C2

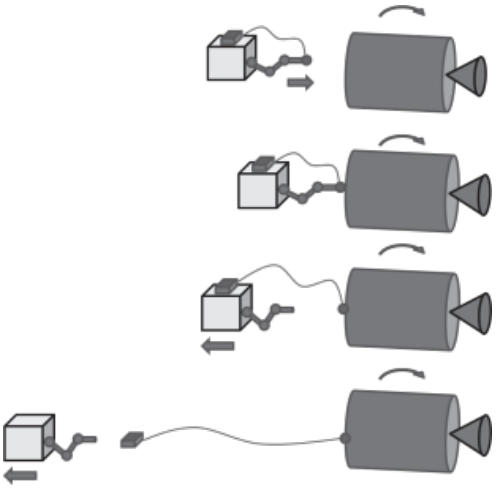
推進系取付のストラテジ・機構の検討

The Strategy and Technology for Non-cooperative Target Capture

○中西洋喜, 河本聡美（宇宙航空研究開発機構）
○H. Nakanishi and S. Kawamoto (JAXA)

デブリの除去を継続的に実施していくためには、安全及びコストの面から無人の軌道上作業ロボットで行うことが必須であると考えられるが、実現には多くの技術的な課題がある。その中の大きな一つが、非協力ターゲットであるデブリを安全かつ確実に捕獲する技術である。ここで非協力ターゲットとは、専用の被把持機構を持たず、姿勢が制御されていない状態の捕獲対象のことを指す。現状、このようなターゲットの無人宇宙機による捕獲は成功例がなく、早急な技術確立が必要である。本発表では、デブリ捕獲技術に関する要求や必要技術の整理、および具体的な検討例について紹介する。

In the debris removal mission, the target (debris) capture is one of the biggest issues. The targets are non-cooperative in terms of the lack of dedicated fixtures and attitude stabilization. The established capture technology is not enough for such target. In this presentation, the requirements, strategy and technology for the capture of the non-cooperative target are discussed.



5th Space Debris Workshop, Jan. 22nd, 2013

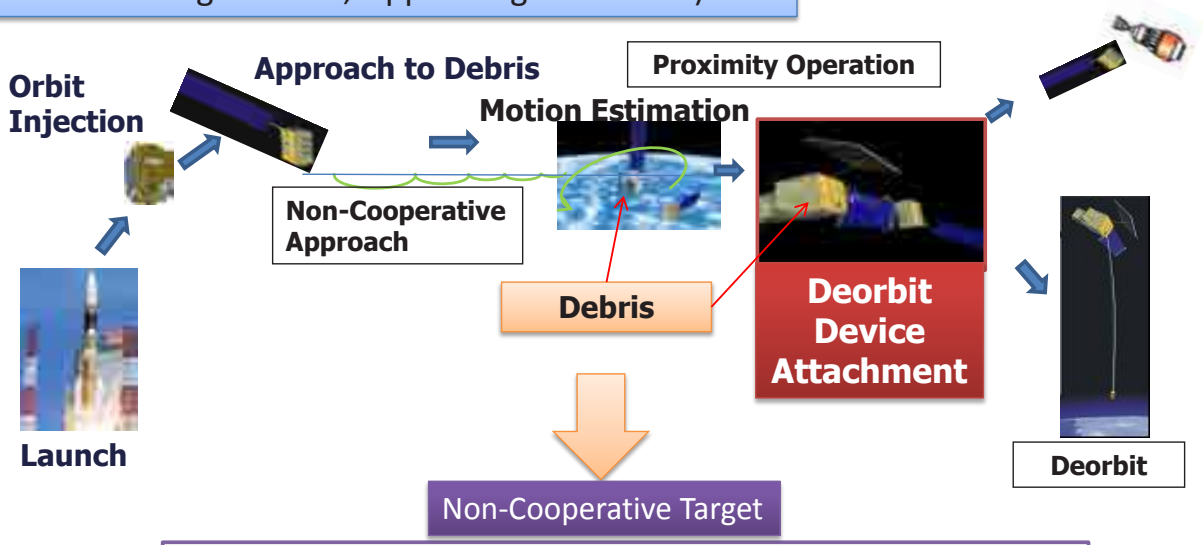
推進系取付のストラテジ・機構の検討
The Strategy and Technology for Non-cooperative Target

