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デブリ除去のロボティクス技術

Robotic Technology on Space Debris Capture & Beyond

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Robotic technology on space debris capture and beyond is introduced. Our space debris capture capability enhancement aims for post-2020 mission, including capturing large tumbling debris with contact interface besides rocket payload adapter ring. Our research activity includes caging-based grasp with flexible manipulation, contact dynamics testing, pre-contact phase navigation, and critical computing system study.

Robotic Technology on Space Debris Capture & Beyond

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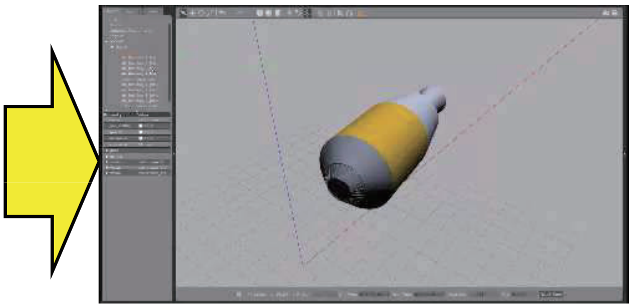
Scope

■Robotic technology on space debris capture and beyond is introduced.



■The JAXA 2020 mission
- –Specific target

■*Generic* space debris removal
- –Can be tumbling
- –Contact point interface besides rocket's payload adapter ring

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Items for *generic* space debris removal

1. Grasp with flexible manipulation
2. Contact phase navigation
3. Contact dynamics simulation & testing
4. Critical computing system study

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Grasp with flexible manipulation

- [Goal] Realizing tumbling debris robust capture
- [Challenge] uncertainty in measurement and control delay

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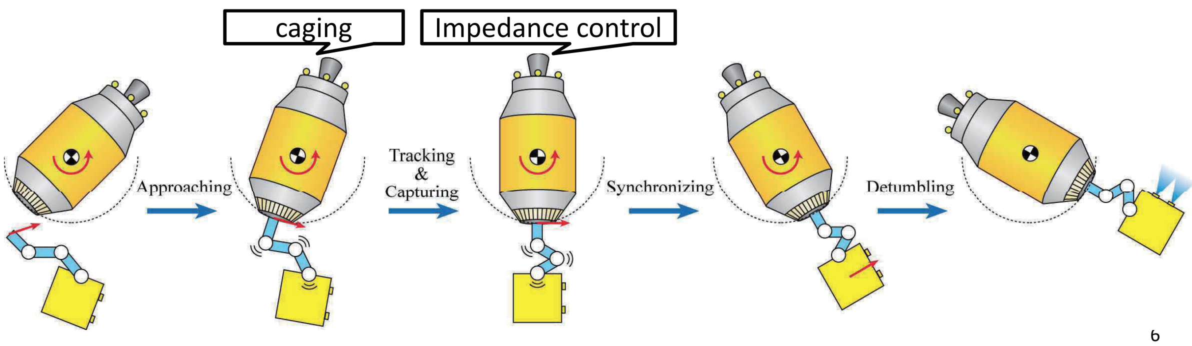
Grasp with flexible manipulation

- [Approach]
  - Robust capture by "Caging (geometrical enclosure)"
  - then tracking & impedance (force-based) control



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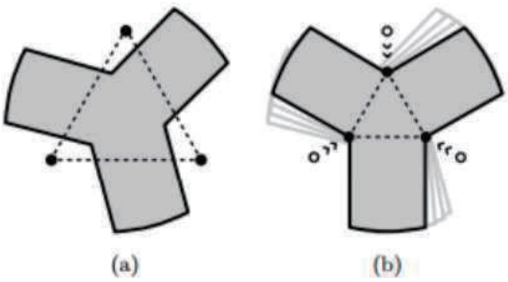
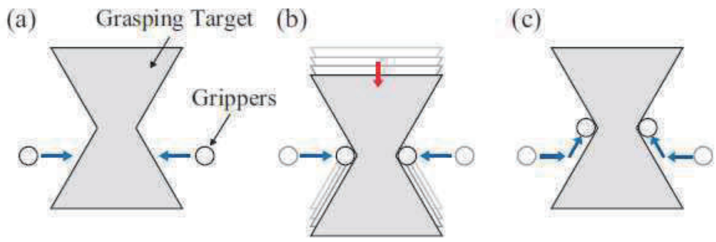
“Caging”

- “Caging”: geometrical enclosure



Top figure:
A. Rodriguez, M. Mason, and S. Ferry.
From caging to grasping. In RSS, 2011.

