

Satellite Servicing Capabilities Office

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Who We Are



Proud to be part of America's servicing tradition – from Solar Max, to Hubble, to the new robotic servicing frontier.

SSCO Programmatic Objectives



The Satellite Servicing Capabilities Office (SSCO) at NASA's Goddard Space Flight Center exists to:

- Advance the state of robotic servicing technology to enable the routine servicing of satellites that were not designed with servicing in mind.
- Position the U.S. to be the global leader in in-space repair, maintenance and satellite disposal.
- Help to enable a future U.S. industry for the servicing of satellites.

Satellite Servicing: Customers and Benefits



Satellite Servicing provides critical technologies for:

Strategic/National Interest

- Reconnaissance/Situational Awareness
- AR&D non-cooperative customers (legacy satellites)
- Repair, Refuel, Replace, Relocate assets

Orbital Debris Removal

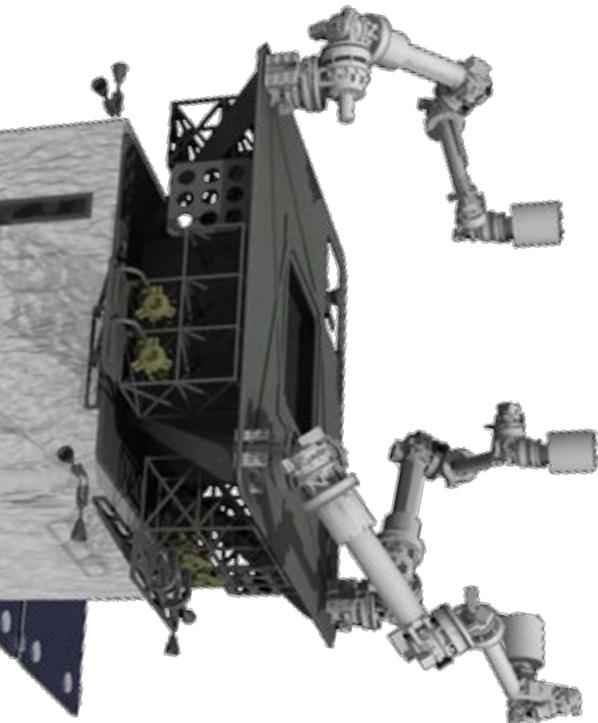
- AR&D non-cooperative customers (legacy satellites, spent rocket bodies)
- Relocate orbital debris
- Refuel to allow satellite self-disposal

Continued Human Exploration of the Solar System

- AR&D non-cooperative customers (asteroids, legacy satellites)
- AR&D with cooperative elements (habitats, airlocks, fuel depot)
- Relocate, Refuel, Repair, Replace, Assemble

Communications Industry

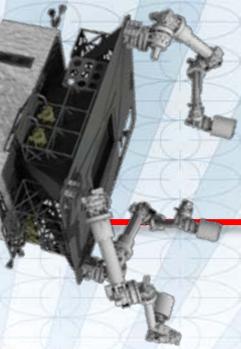
- Reconnaissance/Situational Awareness
- AR&D non-cooperative customers (legacy satellites)
- Repair, Refuel, Replace, Relocate assets
- Jumpstarts commercial servicing



Moving Robotic Satellite Servicing Forward



- Satellite servicing has been discussed and advocated for decades
 - **Reconnaissance:** situational awareness, inspection
 - **Relocation:** fleet management, disposal, inclination change
 - **Refueling:** life extension
 - **Repair:** releasing stuck appendage, deployment anomaly
 - **Replacement:** black box augmentation
- Most past servicing missions were conducted from the Shuttle. For servicing to continue and grow, it must be done robotically.
- For robotic satellite servicing to take flight, two factors must be resolved:
 - The Risk Factor
 - Fully robot satellite servicing to an operational satellite has never been attempted
 - Pathfinder mission to an operational satellite needed to establish technology capability
 - The Business Case
 - Need right combination of private and public support to make business case close
 - Must balance capabilities with viable customers



Past and Future Services



Service	What's Been Done	Our Vision for Robotic Servicing
Reconnaissance	Hubble (cracked thermal blanket inspection, MMOD survey)	Inspection; Visual Diagnostics
Relocate	Hubble and ISS orbit boost	Relocates vehicle to correct orbit
Refuel	ISS, Orbital Express	Life extension of vehicle; fleet management
Repair	Hubble Instruments, ISS	Unplanned repair
Replace	Solar Max, Hubble, Orbital Express	Instrument upgrade through swap-out



HST Servicing Mission 4 Instrument Repair



Astronaut Mike Massimino practices removing 111 fasteners (#6 and #8's) on the STIS Instrument trainer in preparation for HST SM4



