NETWORK SCIENCE LANDERS FOR MARS


ABSTRACT

The NetLander Mission will deploy four landers to the Martian surface. Each lander includes a network science payload with instrumentation for studying the interior of Mars, the atmosphere and the subsurface, as well as the ionospheric structure and geodesy. The NetLander Mission 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. It is managed by CNES (the French Space Agency), with other major players being FM1 (the Finnish Meteorological Institute), DLR (the German Space Agency), and other research institutes. According to current plans, the NetLander Mission will be launched in 2005 by means of an Ariane V launch, together with the Mars Sample Return mission. The landers will be separated from the spacecraft and targeted to their locations on the Martian surface several days prior to the spacecraft’s arrival at Mars. The landing system employs parachutes and airbags. During the baseline mission of one Martian year, the network 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 Mission’s operational phase. Communication between the landers and the Earth would take place via a data relay onboard the Mars Express Orbiter.

1 INTRODUCTION

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 temperature conditions incompatible with the presence of surface liquid water. The dynamics and convection of the mantle, despite a strong past vigor very likely at the origin of the Martian volcanoes, were probably never sufficient to initiate plate tectonics and is today probably weak, and in the form of a stagnant lid, leading to a single plate covering all the planet. When compared with the Earth, all these differences in the formation and evolution of both the internal part and its outer atmospheric envelope encourage a comparative planetology approach for the two planets, and therefore toward a complete scientific exploration of Mars. See Kieffer et al. (1992a) for a general review on Mars.

Lander observations on the surface of Mars, especially when combined with data from Orbiter instruments and sample return missions, will shed light on the contemporary Mars, its formation and evolution. The studies of the interior of Mars (Anderson, 1977; Lognonné and Mosser, 1993) and the Martian atmosphere (Zurek, et al., 1992; Farmer, 1977; Clancy et al., 1992; Jakosky, et al., 1992; Kahn, 1992; Savijärvi, 1995; Tillman et al., 1994), as well as geodetic and ionospheric investigations require several observation posts that are geographically distributed over the Martian surface, and which operate simultaneously. The scientific data could be combined with simultaneous observations of the atmosphere and surface of Mars from the orbit; this is especially required in the investigation of the large scale atmospheric flows. Such scientific disciplines are commonly called network science. While various landing missions focusing on network science have been proposed (METEGG report 1988; Linkin et al., 1988, Solomon et al., 1991, Chicarro et al., 1993; Banerdt et al., 1996), up to now no successful network science mission has been carried out.

Both Mars and the Earth have atmospheres that allow a substantial fraction of the incoming solar radiation to reach the surface. The fraction absorbed by the atmosphere is approximately 34-41% for the Earth, while for Mars the same fraction is of the order of 8% to 20% or more. Hence, the atmospheres of both planets are heated by a combination of direct absorption of sunlight and indirect surface heating. Among the key differences are orbit--Mars is farther from the Sun, resulting in lower solar insolation, and has a larger orbital eccentricity—as well as atmospheric composition and thickness. In addition, the history of Mars is partially preserved in its surface structures, due to the lack of open bodies of water and surface vegetation, and the cold, thin atmosphere. The similarities and differences between Earth and Mars makes Mars an ideal laboratory for comparative studies of atmospheric dynamics of small solid planets with high rotation rates and differentially heated atmospheres.

Much less is known about the internal structure. The earlier missions have yielded values for the mean density and inertia factor (Folkner et al., 1997). The secular acceleration of Phobos gives a constraint on the mantle temperature (e.g. Lognonne & Mosser, 1993), while the gravity and geomorphological data gave a constraint on the thickness of the crust. As such, this set of data is however only able to constrain a crude model of Mars, with severe tradeoff between the size and density of the core. The state, composition and size of the core remain therefore unknown, as well as any detailed structure of the mantle. All internal models were then done with strong hypotheses, such as a Martian origin for SNC meteorites or a planetary bulk composition with non-volatile element ratio comparable to those of C1 carbonaceous chondrites (e.g. Dreibus and Wänke, 1985). These models are however now challenged by confrontation with the improved inertia factor (e.g. Sohl et Spohn, 1997, Bertka and Fei, 1998), which demonstrate the need for much more geophysical data.

