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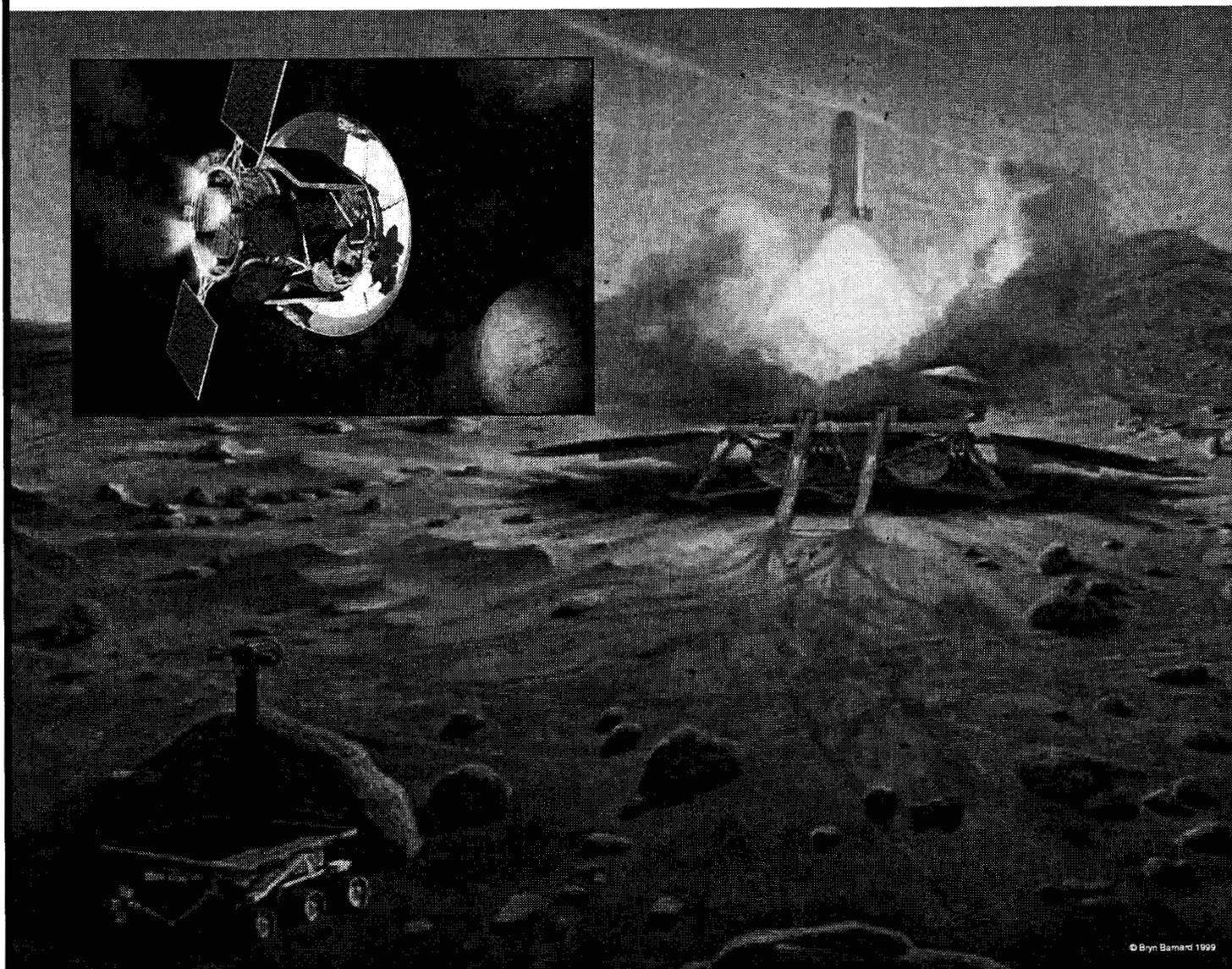
THE MARS SAMPLE RETURN PROJECT

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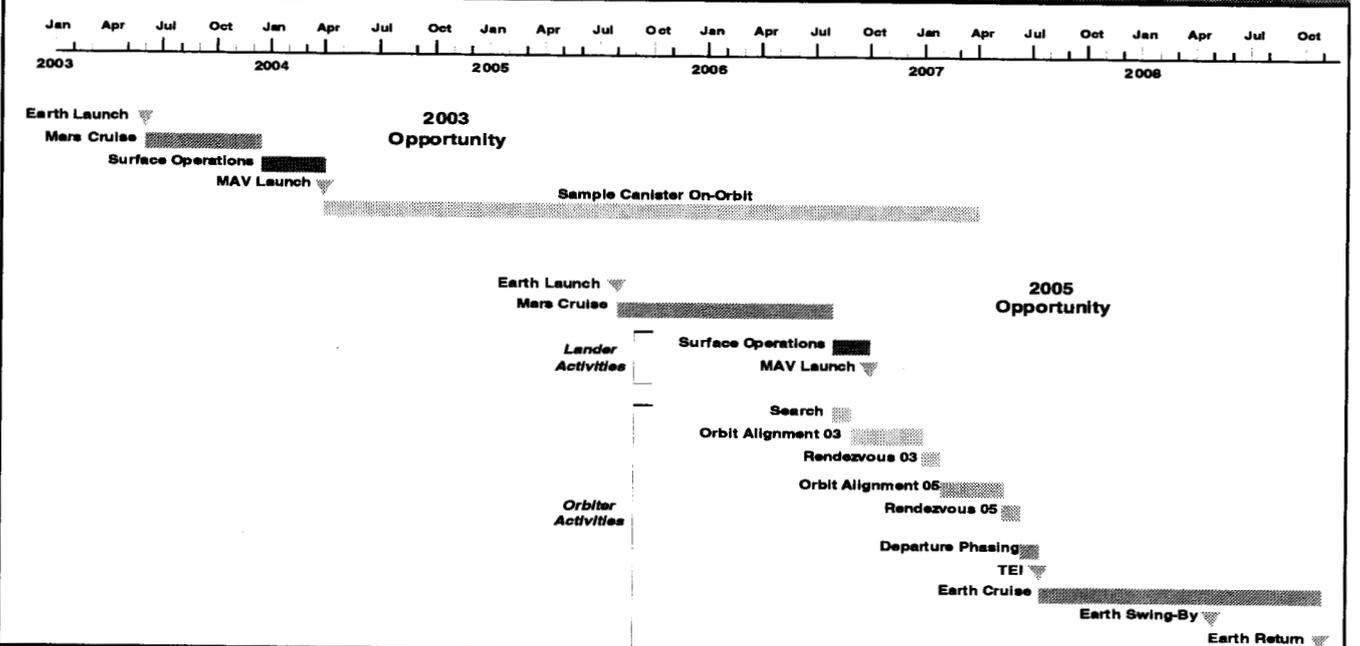
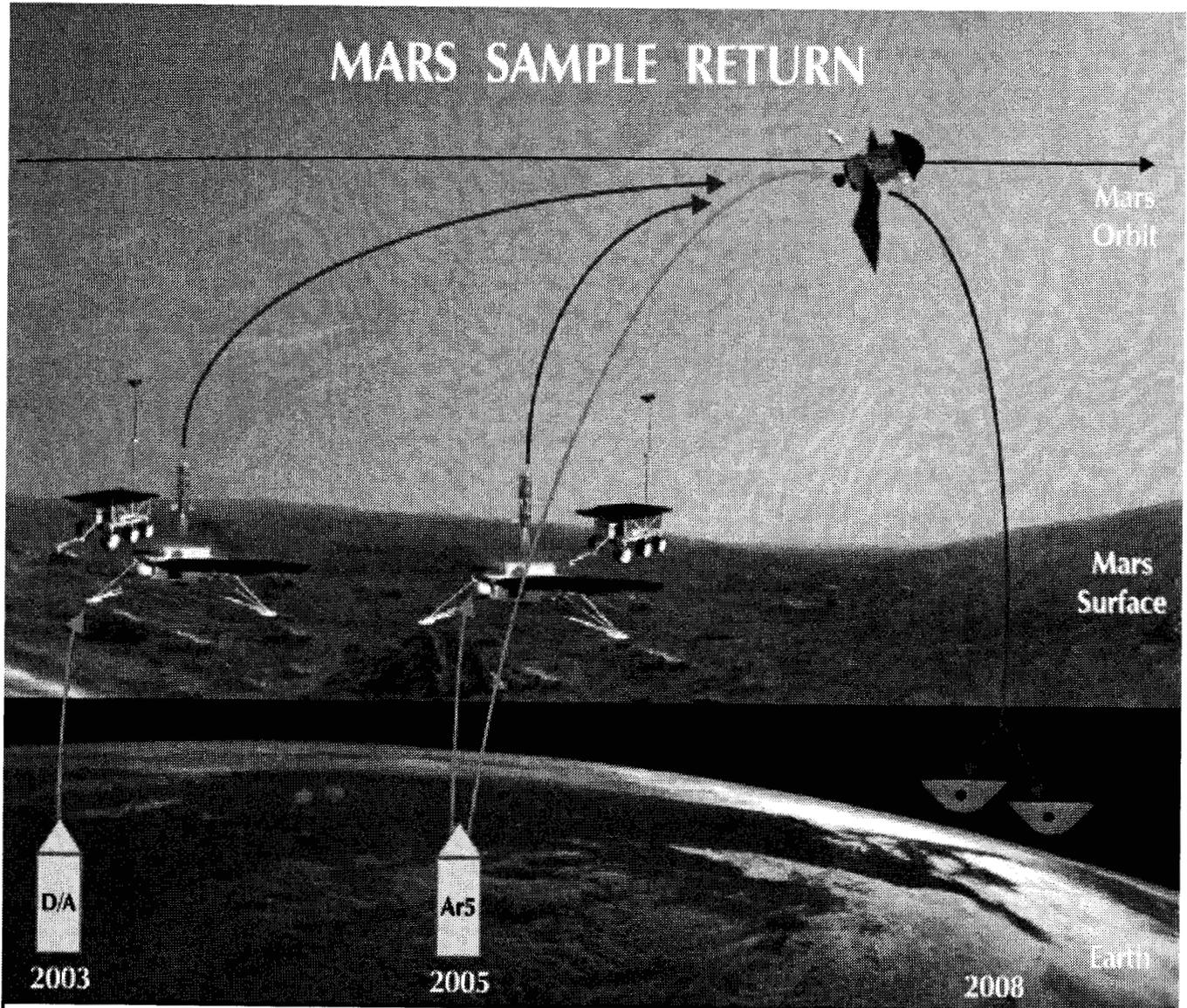


