TIME-DELAY TELEOPERATION TO ENABLE MARTIAN SURVEY AND SAMPLING MISSIONS. H. Charles Dischinger, Jr.[1], [1]NASA George C. Marshall Space Flight Center; EV74, MSFC, Alabama 35812, charles.dischinger@nasa.gov.

A significant challenge for robotic exploration of the Martian surface is the time delay for commands to accomplish mission objectives. While the Mars Exploration Rovers have been wildly successful, future missions will need to be more so. The typical off-the-cuff solution is that future exploration robots will be "autonomous." In reality, they will be automated but will rely for the foreseeable future on human planners for mission tasks. Again, the MER missions have demonstrated what the Apollo missions to the moon had done before: that human senses and analysis are more effective in determining geologic research tasks than any current or foreseeable onboard capabilities of robots are. Teleoperation is a solution which is logical for future operations, even under the time delay constraints imposed by such missions. Teleoperation through virtual interfaces would provide both deep insight into the environment under exploration (planetary, planetary moon, asteroid) and a method of scripting tasks to be performed by the robotic – automated – rover.

The next generation of robotic explorers in the Martian environment will take advantage of advances in in-space automation systems that will allow more flexibility of operations while achieving greater depth of scientific research. For example, the sensor and software systems used for autonomous rendezvous and capture (docking) could be used by surface rovers. These systems would allow the vehicle to precisely range objects of potential interest as the robot is moving, and thereby, to develop onboard 3D models of objects in a terrain. With appropriate traverse strategies, this would allow the vehicle to create a map-type model of an area of interest in an automated manner, during the earth control center night. After building its on-board model of the terrain, it would send the model to the control center. This would enable a virtual world to be created that would allow investigators to utilize virtual reality methods to teleoperate the robot, giving researchers improved capability to control their research. They would select the particular objects in the locale that they wish to investigate, drive the rover to that object, and dig it, up or pick it up, or drill into it, in a seemingly-real teleoperation.

The teleoperations capability will allow the deployed robot to be used in a national laboratory or observatory fashion (*e.g*., analogous to Hubble Space Telescope Science Institute, or U.S. Antarctic Program). Researchers would become investigators in the Mars robotic observatory by application to a review board that would determine the relative importance of the research and assign blocks of "observatory time." Selected geological and geochemical researchers could be allowed to define the region of Mars of interest to them, and robot operators would plan exploration according to research request priorities. As the robot reaches the area of interest, researchers would travel to the mission control center to operate the robot directly, through virtual reality interfaces. When an investigator arrives for his or her observatory time, the first step would be to enter the virtual world created overnight by the rover and sent to the mission control center. The model from the rover would have been further enhanced by the mission control center by layering in imagery from satellites. The observatory time would then consist of selection of target materials from the virtual Mars landscape and manipulation of the targets. The investigator would personally "pick up" the model of the object of interest (rock, soil) and perform, in the virtual space, the task that enables the analysis he or she needs. For example, the investigator might virtually command spectral scans of the material and then place the sample in an analysis chamber. After completing the task, the researcher reviews it in the virtual world and edits or accepts it. The mission control center then uploads the script of the task to the robot. The robot performs the task, and streams the appropriate data back to the mission control center. The researcher re-enters the virtual world to view the incoming downlink, as it is received. He or she can manipulate the imagery and other data to assure the tasks were performed as scripted ("is the sample in the incubation chamber properly; did the door seal?"). If there are changes that need to be made, the investigator can do so immediately, and mission operators will send a new script. Depending on the amount of observatory time allocated, the investigator may perform more tasks in his or her research objective, to be sent to the rover.

This method of operation enables geologists to work as they do on earth. They will enter a terrain model with characteristics of a map, but rich with other information, such as soil structure (information obtained as the robot's wheels sensed granularity and stability), temperatures and other spectral information of the landform, and topology. Earth geologists use a survey approach before deciding on objects of interest to them. The strategy varies from one geologist to another, but many begin by finding the high ground and going there to look the situation over. This will be very simple and quick in the virtual world, much quicker than commanding the rover to what may appear to be the high ground from the vantage point of its current location. Once he or she is "standing" on the high point of the area, decisions can be made quickly about a traverse of the area and selection of targets. The researcher would identify this information by virtual selection, and the robot would begin to move to the first target twenty minutes later. In the meantime, the investigator would have moved his or her virtual perspective and engaged the appropriate manipulators to develop the procedure that becomes the script that will then be sent to the robot while it is in transit. When the robot arrives at the first waypoint target, it executes the tasks the investigator had requested a half-hour earlier. The investigator may wish to review the task completion, in which case he or she would have told the robot to wait until the review has taken place before moving to the next waypoint. Since this process would take nearly an hour, review may be considered less important than getting as many samples evaluated as possible. During lags while the robot is traversing or performing analysis tasks, the investigator is in the virtual world, scripting the tasks for the rest of the waypoint targets.

At the end of a long day for the investigator, mission control transitions to overnight shift, and the robot moves to the next area to be surveyed overnight, as it preforms housekeeping – dumping sample residues, erasing old terrain models, and the like. By the time the next investigator arrives in the morning, a new area has been mapped, and the model for the next virtual world has been created.