2 NETLANDER MISSION SCENARIO

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

- the landers will use the Ariane V launcher which is intended to launch the elements of the Mars Sample Return mission in 2005 (as depicted in Figure 1).
- once on the Mars surface, they will be operated through the Mars Express Orbiter, which will provide the telemetry and telecommand capability.

The use of Ariane V to launch the Mars Sample Return (MSR) mission in 2005 is the baseline for the current NASA-CNES discussions of joint Mars exploration. The lift capacity of Ariane V will be enough to include 4 NetLanders in addition to the main payload, the MSR spacecraft. During the cruise phase a link between the spacecraft and the NetLanders will provide the landers with the required power and telemetry for periodical checkups and secondary battery refreshment during flight phase, as well as full charge at the end of cruise phase. The NetLanders
will be separated from the spacecraft several days before arrival at Mars; this strategy gives a lot of freedom in the choice of the landing sites. Propellant provision is included to allow for the delta-V needed to perform the orbit maneuvers in order for the landers to land at the required sites. The entry, descent and landing phase are performed autonomously. The Front Shield provides efficient braking of the NetLander, allowing parachute deployment at velocity and altitude conditions compatible with the required velocity at impact (about 25 m/s). The impact shock is then absorbed by means of airbags. Once the airbags are released, a Surface Module is put in its correct position, the solar panels (located on 3 petals) are deployed, and the instruments are activated. The entry and landing sequence is depicted in Figure 2.

The landing site latitudes are constrained by the available solar power, and the altitudes by the performance of the parachute system. A possible network configuration would deploy three landers in an equilateral triangle (at latitudes 0°N, 40°N and 40°S), the fourth on the opposite side of the planet. The final landing sites will, however, be a compromise between the possibly conflicting science requirements set by the various disciplines, and the operational constraints. In particular, the altitude of the landing site is limited by the performance of the parachute system, while the availability of sufficient solar power poses restrictions on the latitude range (e.g. ±40°). Preliminary calculations show that to deploy such a network, a total ΔV = 100 m/s is required. The lander-carrier separation takes place approximately 5 days prior to arrival at Mars.

The baseline for communications between the landers and the Earth uses the Mars Express Orbiter. Each lander will send data related to the descent and general technical information, and will then be ready to receive telecommands to begin scientific operations on the surface. Operation of the network will be carried out through the Mars Express Operations Center, while a specific NetLander Mission Center will be set up to coordinate the scientific operational requirements and to prepare the commands to be sent to the landers through the Mars Express Operations Center. It will also collect the data received from the landers, pre-process them for technical purposes, and transmit the scientific data to the primary investigators. Surface operations are expected to last over one Martian year, from August 2006 to July 2008, thus requiring an extension of the Mars Express mission duration. Even if this seems feasible, a back-up scenario is necessary. The most promising solution appears to be the use of a micro telecomm satellite, which would be placed into a geosynchronous transfer orbit as an Ariane V auxiliary payload, which would then be targeted to Mars and inserted into a Mars orbit.

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

Fig. 2. The entry, descent, and landing of the NetLander Mission.

3 NETLANDER MISSION SCIENTIFIC OBJECTIVES AND PAYLOAD

General 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 characterization 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,
- subsurface structure at the km scale, down to water rich layers,
- surface mineralogy and local geology
- 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.