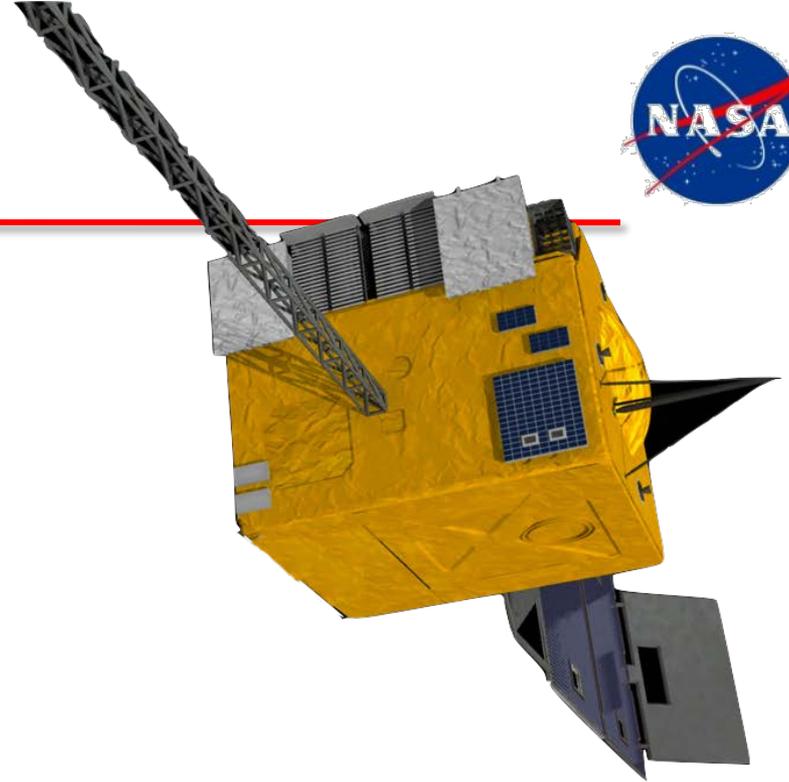
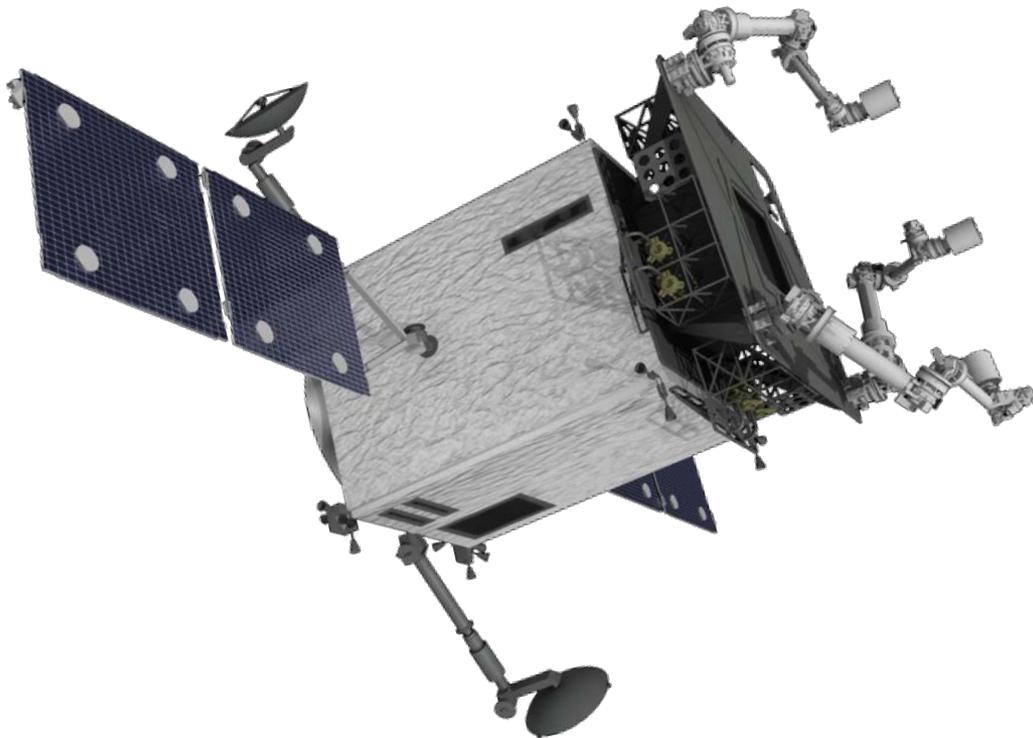
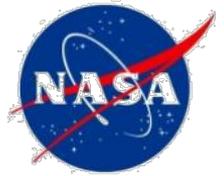
The card extraction tool attached to the failed printed circuit card ready to be removed from the STIS Instrument



HOW WE WILL ACHIEVE OUR GOALS

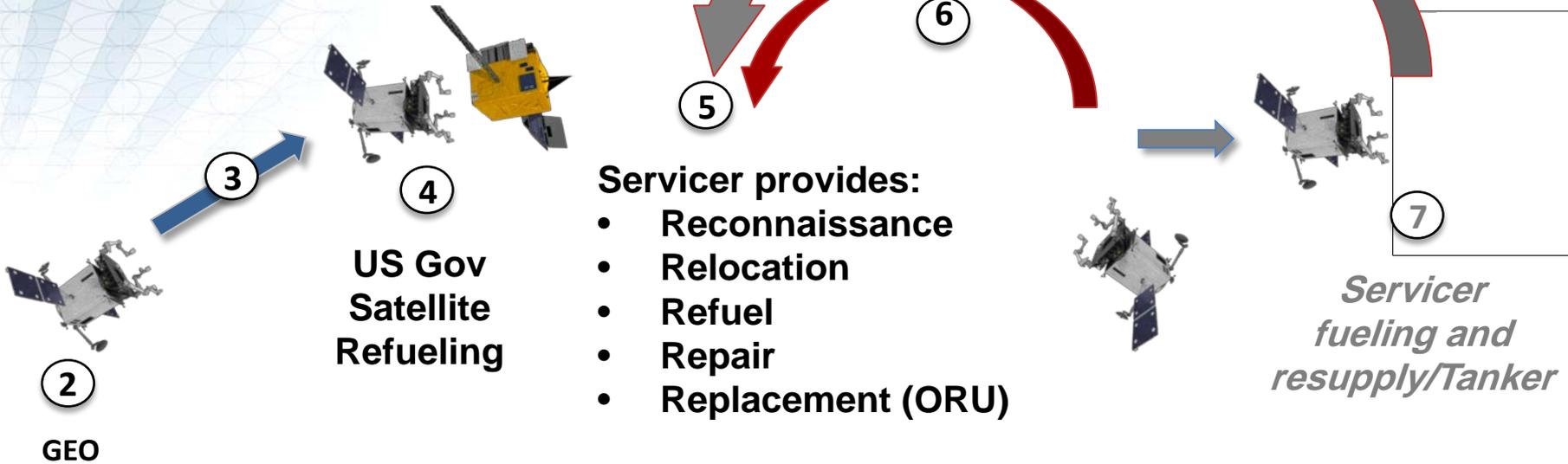
Achieving Our Goals

SSCO is investigating a mission with a U.S. industry partner to fulfill our programmatic objectives and to move robotic satellite servicing forward.



