

B4

デブリ除去プロジェクト立上げとビジネスへの展開

Promoting the Active Debris Removal Project on Business

SJAC 次世代プロジェクト推進委員会
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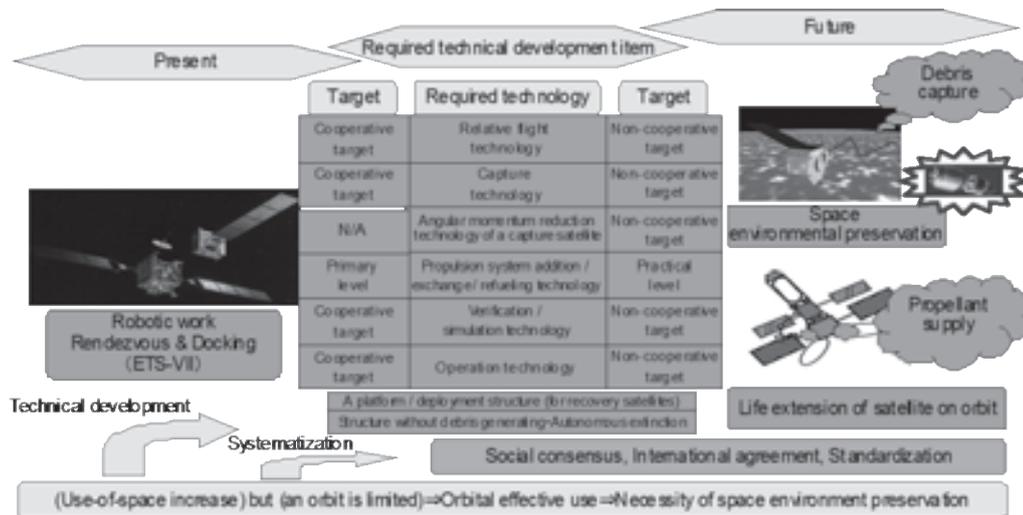
Committee for Next-generation Space Project Promotion,
The Society of Japanese Aerospace Companies (SJAC)
co-chairman Masaya Mine (NEC)

現在、宇宙環境は、新たに衛星を打上げなくても、軌道上に存在するデブリのみでデブリ増殖される状態となっている。一方、人類は、宇宙からの観測、通信、測位等々、宇宙環境を利用することで豊かな生活を送ることに慣れてしまっている。従って、未来永劫、宇宙環境を利用出来るという状態は、維持さねばならない。

このことから、少なくとも、現有の軌道上デブリを除去することが必須となる。

SJACでは、2006年から、この軌道上デブリをアクティブに除去するプロジェクト立上げの検討を行って来た。当然の事ながら、このプロジェクトは一過性ではない実用プロジェクトであることから、ここには、誰がどう言う形で行い、実施するためのお金をどの様に導出していくかの検討も含んでいる。

実現のために設定した 7 つのアクションの実施状況をチェックするとともに、これを加速する必要があることを述べる。



Road Map for the Active Debris Removal System

Promoting the Active Debris Removal Project on Business

January 22nd , 2013

Committee for Next-generation Space Project Promotion,
The Society of Japanese Aerospace Companies
(SJAC)

Co-chairman Masaya Mine (NEC)

Propositions

■ Facts about space environment

- ① Even if we don't perform new launches, debris that have already been on the orbit will grow to bring about an unusable condition of the space (the results of analysis coincide in many countries and regions such as Japan, the USA, Europe and Russia).
- ② Human beings want to keep using the space environment because of convenience and usefulness of using the space for earth observation, communication, global positioning, etc. (trivial)

⇒ We need to eliminate debris located on the orbit.

■ Implementation status of debris removal analysis

- ① Many countries analyzed the relationship between the state of on-orbit debris and the active debris removal which will have removed five ,ten, or more life-ended satellites per year in early 2020s.

Start up a debris removal business in early 2020s!

What we must do to achieve our goal

- ① Building of international consensus at legislative level, if possible
Authorize a business to remove debris on a global basis by 2020 (Is it positioned as a global public project?)
- ② Having an ability as project promoter
Work to ensure the preferable position of Japan at the time of launch of the debris removal project

Japan should play the role in above 2 actions.

