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## 宇宙デブリ捕獲・除去システムの研究

### Study of Active Debris Removal System with a Light Weight Robot Arm

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除去対象として過去に衛星を打上げた H シリーズロケットの上段残滓を想定し, 軌道上から除去する小型ロボット衛星システムの研究・開発を行っている。ロケット上段は, 長い概円柱形状であるため, 経年により地球に対し鉛直な姿勢に収れんする。このため, 減速推進系として有望な EDT の取り付け部位は長軸の両端にあるノケットノズル, PAF となる。このいずれの捕獲にも対応でき, 失敗時のリトライが可能で, 以下に示す特徴を有する小型・軽量のロボットアームや画像処理系を有したシステムを提案し, 部分試作・試験結果につき報告する。

- ・軌道上での対象の姿勢運動につき, 固有空間法で効率的な画像計測/推定を行うシステム
- ・捕獲対象部位にロボット手を誘導するステレオ画像計測システム
- ・二指で着実な捕獲・緩衝・把持ができ, 無電力で把持状態を維持できるハンド機構
- ・関節弾性機構とインピーダンスによる緩衝機能を有した3関節の軽量ロボットアーム

Active removal of space debris presents the most effective measures. This study examines a micro robotic satellite with a simple robot arm for active space debris removal.

The upper stages of the H series rocket were selected as target debris objects to be removed.

In this study, the details of a proposed active space debris capture/removal micro satellite system, vision sensing system of target attitude/motion and its robot arm with three flexible joints for capture of targets are described. A mechanism to capture the target space debris, namely, a control method for buffering force while capturing the target with the lightweight robot arm with flexible joints, is proposed. The results of feasibility studies, the performance assumed at each step, prototyping of the capture mechanism, and experimental results are also presented.



図 デブリ捕獲用軽量ロボットアームの試作機

Fig. Prototype of lightweight robot arm for capturing debris

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# Study of Active Debris Removal System with a Light Weight Robot Arm



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As a mechanism for debris capture, the followings are listed as candidates.

- a. Precision robot arm
- b. Flexible joint arm
- c. Extensible capture mechanism
- d. Throw-Nets
- e. Eject-Pile

The flexible joint arm has following advantages.

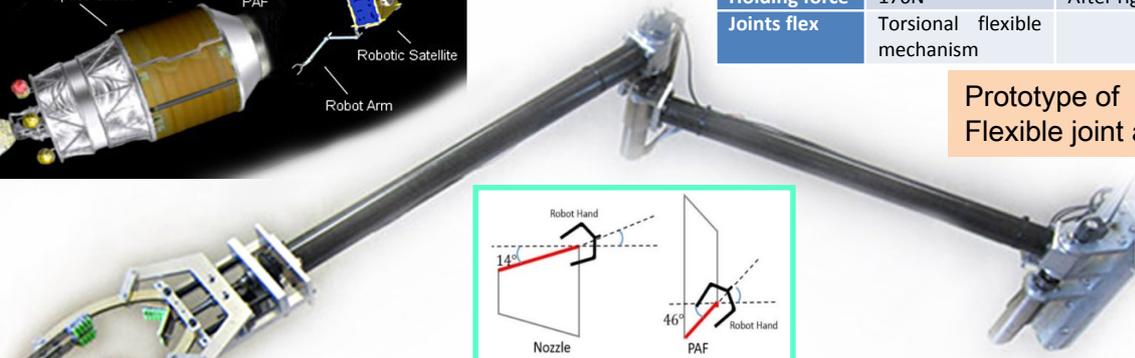
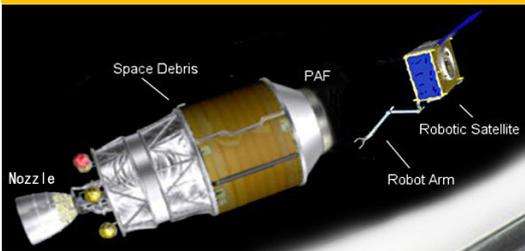
- ① Even if it can't be captured well, the arm would be able to re-try it.
- ② Both PAF and Nozzle of a target can be captured by the arm.
- ③ The arm can maintain connection of the end of a EDT to a target stably without an electric power supply

The feature of the flexible joint arm are,

- The dynamic load when capturing, is buffered by elastic mechanism inside each joint and virtual depth control.
- It consists of small numbers of joints, and lightweight.
- With a linkage mechanism and leaf springs, it can maintain grasping the target without an electric power supply in high pressure.
- Both PAF and Nozzle can be captured.

Table Characteristics of light weight robot arm

Items	Characteristics	Remarks
Arm length	1.5m	
Stowed length	0.7m	
No. of DOF	3	2 ~ 3
Tip force	10N	
Capture force	10N	Before rigidize
Holding force	170N	After rigidize
Joints flex	Torsional flexible mechanism	



Prototype of Flexible joint arm

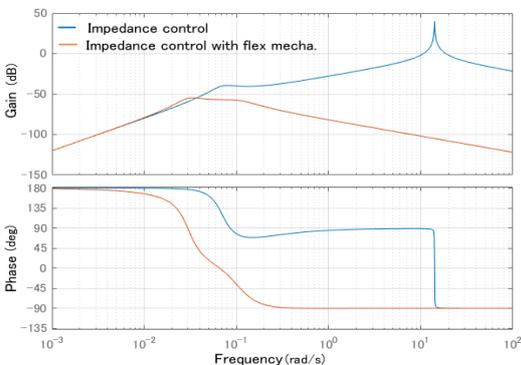
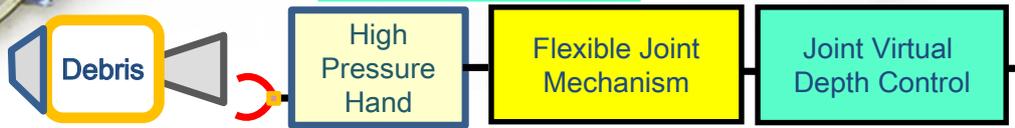
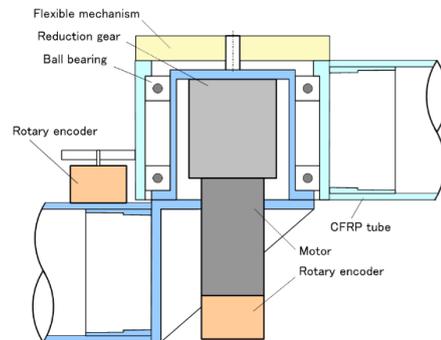


Figure Bode plot of torque produced in the joint output part to the compulsory displacement from the outside



Composition of the flexible joint mechanism