



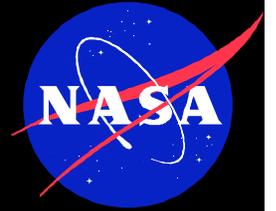
# Opportunities for Model-Based Learning Systems in the Human Exploration of Space

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**Chief Scientist, Human-Centered Computing**

**NASA Ames Research Center**

**& Institute for Human and Machine Cognition, UWE**



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**This presentation relates the various themes of ITS to new plans for the human-robot exploration of space**

- **NASA's Exploration Vision**
- **Astronauts as Students**
  - **The Hubble Repair Training System**
- **Foundations for Revitalizing ITS at NASA**
  - **BrahmsVE & Mobile Agents**
  - **Future Trends and Opportunities**

The background is a composite image. In the top left, there is a spiral galaxy with a bright core. In the bottom left, there is a reddish planet, likely Mars. In the bottom center, there is a blue and white planet, likely Earth. On the right side, there is a complex molecular model with various colored spheres (red, white, blue, purple) and connecting lines, resembling a DNA double helix or a protein structure. The overall background is a dark, starry space with some nebulae.

# The NASA Vision

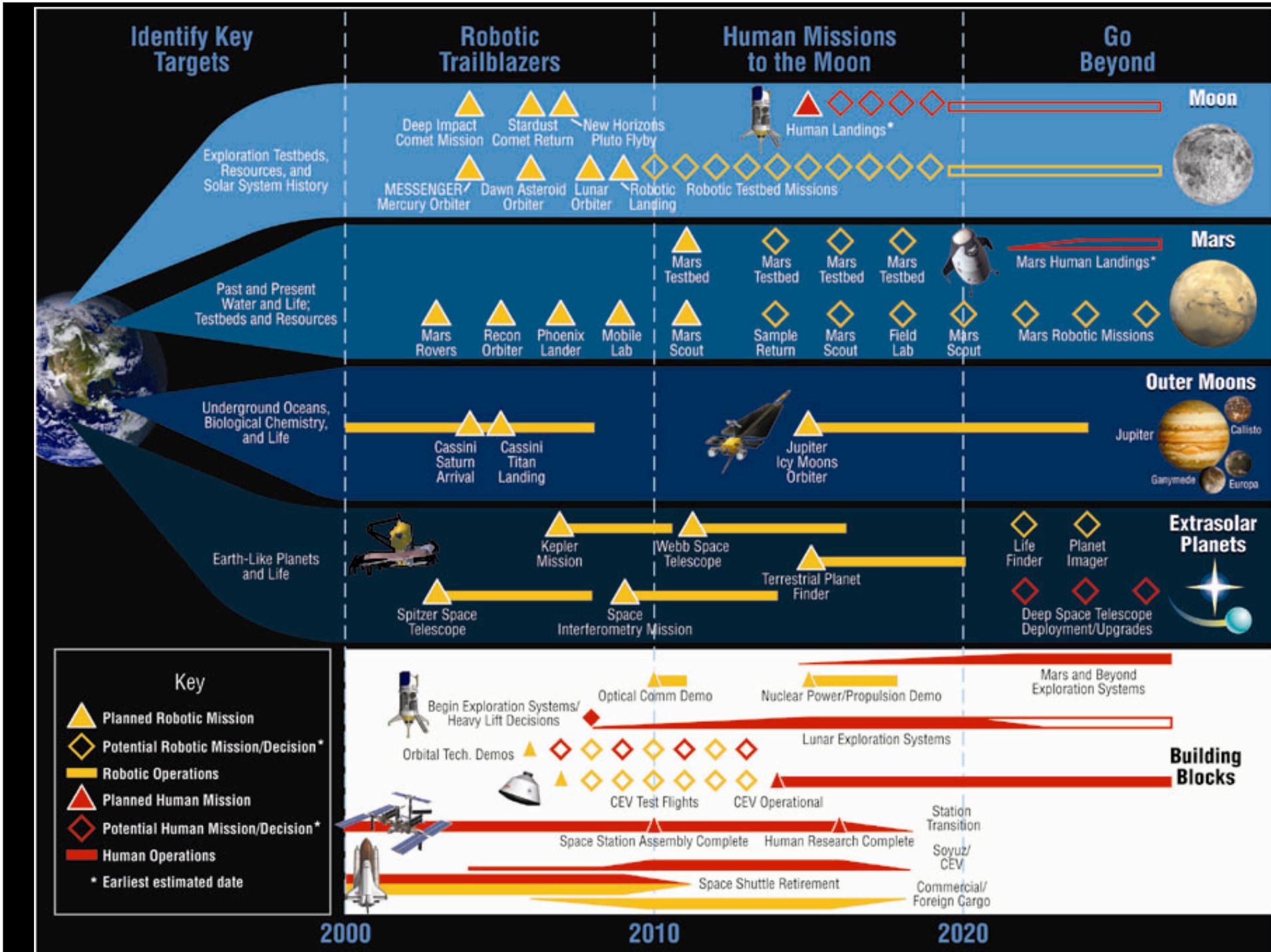
To improve life here,  
To extend life to there,  
To find life beyond.

## The NASA Mission

To understand and protect our home planet  
To explore the universe and search for life  
To inspire the next generation of explorers  
...as only NASA can

# New Space Exploration Vision

- *Implement* sustained & affordable human/robotic program to explore the solar system and beyond
- *Extend* human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations
- *Develop* the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration
- *Promote* international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

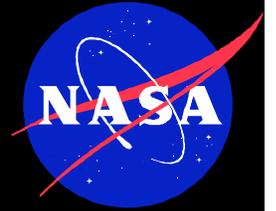


# Astronauts as Students



- Multiple PhDs/MD
- Insufficient time from specs to flight to formalize domain knowledge
- Highly procedural, mission critical, manipulative skills
- “Practicing understanding”
- Tasks open to alternatives
- Comprehensive ground support “coach in your ear”

