

National Aeronautics and Space Administration

Satellite Servicing Technology Development

Dr. Robert O. Ambrose

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Rev. A

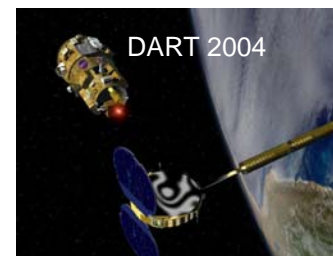


Space Technology Program, Office of Chief Technologist

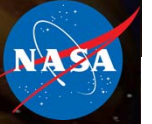
Satellite Servicing History and Present



- **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

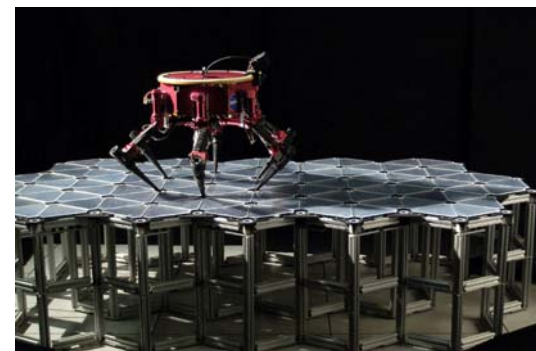


- NASA Technology Roadmaps (Under Review by NRC)
 - Tech Area 2, In-Space Propulsion Technologies
 - Upper Stages, Transfer Missions, Tethers, Beyond Chemical Fuel
 - Tech Area 4, Robotics, Tele-Robotics and Autonomous Systems
 - Autonomous Rendezvous and Docking, Grappling, Berthing, Servicing Manipulation, 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)

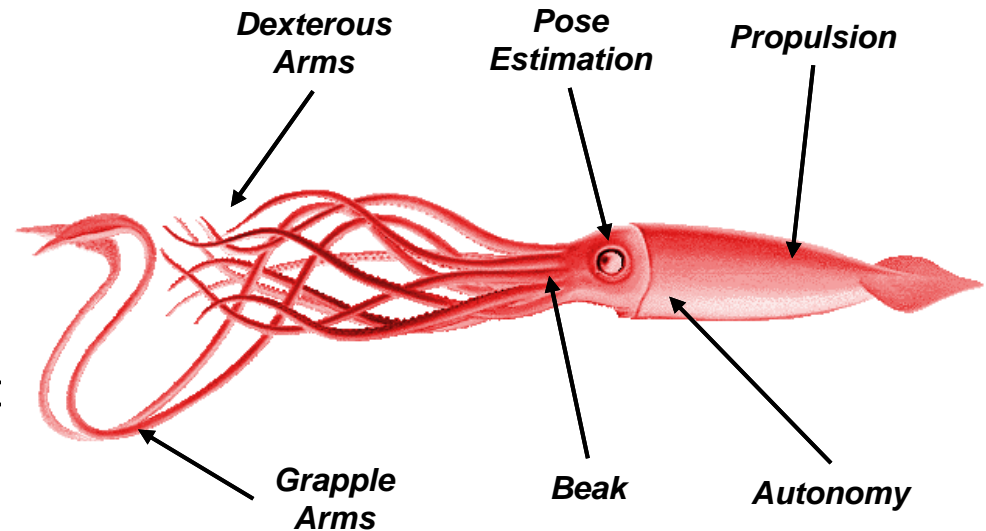


- **Inspection**
 - External, In Structure
- **Relocation**
 - Solve Launch Failure, End of Mission
- **Resolve Deployment Failure**
 - Antennae, Solar Array, Mechanisms
- **Refuel**
 - Handle Connectors and Hoses
- **Add Components**
 - De-Orbit stages, new Elements
- **Swap Robot Compatible Parts**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

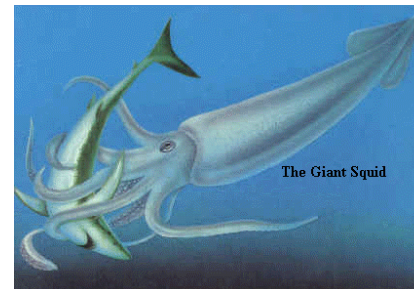


- Squid Design
 - Neutral Buoyancy Specialist
 - 6 Axis Thrust Control
 - Long Reach Grapple Arms
 - Dexterous Work Arms
 - Beak for Final “Docking”
 - Eye for Rendezvous and Proc
 - Fully Autonomous Control
- Squid Tactics and Prey
 - Neutral Buoyancy Pursuit
 - Non Cooperative Targets
 - Grapple, Manipulate, Bite

