On-Orbit Servicing and Beyond: A Canadian Perspective

Jean-Claude Piedbœuf
Deputy Director
Spacecraft Engineering, Space Technologies
Canadian Space Agency
DLR/CSA Workshop on On-Orbit Servicing, Cologne, Germany Nov. 24-26, 2002

Why On-Orbit Servicing?

- It's 3am, on a highway going in Abitibi, north of Canada, a tractor-trailer breaks down on the side of the road...
- The Ground Solution:
  - Send in a Servicing Vehicle!
- The Space Solution:
  - Write off the Truck as a total loss
  - Abandon the cargo & collect insurance
  - Leave the Driver for the wolves
Why On-Orbit Servicing?

- Why is Abandonment the Norm?
  - Cannot reach the satellite
    - launch vehicle shortages
  - Replacement cost same or lower than repair
  - Unable to fix current satellites on-orbit
- Space servicing architecture needed to reduce cost

On-Orbit Servicing & Assembly

- Important thrust in CSA Tech. Req. Doc.
- Scenarios defined for horizon up to 30 years
  - Potential missions or activities
- Focus on technologies required
  - Robotics and intelligent systems
  - Miniaturisation
  - Communication
0-5 yrs: MSS Ground Control

- Ground control of MSS using pre-scripted operation sequences
  - Wake-up procedure
  - Automatic trajectory
  - Capture of payloads
- For safety, autonomy limited to reactive actions
- RT supervision from ground
  - Decisions taken on the ground
- Ground segment equipped for:
  - Calibration of the MSS sensors
  - Fault-detection based on telemetry data
5-10 yrs: Cooperative Spacecrafts

- Chaser with special tools capture satellites
  - designed to be serviced or not
- Ground teleoperation but more autonomy
  - e.g. navigation and inspection
- Free-flyer relocates satellite on a new orbit
  - Refuelling or by adding new bus
- Servicing part of design for new satellites
- Service spacecraft put microsatellites in orbit
  - Reduce launch mass

10-20 yrs: Servicing & Assembly

- Robotic spacecrafts collaborate autonomously to perform complex tasks
  - Capture of uncontrolled spinning satellites
  - Build simple space structure
  - Clean space debris
- On-orbit refuelling and upgrading is common
- Many spacecrafts servicable
  - Specialized EE exist to capture others
- Satellites designed with upgradable modules
  - e.g. communication satellites T/R module
- Dexterity and level of intelligence is now enough to permit maintenance and repair
- Network of robotic spacecraft collaborate
  - Inter-spacecraft communication: optical
10-20 yrs: Preparing for Human

- Cost of unmanned space systems is coming down considerably
- Launch is main driver for high costs
- Space based resources is underway:
  - Fuel generation
  - Space manufacturing of simple structures
- Technologies to support permanent human presence in space:
  - Radiation protection
  - Medical diagnosis

20-30 yrs: Spaceship Assembly

- Colony of heterogeneous robot is used to build the first manned spaceship for exploration
- Wireless communication allows exchanges of robot sensor data and sharing of computation resources among the robots
- Collaboration of robots to perform advanced tasks:
  - Grasping
  - Assembling
  - Moving of structures
- Some robots are dedicated to quality assurance to insure the proper ship assembly
- Pico-satellites reporting to the robots are used for inspection and detection of potential problems
- First LEO hotel is being constructed using space-based resources
30 yrs+: Large Structures

- Building big solar power structures more common
- Intelligent robotic spacecraft colonies
  - No operator in the loop required
  - Autonomous planning and execution
- Knowledge sharing within colony
- Robotic S/C recombine to form new topologies
- Robotic S/C life increased with the self-diagnostic/repair capability

Back to the Present
Orbital Express Program

- Increasing interest of US Air Force in space servicing
  - Change orbit of defence satellites on-demand
  - Refuelling capability needed

$100 million contract for Phase II of Orbital Express program to Boeing Phantom Works

MDR part of the team to develop autonomous techniques for:
  - On-orbit re-supply
  - Upgrading
  - Refuelling
  - Satellites reconfiguration
MicroSatellite Capability / Architecture

- Orbital Express ASTRO vehicle can provide bus functions to MicroSatellites
  - Maneuverability / orbit raising
  - Power
  - Communications
  - Attitude control
- More satellite mass devoted to payload

Canadian Developments

- Focused on enabling technologies
- Ground control technologies
- New arm/docking mechanisms
- Vision for rendez-vous & docking
- Simulation & experimental validation

DLR/CSA On-Orbit Servicing Workshop, Nov. 24-26, 2002
Presentation by J.-C. Piedboeuf, copyright Canadian Space Agency 2002
Robotics Ground Operations

- Simplify space robot operation
  - Not enough crew time available
  - Issue with MSS is safety
- Existing ground control technologies
  - Canada: IIRO/ROSA (MDR-CSA)
  - Germany: Rotex/Marco (DLR)
  - ESA: Dream (Trasys in Belgium)
- MSS Ground Control
  - Operation concept for March 2003
  - Independent safety monitoring
  - Space demonstration: SSRMS

Autonomous Robotics & Ground Operation

- R&D platform to test advance concepts for autonomous robotics and ground operation
- Applications: increase autonomy
  - MSS ground control
  - On-orbit robotics
  - Planetary rovers.
- Implementation on CART
  - SPDM likes operation
  - On-orbit servicing
Existing Docking Mechanisms

- Orbiter Docking System (NASA) and Adroynous Peripheral Assembling System (Russia)
- Capture mechanism of ETS-VII (NASDA)
- LEE & PDGF (CSA/MDR)

New Docking Mechanisms

- MD Robotics end-effector
- Michigan Aerospace Corporation docking mechanism
- DLR Capture Mechanism
- Starsys three-fingered grappling and docking mechanism
Vision Systems for Space

- Key Canadian technology for space robotics
- New generation (target free)
  - Laser Camera System (Neptec)
    - robust versus lighting condition
    - tested on Space Shuttle 2001
  - Object Recognition and Pose Estimation (MD-Robotics)
    - based on natural features
  - LIDAR System (Optech)

Experimental validation

- Hardware-in-the-loop simulation of spacecrafts servicing
- Capture of a floating object
Hardware-in-the-Loop Verification

- Hardware-in-the-loop simulation of spacecrafts docking using SMT robot

Other Testbeds

- 6 dof parallel platform for higher bandwidth, positions accuracy, and payload capacity
- Japanese facility for full scale satellite rendezvous testing
Modeling & Simulation

- Simulation required for
  - Operation and predictive control
  - Training and on board training
- Simulators developed:
  - MSS Operation and Training Simulator
  - SYMOFROS: CSA environment for modeling, simulation, control and real-time implementation

Contact Dynamics Simulation

- MDR Contact Dynamic Toolkit: simulation
  - Non-real time
  - Real-time
  - Parameter identification still issue
- Advanced research in contact dynamics
  - Contact Detection
  - Contact Response
  - Numerical Integration
- Experimental verification
Conclusion

- On-orbit servicing & assembly
  - Promising potential
  - Next commercial business
- Required concerted efforts
  - Technologies
  - Satellite developer
  - Satellite operator
- Canada investing in enabling technologies

QUESTIONS?