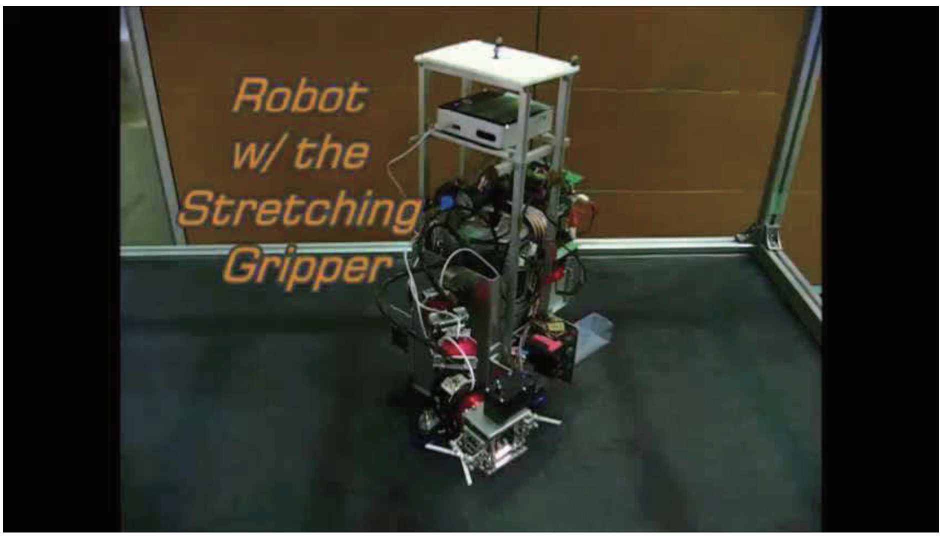


Tracking & impedance control

- Impedance control

$$\ddot{\phi}_m^d = J_g^+ \{ M_e^{-1}(D_e \dot{x}_e + F_e) - \dot{J}_g \dot{\phi}_m - \ddot{x}_{gh} \}$$

  - May improve on tracking and contact mode estimation



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Contact phase navigation

- [Goal] Realizing safe navigation (=possible to abort when needed) during the *contact phase***
- [Challenge] Can be one-shot operation (no rehearsal) with higher uncertainty## in measurement

**Contact phase := before and after contact at very near range from the target

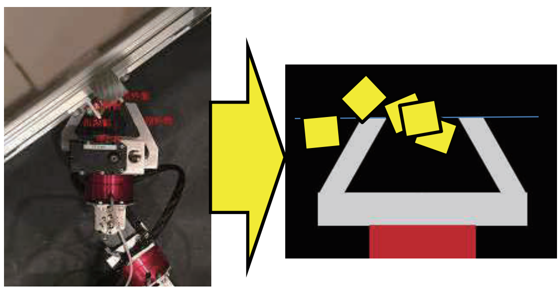
##in the 2020 mission, the capture method is simpler so the problem can be separated bw. navigation (rendezvous) and contact (docking)

Contact phase navigation

- [Approach]
  - Seeing on the robotics latest technologies; including deep learning based measurement, 3D SLAM and contact mode estimation

Contact phase navigation

- deep learning based measurement, 3D SLAM and contact mode estimation



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Contact dynamics simulation & testing

- [Goal] To prove flight feasibility of debris capture involving both contact dynamics in micro-gravity and navigation of contact phase
- [Challenge] How to conduct a ground test for contact dynamics in micro-gravity under measurement uncertainty