- ①⇒ Implementation at the initiative of Japan
(Bilateral negotiation to multilateral negotiation)
- ②⇒ Verification of technological/business (cost) appropriateness of the project through demonstration

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Summary of necessary actions

- In the investigation report on space debris for FY 2006/2007, SJAC explained the necessity of the following actions.
 - ① Spread into general ideas
 - ② Recommendation of Japan to United Nations/Committee of the Peaceful Uses of Outer Space
 - ③ Adoption of appropriate ISO standards and business model which is advocated by Japan
 - ④ Setup of a space environment preservation body by Japan
 - ⑤ Validation of debris removal satellite by Japan
 - ⑥ Japan's idea of debris observation
 - ⑦ Establishment of backup think tank and materialization of the above ① to ⑥.
- By *realizing these as a national strategy*, we would like to achieve *the global industrialization launched by Japan* that leads the world.

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Consideration status of the current state

① Spread into general ideas (△)

- In 2008, Yomiuri Shimbun wrote the article about the necessity of active removal of debris and its business model (industrialization model). However, the boost was within the level of impulse at that time. The boost of the A-SAT coverage of China after that was also within the level of impulse.
- In 2009, IRIDIUM-33 and Russian satellite COSMOS-2251 collided against each other on the orbit. Mass media reported that there was an actual possibility of collision of satellites and debris rapidly increased as a result of such an accident.
- Within the theme of global environment, a TV program (NTV: Sho Sakurai appeared) covered that not only the earth but also the outer space had been contaminated (a remark by Mr. Mohri).
- Although there were some coverage by media on robot/debris removal after that, they mainly focused on technical appeal. Understanding of Japanese people about the necessity and the appropriateness of debris removal has not been obtained yet.
- To spread this issue into the general public, not a impulsive coverage but a continuous one is required. We should promote it as part of the (global) environment problem.

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Consideration status of the current state

② Recommendation of Japan to United Nations/Committee of the Peaceful Uses of Outer Space (COPUOS) (△)

- At a subcommittee meeting within IADC held in 2009, the necessity of ODR (orbital debris removal) was discussed. The sub-committee decided to formally discuss the theme as IADC starting from the next meeting.
- Although it was at the initiative of the USA, the first international conference related to the issue was held in December, 2009. Japan also participated in the conference to make three reports. They reported that not technological feasibility but also a business model (an industrialization model) had been considered in Japan.
- The report on discussion at the meeting hosted by McGill University in Canada was submitted to the United Nations Scientific and Technical Subcommittee and registered as a United Nations Document (see next page: McGill Declaration).
- Since 2011, the international best practices/guidelines have been reviewed at the UN COPUOS/Scientific and Technical Subcommittee/Space Activity Long-term Continuity Workshop/Specialist Meeting “B” (space debris, space operation and space state recognition) and the description has been drawn up to the necessity of ODR. Specific consideration of ODR will be done in the future, including the decision about whether the description of ODR is drawn up or not.
- We will not be able to achieve our initial goal unless we play at least a central role in advancing the above UN-related activities.

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Consideration status of the current state

- McGill Declaration on active space debris removal and on-orbit satellite servicing (November 2011)
 - Discussion on the following subjects had been made at the meetings hosted by McGill University in Canada over three years: the current state and the problem of debris in the first year, reduction of debris in the second year and removal of debris and its implementation structure in the third year. The results were compiled in the report, which was submitted to the United Nations Scientific and Technical Subcommittee. After being published at the meeting, it was registered as a United Nations document. Details of the report are as shown below.
 - To promote the removal of debris and on-orbit services, United Nations and international organizations should work to improve not only the responsibility for space activities but also international treaties to address especially control right and control over objects in the outer space.
 - National governments and international organizations should consider the legislative and regulatory mechanism and process to promote debris removal.
 - They should also consider establishing an international fund to support debris removal.
 - We should promote the international obligations of registering space objects and international recognition of the control right about them. 7

Consideration status of the current state

- ③ Adoption of appropriate ISO standards and business model which is advocated by Japan (△)
 - Except for on-orbit debris removal (ODR), the work to create ISO standards for debris mitigation have advanced.
 - As to the debris treatment including ODR, a business model considered by SJAC (and published at ISTS in 2008) was introduced at ISO Conference in 2008 but there has been no progress on this issue.
 - About consideration of business model and how to raise fund ...
 - (Plan 1) Collect money depending on the level of responsibility for generating debris in the past
 - (Plan 2.1) Collect money in the form of something like space environment utilization tax (Allocation simply depending on the volume)
See Slide No.9
 - (Plan 2.2) Collect money in the form of something like space environment utilization tax (Allocation based on debris index)
See Slide No.10
 - As an implementation body, "Collect money as an international public work company" or "Only perform coordination in the form of international coordination body" (See Slide No.11)

Consideration status of the current state

Tradeoff of fund raising methods

Proposed plan (Note 1) (Note 3)	Overall judgment	Fairness	Transparency/Verifiability	Comment
Uniform rate across all countries	×? (Note 4)	×? (Note 4)	○	This plan is in favor of advanced countries and those that highly utilize the space. Developing countries may be opposed to it. <i>Also to be considered from the viewpoint of (Note 4)?</i>
Rate in proportion to price	○	○	△	Is it difficult to ensure transparency of price?
Rate in proportion to the number of launched rockets	○	△	○ (Note 2)	We can check it with the ground debris observation network.
Rate in proportion to weight/size	○	○	△ (Note 2)	We can check the size, etc. with the ground debris observation network.

