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The exploration of Mars, martian meteorites, and the search for life

The failure of three missions to Mars caused NASA to hold several enquiries into the missions and the whole program. Reports in hand, they then called for advice from the science community, the aerospace industry, and the NASA centers as to what to do next. The scientist input was a workshop "Concepts and Approaches for Mars Exploration" that was held at the Lunar and Planetary Institute, in Houston, July 18–20. About 250 scientists attended and made over 200 ten-minute presentations as five "working groups": basic science, biocompatibility, exploration, missions and architecture. Finally, each group reported to a plenary. The workshop was not restricted to U.S. participants, and an important element was the presence of many non-U.S. participants. Mars exploration is alive and well throughout most of the world.

The meeting opened with a summary by Carl Pilcher of the existing strategy as developed by three NASA advisory groups. The Mars program is now driven by the themes "life", "climate", and "resources": to search for evidence for past or present life, to understand the evolution of the climate, and identify resources that could be of value in the human exploration and development of Mars. The unifying factor is "water". Most of the participants felt comfortable with this approach, recognizing the important role water has played in the history of Mars. Some participants objected to planetary geology being considered a minor element in resource identification and wanted to add another unifying idea, the formation and evolution of the planet (Fig. 1). This recurrent thought was stressed in reports to the plenary by David Des Marais (who co-chaired the basic science working group) and Mike Duke (who co-chaired the biocompatibility working group).

The meeting was characterized by a large number of creative concepts for orbital and *in situ* surface observations. Many participants stressed the need for investigations that bridged the information gap between orbiters and returned samples. Higher resolution imagery at all wavelengths by robotic orbiters and surface rovers like Athena could help. There was also a widespread desire for subsurface investigations to explore the potential role of subsurface water. Imagery from orbit provides abundant physical evidence for water once being present on the surface of Mars, and probably very recently. Yet relatively little is known about the chemical consequences of water's activity. Mineralogical data are required for understanding the processes that shaped Mars' geologic resources, its climate and its potential to support life. Determining timescales is also essential, so there is a need for age-dating martian rocks by *in situ* methods and by analysis of returned samples.

In the light of the mission problems of 1999, NASA suspended its current plans for Mars sample return and sample return was another recurrent theme at the workshop. It is hard to exaggerate the role of returned samples. The breadth and depth of data for individual rocks, and their quality, will never be matched by *in situ* analytical techniques and, once on Earth, returned samples can be archived for future generations of scientists and instruments. While global geophysics and geochemistry requires orbital studies, and regional studies requires rovers, a true understanding of the rocks requires sample return. It was clearly recognized that remote orbital, *in situ* surface observations and sample return are complementary. The question surrounding sample return was "when and how", and the Apollo program was used as example pro and con early sample return. Early return of samples enabled better subsequent site selection, better sampling techniques, and better public engagement. The region of the Moon sampled by Apollo was really tiny, less than about 5%, yet the samples enabled the gross geochemical and chronological properties to be mapped out. On the contrary side, sample return was expensive and public interest rapidly dwindled once samples were in hand. Some participants felt that there was much to be done by remote sensing and *in situ* measurements before we committed to expensive Mars sample return missions.

Under-represented in the presentations were meteorite researchers, the sample analysis sector of NASA's research base. There were four or five presentations discussing how techniques that had grown out of meteorite research could help in the study of the surface of

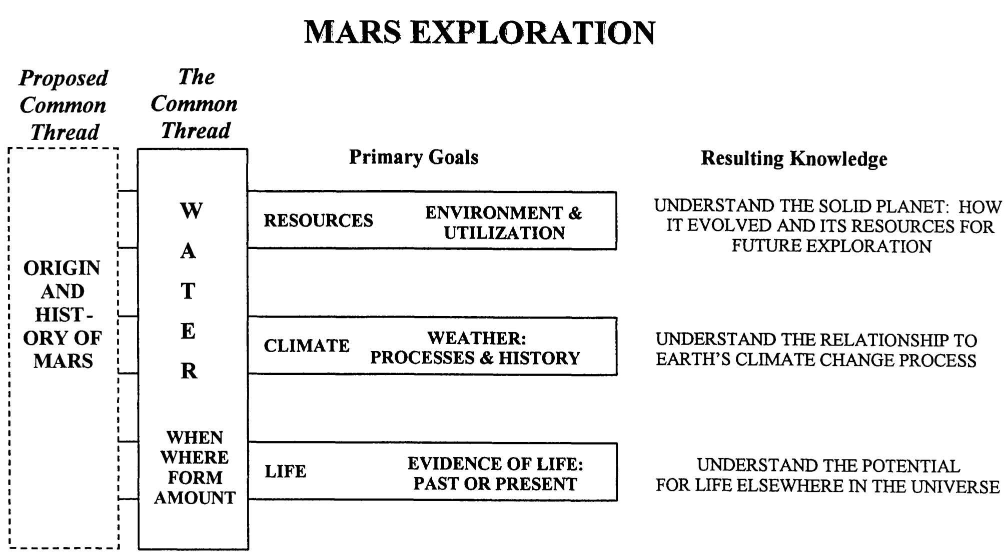

FIG.1. The science themes for NASA's current exploration of Mars strategy. The two science working groups at the workshop advocated adding another vertical column, labeled "Origin and History of Mars".

