Robotic Solutions
For On-Orbit Servicing

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Space Missions
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Technological and Operational Foundation for On-Orbit Servicing

86 Shuttle Missions with Robotic Operations
9 years of ISS robotic assembly and support operations

Shuttle and ISS experience provides foundation for the design and execution of future Servicing Missions
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- Operations planning and workarounds
- Man and machine coordination
- Robotic control from the ground
  - Command path signal delay, safety
- Robotic performance in 0g
  - Handling large structures, contact operations, vehicle capture
  - Force sensing and regulation
  - Design Verification strategies
- Supportable On-Orbit Robotic Equipment
  - Long life,
  - Maintainable and interchangeable parts
Autonomous Servicing of Prepared Clients

DARPA Orbital Express 2007

- Key Servicing Functions Demonstrated in LEO for remote servicing missions
- Autonomous vehicle capture
- Autonomous Computer and Battery exchange
- autonomous fluid transfer
- streamlined operations approach
- candidate servicing interface standard

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Demonstrated Strategies for Clients designed to Non-Robotic Standards

- GSFC and MDA demonstration of dexterous robotics with HST HiFi mockup in 2004-2005
- Planned robotic compatibility can be non-invasive to a client

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• GSFC and MDA demonstration of dexterous robotics with HST HiFi mockup in 2004-2005
  – Tools for non-traditional robotic tasks
    • Latches, J-hooks, ground straps, electrical connectors, large instruments, cables
  – supervised autonomy
    • Combination of automatic modes and tele-operational modes
    • Model based planning with real time correction
    • situational awareness, worksite registration strategies, and local force control to handle planning model errors for trajectories and contact operations
    • Up to 7 seconds of command path latency accommodated
• Demonstrated that robotic servicing can be applied to a client that is designed to any standard and therefore…
• **Planned robotic compatibility can be non-invasive to a client**
On-orbit Test bed for Advanced Servicing Missions

Dextre on ISS – perfect testbed for ground controlled, dexterous servicing demonstrations

Practicing with the 1g SPDM-GT for the upcoming RPCM changeout

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Next Generation Servicing Technologies

• Exploration Missions beyond GEO
• Mass, cost, operational optimization
• Exploration Missions beyond GEO
  – CSA funded development to advance Next Generation Missions, architectures and technologies:
    • Role of robotic servicing
      – Assembly
      – Risk reduction
      – Outfitting
      – Life extension, enhancement
    • Mission compatibility
      – Packaging of large robots
    • Mass optimization
    • cost effectiveness
    • Operational Optimization
      – Consolidated operators console for streamlined mission planning and support
Commercial Satellite Servicing

Robotic technologies are sufficiently mature for GEO satellite servicing

A cost effective servicing mission can validate the operating principles and value of a serviceable space infrastructure

- MDA is designing a servicer that can add 50 years of life to 9-11 existing GEO satellites through the re-supply of propellants
- Able to tow clients to graveyard orbit or adjust orbit
- Combines operational and technical lessons learned from preceding robotic missions
  - robotic arm to expose client FDVs and handle propellant re-supply tools
  - Human aided rendezvous using techniques developed for remote control of robotics
  - automated docking using client apogee engine

SIS: a Commercial On-Orbit Servicer for Multiple Clients in GEO