ESA/SPC(97)40
Att: Annex
Paris, 31 October 1997
(Original : English)

EUROPEAN SPACE AGENCY

SCIENCE PROGRAMME COMMITTEE

MARS EXPRESS Science Management Plan

Delegations will find attached the MARS EXPRESS Science Management Plan.

The SPC is requested to approve the MARS EXPRESS Science Management Plan.

MARS EXPRESS

A European Orbiter and Lander Mission to
Investigate the Interior, Surface and Atmosphere of Mars

SCIENCE MANAGEMENT PLAN

FIRST ISSUE

31 October 1997

ESA/SPC(97)40

MARS EXPRESS MISSION SUMMARY

Scientific Objectives	*Orbiter* to perform high-resolution stereo colour imaging, mineralogical mapping, subsurface sounding, atmospheric sounding and studies of the environment. *Lander Modules* for descent and landing to study the internal structure, meteorology and landing site geology, mineralogy, geochemistry and exobiology.
Model Payload	*Orbiter*: hi-res. stereo colour camera, IR mapping spectrometer subsurface sounding radar, atmospheric sounder and energetic neutral atoms analyser (~120 kg). *Landers*: seismometer/magnetometer, descent/meteorological package, imager, (~6 kg on each of three Network Landers). Suite of imagers and geochemical/mineralogical/exobiological mounted on IDD (~6 kg on fourth Network Lander). Alternatively single Lander including a drill and a suite of geochemical/exobiological instruments (~17 kg).
Launch and Cruise	Launcher: Soyuz class; launch opportunity: May/June 2003. Launch mass: ~1100 kg; direct interplanetary cruise and hyperbolic approach trajectory. Lander Modules independently targeted.
Orbit and Descent	Elliptical orbit: pericentre 300 km, apocentre 8300 km. Period: 5.7 hours; inclination: ~122.6°. Atmospheric entry velocity: 6.4 km/s at 120 km altitude. Atm. descent acceleration: –19 Earth g; descent time: 5 min. Lander impact velocity: <40 m/s; landing ellipse: ~100 km.
Spacecraft	- Orbiter spacecraft with carrier and data relay functions. 3-axes stabilised, dry mass: ~350 kg, propellant: ~500 kg. Available mass for Lander Modules: 150 kg including a combination of: - Several Network Landers: ~40 kg at entry; ~20 kg on surface. - One Exobiology Lander of ~100 kg at atmospheric entry.
Operations	Lander communications (S-band), relay (UHF-band). Data volume: <10 Mb/station/day; for IDD depends on operations. ESA Perth ground station; possibly DLR Weilheim station (if necessary). ESA Mission Operations; ESA Science Operations and Archiving. Operational lifetime at Mars: 1 martian year (687 days).
Programmatics	*Mars Express* is the first flexible (F1) mission of ESA's *Horizons 2000* Scientific Programme with a budget of 150 MAU. ESA will provide a Soyuz type launcher, a carrier Orbiter and the operations. National Space Agencies of Europe are expected to provide up to four Lander Modules. Other international partners could participate at different levels.

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Chapter 1

SUMMARY AND SCOPE

Mars has been an object of fascination for centuries. But only recently has it become possible to visit the planet in order to carry out the detailed scientific exploration, which will reveal the differences between the planets of the Solar System and allow their common origin to be understood.

Spacecraft exploration of Mars started in the 1960's. The first global survey was conducted by *Mariner-9* in 1971, but the most significant and scientifically rewarding mission was *Viking* in 1976 consisting of two orbiters and two landers. Most of the existing environmental models of Mars have been derived from *Viking* data. At present, new missions to Mars have been launched by the US and Russia and soon by Japan. including *Mars Pathfinder*, *Mars Global Surveyor* and the failed *Mars-96* in 1996. *Planet-B* and other *Mars Surveyor* missions in 1998, 2001 and beyond.

As the natural next phase of Mars exploration and following the recommendations of the SSAC Task Force on Mars Exploration (ESA/SPC(97)20, Annex 1) and also the International Mars Exploration Working Group (IMEWG, see note on the next page), to recover the scientific objectives of the lost *Mars-96* mission and the *Intermarsnet* study, the *Mars Express* mission comprises an Orbiter spacecraft capable of carrying up to four Lander Modules.

The Mars Express Orbiter spacecraft represents the core of the mission, being scientifically justified on its own investigations such as high-resolution imaging and mineralogical mapping of the surface, radar sounding of the subsurface structure down to the permafrost, precise determination of the atmospheric circulation and composition, and study of the interaction of the atmosphere with the interplanetary medium, while the Lander Modules are considered a very valuable complement to the mission.

The *Mars Express* Lander Modules may establish the first network of scientific stations on the surface of Mars to study the interior, near-surface, surface and atmosphere of the planet, and as a precursor to more detailed surface exploration (e.g., sample return). With multiple surface stations on Mars. it would be possible to perform seismological and meteorological measurements, in order to infer the internal structure of the planet. the atmospheric circulation and the weather patterns. These long-term investigations will require an operational lifetime of a least one martian year (687 days). Other scientific goals of the *Mars Express* Lander Modules will be to study the morphology and geology of the landing sites, the chemical and mineralogical composition of martian surface rocks and soils, and other physical properties of the surface materials. Also, exobiology (i.e. signatures of life) is one of the main objectives of the mission.

Mars Express is an ESA mission for the orbital and in-situ study of the interior, surface and atmosphere of the planet Mars. The Orbiter spacecraft is developed, operated and fully funded by ESA with the exception of the scientific instruments. To complement and enhance the scientific capabilities of the mission. the Orbiter spacecraft is expected to carry up to four Lander Modules provided by consortia under the auspices of National Space Agencies of ESA member states or international

IMEWG partners. The Science Management Plan, as presented, is consistent with the assumption that up to four Lander Modules may be provided.

The *Mars Express* Science Management Plan outlines the management scheme to be implemented for the Scientific Programme from the Announcement of Opportunity to the post operations and archiving phase. The main areas addressed in the plan are the interfaces with the scientific community via external science teams, participation of scientists in the programme and the science operations, including distribution of, and rights to, scientific data products. In particular, the plan defines the responsibilities of the *Mars Express* Science Working Team, the Orbiter Principal Investigators and the Lander Modules consortia including their scientific investigations throughout the mission phases.

Proposals for scientific investigations for *Mars Express* will be solicited through an ESA Announcement of Opportunity, for the Orbiter instruments and for the provision of the Lander Modules including their instruments. The final selection of the complete scientific payload will be through the ESA Science Programme Committee (SPC) following normal detailed procedures outlined in **Section 3.3**.

Mars Express represents a unique opportunity for Europe to join the other major space faring nations in the scientific exploration of the most Earth-like of the planets in our Solar System. A major contribution with outstanding science is possible at relatively low cost and risk. It is an opportunity not to be missed.

<u>*Note:*</u>

The International Mars Exploration Working Group (IMEWG) was created in 1993 by most of the world's space agencies to define a common strategy for the robotic and human exploration of Mars. It was given the mandate to: (i) produce an international strategy for the exploration of Mars beyond the currently approved missions; (ii) provide a forum for the coordination of future Mars exploration missions; (iii) examine the possibilities for an International Mars Network Mission as the next step beyond the 1996 launch opportunity. The present members of IMEWG (in alphabetical order) and the countries they represent (in brackets) are: ASA [Austria], ASI [Italy], BNSC [United Kingdom], CNES [France], CSA [Canada], DLR [Germany], ESA [Europe], FMI [Finland], IKI [Russia], ISAS [Japan] and NASA [USA].

Chapter 2

MISSION OVERVIEW

2.1 INTRODUCTION

Mars Express is planned to be the first flexible (F) mission of the new and inventive scenario of the ESA long term Scientific Programme *Horizons 2000* and will be launched in May/June 2003. The mission is dedicated to the orbital and possibly in-situ study of the interior, surface and atmosphere of the planet Mars. The mission nominal lifetime is one martian year (687 days).

A mission to Mars was always present in the planning of the Scientific Programme of ESA. In particular, the *Horizon 2000 Plus* plan (ESA SP-1180, August 1995) included the following recommendation: *'In view of the great international interest in the study of Mars, ... ESA participates at a level of a medium-class mission in opportunities that may arise in the international context of Mars exploration.'*

A first opportunity arose with the *Intermarsnet* mission (ESA SCI(96)2), which however was not selected in 1996, leaving a programmatic and scientific vacuum to be filled as soon as possible. In November 1996, the *Mars-96* mission, which carried a large number of European experiments, was lost. To remedy the worsened situation the Space Science Advisory Committee (SSAC), at its April 1997 session, recommended that a high-visibility, low-cost mission be implemented, if possible, with a preferred launch date of 2003.