Mars. However, presentations on the martian meteorites, as unique harbingers of information about the planet, were essentially absent from the workshop. Whether this reflected the nature of the workshop announcements, a decoupling of the meteorite and missions communities, or a suppressed disbelief that the meteorites come from Mars, was unclear. However, I couldn't help wonder what effect more martian meteorite experts would have had on discussions. Presumably there would have been a greater advocacy of sample return. Probably there would have been more enthusiasm for sooner rather than later. The debate over our lack of knowledge of the surface geology and our inability to select appropriate sites might have been different.

A question that occurred to me was the wisdom of basing the whole exploration of Mars program on the search for life. What if, after 10 years and 10 billion dollars, nothing is found? What if our equipment detected life, but we reinterpreted the data in terms of other unforeseen affects, "the Viking scenario". Or what if life is found in the form of microorganisms that only a microbiologist could recognize? The scientific and philosophical ramifications might be profound, but the public—denied of their mammalian life forms—might just turn away in their droves. The Apollo program suffered greatly from public post-landing apathy. A search-for-life driven Mars program might go the same way. A recent CNN poll (how often we hear that phrase) said that even in the wake of the mission failures, 70% of the American public favored the exploration of Mars, not that they favored a search for life on Mars.

The exploration of Mars is to be a total agency endeavor, with the Human Exploration and Development of Space initiative cooperating with Space Science. As one speaker remarked, "think not of the HEDS 'tank' rolling over us, but of the superb science all that extra energy and resources could facilitate". It was the human exploration of the Moon that brought us the Apollo samples, and human exploration and resources exploitation has always gone hand-in-hand with scientific exploration, whether is was the opening of the west or the exploration of the world. Provided we learn the lessons of Apollo, such interactions can hardly fail to be highly productive. Like the Apollo program, sample return is an essential element of the Mars exploration program, both facilitating and enhancing its other elements. The American public understands that the exploration of Mars is an expensive multifaceted social, scientific and engineering venture in which the search for life is only a part.

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Editor

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"Follow the water"

This promises to be a long hot summer (and fall) for NASA's Mars Program Office as it seeks to reconstitute the Mars exploration strategy and resume flight missions. Not only does the new strategy have to be responsive to the recommendations of the Young Committee in the wake of last year's several mission failures, the strategy also has to be responsive to our growing knowledge of Mars and its astrobiologic potential. With prescience, the Mars science goals have been formulated in terms of three main thrusts—the search for evidence of life, past or present; the elucidation of martian climate history; and understanding the solid planet, how it evolved, and its resources for future exploration. The common thread that links all of these science goals is the history of martian water so that a shorthand way of summarizing the science program's goals has been "follow the water". The evidence accumulates that this will be a fruitful approach.

Even before the recently announced discoveries by Malin and Edgett (2000) regarding geologically-recent water seepage, the modelling of Clifford (1993) had alerted us to the likelihood that the martian subsurface contains a deep (several kilometers) hydrosphere where conditions might not be so different from the Earth's subsurface where terrestrial microbes eke out a frugal existence (Stevens and McKinley, 1995). As a result, NASA has begun to study approaches to directly explore the interior of Mars by drilling and retrieving samples.

It may not, in fact, be necessary to penetrate to kilometer depths to search for extant martian life because Mars gives every sign of active volcanism; recent papers by Hartmann and Berman (2000) and by Keszthelyi *et al.* (2000) discuss the remarkably young age (~100 to 10 Ma) and vast size (nearly the area of Canada) of flood lavas in the Elysium region. It is plausible that future orbiters will identify sites of hydrothermal activity—sites that will be exciting targets for future lander and sample return missions. European Space Agency's Mars Express mission, planned for launch in 2003, could make such a discovery because this orbiter will carry a ground-penetrating radar capable of detecting liquid water to depths of hundred's of meters.

For some time, NASA's Space Science Office (OSS) has been working closely with the two offices responsible for the Human Exploration and Development of Space (HEDS) Enterprise to ensure that the ongoing robotic exploration of Mars will lay the groundwork for eventual human exploration of Mars. There are science interests and technology needs in common, especially for the precise targeting and terminal hazard avoidance of soft landers (the cancelled 2001 Mars Lander was to have carried a payload made up of both OSS and HEDS experiments). Human explorers, assisted by robots and supported by a base laboratory, will have the potential to multiply the exploration effort many-fold and to achieve a definitive understanding of Mars in a finite time. It is hard to think of another application for human spaceflight that compares in potential value.

The Mars Program Office, therefore, has the challenge of developing a program of growing scientific richness and technological capability from a recent history of failure. The new program needs missions that (1) return science data and samples, (2) demonstrate new technologies, (3) survey candidate landing sites, and (4) provide infrastructure (communication/navigation satellites). These missions will include orbiters, rovers, deep drills, reconnaissance probes (including airborne platforms), and sample returns all carried out in a responsive time sequence. Ideally, some of the missions would be carried out in the manner of the Discovery program, tapping directly into the demonstrated creativity of the space science community, and there would be substantial international collaboration.

In recent years, the Mars program had focused on early sample-return missions and had run-out funding at a sizable level. The rich potential program sketched out above would require even greater resources if it is to be accomplished in less than several decades. Indeed, such a program would need to be an agency-wide effort supported by the Space Science and the HEDS Enterprises and with at least one other NASA Center besides Jet Propulsion Laboratory