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AVATAR

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

Image credit: NASA



Assembly of Large Space Structures

Image credit: NASA

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

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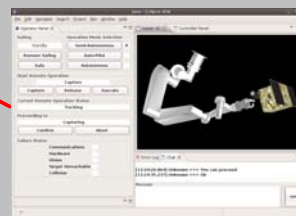
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Concept of Avatar RESCUE

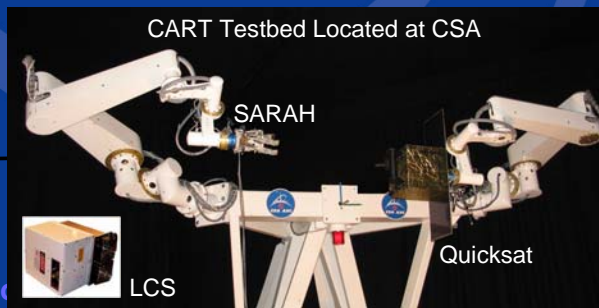


Russian Segment on ISS



Avatar Operator Station

Amateur radio link



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Outline

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



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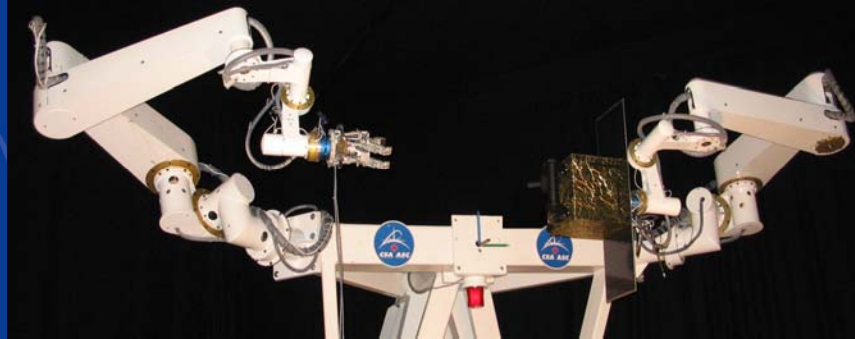
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Laboratory Setup



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



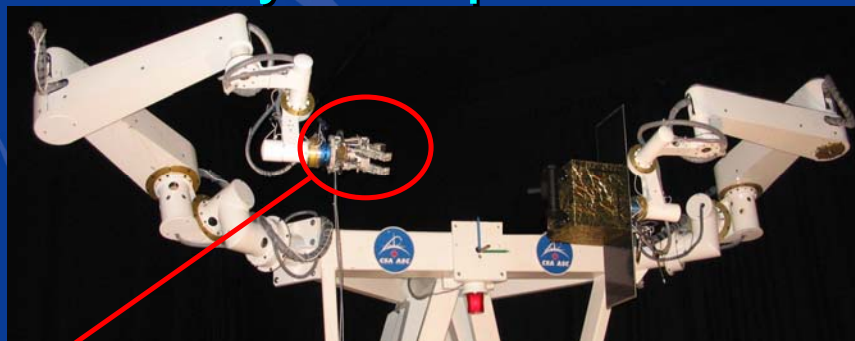
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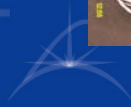
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Laboratory Setup



- Self-Adapting Robotic Auxiliary Hand (SARAH)
- Developed by Université Laval
- Underactuated: 10 dof but only two motors



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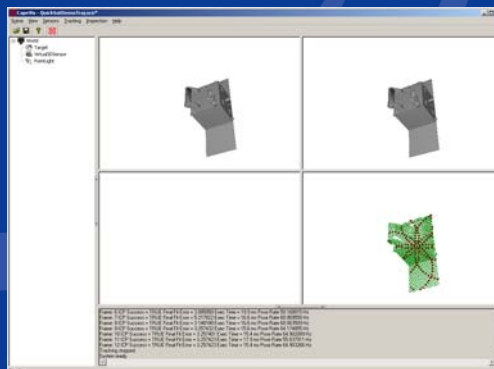
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Laboratory Setup