Fig 1. Mars Sample Return Overview (above).

Fig 2. MSR Mission Events Timeline (below).

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ABSTRACT

The Mars Sample Return (MSR) Project is underway. A 2003 mission to be launched on a Delta III Class vehicle and a 2005 mission launched on an Ariane 5 will culminate in carefully selected Mars samples arriving on Earth in 2008. NASA is the lead agency and will provide the Mars landed elements, namely, landers, rovers, and Mars ascent vehicles (MAVs). The French Space Agency CNES is the largest international partner and will provide for the joint NASA/CNES 2005 Mission the Ariane 5 launch and the Earth Return Mars Orbiter that will capture the sample canisters from the Mars parking orbits the MAVs place them in. The sample canisters will be returned to Earth aboard the CNES Orbiter in the Earth Entry Vehicles provided by NASA. Other national space agencies are also expected to participate in substantial roles. Italy is planning to provide a drill that will operate from the Landers to provide subsurface samples. Other experiments in addition to the MSR payload will also be carried on the Landers. This paper will present the current status of the design of the MSR missions and flight articles.

INTRODUCTION

The United States (NASA) and France (CNES) are embarking on a bold, exciting, and pioneering joint scientific endeavor to bring to Earth selected samples of the planet Mars. It is called Mars Sample Return (MSR). This endeavor spans two Earth launch opportunities in 2003 and 2005 with three major robotic spacecraft: two landers and a return orbiter. The samples are to land on Earth in 2008. MSR is expected to be the first in a series of Mars sample return missions extending well into the second decade of the next century. Italy (ASI) is planning to provide subsurface drills for MSR. MSR is not just first-of-a-kind, but it is in fact a mission of truly historic significance like Sputnik and Apollo since this will be the first time material from another planet has been brought to Earth.

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. This paper focuses on the 2003/2005 MSR missions, but it is important to note that the missions are 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 based on a Mars Orbit Rendezvous scheme similar to the Lunar Orbit Rendezvous used by the Apollo missions. Landed elements place samples in Mars parking orbit, which a return orbiter then finds, captures, and brings to Earth. Figure 1 illustrates the MSR Plan. Figure 2 shows the mission events in timeline form. In May 2003 NASA will use a Delta III or Atlas III class launch vehicle to launch a Mars Lander carrying a Rover and Mars Ascent Vehicle (MAV). The landing in December 2003 will be targeted to a very carefully selected site on Mars. The Rover will be deployed from the Lander via a ramp extended from either end of the Lander and ground-commanded to do point-to-point traverses in the vicinity with its Athena Payload remote sensing instruments providing data to scientists allowing them to select the best rocks and other sites from which to obtain cores. Coring makes it possible to recover "subsurface" materials unaltered by the planet's atmosphere or by water. The sample cores (8mm x 25mm typically) will be stored on the Rover until it is commanded to return to and remount the Lander where it straddles the horizontally mounted MAV. The samples will then be transferred to the Orbiting Sample Canister (OS) in the MAV nose cone. Then another and perhaps several more such sorties will be performed gathering more samples becoming more and more ambitious. The Rover may only need to traverse tens of meters to gather the most im-

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portant samples, but may traverse over one hundred meters from the Lander in acquiring samples on its final sortie.

While the Rover is gathering samples, a subsurface drill on the Lander will obtain samples to a depth of 0.5 m (perhaps deeper on 2005 mission) and these will also be placed in the OS. Also, the drill is envisioned to provide sample material to experiments on the Lander deck.

The Rover sample gathering is to be completed within 90 sols (sol=Mars day=24.6hr). After 90 sols or earlier whenever sufficient samples have been loaded in the OS, the MAV will be launched to place the OS into a 600 km altitude near circular Mars parking orbit at 45 deg inclination. The 3.6 kg, 15 cm diameter OS sample container and its precious cargo of at least 500 grams of Mars material will have a solar-powered radio transmitter to allow its orbit determination.

In August 2005, an Ariane 5 launcher equipped with the new ESC-A cryogenic upper stage will lift off from the Guyana Space Center with a 5.2 tons launch payload mass. This joint NASA-CNES mission will be carrying a Lander with Rover and MAV nearly identical to the 2003 mission, and an Orbiter supplied by CNES with a NASA/JPL Rendezvous and Capture payload with NASA/LaRC Earth Entry Vehicles to bring back the first samples from the Red Planet. The Orbiter will also carry four small CNES Netlander geophysical stations.

The Lander and Orbiter are carried independently in the Ariane payload section using the Ariane Sylde and adapters. The Orbiter and Lander both have their own cruise module and will complete the journey from Earth to Mars separately. Within days after launch an arrival time separation maneuver will be performed so that the Lander and Orbiter arrive at Mars several days apart for operational reasons. Upon arrival in July 2006, the Landed elements perform a sample gathering mission much like the 2003 mission. This second surface mission will be landed at a distinctly separate Mars site again chosen with the utmost care and to complement the first mission.

The Orbiter carries four CNES Netlanders to Mars, which are sequentially deployed to different landing sites during the last few weeks of Mars approach. Each Netlander will enter the atmosphere directly and land with parachute and airbag. The Netlander mission is to get data on the Mars atmosphere, the internal structure, and the magnetism of the planet.

The CNES Orbiter will be the first spacecraft to use aerocapture instead of rocket propulsion to become captured into orbit by the planet's gravity. After release of the Netlanders and of the cruise module, the Orbiter will

cross the Martian atmosphere at an altitude of around 40 kilometers. The deceleration given by this atmospheric braking will result in an elliptical orbit with an apoapsis of about 1,500 km thus achieving the first aerocapture—one of the most critical phases of the mission. An essential propulsive maneuver must be performed one-half revolution after orbit insertion in order to raise the periapsis out of the atmosphere. After capture the Orbiter will jettison its heatshield, determine its attitude and perform the firings at apoapsis to raise the periapsis to around 200 km.

From this orbit, the Orbiter's mission will be to locate the 2003 mission sample container with its radio direction finder receiver. Once the Orbiting Sample (OS) canister's orbit parameters have been determined by the ground control center, the Orbiter will be commanded to perform a series of maneuvers to transfer to the same orbital plane and circularize its orbit to be prepared for the final rendezvous. Provisions are being made so that other Mars orbiters (e.g., Mars '01, Mars Express, etc.) might also acquire the 2003 OS signal and thereby enable determining the 2003 OS orbit well before the Orbiter arrives, but while highly desirable this is not required. Once the ground-based navigation has brought the Orbiter to within two km of the OS, control will be switched to the autonomous onboard system that will use a laser measurement system in determining Orbiter thruster commands to cause the Orbiter to "swallow" the OS in its capture basket (fig 3). Mechanical gates will sweep the OS to the mechanism that places it in the awaiting Earth Entry Vehicle (EEV). This recovery phase of the 2003 canister could last about six months.