Mother Nature’s Solution: Giant Squid



Non cooperative Targets (Fact and Fiction)

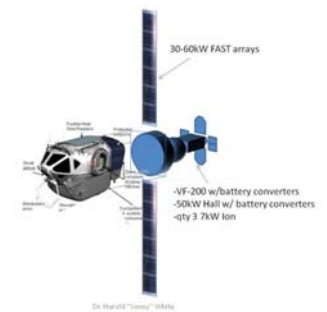
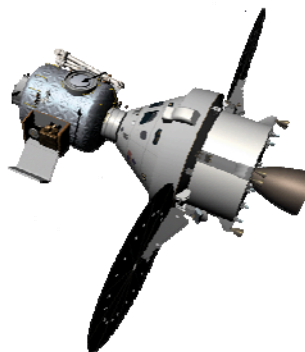
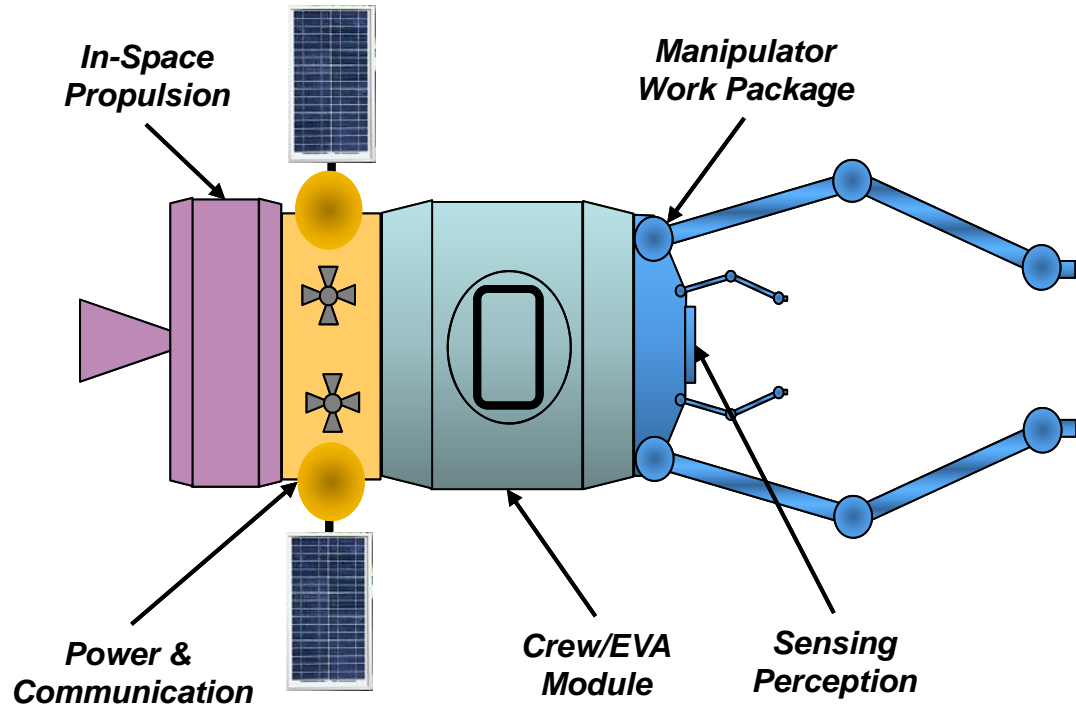


For exploration capability we need the ability to capture, control, and manipulate in space for servicing, assembly, and mobility

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



Recommended Path Forward



- Develop Key Space Technologies
 - In-Space Propulsion
 - Robotic Manipulation
 - Rendezvous and Docking
 - Sensing and Perception
 - Navigation
- Technology Push with Flight Experiments
 - On NASA's ISS
 - With Collaborators
 - As Secondary Payloads
- Provide Matured Technology
 - For ISS Visiting Spacecraft
 - For Commercial Efforts

