National Aeronautics and Space Administration

Satellite Servicing Technology Development

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OCT
Rev. A

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Space Technology Program, Office of Chief Technologist

Theme

- **Mason Peck asked me to represent OCT at today's workshop.**
- **Ben Reed asked me to address the "How?" aspects of satellite servicing.**
- **These are a natural fit, focusing on technologies for robotic satellite servicing.**

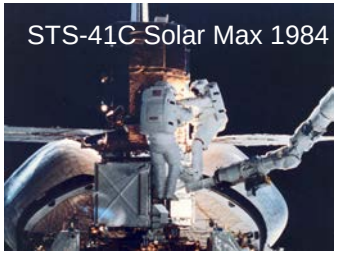
How have we done satellite servicing in the past?

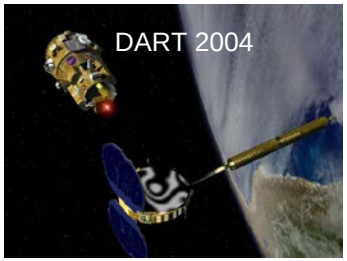
Satellite Servicing History and Present

- **NASA**
  - **1984: Solar Max Capture, Repair and Re Deploy**
  - **1992: Intelsat VI Capture and Re Deploy**
  - **1993: Hubble Repair, Servicing Missions 1-4**
  - **2004: Demo of Autonomous Rend. Tech.**
  - **2011: DARPA/OCT Manned Geo Servicing Study**
  - **2012: Robotic Refueling Mission on ISS**
  - **2012: Robonaut 2 Task Board on ISS**

- **Other US Agencies**
  - **2004: Air Force XSS 10 and 11**
  - **2007: DARPA Orbital Express**

- **Other Countries**
  - **1997: NASDA ETS-VI Rendezvous and robotics**





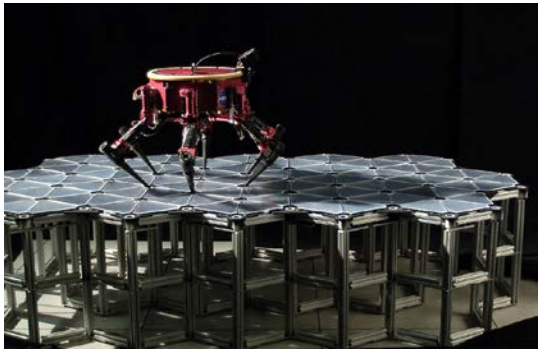
Satellite Servicing Critical Technologies

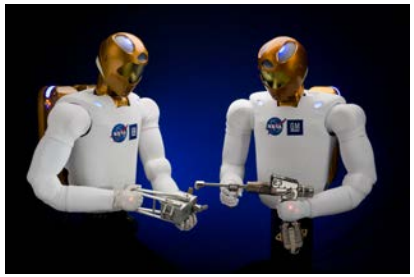
- NASA Technology Roadmaps (Under Review by NRC)
  - Tech Area 2, In-Space Propulsion Technologies
    - Upper Stages, Transfer Missions, Tethers, Beyond Chemical Fuel
  - Tech Area 4, Robotics, Tele-Robotics and Autonomous Systems
    - Autonomous Rendezvous and Docking, Grappling, Berthing, Servicing Manipulation, Sensing and Perception, Inspection, Repair
  - Tech Area 5, Communication and Navigation
    - Position, Navigation and Timing, GPS, Relative Proximity Navigation

- Development Approaches
  - NASA will continue collaboration with industry, and other agencies and organizations
  - Where possible we use lab, facility and analog testing of approaches
  - We utilize the ISS for technology demonstrations with diverse vehicles

Robotic Servicing Functions (LEO, GEO and Beyond)

- **Inspection**
  - External, In Structure
- **Relocation**
  - Solve Launch Failure, End of Mission
- **Resolve Deployment Failure**
  - Antennae, Solar Array, Mechanisms
- **Refuel**
  - Handle Connectors and Hoses
- **Add Components**
  - De-Orbit stages, new Elements
- **Swap Robot Compatible Parts**
  - Instruments, Batteries
- **Dexterous Manipulation**
  - Non Robot Compatible Tasks, Contingency

