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MARS GLOBAL SURVEYOR: READY FOR LAUNCH IN NOVEMBER 1996

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ABSTRACT

The Mars Global Surveyor (MGS) spacecraft will be launched toward Mars in November 1996. This mission is the first in the NASA Mars Surveyor Program and has been under development for the past two years. In this report the status of the MGS mission, three months prior to launch, will be described along with three specific topics: aerobraking, the lander to orbiter relay and the common operations project for the Mars Surveyor Program. The Mars Global Surveyor mission is intended to accomplish a portion of the scientific objectives of the Mars Observer Mission which was lost in 1993, three days before entering Mars orbit. To meet the established objectives a low, sun-synchronous, near circular, polar-mapping orbit is required which drives the need for aerobraking before mapping begins. MGS will carry a lander to orbiter relay capability for use with the Russian 1996 hinder and small probes to be dropped to the surface of Mars by the 1998 Surveyor Mission. For the Mars Surveyor Program operation of all the landers and orbiters will be conducted under a single cost constrained Mars Surveyor Operation Project.

INTRODUCTION

Mars Global Surveyor is to be the first mission in a series of Mars orbiters and landers planned by the United States (US) National Aeronautics and Space Administration (NASA) over the next decade. MGS has been under development since October 1994 with a budget of $ 154 million. The Jet Propulsion Laboratory is responsible for the execution of the Surveyor Program and the management of MGS. In a competitive selection process Lockheed Martin Astronautics (LMA) of Denver, Colorado was selected as the industrial partner responsible for the design, building and testing of the MGS spacecraft. Launch of the MGS spacecraft to Mars will occur in the period 6-25 November 1996 from the Cape Canaveral Air Force Station using a McDonnell Douglas Delta 117925 launch vehicle.

Lockheed Martin Astronautics proposed a spacecraft to be built from the existing set of spare electronic assemblies from Mars Observer with a new composite spacecraft bus structure and a new dual mode (bi-propellant or hydrazine) propulsion system. The spacecraft is composed of two modules: an equipment module which carries the science instruments and most of the spacecraft electronics and a propulsion module which contains all the propulsion components, the spacecraft fuel, oxidizer and pressurant tanks and the batteries. Other principal new elements of the spacecraft include two solid state recorders (1.5 Gbits each), two 20 A-hour nickel hydrogen batteries, a single 596 N bi-propellant main engine, a four panel solar array (two panels each of Si and GaAs cells), drag naps at the end of each solar array, two Thompson 25 watt traveling wave tube power amplifiers and a set of new low gain antennas. The dual mode propulsion system has significant heritage from the Cassini spacecraft propulsion design with care taken to avoid problems with propellant vapor mixing as this has been suggested as the cause of the failure of Mars Observer. The spacecraft has been designed for aerobraking at Mars with the back of the solar arrays being the main drag Clement. The spacecraft is generall y single fault tolerant with the redundant hardware elements managed by the spacecraft's central computers.

The MGS science payload consists of the following instruments: Magnetometer/Electron Reflectometer, Mars Orbiter Camera, Mars Orbiter Laser Altimeter, Thermal Emission Spectrometer and an Ultra-Stable Oscillator for Radio Science. A Mars Relay system is provided to assist the data return from surface vehicles. Both the lower launch mass and budget for MGS versus Mars Observer meant that two instruments carried by Mars Observer are not a part of the MGS payload, These instruments are: the Pressure Modulator Infrared Radiometer (now selected to fly on the 1998 Surveyor Orbiter and the Gamma Ray Spectrometer (which is a candidate for flight on the 2001 Surveyor orbiter).

DEVELOPMENT STATUS THREE MONTHS BEFORE LAUNCH

At the end of July 1996 all the elements of the spacecraft and payload have been built, integrated and tested as a system. Thermal vacuum testing of the integrated system and all the instruments was completed in early July. Final packaging of the spacecraft for air shipment to Cape Canaveral will be completed in early August

A critical design review of the multi-spacecraft Surveyor Flight Operations Project was successfully conducted in February 1996. The Surveyor Flight Operations Project formally started in March 1996 using elements of the. MGS operations system as the initiat basis for this new multi-mission capability which will extend to all the vehicles in the Surveyor series.