Hiroki NAKANISHI and Satomi KAWAMOTO
Japan Aerospace Exploration Agency

Table of Contents

Debris Removal Mission

Removal mission for existing Debris
(Malfunctioning Satellite, Upper Stage of Rocket)



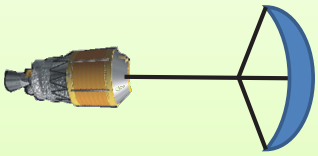
Non-Cooperative Target

- No Dedicated Fixture
- No Attitude Control (Tambling motion)

Breaking and Pushing away of the target should be avoided.
However, the capture system which provide safely capture has never been established yet.

Debris Deorbit Device

EDT(Electrodynamic Tether)



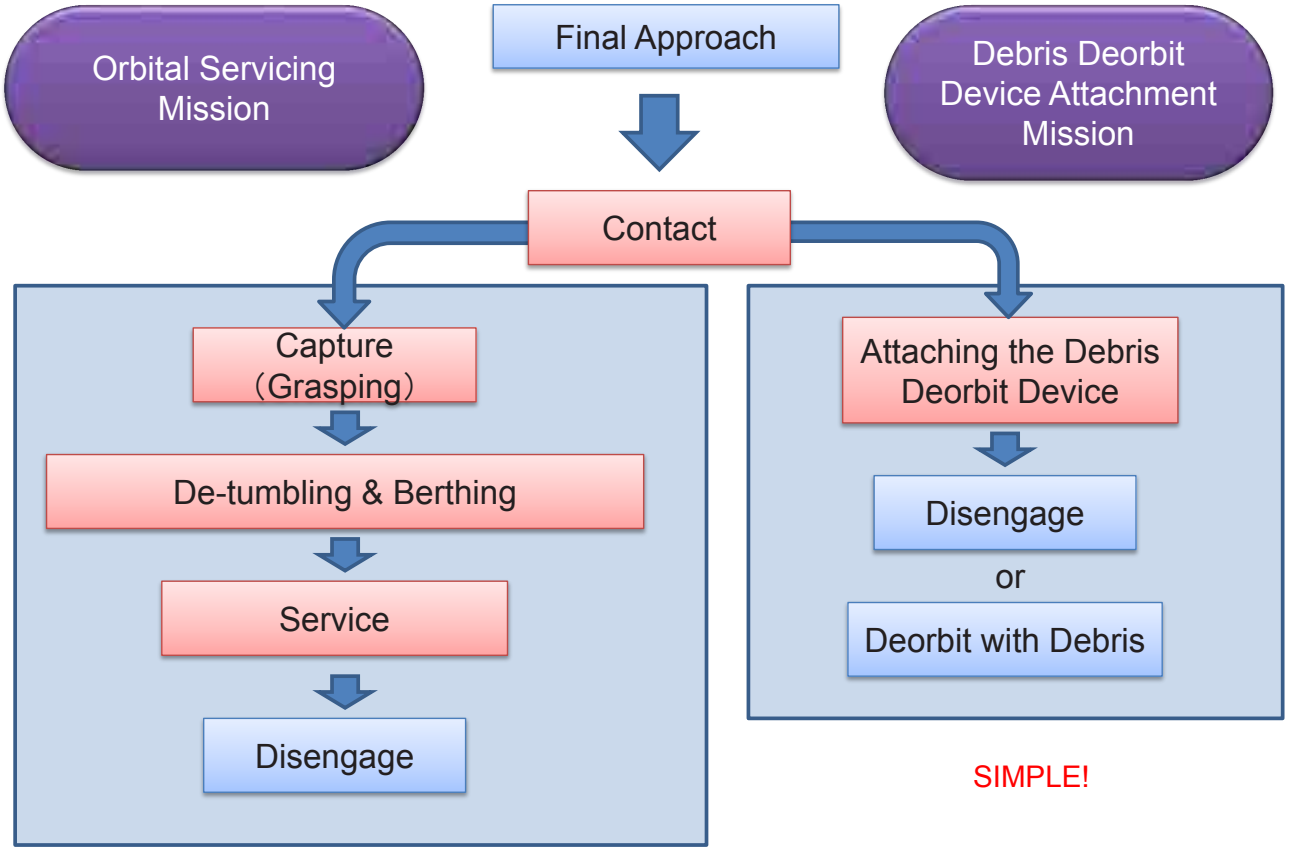
Air Brake

etc.

