C07

スペースデブリ捕獲機構の検討

Study of Space Debris Capture

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スペースデブリ捕獲を含む回転する大型物体の非協力捕獲が難しい理由は、これまでのような協力物体に対するランデブドッキングのようにランデブ部とドッキング（捕獲）部を分離することが難しいからである。本講演では、そのような問題意識のもと現在 JAXA で実施しているスペースデブリ捕獲機構の検討状況を報告する。

This presentation introduces our research investigation on capturing mechanism and capture control method. The capturing mechanism is to grasp the metal adapter (Payload Adapter Fitting / PAF) at rocket / satellite separation commonly installed on large space debris.

Study of Space Debris Capture

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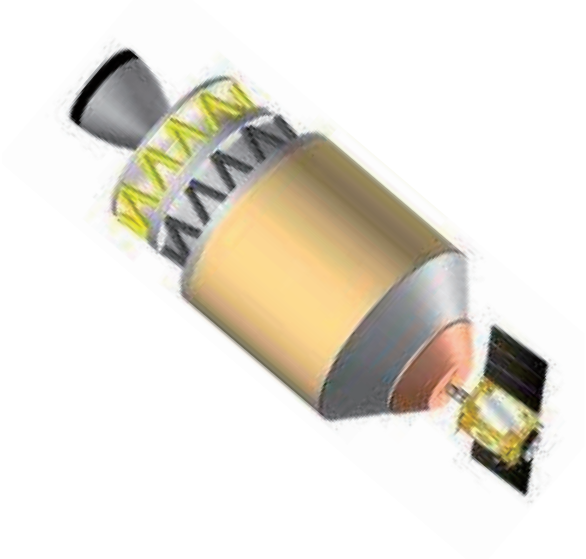
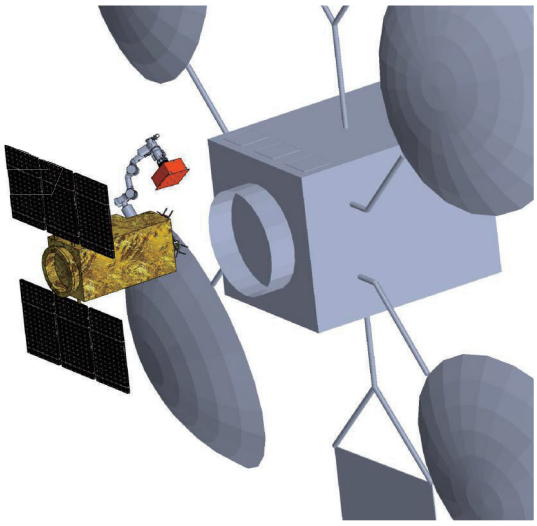
Scope of Space Debris Capture Technology





■Space debris removal

■On-orbit servicing
–Incl. "recycling" of the spacecraft on orbit

K. Nishi, S. Ozawa, A. Okamoto, H. Kato, N. Inaba, "A Concept Study of Unidad Reemplazable en Órbita for Communications Satellites in Geostationary Orbit " in Proceedings of International Astronautical Congress (IAC2018), Bremen, 2018.

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New Technological Challenges

Our heritage: rendezvous docking technology	New technological challenges
The target has a docking port	No docking port
Navigation friendly -The target has a target marker -The target is controlled	Difficult navigation -No marker, with additional sensing to measure the relative position to the space debris -Not under control, even assumed to be rotating