Targeted Launch
Date: 2016

Mission Profile



Multi sortie mission scenario



1. ATLAS launches servicer into GEO
2. Servicer check-out
3. Orbit transfer to and AR&D with US Gov Satellite
4. Refuel first customer then release
5. Perform servicing tasks on subsequent customers
6. Repeat services until propellant nearly depleted

-
1. *Servicer fueling and resupply at Tanker*
 2. *Repeat*
- } **Program Options**



TECHNOLOGY ROADMAP

IN ORBIT AND ON THE GROUND



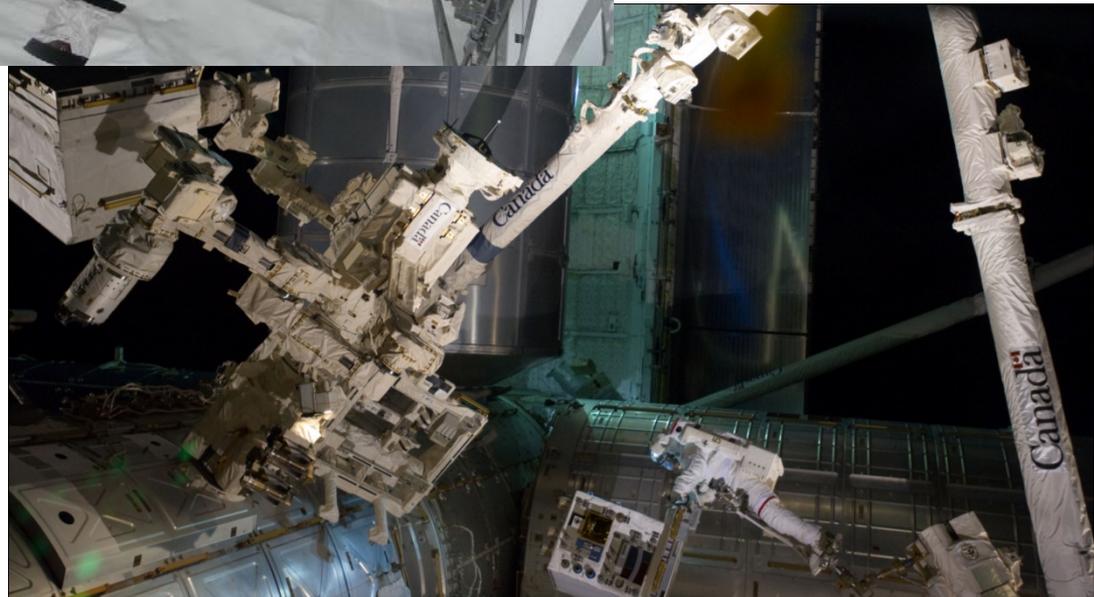
Robotic Refueling Mission (RRM)



Final Shuttle Launch (View from Chase Plane)



**RRM in
Atlantis Cargo
Bay**



EVA Transfer of RRM to Dextre Platform on



Robotic Refueling Mission (RRM)



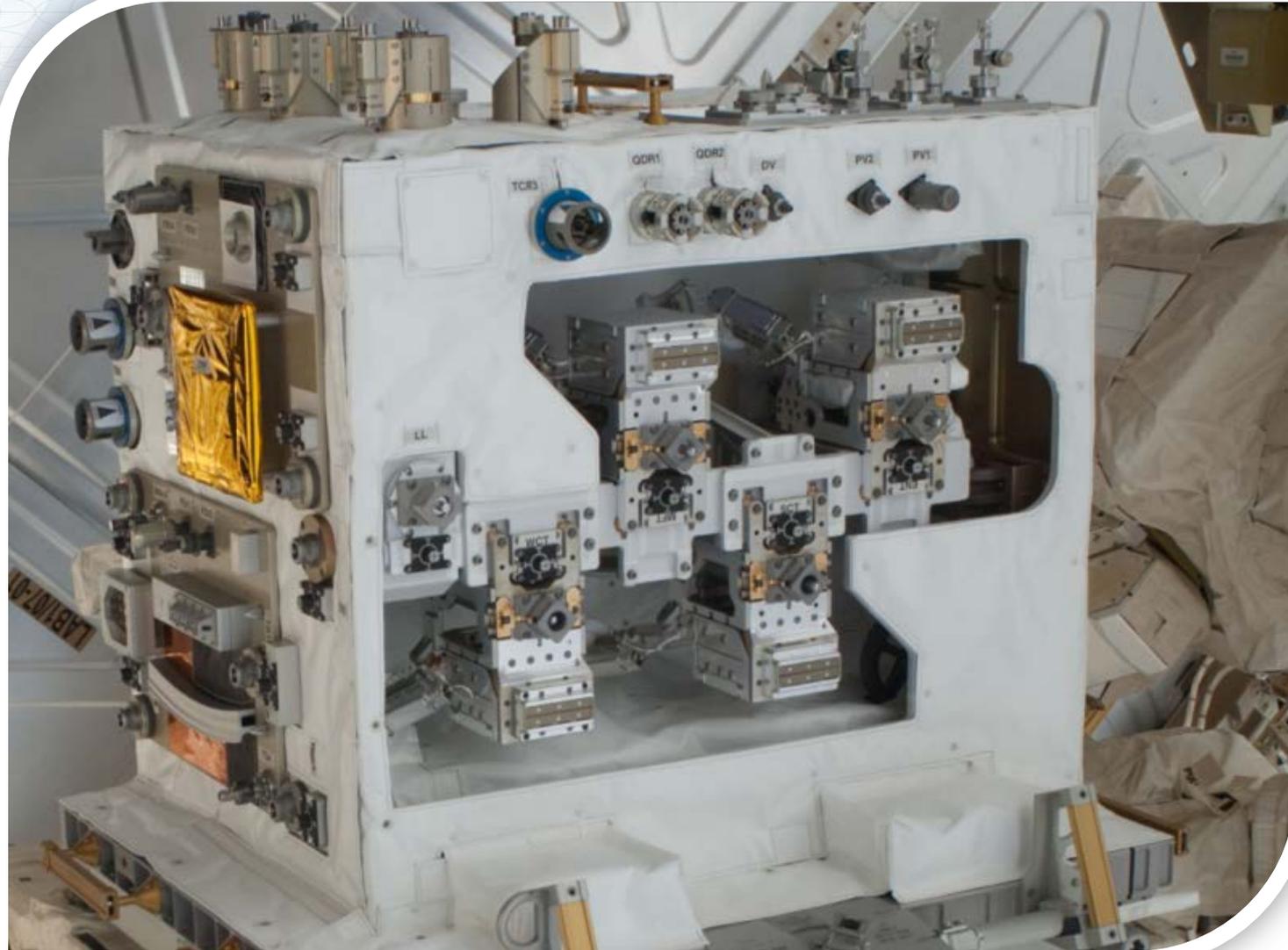
RRM demonstrates satellite-servicing tools, technologies and techniques for legacy spacecrafts. Six RRM tasks will be conducted over 15 months:

