IMMERSIVE TELEPRESENCE AS A NEW PARADIGM FOR MARS EXPLORATION. R. J. Terrile[1], [1]Jet Propulsion Laboratory/California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, rich.terrile@jpl.nasa.gov

Introduction: Progress in the information technology field is creating compelling alternatives and augmentations to traditional methods of exploration of distant planetary surfaces. One such alternative is immersive telepresence where the human explorer is Earthbound (or in planetary orbit) but able to remotely interact with a distant environment. Exploration goals for science, operational development and public engagement each have unique requirements on immersive systems [1]. Understanding the future capabilities of these systems is essential for deriving requirements of data volume, bandwidth and latency for future robotic missions. Immersive systems have made significant advances and are now being driven by the entertainment and game industries.

These systems allow the observer to experience the virtual environment through head movements and feel immersed into the simulated environment. It is also possible to introduce avatars of the observer into the scene that can interact with the physical 3-D environment. When the simulation fidelity is equivalent to the observations of an in-situ explorer, the visual experience is the same as being there. Additionally, the experience of exploration is not limited to the one in-situ explorer, but can now be interactively shared by anyone with the computational resources and virtual reality immersive systems. This can allow viewing of surface operations from virtual and selectable vantage points. Not only will these immersive data sets provide excellent training opportunities for future explorers, but may also have profound effects as they become available to the general public. How will our feelings toward planetary exploration change when we all have the ability to walk on other worlds and cast our shadows on the rocks? Immersive telepresence offers a new near-term paradigm to how we explore, how we prepare and train, and how we share the experience of robotic and human Mars exploration.

Near-Term Applications: Hardware development and commercial applications for immersive telepresence are benefiting from Moore's Law advances in computation, modeling, bandwidth and minuaturization and affordability of immersive imaging systems (tablet virtual and augmented reality windows, head mounted displays and glasses). Even current systems can use tablet displays to create a moveable window into a simulated, 3-D virtual environment. Data from the MSL and MER rovers can be used to create high fidelity 3-D terrains that can be explored with these hand held tablets and will certainly become early tests of more advanced imaging glasses and head mounted devices. Current head mounted displays can already deliver HD TV bandwidth (resolution and frame rate) with a large community engaged in improving the performance and lowering the cost. HD TV bandwidth is sufficient for full human field of view vision immersion if pupil tracking is used [1].

Additionally, Mars surface 3-D models and simulations will be used to support the development of operational procedures and training for both robotic and human supported surface operations. Immersive telepresence allows robotic exploration to combine with human operations by using agile machines that are surrogates for human explorers. In this way humans can efficiently respond to the Mars surface environment while located either on Earth or preferably, to avoid the long latency created by the light travel time, in Mars orbit.

Once immersive and interactive data sets become available and commonplace there will be increased pressure on NASA to provide similar experiences from future space missions. The step-wise increase in value of higher fidelity public education products like full color panoramas, stereo views and time lapse movies has been demonstrated as they became ingrained in our culture. Just as live television transmissions from astronauts on the lunar surface four decades ago, created an irrevocable expectation for public engagement, so too will immersive telepresence.

Bridging Science With Human Exploration: NASA directed goals for future Mars missions fall into several categories including science driven goals, operationally driven goals for preparing or enabling future human or complex robotic exploration and public engagement goals to stimulate education and support for exploration. Generally the NASA Science Mission Directorate (SMD) missions are primarily science driven while the Human Exploration and Operations Mission Directorate (HEOMD) missions are primarily operationally driven. However, all sets of mission goals comprise aspects of mission priorities. Immersive telepresence, as a method of exploration has direct implications and unique requirements for each of these science, operational and public goals [1].

Requirements for Science Mission Goals: Science exploration, discovery and surface interactions require the creation of an interactive link with the planetary environment that accommodates the effects of latency. This allows real physical interaction and measurement of the response of the environment. Immersive telepresence data sets could be acquired over a long period of time, constrained by the bandwidth limitation (similar to current return of data from robotic missions). However, a closed action and response loop is required that must fit the bandwidth and latency constraints. For exploration on surfaces further away than lunar, the latency limitations mean that immersive telepresence is used to simulate, plan, practice and interpret interactions, but the actual interactions are treated in the same way as current robotic exploration. If the light-time created latency of Mars exploration is shortened, direct, real-time immersive telepresence on the surface is possible.

Human Mars Exploration: Immersive telepesence offers the motivation for sending astronauts to the vicinity of Mars (short of landing on the surface) because it allows them to interact and explore the surface with dexterous robotic proxies (like Robonaut 2 [2]) without suffering the speed of light latency of operating from Earth. In this way human directed Mars surface exploration can occur earlier and more economically by combining with robotic science missions.

It further enables all of Earthbound humanity to take the journey as well and sense the thrill of walking on a alien world. Three-dimension surface models with real physical properties and used with avatars further allow the simulation of surface deformation. Thereby, the public can virtually explore, dig holes, move rocks and leave footprints on Mars.

Training and Operational Readiness. Surface simulation with physical properties will also play an essential role in training for eventual human presence on the Mars surface as well as planning robotic operations for all future missions. Early engagement of the science, human exploration and public engagement communities is essential for defining the data products required to support immersive telepresence.

Recommendation: The recommendation that surfaces out of the technical readiness of immersive telepresence and its potential to become an irrevocable expectation is to prepare our future Mars missions for it. Consideration of future mission requirements should acknowledge the benefits of immersive data sets for science, operations and public engagement. An analysis of how to tailor surface imaging spatial coverage with available bandwidth, time and latency to produce immersive data products should be included in proposed data plans. Every new Mars mission will be an affordable opportunity to include immersive data products in our returned data. Lunar or near-Earth missions with low latency may also include immersive telepresence operations as part of the eventual Mars planning. Immersive telepresence will be the next step to engaging the public into Mars exploration in ways that can only be imagined

References: [1] Terrile R. J. and Noraky J. (2012) *IEEE Aerospace Conf. Proceeding, Big Sky, MT, March 2012*. [2] Diftler M. A. et al. (2012) *IEEE International Conf. on Robotics & Automation.*