Internal structure and dynamics investigations

Deep Interior of Mars. Simultaneous measurement of geophysical parameters on various locations (seismological, tidal, geodetic and magnetic experiments) are the key to learn about the interior of the planet. The first will determine the mean values of the shear and bulk elastic moduli as a function of depth, the position of the interfaces between the mantle and core, the state of the core, the position and characteristics of mantle discontinuities, the lithospheric and crustal thickness, and the mean value of the seismic attenuation as a function of depth. It will use the Marsquakes as natural sources of seismic events: indeed, Mars is expected to have a relatively low (by terrestrial standards) but significant level of seismic activity. Theoretical estimates (Phillips, 1991) and Moon/Mars comparative faults calibrations (Golombek et al., 1992) indicate that the thermoelastic cooling of the lithosphere can supply enough strain energy to produce about 100 quakes Earth magnitude greater than 3.8 and 20 quakes with Earth magnitude greater than 4.5 during the lifetime of the NetLanders. A few (2-3) per year should have a magnitude greater than 5. The second method, the study of the tides, will provide us with additional information about Mars interior. The seismometer will indeed be a Very Broad Band seismometer with a tidal output (Lognonné et al., 1996), contrary to the previous Mars developed seismometer, such as the Viking seismometer (Anderson et al., 1977) or Optimism (Lognonné et al., 1998). The observation will focus on the tides produced by Phobos and the Sun, the latter producing a displacement of a few cm, or $10^{-7}$ m/s² in acceleration. These observations do not only give information on the direct attraction of these bodies on Mars, but also on the surface deformations (Love number h) and on the induced mass redistribution (Love number k). The contribution of the core to the tidal response could be of the order of half a millimeter. The third method will be geodesy. The precession measurement will be first improved, and the nutations of the planet, which are related to the non-rigid Mars response (transfer function) and therefore to an integration of Mars’s interior parameters, will also be measured. In particular, if the core is liquid, the nutations could be influenced via a resonance effect by Mars’ Free Core Nutation (FCN). These observations will enable us to confirm seismic measurements about the state of the core, liquid or not, and to determine the density of the mantle and core. The last method will investigate the electrical structure of Mars by means of magnetic sounding methods by using the external magnetic field induced by ionospheric sources. The probable existence of natural variations of the magnetic field of Mars the Martian day period should allow the sounding up to thousand kilometers in depth and the constraining of the temperature gradient within the upper mantle of Mars. Results of laboratory measurements on samples of geological materials show that the electrical conductivity significantly decreases at temperatures on the order of 1000°C (see e.g. Shankland and Waff, 1977; Olhoeft, 1980). Electromagnetic soundings with the low frequency spectrum of the magnetic variations would therefore allow to determine the thickness of the thermal lithosphere, important data for convection models of Mars mantle. Deeper, the example of the Earth shows that the electrical resistivity significantly varies at the phase transitions present in the upper mantle. The corresponding transitions, if present, would therefore be associated to a significant decrease in the Mars resistivity.

These measurements will constrain the variations of the bulk and shear modulus, density, electrical conductivity, and seismic attenuation quality factor. This multi-parameter approach is the key issue for understanding of interior of the planet in terms of mineralogy and temperature profile with depth. The velocity and density gradient, the presence of discontinuities and their shape will of course be strong indicators for any major mineralogical difference with respect to Earth in the Martian mantle and core, such as those recently proposed by Bertka and Fei,
1998. More detailed studies will also be possible, for example for the determination of the iron content of the mantle: for a Martian mantle composition similar to the Earth’s, the density and seismic velocity discontinuities expected to be present between 1100 km and 1500 km in depth (Okal and Anderson, 1978) will be sharp (~0.5 km/s²) and mainly associated with the phase transitions of olivine in the 12 to 16 GPa pressure. They will be smoother for an enrichment in iron with respect to the Earth’s mantle (e.g. Ringwood, 1979; Dreibus and Wänke, 1985) due to the coexistence of α- and γ- phases of olivine over an extended domain of pressures, around 2 GPa wide, between 1000 km and 1200 km depth (Bertka and Fei, 1996; Mocquet et al., 1996) (Figure 3). The determination of the focusing of seismic rays in this depth range, and of the amplitude of body wave tripliation (Vacher, 1995) will constrain these detailed models. In addition, the measurements of the surface magnetic field indicate whether the Martian magnetic field is primarily of internal origin or due to crustal magnetization caused by an ancient planetary dynamo. Magnetic field measurements will thus also contribute to our current understanding of the thermal history of Mars.

Shallow and subsurface structure: Water reservoirs. An important objective will be the search for ground reservoirs of water, either as ice or as liquid water. Present models of the thermal flux suggest that liquid water should be encountered at depths of ≤1 km near the equator increasing to 3 to 5 km in the polar regions (Squyres et al., 1992). The study of the subsurface, including the permafrost, will be actively performed with a geo-radar, and passively with the magnetometer and seismometer. The ground penetrating radar will probe the subsurface down to depths of the order of ~2 km to search for signatures of ice reservoirs and possible transition to liquid water layers. Simultaneously radar data will give access to the main structural and geomorphological features of the subsurface. Below 1-2 km, the determination of the mean resistivity profile will be done with the magnetometer. This will allow the determination of the thickness of the resistive permafrost, and will provide information about the presence (or absence) of liquid water under the permafrost. The resistivity of cold dry rocks is very high, generally on the order of, or greater than a few tens of thousands of Ωm. In presence of a conductive liquid phase, the resistivity sharply decreases, and falls down to values of the order of a few tens of Ωm in the presence of 1% of water rich fluids (Figure 3). As the resistivity of the permafrost is very high, the presence of liquid water at the bottom of the permafrost will then correspond to a decrease of the resistivity by two or more orders of magnitude. Electromagnetic sounding with the high frequency spectrum of the magnetic variations is then very well suited for detecting the presence of liquid water in the Martian crust. A last piece of information will be obtained with the seismometer, assuming that a few regional quakes are detected with small epicentral distances. The body wave will then be the subject of site effect (see Horwarth et al., 1980 for the use of this method on the Moon). The subsurface profile of velocities will then be used to invert the position of the subsurface discontinuities, the latter being smoothed by the magnetic inversion, mostly sensitive to the resistivity jumps.