# Astronaut Basic Training

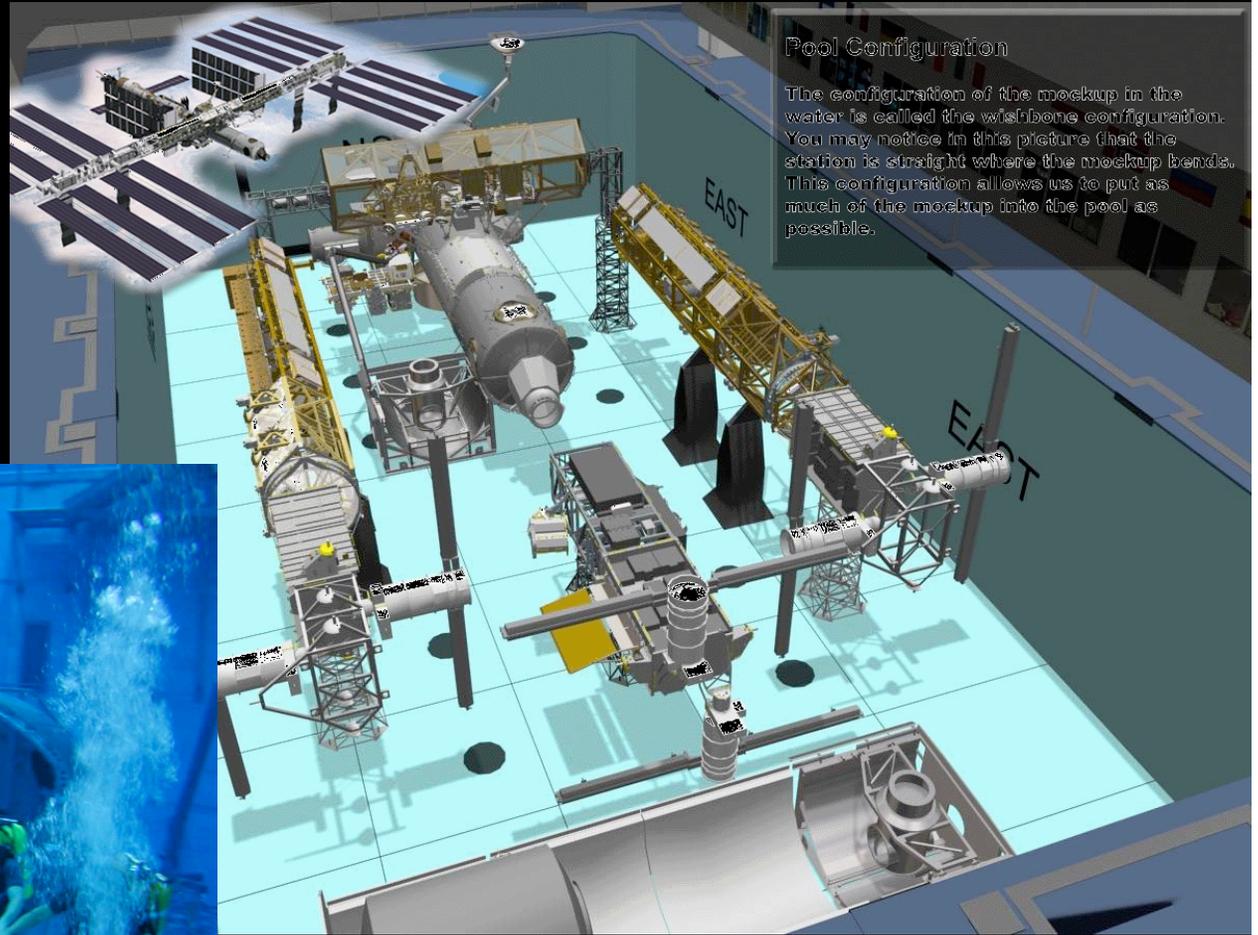


- Pilot & SCUBA Certification
- Manuals
- Classes: basic science and technology: mathematics, geology meteorology, guidance and navigation, oceanography, orbital dynamics, astronomy, physics, and materials processing
- CBT Orbiter Systems
- Single Systems Trainer
- Part-Task Trainers
- Shuttle Mission Simulators
- Neutral Buoyancy Lab
- Shuttle Training Aircraft