- (Note 1) The above ratios are those taking into account of carrier rocket and satellite.
- (Note 2) Although these values are based on notifications, we can validate those for objects with shape as we can observe them from the ground.
- (Note 3) The space environment is the common resource given to all nations. Collect money from a viewpoint of utilization tax (cf: Land use)
- (Note 4) The USA and European countries provided data from the debris observation net. Is it possible to make a balance with the facilities maintenance expense?

Consideration status of the current state

Numerical example of debris index (Yasaka, 2009, 2011)

If one Collision Avoidance (CA) maneuver is performed.

$$I_{DEB} = \alpha M \cdot A \cdot F(h) \cdot \epsilon_{AVOI} \cdot T_{orb}$$

If multiple CA maneuvers are performed.

$$I_{DEB} = \alpha M \cdot A \sum_i F(h_i) \cdot \epsilon_{AVOI,i} \cdot T_{orb,i}$$

Where,
 αM : Number of fragments created by mass M of object (ex. spacecraft, rocket body, etc.)
 A: Cross sectional area of the object
 F(h): M&D flux at altitude h
 T_{orb} : Orbital life of the object

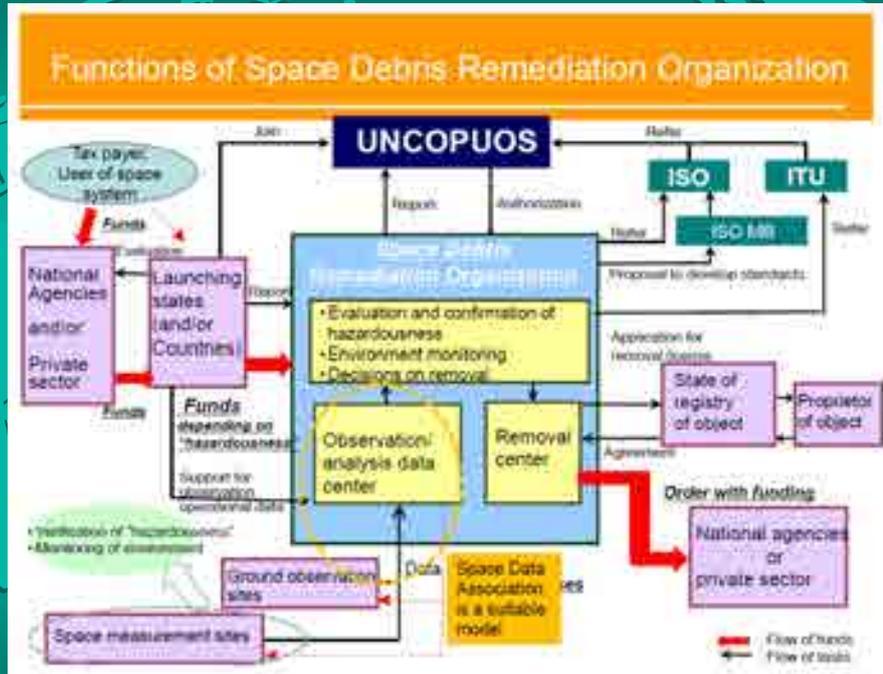
Satellite Type	α 1/kg	Altitude km	Flux 1/year/m ²	Orbital Life year	Mass kg	Area m ²	Debris Index	
							w/o CA	CA
Typical SSO Sat	30	800	10 ⁻⁴	25	800	4	269	27
Typical GEO Sat	3	36000	10 ⁻⁶	10	2000	10	0.6	0.1
Object in SSO	30	800	10 ⁻⁴	100	2000	10	6000	N/A
Small Sat	30	800	10 ⁻⁴	25	50	0.25	0.9	N/A
Cube Sat	30	800	10 ⁻⁴	25	1	0.01	0.001	N/A

Fragments/Flux considered > 1cm
 Tentative Assumptions

$\alpha = 30(\text{LEO}), 3(\text{GOE})$ $\epsilon_{AVOI} = 0.1$
 $F(800) = 10^{-4}(\text{1year/m}^2)$ $F(36000) = 10^{-6}(\text{1year/m}^2)$