The mission envisaged by the SSAC for a Study Phase consists of a simple orbiter with, as an option, a lander or a set of landers. The proposal was discussed and agreed in principle at the Science Programme Committee (SPC) meeting of 2–3 June 1997 and again at the SPC Oxford Workshop of 9–11 September 1997. The consensus was that, in order to alleviate the costs to the ESA Member States, the mission should be based on existing payloads, without however excluding new instruments or landers. It was however clear that the *Mars Express* mission would be fully justified even if it should be confined to the Orbiter only.

As described in the present document, *Mars Express* consists of an Orbiter and possibly up to four Lander Modules (LM), which are expected to be deployed on the surface of Mars. A number of possibilities exist for the provision of the Lander Modules, ranging from one large Lander Module focusing on exobiology to four Lander Modules concentrating on network science, and including some intermediate combination. If three or four Lander Modules are proposed, they would form a network of stations to carry out simultaneous measurements of the interior and the atmosphere. However, one of these Lander Modules would concentrate (while still carrying some network science elements) on geological, geochemical and mineralogical studies with a mobile Instrument Deployment Device (IDD) and/or with a drill capable of reaching down to 1.5 m depth and surrounded by a suite of instruments devoted to geochemistry and exobiology. Descent science, consisting of atmospheric measurements during Lander Module descent through the martian atmosphere, and possibly landing site imaging, is foreseen. However, no cruise science will be performed.

Mars Express will be operated as a Principal Investigator (PI) type mission. A balance between Orbiter and Lander Module investigations within the *Mars Express* Science Working Team (MESWT) will be established.

ESA will be responsible for the overall spacecraft and mission design, Orbiter procurement, Orbiter payload integration, Lander Modules integration into the Orbiter, system testing, Orbiter operations, acquisition and distribution of the science data, and preparation of the final data archive.

The Lander Modules, including communications equipment between the Orbiter and the Lander Modules, will be provided by National Space Agencies of ESA member states or by international IMEWG partners. All scientific investigations on the *Mars Express* Orbiter and Lander Modules will be nationally funded through an agency, institute or through an international consortium.

2.2 SCIENTIFIC OBJECTIVES

In the broad context of planetary science, Mars represents an important transition between the outer volatile-rich, more oxidized regions of the accretion zone of the terrestrial bodies (asteroid belt) and the inner, more refractory and less oxidized regions from which Earth, Venus and Mercury accreted. This special position of Mars and its transitional character is also manifested by its size, the degree of internal activity, the age of its surface features, and the density of its atmosphere – properties that are intermediate between those of the large terrestrial planets (Earth, Venus) and the smaller planetary bodies (Mercury, Moon, asteroids).

Although geologically less evolved, Mars is more Earth-like than the other terrestrial planets. Its internal structure is yet unknown although it is commonly accepted that Mars has an iron–rich core of approximately half the planetary radius, a peridotite, relatively FeO-rich mantle and a basaltic crust. The outer layers of the mantle and the crust together are thought to form a rigid lithosphere while the underlying mantle is thought to deform plastically on geological time scales. The state of the core, (partially) liquid or solid, the occurrences and the depth of prominent mantle phase transformations, and the thicknesses of the crust and lithosphere are unknown.

Mars internal evolution, and the exogenic processing of its surface have extended over several billion years. The planet displays a wide variety of surface features formed by exogenic processes whose controlling factors are distinctly different from the corresponding factors on Earth. Also, the morphology and scale of tectonic and volcanic landforms resulting from endogenic processes (controlled by the composition, structure and energy budget of the interior of the planet) are particularly different from the equivalent features on the Earth. All this provides an as yet unexplored set of boundary conditions for most of those fundamental geological processes that we also encounter on our own planet. Consequently, Mars exploration is crucial for a better understanding of the Earth from the perspective of comparative planetology.

The early histories of Mars and Earth clearly show some similarities. Geological observations collected from previous martian orbiters suggest that liquid water was once stable on the surface of Mars. The martian SNC meteorites show the presence of organic molecules suggesting that the ingredients required for the emergence of primitive life may have been present on the surface of the planet. Therefore, microorganisms may have developed until liquid water disappeared from the surface. Since the surface is subjected to permanent UV photolysis, signatures of potential microorganisms must be searched in the subsurface.

The International Mars Exploration Working Group (IMEWG) has developed an international strategy for the future exploration of Mars that addresses the key scientific objectives at Mars and that is consistent with the strengths, interests and constraints of all the participating agencies. The IMEWG recommended that the lost scientific objectives of *Mars-96*, both from orbit and from the martian surface, be recovered at the earliest opportunity.

Orbiter Spacecraft	- Global high-resolution photogeology (incl. topography, morphology, paleoclimatology, etc.) at 10 m resolution - Global spatial high-resolution mineralogical mapping of surface at 100 m resolution - Global atmospheric circulation and high-resolution mapping of atmospheric composition - Subsurface structure at km scale down to permafrost - Surface–atmosphere interactions - Interaction of atmosphere with interplanetary medium
Lander Modules	- Internal structure and dynamic activity - Meteorology and climatology - Landing site geology, mineralogy and geochemistry - Physical properties of atmosphere and surface layers - Exobiology (i.e. search for signatures of life)

Table 2.1: *Mars Express Scientific Objectives*

The scientific objectives of the *Mars Express* mission represent an attempt to fulfill in part the lost scientific goals of the *Mars-96* mission, and also the *Intermarsnet* study, both in terms of orbital and in-situ landing science addressing the interior, subsurface, surface, atmosphere and environment of the planet.

The scientific objectives of the mission are summarized in **Table 2.1**. These objectives were identified by the SSAC Task Force on Mars Exploration (ESA/SPC(97)20, Annex 1), and refined by the *Mars Express* Science Definition Team (SDT).

2.3 MODEL PAYLOAD

The design goal of the Orbiter is to carry up to 120 kg of Orbiter payload (plus up to four Lander Modules). Five investigations have been recommended by the *Mars Express* Science Definition Team for the Orbiter model payload (see **Table 2.2**). This payload addresses all the major science objectives which have been presented in **Table 2.1** for the Orbiter.

The Orbiter payload and the Lander Modules will be open to an Annoucement of Opportunity. The launch date is May/June 2003, 5 months later than the launch of the *Rosetta* mission. The development time is short and resources in the member states from 1999 to 2003 are limited. Three reference experiments from *Mars-96* and two new developments have been used to define mass and power resources for the Orbiter. The three reference experiments had been defined as the highest reflight priorities by the IMEWG after the failure of *Mars-96*. The existence of *Mars-96* spares guarantees that the science goals of these three investigations can be reached within tight budgetary and schedule constraints. Given the short time scale, existing experiments are encouraged to minimize costs, but innovative instruments will be taken into account if they are funded and can show technical readiness.

A list of available instruments for the *Mars Express* Orbiter, either carried by *Mars-96* or new developments, is shown in the **Appendix A.1**. These instruments were proposed in answer to the request for Letters of Intent issued by ESA in June 1997.

MARS EXPRESS ORBITER MODEL PAYLOAD				
Objectives	**Instrument**	**Acronym**	**Mass** (kg)	**Power** (W)
Surface Imaging	High-Resolution Stereo Colour Imager	HSCI	21.4	40
Surface Composition	IR Mapping Spectrometer	IRMS	32.6	42
Atmosphere	Atmospheric Spectrometer	ATSP	42.6	45
Subsurface Sounding	Subsurface-Sounding Radar/Altimeter	SSRA	15.0	60
Environment	Energetic Neutral Atoms Analyser	ENAA	5.0	6
TOTAL MASS			**116.6**	
Design Goal			*120.0*	

Table 2.2: *Proposed Orbiter Model Payload*

Examples of potential instrument payloads for the different types of Lander Modules – Exobiology Lander and Network Landers – can also be found in the **Appendix A.1**.

2.4 SYSTEM REQUIREMENTS

Owing to an innovative, flexible and fast way of implementing the first of the new type of F missions of ESA's Scientific Programme, Industry will be asked to bid for a ceiling price contract to design and build an Orbiter which shall meet the following requirements:

- 3-axis stabilisation with nadir pointing capability.
- A pointing and stability performance compatible with the basic payload needs, as given in the Payload Definition Document (PDD).
- Support a payload of up to 120 kg (to be confirmed during the study), including the normal services, eg. power, data, thermal and pointing.
- On-board data storage of sufficient size to allow storage of scientific data during periods with no communications coverage.
- On-board propulsion sufficient for Mars capture, orbit insertion, station keeping and attitude manoeuvres during a nominal operational period of one martian year (687 days) and possibly for an extension of the mission of another martian year.
- Accommodation of Lander Module data relay transponder.
- The Lander Module carrier function if a composite configuration is selected by the contractor.
- The necessary data to allow navigation during the cruise phase, Mars capture, Mars orbit insertion and Mars orbit maintenance.
- Compatibility with both Ariane-5 in dual launch configuration and one of the Soyuz family of launch vehicles.
- In the case of an Ariane-5 launch the propulsion system for transfer from the Ariane-5 GTO to the Mars transfer orbit.

