Contursi_2003

REDEFINING THE MARS SAMPLE RETURN MISSION:

Paul Contursi
Mars Society of New York
490 Third Street
Brooklyn, New York 11215
pcon@pipeline.com

ABSTRACT

Shortly after the back-to-back failures of the Mars Climate Orbiter and Mars Polar Lander in 1999, the NASA Mars Exploration Program was reorganized and plans for the Mars Sample Return mission were put on hold. Now that the program seems to be back on track and attention is once again being focused on a sample return mission, an important political opportunity for the Mars Society has emerged. As it was originally conceived, the sample return mission plan was excessively costly and complex. The plan required long lead times, many launches and very high levels of technological risk. The Society's Political Task Force should take the initiative and begin a campaign for a sample return mission based on the application of In-Situ Resource Utilization as soon as possible. An ISRU based mission could be accomplished at a much lower cost in a shorter time with fewer technological risks. Most important, it would serve as an undeniable proof of concept for the Mars Direct mission architecture and would greatly strengthen the case for the human exploration of Mars in the near term. The presenter posits that the Society should not squander this important opportunity.

INTRODUCTION

In the summer of 1997, interest in Mars exploration reached a new zenith with the triumph of the Mars Pathfinder mission. The first successful robotic landing on Mars in a generation was the source of tremendous interest by the public and the space advocacy community alike. On the first day of the mission, the NASA/JPL web sites received 50 million hits. In the two months that followed, another *three quarters of a billion hits* were received. Fueled in part by the public reaction and, in part, by the success of the Pathfinder mission, NASA announced a dramatic acceleration of the robotic Mars exploration program with a commitment to a mission for each launch window over the next decade. A program that had only launched sporadic missions to Mars for a generation was being replaced by a much more robust effort that would dispatch a lander and/or orbiter to the Red Planet every 26 months. The new emphasis on Mars gave rise to more ambitious planning for future missions and the NASA/JPL team began to consider one of the most dramatic robotic challenges: a sample return mission.

Unfortunately the enthusiasm was short-lived. In 1998, two ambitious missions were launched and both ended in failure. The Mars Climate Orbiter was to perform the first search for water from orbit and study the dynamics of the climate over the course of a full Martian year (687 days). Poor management oversight led to confusion between metric and English units resulting in a navigation error. The discrepancy went unnoticed until the spacecraft burned up when it entered the denser regions of the Martian atmosphere during orbital insertion. The Mars Polar Lander was the first attempt to explore the Martian polar region. Mission planners had high hopes that this spacecraft would return unambiguous data regarding the presence of water ice on or near the Martian surface. But the spacecraft was destroyed when a software glitch prematurely shut down the descent engine at an altitude of approximately 100 feet. A review of these failures exposed significant weaknesses in program management that needed to be addressed before the Mars Exploration Program could be resumed, As a result, the landing mission planned for 2001 was replaced with an orbiter intended to achieve objectives that were similar to the failed Mars Climate Orbiter (the 2001 Mars Odyssey) and plans for the Mars Sample Return were put on hold.

MARS OPPOSITION 2003

Mars Odyssey was a tremendous success. From its vantage point in Mars orbit, the science team could correlate the data from the new orbiter with images and altimeter readings from the Mars Global Surveyor. In the two years following the spacecraft's arrival, scores of papers were published in scientific journals announcing indications of substantial amounts of water ice under the Martian surface. Some researchers estimated that there was enough water in the Martian hydrosphere to fill Lake Michigan twice. While earlier theories predicted that the Martian water table would be found at a depth of a kilometer or more, the new data indicated that much of the water ice was less than a meter from the surface. If subsequent missions confirm these findings, future explorers will have easy access to plentiful supplies of water that can be converted to oxygen and hydrogen by simple chemical processes. As the summer of 2003 approached, a growing number of biologists, encouraged by their discovery of hardy life forms thriving in extreme environments here on Earth, began to express more optimism about finding evidence of existing or extinct life forms below the Martian surface.

The Mars opposition of 2003 is another factor giving Mars a higher public profile. On August 27, Mars will be closer to Earth than it has been in approximately 60,000 years. The planet will become so large and bright that it will be impossible to ignore, even in urban skies. Modest amateur telescopes will reveal a surprising level of detail. Large features, such as the light and dark areas and the south polar cap will be plainly visible in instruments with apertures as small as three or four inches.