W/O CA: No CA maneuvers
 CA: 10 CA maneuvers

Consideration status of the current state



Kitazawa, "Organizational and Operational Requirements for Space Debris Remediation", International Interdisciplinary Congress on Space Debris Remediation, 2011, McGill University

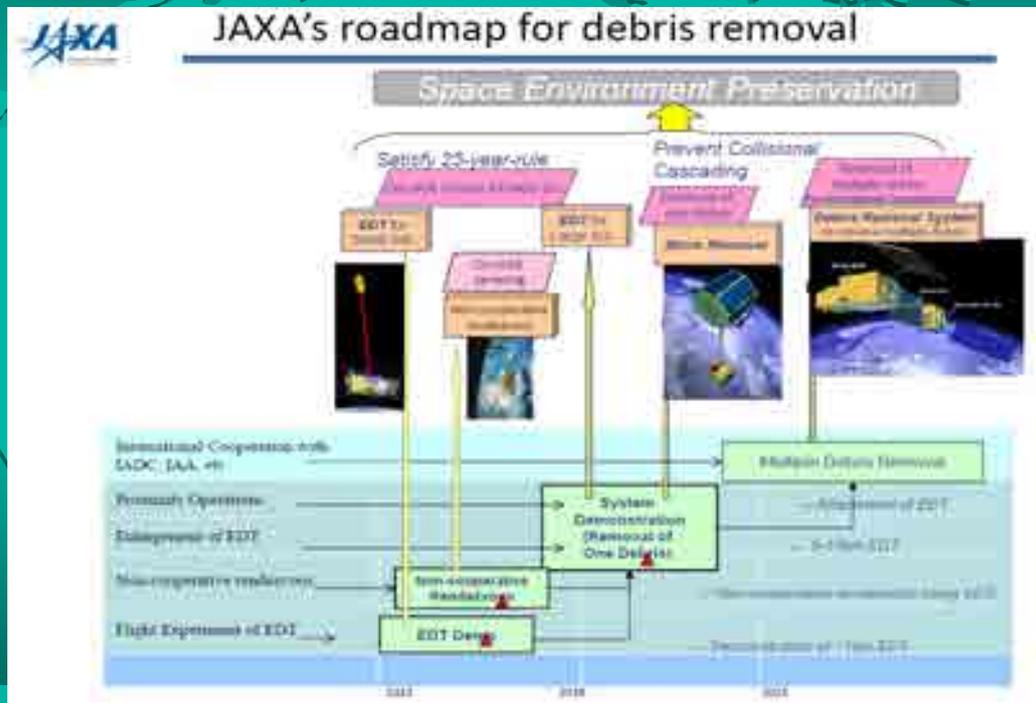
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Consideration status of the current state

- ④ Setup of a space environment preservation body by Japan (×)
 - We have not got into action yet.
- ⑤ Verification of debris collection/recovery satellite by Japan. (△)
 - JAXA has started the feasibility study for realizing this project to support SJAC.
 - They created the roadmap including on-orbit verification for debris removal. (See next slide)
- ⑥ Japan's idea of debris observation (△)
 - We are considering various issues including its positioning such as to what extent we have to make observations. We also study how far we can go using existing facilities of JAXA only.
- ⑦ Establishment of backup think tank and materialization of the above ① to ⑥ (×)
 - We have not achieved yet.

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Consideration status of the current state



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Development status of the World and Japan related to this issue

■ What has the world done?

- Has started to take actions proactively since around 2007
 - DARPA / Orbital Express Mission
 - DLR / DEOS
 - NASA / GEO Supersync
 - NASA / Robot and Humans in HEO
 - MDA / Space Infrastructure Servicing

■ What has Japan done?

- No study has been made since Japan succeeded in making an on-orbit verification with ETS-VII in 1997.

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Development status of the World and Japan related to this issue



Orbital Express Mission of DARPA

- Orbital Express is a technical verification satellite aiming to provide unattended services including fuel supply/parts replacement to an on-orbit satellite that DARPA have worked on development. It was launched in March 2007 and succeeded in the verification experiment.
- It is composed of ASTRO (Autonomous Space Transport Robotic Operations), a parent satellite which provides unattended services, with mass of 700 kg, an NEXTSat/CSC, a client satellite which receives services, with mass of 226 kg. Although they were coupled at the time of launch, they were separated after having been placed on the orbit.
- We conducted a rendez-vous docking to NEXTSat, fuel supply, a device replacement experiment and a capture experiment.
 - All of the above were conducted with ETS-VII more than ten years ago.