Up to four Lander Modules are expected to be deployed on the surface of Mars, depending on available resources and on scientific and mission goals. Three possibilities are foreseen:

- A single large Lander Module carrying a drill, and geochemistry and exobiology instruments.
- Up to four smaller Lander Modules forming a network and carrying seismology, meteorology, geology and chemistry instruments, including an Instrument Deployment Device (IDD) on one of them.
- One larger and two smaller Lander Modules combining the previous two objectives.

The Lander Modules may either be inserted simultaneously with the Orbiter (carrier spacecraft scenario) or separately (free flyer scenario) into a Mars transfer trajectory. In the former case the Orbiter shall carry the Lander Modules and provide the navigation function up to the point of release of the Lander Modules. In the latter case, the means for bringing the Lander Modules to Mars and inserting them into the correct descent trajectory shall be provided. Both the Orbiter and the Network Landers lifetime goal is of one martian year (687 days). The exobiology and geochemical investigations could have a more limited duration (e.g., 100 days). The Lander Modules shall be provided by National Space Agencies of ESA member states or by international IMEWG partners. The interface between the Lander Modules and the Orbiter spacecraft shall be defined by the prime contractor and agreed with ESA and the Lander Module providers.

2.5 MISSION SCENARIO

The development of the precise *Mars Express* mission concept will be part of the industrial system studies to be carried out in 1997/1998. The current mission scenario baseline is described hereafter.

The *Mars Express* spacecraft will be launched in May/June 2003 on a Molniya/Soyuz launch vehicle. The expected launch mass is 1100 kg. 2003 represents the best launch window in terms of mass for the foreseable future (see **Table 2.5** as an example of launch mass capability of a given rocket during a number of launch windows to Mars). Two flight elements are foreseen:

- An Orbiter spacecraft carrying remote sensing instrumentation and serving as a communications relay for the Lander Modules.
- Up to four Lander Modules may be deployed on the surface of Mars, depending on available resources and on scientific and mission goals. Three possibilities are foreseen:

  * A single large Lander Module carrying a drill, and geochemistry and exobiology instruments.

  * Up to four smaller Lander Modules forming a network and carrying seismology, meteorology, geology and chemistry instruments, including an Instrument Deployment Device (IDD) on one of them.

  * One larger and two smaller Lander Modules combining the previous two objectives.

In the more likely scenario of the Orbiter spacecraft carrying the Lander Modules from Earth to Mars (rather than the free flyer scenario where each Lander Module travels independently to Mars), the Orbiter will perform a sequence of orbit manoeuvres during the Mars approach phase (from about 10 days from arrival) to deliver one Lander Module (containing the Lander) after the other to hyperbolic entry conditions into the martian atmosphere such that, after dissipation of the arrival energy and descent with a parachute, a suite of prescribed landing points is reached with a landing dispersion of about 100 km.

After delivering the last Lander Module the Orbiter spacecraft will be redirected (about 2 days before arrival) to reach the conditions required for the capture manoeuvre into an initially highly eccentric orbit (apocentre around 120000 km) at Mars. The arrival hyperbola has an inclination of 15° such that the pericentre is placed on the illuminated side of Mars. At the first apocentre the orbit plane is turned by a manoeuvre to reach the final inclination. The apocentre altitude will then be reduced in several steps by manoeuvres at pericentre. This procedure can be carried out with chemical propulsion or with aerobraking techniques. An appropriate trade-off between the two types of manoeuvres will be studied in due time.

As an example, one possible orbit which can be reached within about one week from arrival at Mars and within the propellant budget limit imposed by the launcher performance, is an orbit with an

LAUNCH WINDOWS TO MARS WITH ARIANE-5							
Year/Month	2001/04	**2003/06**	2005/08	2007/09	2009/10	2011/11	2013/12
Launch Mass (kg)	2850	**3300**	2500	2800	2950	2900	3200
Arrival Velocity (km/s)	4.0	**2.7**	2.9	2.6	2.7	2.8	3.4
Flight Time (days)	270	**206**	360	346	304	297	437

LAUNCH WINDOWS TO MARS WITH SOYUZ–MOLNIYA							
Year/Month	2001/04	**2003/06**	2005/08	2007/09	2009/10	2011/11	2013/12
Launch Mass (kg)	1100	**1100**	930	1000	1100	1130	1130
Arrival Velocity (km/s)	3.5	**2.7**	3.0	2.5	2.5	2.8	3.2
Flight Time (days)	230	**200**	210	340	320	300	290

Table 2.3: *Characteristics of Foreseable Launch Windows to Mars*

inclination of 122.6°, a pericentre altitude of 300 km and an apocentre altitude of 8300 km. The orbital period is 5.7 hours. The circularisation of this elliptical orbit could be implemented to improve communications of the Orbiter with the *Mars Express* Lander Modules during the nominal mission or with landers from another partner during the extended mission.

The pericentre of this orbit prescribes a figure of 8 on the surface of Mars in a system rotating with the Sun direction. This means that observations taken at low altitudes near pericentre will find favourable illumination conditions throughout the mission. The orbit is also suited to collect the required volume of data, over the first martian year of operations, from Lander Modules which are placed at not too high latitudes.

During surface observations an attitude strategy will be flown such that the instruments can be pointed towards nadir or to a prescribed direction not far from nadir. The Earth communications are assumed to be done during mission phases in which the observation payload will not be operated (e.g. near apocentre), by turning the Orbiter spacecraft high-gain antenna into the Earth direction. The Orbiter spacecraft will have the necessary data storage capacity and the necessary autonomy for both remote sensing and communications relay operations.

Chapter 3

PROGRAMME PARTICIPATION

3.1 INTRODUCTION

The fast way of implementing the *Mars Express* (F1) mission requires a fast selection of the scientific payload, including the Lander Modules. Indeed, following the recommendation of the SSAC Task Force on Mars Exploration in April 1997 (when *Mars Express* was proposed for the first time), less than one year will pass between the approval of the Science Management Plan and the final approval of the *Mars Express* project by the SPC, while the time between issue of the Announcement of Opportunity (AO) and the payload selection has been compressed to about six months.

This represents an enormous saving of time compared to previous study cycles of medium-size missions of the Scientific Programme (e.g., more than six years between the issue of the Call for Ideas (February 1992) and the payload selection (May 1998) for M3). Likewise, the time between the final SPC approval (November 1998) and launch (June 2003) has been reduced to only four and half years for *Mars Express*, which is comparable to the very tight schedule of the *Giotto* mission and proves that Europe can successfully sustain such rapid mission cycles if flexibility is allowed.

After approval of the Science Management Plan by the SPC, an Announcement of Opportunity will be issued by ESA covering both the *Mars Express* Orbiter investigations and the provision of the Lander Modules, including their scientific payload. Through publication of this *Mars Express* AO, the scientific community will be invited to participate in the *Mars Express* programme by:

- Providing scientific investigations for the *Mars Express* Orbiter – Principal Investigator proposals (see **Section 3.3.1**).
- Providing up to four Lander Modules including their scientific investigations – Consortium Leader proposals (see **Section 3.3.2**).

3.2 SCHEDULE

The *Mars Express* Announcement of Opportunity is planned to be issued by ESA in December 1997. The receipt of all proposals by ESA is due in February 1998.

The AO will be open to the scientific groups within those European Countries which participate in the ESA Scientific Programme and to the scientific groups in the United States of America (via NASA), in accordance with the ESA/NASA agreement on the principle of reciprocity. Scientific groups from other countries (in particular Russia and Japan) are invited to join proposing teams in ESA member states or in the USA (as Co-Investigators).

SCHEDULE FOR MARS EXPRESS AO SEQUENCE	
SPC Approval of Science Management Plan	17–18 November 1997
Issue of AO for Orbiter Payload and Lander Modules including their Payload	2 December 1997
Letter of Intent Due	7 January 1998
All Proposals to AO Due	24 February 1998
Evaluation Phase for All Proposals	end February 1998 – early May 1998
Discussion with Funding Authorities	early March 1998 – early May 1998
Recommendation by Peer Review Committee	early May 1998
SSWG/SSAC Reviews	early May 1998
SPC Selection of Orbiter Payload and Lander Modules including their Payload	28–29 May 1998
SPC Approval of *Mars Express* Project	2–3 November 1998

Table 3.1: *Schedule for Mars Express AO Sequence*

MARS EXPRESS PROGRAMME SCHEDULE	
SPC Approval of *Mars Express* Study	2–3 June 1997
Issue Orbiter Spacecraft ITT	October 1997
Study Phase	December 1997 – September 1998
SPC Approval of *Mars Express* Project	2–3 November 1998
Experiment Interface Document (EID) Freeze	TBD
Design Phase	February 1999 – November 1999
Development Phase	November 1999 – April 2003
Instrument Flight Model Delivery	TBD mid 2002
Launch	May/June 2003
Arrival at Mars	TBD 2004
Landing on Mars	TBD 2004
Orbit Insertion	TBD 2004
End of Nominal Mission	TBD 2006
Archiving Phase (after end nominal mission)	2006 – 2008

Table 3.2: *Mars Express Programme Schedule*

In order to facilitate the flow of information in the scientific community between the different disciplines and the possibility for potential individual instrument providers to get in touch with the appropriate consortia providing the Lander Modules, Letters of Intent (LOI) to ESA will be due shortly after the AO issuance by potential Orbiter and Lander Module Investigators. ESA would then be responsible for advising the potential instrument or Lander Module providers on matters related to on-going activities within the community on the basis of the information acquired via the LOI (see **Section 3.4**).