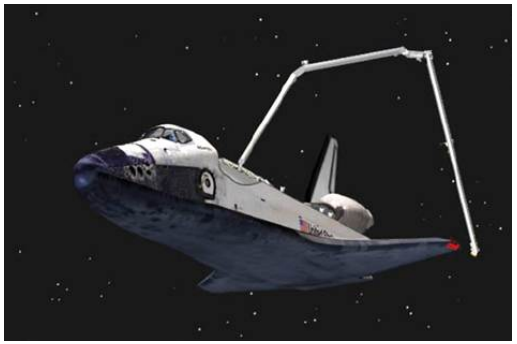


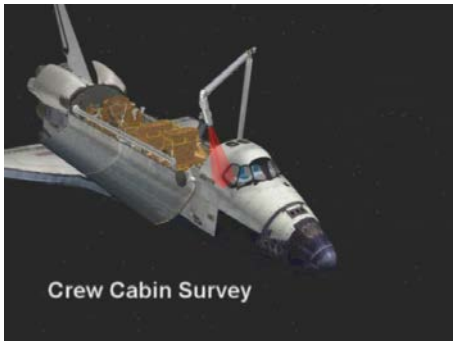


Robotic Servicing Functions: Inspection

- **Free Flying Inspection**

- **Manipulator Inspection Wand**





- **New Inspection Technologies**

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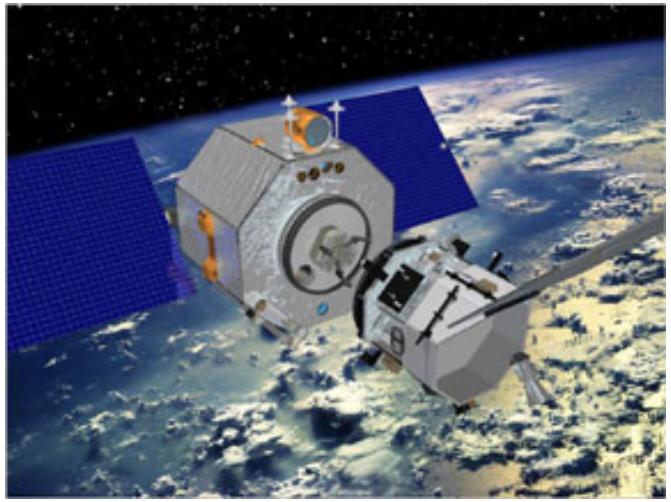
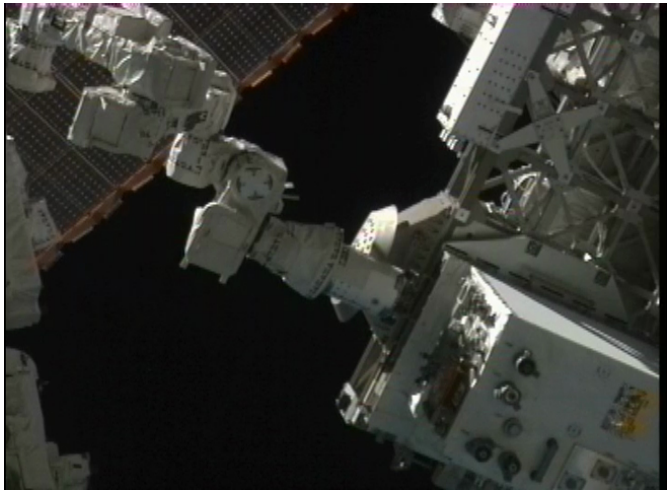
Robotic Servicing Functions: Refueling

- **Orbital Express Refueling Mission**



- **ISS Robotic Refueling Mission Demo**



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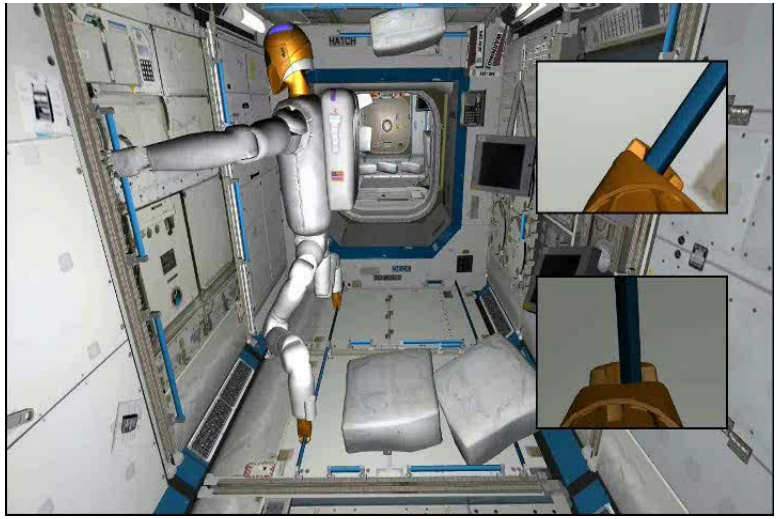
Robotic Servicing Functions: Dexterous Manipulation

