MOBILE AGENTS ARCHITECTURE: VOICE-COMMANDED EVA SYSTEM TO ASSIST ASTRONAUTS WITH SCIENTIFIC EXPLORATION ON THE MOON AND PREPARATION FOR FUTURE MARS MISSIONS.

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Introduction: The incorporation of technology to help in the documentation and communication of science data collected during extravehicular activities (EVAs) on the Moon needs to be discussed in parallel with the prioritization of science goals and development of equipment for lunar exploration. Teams at NASA Ames, NASA JSC, and NASA Glenn in collaboration with other organizations and universities have designed, built, and field tested a system to assist Astronauts with data collection and real-time dissemination of data during an EVA [1].

The Mobile Agents Architecture (MAA) is a voice-commanded system that monitors and manages EVA navigation, scheduling, equipment deployment, telemetry, health tracking, and data collection [1, 2]. Using a suite of voice-commands (Table 1) [3], Astronauts can communicate and interact with their personal agents (EVA schedule, health/bio-sensors, GPS, digital camera), external agents (e.g. EVA Robotic Assistant (ERA) [4, 5], lunar rover, science equipment), and software agents (e.g. Compendium, Science Organizer). Agents are connected wirelessly through a relay system [6] to participating members of the EVA (Astronauts, Robots, Lunar Base, Mission Control, Remote Science Team/Science Backroom) (Figure 1).

Table 1. Examples of Voice Commands

Call my location <*location name*>.
Boudreaux (robot), take a panorama.
Create sample bag <*AA/##/##*> (e.g. WL/25/03)
Create a voice note.
Download all images and associate with last voice note.
Track my location every 30 seconds.
Change the duration of current activity to < *X* > minutes.

Background and Previous Work: Analysis of dialogues between the CapCom and Apollo Astronauts during EVAs revealed that the CapCom provided a lot of assistance with regard to keeping the Astronauts on schedule, relaying requests from the science backroom, confirming tasks to be done, and locating equipment. On Mars, real-time discussions with Mission Control will not be possible, therefore EVA Astronauts will need a method to access information typically given by the CapCom. The MAA has been utilized during simulated EVAs at the Mars Society's Mars Desert Research Station (MDRS) in Utah from 2003 – 2006 (Crews 16, 28, 37, 49) (Figure 2) and integrated with the next generation spacesuits, lunar rover, and robots during field tests conducted by NASA Desert Rats in 2005 – 2006.

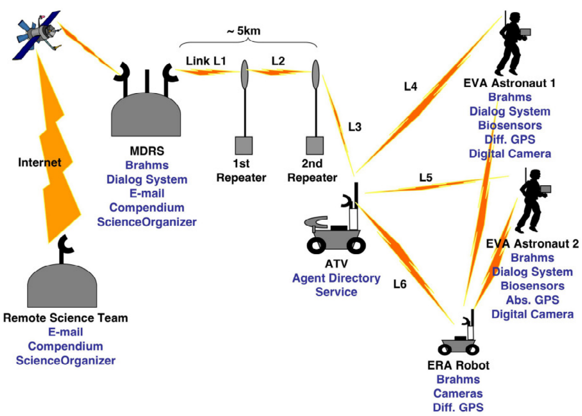

Figure 1. Network configuration for the Mobile Agents Architecture used during the 2004 field test at the Mars Desert Research Station (MDRS). Agents are listed below each participant. From Clancey et al. [1].

MAA and the Lunar Exploration Objectives: NASA has identified over 180 individual objectives for the moon, pertaining to various categories. Capabilities of the MAA relate to achieving several of these goals listed in parentheses.

1) **Lunar Geology:** Documentation of samples collected (mGEO2, mGEO5) and curation (mGEO15). Astronauts will have immediate access to data (voice notes, images, and samples) for post-EVA analysis. They can add or revise observations and interpretations back in the lunar base (mGEO16).
2) **Human Health:** Bio-sensors monitor vital signs and provide automatic updates or warnings when threshold levels are crossed (e.g. high body temperature, increased heart rate) (mHH4). MAA can provide instructions pertaining to EVA protocols (e.g. advised to rest and sip water, abort EVA and immediately return to lunar outpost).