While the Orbiter is rendezvousing with the 2003 OS, the 2005 surface mission is executing and on or before

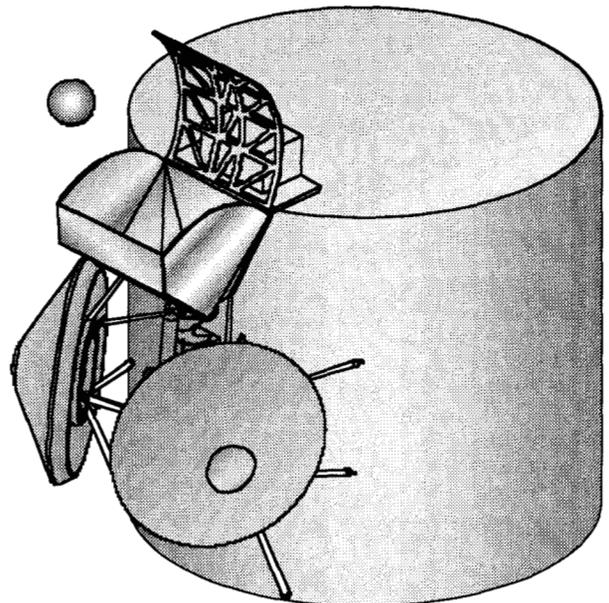


Fig 3. Orbiter about to Capture the OS in Its Basket.

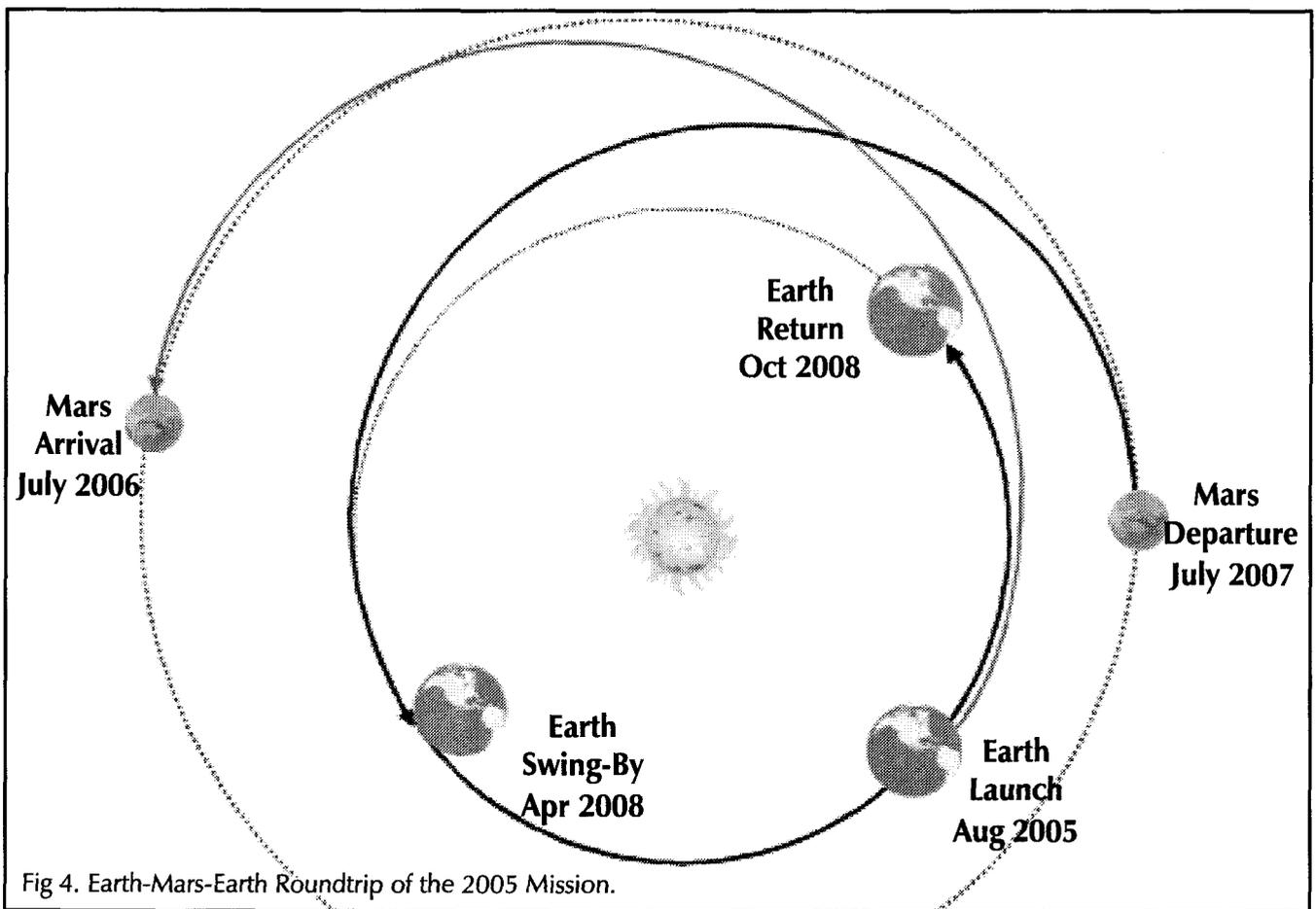


Fig 4. Earth-Mars-Earth Roundtrip of the 2005 Mission.

90 sols the 2005 MAV will launch that mission's samples into a 600 km, 45 deg inclination Mars parking orbit, but unlike the 2003 launch, the node of the 2005 launch can be targeted to facilitate the rendezvous with the 2005 canister. The rendezvous and OS capture is performed as before although in less time and the OS is placed in the second waiting EEV.

With both OS Canisters now in their respective EEVs, in July 2007 the Orbiter does departure phasing maneuvers and moves to a highly elliptical orbit to establish the proper geometrical conditions for the Trans-Earth Injection (TEI) Maneuver, which is performed with the rocket engine. This is completely analogous to meeting the Earth launch window for any of the planets. It is remarkable that even though aerocapture is being used for orbit insertion providing roughly 2.0 km/sec delta-V, the Orbiter propulsion system must deliver 3.5 km/sec mostly to do the orbital rendezvous and the TEI.

The Orbiter will fly by Earth in April 2008 to get a gravity assist to change its heliocentric orbit such that it approaches Earth again in October but then on an approach asymptote that enables the direct entry EEVs to land in the United States. Without this gravity-assist the only accessible landing areas are in the Southern Hemisphere. On approach to Earth in October 2008 the Orbiter will

perform maneuvers to put itself into a precise reentry trajectory from where it will release the two EEVs. A second series of maneuvers will then place the Orbiter back into a solar orbit or retarget it to land in the ocean.

The EEVs will reenter the Earth's atmosphere on a ballistic trajectory at a speed of 11.5km/s. They will impact on land and are equipped with a redundant radio beacons for quick location and recovery. Figure 4 shows the heliocentric view of the Earth-Mars-Earth roundtrip of the 2005 Mission.

MARS SURVEYOR PROGRAM SCIENCE

On the NASA-side, MSR is a part of the overall Mars Surveyor Program (MSP). MSP will conduct detailed surface and orbital studies to expand our knowledge of Mars and enable the selection of samples to bring to Earth. MSP includes the Mars Global Surveyor currently mapping Mars, the Mars'98 Climate Orbiter and Polar Lander now approaching Mars, and the Mars'01 Orbiter and Lander. The MSP scientific goals are to understand the climate, resources, and potential for life on Mars. The science strategy includes the completion of the global reconnaissance of Mars, surface exploration, and sample return missions. The 2003/2005 MSR missions support

these science objectives by exploration of the ancient highlands of Mars in order to characterize the surface environments in terms of geologic and hydrologic history.

Specifically, the MSR missions will conduct Mars sample collection, analysis, and return in support of the following science objectives:

- 1) Further understanding of potential and possible biological history of Mars;
- 2) Search for indicators of past and/or present life on Mars;
- 3) Improve understanding of Mars' climate evolution and planetary history;
- 4) Improve understanding of constraints on amount and history of water on and within Mars;
- 5) Acquire data to identify areas of possible interest for future scientific exploration;
- 6) Determine nature of local surface geologic processes from surface morphology and chemistry;
- 7) Determine spatial distribution and composition of minerals, rocks, and soils surrounding the landing sites.