- 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



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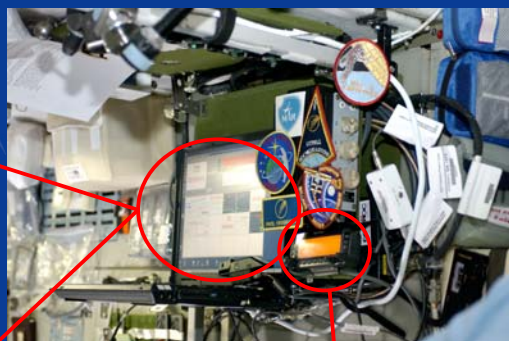
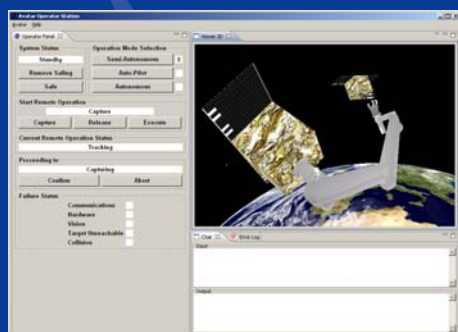
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Avatar Operator Station

- IBM ThinkPad A31
- Operator Station GUI



- Kenwood TM-D700A
- Built-in Terminal Node Controller (TNC)

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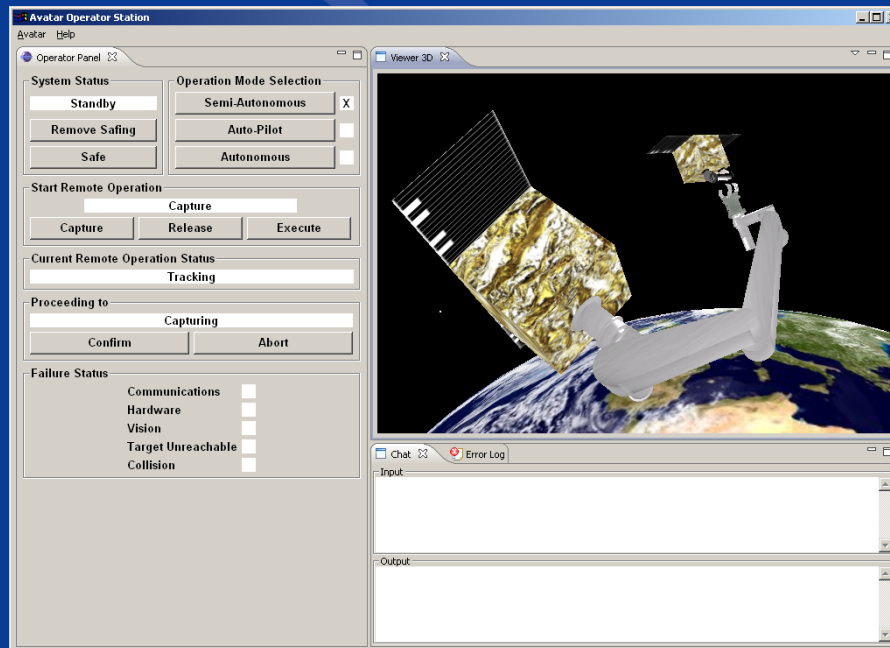
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Avatar Operator Station



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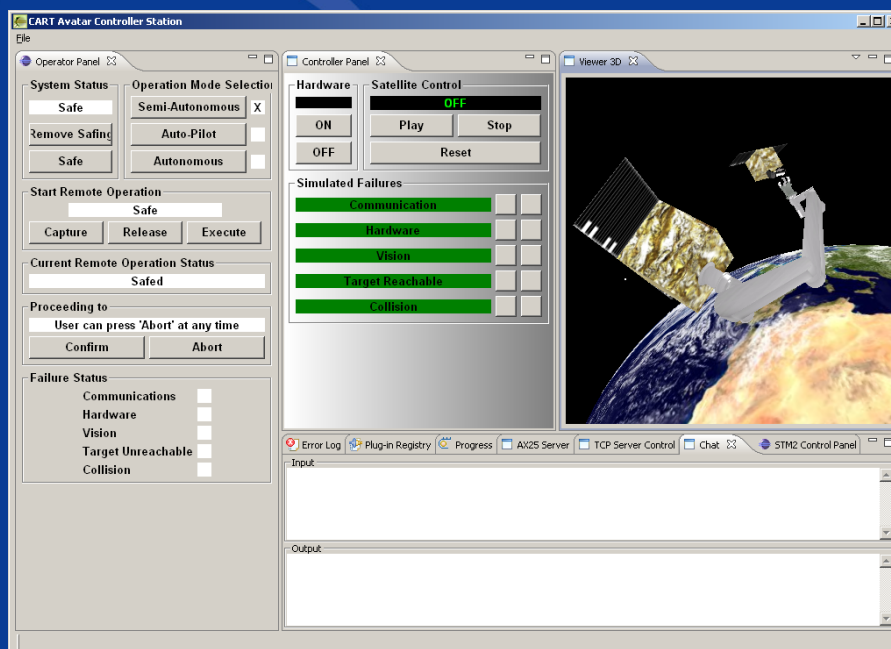
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Avatar Controller Station