AEROBRAKING

A 10W, sun-synchronous, near circular, near polar mapping orbit was selected for MGS because it allows uniform coverage independent of latitude for almost all of the planet, permits relatively high resolution observations of the surface and allows separation of diurnal and longitude variations. The use of such orbits is common for terrestrial remote sensing spacecraft but they have not been used for planetary missions, despite the observational advantages, because they are energetically expensive.

A good way of examining the energy and ΔV requirements for such orbits and the difference between using chemical propulsion and aerobraking is to compare MGS and Mars Global Surveyor. The mapping orbit at Mars is the same for these two missions. These missions differ in that MGS will carry two fewer instruments and will use aerobraking to circularize the initial capture orbit about Mars rather than using a series of chemical propulsive maneuvers. This comparison is shown in Table 1 where it can be seen that while the while the dry spacecraft mass differs by 288 kg the launch mass differs by 1512 kg with only 81 kg of this difference being due to the two additional instruments carried by Mars Observer. The differences become even larger when the Table 1.

TABLE 1: MASS AND ΔV COMPARISON

Mass Or ΔV Element	MGS	Mars Observer
Payload (kg)	76	157
Dry S/C (kg)	591	879
Fuel & Oxidizer (kg)	393	1536
Launch Mass (kg)	1060	2572
Orbit Insertion ΔV (m/s)	989	816
Circularization ΔV (m/s)	125	1367

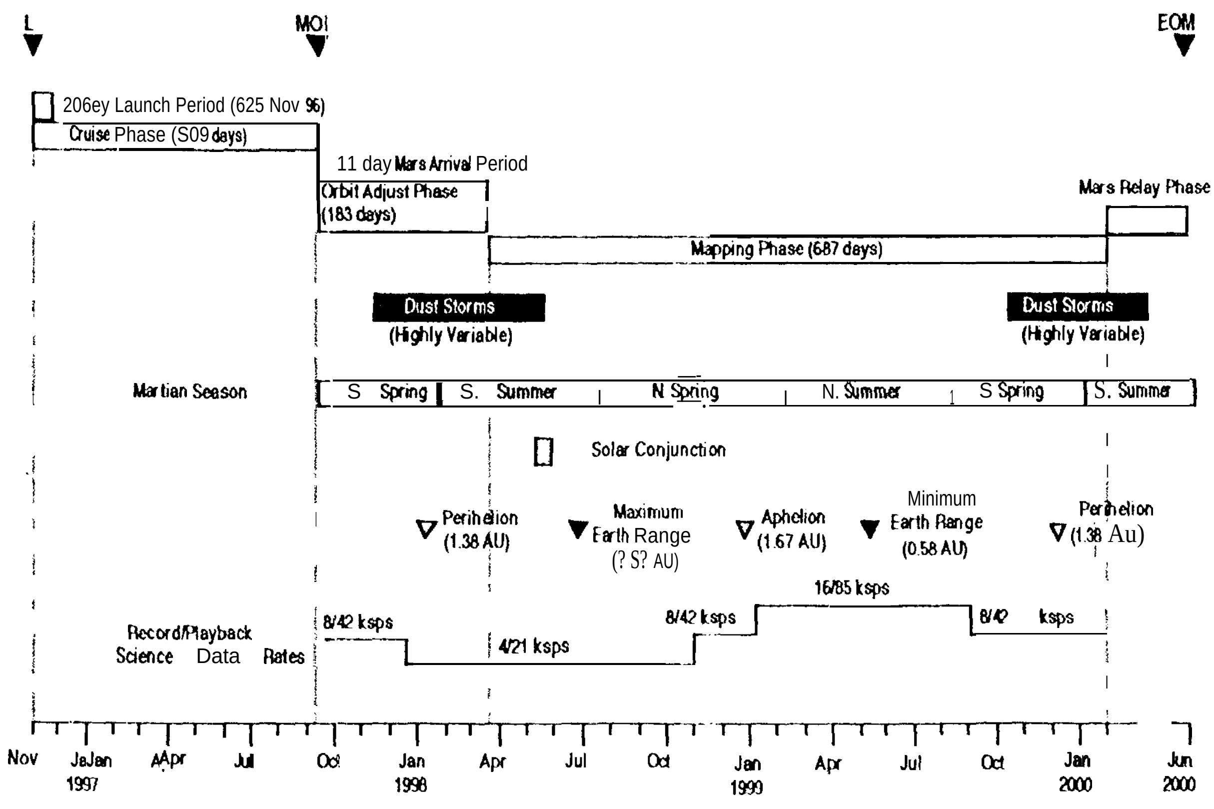
entries for ΔV are examined. Here it can be seen that while MGS requires a higher ΔV for the initial capture into Mars orbit the ΔV for circularization is very nearly eleven times smaller than that to have been used by Mars Observer. Thus the majority of the difference in launch mass between MGS and Mars Observer (1060 vs 2572, kg) is in the fuel and oxidizer required by Mars Observer for circularization of the orbit. By using aerobraking for circularization, MGS is able to use a much smaller and less expensive launch vehicle. This saving is sufficiently dramatic that future Mars missions which require a low circular orbit will likely take this approach, as indeed, the 1998 Mars Surveyor Orbiter has done.