The Mars Surveyor Program will also provide payload accommodation on the MSR Landers for Human Exploration and Development of Space (HEDS) experiments. HEDS goals for these experiments relate to preparing for the eventual human exploration of Mars and astrobiology. HEDS objectives for these experiments include:

- 1) Understand and characterize the physical and chemical environment of Mars related to the risk to and resources for human explorers;

- 2) Characterize response of biology to Mars environment;
- 3) Demonstrate technologies critical to human exploration which require testing in the actual Mars environment in order to gain sufficient confidence for their use in an operational human system.

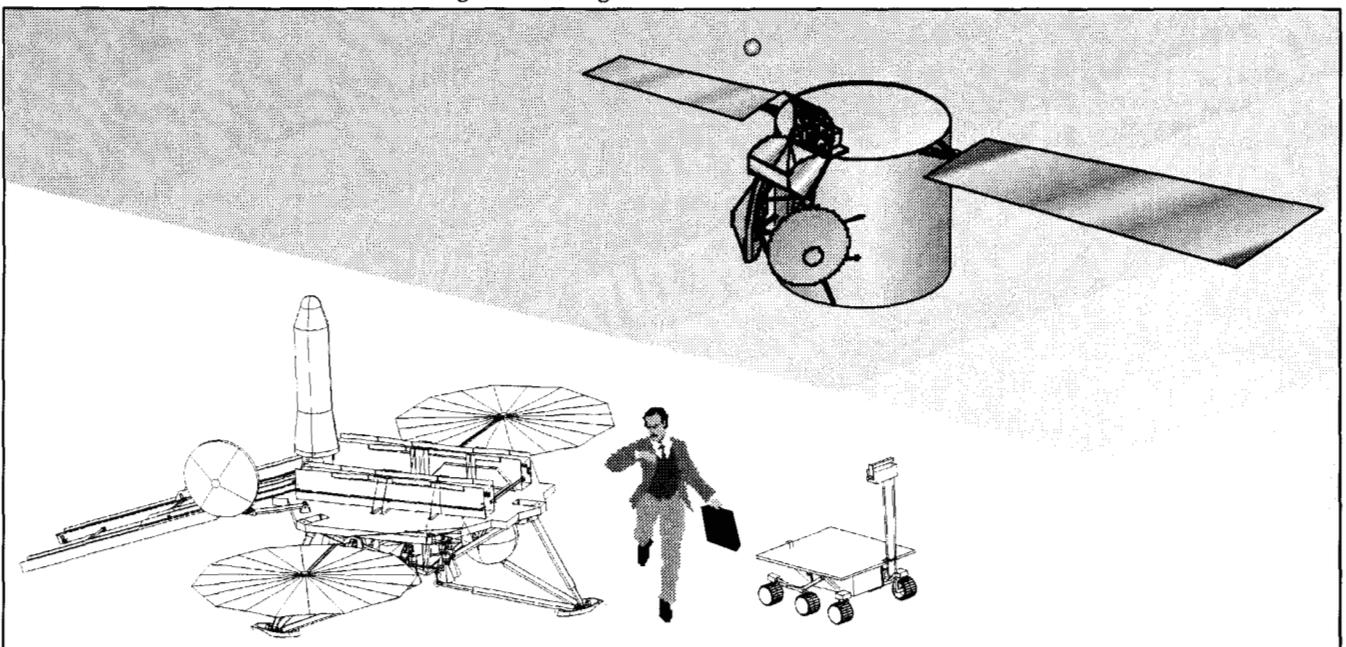
MARS SAMPLE RETURN FLIGHT ARTICLES

To provide a quick appreciation for the size of the flight articles, Figure 5 shows them to the same scale as an average-sized adult.

Lander

An exploded view of the Lander in its fully tucked configuration, the aeroshell, the aft-body, and the cruise stage is provided in Figure 6a. A more detailed view of the Lander showing the placement of the Rover and the MAV is shown in Figure 6b. The surface configuration is shown in Figure 6c with the MAV erected to its launch position. Figure 6c also shows candidate volumes for the HEDS experiments and any other additional payloads. Payload items not specifically required for the sample return are called "additional payloads". Presently, it is expected that the Italian Space Agency (ASI) will provide a subsurface drill that will be mounted on the Lander to obtain "Lander-based" subsurface samples to a depth of 0.5m (perhaps 2 m for '05). This drill will be part of the (primary) sample return payload (not additional payload). Samples from the drill will be placed in the sample canister in the MAV along with the Rover samples. It is further envisioned that the drill will provide material to an ASI in-situ science package which will be carried on the Lander as one of the Additional

Fig 5. MSR Flight Articles Shown to Scale.



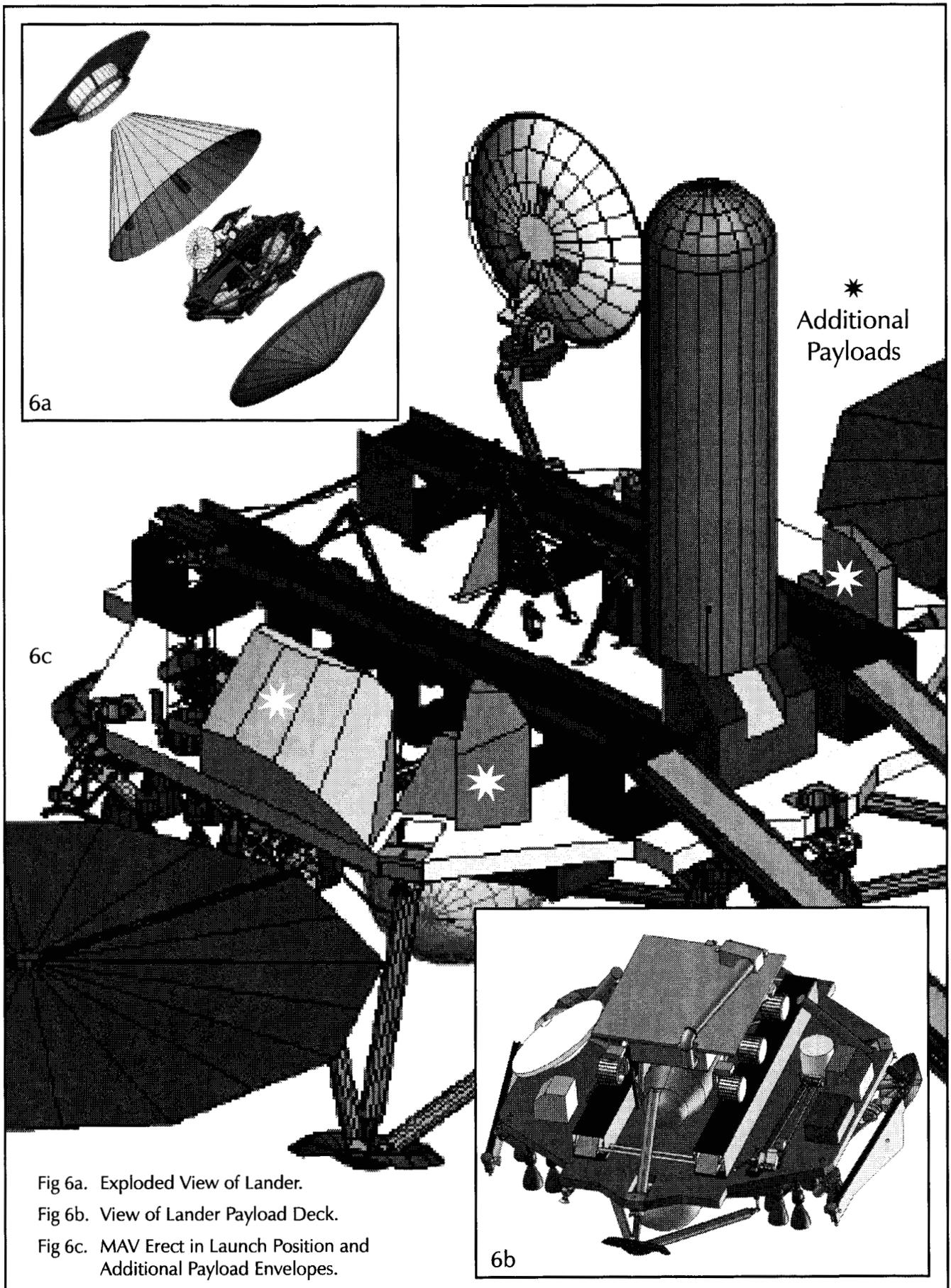


Fig 6a. Exploded View of Lander.

Fig 6b. View of Lander Payload Deck.

Fig 6c. MAV Erect in Launch Position and Additional Payload Envelopes.

Payloads. The Canadian Space Agency has proposed to NASA to provide a robotic arm for the Landers and this remains a possibility pending the selection of the additional payloads.

