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"Mars Sample Return Mission Scenario"
A Presentation to be given by Mark Adler
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NASA and CNES are about to embark on a bold, exciting, and pioneering joint scientific mission to bring to Earth selected samples of the planet Mars. It is called **Mars Sample Return (MSR)**. This single mission spans two Earth launch opportunities in 2003 and 2005 with three major **robotic spacecraft**: two **landers** and a return **orbiter**. The samples will land on Earth in 2008. This mission is expected to be the first in a series of Mars sample return missions extending well into the second decade of the next century.

Random samples of Martian material are delivered naturally to Earth as meteorites, and a small number have been found and identified as such. They have significantly advanced our understanding of Mars and continue to do so. MSR will go well beyond the science contained in random samples by going to selected sites on Mars, by investigating the context of those sites, and by carefully selecting samples at those sites for return. This requires considerable sophistication both in the survey of Mars preceding MSR in order to select appropriate sites, and in the MSR landed equipment to land accurately, to survey the site locally, and to select and acquire samples. We will focus here on the MSR mission itself, but it is important to note that the mission is significantly enhanced and much of the desired science return enabled by being part of an international program of Mars exploration including orbital surveys and in situ surface investigations.

MSR is in an early phase of development, and we expect that some aspects of the mission may change as we gain a better understanding of the intricacies of this endeavor and how to design the systems to fit within the allocated resources. What follows is a snapshot of how we envision the mission today.

MSR is based on a Mars Orbit Rendezvous scheme similar to the Lunar Orbit Rendezvous used by the Apollo missions. Landed elements place samples in Mars orbit, which a return orbiter than finds, captures, and brings to Earth. The mission consists of two NASA-supplied landers, the first launched by a NASA provided vehicle in 2003, and the second launched by a CNES provided Ariane 5 in 2005. The same Ariane 5 launches the CNES provided return orbiter carrying a NASA provided payload of rendezvous sensors, capture mechanisms, and Earth entry vehicle.

The first launch is in May of 2003 from Cape Canaveral of an intermediate class launch vehicle, for example a Boeing Delta 3 or a Lockheed Martin Atlas 3A, carrying the first MSR Lander with a launch mass of 1800 kg. It arrives at Mars in December of 2003, landing near the equator for a mission of approximately 90 Martian days. The Lander uses precision approach navigation and a guided hypersonic entry to achieve a 10 km or better landing accuracy. It lands softly on legs using a terminal descent propulsion system.

The Lander can carry approximately 350 kg of payload and provide that payload with power, thermal, and communication services. The Lander communicates directly with Earth through a high gain X-band antenna and may in addition be able to communicate with Earth through Mars orbiting communications assets, such as the Mars Surveyor 2001 orbiter or the Mars Express orbiter. The MSR Lander payload is divided into four major elements: the Rover, the Sample Transfer Chain (STC), the Mars Ascent Vehicle (MAV), and the Auxiliary Payload (AP).

The Rover is an independent six-wheeled vehicle carrying extensive instrumentation for characterizing the local context of the site, providing the information needed for the selection of sample targets, the acquisition of rock cores and small surface soil samples, and the documentation and storage of collected samples. The instrumentation includes a color stereo panoramic imager and thermal emission spectrometer for remote sensing; a microscope, Raman spectrometer, Mossbauer spectrometer, Alpha-Proton-X-ray spectrometer, and a metal brush for sample target characterization and collected sample documentation; and a rock coring drill. The rover carries a segmented sample storage cache that stores the samples, which is eventually returned to Earth still holding those samples. The Rover has a direct S-band communications link with the Lander and may in addition be able to communicate with Earth through Mars orbiting communications assets. The Rover will cover a distance of several hundred meters and collect on the order of 20 samples in a full 90 sol mission. Most of the samples will be rock cores, each with a mass of approximately three to five grams.

The Mars Ascent Vehicle is a three-stage, solid propellant rocket that carries to low Mars orbit and deploys a spherical sample container, the Orbiting Sample (OS). The OS is on the order of three kg in mass and 14 cm in diameter. The first stage is guided and lofts the system above the bulk of the Martian atmosphere. The second and third stages are spin stabilized. The second stage is pointed, spun up, and initiated by the first stage guidance system. The second stage provides most of the velocity for orbit, the remainder coming from the residual horizontal velocity provided by the first stage. That orbit has a low periapsis at the second stage initiation altitude around 90 km, and an apoapsis at the final orbit altitude of around 600 km. The vehicle then proceeds half an orbit to its apoapsis. The third stage is pointed opposite the first two stages so that the spin stabilization provides an inertial attitude that points the "backwards" third stage approximately in the velocity direction near apoapsis. A timer then initiates the third stage to raise the orbit periapsis to around 600 km to reach a near circular orbit. This scheme allows the second and third stages to be "dumb" and carry only minimal electronics to initiate the third stage. This allows for a relatively low mass ascent vehicle by avoiding having to carry guidance sensors and control systems all the way to orbit. This scheme has a somewhat lower accuracy than a completely guided ascent. It then requires a little more time and propellant for the Return Orbiter to chase down the OS. In exchange the MAV is much lighter and lower cost than a completely guided system.

