MARS EXPRESS

SPACECRAFT PERFORMANCE SUMMARY

&

SCENARIO FOR 2005 RE-USE
# TABLE OF CONTENTS

1 INTRODUCTION ..........................................................................................................................3

2 MARS EXPRESS MISSION SUMMARY ......................................................................................4
   2.1 MARS ORBIT OPERATIONS CONCEPT ..............................................................................5
   2.2 SPACECRAFT CONFIGURATION .....................................................................................5

3 SPACECRAFT PERFORMANCE ..................................................................................................7
   3.1 ORBIT INDEPENDENT PERFORMANCES ..........................................................................7
       3.1.1 Mechanical ..............................................................................................................7
       3.1.2 Data Handling ........................................................................................................7
       3.1.3 Power .....................................................................................................................7
       3.1.4 Attitude Control ......................................................................................................7
       3.1.5 Operations ..............................................................................................................7
   3.2 ORBIT DEPENDENT PERFORMANCES .............................................................................8

4 GENERAL CONSTRAINTS TO RE-USE OF MARS EXPRESS ..................................................9
   4.1 PLATFORM .......................................................................................................................9
   4.2 PAYLOAD ........................................................................................................................9
       4.2.1 Data Interfaces ........................................................................................................9
       4.2.2 Mounting Interfaces ...............................................................................................9
   4.3 PROPULSION ....................................................................................................................9

5 SCENARIO FOR REUSE OF MARS EXPRESS SPACECRAFT TO PERFORM A EUROPEAN
   SCIENCE MISSION IN 2005 .................................................................................................11
1 INTRODUCTION

This document has been prepared as a guide to the re-use of the Mars Express spacecraft for other science projects. The Mars Express project is currently in the development phase and will shortly begin system integration and testing which will confirm the performances outlined below. The most economical re-use of the Mars Express spacecraft would require acceptance of the performances as listed below; otherwise changes to the hardware and software would force additional development work and testing with the concomitant schedule expansion necessary to achieve the additional work beyond a strict rebuild.

The document provides a brief mission summary to enable the reader to judge the mission related design features which are built into the system and to aid understanding of impacts which may arise by choosing different mission profiles for the Mars Express spacecraft. The basic performances of the spacecraft which should be available for any mission type are listed below followed by performances which may be dependent on the mission type. Finally a short section outlining general constraints for use of the Mars Express spacecraft discusses particular limitations which should be considered in any re-use of the spacecraft.
2 MARS EXPRESS MISSION SUMMARY

The Mars Express Spacecraft will be launched on a Soyuz-Fregat launcher from Baikonur 2 June 2003. A cruise phase lasting approximately 7 months includes the targeting and ejection of a lander shortly before Mars Orbit Insertion which will occur nominally on 26 December 2003. After initial capture in the Martian gravity well a series of manoeuvres are performed to reduce the orbit eccentricity and to change the orbital plane. The final operational orbit is an eccentric near polar orbit with a pericentre altitude of about 300 km and an apocentre altitude of 9300 km giving a period of 7.5 hrs. A schematic view of the mission is given in Figure 1.

Figure 1: Mission Overview.
2.1 Mars Orbit Operations Concept

The Mars Express Spacecraft has been designed based on a “Store and Forward” approach where scientific data is collected in the vicinity of the pericentre portion of the orbit and later transmitted to earth during the apocentre portion of the orbit. To accomplish this, the majority of science measurements are taken in a NADIR pointing mode activated during the pericentre period followed by spacecraft manoeuvres to direct a high gain antenna to earth for dumping the data from a mass storage device. The next orbit of observations then requires the spacecraft to manoeuvre again to start the next cycle.

The orbit operations are planned on a 2 day cycle basis (~7 orbits) and the commands are stored on-board with daily uplinks for modifications and additions. Data dumps are performed when station visibility permits. Occasional spacecraft maintenance activities such as momentum dumping are performed at convenient times not to interrupt science.

This operations cycle has driven the Mars Express spacecraft design architecture and must be considered in any re-use scenarios.

2.2 Spacecraft Configuration

The basic spacecraft layout is shown in Figure 2 where the accommodation of most experiments is arranged on the NADIR pointing face of the spacecraft while the High Gain Antenna is located on an adjacent face.
FIGURE 2  MARS EXPRESS CONFIGURATION

NADIR FACE
(1.5 m x 1.5 m)
3 SPACECRAFT PERFORMANCE

The basic spacecraft performances are listed below with some explanations as needed. The performances are categorised with respect to the influence of the mission orbit.

3.1 Orbit Independent Performances

Typically the maximum performance capability of the spacecraft is given even though it may not be used specifically for Mars Express. Due to reuse from the Rosetta spacecraft there are some cases at unit level where the Rosetta performance was more demanding than Mars Express. The Mars Express Spacecraft performance is broken down in typical sub-systems.

3.1.1 Mechanical

- Maximum Wet Mass = 1190 kg
- Spacecraft Dry Mass with all experiments= 680 kg

3.1.2 Data Handling

- Maximum data transmission= 228 kbps
- Maximum command transmission = 2kbs (link dependent)
- Maximum data storage of 12 Gbits at beginning of Life.

3.1.3 Power

- Maximum Battery Power = 750 Watts
- Maximum Power to experiments = 250 Watts
- Maximum Power Handling capability of Spacecraft (Specification Value)=1500 Watts

3.1.4 Attitude Control

- Spacecraft Pointing Capability
  - NADIR for science operations = 0.05 deg. (95 % confidence not including navigation errors) with stability of 0.005 deg over 30 seconds.
  - Slew rate maximum = 0.15 degrees/second (typical time for 90 deg.~ 15 mn)

3.1.5 Operations

- Autonomous operations: 3000 commands in mission time line ( experiment peak command load of 2 TC/sec)
- Simultaneous operation of all orbiter payload

3.2 Orbit Dependent Performances

In order to judge the peculiarities of the Mars Express mission some performances which are directly attributable to the mission are listed below.