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Development status of the World and Japan related to this issue



DEOS project of DLR

- DEOS project of DLR is a technology verification project to control on-orbit disposals of nonfunctioning satellite. It also aims to acquire technologies to successfully conduct on-orbit maintenance (especially fuel supply).
 - Conducted Phase-0 study in 2007, Phase-A study in 2008 and Phase-B study in 2010.
- DEOS is a system composed of two satellites, "Client" and "Servicer." The two satellites are launched at the same time to be placed on an orbit at the height of 550 km. According to the current plan, it is scheduled to be launched in 2018.
- On September 13, 2012, DLR awarded Astrium GmbH the management contract for the entire system in the DEOS definition phase (the final design phase before the hardware creation stage). The contract is the value of approximately 13 million Euros for one year.

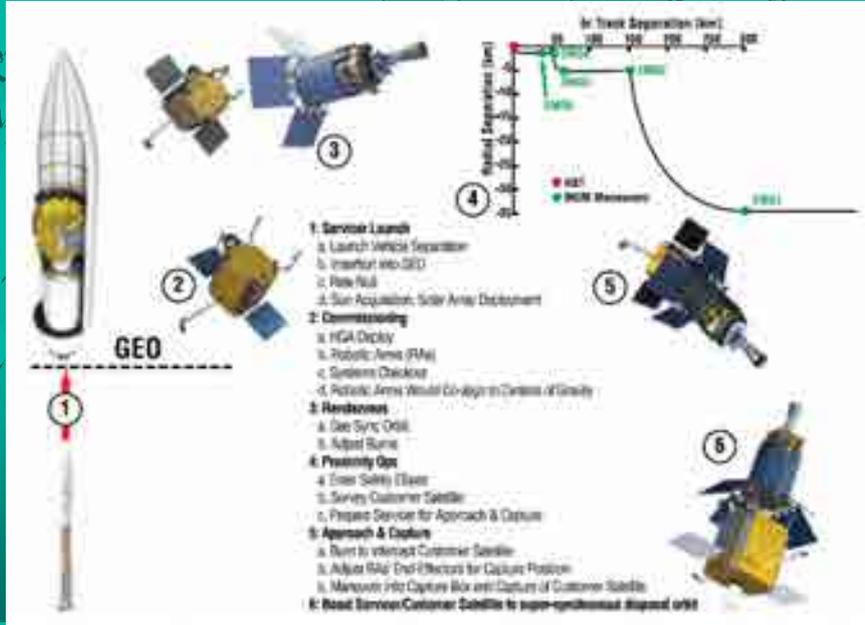


Credit: Astrium

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Development status of the World and Japan related to this issue

NASA: GEO Supersync



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Development status of the World and Japan related to this issue

NASA: Robot and Humans in HEO



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Development status of the World and Japan related to this issue



SIS (Space Infrastructure Servicing) of MDA Corp.

- MDA Corporation of Canada announced that it would focus on an on-orbit solution called SIS (Space Infrastructure Servicing) (in 2010).
 - SIS is to supply propellant of communication satellite located on a stationary orbit, docking with Apogee Kick Motor of a subject satellite to inject propellant.
 - It was announced that Intelsat became the first partner in March 2011. However, MDA left the plan in January 2012. This project returned to the research phase again.
- SIS capability of MDA Corporation
 - First, focus on fuel supply/services at GEO.
 - Deliver fuel to Client satellite by "per kg" system. Therefore, the service is applicable to satellites of various sizes.
 - Services are performed quickly (within a few weeks) and effects on Client satellite are minimized.
 - Can also conduct services, such as inspection, towing, relocation and small repairs.



Each dot above represents a satellite in the Geostationary Earth Orbit (GEO) worth hundreds of millions of dollars

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Summary

- At the SJAC Committee for Next-generation Space Project Promotion in fiscal year 2004, we advocated the necessity of debris removal project utilizing space robot and recommend setup of the project. We also conducted further study at the committee in fiscal years 2006/2007 and advanced the study by setting up action items for it.
- In the meantime, the space basic law in Japan was established. We could incorporate the necessity in the law in the form of necessity of space environment preservation.
- However, we have not yet realized a satisfactory promotion/project.
- Meanwhile, studies by other countries, which had no movement at first, have made a rapid progress. Their on-orbit verification and the consideration as a project, which Japan had taken a lead, have reached at the same or advanced level compared to Japan.
- We would like to remind the current status and recommend you to promote the project as one of the Japan National Strategies.

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