Technologies for the International Space Science Station

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Program: Strategic Initiative

RPC-156

Jet Propulsion Laboratory
California Institute of Technology

Virtual Research Presentation Conference

Assigned Presentation

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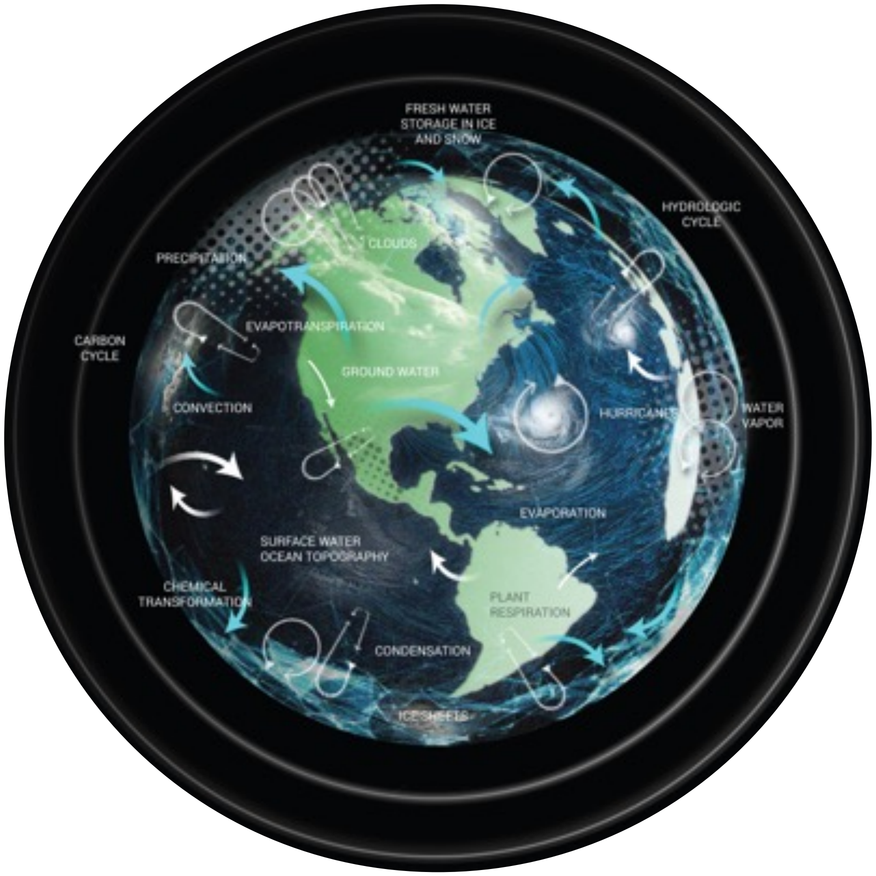
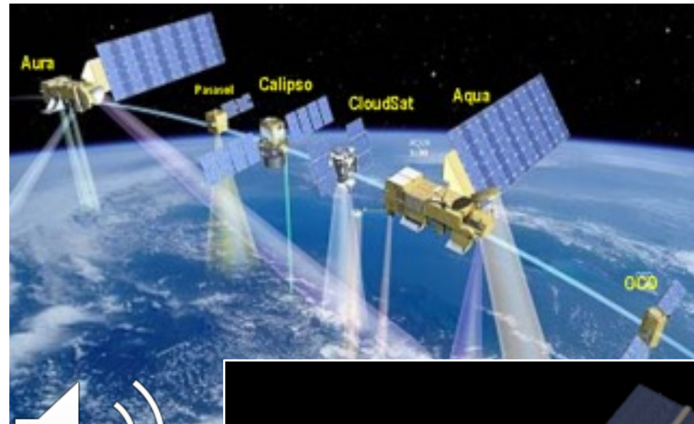
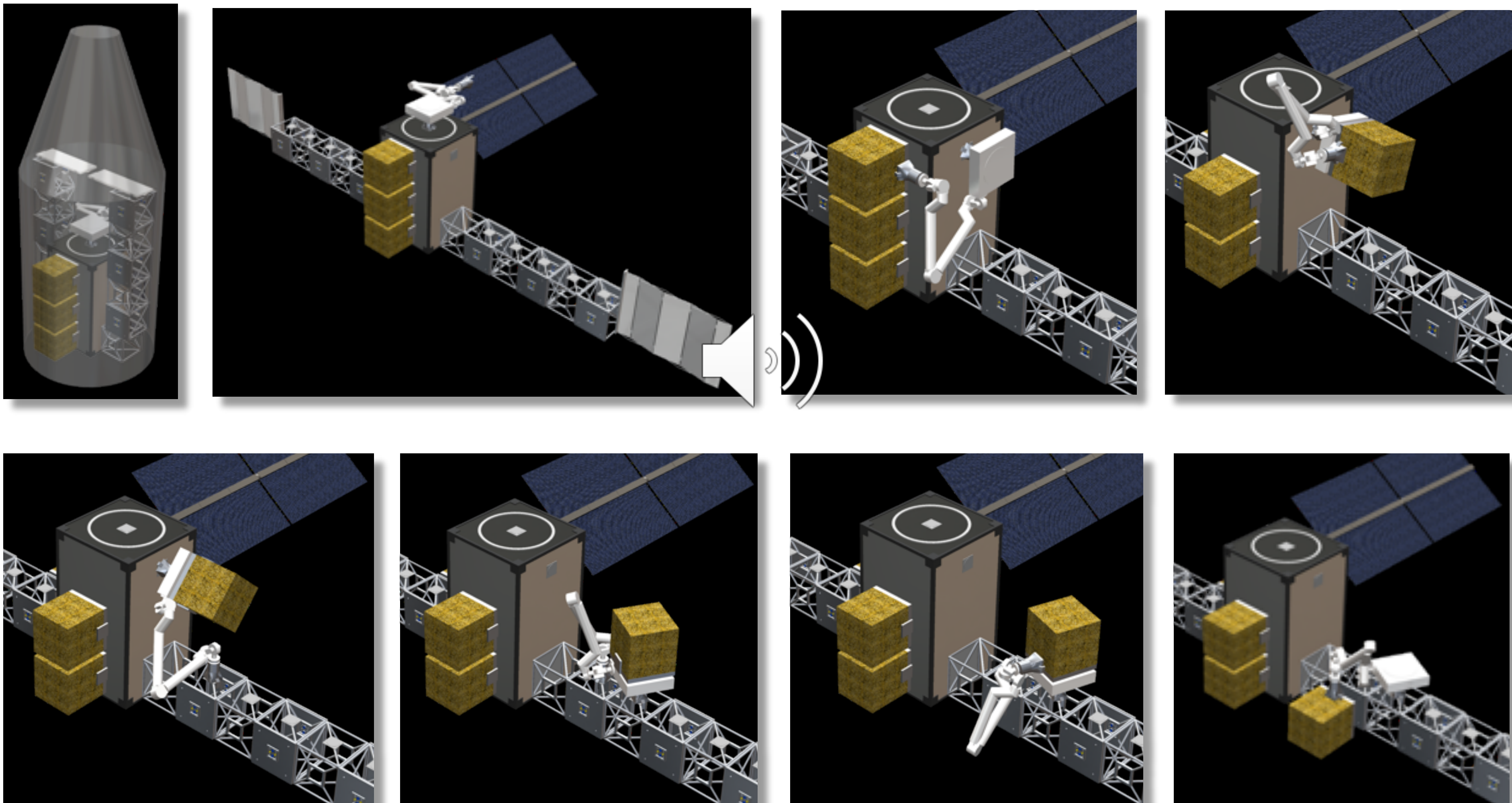


