ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

RAPORTTEJA
RAPPORTER
REPORTS
2007:3

MetNet - In Situ Observational Network and Orbital Platform to Investigate the Martian Environment

Raportteja Rapporter Reports

No:2007:3 UDC 52

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Finnish Meteorological Institute
Space Research

ISBN 978-951-697-625-2
ISSN 0782-6079

Painopaikka: Yliopistopaino
Helsinki 2007

FINNISH METEOROLOGICAL INSTITUTE

Reports 2007:3

Published by Finnish Meteorological Institute
(Erik Palménin aukio 1) , P.O. Box 503
FIN-00101 Helsinki, Finland

Date

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Name of project

MetNet

Commissioned by

Title

MetNet - In Situ Observational Network and Orbital Platform to Investigate the Martian Environment

Abstract

MetNet Mars Mission is an *in situ* observational network and orbital platform mission to investigate the Martian environment and it has been proposed to European Space Agency in response to Call for proposals for the first planning cycle of Cosmic Vision 2015-2025 D/SCI/DJS/SV/val/21851. The MetNet Mars Mission is to be implemented in collaboration with ESA, FMI, LA, IKI and the payload providing science teams.

The scope of the MetNet Mission is to deploy 16 MetNet Landers (MNLs) on the Martian surface by using inflatable descent system structures accompanied by an atmospheric sounder and data relay onboard the MetNet Orbiter (MNO), which is based on ESA Mars Express satellite platform. The MNLs are attached on the three sides of the satellite and most of the MNLs are deployed to Mars separately a few weeks prior to the arrival to Mars. The MetNet Orbiter will perform continuous atmospheric soundings thus complementing the accurate in situ observations at the Martian ground produced by the MetNet observation network, as well as the orbiter will serve as the primary data relay between the MetNet Landers and the Earth.

The MNLs are equipped with a versatile science payload focused on the atmospheric science of Mars. Detailed characterisation of the Martian atmospheric circulation patterns, boundary layer phenomena, and climatological cycles, as well as interior investigations, require simultaneous in-situ meteorological, seismic and magnetic measurements from networks of stations on the Martian surface. MetNet Mars Mission will also provide a crucial support for the safety of large landing missions in general and manned Mars missions in particular. Accurate knowledge of atmospheric conditions and weather data is essential to guarantee safe landings of the forthcoming Mars mission elements.

Publishing unit

Classification (UDC)
523.43-852

Keywords
MetNet, Cosmic Vision, Mars, Space mission

ISSN and series title
0782-6079 Raportteja - Rapporter - Reports

ISBN
978-951-697-625-2

Language
English

Sold by
Finnish Meteorological Institute / Library
P.O.Box 503, FIN-00101 Helsinki
Finland

Pages 35

Price

Note

ILMATIETEEN LAITOS

Raportit 2007:3

Julkaisija: Ilmatieteen laitos, (Erik Palménin aukio 1)
PL 503, 00101 Helsinki

Julkaisuaika

Tekijä(t)

A.-M. Harri, J. Leinonen, S. Merikallio, M. Paton, H. Haukka, J. Polkko (FMI), Prof. V. Linkin, V. Lipatov (IKI), Director General K. Pichkadze,A. Polyakov (LA), M. Uspensky (FMI / SpaceTec Inc), Prof. L. Vasquez (Univ. Complutence, Madrid) Dr. H. Guerrero (INTA, Spain), D. Crisp (NASA/JPL), R. Haberle (NASA/AMES), S. Calcutt, C. Wilson (Univ. Oxford), Prof. P. Taylor (Univ. York, Canada), Prof. C. Lange (Univ. of Alberta, Canada), M. Daly (MDA Inc, Canada), L. Richter (DLR, Bremen), R. Jaumann (DLR, Berlin), J.-P. Pommereau (Service d'Aeronomie, Paris), F. Forget (LMD, Paris), Ph. Lognonne (IPGP, Paris), J. Zarnecki (Open University, London).

