RAPID ON-SITE SCIENCE OPERATIONS AND HUMAN-ROBOT INTERACTIONS AT LUNAR AND MARS ANALOGUE SITES. J. Maule[1,2], M. Fries[1], A.Steele[1], H. Amundsen[3], N. Wainwright[4], M. Damon[2] and the AMASE, Desert-RATS[5] and LOCAD[2] Teams. [1]Carnegie Institution of Washington, Geophysical Laboratory, 5251 Broad Branch Road N.W., Washington D.C. j.maule@gl.ciw.edu. [2]Lab-On-a-Chip Application Development (LOCAD), NASA Marshall Space Flight Center, Huntsville, AL. [3]PGP, University of Oslo, Norway. [4]Charles River Laboratories, Charleston, SC. [5]EVA and Space Suit Systems Branch, NASA Johnson Space Center, Houston, TX

Abstract: On-site mineralogical and microbiological analyses of rock samples were performed by human operators during simulated surface extra-vehicular activity (EVA) at lunar and Mars analogue field sites. Operations were facilitated during AMASE by JPL's Cliffbot Rover, which obtained rock samples from inaccessible sites e.g. 80-90 degree slopes. These tests provide an example of what humans could do on the Moon to address challenges facing future crews on Mars e.g. planetary protection, life detection and performing science on the surface as 'scientists', with greater flexibility and less direct guidance from mission control. Mineralogical analysis of rocks was performed (within seconds) with a hand-held Raman spectrometer to verify geological field observations; microbiological analysis (within minutes) with the Lab-On-a-Chip Application Development Portable Test System (LOCAD-PTS), a handheld device for biochemical analysis – now aboard the International Space Station (ISS).

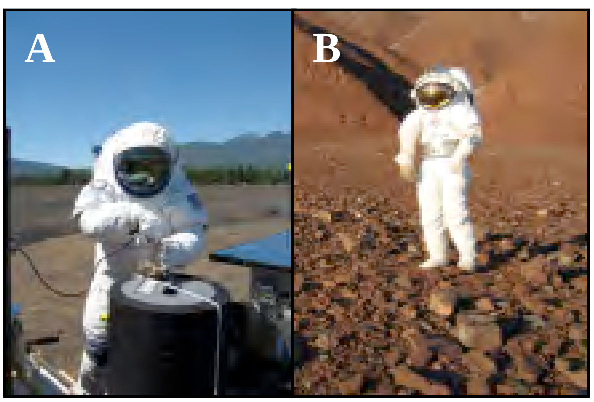

Figure 1. A. Lunar analogue site (Cinder Lakes, Arizona). **B**. Mars analogue site (Bockfjorden, Arctic).

Introduction: The *Vision for Space Exploration*, announced by the President of the United States in January 2004, stated that NASA would work towards a "human return to the Moon before 2020, in preparation for human exploration of Mars" [1]. Mendell has summarized various ideas concerning exactly what humans should do on the Moon [2]. The remoteness of Mars from Earth – in terms of distance and communications delays – necessitates greater crew autonomy, in science as much as mission operations. Science instruments that are small, easy to use and provide rapid results (in space) encourage iterative scientific thought processes in the field. We have used this approach to perform microbiological and mineralogical research at remote field sites on Earth [3-6] and suggest that it could be extended to human exploration of the Moon and Mars. While the potential for life on the Moon is negligible [7], it's absence (apart from those organisms introduced by spacecraft) makes it an ideal place to understand how humans and their microbe-laden spacecraft [9,10] bio-contaminate a planetary surface [8]. Studies on the Moon will help us limit bio-contamination of the Martian surface - which threatens to interfere with life detection experiments and endanger planetary protection [11-14].

