Final Report Abstract

NETLANDER 2005
Lander Network to Mars

ESA-ESTEC Contract No 12722/98/NL/JG

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FINNISH METEOROLOGICAL INSTITUTE

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Appendix 3 to
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ESA STUDY CONTRACT REPORT - SPECIMEN

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ESA CONTRACT No	SUBJECT		CONTRACTOR
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ABSTRACT: Work on a European Mars surface network mission – NetLander – deploying four landers with appropriate payload for studies of the Martian interior and subsurface structures, atmosphere, ionosphere and geodesy, has been underway since 1997. The current mission plan implies a payload with launch in 2005 on an Ariane 5 together with the Mars Sample Return orbiter. Related to this effort, Finnish Meteorological Institute's Geophysical Research (FMI/GEO) has together with industry subcontractors carried out in 1998-99 an ESA - contracted assessment study with the result of demonstrating the feasibility of the implementation and design of a number of key components and subsystems of the NetLander mission: deployment of four solar-powered, 60-kg mass range, 90-cm diameter, 50-cm high landers for a time-of-operation of at least a Martian year, using existing or readily available technologies. The study also concludes that the will, desire and resources are available to curry out such a mission in the planed timeframe.

The work described in this report was done under ESA contract. Responsibility for the contents resides in the author or organisation that prepared it.

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NetLander Study Final Report

Abstract

ESA/ESTEC Contract No 12722/98/NL/JG

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1 Introduction

While Mars exploration has revealed a great deal about the Red Planet – solving some earlier mysteries, and introducing some new ones – nonetheless many questions are still open. Among these are the questions of the structure of the interior and subsurface, the behaviour of the atmosphere, and the source and nature of the planet's weak, but measurable magnetic field. These questions fall into a class that can be answered only by making measurements at several (even many) places at the same time, that is, by implementing a network of measurements. Although many such networks (*e.g.*, MESUR, MarsNet, InterMarsNet; MESUR 1991; Chicarro 1993, 1994) have been proposed, to date none has been successfully carried out.

This summary gives an overview of the work done by the Finnish Meteorological Institute's Geophysical Research (FMI/GEO) as part of the International Mars NetLander Study. The major goal of the study was to demonstrate the feasibility of placing a number of measurement stations on Mars' surface, with sufficiently sophisticated instruments to address major issues concerning Mars' internal structure, subsurface, atmosphere (including its ionosphere), and magnetic field. The focussed goals and constraints of the study included

- deployment in the 2000-2010 time frame,
- definition of the science goals and expected findings,
- definition of the required and available instrumentation as well as the lander design,
- fitting into the mass, power, accommodation, and schedule constraints of foreseeable missions,
- use of established and/or reliably foreseeable technologies, to avoid the need for inventing new capabilities,
- financial affordability, in the current state of potential participants' national science programs.

Under FMI/GEO's leadership, the study has addressed in great detail all the questions surrounding a plan to place a number of small stations distributed over the surface of Mars. The initial defining context was taken to be the ESA Mars Express Mission, (launch in 2003; Schmidt *et al.,* 1999), which called for proposals for *in situ* surface measurements to be carried out by proposer-provided additions to the mission. In fact, the results of this study are applicable to any of several possible missions. At present the NetLander Mission is heading for the 2005 launch window together with the Mars Sample Return Mission. The NetLander is now going forward as a Phase A Study, led by the French space agency CNES, with FMI/GEO assuming *(inter alia)* responsibility for leading the design of the Surface Module.

2 NetLander mission scenario

The NetLander Mission will deploy four landers to the Martian surface. Each lander includes a network science payload for study of the Martian interior, atmosphere and subsurface, as well as the ionospheric structure and geodesy. The NetLander is the first planetary mission focusing on investigations of the interior of the planet and the large-scale circulation of the atmosphere. A broad consortium of national space agencies and research laboratories will implement the mission. The consortium is led by CNES, with other major players being FMI and DLR (the German Space Agency). A mission description can be found in, *e.g.,* NetLander, 1998 and Harri *et al.*, 1999.

