IMMERSIVE VIRTUAL REALITY: ADVANCED VISUALIZATION IN SOLAR SYSTEM EXPLORATION AND RESEARCH (ADVISER) AND APPLICATION TO MARS: **J. Head[1], A. van Dam[2], S. Fulcomer[3], Prabhat[3], A. Forsberg[2], G. Rosser[2], S. Milkovich[1], S. Pratt[1]; [1]Dept. Geol. Sci., [2]Dept. Comp. Sci., [3]Center for Comp. & Vis., Brown University, Providence, RI 02912 USA.**

Background and History: The successful Spirit and Opportunity rover traverses highlight the context provided by the rover moving from place to place and underscore the basic importance of human telepresence at scales commonly experienced by geologists on Earth. Indeed, recent developments in computer science (visualization, rendering and immersive virtual reality) and acquisition of high-resolution data sets of planetary surfaces have provided the capability to place scientists virtually on the surface of planets, where they can attack important multidisciplinary scientific problems that have heretofore gone unexamined.

In the past, high-resolution terrain visualization and other forms of planetary data visualization have taken separate paths. High-resolution 3D representations of terrain data have typically been computed off-line as fixed sequence movies, while at the same time planetary data sets are commonly presented for query in mapping format. While many presentation tools exist for producing batch animations and still images, we know of no interactive tool that offers the functionality proposed by ADVISER–namely, real-time visualization and user interaction with high-resolution planetary datasets including geology analysis tools that facilitate exploration of the data to help address scientific questions. Therefore, we see the demonstration of this synergism as a fundamental first step in establishing the importance of these techniques so that they can be developed further and be routinely applied to scientific problems.

Establishing the scientific imperative for visualization and immersive virtual reality (IVR): Geologists explore the Earth primarily through fieldwork and analysis of the geological record at various points on the surface of the Earth. They then integrate these individual points of understanding about the Earth's surface through more synoptic analyses, often aided by the integrating perspectives seen from image and topographic data acquired from Earth orbit. Planetary geoscientists commonly work toward an understanding in the reverse order. The distances and times involved dictate that the first data from individual moons and planets comes from flybys and orbital spacecraft, perhaps in some cases evolving towards the deployment of a few landers and rovers, and for the Moon, human explorers. Now that we have global data sets for the Moon, Mars and Venus, comprehensive regional data sets for many of the outer planet satellites, and soon to be obtained global data for Mercury, we can begin to undertake the detailed exploration of planetary surfaces that is required for the full understanding of the evolution of planets.

How do we accomplish this? In only a very few cases can we expend the resources to put a lander and rover, and thus our eyes and ears, down onto the surfaces of the planets. The successful Pathfinder and Mars Exploration Rovers are testimony to the exciting results that can be obtained by such real surface exploration. Fortunately, developments in advanced visualization and immersive virtual reality environments have created the ability to place the geoscientist back down on and near the surface, to visit virtually any part of the planet they wish to see, and to regain the perspective that is the foundation for the understanding of the geological relationships necessary to unlock the record of the history of the planets.

Figure 1. Interactively visualizing high-resolution MOLA terrain and other data is a key objective of our interactive system, ADVISER. Shown here is a view along an approach to the north polar cap on Mars made possible by our prototype of the system. Guided by three scientific problems, our vision for ADVISER will lead to new visualization tools for solar system exploration. Vertical exaggeration is ~25x.

The ADVISER Problem Solving Environment: ADVISER is a "problem solving environment" (PSE) for planetary geosciences. We define the PSE as a set of tools that provide the planetary geoscientist with the capability to explore and analyze data as if they were on or near the surface of a planet. The ADVISER PSE has four basic parts:

1) Geoscientist on the Surface: Visualization capabilities that enable the placement of the geoscientist onto the surface and near surface environment through immersive virtual reality (IVR) (Figure 2) or related desktop capabilities using topographic data and surface rendering programs.

2) Importation and Visualization of Multiple Data Sets: On-demand importation, co-registration and overlay of relevant image format data sets to enhance the eyes of the geoscientist and their ability to correlate and interpret data for scientific analysis. This includes high-resolution data sets such as MOC, THEMIS, HRSC, OMEGA (and derived data products), CRISM (in the future) and synoptic GRS, TES, and other types of derived regional data sets (slope, mineralogy, temperature, etc).