These Devices give the debris low-thrust over long term

Fixing the tether end of the de-orbit device on the target surface is required!

Orbital Service and Debris De-orbit



Assumed Target

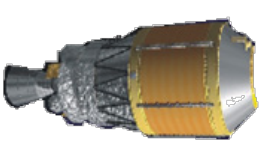
Over 10,000 Target ➡ Prioritization is important!

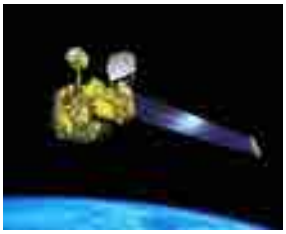
Preferential Target:

- Large size debris which makes more small debris with a collision.
- Debris which is easy to access and operation.

Upper stage of Rocket or Large satellite

- Weight: 3~4[t], Size: ~10[m]
- Max 1[deg/s] of flat-spin or swinging by gravity gradient





Mission Scenario

- Assume the EDT or tether towing type device.
- Attach the tether's end to the target while short time of relative control.
  (No target handling, No berthing)

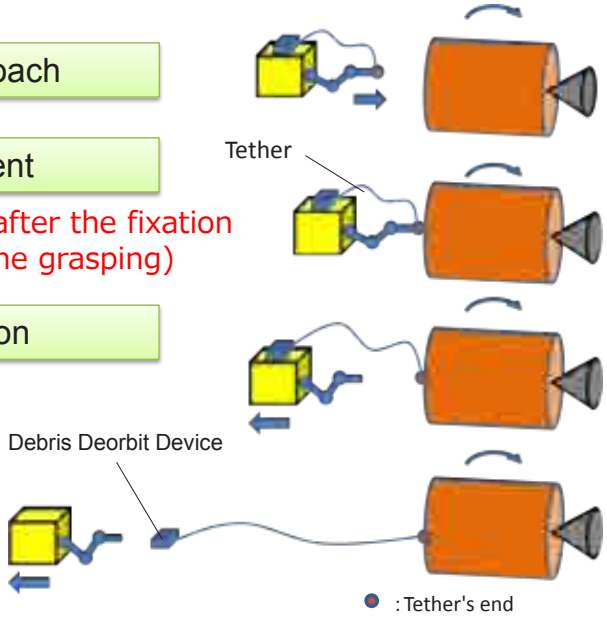
Final Approach

Attachment

Separate the tether's end right after the fixation
(Separate the hand right after the grasping)

Separation

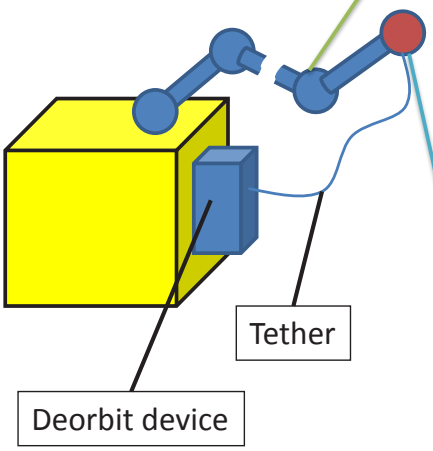
Disengagement
or
Deorbit with Target



Requirement for Device Attaching System

for Arm

- Stiffness against contact force and reaction force
- Enough clearance between main body and target (1~2m)
- Enough velocity and accuracy
- Light weight, Low power and simple mechanism



for End-effector

- Endurance and absorption for contact force
- Fixation with enough force
  (Endure de-orbit force > Low but long term)
- Wide allowable attitude for attach motion
- Quick fixation
- Light weight, Low power (no power after fixation) and simple mechanism