The Lander will perform a direct entry into Mars atmosphere. Its Lift/Drag ratio is about 0.2. Lift is required to compensate for the rather large ballistic coefficient of this vehicle resulting from the heavy payload and the launch vehicle fairing limit on the aeroshell diameter. Aero maneuvering will be used autonomously during the hypersonic phase to roll the lift vector to minimize atmospheric trajectory dispersions in order to achieve a landing accuracy of 10 km (99%). The Entry-Descent-Landing system follows the Viking, Mars'98, and Mars'01 heritage, namely, aeroshell, parachute, and rocket engine terminal descent to touchdown following a specified altitude-velocity profile. Mass alone precludes the use of Pathfinder-style airbag landing system for these heavy payload missions.

The Lander payload deck is about 2.6 m across. Total Lander launch mass allocation including payloads is 1830 kg for 2003 mission (1800 kg for '05). Of the 1830 kg for the '03 Lander, 400 kg is payload, which is tentatively allocated as follows: Rover System including Lander Mounted Rover Equipment (LMRE) that stays with Lander 120 kg; MAV including Lander Mounted MAV Equipment (LMME) that stays with Lander 160

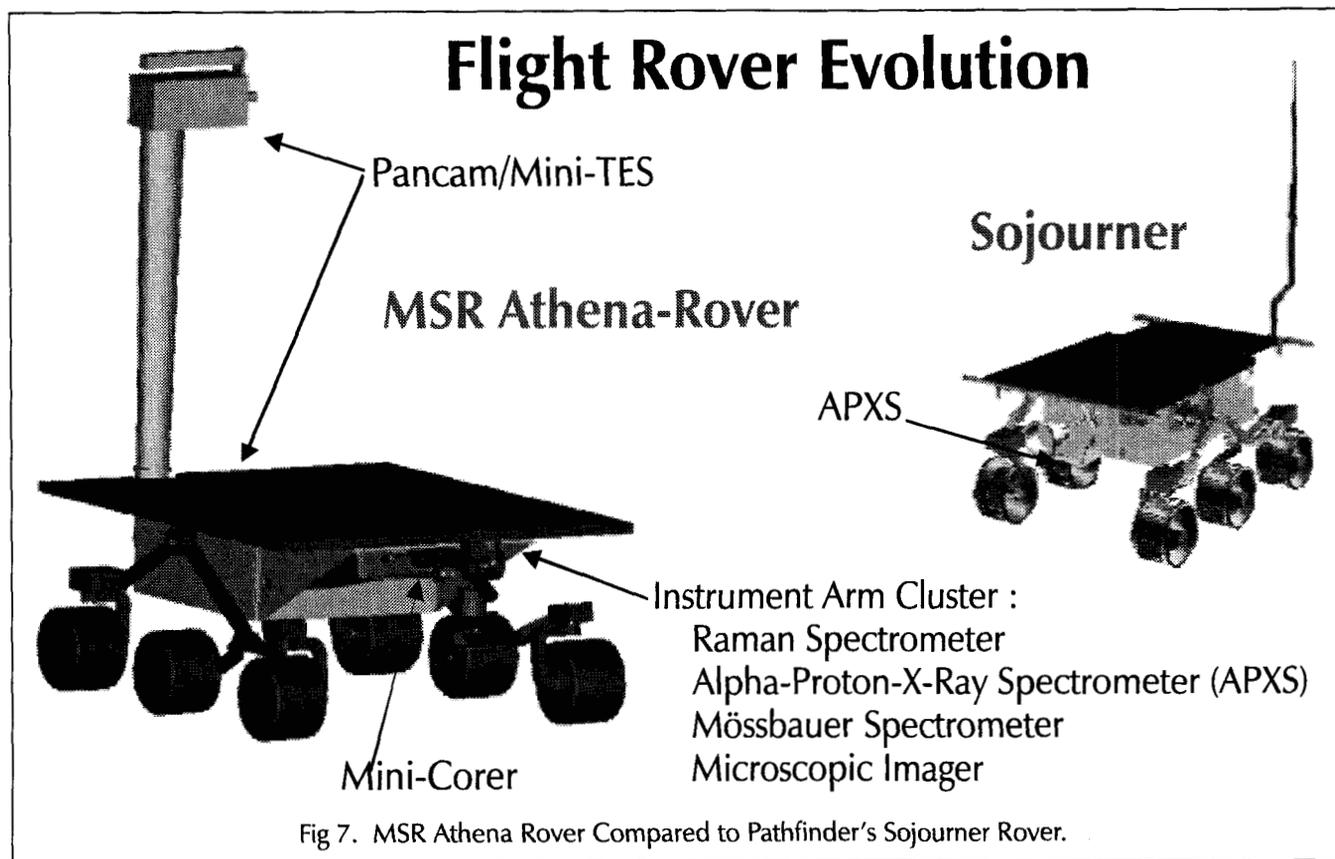
kg; Sample Transfer Chain 35 kg; Imager 5 kg; Drill 15 kg; Additional Payloads 50 kg; Payload System Reserve 15 kg.

The primary direct two-way communications link to Earth is provided by the Lander at x-band. Primary communications with the Rover is via two-way s-band link with the Lander. Provisions are being made to have two-way UHF equipment on the Lander and the Rover to communicate at higher data rates with any orbiter that might be available, but these communication links are strictly auxiliary and not essential to the mission. The UHF Rover link could be the only means of conducting an extended Rover mission if the MAV launch damages the Lander communications. All parties are working to ensure RF compatibility between Mars landed and orbiting spacecraft assets (e.g., Mars Express, Mars'01, etc.)

The payload performance improvement provided by the MSR Lander is notable. A payload mass fraction of 400/1040 (40%) is being achieved with a 3.65 m (dia) aeroshell compared to Mars'01 at 67/346 (20%) using a 2.65 m aeroshell. Interestingly, the entire '01 Lander could be carried on the MSR Lander.

The Athena Rover

The Rover is the robotic instrument of the scientists. Its Athena payload was selected to provide the best pos-



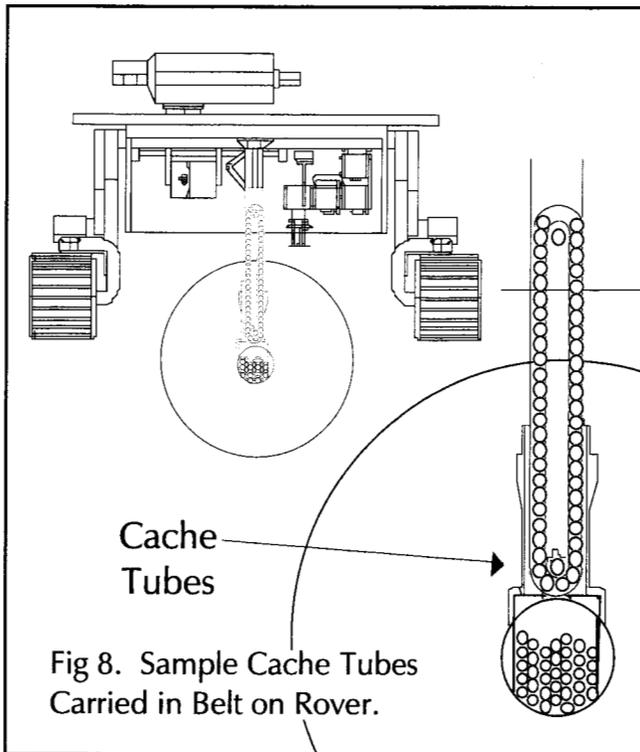


Fig 8. Sample Cache Tubes Carried in Belt on Rover.

sible information about potential coring sites. Athena is comprised of a panoramic camera (Pancam), mini-Thermal Emission Spectrometer (mini-TES), microscopic imager, Alpha-Proton X-ray, Mossbauer, and Raman spectrometers, and the sample collecting mini-corer. Figure 7 shows the Rover, the instrument locations, and a size comparison to Pathfinder's Sojourner Rover. The mobile mass of the Rover is 80 kg compared to 10.5 kg for Sojourner. The size and mass of the Rover are dictated by the extensive instrument complement and the required authority to drill the rocks. The scientists will command the Rover to go to an interesting-looking site based on Pancam and mini-TES and, once there, measure the candidate with the Athena in-situ instruments and determine whether or not to core that particular rock. The measurements will also provide scientific context for the site. It is envisioned that about 20 different sites will be visited and sampled in the 90 sol sample gathering mission. The mini-corer takes cores 8 mm in diameter and typically 25 mm long. The Rover is expected to obtain 50 to 60 rock cores total from the 20 sites. With an expected density range this amounts to 150 to 250 g total. The Lander drill is expected to provide another 250 g so a total of at least 500 g will be in the sample canister.

