AVATAR: Operations of Ground-Based Robots from the ISS using an Amateur Radio Link

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Introduction

- Exploration initiatives place a strong emphasis on robotics
- Operation of robots on planetary bodies from orbiter

Robotic Sample Collection

- Robotic operations for assembly and maintenance of spacecraft
- For efficiency, autonomous operations required
Concept of Avatar RESCUE

Avatar Operator Station
Amateur radio link
Russian Segment on ISS
Avatar Operator Station

CART Testbed Located at CSA
SARAH
LCS
Quicksat

Outline

- Laboratory Setup
- Avatar Operator Station
- Communication Architecture
- Autonomy and demo movie
- Avatar Status
- Next: Avatar EXPLORE
Laboratory Setup

- CSA's Automation & Robotic Testbed (CART)
- Two 7-dof arms, Maximum payload of 10 kg
- 2/3 scale satellite mockup of Quicksat

Laboratory Setup

- Self-Adapting Robotic Auxiliary Hand (SARAH)
- Developed by Université Laval
- Underactuated: 10 dof but only two motors
Laser Camera System (LCS-DTO) from Neptec
- Short range sensor only using triangulation
- Target 3D pose determined at 2 Hz with 0.5 second delay
- Extended Kalman filter to obtain a continuous 3D pose

Avatar Operator Station
- IBM ThinkPad A31
- Operator Station GUI
- Kenwood TM-D700A
- Built-in Terminal Node Controller (TNC)
Avatar Operator Station

Avatar Controller Station
ISS-CSA Ham Radio Link

- Communication link uses AX.25 protocol equivalent to IP protocol in the TCP/IP paradigm.
- Delay Tolerant Protocol (DTP) was developed over the AX.25 protocol.
- TNC connected to ham radio through serial link with KISS protocol.

Communication Architecture

Diagram showing the communication architecture includes:
- Avatar Controller Station
- CART Controller Station
- Camera Views
- CART Testbed
- ISS Hardware
- CSA Antenna
- CSA Amateur Radio Gateway
- ISS Antenna
- CSA
- TNC
- AX.25
- KISS
- Ground station
- Space station
Autonomy Software

- Developed using ARGO architecture (Autonomous Robotics and Ground Operations)
- Cortex Autonomy Engine
  - Toolbox for Reactive Autonomy
  - Finite State Machines
### Avatar Operation Modes

<table>
<thead>
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<th>States</th>
<th>Semi-Autonomous</th>
<th>Auto-Pilot</th>
<th>Autonomous</th>
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<tr>
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<td>Capture + Execute</td>
<td>Capture + Execute</td>
<td>Capture + Execute</td>
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<td>Initial Approach Completed</td>
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<tr>
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</tr>
<tr>
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<td>Release + Execute</td>
<td>Release + Execute</td>
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<tr>
<td>Comm. Link Required</td>
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<td>NO</td>
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</table>

**Avatar Capture Movie**

![Avatar Capture Movie]
Avatar RESCUE Status

- Software delivered Feb. 12, 2008
- Training performed Feb. 13, 2008
- Experiments planned for Expedition 17 (Launch on April 8, 2008)
- Cable problems delayed experiments
- Comm. check on October 9, 2008

Next: Avatar EXPLORE

- Russian Segment on ISS
- Avatar Operator Station
- Amateur radio link
- Rover in Mars Emulation Terrain
Avatar EXPLORE Mission

- Planned for the flight of Bob Thirsk on ISS Expedition 20 (May to October 2009)
- Exploration of CSA Mars Emulation Terrain
- Identification of a hot spot over few orbital passes
- Autonomous operation of the P2-AT rover

Conclusions

- Avatar RESCUE will demonstrate:
  - Robots operation over low-bandwidth comm. link
  - New Delay Tolerant Protocol developed at CSA
  - Cortex autonomy software in a realistic setting
- Avatar EXPLORE will be much more challenging:
  - More data over same low bandwidth comm. link
  - More autonomy for operations during LOS