The Magellan spacecraft at Venus was the first planetary spacecraft to try aerobraking as a demonstration in the summer of 1993. The success of this demonstration was the predicate for the adoption of aerobraking on MGS. Aerobraking on MGS will differ from that done on Magellan in two important respects. First, on MGS aerobraking will be done before the start of the main mapping activity. Thus, aerobraking success is required if the full set of mission objectives are to be accomplished. Second, to be successful not only must the aerobraking procedure result in a circularization of the orbit at the proper altitude but it must be accomplished such that the local time at sunward equator crossing is within a few minutes of 2:00 PM with respect to the mean sun. This latter constraint, which is essential if the complete science objectives of all the experiments are to be possible, requires that aerobraking proceed in a deliberate manner without significant interruption, If a delay in aerobraking occurs in the early phases, the motion of Mars around the sun will cause the orbit plane to move closer to the sun-Mars line resulting in a local time at sunward equator crossing that is nearer to noon than 2:00 PM. These two factors make aerobraking the most challenging element of the MGS Mission.

The MGS spacecraft has been designed to meet the aerobraking requirements, including the local time constraint, with margin for any day within the twenty day launch period. For the drag portion of each periapsis passage the solar arrays are canted back from the direction of flow to create a dynamically stable configuration with the center of pressure behind the center of mass of the spacecraft. The design has a margin of 90% with respect to unexpected than.gcs in atmospheric mass density at periapsis. This means that the spacecraft can tolerate an unpredicted change of 90% in the periapsis density without exceeding the heating constraint of 0.76 w/m^2. This level of margin substantially exceeds the level of density fluctuations experienced in the hundreds of periapsis passage during Magellan aerobraking. However, the region where aerobraking will occur on Mars (115 ± 15 km) has not been well characterized on any planet and the additional margin is prudent.

As shown in the MGS Mission timeline of Figure 1, the historical record of global dust storms indicates such

Figure 1: MGS Mission Timeline



global storms can occur during the aerobraking orbital adjustment phase of the mission. It is not the dust itself which is a concern, since there is no evidence that it reaches anywhere near the attitudes at which aerobraking will occur, but the increase in density at the aerobraking altitude associated with the expansion of the atmosphere due to the heating the dust induces. Examination of the record of atmospheric temperature changes during the two global dust storms in 1977 observed from the Viking orbiters provides exampl es of rapid increases in atmospheric temperat ure associated with global storm development. Modelling of these temperature increases including the use of the Mars global circulation model at the NASA Ames research Center indicates that the density at aerobraking attitudes could increase by as much as a factor of ten in a time as short as two days following the start of a major storm. The circulation model results also indicate that for a storm that originates in the southern hemi sphere on Mars, which has been tbc historical pattern, the temperature in the atmosphere of the northern hemisphere will start to increase before the dust itself crosses the equator and move-s into that hemisphere. 'Ibis is of importance for MGS as the periapsis latitude is in the northern hemi sphere at the beginning of aerobraking and remains in that hemisphere for a major portion of the aerobraking time period.