Time Constraint

Operation must be done within 1 AOS → 40min (with Data relay Sat)
10min (w/o Data relay Sat)

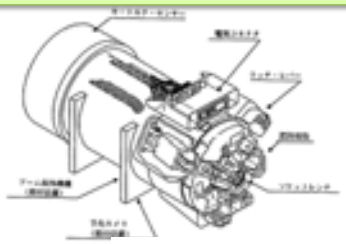
Conventional Grasping System (for Cooperative Target)

LEE (Latching End Effector)

LEE

FRGF

JEMRMS Small Fine Arm End Effector



EE

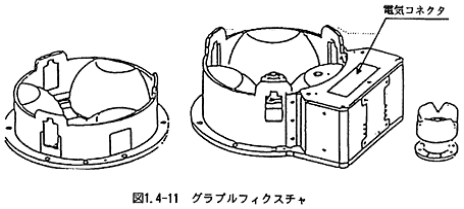


図1.4-11 グラプルフィクスチャ

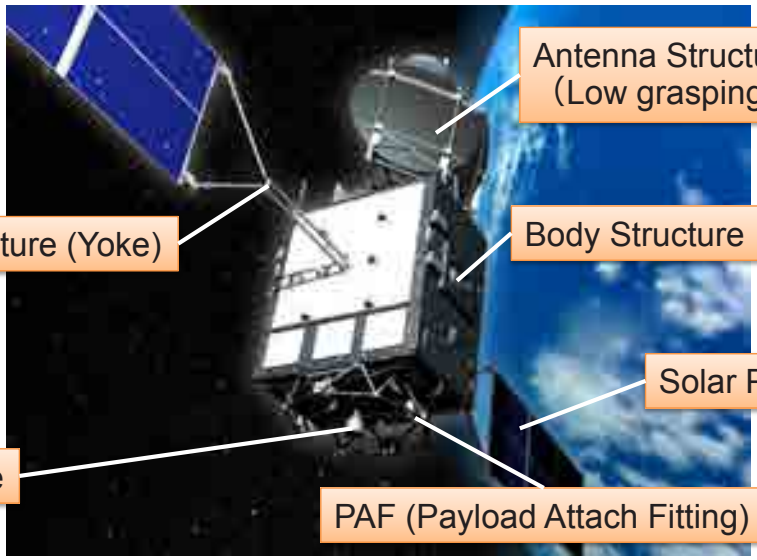
GF

Combination of EE and Dedicated GF is MUST ⇒ Useless for Non-cooperative Capture

Where is de-orbit device fixed?

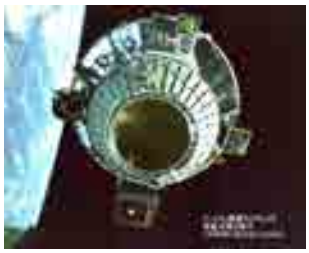
Requirements for fixation/grasping point

- Easy to access
- Easy to grasp
- Easy to identify
- Enough stiffness for grasping / contact force



PAF (Payload Attach Fitting)

- High Stiffness
- Suitable Shape for Grasp (Cylinder, Truss, etc.)
- Easy to Access (Edge of body)
- There are often Obstacles