- **Coolant Valve Panel Task**
 - Cutting wire and unscrewing gas fittings found on many NASA satellites
- **Refueling Task**
 - Cutting wire, removing tertiary and safety caps, threading onto propellant fill valve and then transferring a referee fluid across the interface
- **MLI Manipulation Task**
 - Peeling back multi-layered insulation
- **#10 Torque Set Task**
 - removing small fasteners
- **RF Connector Task**
 - removing sub-miniature A termination caps
- **Vision Task**

RRM is a joint effort with the Canadian Space Agency.

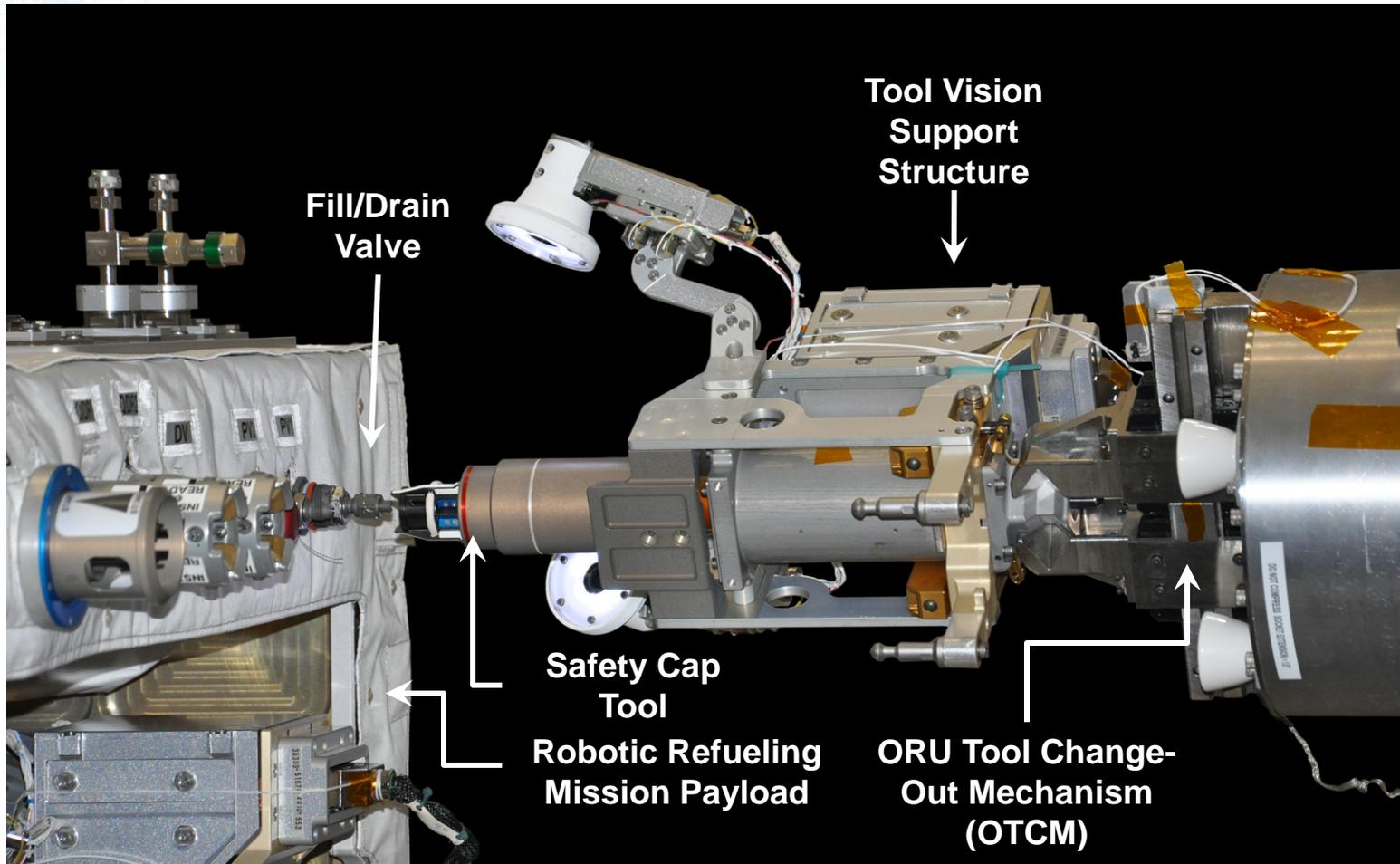
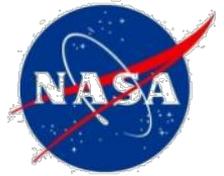