The schedule for the complete AO cycle and project approval is given in **Table 3.1**. The baseline *Mars Express* programme schedule, following completion of the AO process, is outlined in **Table 3.2**.

Additional solicitations to broaden the further involvement of the scientific community may be issued at a later stage (see **Section 3.5**).

3.3 ANNOUNCEMENT OF OPPORTUNITY

The proposals for the *Mars Express* Orbiter and Lander Modules in response to the AO shall be prepared bearing in mind the scientific objectives of the *Mars Express* programme (see **Table 2.1**) and the current programme definition and constraints (see **Section 2.4**).

3.3.1 Principal Investigators for Orbiter Investigations

Proposals for scientific instruments on the Orbiter spacecraft are solicited via the AO. Each Orbiter investigation shall be led by a single Principal Investigator (PI), the team members participate as Co-Investigators. He/she shall have full responsibility for all scientific aspects of the investigation through launch and subsequent in-orbit operations including scientific data analysis and archiving.

Submission of the proposal shall be done jointly between the PI and an Experiment Manager. The Experiment Manager shall propose a team with appropriate hardware, software and procurement expertise, and demonstrate that an efficient management scheme, especially when many institutes are providing sub-assemblies or sub-systems, can be implemented.

The proposal must show that adequate control can be exerted over all aspects of the programme, including the required financial resources (where appropriate via the relevant Co-Is). As the nominated interfaces to ESA, the PI and the Experiment Manager shall be jointly responsible for ensuring that adequate funding and budgetary control procedures are in place for all aspects of the investigation. No funding from ESA shall be assumed for any part of the programme.

In general, the PI and the Experiment Manager are responsible for ensuring that the complete investigation is implemented and executed within the constraints of the approved *Mars Express* programme. The PI and Experiment Manager form a 'ticket' on which the Orbiter instrument proposal will be judged. Detailed responsibilities of Orbiter Principal Investigators and Experiment Managers are listed in the **Appendix A.2**.

The Co-Investigators will assist the PI and the Experiment Manager in meeting their responsibilities as defined in the team's internal management structure. A PI may delegate specific responsibilities to a Co-Investigator.

The Orbiter PIs shall provide active support to the Communications and Public Relations activities of ESA.

After selection, an Experiment Interface Document (EID) will be established for each Orbiter instrument. The EID will:

- Define the *Mars Express* technical and programmatic requirements (including management and control procedures).

- Specify in detail the interfaces between the PIs, Co-Is, their institutes, national funding agencies, Industry and ESA to cover all aspects of their relationship.
- Specify the planning applicable to each instrument.

The EID will become the formal interface control document and formal reference for all progress reporting and it shall be placed under formal configuration and change control once agreed and signed by the parties involved.

3.3.2 Consortium Leaders for Lander Modules Including Scientific Payload

Proposals for Lander Modules including their scientific investigations are solicited via the AO. For each type of Lander Module (e.g., one large Exobiology Lander Module or a set of several identical Network Landers) one Consortium Leader shall be identified, representing the Lander Module as the formal interface with ESA.

The proposal must show that the Consortium Leader can exert adequate control over all aspects of the development of the Lander Module and its payload, including the required financial resources. As the nominated interface to ESA, the Consortium Leader shall be responsible for ensuring that adequate funding and budgetary control procedures are in place for all aspects of the Lander Module provision. The Consortium Leader shall not assume any funding from ESA for any part of the Lander Module programme.

The Consortium Leader shall establish an efficient management scheme, especially in the case where more than one agency shall contribute to the Lander Module, with appropriate hardware, software and procurement expertise. The Consortium Leader will, however, act as a single point interface between ESA and the Lander Module management.

The proposal shall identify a Payload Manager who is responsible for the overall payload development as required by the development schedule of the Lander Module.

In general, the Consortium Leader is responsible for ensuring that the complete Lander Module development programme is implemented and executed within the constraints of the approved *Mars Express* programme. Responsibilities of Lander Module Consortium Leaders and Payload Managers are listed in the **Appendix A.3**.

Up to four Lander Modules are expected to be deployed on the surface of Mars, depending on available resources and on scientific and mission goals. Three possibilities are foreseen:

- A single large Lander Module carrying a drill, and geochemistry and exobiology instruments.
- Up to four smaller Lander Modules forming a network and carrying seismology, meteorology, geology and chemistry instruments, including an Instrument Deployment Device (IDD) on one of them.
- One larger and two smaller Lander Modules combining the previous two objectives.

In order to keep a balance between the number of Orbiter and Lander Module investigations, a Prime Investigator will be identified, as well as his/her Collaborators, for each type of scientific investigation on-board the Lander Modules (and not for each individual instrument).

Therefore, a Prime Investigator will be responsible for one of the following:

- An investigation necessitating several identical instruments on-board different Network and Exobiology Landers (e.g., seismology, meteorology).
- A highly integrated instrument package combining some deployment mechanism with a suite of relevant instruments (e.g., mobile instrument deployment device focusing on geochemistry and mineralogy on a Network Lander, or a drilling and sampling device together with its suite of geochemical and exobiological investigations on an Exobiology Lander).

Individual instruments or sensors within an integrated instrument package shall be provided to the Prime Investigator by a number of Collaborators (e.g., magnetometer within the seismometer package, or Mössbauer spectrometer within the Instrument Deployment Device [IDD]).

Membership of the Lander Module Prime Investigators in the *Mars Express* Science Working Team (MESWT) is defined in **Section 4.1**. The Lander Module representatives in the MESWT are responsible for the preparation of Lander Module scientific operations, including the preparation and coordination of the scientific data archiving for the Lander Module investigations.

In the same manner as the Orbiter PIs, the Lander Module representatives in the MESWT and the Consortium Leaders shall provide active support to the Communications and Public Relations activities of ESA.

After selection, an Experiment Interface Document (EID) will be established for each Lander Module. The EID will:

- Define the *Mars Express* technical and programmatic requirements (including management and control procedures).
- Specify in detail the interfaces between the Consortium Leader, the Prime Investigators and their Collaborators, their institutes, national funding agencies, Industry and ESA to cover all aspects of their relationship.
- Specify the planning applicable to each Lander Module, including its payload.

The EID becomes the formal interface control document and formal reference for all progress reporting and it shall be placed under formal configuration and change control once agreed and signed by the parties involved.

3.4 SELECTION PROCEDURE

ESA's Director of the Scientific Programme will appoint a Peer Review Committee on the advice of the Solar System Working Group to scientifically evaluate all proposals for Orbiter instruments as well as those for instruments on the Lander Modules. The Peer Review Committee will be chaired by the SSWG Chairman.

When evaluating the instrument proposals, the Peer Review Committee should also rank the Orbiter and Lander Module instruments in a priority order. This ranking would facilitate the funding authorities in assigning priorities, should severe funding problems arise at the time of the payload selection. The schedule for proposal evaluation and selection is shown in **Table 3.1**.

ESA reserves the right to assess and accept (or reject) every instrument proposed on each Lander Module payload package in order to best fulfill the scientific and mission goals. In particular, ESA may add (or replace) an individual instrument of a Lander Module payload package if it enhances the scientific return of the mission within the available resources, provided that such an instrument is funded and technically feasible. This will apply in particular in the event that a relevant instrument proposal is brought to the attention of ESA (through a Letter of Intent) and is excluded from the appropriate Lander Module payload package by the Consortium Leader (see **Section 3.2**).

3.4.1 Proposals for Investigations on the Orbiter Spacecraft

ESA will assess the instrument proposals against technical (in consultation and agreement with Industry), managerial and financial criteria. Attention will be paid to establish an efficient and effective management scheme of the Orbiter PI team. The financial criteria will include both the assurance of adequate funding for the investigation and the impact upon ESA accepting that proposal. A report of this technical/managerial assessment will be provided to the Peer Review Committee (see above).

Both the scientific and technical assessment processes may include meetings with the proposers individually and/or collectively to clarify details. During and as a result of these meetings ESA may recommend modifications of the proposals received to satisfy the global needs of the mission within the technical and financial constraints. In parallel, negotiations with national funding authorities will be conducted.