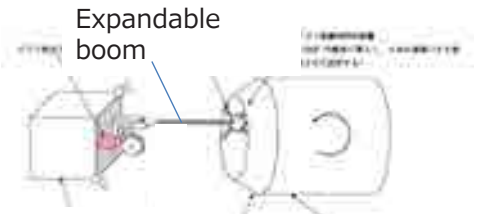
Grasp

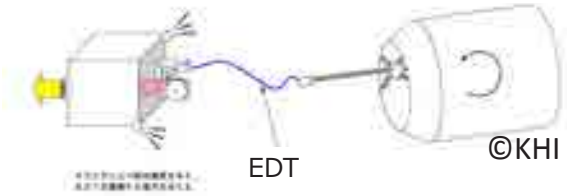
Truss Gripper

Cylinder Edge Gripper

JAXA-THK multi-purpose hand

Fix from Inside





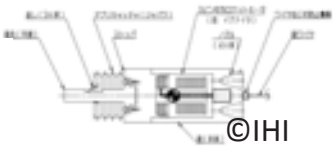
PAF Capture Tool

Main Body

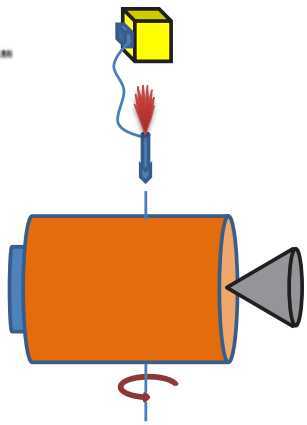
- High Stiffness
- Large Capturable Area

Harpoon (for Rocket)

- Stick a rocket harpoon to LH2 Tank
- Long range (~10m)
- 2DOF Control（Az・El）
- Prevent the penetration trough whole body and production of micro debris are issues.

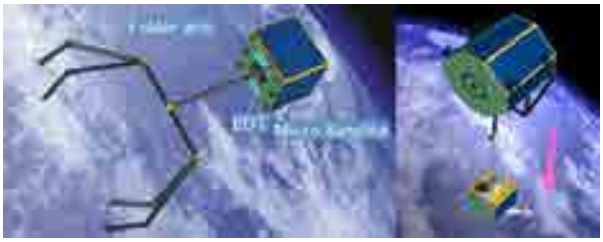


Rocket Harpoon



Grasp

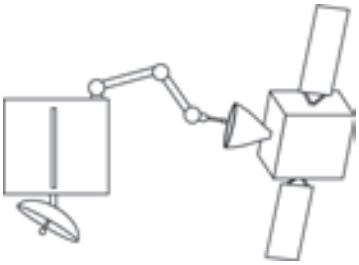
- Low requirement of relative motion.
- Large capture arm is required. (Larger than target)



Whole body capture with extendable arm

Thruster Nozzle

- Easy to Access
- High Stiffness (Base structure)
- Low Stiffness (Nozzle surface)



Nozzle probe insert experiment (for DRTS's nozzle)
（Corroborate with Tohoku University）

NASA's Satellite Capture tool for EVA

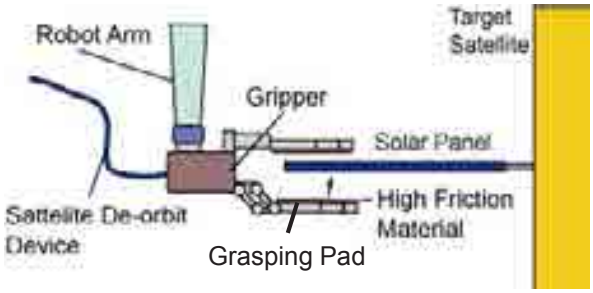
DLR's Nozzle Capture tool

- Capture probe is inserted into nozzle throat.
- The probe is extracted and hold from inside wall.
- Inside wall of nozzle skirt is used as a guide plate.

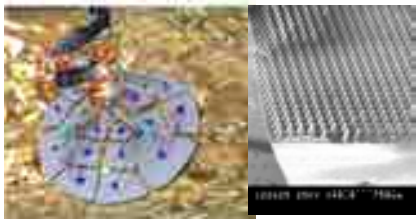
Solar Paddle, Antenna, Plate structure

- Easy to Access
- Low Stiffness

Panel Gripper



CNT Gecko Tape (©Nitto Denko Co.)



Silicon Gecko Hand (©NASA/JPL)

- Low Grasping force but High friction force
- Low concentrated load
- High friction material with resistance to space environment is required.

Summary

- The requirements, strategy and technology for the capture of the non-cooperative target are discussed.
  - ✓ The target assumption is clarified.
    ➡ The first targets are large debris (rocket and large satellite.)
  - ✓ A strategy of de-orbit device attachment to the debris is proposed.
  - ✓ Attachment (grasping) technologies for non-cooperative targets under development are introduced.