NASA's Mars Exploration Program: Scientific Strategy 1996 - 2020

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Introduction: NASA's restructured Mars Exploration Program (MEP) is continuing to unfold with the implementation of the Mars Exploration Rover (MER) mission in summer of 2003, as well as with the continuing science mapping of the Mars Global Surveyor and Mars *Odyssey* orbiter. In addition, the latest US budget blueprint by the Bush Administration (FY04) indicates that the exploration of Mars will continue to be a priority within NASA's Space Science Enterprise, further cementing the first decade of the new millennium as a prime time to understand the "habitability of Mars", including key paleo-environmental aspects of its biological potential. Over the course of the past year, an integrated team of scientists, engineers, and managers has crafted a *next decade plan* for Mars that covers the period from 2010 to 2020. This paper describes the current program for exploring Mars from the perspective of its guiding philosophies, major events, and scientific strategy. It describes a roadmap to the next ~ 20 years of Mars exploration from the NASA viewpoint. The next decade options associated with the MEP will certainly evolve in response to discoveries, successes, and potentially to setbacks as well. However, the design of the newly restructured strategy is attentive to risks and a major attempt to instill resiliency in the program has been adopted. Mars beckons and the next decade of exploration should provide the impetus for a follow-on decade in which multiple sample returns and other major program decisions, including human expeditions, are executed. Ultimately the vision to consider the first human expeditions to the Red Planet must be enabled. By the end of the first

decade of this program (2009), we may know where and how to look for the elusive clues associated with Martian biology, if any was ever established.

With the *Viking* missions of the mid-1970's, the most intensive and comprehensive robotic expeditions to any Deep Space location in the history of humanity were achieved, with scientifically stunning results. Much has been written about what the Viking landers and their in situ biology experiments did not discover, but more should be recognized of the monumental legacy of information Viking provided about Mars. Although evidence of biological potential was not achieved, the Vikings developed both global and local "foundation datasets" describing the surface geomorphology, atmosphere, and basic state variables by virtue of their multi-year presence in the martian "system".

Mars Exploration 1996 to 2010: Begun in 1996, the Mars Surveyor Program (MSP) included missions to the Red Planet every opportunity and ultimately included both orbiters and landers at a highly cost-constrained pace. The addition of the Mars Pathfinder (MPF) to the line of missions to Mars in the middle-to-late 1990's began the revitalization of martian exploration after the 20-year hiatus following Viking. Just before the launches of both the Mars Global Surveyor (MGS) and MPF in Fall of 1996, the discovery of nano-scale Carbon-related features within a meteorite that was likely delivered from Mars to Earth (i.e., ALH 84001) re-energized the international Mars community.

The Mars Pathfinder (MPF) successfully demonstrated surface mobility on Mars as well as a novel and robust "entry-descent-landing" delivery system involving airbags to facilitate surface access. The Mars Pathfinder and its rover "Sojourner" opened the door to tele-robotic scientific exploration of Mars. Beginning in 1997, the Mars Global Surveyor (MGS) orbiter dramatically altered the scientific framework for understanding the planet. It is undeniable that MGS has rewritten the textbooks about Mars by discovering its relict magnetic field, quantifying its landscapes in 3D at geodetic precision, measuring its crustal structure (via combined gravity field and topography analysis), cataloguing its most compelling landforms including potentially water-formed gullies, and mapping the mineralogy of its surface on a global basis.

Following the successes of Mars Global Surveyor, the Mars Exploration Program (MEP) integrates the science "push" provided by MGS and the "Mars Rock" (ALH84001) with the technology "pull" required to implement advanced missions designed to address whether Mars has ever harbored life. In conceiving the new program, several guiding philosophies have been imposed. First, the program is to be science-driven, attacking key questions in a directed approach, with attention to both resiliency and responsiveness. Second, the program is technology-enabled, building new technological capabilities as it pursues its science objectives in a step-wise, incremental fashion, rather than attempting to integrate several new technologies in a single step, as in previous architectures.

The present Mars Exploration Program is all about reconnaissance of Mars from an ever-changing array of vantage points, beginning with global and then targeted remote sensing from orbit, and continuing with surface-based reconnaissance involving in situ sensors and experiments. By continuously refining our ability to measure, predict, and ultimately understand Mars, we can hone a vast array of scientifically interesting surface localities to a manageable few. Then, intensive surface-based reconnaissance and "near sensing" can be used to set the stage for the campaign of sample returns that we will ultimately require to address questions requiring the finest measurement techniques available in Earth laboratories.

Exploration continues with the measurements being made by the Mars Odyssey mission, whose job it is to extend the legacy of MGS by exploring the elemental chemistry of the entire martian surface layer (~ upper meter), while searching for mineralogic indicators of water-processed materials at scales as small as the area explored by the Sojourner rover in 1997 (< 100m). Odyssey also serves as a part of the telecommunications infrastructure for Mars, by operating as a relay satellite for the data from the Mars Exploration Rovers (MERs). Landing on Mars early in 2004, the MERs will explore regions up to one hundred times larger in areal scale than that accomplished by the Mars Pathfinder, with an optimized set of geological sensors tuned to the rocks and soils we know to exist at the martian surface. These instruments can tell us about past climates, and ultimately whether water factored into the history of any of the near surface materials where they are landed. In addition, the MERs will provide ground truth for the remote sensing observations acquired by the MGS and Odyssey reconnaissance orbiters, as well as future orbiters such as the 2005 Mars Reconnaissance Orbiter (MRO). MRO will carry a very high resolution imaging system capable of resolving features smaller than 1 m from orbit. A visible through near IR imaging spectrometer is carried that seeks to find, spectroscopically, evidence of persistent past liquid water on the surface. MRO will tell us

where we must go with future landed missions, starting in 2010. In 2010, we expect to land a mobile science laboratory at one of the most compelling places we identify from earlier missions. The 2009 Mars Science Laboratory (MSL) conduct the most definitive in situ scientific experiments the science community is able to muster, with a concerted effort to search for the so-called "missing Carbon" and other elemental, isotopic, and molecular building blocks of life.