The summer of 2003 also ushered in an era of unprecedented robotic exploration. In the space of a few short weeks during this year's launch window, a virtual fleet of spacecraft was dispatched to Mars. The Japanese Nozomi orbiter, arriving years late due to a propulsion problem, was finally on its way. The ESA's Mars Express orbiter was launched on a Russian Soyuz/Fregat rocket. The United Kingdom's first Mars mission, a microlander called Beagle II, rode along with Mars Express as a piggyback payload. The United States launched two sophisticated Mars Exploration Rovers that represented a quantum leap in capability from the little Sojourner rover that captivated the world during Pathfinder in 1997.

MARS SAMPLE RETURN MISSIONS

At the time of this writing renewed interest in a Mars Sample Return mission on the part of various officials at NASA and the ESA is stirring. Even if only some of the missions currently on the way to Mars are successful, or return more dramatic findings, it is obvious that there will be great pressure to put the sample return mission back on the front burner.

While this will be a positive development, the original mission architecture is unnecessarily complex, expensive and prone to failure. In addition, some of the programmatic difficulties that have plagued the International Space Station project have been reflected, albeit on a much smaller scale, in the current sample return plan. In light of these problems, the Mars Society should consider offering an alternative that will be faster, less risky, cheaper and more directly help pave the way for human exploration in the near term.

The original plan calls for the launch of two NASA surface packages on the same Delta II class launchers that we have used for Mars missions in the recent past. Each package consists of a lander, a rover and a solid fueled Mars Ascent Vehicle (or MAV). After landing on Mars, each rover will conduct a 90-day surface traverse that will include the collection of approximately 500 grams of soil. When the traverses have been completed, the rovers will load their samples aboard the Mars Ascent Vehicles. The MAVs will be launched from the surface into orbit around Mars to await collection.

During the following launch window, an Ariane V booster lifts off from French Guiana carrying a large orbiter (2700 kilograms) supplied by the France and Italy. Upon arrival in Mars orbit, the Orbiter will rendezvous with the Mars Ascent Vehicles and transfer the samples to two Earth Entry Vehicles (EEVs). The orbiter will then fire its engines and insert itself into an Earth return trajectory. Upon close approach to Earth, the orbiter will jettison the EEVs into the Earth's atmosphere for reentry and recovery.

Even though robotic and human missions are managed by different organizations within the space agency, some of the parallels between the Mars Sample Return and the International Space Station are striking. One factor that has contributed heavily to our current difficulties with the International Space Station was the political requirement to include the participation of the former Soviet Union. International cooperation is generally a positive element, but only if it adds resources or enhances scientific return. It should be noted that the United States had no trouble managing its own space station effort unilaterally when it launched Skylab in 1973. While there is no question that the Russians have a tremendous track record in long duration space flight aboard the Salyut and Mir space stations, that was not the primary motivation for the requirement of including them in the ISS project. At the time of the USSR's collapse, we became concerned that their underemployed and unemployed space engineers might succumb to the temptation of selling weapons of mass destruction to rogue states or terrorist groups. ISS was intended as a way to keep them busy in a non-threatening way. However, the necessity to include Russian participation is one of the key factors that has dramatically increased the cost and complexity of building and maintaining the ISS. Including international partners in the Mars Sample Return mission without a properly focused reason for doing will almost certainly yield similar results.

The original mission plan requires multiple launches and the development of several different kinds of spacecraft. Most of these systems would have high levels of mission criticality. For example, a major failure aboard the Orbiter will make it impossible to recover the samples waiting in Mars orbit. All tolled, the shopping list for the mission is long and expensive. Delta launch vehicles cost up to $75 million each and the Ariane V is about twice as expensive. The requirements also include two landers, two rovers, two MAVs, two EEVs and the Orbiter. There are several variations but no matter which one is chosen 11-15 major hardware systems will have to be developed and/or procured.

The most imposing of the many technical challenges will be the Orbiter's recovery of the samples and transfer to the Earth Entry Vehicles. Automated rendezvous and docking in low Earth orbit has a spotty record. Performing such maneuvers under conditions in which the relative distances between Earth and Mars could delay radio signals by as much as 20 minutes represents a highly sophisticated semi-autonomous capability that will require a major hardware and software development effort.
All these factors endow the original mission architecture with a high, but as yet undetermined, price tag. Some NASA estimates are as low as $2 billion but experts outside of the space agency maintain that the price could easily exceed $5 billion.