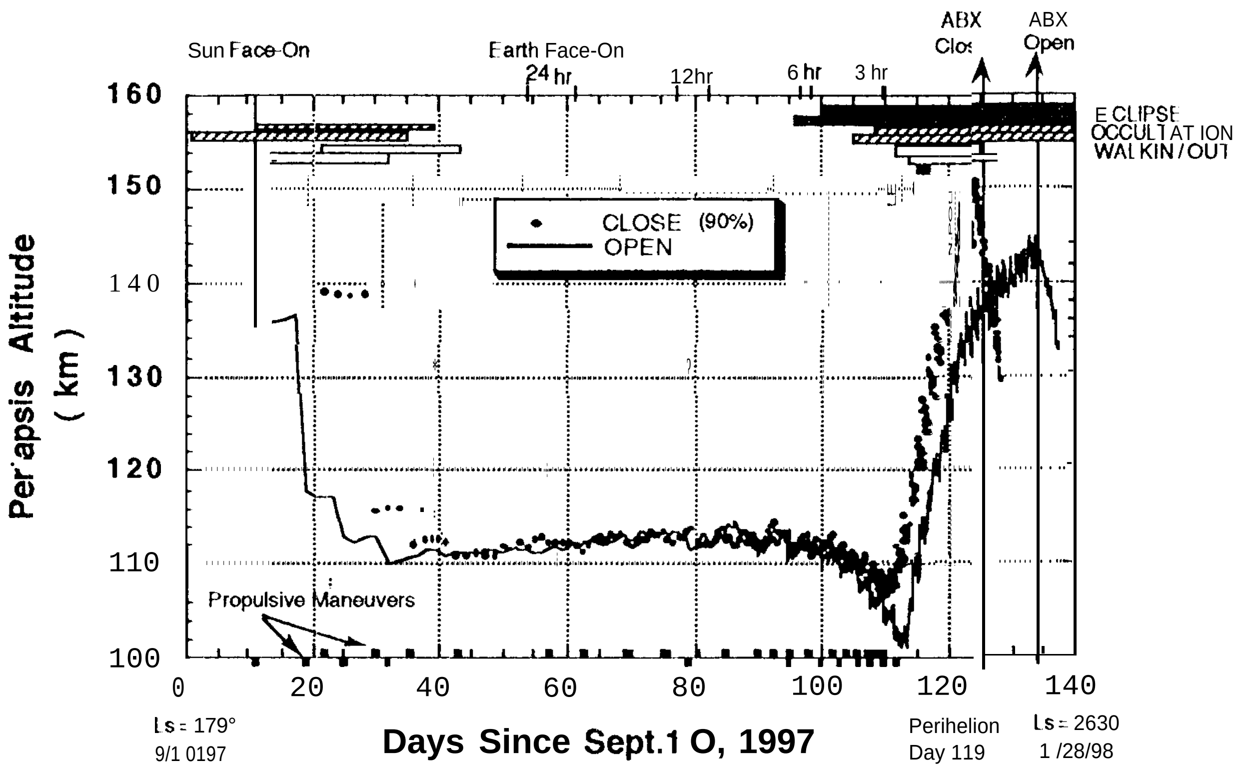
Since the aerobraking altitude is selected based on the anticipated atmospheric densit y at that attitude the occurrence of a global dust storm necessi tates moving periapsis to higher attitude as the storm builds but dots not necessaril y interrupt aerobraking. Anticipating this possible density change will be accomplished using the spacecraft i tsel f, some of the MGS science instruments terrestrial bawd measurements and measurements from the Pathfinder vehicle on the surface of Mars. Doppler tracking of the spacecraft will be nearly continuous during the aerobraking time period and the orbit determination process will provide an estimate of the periapsis atmospheric densit y each orbit, The spacecraft accel erometers may also he able to provi dc densi t y estimates based on the drag induced acceleration imparted to the spacecraft, Images from the Mars Orbiter Camera will be used to examine the planet for evidence of dust storm activity. Spectral measurements from the Thermal Emission Spectrometer will be usc to monitor the atmospheric temperat arc. The spacecraft infrared bawd horizon sensor will also be used to track the time history of atmospheric temperature. From earth, passive microwave measurements of Mars will be conducted from which the trend of atmospheric temperature with time can be derived. The Pathfinder lander will have been on the surface of Mars for five months at the start of MGS aerobraking and the history it can provide of atmospheric opacity and surface pressure will be very valuable in providing an indication of increased dust activity. These many sources of information on the Mars atmosphere will be used in a structured decision process to make judgements about the near term behavior of the atmosphere and the magnitude and direction of small propul sive maneuvers which are used throughout the aerobraking time period to adjust the periapsis altitude.