Atmospheric and ionospheric investigations

The goal of the NetLander/ATMIS instruments is to increase our understanding (see, e.g., Kieffer et al., 1992a) of the contemporary of Martian meteorology and climate by providing new data on the atmospheric vertical structure, regional and global circulation phenomena, the Martian Planetary Boundary Layer (PBL) and atmosphere-surface interactions, dust storm triggering mechanisms, as well as the climatological cycles of H₂O, dust and CO₂. To obtain such an increase in characterization of a number of phenomena exhibiting both spatial and temporal variations, simultaneous observations of multiple variables at spatially displaced sites – forming a network – are required.

The atmospheric vertical structure is a function of local time, latitude, season, and dust loading. The NetLander profiles of density (p), pressure (p), wind (V), and temperature (T) – with choice locations and local times – will crucially expand on the existing three profiles (Seiff and Kirk, 1977; Sciff, 1993; Schofield et al., 1997).

The main identified components of the Martian global circulation are (Zurek et al., 1992): a Hadley cell between the summer hemisphere tropics to the winter hemisphere subtropics, baroclinic eddies in the winter hemisphere,
stationary eddies induced by topographical and other surface variations, condensation/sublimation flow between the CO$_2$ polar caps, thermal tides, and normal mode oscillations (Figure 4). The main ATMIS-measured variable is $p$, supplemented by $T$, $V$, relative humidity (RH) and optical thickness ($\tau$) observations at the surface as well as by global/synoptic scale orbital measurements. In the landing site selection the small number of landers forces a choice between either a more regional/sub-global focus or a wide site dispersion and hence poor observational correlations between the landers. As a result the four-lander network’s global circulation investigations are limited to some – but not all – of the circulation components above. As wide latitudinal coverage as feasible on both hemispheres and at different terrains is needed to investigate, e.g., the still unconfirmed occurrence and characteristics of mid-latitude baroclinic eddies in the south. Longitudinal site coverage can account for the effect of large topography features and to resolve atmospheric waves extending over many longitudes. A robust characterisation of the full global circulation requires a more comprehensive surface network, using, e.g., the Haberle and Catling (1996) concept or building a larger network of more capable NetLander-type landers over several launch windows.

**Boundary layer phenomena.** Viking landers observed summertime slope winds (Hess et al., 1977), modeled by, e.g., Blumsack et al. (1973), Ye et al. (1990), and Savijärvi and Siili (1993). Modeling suggests circulations driven by surface thermal contrasts due to CO$_2$ ice cover (e.g., Siili et al., 1997), surface albedo and soil thermal inertia (Siili, 1996), as well as air mass modifications (Segal et al., 1997). Measurements performed during the last few km of the descent may provide in situ data on the PBL height. The NetLander surface observations will characterize the PBL phenomena and the surface-atmosphere interactions at varying sites and terrains (Harri et al., 1998). Stability, surface fluxes of momentum and heat, and growth of the mixed layer (Tillman et al., 1994) can be estimated from ground and atmospheric temperature (at 2-3 vertical levels), and high time resolution wind data. Humidity measurements may provide important in situ data on seasonal and diurnal variations as well as on the exchange of H$_2$O between the atmosphere and the regolith. Dust devils and their role in dust lifting will be monitored through imaging and atmospheric pressure observations. The electro-magnetic noise due to the planet’s magnetic field and the presence of charged dust particles will also be monitored, especially during storms, leading to a better understanding of the influence of the magnetic field on transport of dust particles.