The perception and political issues raised by such a plan couldn't come at a worse time. We are still in the throws of trying to recover from the Columbia accident, with all that implies in terms of critical decisions that must be made with regard to ensuring safe and reliable access to low Earth orbit. As a result, NASA is frantically devising workarounds to maintain our space assets. At the same time, politicians and space activists alike question the value of the overpriced and poorly focused International Space Station with increasing intensity. The current incarnation of the Mars Sample Return confirms the worst fears of space critics due to its high cost, complexity and long development lead-time. It is difficult to see how the implementation of this plan, even if it is successful, will help to foster an environment in which the Mars Society can credibly argue that the human exploration of Mars is within our grasp at a price we can afford. A poorly conceived robotic mission that recovers two pounds of Martian soil at a cost of $5 Billion, offers very little hope to the man on the street that we can build a human Mars capability for $20-25 Billion.

Needless to say, this creates something of a conundrum for the Society on the political action front. Opposition to a sample return mission would be disturbingly out of character for our organization's charter. However, we might be able to offer an alternative that not only rectifies the shortcomings of the original plan but also provides a working model, on a smaller scale, of the kind of human capability that we would like to build.

In the late1990s, Dr. Robert Zubrin published an article that compared the different methods of Mars sample return. The article posits that a mission based on In-Situ Resource Utilization (ISRU) would be the fastest, most cost effective and least risky of several leading scenarios. As in the Mars Direct human mission architecture, the key to the ISRU sample return is the capability to manufacture the propellant used to launch the samples back to Earth from gases easily accessible in the Martian atmosphere. Since the Martian atmosphere is 95% carbon dioxide, simple chemical processes that have been thoroughly understood since the late 19^{th} Century can be used to produce methane propellant and oxygen on the surface. Several researchers have successfully built prototypes of this type of automated fuel factory and they have operated at high levels of efficiency.

A single Delta II class booster could launch a lander, a rover and a Mars Ascent Vehicle whose fuel tanks are nearly empty. After landing on Mars, the rover begins its traverse and sample collection as in the NASA plan. In the meantime however, an ISRU system aboard the lander uses a small amount of hydrogen from Earth to react with Martian carbon dioxide to produce methane and oxygen. By the time the launch window for the return to Earth opens, the MAV is fully fueled. No orbital rendezvous or sample transfer is needed because the locally produced propellant can be used to launch the samples directly back to Earth for reentry and recovery.

By obviating the need to include the propellants required to bring the samples home, payload mass can be vastly reduced and the mission can be dramatically simplified. Only one launcher, one lander, one rover and one Mars Ascent Vehicle are required. However, the ISRU mission is not without its own set of challenges. Considerable development will be required before today's laboratory prototypes of fuel manufacturing systems can be turned into flight ready hardware. The extreme low temperatures and the ubiquitous Martian surface dust are just a few of the obstacles that mission designers will have to overcome. However, the overall level of technological risk is much less than that of the original NASA plan. One of the most important advantages is that an ISRU sample return mission is essentially a robotic proof of concept for the Mars Direct plan. ISRU systems will no longer be abstractions or laboratory prototypes, they will have a high profile as a methodology that can make Mars exploration much simpler and more affordable. Success will increase confidence that such systems could be scaled up to support human missions.

A MARS SOCIETY ROLE

NASA/ESA interest in a sample return mission should be encouraged. However, the Society should begin working immediately to promote the ISRU architecture as a more desirable method of obtaining pristine Martian material. We need to develop a multi-pronged plan, with a number of contingencies, to promote this alternative as soon as possible.

First and foremost, the Society should state that advocacy for an ISRU sample return mission is a cornerstone of its political action activities. Chapters and Steering Committee members alike should lobby members of the House and Senate for serious consideration of the ISRU sample return architecture. At the same time, our outreach activities should include discussion of the plan as an integral part of our remarks concerning the Mars Direct concept. In light of increased interest in space exploration on the part of the member nations of the European Space Agency and the Peoples Republic of China, our chapters around the world should coordinate their advocacy efforts along similar lines. Another important element of the Mars Society's campaign will be to join forces with other grassroots space advocacy groups in the United States and elsewhere, wherever possible.

The Mars Society membership boasts robust technical expertise that should be drawn upon to submit ISRU mission plans to the NASA Mars Discovery program. If a full-fledged sample return mission cannot be made to fit within the highly constrained Mars Discovery funding guidelines, we should consider proposing a demonstrator project in which a small vehicle can be launched from the Martian surface with locally produced propellant on a sub-orbital trajectory. This payload would also add scientific value by taking airborne images of the landing sight and surrounding areas that could provide valuable geologic context for other surface experiments. Additional opportunities to fly such systems as piggyback payloads on ESA missions should also be sought.

CONCLUSION

The redefinition of the Mars Sample Return mission is an important opportunity for the Mars Society. This project can represent yet another expensive example of NASA's business as usual or it can mark a turning point that will help strengthen the case for near term human missions to the Red Planet. It's up to us.