- Total Propulsion Velocity Capacity ~1500 m/s
- On-orbit fuel requirements for momentum dumping and orbit maintenance~ 27 kg.
- Battery Energy = 1000 Watt-hours at 95% DOD (reflects a worst case eclipse cycle of about 95 mn for small fraction of mission)
- Cryogenic radiator temperature ~ 80 Kelvin (with specific attitude constraints in operations).
- Typical observation time with all experiments~ 40 minutes (excluding pre-observation preparations).
4 GENERAL CONSTRAINTS TO RE-USE OF MARS EXPRESS

4.1 Platform

Mars Express has been designed to accommodate a very low level aero-braking environment around Mars as a backup to the nominal mission for orbit lowering. The spacecraft and solar arrays can accept a loading of not greater than 0.3 N/m² during aero-braking however the actual thermal loading on the solar arrays may necessitate an even lower figure. As an example of what is achieved with aero-braking, a 3-month period with 24 hr daily operations will achieve the equivalent of 26 kg of fuel.

The platform EMC design conforms to normal ESA standards (not designed for magnetic cleanliness, not designed for plasma investigations).

A change of launcher from the Soyuz-Fregat may introduce differences in the environments which could require structural or dimensional design changes.

4.2 Payload

The physical accommodation of payload on the Mars Express spacecraft raises other constraints not directly attributable to performance but which are no less important. Any increases in these items will normally require new spacecraft unit designs and/or structure designs and re-qualification work.

4.2.1 DATA INTERFACES

Mars Express accommodates 6 Orbiter instruments with 4 standard OBDH data connections for science data collection (low rate data ~10-80 kbps) and 2 high rate data connections (IEEE-1355 ~ 10 Mbps). There is also a lander communications package which employs a high rate data connection and an additional low rate data collection interface with the lander to support cruise phase monitoring. For commanding, all payloads receive standard OBDH connections. All telemetry and telecommands are formatted in CCSDS standard packets.

4.2.2 MOUNTING INTERFACES

Experiment accommodation volumes vary amongst the instruments, however all but 2 units (which constitute one experiment) are mounted on interior panel walls. The largest dimension for these experiments is approximately 400x400x500 mm. The overall surface area of the NADIR pointing face of Mars Express is approximately 2.2 square meters (1.5 x 1.5 m) however some restrictions for internal mounting exist due to the underlying structure. The experiment accommodations can be seen in Figure 3.

4.3 Propulsion

The Central Propulsion System (CPS) of Mars Express was designed and optimised for Mars Orbit Insertion. The 400 Newton engine and the eight 10 Newton thrusters are accommodated on the same panel of the spacecraft which serves also as the interface to the launcher via a launch adaptor.
Figure 3: Exploded View of Mars Express Spacecraft showing Payload Accommodation
5 SCENARIO FOR REUSE OF MARS EXPRESS SPACECRAFT TO PERFORM A EUROPEAN SCIENCE MISSION IN 2005.

The Mars Express mission will have a number of spare units available after launch which could be used to begin the construction of a second spacecraft. This fact opens an opportunity to perform another science mission in a relatively short time provided that no substantial changes are made with respect to spacecraft performance and the basic resources already defined for the present Mars Express payload.

With the assumption that a second Mars Express spacecraft were to be procured based on the available spares of the original Mars Express and no substantial changes aside from experiment accommodations (which must still fit in the existing volumes) the minimum schedule requirements of such a programme can be estimated and is shown in shown Attachment 1.

In order to accomplish such a planning it is likely that items requiring a long procurement time, such as electronic components, would have to be ordered prior to the programme start perhaps as part of mission studies. One other important point concerning Mars Express procurements is the fact that shutdown of the Globalstar production means that the Solar Array re-use from this program is not possible. A new solar array would have to be procured to specifications similar to the Globalstar specification.
# Schedule Overview for 2005 Science Mission

## Activity Description

<table>
<thead>
<tr>
<th>Activity</th>
<th>Start Date</th>
<th>Finish Date</th>
<th>Data Date</th>
<th>Run Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return from Baikonur</td>
<td>01JAN01</td>
<td>29JUL05</td>
<td>01JAN01</td>
<td>02MAR01</td>
</tr>
<tr>
<td>Mars Express Refurbishment period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake Units Procurement</td>
<td>01NOV01</td>
<td>31OCT02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start manufacture Structure &amp; Propulsion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM Experiment Delivery</td>
<td>01NOV03</td>
<td>31OCT03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procurement of S/C FM Units</td>
<td>01NOV03</td>
<td>31OCT03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EM Experiment Development</td>
<td>01MAR02</td>
<td>31DEC02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Bench S/W Validation</td>
<td>01NOV02</td>
<td>01JUL03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start FM Integration</td>
<td>01NOV03</td>
<td>01JUL03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM System Integration</td>
<td>01NOV03</td>
<td>01JUL03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM Environmental Testing</td>
<td>01JUL05</td>
<td>01JUL05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM Delivery to ESA</td>
<td>01JUL06</td>
<td>01JUL06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESA Launch Campaign margins</td>
<td>01JUL06</td>
<td>01JUL06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Launch</td>
<td>01JUL06</td>
<td>01JUL06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Schedule Overview

- **Early Bar**
- **Progress Bar**
- **Critical Activity**

**Note:**
- All dates are in MMMDDYY format.
- Critical activities are marked with red bars.
- Progress bars indicate the current status of the tasks.
- Early bars represent the planned schedule.

---

© Primavera Systems, Inc.