At the end of the Evaluation Phase and after confirmation of the funding and endorsement by the relevant national authorities, the Peer Review Committee will recommend an Orbiter payload complement (together with the Lander Modules, see **Section 3.3.2**) to the advisory bodies of the Agency. Based on the advice of the SSWG and SSAC, the recommendation will be presented by the Executive to the SPC for approval. Following selection by the SPC, ESA will confirm participation of PIs and Co-Is.

This process will be completed in time to allow the resources allocated to – and interfaces of – each Orbiter instrument to be adequately defined prior to detailed contract with Industry for the Phase B/C/D of the Orbiter. The evaluation criteria for the Orbiter investigations is listed in the **Appendix A.4**.

3.4.2 Proposals for Lander Modules Including Scientific Payload

ESA will assess the proposals against technical (in consultation and agreement with Industry), managerial and financial criteria and their overall impact on the *Mars Express* programme. Attention will be paid to assess the proposed management scheme of the Lander Module consortium. The financial criteria will include both the assurance of adequate funding for the Lander Module and its payload and the impact upon ESA accepting that proposal. A report of this technical/managerial assessment will be provided to the Peer Review Committee, which will scientifically evaluate the Lander Module proposals. Attention will be paid to the scientific objectives of the Lander Module payload being in line with the overall *Mars Express* scientific objectives.

Both the scientific and technical assessment processes may include meetings with the proposers individually and/or collectively to clarify details. During and as a result of these meetings ESA may recommend modifications of the proposals received in order to satisfy the global needs of the mission within the technical and financial constraints. In parallel, negotiations with national funding authorities will be conducted.

At the end of the Evaluation Phase and after confirmation of the funding and endorsement by the relevant national authorities, the Peer Review Committee will recommend a complement of up to four Lander Modules including their payload (together with the Orbiter payload, see **Section 3.3.1**) to the advisory bodies of the Agency. Based on the advice of the SSWG and SSAC, the recommendation will be presented by the Executive to the SPC for approval. Following identification of the Lander Module representatives in the MESWT by ESA's Advisory Bodies at the time of payload selection by the SPC, ESA will confirm membership in the *Mars Express* Science Working Team.

This process will be completed in time to allow the resources allocated to – and interfaces of – each Lander Module to be adequately defined prior to detailed contract with Industry for the Phase B/C/D of the Orbiter. The evaluation criteria for the Lander Module proposals is listed in the **Appendix A.5**.

3.5 FURTHER SCIENTIFIC PARTICIPATION IN THE MISSION

At a later stage, following approval of the *Mars Express* mission by the SPC and full definition of the scope and scientific content of the mission, the scientific community may be invited to participate in the *Mars Express* mission in a number of additional ways:

- **Interdisciplinary Scientist** proposals may be submitted by individuals – in response to a future ESA AO – for specific tasks in support of the multidisciplinary nature of the *Mars Express* scientific objectives.
- **Guest Investigator** proposals may be submitted by individuals – in response to an ESA AO following a successful launch – using the *Mars Express* Orbiter or Lander Module payload (after peer review and in coordination with the relevant PIs) to enhance the overall scientific return of the mission.
- **Series of Workshops** will be organised by the *Mars Express* SWT in preparation of the mission in which relevant Theory Groups and Geoscience Laboratories from a wider Earth and Planetary Sciences community will be invited to participate (see **Section 4.2**).

All the above individuals, together with the Orbiter Principal Investigators and the Lander Module Prime Investigators will have to support a strong ESA Communications and Public Relations effort during all phases of the mission.

3.6 POTENTIAL INTERNATIONAL COLLABORATION

In addition to the provision of Lander Modules, including their instrumentation, as well as of the Orbiter instruments, by National Space Agencies of ESA member states or by international IMEWG partners, consultations with a number of space organisations are on-going to enlarge the scope and participation in the mission. At present, this enlarged potential collaboration includes:

- NASA: provision of Deep Space Network (DSN) to enhance the performance of the *Mars Express* mission. The provision of two New Millenium micro-penetrators (data on water content at 1.5 m depth, heat conductivity and atmospheric pressure and temperature) has been proposed.
- ASI: provision of communications package on Orbiter to relay data from ESA and NASA landers to be launched in 2003 and possibly NASA elements in 2005 in case of an extension of the *Mars Express* mission. This would allow an ESA spacecraft to participate at nominal cost in the foreseen NASA sample return mission to be launched in 2005. Possible use of 64 m antenna to be built at Sardinia ground station.
- DLR: possible use of 30 m antenna at Weilheim ground station to complement the ESA ground segment.
- Russia: provision of certain surface elements inherited from the *Mars-96* mission is under consideration.

Chapter 4

SCIENCE AND PROJECT MANAGEMENT

4.1 SCIENCE WORKING TEAM COMPOSITION

At completion of the *Mars Express* Announcement of Opportunity (AO) process, the *Mars Express* Science Working Team (MESWT) of external scientists will be established.

The *Mars Express* Science Working Team will monitor and advise ESA on all aspects of *Mars Express* which affect its scientific performance. The *Mars Express* Project Scientist will be the Chairman of the MESWT. The external members of the MESWT will be:

- The Principal Investigators with investigations selected for the *Mars Express* Orbiter;
- A subset of Prime Investigators with investigations selected for the *Mars Express* Lander Modules.

Each Orbiter instrument will be considered as a PI investigation.

For the Lander Modules, it is envisaged that the broad scientific disciplines addressed by the Lander Module investigations be represented at the MESWT. The identification of both the Lander Module scientific disciplines and their representatives in the MESWT is delegated to ESA's Advisory Bodies at the time of payload selection by the SPC. In order to secure a balance between Orbiter and Lander Module investigations within the *Mars Express* Science Working Team (MESWT), the number of Lander Module Prime Investigators should not exceed that of the Orbiter Principal Investigators but should be no less than one representative per Lander Module.

ESA will organise regular MESWT meetings, generally to take place at ESTEC. All MESWT members are expected to provide their own funding to attend the MESWT meetings. In addition, there may be meetings of the Orbiter PIs and the Lander Module Prime Investigators, as and if required, to address specific topical problems and to prepare recommendations in their specific areas of investigation that will be discussed and agreed by the MESWT.

4.2 SCIENCE WORKING TEAM TASKS

The tasks of the *Mars Express* Science Working Team are:

- To assist the Project Scientist in maximising the scientific return of *Mars Express* within the established boundary conditions.
- To act as a focus for the interest of the scientific community in *Mars Express*.

These tasks will be achieved by:

- Reviewing the scientific goals of *Mars Express* at regular intervals taking into account recent results, while considering the technical boundary conditions of the Orbiter, the Lander Modules and their payload.
- Advising on the scientific aspects of the development of the *Mars Express* Orbiter and Lander Modules instrumentation.
- Establishing a baseline payload operations timeline based on the scientific objectives of *Mars Express*.
- Participating in the major project reviews.
- Performing specific tasks as needed during the project's development.

The MESWT will review the tasks and activities of the *Mars Express* Science Operations Centre (see **Section 5.3**). In particular, the MESWT will be responsible for:

- Optimising the science return from a science operations point of view.
- Advising on the development of the science ground segment including the *Mars Express* Science Operations Centre with particular reference to the payload operational scenario, software, ancillary data products and the *Mars Express* science data base and archive for both the Orbiter and the Lander Modules.

The MESWT will organise a series of workshops (after mission approval and in preparation of the mission) in which relevant Theory Groups and/or Geoscience Laboratories from the Geoscience community at large will be invited to participate in order to become acquainted with Mars science and to provide any possible support to maximise the scientific return of the mission.

4.3 THE PROJECT SCIENTIST

The ESA *Mars Express* Project Scientist will be the Agency's interface with the Orbiter Principal Investigators and the Lander Module Prime Investigators for scientific matters. Within ESA, he will liaise with the *Mars Express* Project Manager until completion of the satellite in-orbit commissioning, and thereafter with the Mission Operations Manager.

During all phases of the Project, the Project Scientist (PS) will coordinate all scientific issues with the Project Team. In particular, the Project Scientist will advise the ESA Project on technical matters when they affect scientific performance. During the development and operational phases, the Project Scientist will monitor the state of implementation and readiness of the instrument operations and data processing infrastructure. After the completion of the in-orbit operations the Project Scientist will coordinate the creation of the scientific products, their archiving and distribution to the scientific community.

The ESA Project Scientist will act as the Chairman of the *Mars Express* Science Working Team (MESWT), and as such coordinate its activities (see **Sections 4.1** and **4.2**).

The ESA Project Scientist will assume responsibility for management of the *Mars Express* Project at a suitable time after launch.