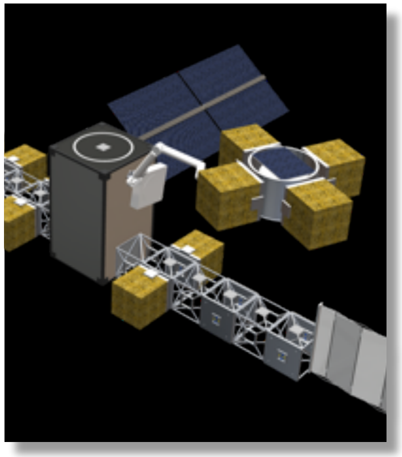
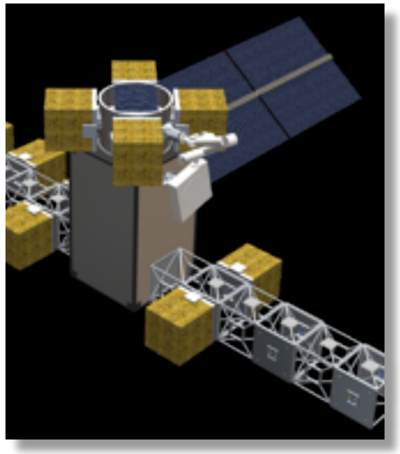
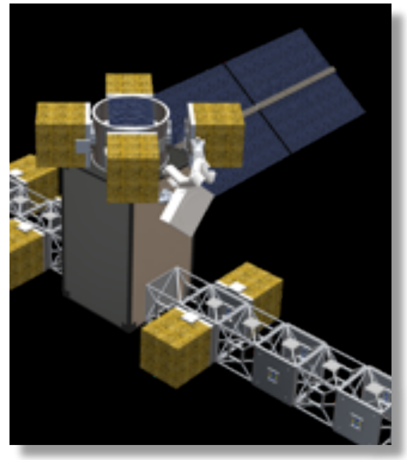
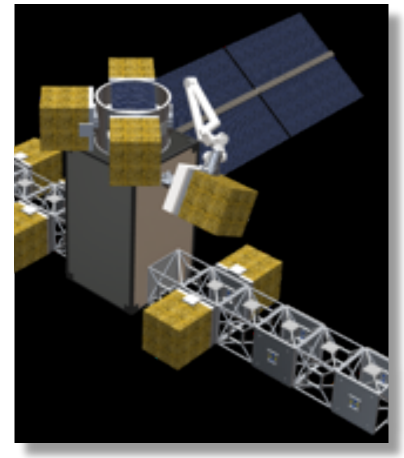
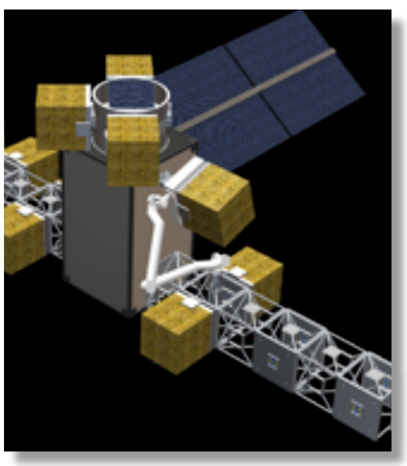
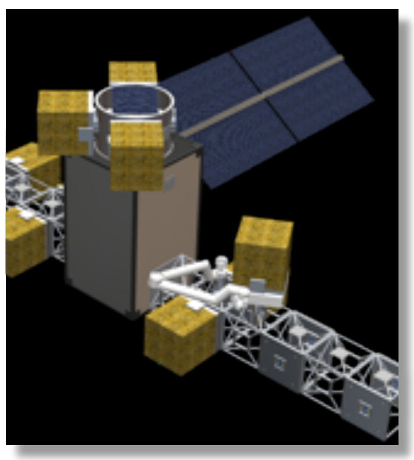
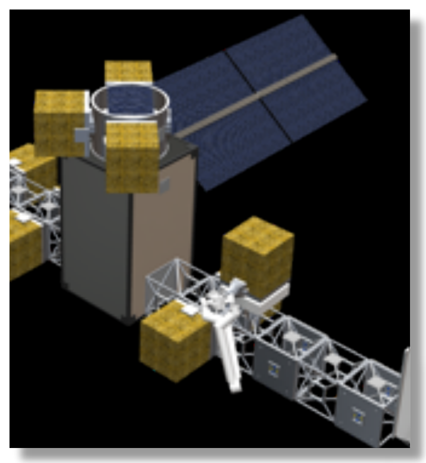
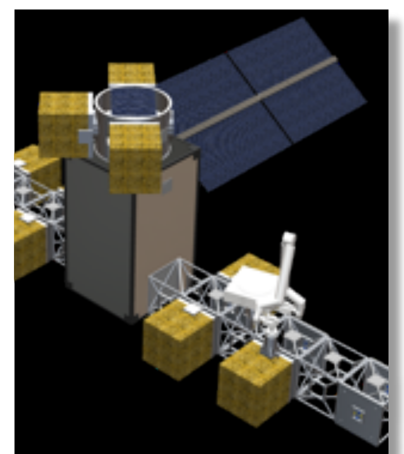