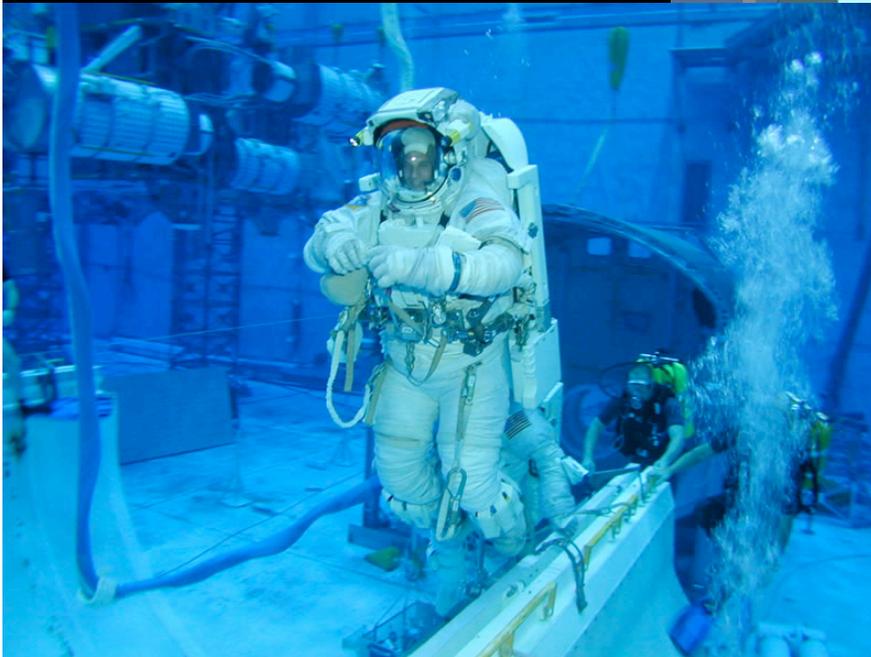


Training  
simulation of  
weightless EVA  
operations

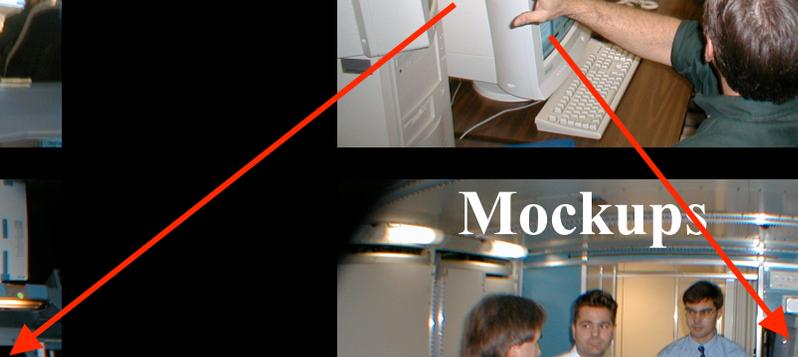
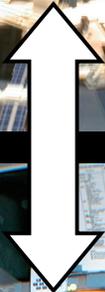
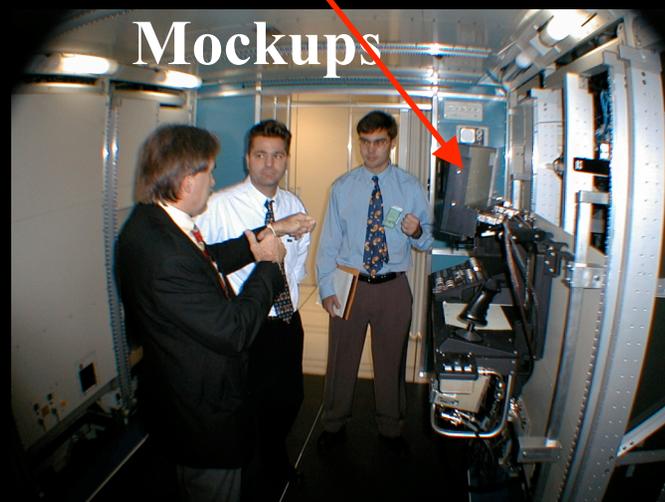
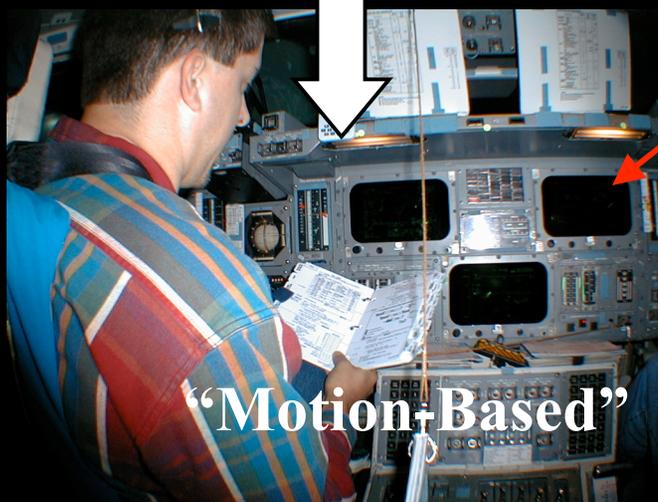
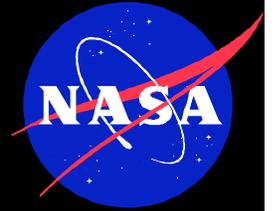


### Pool Configuration

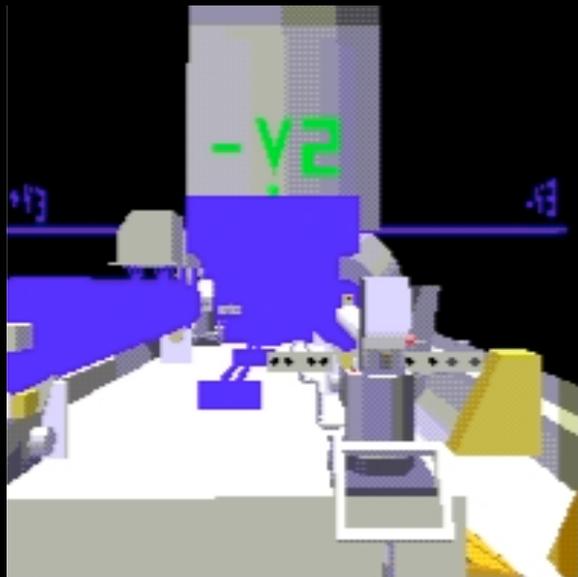
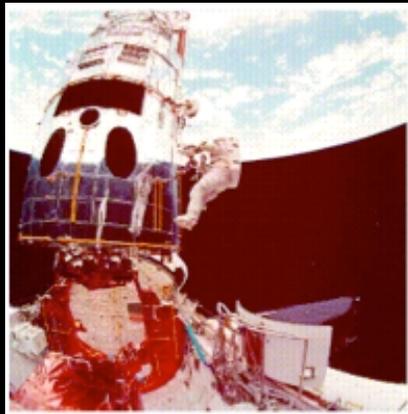
The configuration of the mockup in the water is called the wishbone configuration. You may notice in this picture that the station is straight where the mockup bends. This configuration allows us to put as much of the mockup into the pool as possible.



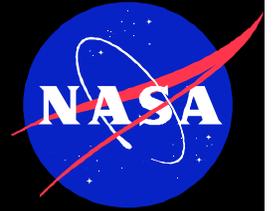
# Varieties of Simulation



# Bowen Loftin's Hubble VE



- Dec '93 Hubble Repair Mission
- Hubble model + Shuttle payload bay
- 100 team members, 200 hrs training
- Feature id & repair constraints; six EVA scenarios (part changes)
- Procedure monitoring, intervention, & assistance



- Part-Task model highly restricted
  - Flattens data-process relation (e.g., comparing alternative methods)
  - Omits contextual information (e.g., orbit #)
  - Omits interaction with other individuals/subtasks
- Increased cognitive demand
  - Undermined learning
  - Misleading evaluation of effectiveness
- Need richer work system conceptualization

S: ... I would tell dynamics to make ephemeris 2 and 4 look like 1.

E: How would you do that?

S: I would tell them exactly that – to make ephemeris 2 and 4 look like 1. So, I'm going to have to do this myself.

# Technology Foundations for Revitalizing ITS at NASA



**MER**

*Work System Design  
& Evaluation*

**MER Analyst's Notebook**  
**OPPORTUNITY MER-B** MER TEAM VERSION

Navigation: Home | Sol Summaries | Navigation | Search | Resources

Instrument	Count	Product
152	1	152
153	1	153
154	1	154
155	1	155
156	1	156
157	1	157
158	1	158
159	1	159
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197	1	197
198	1	198
199	1	199
200	1	200

**Soil 250 Data Product Summary**  
This table summarizes the product counts for each instrument. The colored instrument icons represent the rover instruments.

**Summary**

Total Products	0	0	0	31	59	35	990	3	0
Unique SOLAR Values	0	0	0	2	9	3	72	3	0

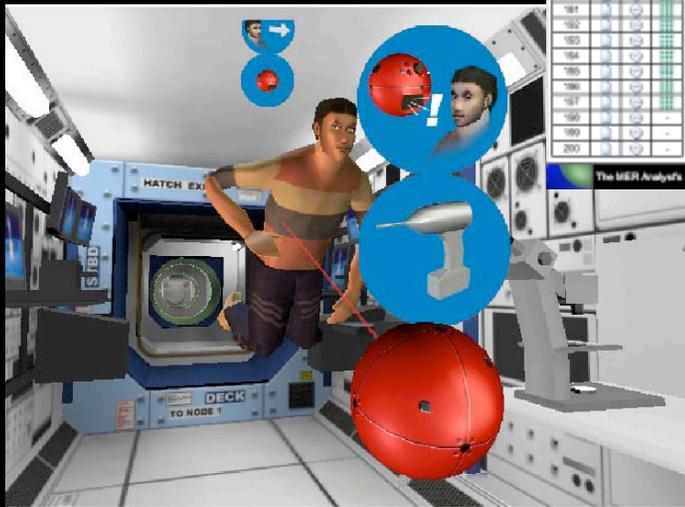
**Primary Products**  
The "highest resolution" EDR for each product is listed below. Click on the image to preview the product, or click on one of the icons described in the options table.