**Climatological cycles.** The H$_2$O content varies by latitude and season with hemispherical asymmetry, the peak occurring in the northern polar region in the spring. The NetLander network’s ability to measure spatial and seasonal variation of the near-surface relative humidity will provide an unprecedented opportunity in characterization of the H$_2$O cycle. Multiple sensors of the ATMIS will provide data relevant to initiation and evolution of the dust-related processes: $\tau$, $T$ (reduced near-surface $T_a$ during dust storms), and $p$ (normal modes and their role in dust storm initialization, passage of dust devils (Tillman, 1988). Selection of (a) landing site(s) from known dust storm onset regions (e.g., Argyre, Hellas) can provide unique opportunities for monitoring the onset and growth phases of Martian dust storms. Several well-distributed stations should allow accurate measurement of the mean global pressure variations, caused by the CO$_2$ cycling between the polar caps. Since the weather component signals are out of phase in the two hemispheres, the simultaneous measurements obtained by the NetLanders should allow us to properly estimate the amount of CO$_2$ in the polar caps, crucial data for understanding the Martian climate and its variation. These data will be complemented by geodetic measurements.

**Ionospheric Measurements:** The ionospheric measurements, required in order to extract the geodesy signal from the Doppler effect data, will allow to study both the large-scale ionospheric variations (horizontal structure) and the small-scale variations (scintillations) These measurements will shed light on the distribution of the ionospheric plasma and its variation with solar zenith angle, the interaction of the ionosphere with the solar wind and the role of the ionized component of the atmosphere in the processes which governs the long-term evolution of the atmosphere. Together with the magnetometer, they will precise the role of the magnetic field on the structure of the ionospheric plasma, either induced from the magnetized solar wind or intrinsic in the locally magnetized regions.

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Fig. 4. Schematic representation of the main Martian wind systems during northern hemisphere midsummer (from Savijärvi 1994).
4 NETLANDER CONFIGURATION

The NetLander scientific payload is based on instrumentation that has been flown on earlier missions to Mars (Mars96, MVACS), Titan (Cassini/Huygens), a cometary mission (Rosetta), or that is proven by tests with prototypes. The payload and its heritage are presented in Table 1. The overall payload mass is about 5 kg.

The NetLanders will be released from the spacecraft bus on its hyperbolic trajectory to Mars a few days before the insertion of the Orbiter into an elliptic orbit around Mars; this saves the fuel required for Mars orbit insertion and gives considerable freedom in the selection of landing sites. A spin-and-eject device will be used to separate and spin the NetLanders. The spacecraft will carry out targeting. The Descent and Landing Subsystem, based on parachutes and airbags, will protect the Surface Module from mechanical and thermal loads up to its landing (Figure 2). The entry vehicle (diameter 90 cm, height 50 cm) with the Surface Module (that finally operates on the surface) inside is depicted in Figure 5. The Surface Module diameter is about 50 cm with a maximum height of 23 cm in the middle of the unit.

Table 1. The NetLander scientific payload mass and current development status. The type 'NET' refers to network science and 'MUL' to multisite investigations.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Mass</th>
<th>Marg</th>
<th>Development status</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEIS + Box 0 + connector</td>
<td>1750</td>
<td>130</td>
<td>Breadboard</td>
<td>NET</td>
</tr>
<tr>
<td>MAG/ELF</td>
<td>295</td>
<td>15</td>
<td>Flight model</td>
<td>NET</td>
</tr>
<tr>
<td>ATMIS surface</td>
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<td>50</td>
<td>Flight Model</td>
<td>NET</td>
</tr>
<tr>
<td>MET-boom + accessories</td>
<td>200</td>
<td>30</td>
<td>Study</td>
<td>NET</td>
</tr>
<tr>
<td>PANCAM</td>
<td>850</td>
<td>50</td>
<td>Breadboard</td>
<td>UL</td>
</tr>
<tr>
<td>Cam. boom + accessories</td>
<td>200</td>
<td>30</td>
<td>Study</td>
<td>MUL</td>
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<tr>
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<td>Total Core</td>
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<td>9% mean</td>
<td></td>
</tr>
<tr>
<td>supplemental payload</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATMIS Descent</td>
<td>120</td>
<td>25</td>
<td>Study / Flight model</td>
<td>MUL</td>
</tr>
<tr>
<td>MEGE &amp; TEC</td>
<td>450</td>
<td>70</td>
<td>Study</td>
<td>MUL</td>
</tr>
<tr>
<td>Radio plus-in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geo-Radar + Antenna box +connns</td>
<td>400</td>
<td>60</td>
<td>Study</td>
<td>MUL</td>
</tr>
<tr>
<td>FULL TOTAL</td>
<td>4800</td>
<td>500</td>
<td>10% mean</td>
<td></td>
</tr>
</tbody>
</table>