RRM On Orbit



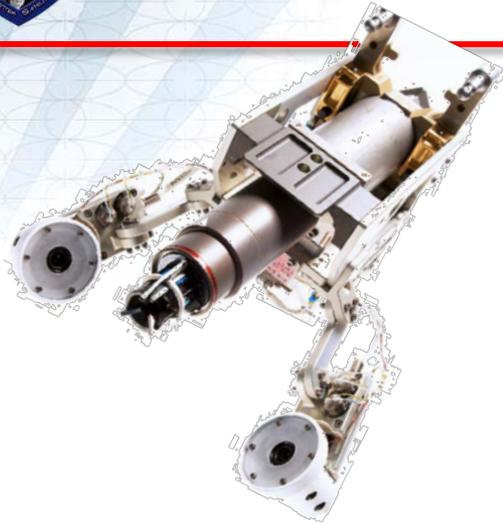


RRM Hardware

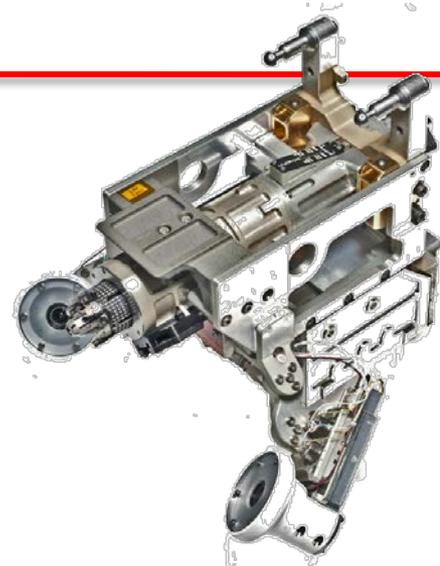




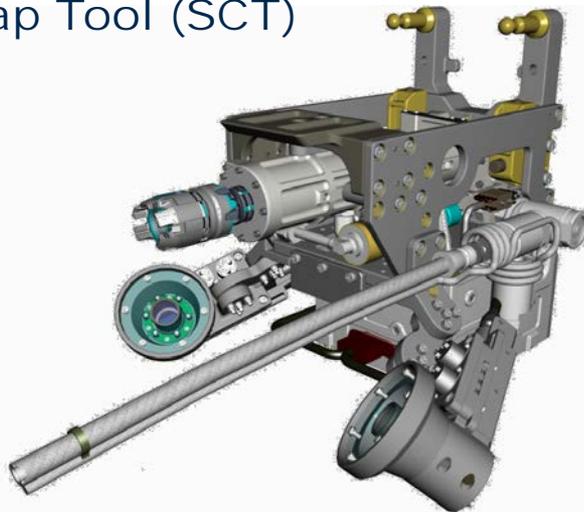
RRM Tools



Safety Cap Tool (SCT)



Multi-Function Tool (MFT)



EVR Nozzle Tool (ENT)
For Spacecraft Refueling



Wire Cutter Tool (WCT)



ON THE GROUND: TECHNOLOGY TEST CAMPAIGN

Technology Validation For Flight Hardware Success



Robotic Hose Management at GSFC/KSC



Robotic Refueling Mission



Zero-G Flights



Autonomous Capture Tests at GSFC

Dexterous manipulation

Fluid transfer

AR&D Algorithm Development

AR&D Sensors/Pose

Contact Dynamics Simulations/
Robotic Arm

End-to-End Systems Level Testing



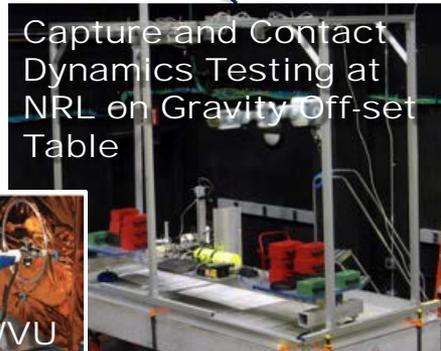
GSFC/NRL



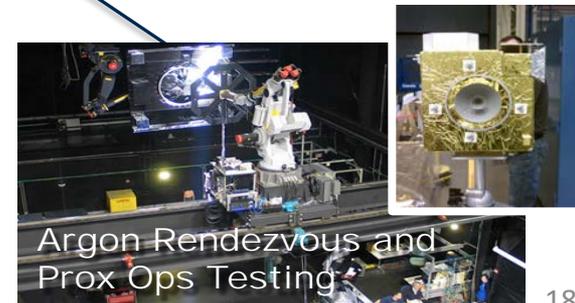
Tool Stowage Test, GSFC



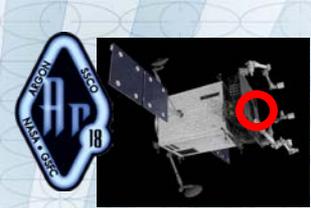
WVU



Capture and Contact Dynamics Testing at NRL on Gravity Off-set Table



Argon Rendezvous and Prox Ops Testing



Argon Rendezvous and Prox Ops Testing

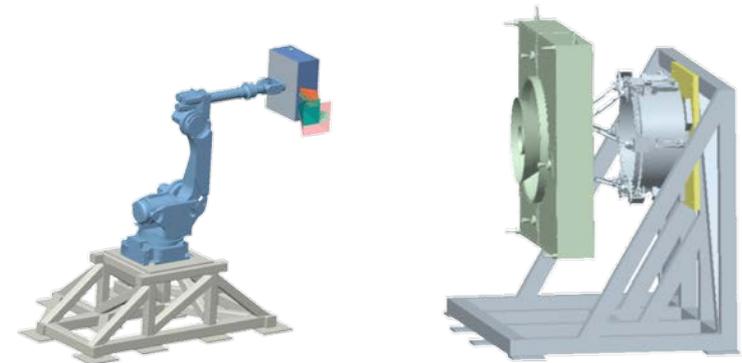


Argon—Ground-based Autonomous Rendezvous and Docking (AR&D) Demo

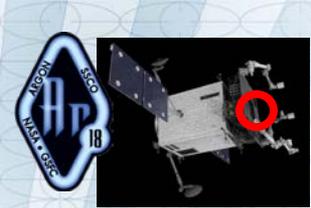
- Tests and evaluates system comprised of avionics, sensors, and algorithms
- Elevates key AR&D technology to TRL 6 in preparation for Servicing mission
- Developed from cancelled International Space Station demo “Dextre Pointing Package” as a quicker and less costly approach