- **Hubble Servicing Experiments**

- **ISS Robonaut Plans**



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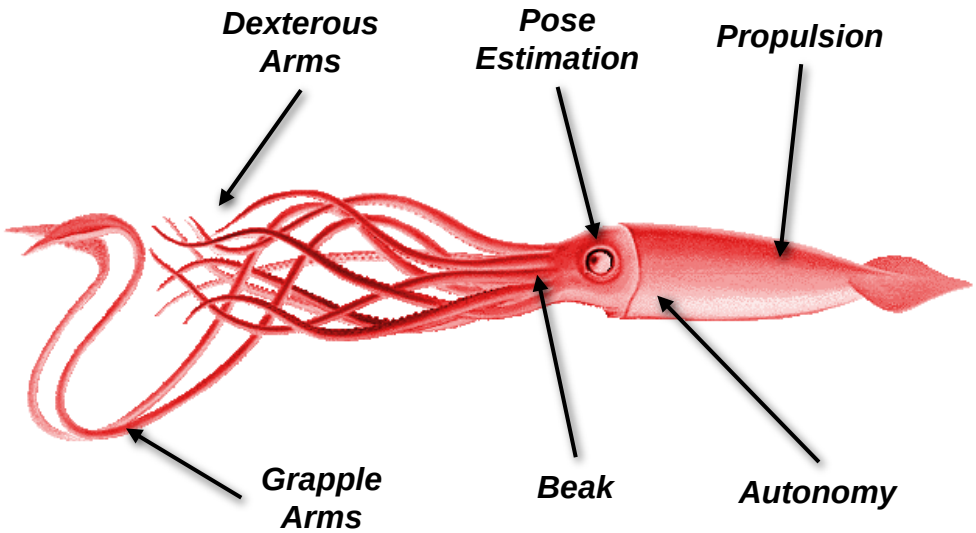
How would “Mother Nature” do satellite servicing?

Exploration Robotics Servicing

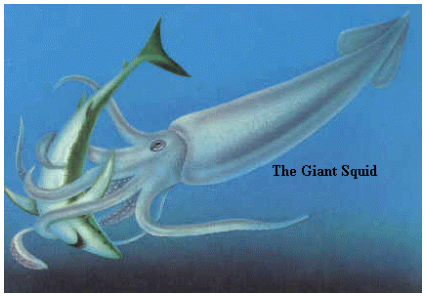
- Squid Design
  - Neutral Buoyancy Specialist
  - 6 Axis Thrust Control
  - Long Reach Grapple Arms
  - Dexterous Work Arms
  - Beak for Final “Docking”
  - Eye for Rendezvous/Prox Ops
  - Fully Autonomous Control

- Squid Tactics and Prey
  - Neutral Buoyancy Pursuit
  - Non Cooperative Targets
  - Grapple, Manipulate, Bite