Figure 2. Using our prototype system running in a Cave immersive virtual reality system, two participants collaboratively examine a trough and a distant polar plateau. Note the already detailed Mars Orbiter Laser Altimeter (MOLA) terrain is made clearer by attention to lighting effects. Fractal geometry added to the closest terrain can be turned on or off; while not accurate terrain data, its important benefit is enhanced stereo viewing of the 3D form through the subtle textured look it creates.

3) Development of the Field Kit: This is analogous to the geologist's field kit and will consist of a set of software functions that has the capabilities commonly carried out by the geologist in the field using things such as the Brunton compass, altimeter, etc. It will consist of selectable items including elevation of any point chosen, relative elevations, slope determinations, strike and dip of planes defined by several points on the surface (say a continuous layer in the polar layered terrain or an outcrop in Valles Marineris), ability to produce variable lighting and different illumination geometries, ability to determine wind directions and velocities.

4) Development of Ancillary Virtual Field Instruments: This is analogous to the additional tools that the geoscientist carries in the field such as cameras, GPS, and field notebooks. Specifically, we have developed the capability for: a) Virtual Photography: This capability permits documentation of individual images or video streams from a menu and the ability to store them for incorporation in electronic form for export to other remote collaborators, storage for further analysis or insertion in manuscripts and meeting presentations. b) Virtual GPS: This virtual global positioning system permits exact location at any point in the analysis and permits tracking of traverses and storage of these data so that they can be readily repeated or exported to other systems for collaborators to use. c) PDA: This is the equivalent of the field notebook and permits the investigator to record a host of information including notes and documentation as well as any of the data derived from the Field Kit (Figure 3). This is a major part of the written record of the use of the exploration tool, and serves as the basis for the documentation of the analysis and solution of the scientific problems. These data form a permanent record and permit the synthesis of information for professional publication. Together, these four parts form the foundation of the ADVISER PSE.

Planetary Geoscience Demonstration Projects: We are undertaking a three-pronged approach of geosciences investigation to demonstrate the scientific usefulness of visualization and IVR in planetary geosciences with the ADVISER PSE. The three projects will use the visualization of large martian terrain and image/map databases and will provide the basis for developing a visualization system generalized to complex GIS terrain, image and volumetric data. This system will integrate state-of-the-research geometric and volumetric rendering software with parallel graphics hardware to allow interactive exploration and analysis of data at the highest available resolution and with synthesis of all available modalities. Research will be carried out to develop science domain-specific instrumentation to support interactive query and analysis. The demonstration projects for our geosciences investigation will be a) Mars Polar Evolution, b) Mars Tropical Glaciers, and c) Noachian Hydrological Cycle.

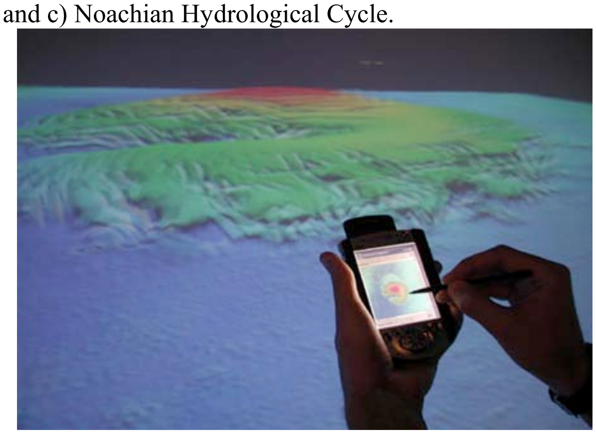

Figure 3. Navigating terrain using a wireless PDA. Here a user can click on a point they wish to explore, and then they are automatically navigated to that area. Fine-grain navigation could be accomplished in a point-and-fly style metaphor subsequently. The PDA can also be used for a variety of other user interface elements. The terrain appears blurred because it is displayed as a field-sequential stereograph for viewing with LCD shutter glasses.