Argon features Goddard SpaceCube

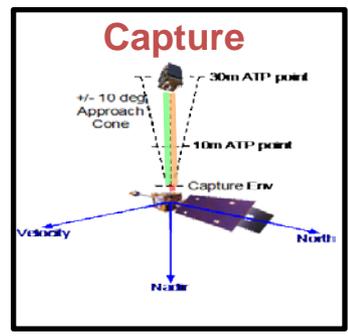
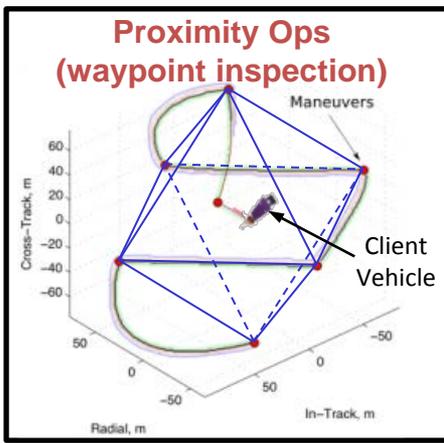
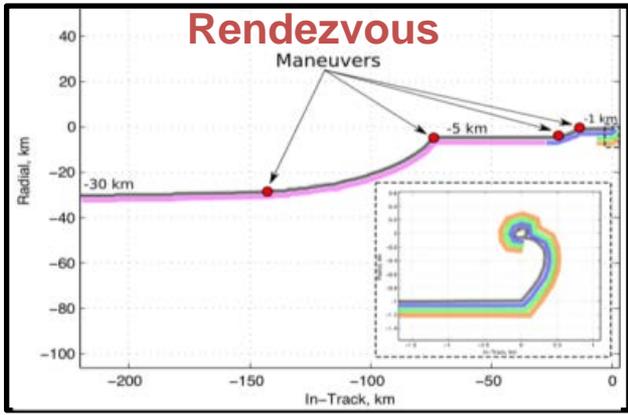
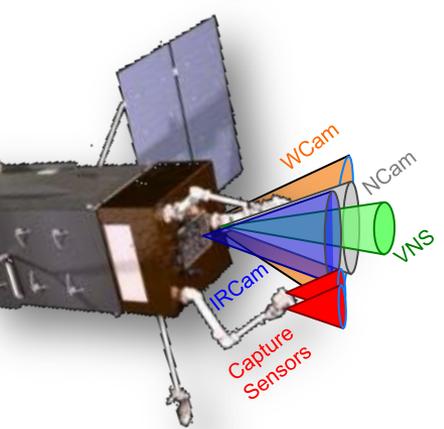
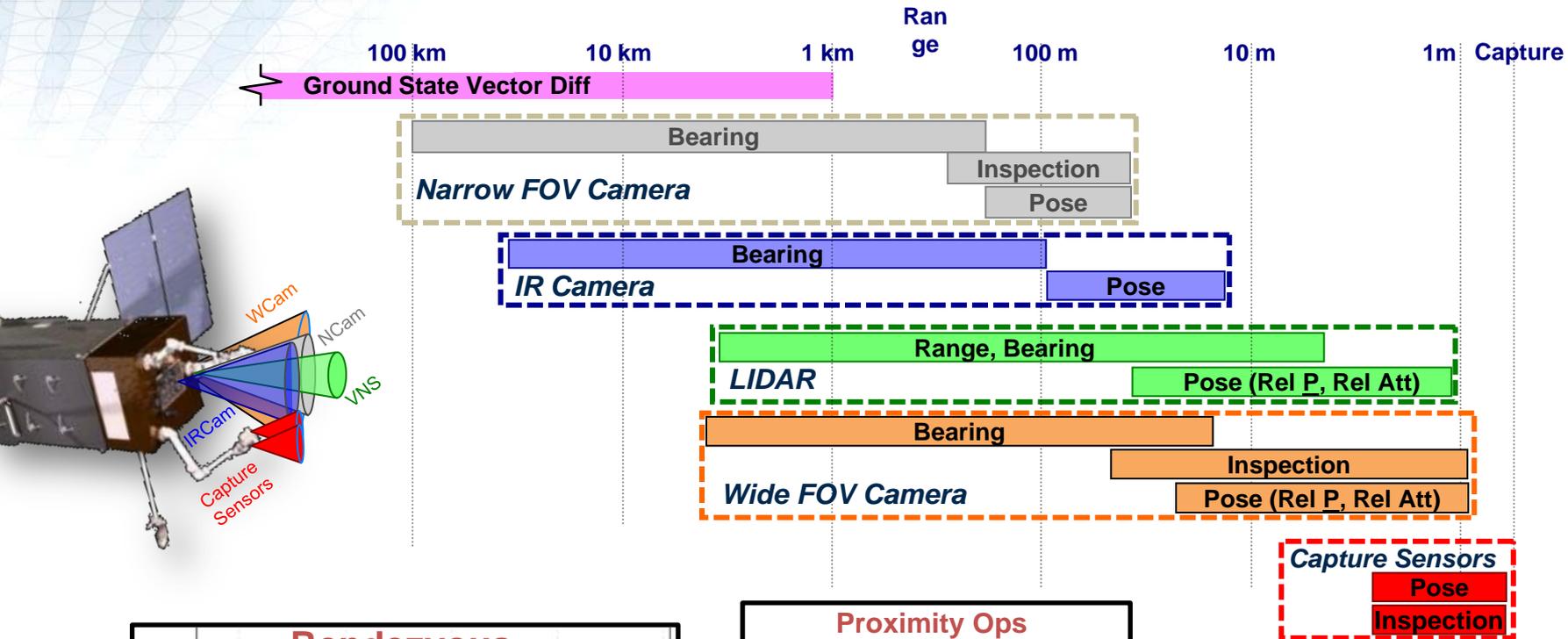
- High performance, compact, reconfigurable space processor
- Provides 15 to 25 times the processing power of a typical Rad750 flight processor used on most command, data, and handling flight computers
- Supports flight grade or commercial grade parts for cost savings