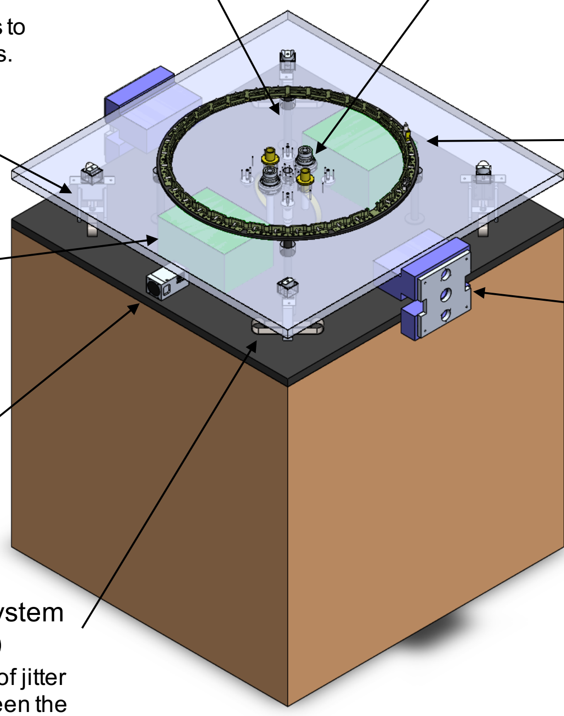
Through innovation and use of commercial capabilities, we enable the decadal survey science objectives cost effectively, especially in coincidental measurements and temporal resolutions