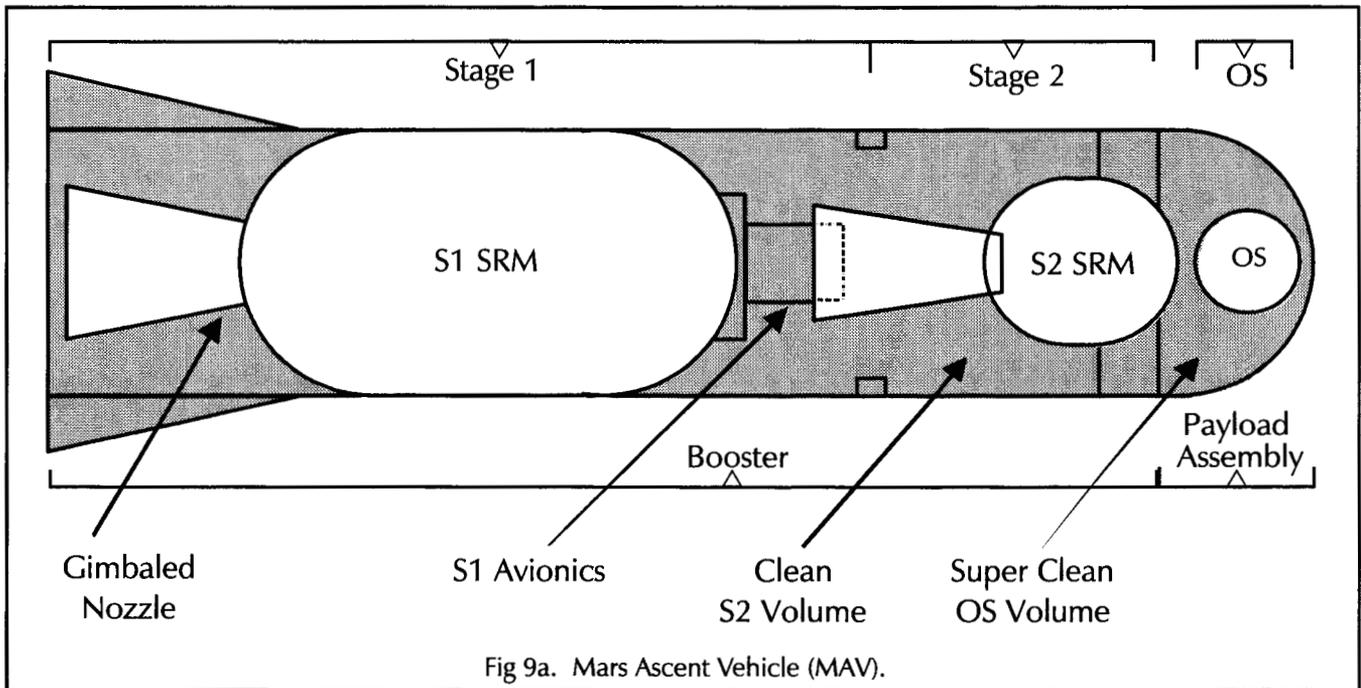
The Sample Transfer Chain

The system that comprises most all the elements that move the samples across the flight articles is defined as The Sample Transfer Chain (STC). As currently envisioned, STC begins with the sample tubes. These tubes are carried in a belt on the Rover as illustrated in Fig-

ure 8. After each core is taken the belt is indexed and the sample core is transferred from the corer into the tube on the belt and the tube will be closed. When the sortie is finished the Rover returns to the Lander and drives back up the ramp and positions itself over the MAV. STC hardware then opens the MAV nosecone and the sample canister. The belt then moves to drop the filled tubes into the sample canister and then the canister is reclosed. STC also provides tubes for the Lander drill samples and drops them into the canister when the Rover is not in position. When the last batch of sample tubes has been dropped in, the canister is closed for the final time and this closure captures an atmosphere sample of about 50 cc. Following MAV ascent and burnout, the canister is permanently bio-sealed and separated from the nosecone in an essentially simultaneous action. The design is such that no external part of the canister has ever "seen" Mars environment and if the bio-seal does not function the nosecone remains attached as a fail-safe feature preventing capture of an unsealed canister (OS). Next the STC provides the Sample Capture And Transfer System (SCATS), which is part of the NASA/JPL Payload on the CNES Orbiter (Fig 3). The SCATS "sweeps" the canister into the Earth Entry Vehicle (EEV). Finally, the STC provides the Containment Vessel mounted in the EEV that receives the OS. The CV features a double-wall construction sandwiching HEPA filter material that guarantees no escape of spores even if the canister is not completely sealed.

Mars Ascent Vehicle (MAV)

The most significant outcome of the community-wide Mars Sample Return Architecture Workshops conducted by JPL in the Summer of 1998 was the introduction of the concept of a very simple, spinning, unguided, solid propellant Mars Ascent Vehicle (MAV) subsequently referred to as the mini-MAV. The mini-MAV was inspired by a review of the Pilot Project conducted at China Lake Naval Weapons Lab (California) in the late 1950's. The Pilot Project was an attempt to orbit the first artificial Earth satellite by launching a spin-stabilized three-stage solid propellant rocket from an airplane. The first two stages were to produce the speed for transfer to orbital altitude and the third stage would circularize the satellite at that altitude. The novel concept was to mount the third stage "backward" so it would thrust in the velocity direction at apogee one-half rev after the first and second stage burns and the whole system would remain at high spin throughout and require no attitude change. This concept was adopted by MSR Project as most robust and simple enough to enable producing such a MAV in time for the 2003 mission and thereby place 2003 mission samples in Mars parking orbit. The previous MSR baseline used a sophisticated liquid-propellant, fully-guided MAV that maintained attitude control long after burnout in order to cooperate in the docking of the Or-

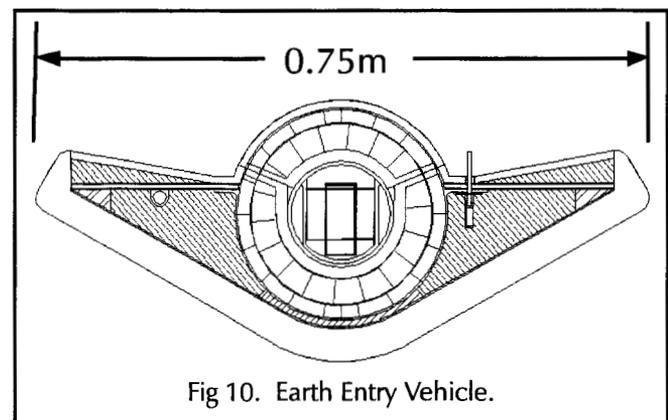


biter with the final stage. Difficult required technology developments then underway included developing propellants that could store and ignite at -40 deg C and lightweight tanks and valves to make the mass affordable. This MAV was about 400 kg compared to the mini-MAV at 120 kg. The Lander could carry both this new mini-MAV and the Rover making orbital caching of the samples (canisters) doable. Incidentally, for the previous docking approach the sample transfer from MAV to Orbiter had not yet been determined. Further elegance in the new approach is that the sample canister is completely passive (except for radio signal) and is literally swallowed by the Orbiter.

At first there was concern about high-spin of the solid motors, but this was quickly resolved by solid motor experts agreeing that reducing the metallization of the propellant mix would solve the slag problem albeit at some performance (ISP) loss. Originally the MAV would be erected by an az-el mount to provide vertical launch regardless of Lander tilt. The mass penalties of this plus the dispersions due to winds and plume reflections off the Lander led to a three-axis stabilized, guided first stage. The MAV will be launched perpendicular to the Lander deck and the lightweight simple guidance system will enable the spin up the MAV before stage 1-2 separation. Very recently it has been determined that the third stage is not desirable and the second stage can achieve the circular parking orbit directly with better accuracy and simplicity. The launch mass of the MAV is 120 kg. A typical current configuration is shown in Figure 9a. An artist rendering of MAV launch is shown in Figure 9b (on the cover of this paper). MAV will place the sample canister in a 600 km near circular orbit at 45

deg inclination with an accuracy better than 100 km and 1 deg (99%). The structure carrying the canister will be yo-yo despun before canister release. Work is ongoing to determine what diagnostic data if any might be sent to a Mars orbiter (assuming one exists) during ascent. An insulation "igloo" is planned to limit the diurnal temperature excursions of the solid propellants. The MAV payload is the sample canister having a not to exceed mass of 3.6 kg including its 500+ grams of samples; canister diameter will be about 15 cm.