The NetLander Mission is to be considered in the general context of international Mars exploration. To reduce mission cost, NetLander relies on contributions from other Mars missions. Current assumptions include:

- the four NetLanders will share an Ariane V launch with elements of the Mars Sample Return (MSR) mission in 2005 (Fig. 1).
- the telemetry and telecommand relay functions will as a baseline be provided by the ESA Mars Express Orbiter, supplemented by one or more dedicated Mars communications satellites.

The use of Ariane V to launch the MSR mission in 2005 is the baseline in the current NASA-CNES agreement of joint Mars exploration.

During the cruise phase, an umbilical link between the MSR orbiter (MSRO) and the NetLanders will provide the landers with the required power and telemetry for both periodical check-ups as well as for secondary battery refreshment. The NetLander separations from the MSRO begin at 20-30 d before arrival at Mars. The MSRO targets each NetLander turning to the desired attitude and imparting a ΔV on each lander. The interval between consecutive separations is approximately 6 d. This strategy gives a lot of freedom in the choice of the landing sites and saves fuel otherwise required for Mars

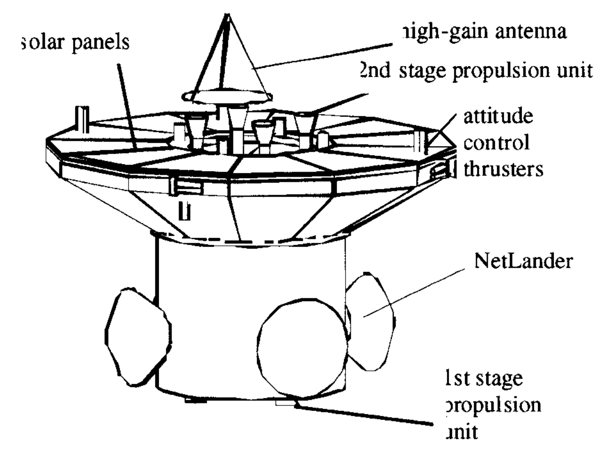

Fig. 1 The NetLanders mounted on an additional stage of the Mars Sample Return Orbiter (MSRO).

orbit insertion of the landers' mass. Propellant provision for targeting to the required landing sites (corresponding to a total ΔV-budget of 50 m/s) is included. The entry, descent and landing are performed autonomously. The Front Shield provides efficient braking, allowing parachute deployment at velocity and altitude conditions compatible with the required velocity at impact (about 25 m/s). The impact shock is absorbed by airbags. Once the airbags are released, the Surface Module is put in its correct position, the solar panels (located on three petals) are deployed, and the instruments are activated. The entry and landing sequence is depicted in Fig. 2.