Figure 2. An Astronaut-Scientist collects a sample during a simulated EVA using MAA at the MDRS. Cameras on the EVA Robotic Assistant (ERA) can automatically track the Astronauts and relay the video back to the Habitat. A science trailer, used to carry field equipment and samples, is attached to the ERA. Photo by W. J. Clancey (NASA).

3) **EVA Planning & Protocols:** Crew-centered planning (mOPS3) and real-time changes to the plan during the EVA. Astronauts can extend or shorten time at a certain site or add a new activity when an unexpected opportunity presents itself (e.g. Apollo 17 collection of orange soil). Personal agents can be used to remind Astronauts of EVA protocols (mOPS1). Comparison of the actual EVA schedule versus the planned EVA will allow for more efficient planning in future EVAs. The time required to complete common tasks can be tracked over several EVAs as certain tasks may require more or less time than initially thought (mOPS2).

4) **Mars Analog Tests:** Astronauts, Mission Control, and Science Teams will gain experience using the MAA during lunar surface activities. They will be able to fine tune the methods and software programs used for collecting and discussing data, and formulating new EVA plans based on these discussions (mOPS5).

5) **Robotic Crew Support:** Astronauts can command robots to do specific activities. These include having the robot move to a specific location, automatically tracking the astronauts with video cameras, taking panoramic pictures, collecting soil samples, or deploying equipment (mCAS2, mCAS3).

6) **Site Surveys:** Astronauts would be able to access data from a past EVA to compare it with their current location while on an EVA (e.g. mA9). Querying past data could also be helpful when mapping geologic units.

7) **Public Engagement:** Data from an EVA can be made available to the public in real-time. MAA can automatically upload video clips, images, and voice notes to a public NASA website tracking the progress of the EVA (mEOR1.1). MAA systems can be made available for use by the general public (mEOR1.3). For example, students can conduct simulated using the individual Mobile Agent System (iMAS) and mock suits (as seen in Figure 2) distributed to schools and educational facilities (e.g. Space Camp, Challenger Centers, Smithsonian Air and Space Museum. Also, at certain facilities, the public can use voice commands to control and manipulate equipment on the lunar surface (e.g. robot, trench tool) (mEOR1.3).

8) **Hazard Mitigation:** The MAA could integrate specific instruments that monitor solar and seismic activity and provide automatic alerts and instructions to the Astronauts when hazards (e.g. solar flares, moonquakes) are detected (mEHM1, mENVMON1, mENVMON2).

Summary: Methods for using technology to document and distribute the science data collected on the Moon is a necessary component for communication among NASA, the science community, and the general public. The capabilities of the Mobile Agents Architecture are applicable to several objectives identified by NASA and most importantly provide a system for communicating science data on future manned missions to Mars.
For more information please visit these websites.
WJ Clancey's Homepage: http://bill.clancey.name/
MDRS: http://www.marssociety.org/mdrs/mdrs07.asp
NASA Exploration Objectives:
http://www.nasa.gov/mission_pages/exploration/mmb/why_moon_process.html

References: [1] Clancey W. J. et al. (2005), *AIAA 1st Exploration Conf.* [2] Clancey W. J. (2004) *in* Cockell C. Martian Expedition Planning, *AAS Science and Technology Series, 107,* 411-430. [3] Dowding J. and Clark K. (2005) *Mars Society 8th Int'l. Conf., Abstract.* [4] Burridge R. R. et al. (2003) *iSAIRAS*, *Abstract*. [5] Graham J. and Shillcutt K. (2003) *iSAIRAS, Abstract*. [6] Alena R. L. et al., (2004) *IEEE Aerospace Conference, Abstract.*