Projektin nimi

MetNet

Toimeksiantaja

Nimeke

MetNet - In Situ Observational Network and Orbital Platform to Investigate the Martian Environment

Tiivistelmä

MetNet Mars Mission on *in situ* -tutkimushanke joka koostuu useista Marsin pinnalle laskeutuvista havaintoasemista, jotka muodostavat havaintoverkoston, sekä Marsia kiertävästä havaintosatelliitista. MetNet Mars missiota on esitetty Euroopan avaruusjärjestölle (ESA) hyväksyttäväksi osana Cosmic Vision 2015-2025 D/SCI/DJS/SV/val/21851 –hakua. MetNet Mars missio on toteutettu yhteistyössä ESA:n, Ilmatieteen laitoksen, LA:n, IKI:n ja hyötykuorman toimittavien tiederyhmien kanssa.

MetNet Mars mission tavoitteena on lähettää 16 MetNet laskeutujaa (MNL) Marsin pinnalle kayttäen hyväksi kaasutäytteistä laskeutumisjärjestelmää joka on varta vasten suunniteltu käytettäväksi Marsiin laskeutumiseen. Lisäksi Marsin kiertoradalla on ESA:n Mars Expressiin pohjautuva kiertolainen (MNO) joka tekee Marsin kaasukehän mittauksia ja toimii tietoliikennelinkkinä Maahan. MetNet –laskeutujat on kiinnitetty satelliitin kolmelle sivustalle ja suurin osa laskeutujista irroitetaan muutamaa viikkoa ennen Marsin kiertoradalle saapumista.

MetNet –laskeutujat on varustettu tieteellisellä hyötykuormalla joka on erityisesti suunniteltu mittaamaan Marsin kaasukehää ja sen ominaisuuksia. Tarkat mittaukset Marsin kaasukehän sekä maaperän ominaisuuksista vaativat meteorologisia, seismologisia ja magneettisia *in situ* –mittauksia useilta Marsin pinnalla olevilta havaintoasemilta. MetNet havaintoverkosto tuottaa uutta ja tarkempaa tietoa Marsin kaasukehästä joka on erityisen hyödyllistä tuleville Mars missioille, koska tarkat kaasukehän mittaukset ja säätiedot ovat tärkeitä kun valmistellaan laskeutumisia Marsin pinnalle.

Julkaisijayksikkö

Luokitus (UDC): 523.43-852

Asiasanat: MetNet, Cosmic Vision, Mars, Space mission

ISSN ja avainnimike: 0782-6079 Raportteja - Rapporter - Reports

ISBN: 978-951-697-625-2

Kieli: Englanti

Myynti: Ilmatieteen laitos / Kirjasto
PL 503, 00101 Helsinki

Sivumäärä 35 Hinta

Lisätietoja

Proposal in response to Call for proposals for the first planning cycle of Cosmic Vision

2015-2025 D/SCI/DJS/SV/val/21851

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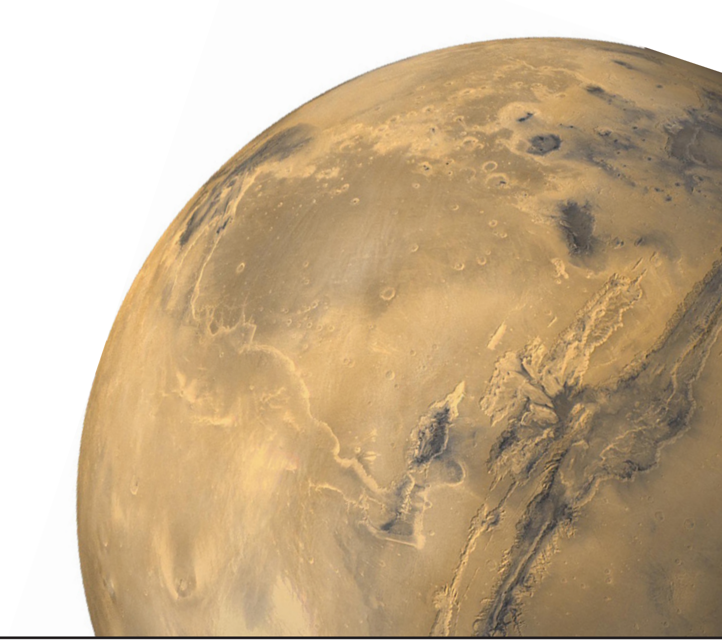