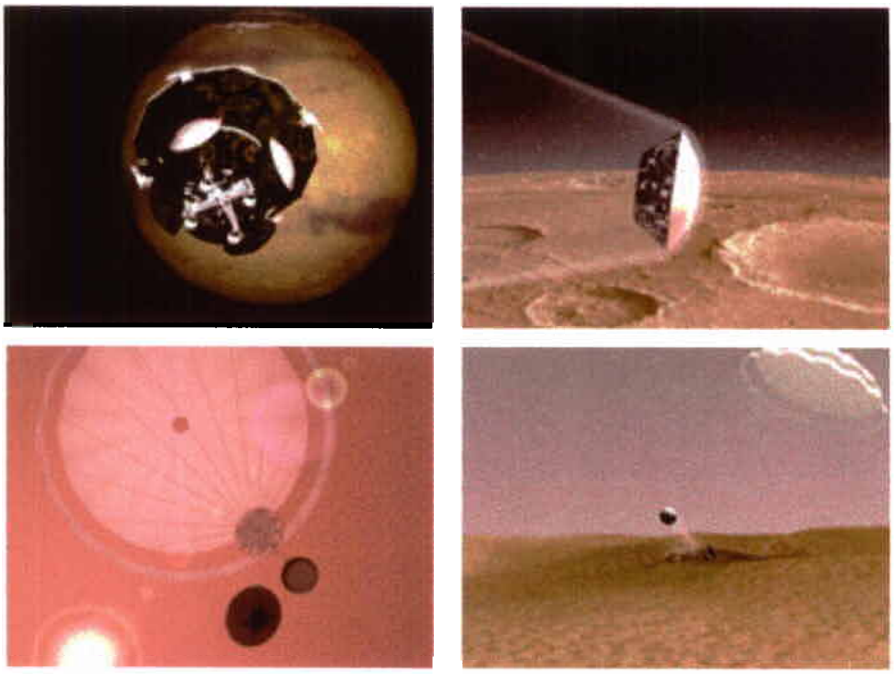

Fig. 2 The entry, descent, and landing of a NetLander.

The landing site latitudes are constrained by the available solar power to ≤ 40° latitude from the equator and the altitudes by the performance of the parachute system (tentatively to altitudes < 2 km from the reference level). A possible network configuration would deploy three landers in an equilateral triangle (*e.g.,* at latitudes 0°N, 40°N and 40°S), the fourth on the opposite side of the planet. The final landing sites will, be a compromise between the possibly conflicting requirements of the various science disciplines, and the operational constraints.

The baseline for communications relay between the landers and Earth is the Mars Express Orbiter. The backup concept relies on one or several dedicated telecommunications microsatellites, as envisioned in the Mars Network concept currently studied by NASA/JPL (*e.g.,* Hastrup *et al.,* 1999). After landing, each lander will transmit descent science and general housekeeping data, after which it will be ready to receive telecommands to begin operations. The network will operated from the Mars Express Operations Centre (MEOC), while a NetLander Operations Centre (NLOC) will co-ordinate the scientific operational requirements and prepare the commands to be sent to the landers through the MEOC. The NLOC will also collect the data received from the landers, pre-process them for technical purposes, and transmit them to the primary investigators. Operations are expected to last over one Martian year, from August 2006 to July 2008, requiring an extension of the Mars Express mission duration.

3 NetLander mission scientific objectives and payload

Mars is an important planet for a better understanding of the formation, evolution and dynamics of a terrestrial planet with an atmosphere. As the last inner planet before the outer giant planets, Mars was probably accreted differently from Earth and has a different Si/Fe ratio. The atmosphere and surface of Mars, despite their early similarities with those of Earth, have evolved in a different direction, leading to a severe escape of the atmosphere and to current conditions incompatible with liquid water on the surface. The dynamics and convection of the mantle, despite being relatively strong at the time-of-origin of the Martian volcanoes, were probably never sufficient to initiate plate tectonics and are today probably weak. Consequently, a single plate most likely covers the entire planet. When compared with the Earth, these differences in the formation and evolution of both the interior and the atmosphere encourage a comparative planetology approach for the two planets, and point toward a comprehensive scientific exploration of Mars. See Kieffer et al. (1992) for a general review on Mars.

Scientific payload

The NetLander scientific payload is based on instrumentation that has been flown on earlier missions to Mars (Mars-96, Mars Polar Lander; *e.g.*, Linkin *et al.*, 1998), Titan (Cassini/Huygens; *e.g.*, Kohlhase, 1993), a cometary mission (Rosetta; *e.g.*, Schwehm and Hechler, 1994), or that is proven by tests with prototypes. The payload and its heritage are presented in Table 1. The overall payload mass is approximately 6.5 kg.

Table 1 The NetLander scientific payload mass (in g) and the current development status (NET = network science, MUL = multi-site investigations, SYS = system device).