Mother Nature’s Solution: Giant Squid



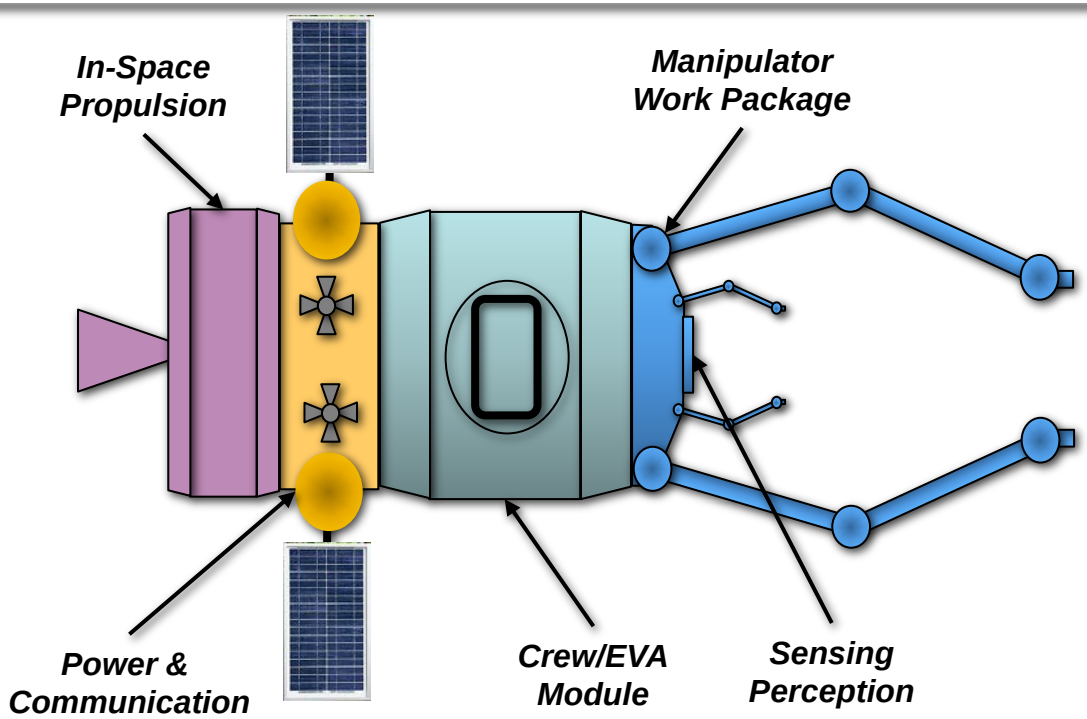
Non cooperative Targets (Fact and Fiction)

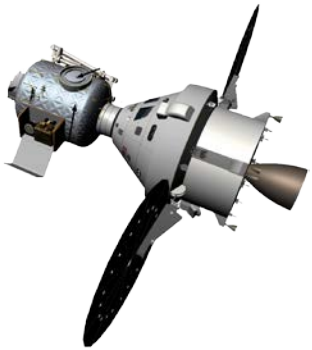


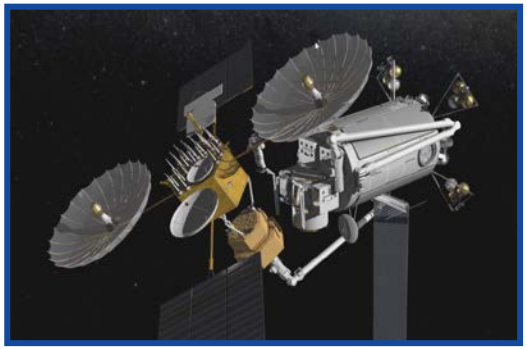
For exploration capability we need the ability to capture, control, and manipulate in space for servicing, assembly, and mobility

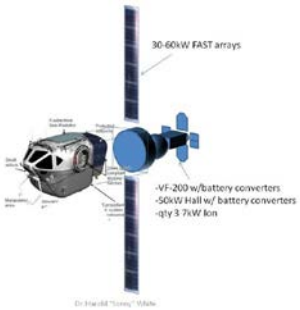
Engineering Solution: Building Block Approach

- Manipulator Work Package
  - Long Reach Grapple Arms
  - Dexterous Work Arms
  - Docking Fixtures/Decks
- Sensing and Perception
  - Long to Short Range
  - 6 Axis Pose Estimation
- Communication
  - In-Space Assets
  - To Earth
- Power
  - Solar Arrays
  - Batteries
- In-Space Propulsion
  - Upper Stage
  - RCS
- Pressurized Human Modules
  - Living Quarters/Protection
  - Command and Control
  - EVA Suit Ports/Locks









Technologies Transcend Single Missions

- Key Space Technologies
  - In-Space Propulsion
  - Robotic Manipulation
  - Rendezvous and Docking
  - Sensing and Perception
  - Navigation

- Technology Applications
  - ISS caretaking and utilization
  - Satellite servicing
  - Orbital debris removal
  - Deep space vehicle stack assembly
  - Telescope assembly