ROBOTIC AND HUMAN EXPLORATION OF MARS: Carr, M. H., U.S. Geological Survey, Menlo Park, CA 94025

Humans will ultimately land on, and explore, the surface of Mars. The prime reasons for sending them to Mars may not be scientific, but the prospect of human exploration provides both obligations and opportunities for the science community. We must examine what knowledge of the planet is needed so that we can deliver people to Mars and return them safely to Earth. We must also examine what knowledge of the planet is needed so that the people can be used effectively at the planet. This implies that, prior to any human landing, we must have better knowledge not only of those characteristics of the planet that are of engineering interest, but also of those that are of broad scientific interest. For people to do useful work, they must go to the right places with the right tools, and have the right science objectives.

Over the last two years several groups have been examining how we should prepare the way for human exploration of Mars. They have been examining what knowledge of the planet is needed before human missions are undertaken, what robotic missions need to be flown to acquire that knowledge, what people might do on Mars, and how people and robots might interplay at the planet's surface. Mars is more complex than the Moon. It has an atmosphere, a potential for past and present life, and a much more diverse geology. Mars also appears to be more dangerous than the Moon. The two Viking landing sites are more hazardous to landing than typical lunar sites, and there are good reasons to think that hazards such as dry river beds, crevasses, fault scarps, porous dusts and block fields are common. Robotic missions are, therefore, likely to play a more prominent precursor role in the exploration of Mars than they did with the Moon. Robotic missions are also of immediate interest because of their near-term programmatic implications. A set of robotic precursor missions was proposed in the 90-day report (1), written at the end of 1989. Since that time, the robotic mission set has been re-examined (2) as different architectures for human missions have been proposed, each with different objectives and different schedules. In addition, different ways have been explored for implementing the various missions within the set. These activities have resulted in several changes to the robotic mission set as originally proposed, but the basic strategy remains the same. An initial reconnaissance phase involving network science, orbiters and sample return, is followed by a phase in which we more narrowly focus on evaluating potential landing sites for human missions.

The first mission in the robotic mission set is Mars Observer, which is to be launched in 1992. This will provide global topography and gravity that is probably sufficient for human mission needs. Mars Observer will also result in improved knowledge of the global chemical and mineralogical diversity of the surface, an improved model of atmospheric circulation, and, from the high-resolution imaging, improved knowledge of fine-scale surface features. The next Mars mission will be the Soviet Mars-94 mission. This is currently planned to include a two orbiters, four small meteorology stations, four penetrators, two balloons and two rovers. Observations from the balloons, rovers, and penetrators will provide direct in situ measurements of composition and surface conditions, and, in addition, should greatly improve our ability to assess how difficult it is to land on, and move around the martian surface.

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A network mission is currently being proposed as the next US mission after Mars Observer. A concept is being examined which involves sending small, independent spacecraft that hard land on the surface of Mars and make measurements for ten years. The mission is called the Mars Environmental SURvey or MESUR. At each launch opportunity 8 such spacecraft could be launched, 4 on each of 2 Deltas, so that over 2 or 3 launch opportunities, 16 to 24 stations could be established. The payload is still being discussed but would likely include at least seismometry, meteorology, inorganic analysis, low temperature mineralogy imaging, and entry science. In addition to the science return, the planning of human missions would benefit directly from calibration of orbiter geochemical measurements with surface measurements, and from improved knowledge of the range of terrains expected on landing, the structure of the upper atmosphere, and meteorological conditions at the surface.

A rover/sample-return mission has long been the mission of highest science priority. Experience with the Moon points to the enormous value of returned samples. Samples permit us to use the full intellectual and instrumental resources of the science community to resolution of science issues, and allow response to unforseen results on time scales of months rather than decades. For Mars, rovers may be required for sample diversity. Unfortunately, sample return missions are too expensive to be supported within the current funding expectations for OSSA. Sample return missions will be dependent on additional funding, such as could be provided by the SEI.

In order to implement both human and robotic landings on Mars with low risk, a high resolution imaging orbiter may be required to survey the landing sites. Where such an orbiter fits within the robotic mission sequence is being debated. It is generally perceived as a requirement for human missions, but whether it must precede a sample return is unclear. Another type of robotic precursor mission that is being discussed is a site characterization rover that will survey a potential human landing site in detail.

One function of the precursor missions is to better define the characteristics of the subsequent human missions. What should the operating range of humans be? Can this range be usefully extended through robotic surrogates and telepresence? What robotics are needed at Mars to support early human missions? How long would people be on the surface? What useable resources are available at the planet? Where should the first landings be? What should the first astronauts do? Questions such as these must be addressed before the first humans go, and they will inevitably influence what robotic missions are ultimately flown.

REFERENCES. (1) NASA (1989) Report of the 90-day Study on Human Exploration of the Moon and Mars. *NASA, 1989*. (2) Mars Science Working Group, (1990) A strategy for the Scientific Exploration of Mars. *In Press*.