Contact dynamics simulation & testing

- [Approach]
  - (Step1/2) Basic control evaluation by combination of 2D air-floating system and 3D dynamics simulation.
  - (Step2/2) Then integration test by hardware-in-the-loop (HIL) testing with air-floating system with the elevation direction

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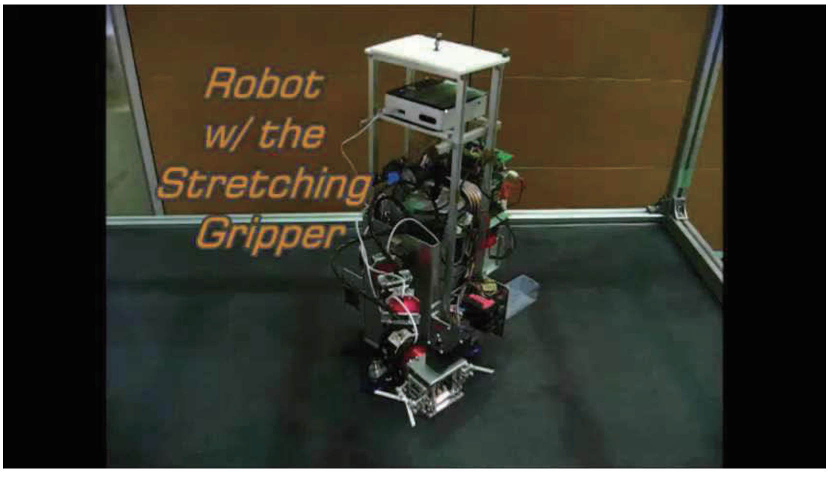
2D Air floating system testing

- Air floating system can replicate gravity-free environment in the horizontal direction
  - (clip) preliminary 2D control evaluation on the air floating system



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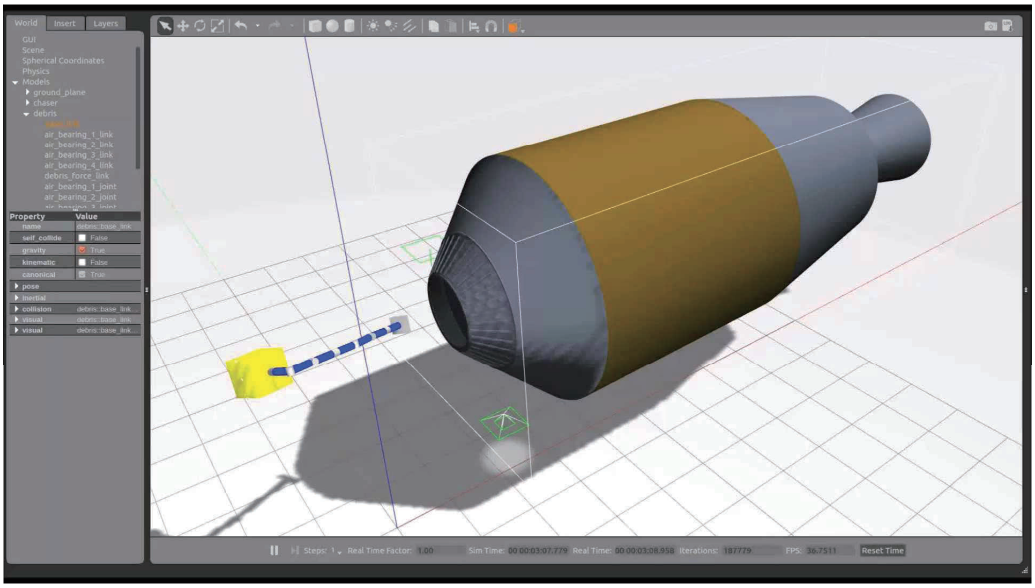
3D dynamics simulator

- Testing 3D contact dynamics control
  - Critical parameters obtained from 2D Air floating system testing