4.4 THE PROJECT TEAM

ESA will maintain a *Mars Express* Project Team, directed by a Project Manager, until completion of the satellite in-orbit commissioning phase. ESA, via the Project Manager and his Project Team, will retain overall responsibility for the mission.

ESA will embark on a procurement approach for *Mars Express*, different from previous ESA scientific missions. This new approach will be developed over the Study Phase of the mission, but it is expected that more tasks will be delegated to industrial contractors than in previous ESA scientific missions. Notwithstanding this fact, the Project Team will control the process of definition of mission requirements and payload interfaces, and will finally be responsible for the selection of a Prime Contractor and a preferred spacecraft design.

With respect to the Orbiter and Lander Module Investigator teams, the Project Team will be responsible for the procurement of the Orbiter (with the exception of the instruments), instrument integration into the Orbiter/integration of the Lander Modules, system testing, launch and orbiter operations, and acquisition and transmission of the Orbiter and Lander Modules data to the Mission Operations Centre. The Mission Operations Centre will distribute the scientific data to the relevant Orbiter and Lander Module Investigator teams.

The scientific payload will have been selected prior to the Design Phase of the mission. The ESA Project Team will monitor the development of the instruments until final sign-off of the EID by all parties. This milestone will be achieved towards the end of the spacecraft Design Phase. Following this the spacecraft Development Phase will commence, during which the ESA Project Team will monitor the instruments adherence to the agreed Development Phase and schedule.

The Project Team will monitor and control the work of the *Mars Express* Orbiter industrial contractor(s), and determine the launch date. During the Development Phase of the mission, the Project Team will also monitor the development of the instruments, and ensure their readiness by monitoring the adherence of development plans to agreed-to schedules. In addition, the Project Team will monitor and control all interface specifications; these include technical specifications between the Orbiter instruments, the Orbiter and the Lander Modules, as well as data and information exchange specifications among all parties involved (ESA, Orbiter PIs, Lander Module Consortium Leaders, and Industry). Within the scope of this procurement approach, the Project Team may decide to delegate the execution of all or some of the above tasks to industrial contractors.

4.5 MONITORING OF INSTRUMENT DEVELOPMENT

ESA will monitor the progress of the design, development and verification of all *Mars Express* scientific instruments. The Orbiter PIs and Experiment Managers, and the Lander Module Payload Manager and Prime Investigators will have to demonstrate to ESA in regular reports and during formal reviews compliance with the scientific mission goals, the spacecraft system constraints, the spacecraft interfaces and the programme schedule as defined in the mutually agreed Experiment Interface Document (EID).

development of the Lander Modules will undergo reviews and be controlled by ESA in a similar way as the Orbiter development. The technical and programmatic compliance will be monitored by a dedicated engineer of the ESA *Mars Express* Project Team.

Chapter 5

OPERATIONS AND SCIENTIFIC DATA

Mars Express will be operated as a Principal Investigator (PI) type mission. From the operations point of view, a Lander Module will be treated as a PI instrument.

The *Mars Express* ground segment will be defined during the mission Study Phase, however it is expected to consist of two major elements: the *Mars Express* Mission Operations Centre (MEMOC) and the *Mars Express* Science Operations Centre (MESOC). The combination of these two elements may be addressed to reduce cost.

The primary responsibility for developing the payload operations strategy for the *Mars Express* Scientific Mission will be with the *Mars Express* Science Working Team (see **Section 4.2**).

5.1 MISSION OPERATIONS

ESA will conduct the Mission Operations of the *Mars Express* mission via the Mission Operations Centre. The basic operations are classified as:

- Orbiter spacecraft operations consisting of mission planning, spacecraft monitoring and control and all orbit and attitude determination and control. This in particular comprises the targeting and delivery of the Lander Modules.
- Support to Orbiter scientific instrument operations and Lander Module operations. The Orbiter instrument operations and the Lander Module operations as a whole will be under the responsibility of the Orbiter and Lander Module Investigators.

Mission operations commences at separation of the *Mars Express* spacecraft from the launcher and continues until the end of the mission, when ground contact to the spacecraft is aborted. Mission Operations will be precisely defined during the Study Phase in 1998, but will include the following tasks:

- Mission planning
- Spacecraft monitoring and control
- Orbit and attitude determination and control
- On-board software maintenance
- Operations support for the Orbiter experiments
- Operations of the Lander Module relay link
- Distribution of scientific data.

The prime ground station for *Mars Express* will be the 32 m X-band station at Perth (Australia) which is currently being built for *Rosetta*. In this case, the use of the ground antenna will be in time-sharing with *Rosetta*, therefore availability of a second (non-ESA) ground station in Europe (30 m Weilheim station or 64 m Sardinia station) would be desirable to dump payload telemetry data. Also, full use of the DSN network is under evaluation with NASA.

Local support centres for the Lander Module instruments may be implemented under responsibility of the Consortium Leaders. Distribution of the science data from the investigations on the Lander Modules to the ESA Archive will be the responsibility of the Lander Module Prime Investigators. For ESA the interface to each type of Lander Module is handled similarly to a PI instrument.

5.2 MISSION OPERATIONS CENTRE

It is expected that the *Mars Express* Mission Operations Centre (MEMOC) would be responsible for the Orbiter spacecraft operations as well as for providing support for the Lander Module operations and all real time contacts with the various spacecraft and payload, the overall mission planning, flight dynamics and Orbiter and Lander Module payload data distribution. In addition, the MEMOC will:

- Directly supply the Orbiter and Lander Module Investigators with raw science telemetry from their respective instruments, housekeeping and relevant auxiliary spacecraft data in an agreed format over communication links in near real time;
- Provide the Science Operations Centre with a subset of payload data;
- Be responsible for the data lines within Europe and to one of the gateways at a NASA DSN facility if required (e.g., Madrid);
- Perform anomaly checks (out of limit checks) for a set of parameters for both spacecraft and payload in real time, and to notify the Science Operations Centre on payload anomalies;

In general, the MEMOC follow a time line agreed with the MESOC and not have to react in real time. This means that nominally no real time responses to experimenter requests are required. All command sequences and science operation timelines shall be prepared in advance by the science operations team. This means that under nominal conditions no experiment adjustments will be foreseen, after the verification and commissioning phase and as long as there are no anomalies and emergencies reported or declared.

5.3 SCIENCE OPERATIONS CENTRE

It is expected that the *Mars Express* Science Operations Centre (MESOC) would be responsible for the Science Operations of the mission which include the following functions and responsibilities:

- Optimising the science return from the *Mars Express* mission by defining and implementing an efficient and cost-effective science ground system.
- The definition of scientific operations for all mission phases.
- Preparation of martian environmental models (atmosphere and surface), in collaboration with specialists from the Orbiter and Lander Module Investigator teams.
- Provision of science-related inputs (and updates) to the Flight Operations Plan (FOP).
- Planning and implementation of instrument operation schedules and command sequences as inputs to the FOP.
- Coordination and pre-checking of command sequences generated by the Orbiter and Lander Module Investigator teams for the operation of their payload before submission to the MEMOC.

- The analysis (with Orbiter and Lander Module Investigator teams support) of all mission critical science data necessary for spacecraft navigation, orbit insertion, Lander entry, descent and landing, and for martian environmental hazard assessment.
- Creating together with the Orbiter and Lander Module Investigators at regular intervals or for mission highlights a summary of the main scientific results.
- The preparation of guidelines for science data archiving and – supported by the Orbiter and Lander Module Investigator teams – the creation of the *Mars Express* Scientific Data Archive (MESDA).
- Making pre-processed data and the *Mars Express* Scientific Data Archive available to the scientific community in accordance with approval procedures and schedules as defined in the EID.

Most of these Science Operations tasks will be the responsibility of the Orbiter and Lander Module Investigator teams, coordinated by the Project Scientist (with additional ESA staff support) and the MESWT.

The staffing of the MESOC should be minimised by ESA to reduce costs, and a frequent turnover of the staff provided by the Orbiter and Lander Module Investigator teams is to be expected. Consequently, continuous communications links will have to be maintained with the involved national scientific organisations, which are represented by the Orbiter and Lander Module Investigators, via Internet. In this way, electronic communications, conferencing and consultations of the Orbiter and Lander Module Investigators can be obtained in real time, with special emphasis on ad-hoc mission observation and deployment campaigns and on public relations events.

The MESOC would conduct the scientific operations not only during the complete nominal mission of one martian year (687 days), but also if the mission duration is extended for another martian year.

5.4 SCIENTIFIC DATA ARCHIVE

The *Mars Express* data rights will follow the established ESA rules (ESA/C(89)93). Therefore all scientific data obtained during the full mission duration will remain proprietary of the Orbiter and Lander Module Investigator teams for a period of up to 6 months after they have been received from ESA. After this period, the scientific data products (in a reduced and calibrated form) from the mission will become accessible by the scientific community via Internet. However, the scientific data that ESA considers useful for its Communications and Public Relations effort will be made immediately available on the World Wide Web.

