THE FIRST EXPLORATION TELEROBOTICS SYMPOSIUM – TELEPRESENCE: A NEW PARADIGM FOR HUMAN-ROBOTIC COOPERATION.

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Introduction: We present findings and observations from the *Exploration Telerobotics Symposium* held at Goddard Space Flight Center, on May 2-3, 2012. This symposium was devoted to opportunities and challenges of telepresence for exploration. A hundred participants from science, robotics, and human space flight stakeholder communities attended, representing space agencies, industry, and academia.

Telepresence as an Exploration Strategy: Telepresence is the placing of human cognition telerobotically at an exploration site, which may be hazardous to humans. This strategy is now being used routinely for undersea science, oil and cable maintenance, high-dexterity surgery, the mining industry, and for surveillance and munitions in airborne drones. An important goal of the symposium was to bring representatives of these applications to share their perspectives.

The *Exploration Telerobotics Symposium* considered a strategy whereby human operators could be sent close enough to their telerobotic surrogates that high bandwidth and low-latency communication could be assured. In the case of the Moon, this could be from low lunar orbit, or Earth-Moon L1 or L2 [1]. For Mars, this could be done from martian orbit [2] possibly from martian moons. For asteroids, work could be done from a convenient stand-off site, in orbit, or formation flying. For a gravity well, EDL (as well as safe return) is an expensive and risky part of the trip, perhaps the hardest part of the journey. This strategy is enabling for contamination control (forward, for planetary protection, and backward, for human safety).

The L1 and L2 locations, about 50000 km over the near- and far-sides of the Moon respectively, offer two-way control latencies to the lunar surface of order 400 ms, *six times smaller than the control latency from the Earth*. This allows for a high degree of cognitive coupling and likely enables complex tasks that would otherwise require in situ humans [3].

Symposium Organization: The two-day symposium included plenary talks and panel discussions on the first day. These are available at the symposium website -- http://telerobotics.gsfc.nasa.gov. Four plenary sessions addressed several key themes; (1) The historical context of telepresence; human cognition, performance, and human factors; and the relationship of telepresence to exploration; (2) Field science: what it is, and how it differs fundamentally from remote sensing science; the value of "being there" at least cognitively; (3) State-of-art space telerobotics, and directions for expansion of capability; future expectations; (4) terrestrial telerobotics, and feed-forward to space exploration; sensory extension and dexterity for surgery, mining, undersea operations.

The second day was devoted to breakout sessions to produce actionable findings to be delivered to an integration panel, which would distill these findings and observations. These three breakout groups were (1) identification of priority goals in science enabled or enhanced by telepresence, (2) assessment of the relationship of telepresence and human exploration, and (3) identification of priority capabilities to enable telepresence: technologies and operations.

Breakout Session Findings: The science breakout group recognized strong potential for this strategy. New science is enabled at distant locations where very long communication latency is a serious handicap to efficient operations from Earth. For the Moon, science activities in permanently shadowed regions (in particular for access of volatiles) can be particularly enhanced. In addition, construction of far-side facilities by on-orbit control at EM L2 is of interest. Robotic telepresence could be an especially useful strategy in areas that might be hazardous to humans such as mare pits, escarpments, and fresh craters. Telepresence should provide improved access to better samples, perhaps in the South Pole Aitken basin. It was pointed out that the impact of communication latency on planetary field geology [4] is poorly understood, and analog efforts to understand natural breakpoints in communication latency for science task completion should be carried out.

Advantages for Mars are much more significant, because of the vastly longer two-way latency to Earth, but science advantages on the Moon have parallels on Mars. In this respect, telepresence control of science experiments on the Moon exercises capabilities that will be needed for Mars. Symposium results have been briefed at GLEX2012 and NASA HQ, and a report is in production. Follow-on activity is being planned.

References: [1] Lester, D. and Thronson, H. 116-RSA-7, AIAA Space 2011 Conference. [2] Schmidt, G., et al. AIAA-2010-0629, AIAA Aerospace Sciences Meeting. [3] Lester, D., and Thronson, H. 2011, *Space Policy 27, 89-93.* [4] Hodges, K.V. and Schmitt, H.H. Geological Society of America Special Papers, December 2011, v. 483, p. 17-31.