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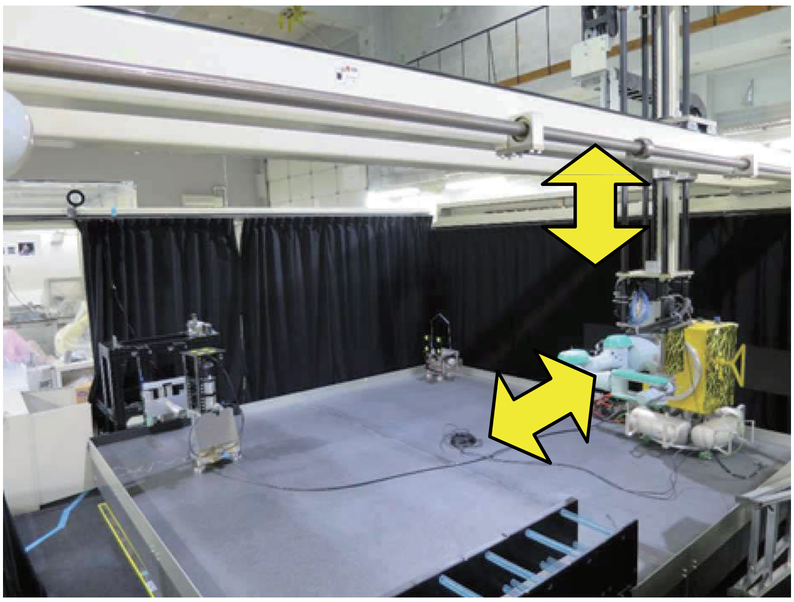
Integrated HIL testing

- Conducting integrated test of entire contact phase
- Plan (TBD): 2-by-2m floating system with vertical direction simulated robot arm



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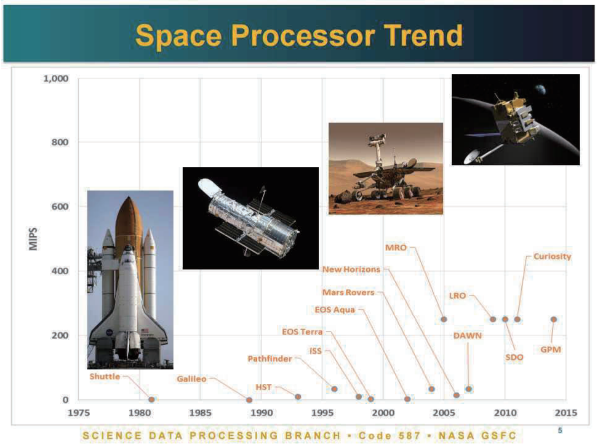
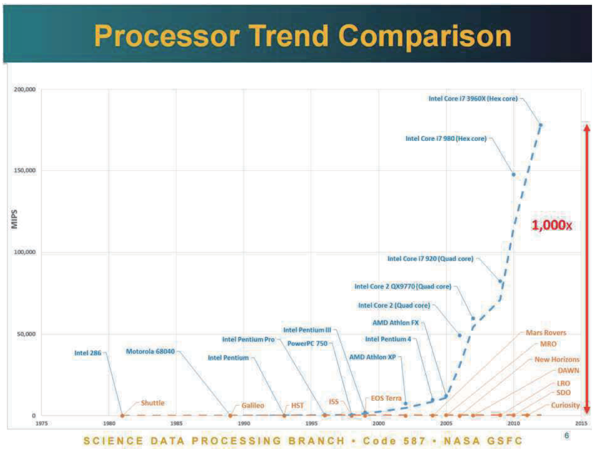
Critical computing system study

- [Goal] To realize a computation system in space missions like ours
  - grasp with flexible manipulation
  - contact phase navigation
- [Challenge] Current space qualified processing systems for critical operations is shorting in computation power. FPGA is difficult to develop and expensive.
  - rendezvous docking
  - planetary lander

Critical computing system study

- [Approach] TBA (search in progress)
  - Currently conducting processing requirements search for grasp with flexible manipulation and contact phase navigation





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end of presentation