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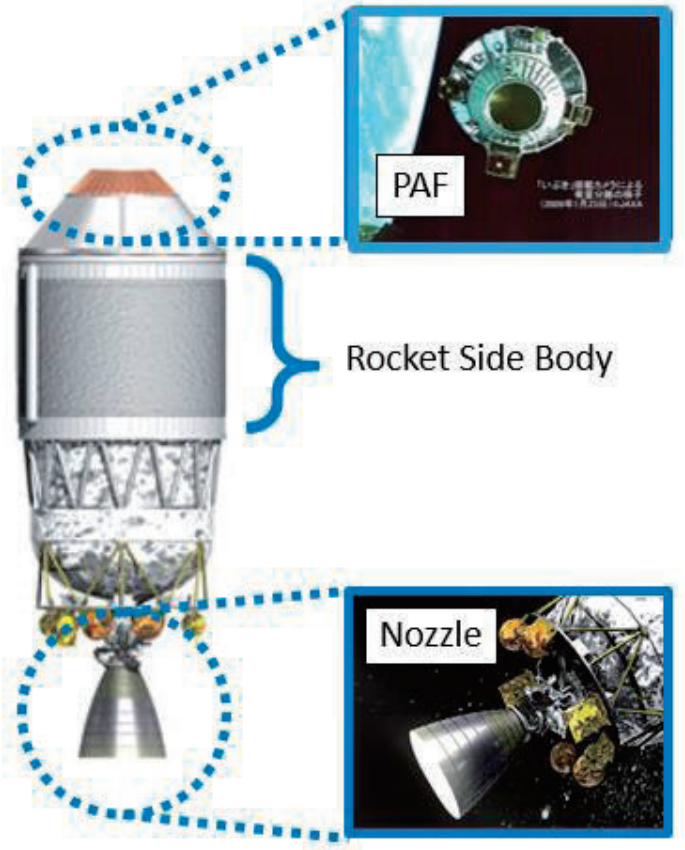
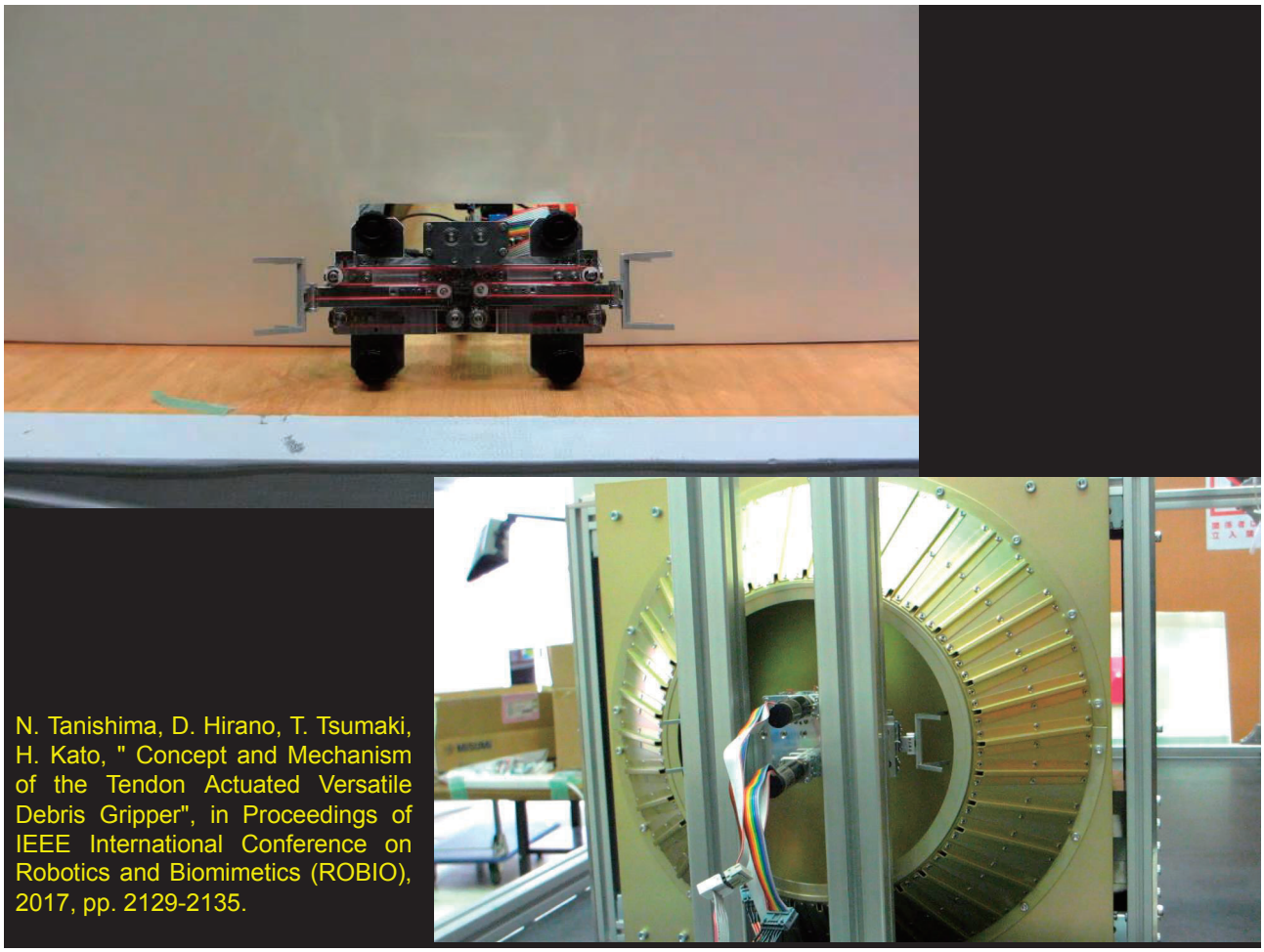
Approach to “No docking port”/1

- Capture Mechanism that grasps the metal adapter (Payload Adapter Fitting / PAF) at rocket / satellite separation
  - Commonly installed on large space debris.
  - For the upper stage of rockets, the capturing mechanism can grasp both PAF and the main engine nozzle





N. Tanishima, D. Hirano, T. Tsumaki, H. Kato, " Concept and Mechanism of the Tendon Actuated Versatile Debris Gripper", in Proceedings of IEEE International Conference on Robotics and Biomimetics (ROBIO), 2017, pp. 2129-2135.