Instrument	Abbreviation	Mass (g)	Margin	Development status	Type
ATMIS (descent & surface)	ATMIS	945	100	Flight or qualification model	NET
Accelerometer & inclinometer	ACC	150	25	Study/flight model	MUL
Seismometer	SEISMO	1935	100	Breadboard	NET
Magnetometer	MAG	235	25	Flight model	NET
Electric field	ELF	125	25	Flight model	NET
Panoramic camera	PANCAM	1400	100	Breadboard	MUL
ATMIS+ELF boom		425	50	Study	
MAG boom		85	50	Study	
GEO-radar	GPR	490	50	Study	MUL
Radio science & NEIGE	NEIGE/TEC	300	50	Study	MUL/NET
Full total		6090	575		

Principal scientific objectives and key questions

The NetLander mission is going to enable a leap forward in our understanding of the contemporary and past state of Mars. To further improve the characterisation of Martian atmospheric, surface and internal phenomena – exhibiting both spatial and temporal variation – simultaneous observations at spatially displaced sites are required; hence, the logical next step is a *network* of observation sites on the surface. Several network concepts have been proposed in the past, with meager success. The NetLander mission would hence be the first mission to deploy a network of a moderate number of well-instrumented geophysical and meteorological observation posts onto the Martian surface. The following specific scientific disciplines will be addressed:

- deep internal structure,
- large scale atmospheric circulation (together with orbital observations)
- planetary boundary layer (PBL) phenomena,
- surface mineralogy and local geology
- subsurface structure at the km scale, down to water rich layers,
- alteration processes and surface/atmosphere interaction,
- atmospheric electricity, and ionospheric structure

The primary scientific disciplines are investigations of the interior of Mars and the atmosphere that benefit the most from the network concept. By deploying landers at multiple locations, the other objectives mentioned above will also be addressed by the NetLander Mission.

4 NetLander configuration

A spin-and-eject device (SED) will be used to separate the NetLanders from the MSRO and spin-up the landers. The Descent and Landing Sub-system, based on parachutes and airbags, will protect the Surface Module (SM) from mechanical and thermal loads up to its landing (Fig. 2). The entry vehicle (diameter 90 cm, height 50 cm) with the SM (that finally operates on the surface) inside is depicted in Fig. 5. The SM diameter is about 50 cm with a maximum height of 23 cm in the middle of the unit.

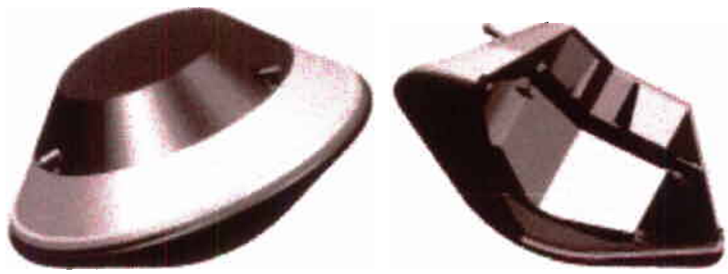

Fig. 5 External and cross-sectional 3-D views of the NetLander entry vehicle (height 50 cm, heat shield diameter 90 cm).

The baseline configuration of the Surface Module includes the following subsystems:

- Payload Complex: Scientific instruments, sensors, and system devices (command and data handling system, telecommunications system, power supply)
- Platform: Primary and Secondary Structure, Opening and Put-up Mechanism, and Thermal Subsystem

After landing with the aid of a parachute and an airbag, the Surface Module will be in an undefined position. The spring-loaded petals turning the surface module into upright position provide the correct working position. After the module reaches the correct attitude the core science payload is deployed via two booms accommodating the PANCAM, antenna, ATMIS package, and Magnetometer, as shown in Fig. 6. The Seismometer will be mechanically decoupled from the primary structure, and protected from the wind by the lander body.

The main energy source is solar panels. The primary battery will be reserved for supplying the required power for the NetLander during descent, landing, and initialisation phases on the Martian surface. The secondary battery will be used for NetLander night-time surface operations and for operations during the landing phase. The solar arrays are accommodated on the inner surface of the three petals and on the top of the electronics box insulation, having a total surface area of roughly 0.63 m^2.