Options:

- Preview product in preview window
- Open product in web browser window
- Download the product
- Download the detached label

**Preview Window**  
This is a downscaled preview of product 1 N 14504957 EFF 35 05 P1555 LO M1. Click on the image to see a full-size version of the product.

*Mobile Agents*



*BrahmsVE  
Human-Robotic  
Systems*

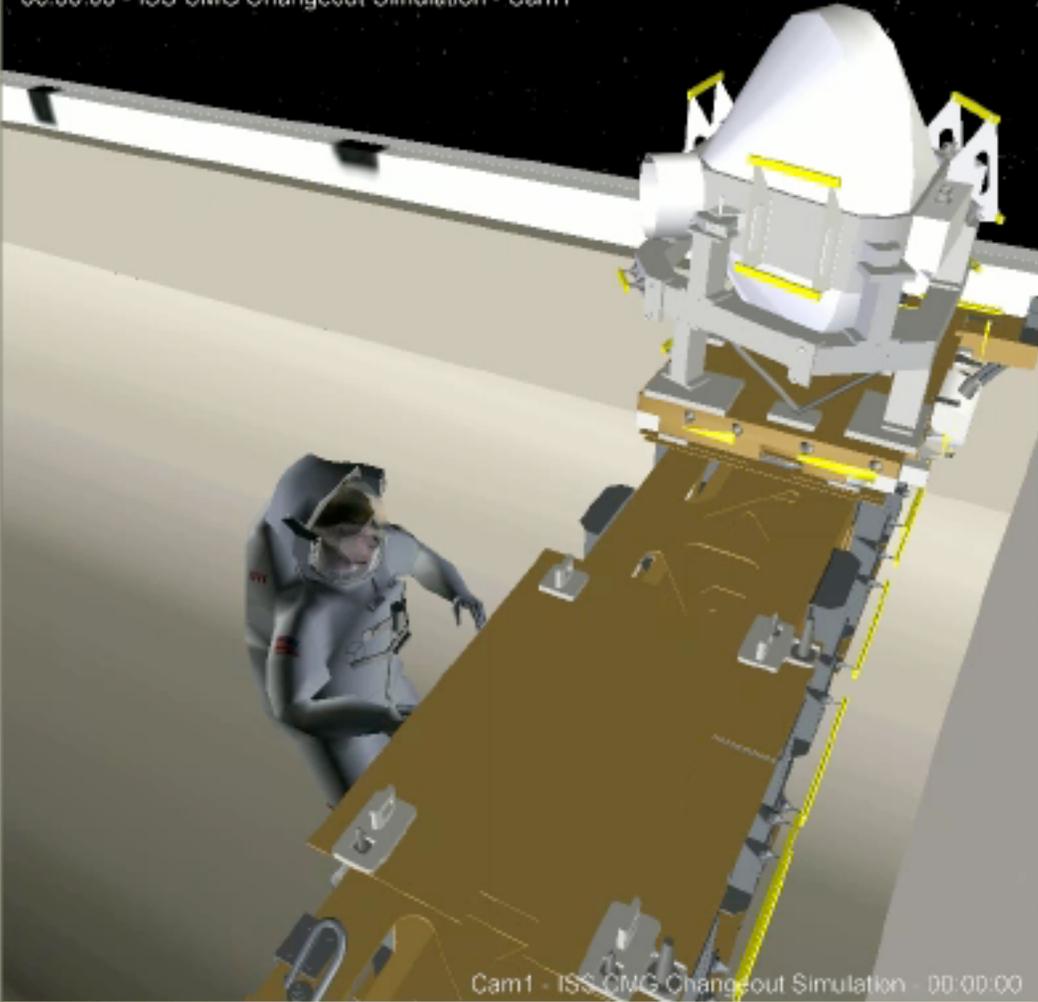


- Web-based systems for representing and sharing scientific discoveries
- Virtual environments for design and training of human-robotic systems
- Multiagent systems using NL for life support and surface exploration

# ISS Assembly Training



00:00:00 - ISS CMG Changeout Simulation - Cam1



Camera: 1 2 3  
 Automatic Camera

**SimCMGChangeOut**  
▶ Start ◻ Stop

- ▶ Prepare Ballstacks
- ▶ Position old CMG on Ballstack
- ▶ Attach old CMG to Ballstack
- ▶ Prepare to approach LMC
- ▶ Approach LMC
- ▶ Detach CMG from LMC
- ▶ Prepare to remove CMG from LMC
- ▶ Remove CMG from LMC
- ▶ Position new CMG on Ballstack
- ▶ Attach new CMG to Ballstack
- ▶ Move to old CMG
- ▶ Detach old CMG from Ballstack
- ▶ Prepare to approach LMC with old CMG
- ▶ Approach LMC with old CMG
- ▶ Prepare to attach CMG to LMC
- ▶ Attach CMG to LMC
- ▶ Move to new CMG on Ballstack
- ▶ Detach new CMG from Ballstack