Dynamic testing



Sensors and Algorithms for Non-Cooperative AR&D



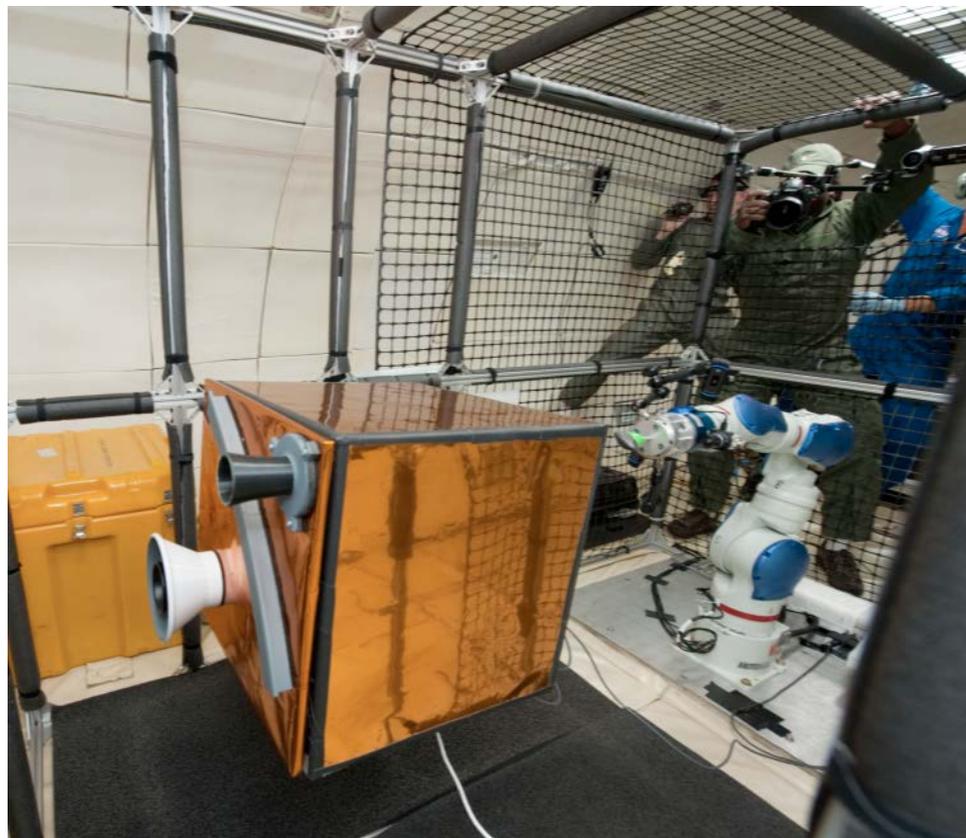


Zero-G Autonomous Tracking Demonstration



Objective:

- Validate ground-based contact dynamics simulation of space operations
- Mature autonomous capture algorithms
- Quantify a ground-based simulation platform to support future GEO and LEO AR&C/D missions





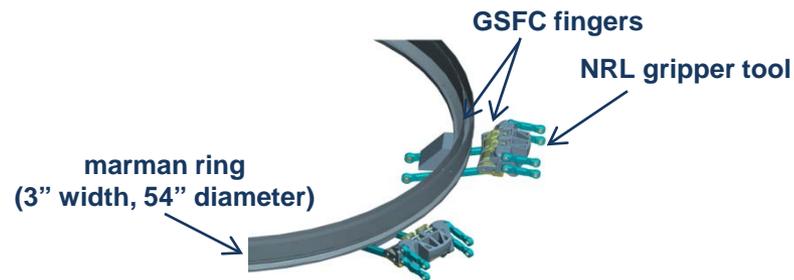
Capture and Contact Dynamics Testing at NRL on Gravity Off-set Table



Objective:

Robotic evaluation and marman ring capture using the new GSFC gripper concept/tool “jaws” designs in relative environment.

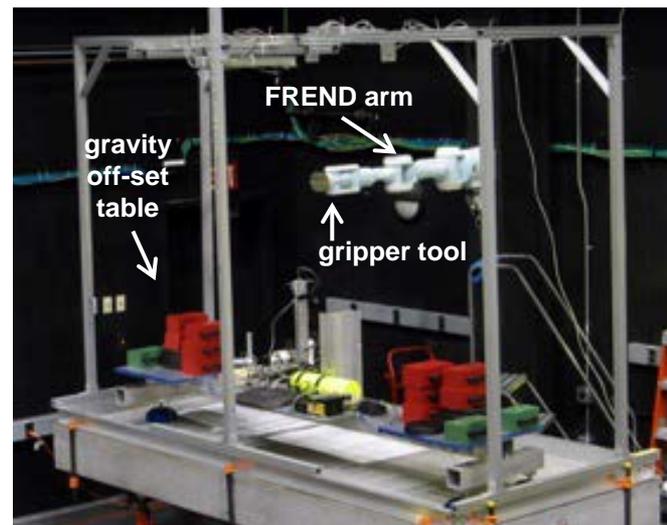
- Contact dynamics (tip off rates) data collection with compliance control
- Preliminary evaluation and feedback of GSFC gripper fingers on NRL Tool Drive



Gripper Tool Conceptual Design

TRL/Test Rational:

- Down select of GSFC gripper tool conceptual designs
- Establishes the capability at NRL to evaluate gripper tool fingers and other servicing tools
- Advances the Gripper Tool “jaws” design by evaluating fingers with contact dynamics



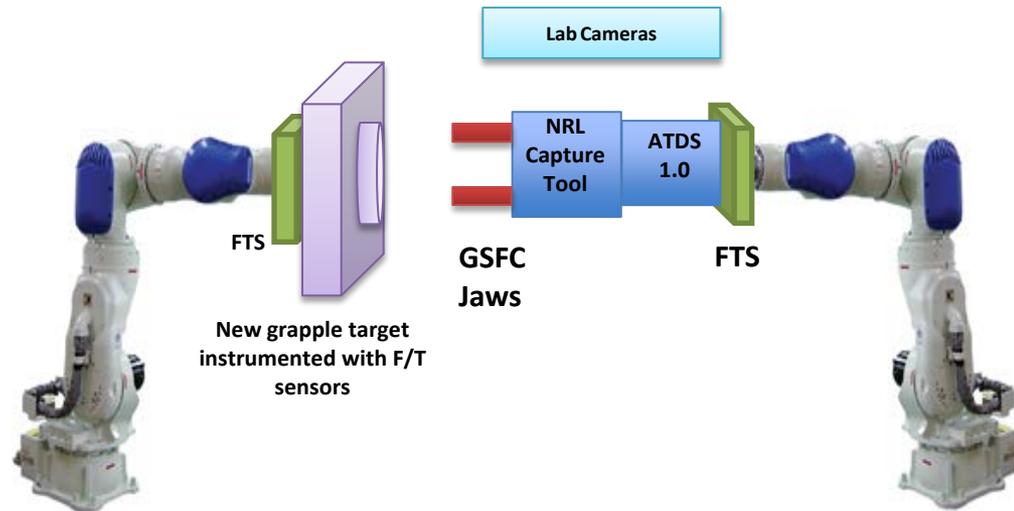


Autonomous Capture Tests at GSFC



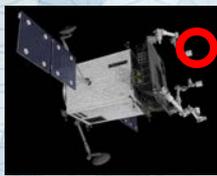
Objective:

- Perform an autonomous capture demonstrations with contact dynamics/initial loads etc... in 6-DOF



TRL/Test Rational:

- Establish the robotic platform capabilities to support simulated capture evaluations with contact dynamics in 6-DOF and with robot control and machine vision feedback in a closed loop.
- Increases TRL of vision processing algorithms (GNFIR [GSFC], Argo [WVU]) by using them in a closed loop integrated robotic control system
- Increase TRL of prototype GSFC capture tool “jaws”
- Increase TRL of prototype GSFC capture tool assembly
- Increase TRL of prototype GSFC Tool Drive - ATDS 1.0



Robotic Evaluations of the Hose Management System at GSFC



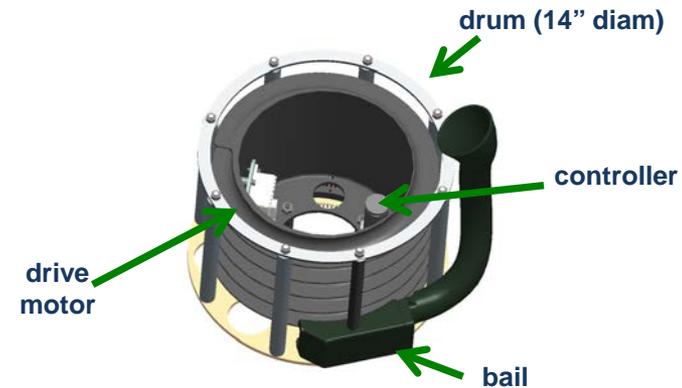
Objective:

Robotic deployment and stowage of the hose management system conceptual designs

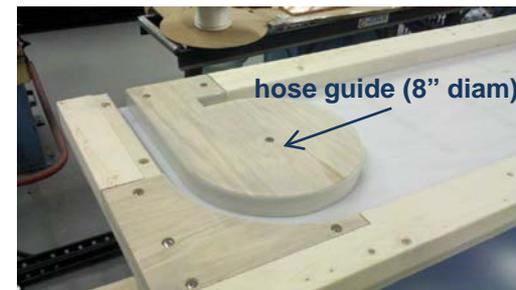
- Slack management/Pressure Management
- Hose management system performance
- Arm-hose interactions (forces, torques, operational coordination)
- In 3-DOF and 6-DOF
- Refueling concept of operations development

TRL/Test Rational:

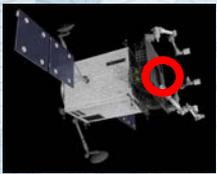
- Down select of hose management system conceptual designs
- Down select of hose swivel conceptual designs
- Advances the Hose Management Control System TRL
- Force/Torque initial characterization of robotic arm in 2-DOF



Hose Management Concept 1: Hose Reel



Hose Management Concept 2: Pizza Box



Robotic Tool Stowage Test at GSFC



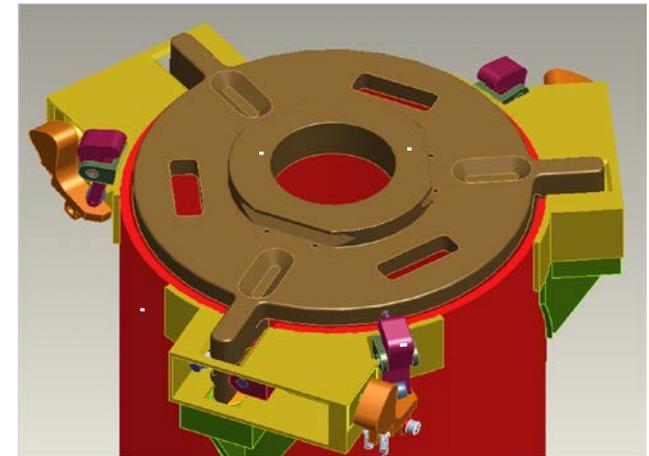
Objective:

Demonstrate the ability to robotically mechanically and electrically interface with a notional servicing tool to retrieve and re-stow the tool. Will mature the hardware design and the requirements for:

- Critical ATDS elements: (tool coupler drives, Linear drive and rotary drives, electrical blind mate connectors, **and** Cameras & Lights mechanisms),
- Tool stowage mechanisms,
- Launch lock mechanisms,
- Targets for robotic tele-operations
- Tool to Tool Drive Interface Plate
- Autonomous Tool Capture

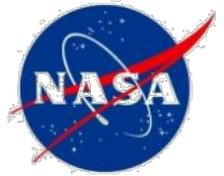
TRL/Test Rational:

- Advances the Tool Stowage System TRL
- Advances the Advanced Tool Drive System TRL
- Establishes the capabilities to simulate and evaluate Robotic Tele-operations of Tool Retrieval and Stowage
- Exercises critical interfaces of the robotic system in a relative operational environment to mature these technology and advance system requirements.



Roller Latch
Mechanism Concept

Typical Robotic Tool Requirements



- Mass: < 5kg
- Power: < 15 watts
- Volume: < 20 cm x 40 cm
- Temperature: -70 to +70°C

In Conclusion



Satellite Servicing provides critical technologies for:

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- Reconnaissance/Situational Awareness
- AR&D non-cooperative customers (legacy satellites)
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