The Sample Transfer Chain consists of all of the elements that participate in the transfer of the samples from Rover to MAV to Return Orbiter, and in fact includes the segmented cache on the Rover, the Orbiting Sample on the MAV, and the capture devices on the Return Orbiter. The STC also includes an as yet to be defined lander-based sample collection system that both augments the Rover-based sample and serves as a backup in the event of a failure of the Rover. The Orbiting Sample is a spherical container that seals in the sample caches with an explosive weld, collecting a Martian atmosphere sample at that instant, and maintains its integrity through landing on Earth. The OS includes a solar-powered radio beacon that allows tracking not only by the Return Orbiter, but also by Mars orbiting communications assets, which are planned to provide the requisite navigational data types for this purpose. The OS has no attitude control or active thermal control. Its spherical shape facilitates capturing the OS in any orientation. The STC will be subject to rigorous cleaning and verification to assure that no Earth material contaminates the samples. The STC will also assure containment of the Martian material and no hitchhiking material on the outside of an OS in order to prevent inadvertent exposure of Earth's environment to Mars samples.

The Auxiliary Payload will perform environmental characterization and technology demonstrations needed in support of the eventual development of human missions to Mars. The AP is yet to be defined in detail.

The bottom line is that the 2003 landed elements will characterize the local context of the landing site and in the Spring of 2004 will place selected and documented samples into low Mars orbit. In addition the Lander will perform precursor experiments to human Mars missions.

In August of 2005 an Ariane 5 will launch from Kourou, French Guiana carrying a second NASA provided MSR Lander and a CNES provided Return Orbiter with a NASA payload. The Ariane 5 will use a dual spacecraft adapter and the two spacecraft will be deployed and cruise separately to Mars after injection. The Lander launch mass will be 1800 kg as in 2003, and the Return Orbiter launch mass will be 2700 kg.

The 2005 MSR Lander and its payload will be identical to that of the 2003 Lander, with the exception that the Auxiliary Payload may be different, though most likely with the same general objectives. The 2005 Lander will arrive in July or August 2006 and perform the same mission as the 2003 Lander, placing a sample in Mars orbit in the Fall of 2006. So by then, if all goes well, there will be two samples in low Mars orbit that can be retrieved by the Return Orbiter.

The 2005 Return Orbiter also arrives in July or August 2006 and must insert into Mars orbit, locate the Orbiting Samples, rendezvous and capture one or both of them, and then leave Mars orbit on a trajectory to Earth. The return of a single OS to Earth represents full mission success, but the systems will be designed to have the capability, if there are no failures, to return both the 2003 and 2005 samples. The return opportunity is in July of 2007, and so there is approximately one Earth year to perform all of the Mars orbit activities. The return trajectory swings by the Earth in April of 2008 in order to allow a Northern Hemisphere landing in November of 2008. The proposed landing site is the Utah Test and Training Range, which is also the planned landing site for several other sample return missions such as Stardust and Muses-C. An alternative may be to land directly to a Southern Hemisphere site in April of 2008.

The CNES Return Orbiter will enter Mars orbit using aerocapture. This involves a deep pass through the Martian atmosphere requiring a heat shield to protect the orbiter components and hypersonic maneuvering to account for atmospheric variations in order to reduce the arrival energy and capture into a specified orbit. The target orbit will have an apoapsis on the order of 1000 km, and an autonomous propulsive maneuver will raise the periapsis out of the atmosphere half an orbit later. The Return Orbiter will have a propulsive delta-velocity capability of about 3.4 km/s in order to do all the maneuvers needed for approach, orbit adjustments, departure to Earth, and Earth swingby and approach. Most of that is for the departure to Earth from low Mars orbit, which is close to 2.5 km/s.

NASA provides the Earth entry vehicle (EEV) that will land the samples on Earth, the deployment mechanisms for the EEV, the mechanisms to capture Orbiting Samples and place them in the EEV, and the sensors needed to locate the Orbiting Samples at both long and short range. The long-range sensors are a radio direction finder to point to the OS beacon and a sensitive camera that can find the OS simply by its reflected sunlight. Those systems can be used together with the radio direction finder data pointing the camera for rapid tracking of an OS. They also provide functional redundancy in that either can do the tracking alone, but perhaps taking more time and permitting the return of only one OS. The long-range sensors provide the data needed for Earth to command the Return Orbiter to maneuver to within two kilometers of an OS. From there an autonomous system using a laser range finder completes the rendezvous from two kilometers on in. The spherical OS is then captured in an arbitrary orientation and inserted into the EEV. The EEV is a parachuteless design that uses a low ballistic coefficient to reduce the terminal velocity to around 30 m/s, and crushable material inside the EEV to limit the G-forces on the sample containers. This is to make the landing as simple as possible for reliability and robustness, and has the benefit of being both low cost and low mass. Just before Earth entry, the EEV is deployed from the orbiter with its precious cargo at a small spin rate to fix the entry attitude. After deployment, the Return Orbiter deflects from the entry target to miss Earth's atmosphere and go into a solar orbit, its mission complete.

In summary, a NASA MSR Lander is launched from the U.S. in 2003, and a second NASA MSR Lander along with a CNES Return Orbiter is launched on a CNES provided Ariane 5 from French Guiana in 2005. Each Lander places a sample in Mars orbit and the Return Orbiter brings one or both samples back to Earth for a landing in 2008.

Mars Sample Return will do what has never been done before, will advance our understanding of Mars, and we hope ultimately will advance our understanding of ourselves and our place in the Universe.