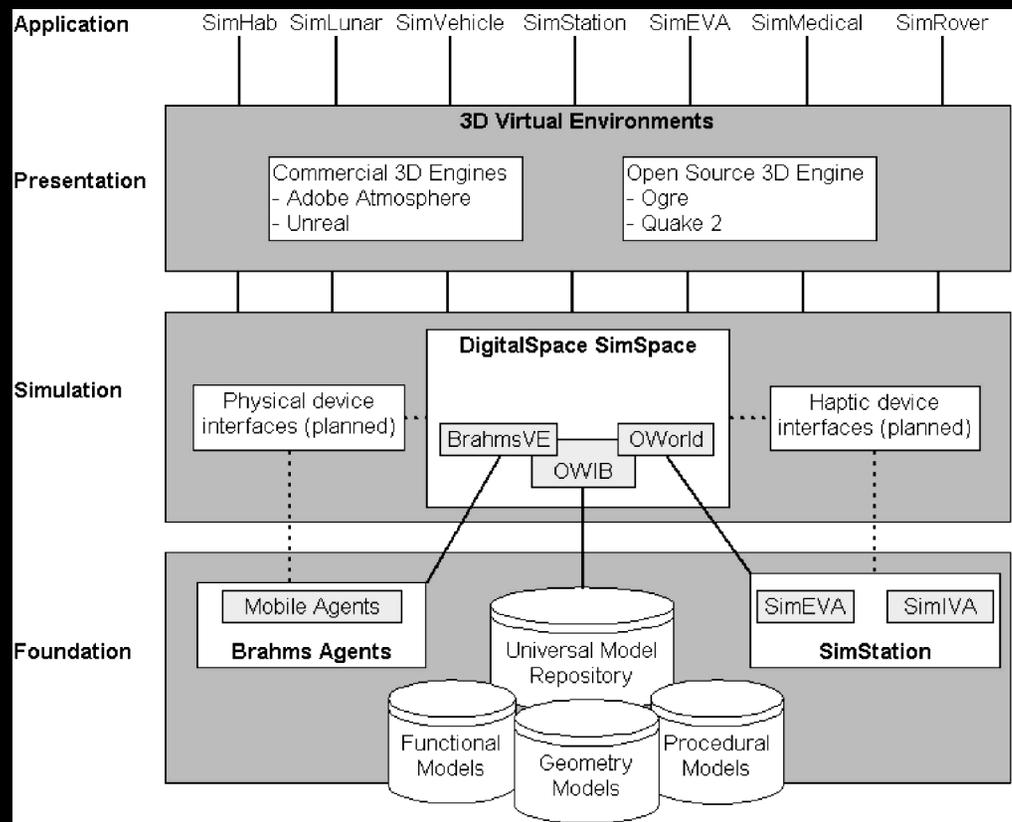
Prepare to move to ISS

Cam1 - ISS CMG Changeout Simulation - 00:00:00

# BrahmsVE Architecture

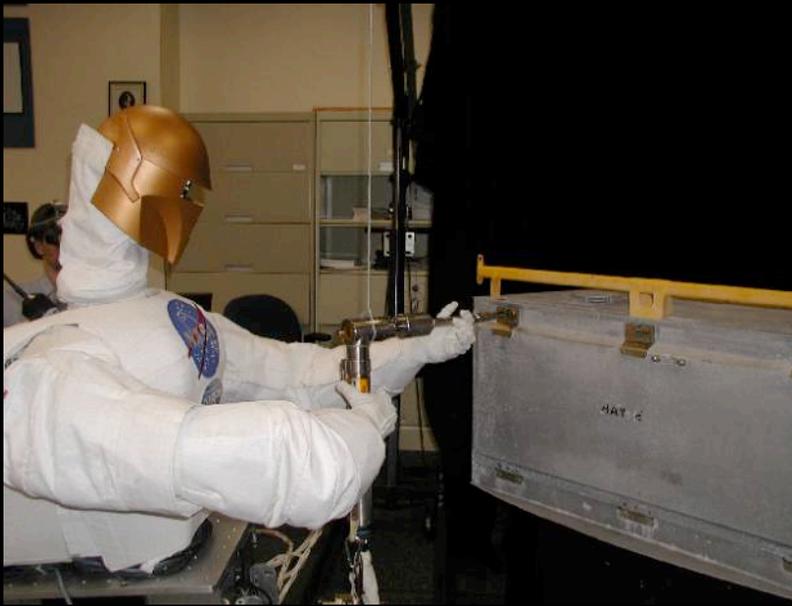
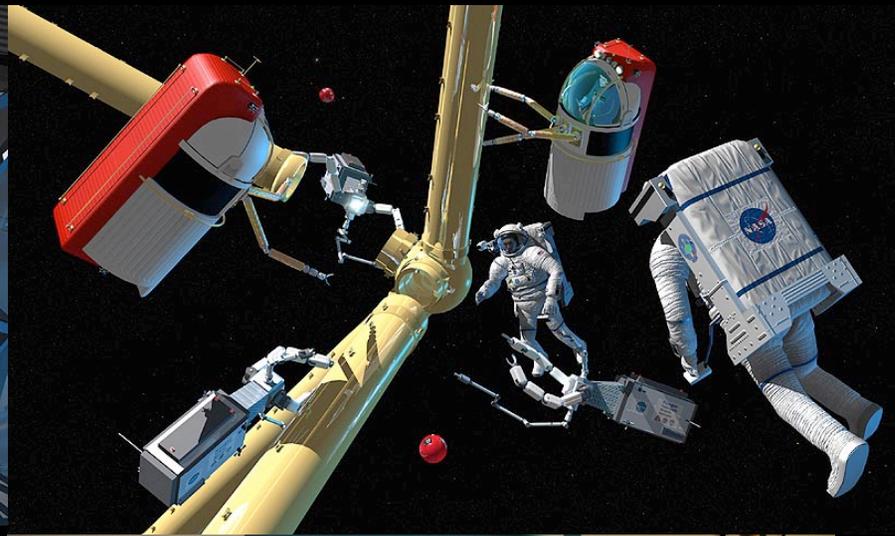
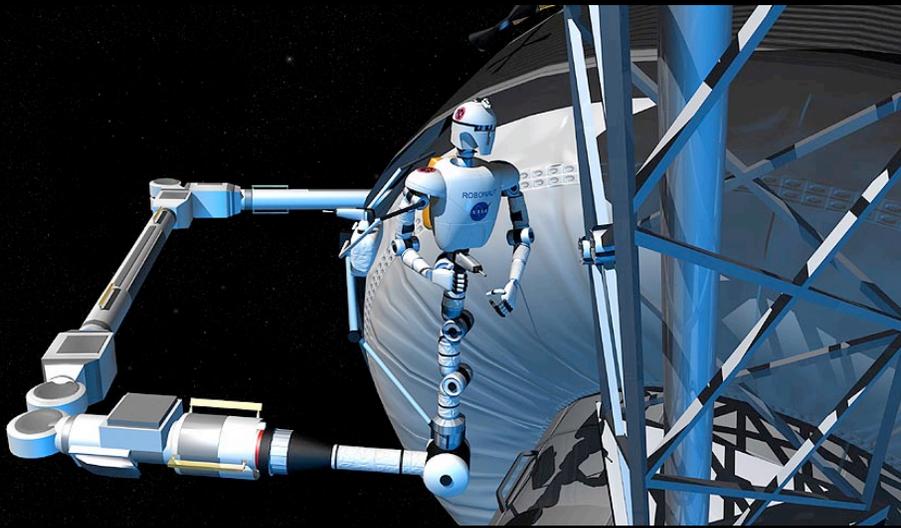
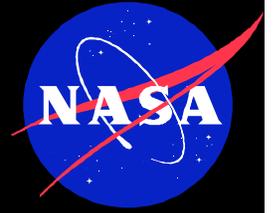


- **Multiagent Work Practice Simulation:** People, systems, places, activities, communications
- Coupled to animation graphics in virtual world
- **Browser-based Visualization** implemented in *Adobe Atmosphere*
- Foundation for interactive distributed training