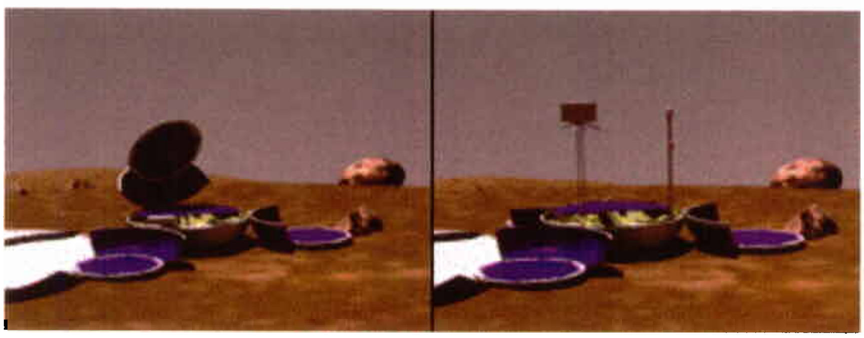

Fig. 6. NetLander turned into upright position by opening petals, after which the booms for camera and atmospheric sensors are deployed. The outer surfaces of the lander parts are covered with solar cells.

All system electronics are accommodated together with the Thermal Control Subsystem in one common Electronics Box, which is surrounded by thermal insulation. The Electronics Box is thermally decoupled from the primary structure, minimising the need for heating power due to heat loss to the ambient environment via conduction through the structure. The inside of the Electronics Box will be kept at temperatures between +50 and -50°C by two continuously operating Radioisotope Heater Units (RHU) and a controllable Heat Rejection System (HRS). The use of RHUs promotes effective operations and facilitates survival in case of a global dust storm.

The estimated mass of one NetLander in atmospheric entry is 60 kg (including margin), and the combined mass of the data relay and radio science components on the Mars Express orbiter is approximately 6.5 kg. The mass of the Spin and Eject Device remaining on the MSRO is 9 kg for the set of four NetLanders. The estimated energy demand by science instruments and the payload service electronics is 20-60 Wh/sol, of which 60 % will be consumed during night-time (17 h max) and 40 % during daytime (8 h). In the beginning of the mission, energy demand is higher due to more intensive measurement operations. The power subsystem will be scaled to meet energy demands also at the end of the mission (one Martian year).

5 Summary and conclusions

During the baseline mission of one Martian year, the NetLander payloads will conduct simultaneous seismological, atmospheric, magnetic, ionospheric, geodetic measurements and ground penetrating radar mapping supported by panoramic images. The payloads also include entry phase measurements of the atmospheric vertical structure. The scientific data could be combined with simultaneous observations of the atmosphere and surface of Mars by the Mars Express Orbiter that is expected to be functional during the NetLander

This study began with an examination of the mission requirements: What science can and should be carried out with a network of small surface stations? What are the operational conditions and constraints? The report presents a practical conceptual design for the NetLander surface module: *e.g.,* structures and subsystems, payload definition, operations on the surface for at least one Martian year, telecommand and data communication. Other major components and functions of the entire NetLander system – *e.g.,* the CNES-designed entry, descent and landing system and surface module interfaces therewith, accommodation on a carrier, launch, transit to Mars, separation from the carrier, etc. – are also described as background and reference information.

The payload consists of scientific instruments (seismometer, magnetometer, atmospheric sensors, ionospheric sensors, ground penetrating radar, panoramic camera, and accelerometer) as well as the support elements (power, command and data handling, thermal control, etc.) necessary to carry out the mission in the Martian environment. With this payload, the NetLander mission will make significant original contributions to understanding Mars, particularly its internal structure and meteorology. The lander has entry mass of less than 60 kg, diameter of 90 cm and height of 50 cm. On the surface of Mars, each lander requires 20-60 Wh/day, depending on the mode-of-operations in effect. The minimum number for an operational network is three stations, so in practice a mission of four would provide redundancy for security, as well as augment the scientific return significantly.

Thus, the conclusion of the study is that it is possible to place a of 3-4 network science stations of individual entry masses of approximately 60 kg on the surface of Mars, that the technical capability and financial resources exist to carry out such a mission in the 2005 launch window, that the resulting science would be a significant contribution to Mars exploration, and that the will and desire to carry out such mission exists within the European scientific community. The NetLander mission is now going forward as a Phase A Study led by CNES, with FMI/GEO assuming *(inter alia)* responsibility for leading the design of the Surface Module.

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