Approach to “No docking port”/2

- The capturing mechanism
- Tendon drive
  - High extension ratio
  - Mass reduction
- Rigidly attached with the target after capture
  - “Controlled reentry“ for debris capture
  - For on-orbit servicing

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New Technological Challenges

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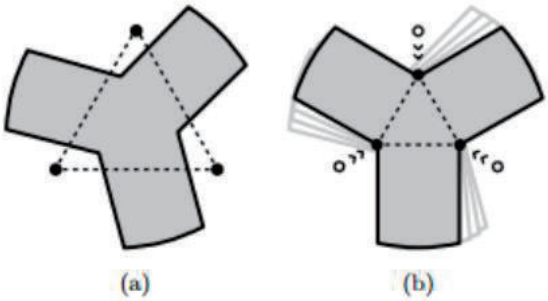
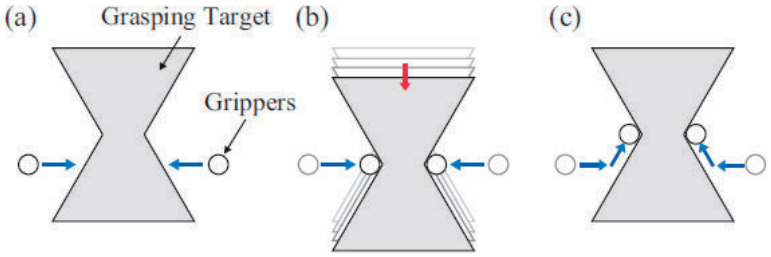
Approach to difficult navigation/1

■ “Caging”: geometrical enclosure



<Top figure>
A. Rodriguez, M. Mason, and S. Ferry. From caging to grasping. In RSS, 2011.
<Bottom figure>
D. Hirano, H. Kato, and N. Tanishima, "Caging-Based Grasp with Flexible Manipulation for Robust Capture of a Free-Floating Target", in Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2017, Singapore, pp. 5480-5486.



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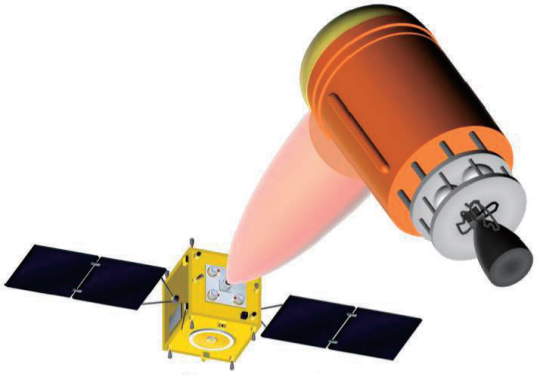
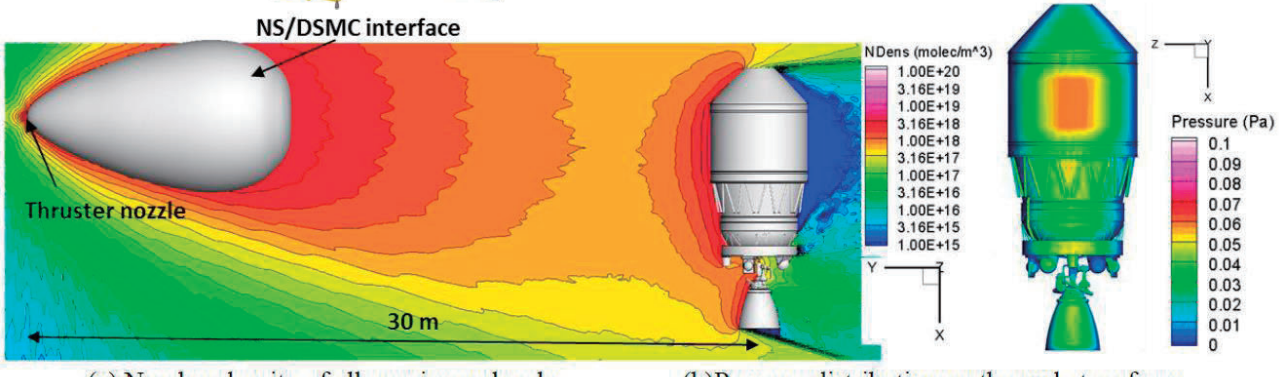
Approach to “difficult navigation”/2

■ “Detumbling” Space Debris via Thruster Plume



Y. Nakajima, H. Tani, T. Yamamoto, N. Murakami, S. Mitani, and K. Yamanaka, "Contactless Space Debris Detumbling: A Database Approach Based on Computational Fluid Dynamics," Journal of Guidance, Control, and Dynamics, Vol. 41, No. 9 (2018), pp. 1906-1918.



(a) Number density of all-species molecules. (b)Pressure distribution on the rocket surfaces.

Figure 8. DSMC analysis of the plume impingement to rocket body.

end of presentation