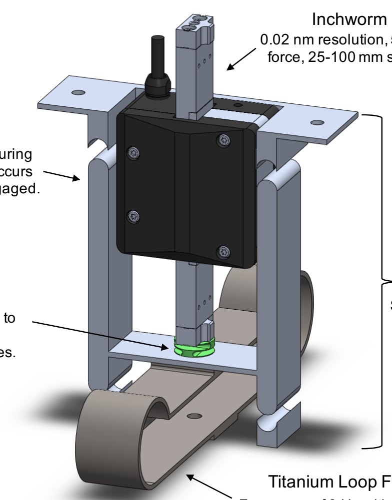
Methodology

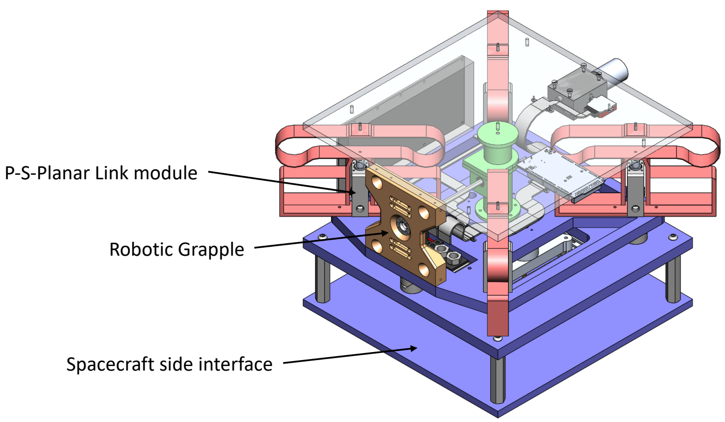
- Survey of instruments (past and formulated) to generate a requirement set
- Detailed systems engineering trades to arrive at a stable configuration of the Science Station and a detailed concept of operations
- Designed architectures for the relevant engineering aspects: thermal control and stability/pointing
- Designed and developed a novel instrument interface that maps the entire life-cycle from launch to de-orbit
- Designed, developed, and prototyped the instrument interface and demonstrated performance
- Conducted a trade study of robotic capabilities needed for the science station, designed, developed, and demonstrated a novel robotic system and supervised autonomy capability for:
  - Mobility, instrument assembly and disassembly, berthing
- Inserted the science station as a viable architecture in the collective analysis of sponsors (Earth Science, NOAA, NRO etc.) and industry
- Transitioned Science Station from a napkin drawing level concept to TRL 4