Discussion of the planetary protection design details—both preventing earth organisms contaminating Mars and preventing Mars material from inadvertent release on Earth—is beyond the scope of this paper. It capesaid that planetary protection very much drives MSR flight article design, particularly, the elements of the Sample Transfer Chain. The designs are being tailored to ensure that all these requirements and regulations will be fully met.



Earth Entry Vehicle (EEV)

The Earth Entry Vehicle is being designed and produced by the NASA Langley Research Center with NASA Ames Research Center providing help with the heatshield design. Two EEVs will be carried by the Orbiter—one for each Orbiting Sample (OS) canister. The design goal is to make the EEV as robust as possible. It is a parachute-less design so there is no risk of a parachute failure. The EEVs will be spin-stabilized at release from the Orbiter. The EEV is designed to be backwards unstable so that even if it would enter backwards it will quickly right itself to nose forward. It has a low ballistic coefficient resulting in a terminal velocity of only about 40 m/sec. Crushable material cushions the Containment Vessel in all directions to make impact loads benign. Redundant radio beacons will provide for rapid landed position determination within the landing area. The launch mass of each EEV is 23 kg and it will be 3.6 kg heavier on entry since it will then contain the loaded sample canister. Maximum diameter is 0.75 m as shown in cross section view in Figure 10.

Orbiter

The Orbiter (Fig 11) will have a total mass of 2,700 kg, a little under half of which will be propellant (making it rather like a large oil tanker in space!) and a capacity of speed variation of 3,500 m/s. Reducing mass is a major challenge. The fact that the orbiter is required to return to Earth has a large “snowball” effect on its mass, which may vary by more than a factor of 4 (1 kg of returned dry mass means over 4 kg on the launch pad).

The Orbiter will be composed of three main elements: the cruise stage, the heatshield and the Orbiter core. The cruise stage will ensure Orbiter life during cruise by supplying electrical energy and it will provide propulsion and attitude control for the Earth-Mars cruise; it will carry the four Netlanders and will be jettisoned before aerocapture. The heatshield, capable of resisting a high temperature, will protect the Orbiter during aerocapture (Fig 12).

Aerocapture is a new technique never yet used for planetary orbit insertion. The speed reduction is provided by friction against the planet’s atmosphere. To obtain the required level of deceleration (greater than 1,500 m/s), a significant surface area is needed which will be heated up by “intense friction” in the atmosphere, receiving a thermal flux of about 400 to 500 kW/m². The overall budget turns out to be positive, as the 300-to-400 kg shield mass is much less than the one ton or more of propellant otherwise needed for propulsive capture. That represents quite a big saving given the mass being placed into orbit!

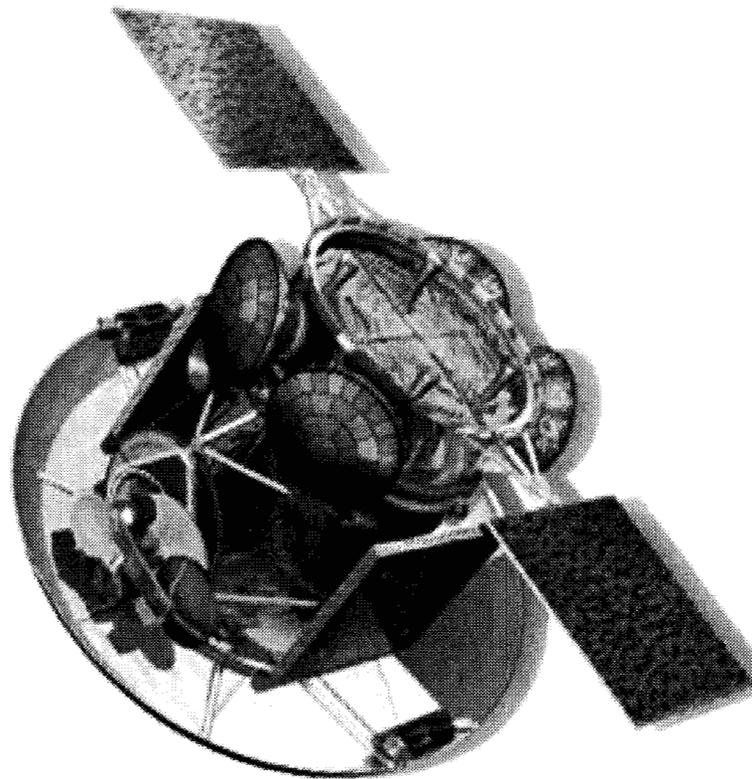
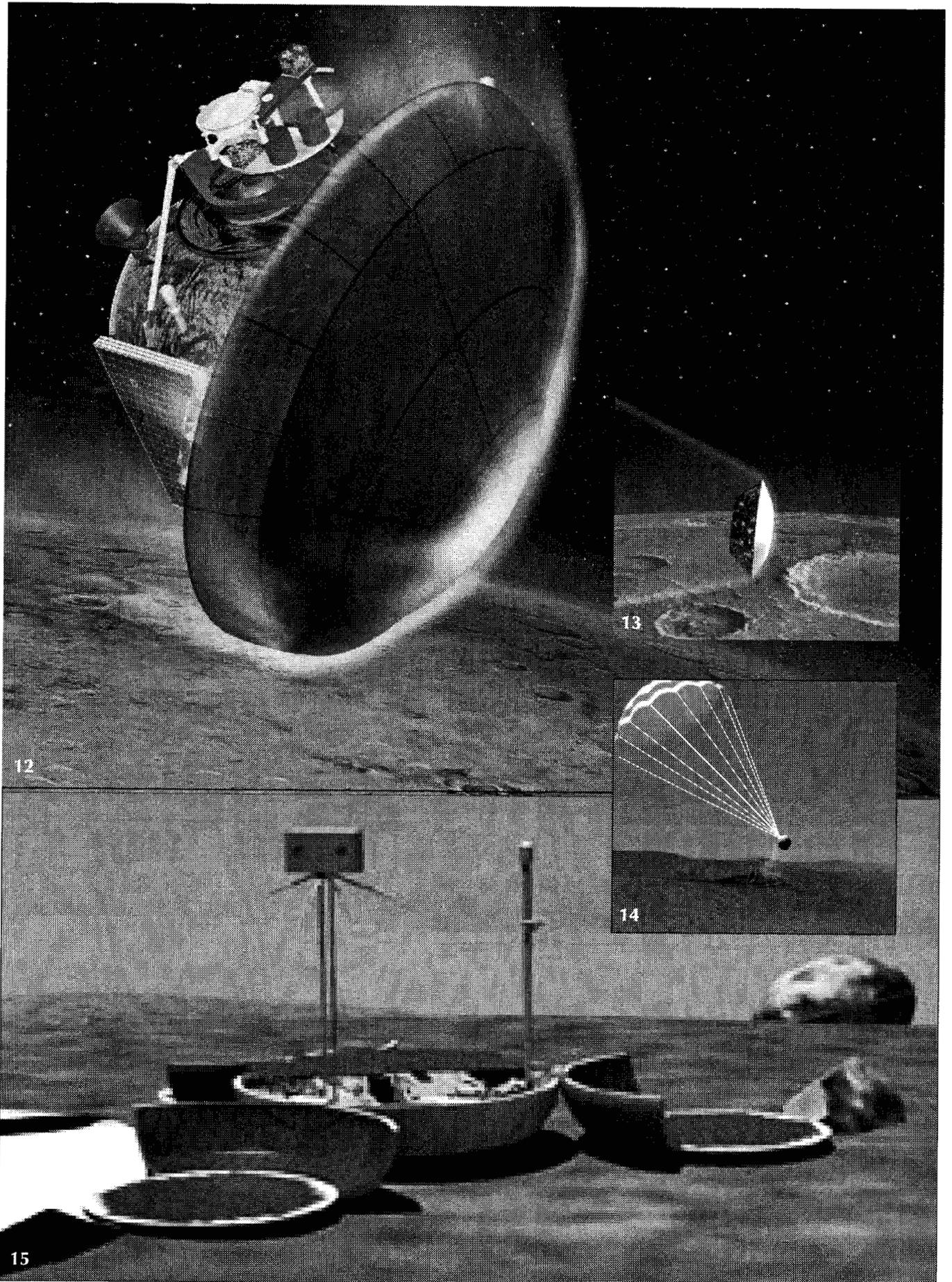


Fig 11. Orbiter during Cruise to Mars. (Payload as shown is earlier configuration.)

One of the difficulties in aerocapture lies in choosing a pass corridor through the atmosphere and finding the right altitude to obtain the correct level of deceleration. Slowing down too quickly would bring the orbiter crashing to the surface. Not slowing down enough would mean the spacecraft is not captured into orbit. To adjust deceleration and compensate for density variations due to local atmospheric conditions, the Orbiter will have to autonomously control its trajectory during the pass by performing roll maneuvers to change the bank angle. This will modify the lift vector direction to increase or reduce the pass altitude, and in turn deceleration.