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University of Helsinki, Finland
University of Washington, USA
University of York, Canada

submitted 29.6.2007

MetNet

Contents

List of Acronyms

AIBU	Additional Inflatable Braking Unit
BoL	Beginning of Lifetime
CCD	Charge-Coupled Device
CDMS	Central Data Management System
CNES	Centre National d'Etudes Spatiales, France
CNRS	Centre National de la recherche scientifique, France
COSPAR	Committee for Space Research
DLR	German Aerospace Center
EDLS	Entry, Descent and Landing System
ESA	European Space Agency
ESOC	European Space Operations Centre
ESRIN	European Space Research Institute
EOL	End of Lifetime
FMAG	Field Magnetometer
FMI	Finnish Meteorological Institute
GRS	Gamma Ray Spectrometer on Mars Odyssey
HiRISE	High Resolution Imaging Science Experiment on MRO
IKI	Russian Space Research Institute
INTA	Instituto Nacional de Tecnica Aeroespacial, Spain
IPR	Immaterial property rights
IR	Infrared
JPL	NASA Jet Propulsion Laboratory
LA	Lavoschkin Association, Russia
LIDAR	Light Detection and Ranging
LMD	Laboratoire de Meteorologie Dynamique du CNRS, France
MCS	Mars Climate Sounder
MDA	McDowell Associates
MDS	MetNet Distribution System
MIBU	Main Inflatable Braking Unit
Mini-TES	Miniature Thermal Emission Spectrometer
MLAM	Mars Limited Area model
MMM	Mars MetNet Mission
MNL	MetNet Lander
MNO	MetNet Orbiter
MRO	Mars Reconnaissance Orbiter
NASA	National Aeronautics and Space Administration
OWLS	Optical Wireless Link System
PBL	Planetary boundary layer
PCB	Printed Circuit Board
PDS	Planetary Data System
PI	Principal Investigator
PMIRR	Pressure Modulator Infrared Radiometer on MRO
PSA	Planetary missions Science data Archive
PSC	Payload System Compartment
RTG	Radio Thermoelectric Generators
SAS	Shock Absorption System
SNC	Shergotty (India), Nakhla (Egypt) and Chassigny (France); first three Martian meteorites.
TPS	Thermal Protection System
TRL	Technology Readiness Level
UHF	Ultra High Frequency

MetNet Executive Summary

We are proposing a new kind of planetary exploration mission for Mars - MetNet in situ observation network at Mars. The mission is based on a new semi-hard landing vehicle called the MetNet Lander (MNL). The scope of the MetNet Mission is to deploy 16 MNLs on the Martian surface using inflatable descent system structures accompanied by an atmospheric sounder and data relay onboard the MetNet Orbiter (MNO). The MNL will have a versatile science payload focused on the atmospheric science of Mars. Detailed characterisation of the Martian atmospheric circulation patterns, boundary layer phenomena, and climatological cycles, as well as interior investigations, require simultaneous in-situ meteorological, seismic and magnetic measurements from networks of stations on the Martian surface. Our team consisting of several leading planetary exploration groups is responding to the ESA Cosmic Vision Call with the proposed Mars MetNet Mission slated for launch around 2016.