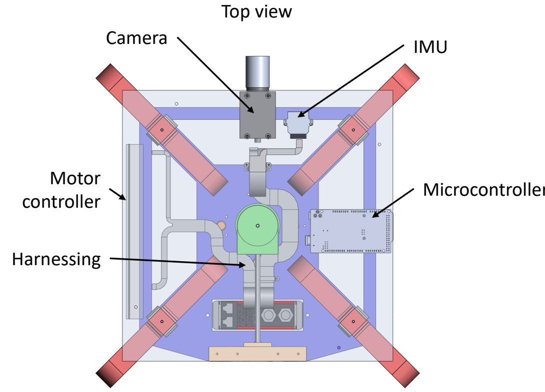


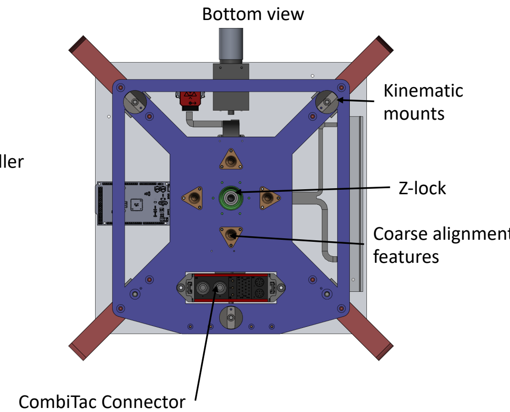









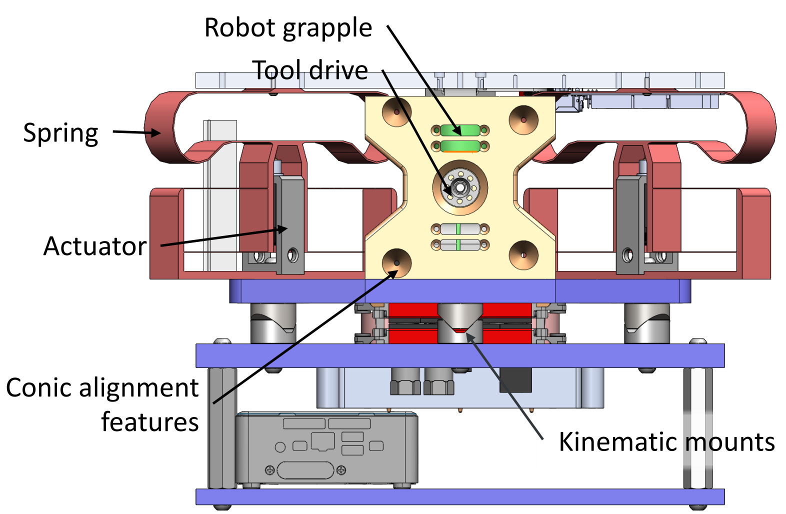

Launch Locks
Rigidly connects pallet and instrument during launch.
Truss Interconnect
Connects pallet and utilities to truss structure.
Active Pointing
Allows fine pointing adjustments to achieve accuracy requirements.
Delivery Vehicle Interconnect
Connects pallet to delivery vehicle during launch.
Electronics/Computers
Processing for star tracker/active pointing, power and data management.
Robot Grapple Interface
Physical, electrical, and data connection to robot.
Star Tracker
Provides absolute knowledge of instrument position and orientation.
Passive Isolation System (Loop Flexure)
Prevents transmission of jitter and disturbances between the instrument and the truss.

