JAXA's Debris Removal Program

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1. Background

1.1 Recent Population of Space Objects

1.2 Scheme for the Promotion of Space Debris Measures since 2016

• JAXA’s R&D activities for space debris measures
  – Proposing the technical guidelines for debris mitigation through the activities on IADC (Inter-Agency Space Debris Coordination Committee).
  – Taking advantage of Japan's strengths and promoting the research and development on the space debris mitigation technologies such as observation, protection and safety removal.

• Framework for the promotion of space debris measures
  – Board for the promotion of space debris measures
  – Research team for space debris comprehensive measures
    • The team consists of 4 sub-teams.
1.3 Framework for the Promotion of Space Debris Measures

The Administrator

Board for the Promotion of Space Debris Measures

Research Team for Space Debris Comprehensive Measures
Heads: M. Ohnishi, S. Kawamoto
- Sub team for International Standards and Guidelines
- Sub team for Mitigation
- **Sub team for Active Debris Removal (ADR)**
- Sub team for Situational Awareness and Protection

Organizations outside of JAXA

Cooperation

Bodies inside of JAXA

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1.4 LEO Environment Projection

- Debris evolutionary models showed the debris population will not stabilize even without any future launches.
- Debris evolutionary models showed that Active Debris Removal (ADR) of currently existing 100-150 debris objects or 5-10 debris objects/year is necessary for stabilizing LEO environment.

2. R & D Plan

2.1 Concept of the R & D

Aim:
1. To maintain or improve the orbital environment for sustainable development of space activities
2. To found an enterprise for the above aim and give large share on the enterprise to the industries

Stability of Space Environment

- Mitigation/Removal of New Debris
- Removal of Existing Debris

Private Sector

Public Sector

International Rules

Goal

Targets and JAXA's contribution

- Target A 【Private Sector】: Mitigation or Removal of New Debris ⇒ Support Private Sectors
- Target B 【Public Sector】: Removal of Existing and Dangerous Debris ⇒ Main Contribution

The 3rd Mid Term Plan ~ Next Mid-Long Term Plan

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Baseline System Demonstration

Extended System Demonstration

Removal Existing Debris as a Public Enterprise (1/year)
2.2 Plan for Demonstrations

- **Component Demonstration(s)**: *Key technologies for future competitiveness*
  - Rendezvous / Capture
    - Heritage (ETS-VII, HTV, etc)
  - De-orbit (ElectroDynamic Tether (EDT), etc)
    - **Lower-Resources, Lower-Cost**

- **Baseline System Demonstration**
  - **Aim:**
    - Found the ADR market by proving the possibility of low-cost ADR.
    - Promote industries entry to the market by extending the ADR enterprise.
  - **Removal Target**: Existing upper stages of H2A or upper stage of H3 piggybacked
  - **Technology Readiness**

- **Public Researches based on the JAXA’s R & D Plan**
  - **Aim:**
    - Accelerate JAXA’s R & D on space debris measures.
    - Enhance the Industry-Academia-JAXA Cooperation from the Beginning.
    - Make the All-Japan framework for the comprehensive measures on Space Debris.
3. Possibility

3.1 Targets of Space Debris Removal

- Targets should exist on clouded orbits.
- Targets are on a few orbital groups, that is, on a few useful orbits.
- Multiple debris removals per one mission might be possible. -> Lower cost
- ADR satellite might take piggyback launch, because a main satellite will be usually inserted to such a useful orbit. -> Lower cost
3.2 Heritage of Technologies

JAXA has been studying cost-effective ADR

Background: experiences through ETS-VII, HTV, Hayabusa, etc.

- Autonomous Rendezvous/Docking
- Image processing to locate a target object
- Autonomous navigation
- Space robotics

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3.3 Technology Readiness

Operation Scenario for ADR

Targets are uncontrolled, non-cooperative objects with no reflector, no marker, no handle to capture.

Targets are heavy objects in high (700-1000km) altitude requiring large ∆V for de-orbiting.