The Science Operations Centre will prepare the final *Mars Express* Scientific Data Archive (MESDA) within one year of the receipt of the complete data sets from the individual *Mars Express* Orbiter and Lander Module science investigations. Based on current technology (and IMEWG recommendation on standards for scientific data of future missions to Mars), the archive would be distributed as a set of CD-ROMs based on the NASA Planetary Data System (PDS) standard.

ESA will have – with the knowledge of the Orbiter and Lander Module Investigators and Team Members – unlimited access to all mission data being obtained, processed and analysed before archiving, for the sole purpose of Communications and Public Relations.

5.5 COMMUNICATIONS AND PUBLIC RELATIONS PLAN

The *Mars Express* mission will attract much public interest. Hence, the importance of careful advance planning of Communications and Public Relations activities. Each Orbiter and Lander Module Investigator must provide material for public relations and other public communications on the available electronic networks (e.g., World Wide Web) in real time. Dedicated media and communications experts will coordinate such activity.

During the Development Phase of the mission, ESA will set up a Web home page on the *Mars Express* mission as an information tool for the scientific community and the general public. After launch, a more elaborated home page will include the latest news on the mission as well as preliminary scientific results obtained by the Orbiter and the Lander Module instruments as soon as they become available.

ESA will have overall responsibility for planning and carrying out Communications and Public Relations (CPR) activities related to *Mars Express*. CPR activities related to the Lander Modules will be coordinated by ESA with the relevant consortium providing the respective Lander Modules. A general outline of CPR activities will be included in the AO in the form of a Communications and Public Relations Plan (CPRP). This plan must be formally agreed and adhered to by the Orbiter PIs and Lander Module Consortium Leaders at the time of selection. However, for the definition and detailed implementation of the CPRP, ESA will make use of professional communications and public relations experts, which will be selected at an appropriate time of the mission. These experts will work under ESA supervision and in full coordination with the scientific individuals responsible for the mission (Project Scientist, Orbiter and Lander Module Investigators).

The active cooperation of all scientists involved in the *Mars Express* mission is essential for the success of the related CPR activities. For this purpose, the Project Scientist will initiate and identify opportunities for publishing project-related progress reports and scientific results. CPR materials suitable for release to the public will be provided by the members of the MESWT upon their own initiative or upon request from the Project Scientist at any time during the development, operational and post-operational phases of the mission. Indeed, as noted in **Appendix A.2**, the PIs have the obligation to supply ESA with such materials. The exact nature of these materials, if not specified in the CPR Plan, is to be defined at the appropriate time.

Chapter 6

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Chapter 7

ACRONYMS

AO	Announcement of Opportunity
DSN	Deep Space Network (NASA)
Co-I	Co-Investigator
CPR	Communications and Public Relations
CPRP	Communications and Public Relations Plan
EID	Experiment Interface Document
EGSE	Electronic Ground Support Equipment
ESA	European Space Agency
ESOC	European Space Operations Centre
ESTEC	European Space Research and Technology Centre
FOP	Flight Operations Plan
IDD	Instrument Deployment Device
IDS	Interdisciplinary Scientists
IMEWG	International Mars Exploration Working Group
ITT	Invitation to Tender
LM	Lander Module (including Lander and descent systems)
LOI	Letter of Intent
MGSE	Mechanical Ground Support Equipment
MEMOC	Mars Express Mission Operations Centre
MESWT	Mars Express Science Working Team
MESDA	Mars Express Scientific Data Archive
MESOC	Mars Express Science Operations Centre
NASA	National Aeronautics and Space Agency
PDD	Payload Definition Document
PDS	Planetary Data System (NASA)
PI	Principal Investigator
PS	Project Scientist
SDT	Science Definition Team (Study Phase)
SMP	Science Management Plan
SPC	ESA's Science Programme Committee
SSAC	ESA's Space Science Advisory Committee
SSWG	ESA's Solar System Working Group
TRP	Technology Research Programme (ESA)

Appendix A

APPENDICES

A.1 POTENTIAL INSTRUMENTS FOR ORBITER AND LANDER MODULES

A list of available instruments for the *Mars Express* Orbiter, either carried by *Mars-96* or on-going new developments, is shown on the **Table A.1**. These instruments were proposed by a number of Member States Delegations to the SPC in answer to the request for Letters of Intent issued by ESA's Director of the Scientific Programme in June 1997. The first five instruments of **Table A.1** are compatible with the Orbiter model payload as defined by the *Mars Express* SDT (see **Table 2.2**).

Up to four Lander Modules are expected to be deployed on the surface of Mars, depending on available resources and on scientific and mission goals. Three possibilities are foreseen:

- A single large Lander Module carrying a drill, and geochemistry and exobiology instruments.
- Up to four smaller Lander Modules forming a network and carrying seismology, meteorology, geology and chemistry instruments, including an Instrument Deployment Device (IDD) on one of them.
- One larger and two smaller Lander Modules combining the previous two objectives.

Examples of potential instrument payloads for the different types of Lander Modules are indicated in **Table A.2** for the Exobiology Lander and in **Table A.3** for the Network Landers, as suggested by the consortia. In case of a network of four identical Lander Modules, three of them would carry the same scientific instruments (payload A on **Table A.3**) focusing on network science (e.g., seismology, meteorology) while the fourth one would have instruments (payload B on **Table A.3**) concentrating on the characterisation of the landing site (e.g., geochemistry and geology on an IDD), and would retain simplified network science instruments.

A.2 RESPONSIBILITIES OF PRINCIPAL INVESTIGATORS AND EXPERIMENT MANAGERS

The responsibilities of the Orbiter Principal Investigators (PI) shall include, but are not necessarily limited to, the following:

- Management:

  - Take full responsibility for the investigations at all times and to retain full authority within the instrument team over all aspects related to instrument procurement and execution of the

AVAILABLE INSTRUMENTS FOR THE MARS EXPRESS ORBITER						
Instruments	**Acronyms**	**Kg**	**W**	**Investigations**	**Characteristics**	**SPC**
High-Res. Stereo Camera	HRSC	21.4	40	Topography, photometry	10 m resolution	D
IR Mapping Spectrometer	OMEGA	32.6	42	Rock signatures	0.5–5.2 μm range	F, I
Planetary Fourier Spectrometer	PFS	42.6	45	IR sensing of atmosphere	3D temp. and press. fields	I, E
Subsurface-Sounding Radar/Altimeter	SSRA	15.0	60	Permafrost Regolith, Basement	New instrument	D, I
Energetic Neutral Atoms Package	ENAA	5.0	6	Upper atmosphere Solar Wind	New instrument	S, SF
Atmospheric Sounder	ATS	12.0	15.0	Thermal mapping	New instrument	UK
Spectrometer for Atmospheric Sounding	SPICAM	27.5		Atmospheric composition and structure	Solar and stellar segments of instrument	F, B
Radio Science	RSE	–	–	Constraints on Mars geodesy and interior	No additional hardware required	D, I
Magnetometer and Electron Analyser	MAREMF	8.9		Magnetic field in plasma environment	2 fluxgate magnetom. 4 nT resolution	A, S
Energy-Mass Ion Analyser and Neutral Detector	FONEMA	6.2		Structure, dynamics & origin of plasma near Mars	3D distribution functions of hot ions	UK
Ionospheric Ion Mass Spectrometer	DIMIO	4.7		Dynamics of ionosphere and magnetosphere	Omni-directional spectrometer	F
Plasma Wave Detector	ELISMA	11		Waves generated by sandstorms and lightning	Electric & magnetic fields sensors, Langmuir probe	F
Detector of Low Energy Charged Particles	SLED-2	3.0		Energetic particle radiation, low energy cosmic rays	Includes four ion and one electron telescopes	IRL

Table A.1: *Available Instruments for the Mars Express Orbiter*

MARS EXPRESS EXOBIOLOGY LANDER MODEL PAYLOAD				
Objectives	**Instrument**	**Acronym**	**Mass** (kg)	**Power** (W)
Organic Geochemistry	Gas Chromatography incl. Pyrolysis incl. Homochirality		5.0	
	Mass Spectrometer			
Inorganic Geochemistry	α-P-X Spectrometer	APX	0.9	
	Mössbauer Spectrometer	MOS		
Imaging Systems	Stereo Camera incl. Microscopy		2.5	
	Mechanisms			
Network Science	Seismometer (3-axes)	SIM	1.7	
	Meteorology Package	MET		
Subsurface Sampling	Drill		5.0	
Contingency ($\star$)			1.9	
TOTAL MASS			**17.0**	
($\star$) may include: Raman Spectroscopy, Polarimeter for Chirality.				