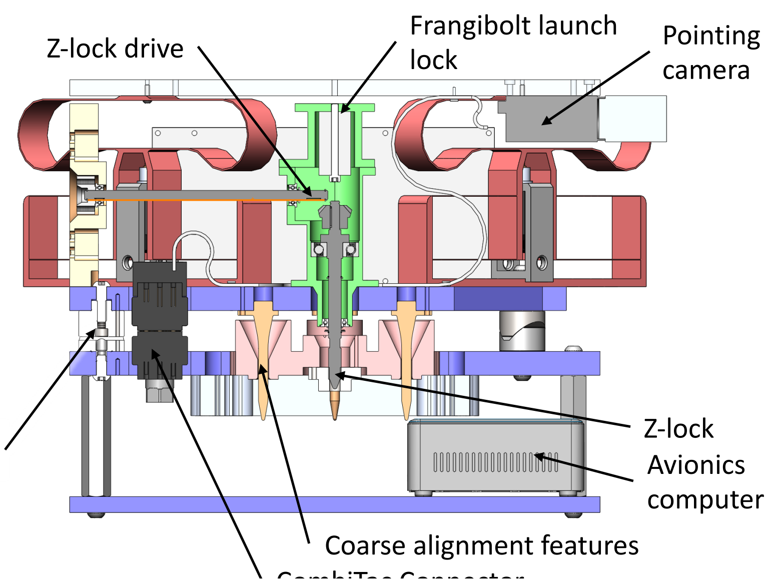

Inchworm Drive
0.02 nm resolution, 50N push/pull force, 25-100 mm stroke length.
Launch Supports
Alternate path for high loads during launch. Physical connection occurs only when launch locks are engaged.
Height ≈ 124 mm
Slightly too tall, but can adjust loop flexure further and look for actuators with shorter strokes.
2 DoF Flexure
Provides freedom of motion to compensate for angular misalignment between plates.
Titanium Loop Flexure
Frequency of 3 Hz with 75 kg load, deforms 4 mm due to actuator force.