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 reaching the correct and stable position the Surface Module will deploy the core science payload via two booms accommodating the panoramic camera, antenna, ATMIS package, and Magnetometer, as shown in Figure 6. The Seismometer will be mechanically decoupled from the primary structure, and will also be protected from the wind by the lander body.
Solar panels will serve as the main energy source. The primary battery will be reserved for supplying the required power for the NetLander during descent, landing, and initialization phases on the Martian surface. The secondary battery will be used as energy storage for NetLander nighttime operations on the Martian surface and also 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 m².

![NetLander](image)

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, minimizing 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 mass of the Data Relay on the Orbiter is approximately 5 kg. The part of the Spin and Eject Device remaining on the Orbiter is 1.1 kg (NetLander, 1998). The estimated energy demand by science instruments and the payload service electronics is 20 to 60 Wh/sol, of which 60 % will be consumed during nighttime (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

The exploration of Mars requires landing missions as one of the means of increasing our knowledge of the planet. The NetLander Mission slated for launch in 2005 will be the first one to place a network of scientific payloads on the Martian surface, specifically addressing the following scientific issues:

- deep internal structure,
- global atmospheric circulation,
- planetary boundary layer phenomena,
- subsurface structure at the km scale, down to water rich layers,
- surface mineralogy and local geology,
- alteration processes and surface/atmosphere interaction, and
- atmospheric electricity, and ionosphere structure.

The selected instruments are a seismometer, atmospheric sensors (ATMIS), an electric field sensor, a magnetometer, a panoramic camera, a ground-penetrating radar, and a transponder for radio-science. The sensors that need to function at a given distance from the lander are placed along two deployable booms. The scientific payload has a mass of 5 kg, and the overall NetLander entry mass is 60 kg. The NetLanders will be released from the spacecraft bus on its hyperbolic trajectory, a few days before the insertion of the Orbiter into an elliptic orbit around Mars. A spin and eject device will be used to separate and spin the NetLanders. The spacecraft will carry out targeting. The Entry, Descent and Landing Sub-system (EDLS) based on parachutes and airbags is designed to protect the Surface Module from severe mechanical and thermal loads up to and including landing.

Performing network science investigations requires at least three operational landers. Having four landers in the NetLander Mission significantly increases the reliability of the whole system, as well as the scientific return.
Science operations on Mars are carried out by the Surface Module, which is expected to perform measurements over one Martian year. During the surface operations, the baseline plan calls for the NetLander Data Relay onboard the Mars Express Orbiter to act as a command and data relay for the NetLanders. Because of the limitations in the transmission capabilities, onboard data processing and data storage are implemented. The telecommunications system will be compatible with NASA standards, which will benefit both ESA and NASA missions, providing redundancy. A back-up and supplemental option for the telecommunications function is a specific micro communications satellite.

The mission enjoys wide support. The NetLander consortium comprises:
- CNES (French Space Agency) as the lead organization,
- FMI (Finnish Meteorological Institute) as the payload management organization,
- DLR (German Space Agency),
and several other European scientific institutes (with the ESA-PRODEX framework for the Belgium and Swiss contribution). NASA/JPL is planning to contribute to the development of the scientific payload as well as to the power supply and thermal control system. CNES is in charge of the entry, descent and landing sub-system, and of the telecommunication sub-system, as well as being a candidate for hosting the NetLander Mission Center. FMI has the responsibility for the development and integration of the Surface Module, and will be directly in charge of the system electronics and software development. The structure elements, thermal unit, and mechanisms of the Surface Module are to be managed by DLR.

The NetLander consortium has decided to embark on a great exploration of Mars. The groups contributing to this mission have long understood the benefits of establishing a network of observation stations on the surface of Mars. There have been numerous, well thought out studies of the scientific return from simultaneous, spatially dispersed observations, particularly in the areas of magnetism, seismology, and meteorology, all of which address key questions about the nature and origin of Mars. This mission is therefore regarded as a unique opportunity to set up the first network of scientific observation posts on Mars.

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