THE “WHY” AND THE “WHAT”: THE SCIENCE FOCUS OF THE MARS EXPLORATION PROGRAM.
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Introduction: The high-level scientific goals and themes of the Mars Exploration Program place important requirements on the nature and architecture of the program. Choices at this level impact not only the particular sequence of missions to be flown, but also the program’s saleability, the extent to which the planetary science community is engaged in the program, and the ultimate value of the program both to our understanding of Mars and as a survey tool for deciding whether humans should venture there. We briefly review the history of scientific interest in Mars, through to the inception of the Mars Surveyor Program (MSP). While the MSP began as a relatively broad-based investigation of Mars, the excitement surrounding the “discovery” of life in the Martian meteorite ALH 84001 redirected the program onto a pathway almost singularly focused on searching for fossil (or even extent) life in returned samples. We support the notion that the question of life is the single most important theme in Martian exploration. However, we argue that the approach that has evolved in the MSP - and would govern missions to be flown beyond 2001 - is overly focused. This threatens the utility of the program as a means of understanding the cause and context of life’s absence or presence. The rush to a yes-or-no answer on life has also placed technical strain on the program, will ultimately disenfranchise a significant fraction of the scientific community, and will seriously limit the ability of the program to “survey” the planet for future exploration.

Interest in Mars Through to Viking: Historically, interest in Mars has centered on perceived Earth-like conditions and the potential for life. This interest can be traced back at least as far the 1698 publication of Kosmotheros, in which the Dutch astronomer Christian Huygens speculated about life on Mars and other worlds. Later astronomers discovered polar caps, a length of day and axial tilt like those of the Earth, a thin atmosphere, clouds, and variations in surface features resembling seasonal changes. Primitive Martian plant life was still considered possible until 1964 when the Mariner spacecraft began reaching the planet and revealed it to be a desolate, dry, and intensely cold world. Mars presented a very “lunar” visage to the earlier Mariners, but excitement about life, albeit microscopic, resurfaced after Mariner 9 provided ample evidence for liquid water at some point in Martian history. However, stock in Mars as a habitable planet fell to a new low in 1976 when twin Viking landers specially designed to look for life were sent to two widely separated locations on Mars Instead of life, they found a soil so highly oxidizing that it is lethal to all life as we know it and would likely obliterate evidence of that life.

The Mars Surveyor Program: Despite the disappointments, the Mariner and Viking spacecraft made fantastic discoveries, including extinct volcanoes, valleys and channels apparently carved by running water, and evidence for ground ice and a thicker early atmosphere. A new paradigm arose of Mars as a planet with a warmer, wetter, and more active past - perhaps similar to the Earth when it hosted primitive life, and motivated ideas of searching for microfossils or hardy subsurface life like that found in "extreme" environments on Earth. The question of life was now set firmly within the context of planetary evolution and climate evolution. The discoveries provided an image of a world far more Earth-like than any other in the solar system, with an active climate system which likely varied significantly through the planet’s history. Successive missions were developed to examine the planet and its environment in greater detail. The establishment of the Mars Surveyor Program (MSP) followed the failure of the Mars Observer (MO) and the cancellation of the Mars Environmental Survey missions, but initially retained their inclusive goals. However, three years after the advent of MSP, the claim of fossil life in the Martian meteorite ALH 84001 generated tremendous excitement and controversy and the search for life once again shifted to dominate Mars exploration. This altered focus provided impetus for ambitious plans to return samples from the surface of Mars in 2005 in hopes of finding life in them. The decision to return samples so soon influenced preceding missions: the primary payload for the 2001 lander was chosen to be a rover that would serve in later missions as a vehicle to find and retrieve samples. On the 2001 orbiter, the reflight of the MO gamma ray spectrometer was to be accompanied by an instrument selected primarily in terms of sample-return landing-site selection. The effort required to develop a sample return vehicle demanded that orbiter science be eliminated after the 2001 mission. Further, instruments on landers were either to address sample return-related issues, or make measurements deemed essential for future human missions to Mars. The exploration program
would thereafter consist of sample return missions into the second decade of the 21st century.