**Agent system simulates behaviors;  
Virtual World simulates spatial relations**

# Robonaut: From Teleop to Teams



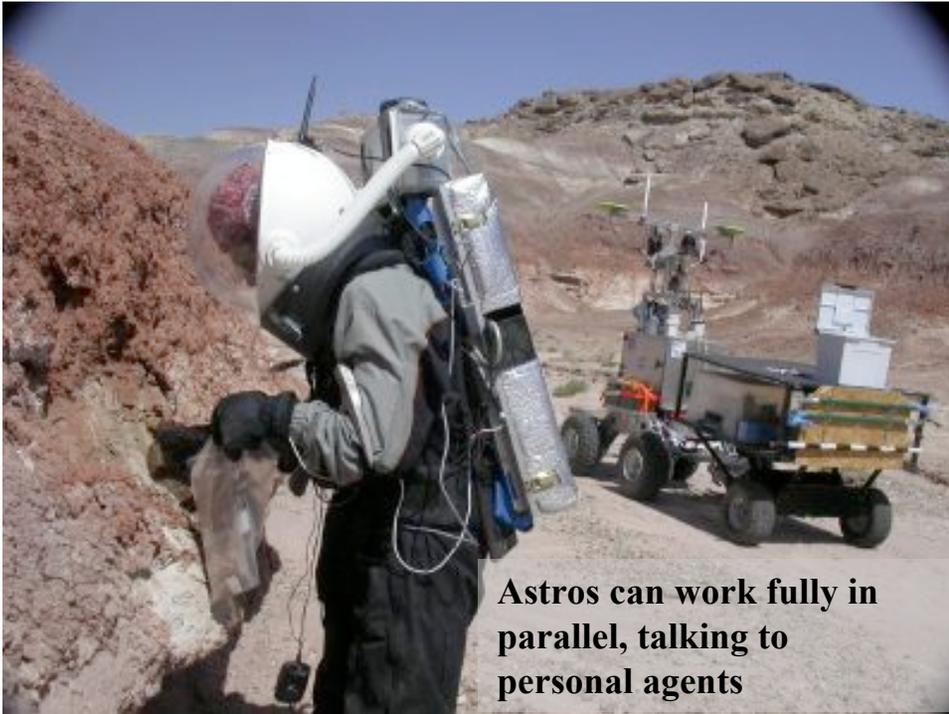


# Mobile Agents Utah Field Test 2004



***Geologists in Lith Canyon  
with EVA Robotic Assistant***

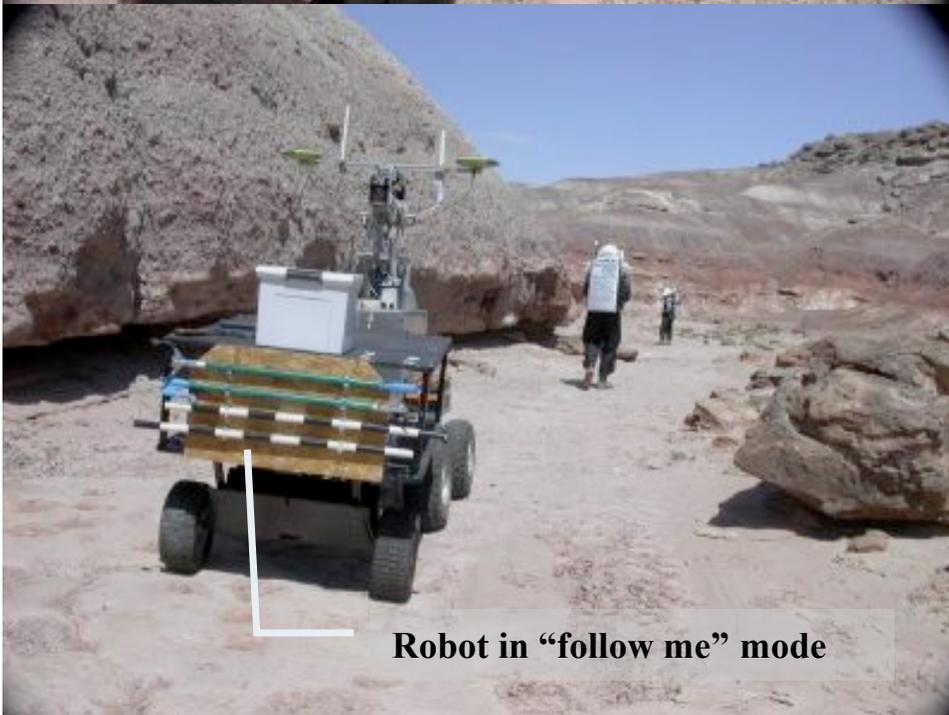
- 50 Participants; 17 days; 3 NASA centers & 2 universities
- Two diverse scenarios
- ERA (work cart, video monitor, pancam, relay) integrated with astronaut operations
- Crew collaboration with well-organized RST
- Contextual voice commanding
- EVA data stored automatically in shared database (RST email)
- Change batteries & continue; restart agents