In order to maximize responsiveness to scientific discoveries a fully competed, cost-constrained mission will also be implemented in the 2007 launch opportunity. This "Mars Scout Mission" (MSM) will be the first of what we expect to be scientifically focused missions led by Principal Investigators and complementary to the "core" MEP missions. Mars Scouts could give us the ability to pursue riskier science investigations. Four finalists in the first MSM competition are currently engaged in intensive studies in preparation for final mission selection in the August 2003 time frame.

Plans for Mars Exploration 2010 to 2020: The strategic plan for the next decade of exploration was developed in 2002 through a close collaboration of members of the Mars science community together with advanced mission planners, technologists, and Mars Exploration Program office. NASA specifically chartered a working group, the Mars Science Program Synthesis Group (MSPSG), with synthesizing a broad range of planning guidance formulated in the recent past by the broad science and engineering communities, including explicit priorities for investigations created by the Mars Exploration Program Analysis Group (MEPAG). Science priorities were coupled with studies of the technical and fiscal feasibility of the missions to Mars that would be needed to conduct the required measurements. It is NASA's intent that the 2010 to 2020 decade stand on the shoulders of the science investigations accomplished in the current decade. It recognizes that the remaining missions in this decade -- MER A and B, MRO, Mars Scout and MSL – will form the base of knowledge that comprises future exploration of Mars.

Recent missions, outlined above, have yielded a wealth of information, much of which indicates that Mars probably did not follow the path of climate evolution described in even very recent models of the planet. Beginning with the Mariner '71 mission, we have seen demonstrated repeatedly that steps of exploration cannot be planned with great certainty. So it is with steps to be taken beyond 2010. Recognizing this reality of exploration, NASA's MSPSG formulated a strategy for step-wise investigation that contains not just one but multiple, alternative lines of future investigation. This approach, embraced by the group, replaces the fixed sequence of missions of earlier plans for studying Mars. The new strategy forecasts potential outcomes of early missions in order to predict the character of downstream missions. In effect, a sequence of decisions is envisioned, timed to coincide with the plausible acquisition of new knowledge that determines the scientific focus of future missions. This process moves the Mars Exploration Program closer to hypothesis-based research. Because space exploration depends upon spacecraft developed over periods of 3 to 5 years or longer, decisions on future directions of study necessarily impact investments in advanced technology. MSPSG describes the integration of scientific investigations and technology and mission developments as *Pathways* of exploration.

The principles driving the next decade of exploration are: MEP will be scientifically balanced to the maximum extent feasible within resource constraints; and the overarching objectives for MEP are: Life, Climate, Geology, and Preparation for Human Exploration. First among these objectives of nearly equal priority is Life. MSPSG defined four *Pathways* of exploration that it perceives as likely to encompass the range of potential avenues of research for 2010 to 2020. The *Pathways* are: *Search for Evidence of Past Life*; *Explore the Evolution of Mars*; *Search for Present Life;* and *Explore Hydrothermal Habitats.* Each *Pathway* includes a sequence of investigations implemented through remote and/or in situ measurements. NASA selects instruments competitively. Human expeditions could logically follow the missions in each of these four pathways, depending on what is learned and programmatic resources.

The 2009 landed mission, Mars Science Laboratory (MSL), occupies a unique position in future Mars exploration because it both concludes the currently planned missions and it initiates the *Pathways* of the next decade. As such, the MSPSG argued very strongly that MSL would be most beneficial to the next decade investigations if it were designed so that it can respond to knowledge gained from the investigations of the Mars Exploration Rovers (2003) and the Mars Reconnaissance Orbiter (2005).

Mars sample return (MSR) continues to rank in the category given highest priority by the science community. Because of the intrinsic limitations on scientific instruments that can be flown on spacecraft, some of the most critical measurements required for all *Pathways* ultimately depend on measurements made on returned samples in laboratories on Earth. However, it

has been evident to the science community for some time that resource constraints and a paucity of flight-proven hardware for MSR argue strongly in favor of a mission of greatly reduced scope when compared with existing concepts for sample return. A new concept, the Ground Breaking MSR, which foregoes the rover-based sample collection scheme, was judged by MEPAG to be a necessary compromise between science and budget. Such a descoped mission could obtain Martian samples early in the next decade. The Ground Breaking MSR concept consists of a simple lander whose only tools is an extendable arm with very simple sampling devices. . The absence of mobility is acceptable because the mission would visit a site that has been previously characterized as exceptionally interesting by earlier *Pathway* landed or orbital missions. It is important to note that success of a Ground Breaking MSR would not diminish the critical scientific need for a future MSR with Rover to gain access to diverse samples and water-lain deposits.

Whatever we may learn, the ongoing Mars Exploration Program will assuredly offer scientific and educational opportunities for an expanding community of interested people, and grow a new generation of Mars experts, from school children to leading scientists, engineers, and managers. Our aim has been and will remain to maximize inclusiveness and participation and the MEP as it is presently unfolding is delivering on this promise.