The four and onc half months of the aerobraking time period have been divided into three sub-phases called walk-in, main and walk-out. In the walk-in phase the orbit periapsis is lowered from the capture orbit altitude of a little over .300 km to the attitude at which aerobraking will occur through a series of four or five propul sive maneuvers as shown in the example contained in Figure 2. The spacecraft will remain at the aerobraking at ti tudc during the main phase for the next three months as the apoapsis altitude is slowly lowered from 57,000 km to about 2000 km and the orbital period is reduced under 3 hours. The fluctuations which can be seen in periapsis attitude in Figure 2 are not the result of time variation in the atmospheric model used but result from variations in the gravity field of Mars. The final three weeks of aerobraking further reduce the apoapsis attitude to 4.S0 km while slowly increasing the periapsis altitude and the descending orbit node location will have rotated from its initial position near 5:45 PM to nearly 2:00 PM. At this point aerobraking is terminated with a maneuver which raises periapsis out of the region of significant drag. Following the completion of aerobraking, Mars gravity calibration measurements arc conducted, final mapping orbit adjustments arc made and the spacecraft and instruments are prepared for the start of mapping which will begin in March 1998. Mapping wilt continue for a full Mars year (687 days) and be followed by a six month Mars relay mission.

MARS RELAY ACTIVITY

The MGS spacecraft carries the Mars Relay system provided to NASA by the French Centre Nationale d'Etude Spatiales. This system will first be used to return data from the Russian '96 lander in the first fcw orbits after the MGS Mars orbit insertion. In order for the MGS orbiter to pass over this lander it may be necessary 10 usc one of the early MGS cruise trajectory correction maneuvers to adjust the MGS arrival time at Mars. A decision on such adjustment will be made following the launch of MGS. The Mars Relay will also be used to support the return of '96 lander data during the MGS mapping mission. 'l'he possibility of providing some relay capability during the MGS aerobraking time period is currently being examined.

Figure 2: Periapsis Altitude Versus Time From Mars Orbit Insertion For The Open And Close Of The Launch Period.



Following the end of the MGS mapping mission there will be a further period of spacecraft operation which will allow the Mars Relay to be used to return data from two small probes the NASA New Millennium Program will send to Mars with the Surveyor 1998 mission. in addition the Mars Relay will serve as a backup to the relay carried by the 1998 Surveyor orbiter for use with the 1998 high southern latitude lander.

MARS SURVEYOR OPERATIONS PROJECT

One of the challenges of the Surveyor Program is to conduct spacecraft system testing, spacecraft flight operations, science instrument operations, navigation, data processing and archiving for multiple spacecraft within an operations budget appreciably smaller that planned for Mars Observer atone. This challenge is being met through the development of the Mars Surveyor Operations Project which will service all the Surveyor missions. In this project the operations activity will be distributed with science instrument operations conducted from the investigator's home institution, spacecraft health and welfare operations at the location of the Project's industrial partner, and mission planing, sequencing, and navigation from the Jet Propulsion 1 Amatory.

'The initial core of this operations project was taken from the MGS operations effort which itself was derived from that developed to support Mars Observer. All of the processes involved in operations have been examined and an organization developed to fit the scale of the. Surveyor Missions making maximum usc of electronic tools. As an example, MGS instrument teams will be able, from their own institutions, to generate commands for their instruments and send them to the spat.ccraft through the Surveyor Operations Project in times a short as a few hours. In this process all the necessary for-matting, constraint checking and machine transfer is done automatically.

MGS will be the first of the Surveyor series to usc the Surveyor operations Project providing an opportunity to test the ncw elements being introduced. When MGS is in i@ mapping phase, support will begin for the system testing of the 1998 Mars Surveyor orbiter and lander which will be launched before MGS completes its mapping mission. The challenge of handling multiple vehicles including a mix of landers and orbiters is significant.

MARS EXPLORATION FUTURE

With the launch of MGS, Mars'96 and Pathfinder in November and December 1996 Mars exploration will begin a new and deeper phase. Global observations will be combined with detailed surface measurement in a process that wit] extend across a decade. 1998 will see the launch of a Surveyor lander and orbiter and an aeronom y orbiter from Japan, The MGS Mars Relay is **the first** element in the building of an infrastructure at Mars which can support multiple missions and a hopeful sign that international cooperation will assist in expanding our understanding of Mars and its hi story.

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