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THE EXPLORATION METAPHOR

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NASA's experience in planetary exploration has demonstrated that the desktop workstation is inadequate for many visualization situations. The primary mission displays for the unmanned Surveyor missions to the moon during the mid-1960s, for example, were environmental images assembled on the inside surfaces of spherical shells. Individual images taken in 1971 by the first Mars orbiter, Mariner 9, were applied to the outside of four-foot diameter spheres, creating composite photographs of the entire planet. During the Viking mission to Mars in 1976, initial orbiter photos were mosaicked on large tables or on walls to serve as group decision-making displays. The environments surrounding the two Viking landers were visualized using stereo and panoramic images, desktop models, and full-sized replicas of the lander and the surrounding rocks.

Future exploration missions will greatly benefit from advances in digital computer and display technology, but there remain unmet user interface needs. Unfortunately, the desktop workstation is generally considered to be the starting point of user-computer interface design, and most current human-computer interface research emphasizes the desktop metaphor. In this view, computing is thought to be comparable to paperwork, and the objects and functions available to the user reflect this emphasis. Point-and-click interaction with icons and windows is supportive of operations performed on text and simple pictures, but this approach is inadequate for planetary exploration.

Alternative user interfaces and metaphors are needed for planetary exploration and other interactions with complex spatial environments. These interfaces and metaphors would enable the user to directly explore environments and naturally manipulate objects in those environments. Personal simulators, virtual workstations, and telepresence user interfaces are systems capable of providing this integration of user space and task space. The Exploration Metaphor is a useful concept for guiding the design of user interfaces for virtual environments and telepresence. To apply the Exploration Metaphor is to assert that computing is like exploration, and to support objects, operations, and contexts comparable to those encountered in the exploration of natural environments. The Exploration Metaphor, under development for user interfaces in support of NASA's planetary exploration missions and goals, will also benefit other applications where complex spatial information must be visualized.

Visualization methods and systems for planetary exploration are becoming increasingly integrated and interactive as computing technology improves. These advances will benefit from virtual environment and telepresence interface technology. A key development has been the processing of multiple images and other sensor data to create detailed digital models of the planets and moons. Data from images of the Earth, Mars, and Miranda (a moon of Uranus), for example, have been converted into three dimensional models, and dynamic virtual fly-overs have been computed as demonstrations. Similar processing of lower altitude photography and the use of computer aided design tools promise to produce very detailed models in the future. Currently, the Magellan spacecraft is

more than half way to Venus on a mission to digitize the entire surface of that planet, and this, too, will provide an interactive digital model for virtual exploration on Earth.

Future plans call for multiple unmanned rovers to traverse the surface of Mars, enabling geoscientists located at a central Mars base to explore the planet via telepresence. In addition, Earth-bound mission operators and scientists will be able to access integrated digital models of Mars as the missions progress. The Exploration Metaphor will contribute to the design of user interfaces for these applications.