites series in the corresponding orbits. With these oppetunities, the monitoring network can be constructed via IDEA satellites in different orbits.

Table 2 Planning orbits and flux values

Initial value of orbit elements			Flux	Parent
Semi-major axis [km]	Eccentricity	inclination [deg]	[#/m²/year]	satellite
7178	0.0	98.6	420.3	GCOM-C1
7078	0.0	98.2	310.3	GCOM-W2
6998	0.0	97.9	175.5	ALOS-3
7178	0.0	98.6	420.3	GCOM-C2

Implementation Plan

IDEA project is organized by Space Systems Dynamics Laboratory in the Kyushu-University. Students in the laboratory are in charge of the design, development, and operation of IDEA satellites. Components are produced by local companies which have experience to produce satellite's components. For IDEA-1, 45 million yen developing cost, 1 million yen testing cost, and 3 million yen operating cost are estimated. Thus, the total life cycle cost for IDEA-1 is about 49 million yen. IDEA-1 needs the S-band ground station facility. Our BBM plan is 10 months, EM plan is 5 months, and FM plan that is upgraded from EM is 4 months. Finally, IDEA-1 is planningto be launched in 2014. We consider the following 5 project risks.

- There is possibility to be rejected from piggy-back launch opportunity which we aim.
- The schedule of development is depended on the schedule of the primary satellite.
- If deployment sail is not extended accidently, IDEA-1 would stay in orbit about 100-years, and conflict with 25-year rule.
- If more than 350 lines of the detector are broken, the detecting performance becomes less than 50 %.
- Because main member of IDEA project are changeable laboratory students by graduation, it is impossible same member to be dedicated in whole span of all satellites operations.

References

1) Liou, J-C., *et al.*, "The New NASA Orbital Debris Engineering Model ORDEM2000," 2002, NASA/TP-2002-210780.
2) Oswald, M., *et al.*, "The MASTER 2005 Model," In: Proceedings of the Fourth European Conference on Space Debris, 2005, pp.235-242.
3) Yasaka, T., "Space Debris Protection: A Standard Procedure in Future?," Acta Astronautica, Vol.53, pp.527-531, 2003.
4) Toshiya H., *et al.*, "Orbital Debris Modeling at Kyushu University," The Journal of Space Technology and Science, Vol. 24, No. 2, pp.23-35, 2009.
5) Kitazawa, Y., *et al.*, "Status Report of Development of Development of a Sensor for In-situ Space Dust Measurement," The 28th International Symposium on Space Technology and Science, 2011-r-11, Okinawa, Japan, 07, June, 2011.