**The Search for Life in Context.** The question of life on Mars is a profound one, but a single-minded focus on a yes or no answer is an intellectually impoverishing reduction of the study of planetary habitability. The search for life is but one of a suite of many questions which provide both cause and context. Over the course of three decades of exploration, we have come to appreciate Mars as a complex world shaped by volcanism, wind, ice, and, at least occasionally, the flow of liquid water. It is a planet whose evolutionary path has diverged from the Earth’s for reasons that are poorly understood but are profound for life. That the non-science public appreciates this is evidenced by the enormous interest in the pictures from the Mars Pathfinder that revealed a landscape far more lifeless than any place on Earth.

**Using Sample Return to Look for Life:** Sample return as a scientific experiment is poorly posed. There is a straightforward reason for this. At its heart is the testable hypothesis that life at one time was sufficiently abundant that it’s signature may now be found in rocks on the Martian surface. This is a non-falsifiable hypothesis in that while it may be proven by finding a single rock with evidence for life in it, it can only be disproved by examining every single rock on the Martian surface. What makes the problem even more serious is that unambiguous “biomarkers” have yet to be identified, while efforts to clearly prove or disprove purported evidence for life in one of the Martian rocks we already have in our laboratories has proven frustratingly unsuccessful and contentious. There is no a priori reason to expect greater clarity in returned samples: our knowledge of how to detect life within its broadest definition is still far from mature. We cannot predict how we will detect signs of life on Mars any better than we can predict if we will detect it.

**Evolving Science Questions:** Our picture of Mars continues to evolve as a consequence of the successes of the Mars Surveyor Program: New data returned by the Mars Global Surveyor (MGS) has not shown the carbonates or diverse minerals, or other evidence expected if there were an early, warm, wet climate. On the other hand, MGS data have uncovered new enigmas, such as the magnetic lineation of the southern highlands, which demand further investigation.

Exploration of a planet within a sustained and aggressive program is novel to NASA’s robotic exploration endeavor. Typically, there has been substantial cycle time between missions to allow results to be digested and new directions discerned. The lack of cycle time within the Mars Surveyor Program undermines long-range planning which seeks to lay out detailed mission scenarios, especially if that program becomes overly focused on a single question. One of lessons of exploration is that our understanding of what is important will continue to evolve as we obtain more data and have additional time to analyze and model them. Neither the oxidizing soils nor the magnetic anomalies of Mars were predicted before the arrival of spacecraft and instruments to detect them. Both are important clues to Mars’ past environment. Should the MSP as planned in late 1999, the return of a small amount of sample from the near surface at a restricted choice of landing sites will provide data for important questions about Mars. The existence of past or present life will probably not be among them - this makes use of sample return as a vehicle to search for life a high risk, long-odds endeavor. If sample return technologies are developed, a better posed and guaranteed scientific experiment would be to absolutely date the early geological provinces. In any case, evidence to date suggests that sample return simply cannot be undertaken within the bounds of the program without eliminating all other science. We seriously doubt whether this is scientifically warranted.

**A Broad Scientific Agenda:** The successes of the Mariner, Viking, and Mars Global Surveyor missions have revealed a complex and exciting world in our planetary neighbor. Many of the questions we have about Mars reflect concerns we have about our own world: How did the planet evolve and what determined the pathways? How does the climate system operate and what feedback systems operate to stabilize or destabilize the climate? How do geologic and tectonic processes operate and what determines their style, how does the planet interact with the solar wind and what does this imply for atmospheric evolution? What is the history of life and what determined this history?

The Mars Surveyor Program represents an open-ended commitment to explore our neighboring planet. This commitment results from the fascinating similarities of this world to our own, and the fact that if humans venture away from the Earth/Moon system, Mars will be the destination. In view of this commitment and the broad range of scientific questions, we see no valid reason to overstrain the program by rushing into sample return. As explorers we seek the thrill of taking each new step, not winning an Apollo-like race. Mars is not going away: As long as the human species endures, it will continue to beckon new generations of explorers.