**Astros can work fully in parallel, talking to personal agents**



**Robot on ledge tracks Astronauts & takes photos when commanded**

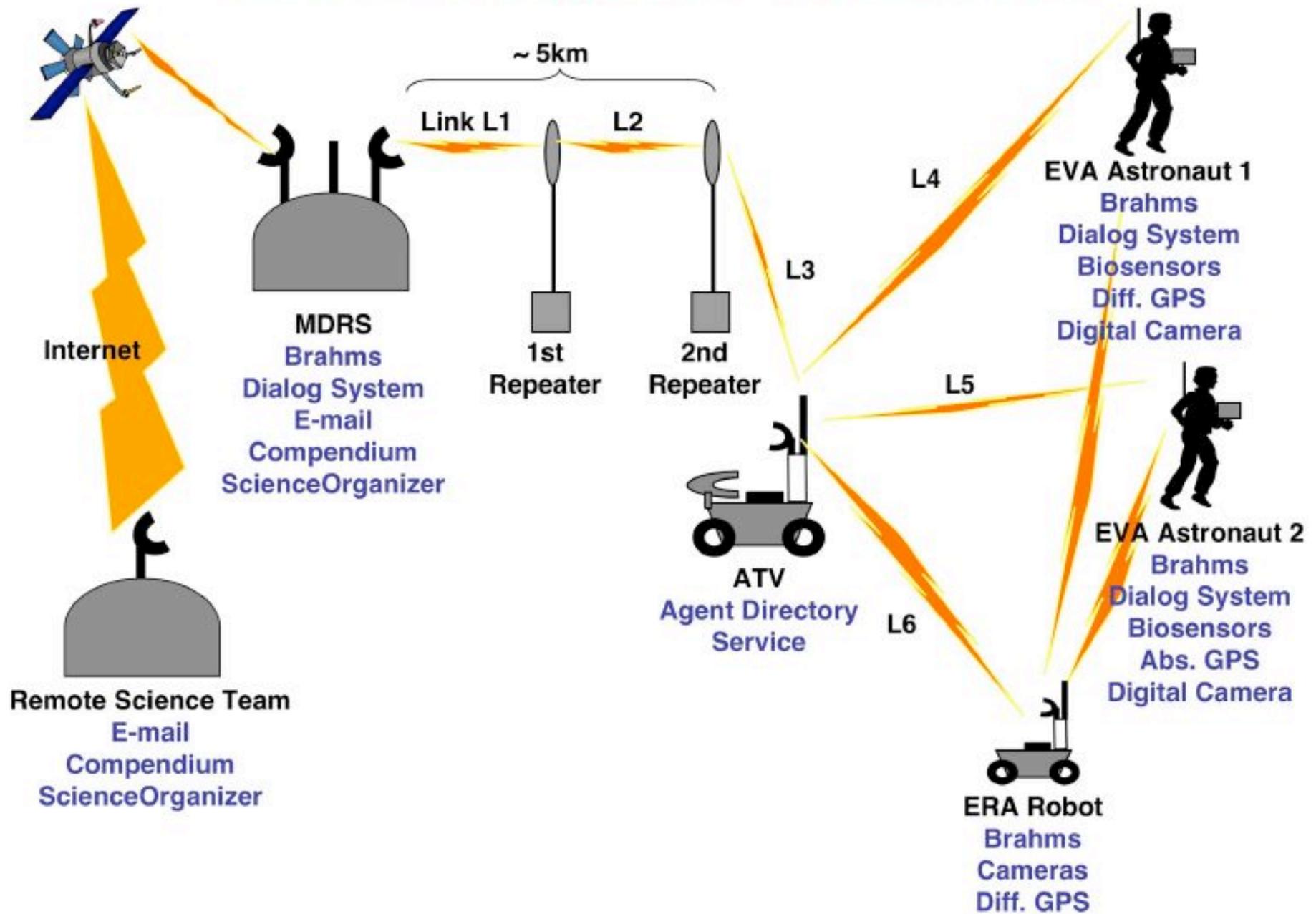


**Robot in "follow me" mode**



**Voice annotation is recorded and transmitted to database in habitat & to RST on earth**

# Mobile Agents at MDRS





# From Mars to Desktop



ScienceOrganizer: An Information-Sharing Tool for Mobile Agents NASA Ames

New Item Search Home Go To Logout Help

View Links Edit Links Modify Permissions Delete Duplicate Put in a Folder

voice\_note\_9 (open all | close all)

- Creator (1 Participants)
  - AstroTwo
- EVA (1 EVAs)
  - Segment\_3\_of\_Lith\_Canyon\_EVA
- Eva Plan (1 EVA Plans)
  - LithCanyon\_SegmenThreeEva\_Plan
- Gps Location (1 GPSData)
  - AstroTwoModel\_GPSDATA\_35
- IsAssociatedWithMapLocation (1 MapLocati)
  - AstroTwoWorkAtWayPoint16WorkSite7
- Plan Activity (1 MA Activites (Planned))
  - WorkAtWayPoint16

**Voice Annotation: voice\_note\_9**

Item ID# 166015 updated 2004/05/07 03:47PM PDT by ScienceOrganizer Com Agent (SOCA)

Send this Item's web address via [Email](#)

[Click here to download associated wav file](#)

[Help with downloading](#)

Creator	AstroTwo
Timestamp	2004-05-07 23:47:12.0
Gps Location	AstroTwoModel_GPSDATA_35
Eva Plan	LithCanyon_SegmenThreeEva_Plan
EVA	Segment_3_of_Lith_Canyon_EVA
Plan Activity	WorkAtWayPoint16
isAssociatedWithMapLocation	AstroTwoWorkAtWayPoint16WorkSite7
isAssociatedWithSampleBag	
isAssociatedWithImage	
Notes	
Write Permission	Mobile Agents Architecture (MAA -- Entire)
Read Permission	Mobile Agents Architecture (MAA -- Entire)



From: [capcom@agentisolutions.com](mailto:capcom@agentisolutions.com)  
 Subject: MDRS New VoiceAnnotation: voice\_note\_9  
 Date: May 7, 2004 3:47:36 PM PDT  
 To: [mdrs\\_rst@agentisolutions.com](mailto:mdrs_rst@agentisolutions.com)

New VoiceAnnotation: voice\_note\_9  
 EVA Plan: LithCanyon\_SegmentThreeEVA\_Plan  
 Activity: WorkAtWayPoint16  
 Creator: AstroTwo  
 TimeStamp: 05/07/2004 23:47:12  
 File Name: voice\_note\_2004-4-7\_23-46-28.wav

Latitude: 3827.3077 NORTH Longitude: 11047.4074 WEST  
 Northing: 4256335.2693082085 Easting: 518312.1563357575 Zone: 12S

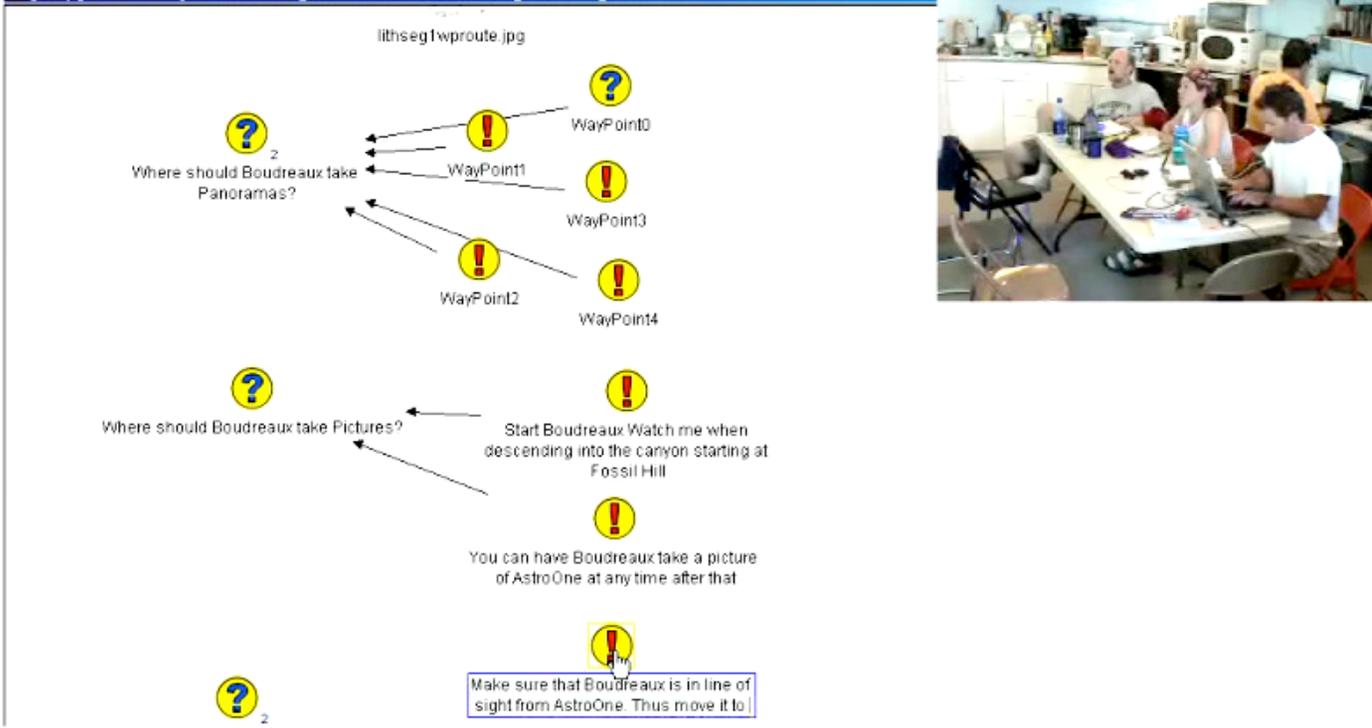
ScienceOrganizer Link : <https://marst.arc.nasa.gov/org/166015>