The Orbiter core will be operant after jettison of the heatshield and deployment of solar arrays. It will be equipped with:

- a bipropellant propulsion and attitude control system,
- a communication system,
- a power system supplying 500 W,
- a dual string avionics system with a JPL-supplied Computer (probably RAD 6000 processor) for data processing, sun sensor, star tracker, accelerometers and gyros,
- a rendezvous system supplied by JPL including rendezvous/capture computer, a capture basket, radio direction finder, and Lidar systems,
- two Earth Entry Vehicles (EEVs) supplied by NASA/LaRC as part of the JPL provided Orbiter Payload.



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Netlanders

The four identical Netlanders will be launched on the Mars Sample Return Orbiter, which will serve as the "bus" for the cruise phase to Mars. In the final weeks before the Orbiter is inserted into orbit around Mars, the landers will be separated from the Orbiter and descend to their target landing sites with the required degree of accuracy. After separation, each Netlander is on a ballistic entry trajectory and will enter the planet's atmosphere (Fig 13), protected by a heatshield. A parachute will then open to reduce vertical speed and airbags will inflate to cushion the shock on landing (Fig 14).

Once the stations are stable, they will jettison their airbag and, then start operating on the planet's surface, first

determining their orientation, righting themselves should they land headfirst! -and deploying "petals" coated with solar cells to enable them to absorb the Sun's energy and recharge their batteries (Fig 15).

The instruments will be successively deployed: the camera will take the first panoramic pictures of the landing sites, the meteorological sensors will start sending back climate data, and the radar will sound the subsurface for traces of water. Setting up the seismometer will probably be the trickiest operation, as it must be placed in contact with the surface and uncoupled from the station to reduce unwanted noise. The network will then be operational. It is to communicate its data to Earth via relay links through Mars Express.

Fig 12. Orbiter during Aerocapture.
(Payload as shown is earlier configuration.)

Fig 13. Netlander Probe during Mars Entry.

Fig 14. Netlander Probe during Mars Landing.

Fig 15. Netlander Station on Mars Surface.

Ariane 5

The Basic Configuration

Ariane 5 is a two-stage launch vehicle consisting of a fixed lower section and an upper section which depends on the launch configuration.

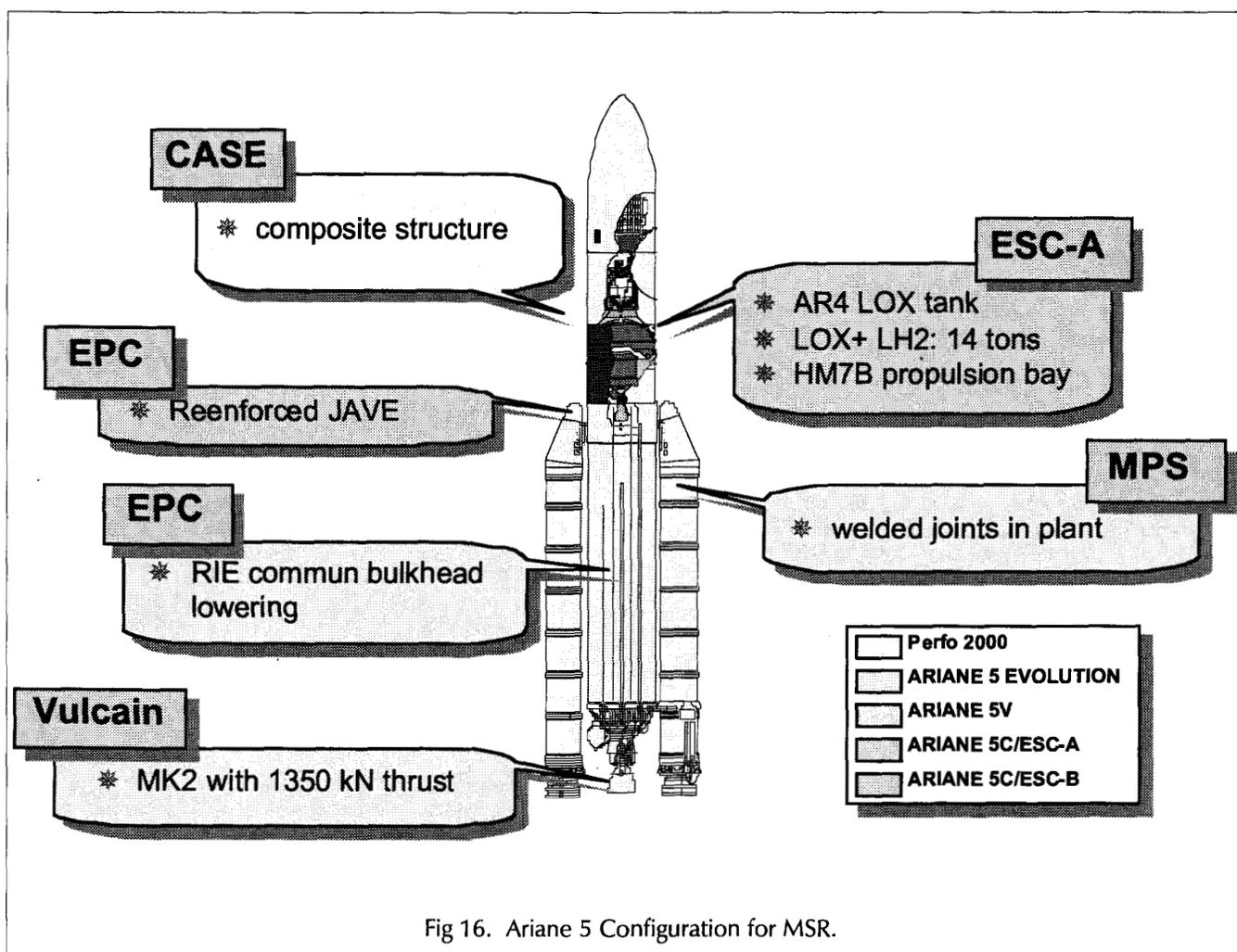


Fig 16. Ariane 5 Configuration for MSR.

The lower section comprises:

- the H155 cryogenic stage EPC powered by the VULCAIN engine (thrust: 1200 kN., burning time : 600 sec) and loaded with 155,000 kg of liquid oxygen and liquid hydrogen
- two solid propellant boosters (P230), each with a propellant mass of 237,000 kg (burning time about 130 sec).

The upper composite consists in:

- the L9 upper stage (EPS) powered by the AESTUS reignitable engine which burns 9700 kg of storable propellants MMH and N2O4 (thrust 29 kN., burning time: 1100 sec)
- the Vehicle Equipment Bay (VEB), carrying all the avionics equipment for the guidance and data processing and the Attitude Control System (SCA) hydrazine tanks
- the payload section which provides various payloads compartment configurations for single or double launch.

MSR launch vehicle configuration:

To increase the performance for the MSR launch the following modifications will be added to the basic Ariane 5 configuration:

“Performance 2000” whose main subject is the optimization of the VEB structure. Ariane 5 Evolution which consists in modifications on the lower composite by increase of the EPC engine thrust (1350 kN.) and introduction of welded joints on boosters. ESC-A which replaces the actual last EPS stage by a cryogenic upper stage using the actual HM7B Ariane 4 engine with a propellant loading capability of 14000 kg, an engine thrust of 63 kn and a specific impulse of 446s.

This configuration will be qualified in 2002. The associated configuration is shown in Figure 16.

With dual launch configuration, the definition of the payload compartment configuration with SYLDA 5 is the following:

- The Lander as upper spacecraft mounted on top of an adapter fixed on the SYLDA 5 upper interface flange,
- The Orbiter as lower spacecraft mounted on top of an adapter fixed on the upper stage.

Each payload (upper or lower) is mounted on an adapter fixed on the reference plane (2624).

The associated performance is 5.2 tons giving 1.8 tons for the lander and 2.7 tons for the Orbiter (0.7 tons is required by the SYLDA and the adapters).

SUMMARY

The Mars Sample Return Project promises to be the most exciting and challenging planetary missions project in the next decade—the first decade of the new millennium! The Mars samples delivered to Earth in 2008 will provide some of the most important planetary science ever. The international collaboration of the MSR Project is providing for a much more ambitious endeavor than any nation could do alone and promotes the international alliances that are fundamental to the concept of the International Astronautical Federation. A worldwide, peer-determined sharing in sample analysis is envisioned. And as earth-based laboratories increase in capabilities, there is the continuing potential for important new discoveries from these precious Mars samples then in hand.

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