Methods: *Analogue Field Sites*. Lunar analogue site: cinder field 'Cinder Lakes' (elevation 2031 meters), near San Francisco Peaks, Flagstaff, Arizona. Site has little/no vegetation, artificially cratered in the 1960s to re-create lunar landing site terrain to train the Apollo 15-17 crews - now used as test site for NASA Desert Research and Technology Study (D-RATS). Mars analogue site located at Bockfjorden, Spitsbergen (79.5°N, 13.5°E), visited during 2006 Arctic Mars Analogue Svalbard Expedition (AMASE), August 2006. *Spacesuits*. Simulated surface EVA performed with Zero Prebreathe System Mark III spacesuit, a prototype for future lunar exploration. *Swab Microbial Analysis*. Swab analysis performed by brushing sterile swab over surface for 10 seconds, swab tip then immersed in 1ml LAL reagent water (LRW, Charles River Labs, Wilmington, MA), mixed 30 seconds, followed by LOCAD-PTS analysis. *Mineralogical analysis*. Raman spectrometry performed by suited subject during EVA with Raman Systems RSL Plus using a 785 nm wavelength laser. Size of Raman spectrometer: 10" x 5" x 3", with small screen (4" x 2.5") to display spectra. *Rover Interaction*. JPL Cliffbot deployed to obtain samples from site inaccessible to the human operator: steep cliff with 80-90 degree slope. Rover and EVA operations coordinated to enable hand-off of rock samples to human operator.

Results: At Mars analogue site, suited subject identified rock of interest, approximately 10" in diameter, reddish color with a white vein (figure 2). Geologists field observations suggested this vein consisted of feldspar (a dark layer of unknown composition was located within the vein). Raman analysis actually showed the vein to be carbonate and dark layer to be macromolecular carbon.

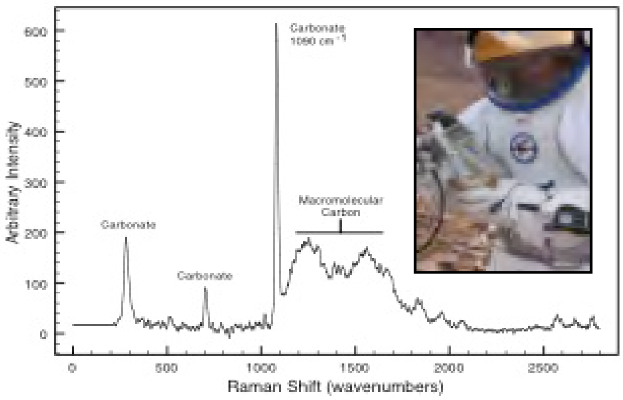

Figure 2. Raman spectrum of white vein in rock collected from Mars analogue site, showing that it consisted of carbonate rather than feldspar. The dark layer consisted of macromolecular carbon. Inset: Obtaining Raman spectra during EVA.

Layer	Raman Identification	LPS/ β-1,3-glucan	
		On-site	+ 15 days
Upper vein	Carbonate	2.83	0.156
Dark layer	Macromolecular carbon (MMC)	1.52	0.258
Lower vein	Carbonate	0.556	0.117

Table 1. Summary of Mineralogical and microbiological analyses of the carbonate vein at Bockfjorden during EVA.

Figure 3 (left). Sample hand-off from Cliffbot to human at Bockfjorden, Spitsbergen. The JPL Cliffbot rover and human EVA operations were coordinated so that the suited subject could obtain samples from inaccessible sites – in this case an 80-90 degree slope of a cliff face.

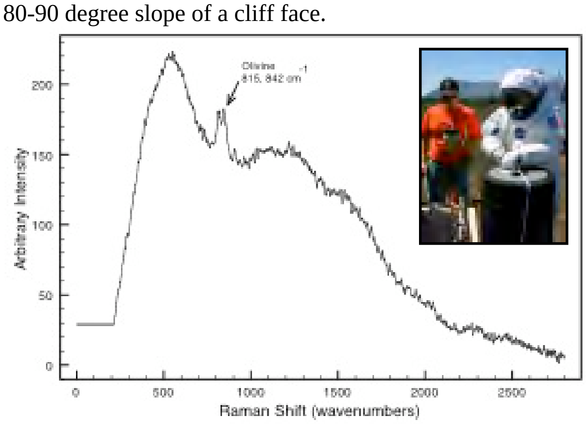

Figure 4 (above). Raman spectra of rhyolite sample at Cinder Lakes, collected by suited subject during pressurized EVA. Inset: Marc Fries observes Raman analysis by suited subject.

Conclusions: Rapid mineralogical and microbiological analysis were integrated into EVA procedures. Hand-held Raman analysis provides a useful tool to verify geological field observations. Science instruments must be user friendly. Further tests required to ensure sterile technique, especially in a dusty/windy environment. Difficult to prevent the human operator bio-contaminating sample material; a defined procedure for sterile donning of a spacesuit during space flight required. Effective interaction was demonstrated between the JPL Cliffbot and human suit subject to accomplish astrobiology objectives.

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