The scientific payload of the MetNet Mission encompasses separate instrument packages for the atmospheric entry and descent phase and for the surface operation phase. During the descent phase an imager, accelerometers and devices for free flow pressure and temperature observations will be used. On the Martian surface the MNL will take panoramic pictures, and perform measurements of pressure, temperature, humidity, wind direction and speed with sensor systems accommodated on the deployable sensor boom. On the deck next to the sensor boom there are an atmospheric optical depth instrument and a LIDAR surveying the surrounding atmospheric dust and other aerosols as well as possible low altitude clouds. A water detection device and thermal conductivity sensors are attached on the probe that will penetrate the Martian ground during the landing.

The MetNet mission concept and key probe technologies have been developed and the critical subsystems have been qualified to meet the Martian environmental and functional conditions. The most demanding work of the MetNet Mars Mission, development and qualification of the new type of Mars entry vehicle, has been performed during the years 2002 - 2004. Prototyping of the payload instrumentation with final dimensions was carried out in 2003-2006. This huge development effort has been fulfilled in collaboration between the Finnish Meteorological Institute (FMI), the Russian Lavoschkin Association (LA) and the Russian Space Research Institute (IKI) since August 2001. Presently a suborbital test launch in 2008 is under preparation to test the descent systems of the MetNet in real-like environment. An ongoing mission planning is under way to send two MetNet Landers to Mars in 2009/2011.

The proposed MetNet Mars Mission is making use of the Mars Express satellite platform. The MetNet Landers are attached on the three sides of the satellite. Most of the MetNet landers are deployed to Mars separately a few weeks prior to the arrival to Mars. The remaining satellite platform with an atmospheric sounder and a few MetNet Landers onboard will be inserted to an orbit around Mars. The few MetNet Landers will be deployed to the Martian surface form the orbit around Mars to be able to land on any place at the Martian surface. This will also give the mission team the possibility to supplement the observational network on the most rewarding locations based on the first data acquired from the landed MNLs. The sounder onboard the Orbiter will perform continuous atmospheric soundings thus complementing the accurate in situ observations at the Martian ground produced by the MetNet observation network, as well as the orbiter will serve as the primary data relay between the MetNet Landers and the Earth.

The MetNet Mars Mission is to be implemented in collaboration with ESA, FMI, LA, IKI and the payload providing science teams. The mission leader responsibility would rest with ESA. The Immaterial Property Rights (IPR) of the entry descent and landing system of the MetNet Landers are the property of FMI, who will license the IPR for this mission. The LA and IKI would manufacture the entry, descent and landing systems of the MetNet Landers.

This collaboration would considerably decrease the overall mission costs. Optionally, also the MetNet orbiter that in this proposal is nominally a derivative of the Mars Express platform, could be replaced by a derivative of the Russian Phobos-Grunt platform. This option would slightly add to the mission complexity but would also further decrease the mission costs. The effects of these mission options are illustrated in the mission financial budgets.

To understand the behavior and dynamics of the Martian atmosphere, a wealth of simultaneous *in situ* observations are needed on varying types of Martian orography, terrain and altitude spanning all latitudes and longitudes. This enables the investigations of the microscale, mesoscale and large scale atmospheric phenomena, as well as to characterization of the Martian atmospheric circulation patterns and climatological cycles. These tasks will be performed by the Mars MetNet Mission. In addition to the science aspects the MetNet Mars Mission will provide a crucial support for the safety of large landing missions in general and manned Mars missions in particular. Accurate knowledge of atmospheric conditions and weather data is essential to guarantee safe landings of the forthcoming Mars mission elements. For various operations of manned Mars missions even weather forecasts are needed. For these mission safety aspects and specific operations a network of observation posts accompanied by atmospheric soundings from the orbit is clearly required. The MetNet Mars Mission is exactly this type of tool that is needed both for the Martian atmospheric science as well as for the mission safety and operations aspects.