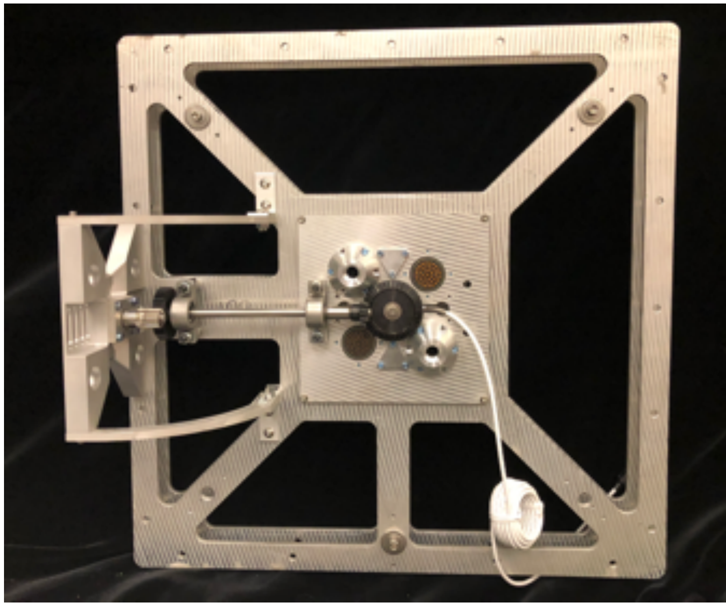

P-S-Planar Link module
Robotic Grapple
Spacecraft side interface

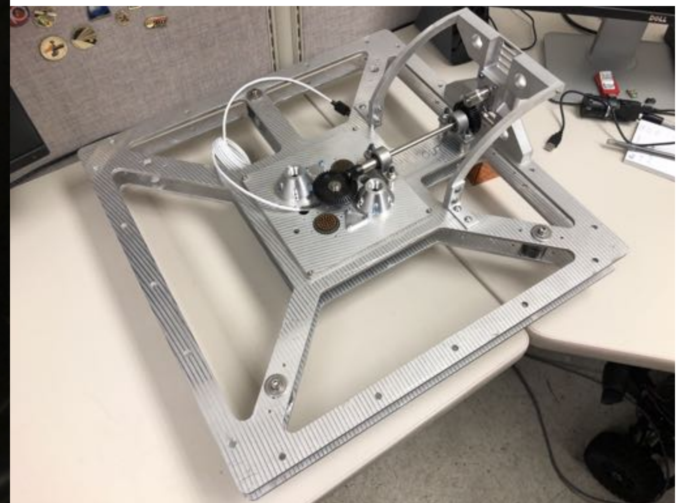

Top view
Camera
IMU
Motor controller
Microcontroller
Harnessing

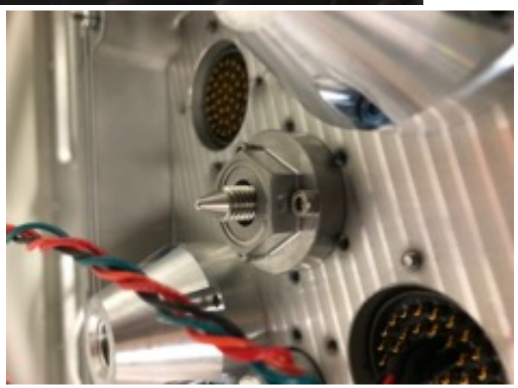

Bottom view
Kinematic mounts
Z-lock
Coarse alignment features
CombiTac Connector

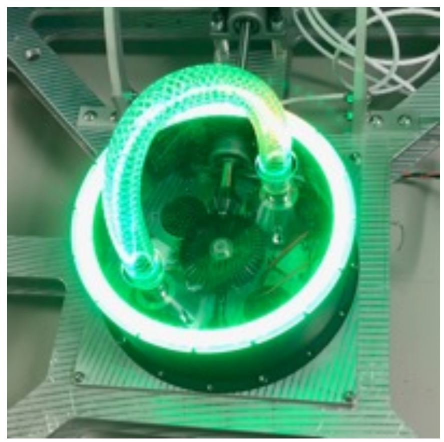

Robot grapple
Tool drive
Spring
Actuator
Conic alignment features
Kinematic mounts

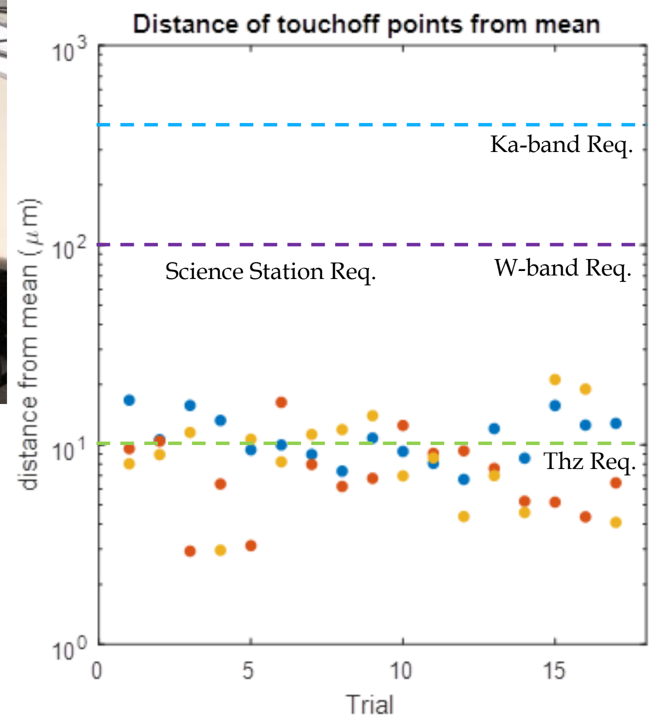

Z-lock drive
Frangibolt launch lock
Pointing camera
Z-lock
Avionics computer
Coarse alignment features