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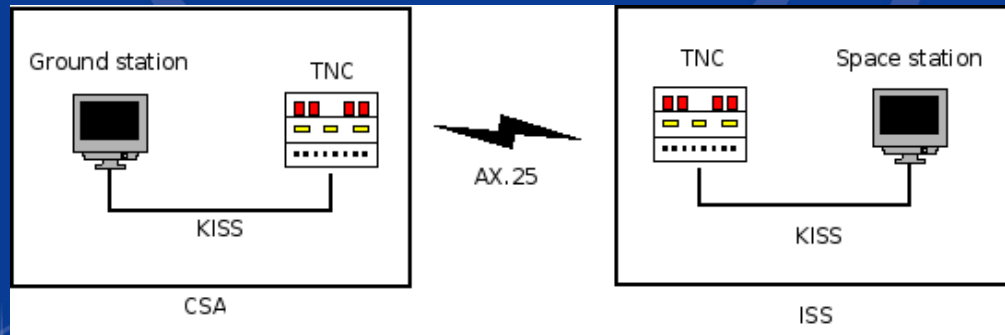
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ISS-CSA Ham Radio Link

- 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



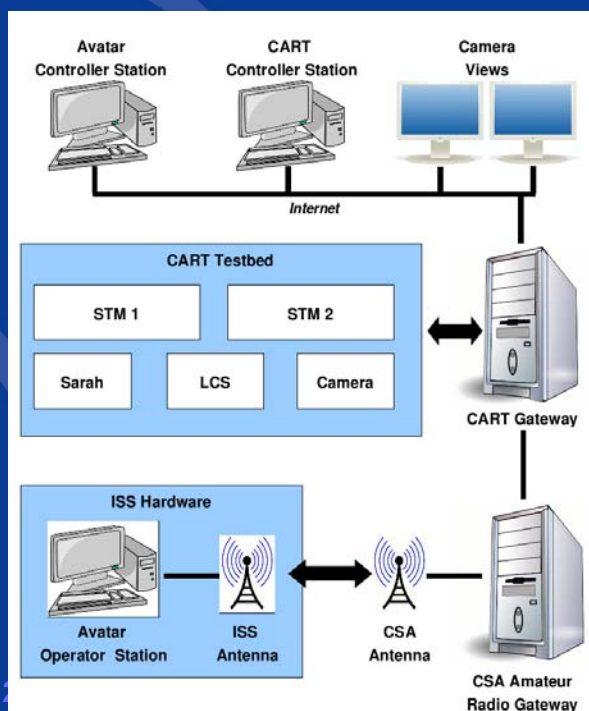
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Communication Architecture



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Autonomy Software

- Developed using ARGO architecture (Autonomous Robotics and Ground Operations)
- Cortex Autonomy Engine
 - ◆ Toolbox for Reactive Autonomy



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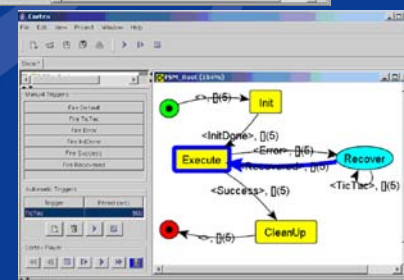
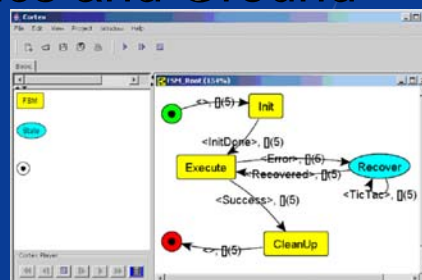
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Autonomy Software

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



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Avatar Operation Modes

States	Semi-Autonomous	Auto-Pilot	Autonomous
Ready	Capture + Execute	Capture + Execute	Capture + Execute
Searching			
Target Spotted	Confirm	Confirm	
Initial Approach			
Initial Approach Completed	Confirm	Confirm	
Final Approach			
Tracking	Confirm	Confirm	
Capturing			
Capture Completed	Release + Execute	Release + Execute	Release + Execute
Releasing			
Ready			
Comm. Link Required	YES	YES	NO

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Operator Input

Automatic Input

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Avatar Capture Movie



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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



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Next: Avatar EXPLORE

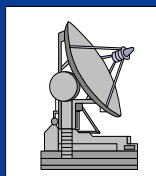


Russian Segment on ISS



Avatar Operator Station

Amateur radio link



Rover in Mars Emulation Terrain

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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



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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

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