The MMM mission proposal is building on the results of many years of hard work and fruitful experience in developing and utilising means to study Mars. By drawing on lessons learned in the course of the Phobos, Mars-96, and the NetLander missions, as well as the earlier ESA Marsnet and InterMarsnet studies, the MMM Proposal Consortium has been working on a mission that is solidly based on demonstrated concepts, technologies and capabilities. This proposed mission will in an excellent fashion contribute to ESA Cosmic Vision Programme, in particular by shedding more light on the themes *What are the conditions for life and planetary formation*, and *How does the Solar System work?*.

The MetNet -type of mission is what the planetary science in general and the Martian atmospheric science in particular currently needs. Detailed characterisation of the Martian atmospheric phenomena extending from microscale to large scale domain, as well as the investigations of circulation patterns and climatological cycles are enabled by simultaneous in situ atmospheric observations by Mars MetNet Mission around the surface of Mars. This type of mission is the logical next mission tool in the field of Martian atmospheric science. The various past and ongoing Martian missions have provided a wealth of observations on individual locations at the Martian surface and remote sensing information provided by orbiting platforms. The MetNet Mars Mission will provide the crucial information to the understanding of the dynamics and general behaviour of the Martian atmosphere, as well as it will provide the knowledge of the Martian atmosphere and the weather forecast facility for safe landings of the forthcoming large Martian landing missions.

1 Introduction

We have decided to embark on the exploration of our close neighbour, Mars. Targeting in particular the Martian atmosphere for investigation will aid our scientific understanding of Mars and prepare the way for future robotic and human explorers. We are proposing a new kind of planetary exploration mission for Mars based on a new brand of entry, descent and landing vehicle developed during the years 2001-2007. The scope of the MetNet Mission is eventually to deploy several tens of scientific observation stations on the Martian surface using inflatable descent system structures. MetNet Landers will have a versatile science payload focused on the atmospheric science and interior of Mars. Detailed characterisation of the Martian circulation patterns, boundary layer phenomena, and climatological cycles can be performed via the simultaneous /it in situ measurements from the network of stations. This is realised by our proposed mission, the Mars MetNet Mission.

The MetNet mission concept and key probe technologies have been developed and the critical subsystems have been qualified to meet the Martian environmental and functional conditions. The most demanding work of the MetNet Mars Mission, development and qualification of the new type of Mars entry vehicle, has been performed during the years 2002 - 2004. Prototyping of the payload instrumentation with final dimensions was carried out in 2003-2006. This huge development effort has been fulfilled in collaboration between the Finnish Meteorological Institute (FMI), the Russian Lavoschkin Association (LA) and the Russian Space Research Institute (IKI) since August 2001. Presently a suborbital test launch in 2008 is under preparation to test the descent systems of the MetNet in real-like environment. An ongoing mission planning is under way to send two MetNet Landers to Mars in 2009/2011.

The Mars MetNet Precursor Mission Consortium is responding with this proposal to the ESA Cosmic Vision Call. The proposal is building on the results of many years of hard work and fruitful experience in developing and utilising means to study Mars. By drawing on lessons learned in the Phobos, Mars-96, and the NetLander missions, as well as the earlier ESA Marsnet and InterMarsnet studies, the Consortium has been working on a mission that is solidly based on demonstrated techniques and capabilities. This proposed mission will contribute to ESA Cosmic Vision Programme, in particular its themes "What are the conditions for life and planetary formation", and "How does the Solar System work?".