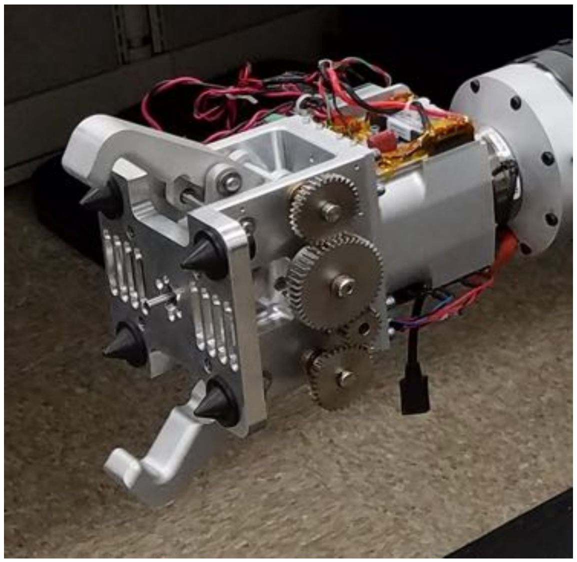


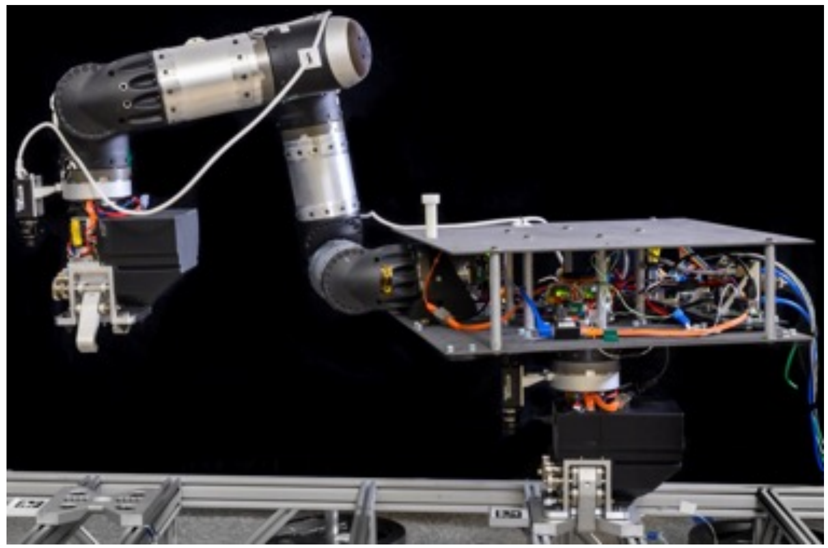


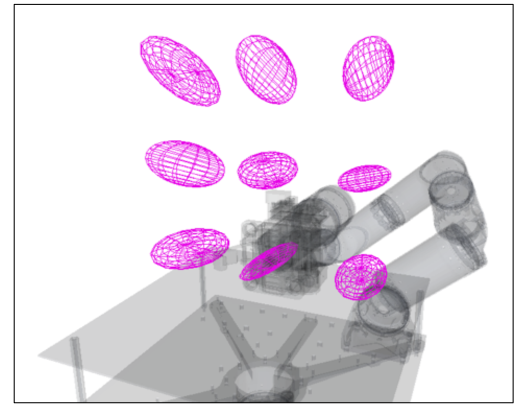


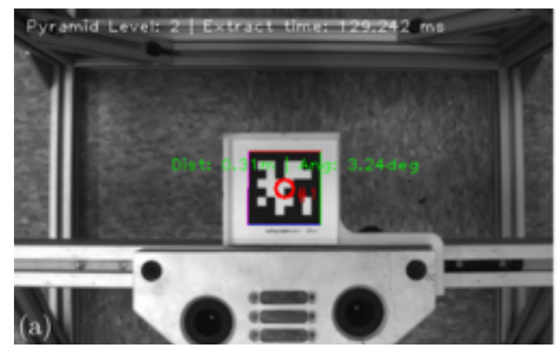


Variation in orientation is also very small
(>0.0054 degrees per axis)









8 dof robotic system with end effectors at both ends and a backpack for payload
Unique JPL Design (Provisional Patent). Distinct Advantages:

- Does not need two robots to carry the instrument while truss walking
- Does not need to put down the instrument to walk
- Ability to grapple and walk on truss, assemble payload on backpack
- Large manipulability and workspace
- Ability to draw power and comm from the truss, distributed MC

IEEE Aerospace

A Robotically Assembled and Serviced Science Station for Earth Observations

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WIP Journal Paper

Ground Demonstration of Autonomous Berthing and Installation of a Payload Using a Robotic Arm

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Abstract

While the technology behind spacecraft buses of Earth-observing satellites evolves relatively slowly, the technology behind onboard scientific instruments evolves relatively rapidly. On-orbit installation of scientific payloads has been proposed to address this identified disparity. For this concept of operations, a host spacecraft bus with slots for payloads is kept on orbit; satlets housing scientific payloads are launched separately, caught by a robotic arm on the host spacecraft, and installed via a standardized interface. To make this a routine operation, it is preferable that berthing and installation be performed autonomously. In this paper, a ground-based robotic arm with eight degrees-of-freedom, two grippers, and two power take-off shafts is used to demonstrate the autonomous execution of three critical operations: berthing of a satlet with residual relative velocity; hand-over-hand walking of the robotic arm and mounted satlet from its pickup location to its installation location; and installation/uninstallation of the satlet onto/from a truss on the host spacecraft. The algorithmic approach, implementation details, and results of each are presented herein.

My thanks to the following:

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- Jason Hyon, Diane Evans, and others at 8x. Rene Fradet and others during formulation. Rafi Some and Greg Davis
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