# EVA Collaborative Planning



[Map]: Lith Canyon EVA Segment 1 Crew Planning Meeting 05/03/04



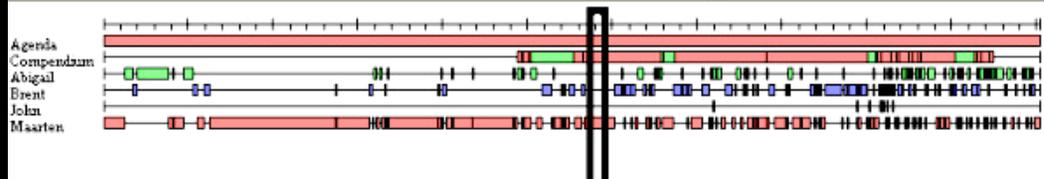
Title: Lith Canyon EVA Segment 1 Planning Meeting - 3rd May 2004

Date: Tue May 4 00:37:00 2004

Participants: [Maarten](#), [Brent](#), [Abigail](#), [John](#).

Current Speaker: Maarten

Nodes: Make sure that Boudreaux is in line of sight from AstroOne. Thus move it to WP 2 and 3 at appropriate times



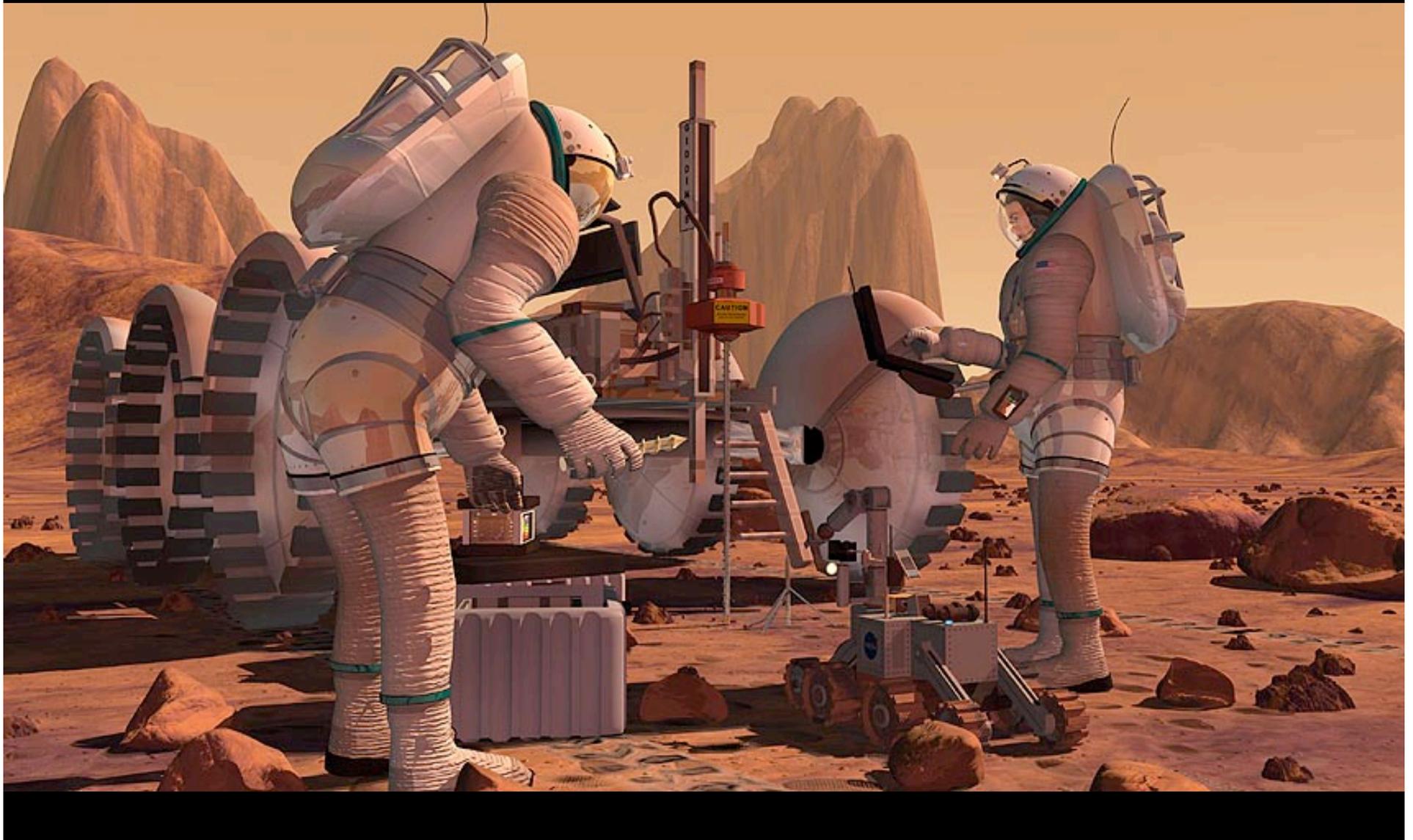
Video **Playing** 00h 29m 09s **Pause**

Group Sync  Offline  Online

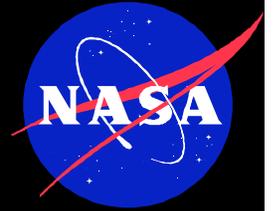
Mode  Master  Slave

Receiving  Yes  No

# Future Opportunities

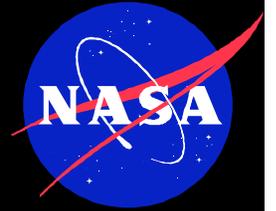


# Key Points



Best opportunity: Job performance aids  
("intelligent agents") that scaffold less experienced  
operators/astronauts & adjust to developing practices

# For more information...



- <http://bill.clancey.name>
  - Simulating Activities
  - Field Science Ethnography
  - Automating CapCom
  - Roles for Agent Assistants in Field Science
  - Mobile Agents (Flairs)
- <http://www.marsociety.org/MDRS/fs03>
  - “Mission Info”
  - Daily reports
  - Photographs
- [www.agentisolutions.com](http://www.agentisolutions.com)



*Devon Island, FMARS 2001*