Table A.2: *Proposed Exobiology Lander Model Payload*

MARS EXPRESS NETWORK LANDER MODEL PAYLOAD A				
Objectives	**Instrument**	**Acronym**	**Mass** (kg)	**Power** (W)
Interior Structure	Seismometer (3-axes)	SIM	1.83	
	Magnetometer	MAG	0.20	
Atmospheric Physics	Atmospheric Structure and Meteorological Package	ATMIS	1.10	
Geology	Panoramic Camera	PAC	0.85	
	Electric Field Experiment		0.07	
Positioning	Accelerometer + Inclinometer		0.18	
Boom	For ATMIS and MAG		0.35	
Contingency			1.00	
TOTAL MASS			**5.58**	

MARS EXPRESS NETWORK LANDER MODEL PAYLOAD B				
Objectives	**Instrument**	**Acronym**	**Mass** (kg)	**Power** (W)
On the Lander:				
Geology	Panoramic Camera	PAC	0.85	
Interior Structure	Seismometer (1-axis)	SIM	0.75	
Meteorology	P and T Sensors	MET	0.30	
Positioning	Accelerometer + Inclinometer		0.18	
On the IDD:				
Geochemistry	α-Proton-X-ray Spectrometer	APX	2.50	
	Mössbauer Spectrometer	MOS		
	Proton Forward Scattering Spectrometer			
Mineralogy	Close-up Imager	CUI		
Nanokhod	Instrument Deployment Device	IDD		
Contingency			1.00	
TOTAL MASS			**5.58**	

Table A.3: *Proposed Network Lander Model Payload*

programme. In this context the PI shall be able to make commitments and make decisions on behalf of all other participants in the instrument team.
- Establish, together with his/her Experiment Manager, an efficient and effective managerial scheme which will be used for all aspects of the instrument programme.
- Define the role and responsibilities of each Co-Investigator (Co-I).
- Identify (by name) key team members responsible for science management, technical management and operational management.
- Organise the effort, assign tasks and guide other members of the team of investigators.
- Provide the formal managerial interface of the instrument to the ESA Project Office and support ESA management requirements. This will entail providing material for and participation in instrument progress reviews and spacecraft and mission programme reviews. In addition, other management requirements (e.g. change procedures, product assurance etc.) will be defined in the EID.

• Science:

- Attend meetings of *Mars Express* SWT to report on instrument development, and to take a full and active part in their work. This will include specific reviews to assess the instrument scientific capability with respect to the performance defined in the proposals in response to this AO.
- Ensure adequate calibration analysis of all parts of the instrument both on ground and also in orbit.
- Support the *Mars Express* Science Operations Centre in the definition of the Science Operations.
- Participate in the definition of the payload operations timeline.
- Exploit to full depth the scientific results of the mission.
- Provide the reduced and calibrated scientific data sets from his/her instrument in a useable form to the Science Operations Centre for inclusion in the *Mars Express* Science Data Archive.
- Provide through all mission phases adequate and active support to the public relation activities of ESA.

• Hardware:

- Define the functional requirements of the instrument and its ancillary equipment (e.g. MGSE, EGSE).
- Ensure the development, construction, testing and delivery of the instrument. This shall be in accordance with the standards, technical and programmatic requirements outlined in the AO including its Annexes and subsequently reflected in the approved Experiment Interface Document.
- Ensure adequate calibration of all parts of the instrument both on ground and also in orbit.
- Ensure that the designs and construction of the instrumentation, and its development test and calibration programmes are appropriate to the objectives and lifetime of the mission, and reflect properly the environmental and interface constraints under which the instrumentation must operate.
- Provide any data storage memories and/or instrument dedicated data handling capability that are required for the instrument.
- Ensure that all procured hardware is compliant with the requirements as defined in the EID, through participation in technical working groups and control boards as requested (e.g. cleanliness control board) and to ensure that the hardware allows system level performance compatibility to be maintained.
- Provide overall documentation during the project as defined in the EID.

- Software:
  - Ensure the development, testing and documentation of all instrument specific software (e.g. necessary for the control, monitoring, testing, simulation, operation, and data reduction/analysis etc.) in accord with procedures and schedules as defined in the EID.
  - Ensure the delivery of such instrument specific software and its documentation including user manuals to the Science Operations Centre in accord with procedures and schedules as defined in the EID.
  - Support the instrument specific software integration and operation activities at the Science Operations Centre.
  - Ensure the development, testing, documentation and delivery of on-board software, and software required during instrument system level tests in the real-time or off-line mode including auxiliary software (individual EGSE and interfaces) as defined in the EID.
  - Maintain and update all software for the duration of the mission including a post-operations (archiving) phase.

- Product Assurance:
  - Provide product assurance functions which are compliant with the requirements of the EID.

- Payload Operations:

Operational phases include pre-launch activities (e.g. instrument software design and development. instrument calibrations), nominal operational phase and post-mission phases with a breakdown as follows:

(a) Pre-launch phase until launch minus two years;
(b) Full operational phase from launch minus two years until arrival and landing at Mars and one martian year operations on its surface and in orbit. Extended mission TBD if approved. One should however, note that cruise science is not planned en route to Mars. There might be some hibernation period for the Orbiter and the Lander Modules in case of a global dust storm for example (the Lander Modules arrive on a hyperbolic trajectory following release from the Orbiter before orbit insertion) and the actual science operations phase will be defined as one martian year (687 days) of operations on the surface and in orbit (until TBD 2006).

The PI for an Orbiter instrument will be responsible for:

  - Supporting all operational phases by providing the necessary manpower and/or expertise (training) to the *Mars Express* Project Team, and supporting the Science Operations Centre with expertise. The level of support shall be defined with the ESA Project Office and will be indicated in the EID.
  - Making the Experiment Ground Support Equipment (EGSE) including software available at Science Operations Centre during critical mission phases to enable real-time scientific data analysis.
  - Supporting operations through his/her expertise including resolution of anomalies and malfunctions of the instrument including recalibrations, etc., as required.

- Finances:
  - Ensuring (through his/her Co-Is, if necessary) that adequate funding is available at the required time(s) for all aspects of the instrument and its support.

- Communications and Public Relations:
  - The Orbiter PIs shall provide active support to the Communications and Public Relations activities of ESA.

A.3 RESPONSIBILITIES OF CONSORTIUM LEADERS AND PAYLOAD MANAGERS

The responsibilities of Lander Module Consortium Leaders and Payload Managers are the same as those of Orbiter Principal Investigators and Experiment Managers respectively, however, they should also coordinate the development of the different instruments and sensors on-board the Lander Modules and supervise the delivery of the instrumentation to the Lander Modules. In addition, Consortium Leaders and Payload Managers should observe the Planetary Protection rules established by the COSPAR, while monitoring the integration of the Lander Modules and their instruments.

A.4 EVALUATION OF ORBITER PAYLOAD PROPOSALS

The selection criteria for individual Orbiter instrument proposals will comprise the following (not in a particular order):

- Scientific compatibility with global mission objectives of *Mars Express*.
- Originality with regard to current and planned missions to Mars (1996–1998–2001 opportunities).
- Merit of specific scientific objectives of proposed investigation.
- Ability of proposed instrumentation to satisfy its scientific objectives.
- Demonstrated technological feasibility, readiness and development status of the proposed Orbiter instrumentation.
- Reliability and space qualification of proposed instrumentation (especially previous space heritage of detectors and other sub-systems).
- Technical compatibility with available spacecraft resources and mission constraints.
- Operational constraints and complexity.
- Adequacy of proposed data handling plan.
- Competence and experience of the team in all relevant areas (e.g. science, management, space technology, proposed techniques, software development and technology etc.)
- Adequacy of proposed management scheme (including organigramme, Principal Investigator, Experiment Manager, Co-Investigators, etc.) to ensure a timely execution of Orbiter instrument development and associated tasks and post launch support.
- Adequacy of human resources and institutional support to ensure a timely execution of instrument development and associated tasks.
- Previous experience in managing a spacecraft instrumentation programme.
- Credibility and compliance of costing of proposed development programme.
- Financial impact upon ESA of proposed instrumentation.
- Assurance of adequate funding for proposed Orbiter instrumentation.

For the overall integrated complement of the payload for *Mars Express* Orbiter instruments, the selection criteria will include:

- Results of the evaluation of the individual proposals on the basis of the evaluation criteria listed above.
- Overall scientific merit of the complete payload with respect to meeting the *Mars Express* scientific objectives.
- Technical compatibility with available spacecraft resources and mission constraints.
- Compatibility with programme constraints.
- Assurance of adequate funding.

A.5 EVALUATION OF LANDER MODULE PROPOSALS

The selection criteria for Lander Module proposals (including their instrumentation) will be similar to that of Orbiter payload proposals. However, the Lander Module proposals should clearly show that the Consortium Leader will be supported by a Payload Manager for the integration of all the instruments on-board the Lander Modules. Each Lander Module Prime Investigator will bear the overall responsibility for his/her instrument set or package, including those individual instruments or sensors to be supplied by his/her Collaborators.