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**Launch**

**Rendezvous**

**Motion estimation**

**Attachment of a propulsion system**

**Debris object in a crowded region**

**Approach to debris (non-cooperative rendezvous)**

**Proximity operations**

**To the next debris object**

(in case of multiple removal)

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**Component Demonstration(s)**

**De-orbit (a candidate)**
Non-Cooperative Rendezvous

Vision-based navigation using cameras (visible and IR)
- Far: Angles-Only Navigation (AON)
- Middle: Model Matching Navigation (MMN)
- Near: PAF-Tracking Navigation (PTN)

Laser sensors are options

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**Proximity Operations (Motion Estimation)**

- Final approach using vision sensors
  - Image processing to identify relative distance and attitude
  - Numerical simulations and on-ground experiments using a model of rocket upper stage and optical simulator
Proximity Operations
(Attachment of Propulsion System)

Attachment of the tether end without need for precise position control

- Hook to the payload attachment fitting of the rocket upper stage using an extensible boom mechanism
- Harpoon or puncher
- Robot arms, stretching gripper etc.

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Electrodynamic Tether (EDT) as One of Candidates for Propulsion

- **Fundamentals**
  - Electromotive force (EMF) by orbital motion
    - $V_{\text{emf}} = (v \times B) \cdot L$
  - Lorentz force
    - $F = (J \times B) \cdot L$

- **Main features**
  - **No need for propellant or high electrical power**
  - **Its thrust is so small and no thrust vector control required**
    - Attaching operation will be less challenging
  - 5-10 km EDT can de-orbit large debris in crowded region within 1 year
  - Demonstration of small EDT on HTV has been studied
HTV#6 was launched on 2016 Dec.
- Objectives: on-orbit bare tether deployment and current emission by field emission cathodes

Endmass that stores tether could not be released from HTV and tether was not deployed
- probably because one of four actuators for fixing endmass did not work

FEC was operated without critical troubles and its ability was better than expected by the ground experiment
- FEC is key device to achieve propellant-less propulsion for cost effective ADR

Technology level of EDT was advanced by analysis and ground tests during development phases
- such as manufacturing and winding of bare tether, dynamics for stable operation and control

Next demonstration plan now being re-examined
System Study

System study
- Small satellite launched as piggyback or cluster

Tethered tug
- Chemical/electric propulsion
- Controlled reentry at a low enough altitude

Block diagram

Small satellite for ADR

Electric propulsion or intermittent chemical thrust should be given to vertical tether

Orbital direction

Removal satellite

Large thrust should be given to horizontally

Tethered tug by chemical/electric propulsion
4. Int. Standards and Guidelines

4.1 Measures to the Standards and Guidelines

Making efficient proposals, in cooperation with other spacefaring agencies, on international standards or guidelines for space debris mitigation, actively adopting the latest technologies and the findings in related researches.

- **COPOUS** (Committee on the Peaceful Uses of Outer Space)
  - STSC (Scientific and Technical Subcommittee)
- **ISO** (International Organization for Standardization)
- **IADC** (Inter-Agency Space Debris Coordination Committee)

**Importance of Discussion in IADC**

- Discussion on standards and guidelines seems to be done parallelly. But key players also take part in IADC and discuss them in advance.

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- **USA**
  - NASA STD revised (2007)
  - JAXA JMR-003/A (2004)
  - JAXA JMR-003/B (2011)
  - JAXA JMR-003/C (2014)

- **Japan**
  - NASDA Standard (1996)
  - JAXA JMR-003/A (2004)
  - European Corp. for Space STD ECSS-U-AS-10C (2012)
4.2 Introduction of IADC
Structure and Purposes of IADC

IADC is an international forum of national and international space agencies for the worldwide technical/scientific coordination of activities related to space debris in Earth orbit issues and provides technical recommendations.

IADC consists of a Steering Group and four specified Working Groups (WGs) covering measurements (WG1), environment and database (WG2), protection (WG3), and mitigation (WG4).

The primary purpose of the IADC is to

– exchange information on space debris research activities between member space agencies.
– facilitate opportunities for cooperation in space debris research.
– review the progress of ongoing cooperative activities.
– identify debris mitigation options.
More than 100 technical experts from member agencies participate in the annual meetings to share information, address issues, and define and conduct studies on all aspects of space debris.

- UKSA hosted the meeting in Harwell Oxford, UK in 2016
- ESA hosted the meeting in Darmstadt, Germany in 2017
- **JAXA will host the next meeting in Tsukuba, Japan in June 2018**
Summary

• JAXA has been promoting the comprehensive approach to space debris measures.
• Now JAXA focuses on the R&D for space debris removal in order to found the new enterprise.
• JAXA will proceed the R & D under the Industry-Academia-JAXA cooperation.

Thank you for your attention!