The proposal team consist of the original MetNet development organisations (FMI, LA, IKI) as well as various Martian research teams and organisations in Europe, the US and Canada. The principal team contact points are A.-M. Harri, J. Leinonen, S. Merikallio, M. Paton, H. Haukka, J. Polkko (FMI), Prof. V. Linkin, V. Lipatov (IKI), Director General K. Pichkadze, A. Polyakov (LA), M. Uspensky (FMI / SpaceTec Inc), Prof. L. Vasquez (Univ. Complutence, Madrid) Dr. H. Guerrero (INTA, Spain), D. Crisp (NASA/JPL), R. Haberle (NASA/AMES), S. Calcutt, C. Wilson (Univ. Oxford), Prof. P. Taylor (Univ. York, Canada), Prof. C. Lange (Univ. of Alberta, Canada), M. Daly (MDA Inc, Canada), L. Richter (DLR, Bremen), R. Jaumann (DLR, Berlin), J.-P. Pommereau (Service d'Aeronomie, Paris), F. Forget (LMD, Paris), Ph. Lognonne (IPGP, Paris), J. Zarnecki (Open University, London). The teams have longstanding collaboration in planetary research and have participated extensively in various earlier missions to Mars. There have been numerous, well thought out studies of the scientific return from simultaneous and spatially dispersed atmospheric observations, which address key questions about the nature and origin of the Martian atmosphere, its current characteristics and evolution. There is a strong scientific and technological rationale behind this type of planetary mission that can now be realised within the framework of the MetNet Mars Mission.

2 Scientific Objectives

2.1 Martian atmospheric investigations

Mars has a thin, cold, dusty and primarily carbon dioxide atmosphere. The Martian atmosphere exhibits a spectrum of circulation phenomena in various spatial and temporal scales; the atmosphere also interacts with the surface and subsurface exchanging heat, momentum and matter (H_2O, CO_2 and dust). In lowest-temperature conditions even CO_2 (the major component of the atmosphere) either condenses onto the surface or forms ice crystals in the atmosphere. H_2O condenses at already higher temperatures. The atmosphere carries hence aerosols of three primary species: dust as well as H_2O and CO_2 ices. They have reservoirs, sources and sinks in the atmosphere, on and within the surface. The aerosols interact with radiation in the solar and thermal wavelengths and have also some lesser effects due to thermodynamic phase changes. The three aerosol populations exhibit feedback of varying significance with atmospheric thermal structure and consequently with circulations.

General circulation and climatological cycles

To date the main identified and indicated components of the Martian *general* circulation — based on both observations and modelling — are as shown in Figure 1; see also (Zurek et al, 1992).

- one or two Hadley cells (depending on the season),
- 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.

The atmosphere is dry in absolute terms (the H_2O column thickness is ≤ 100 μm, typically $\simeq 10$ μm), but *relative* humidity can often reach 100%, hence condensation clouds and near-surface

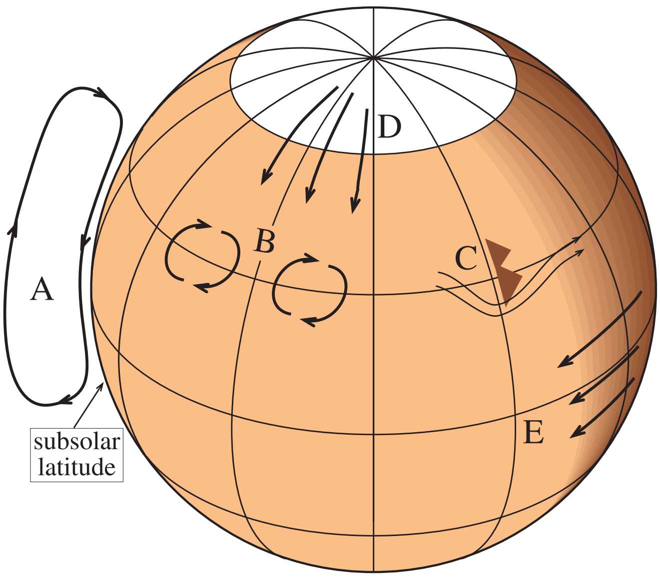


Figure 1: Schematic of the major general circulation patterns occurring in the Martian atmosphere (adapted from Fig. 5 of (Pollack, 1990)). A: (solstitial) Hadley circulation, B: baroclinic eddies, C: stationary eddies resulting from flow over topography, D: CO_2 sublimation flow, E: thermal tides. The Kelvin or normal modes are not included in the Figure.

fogs composed of H_2O ice do occur (*e.g.*, Savijärvi, 1995, 1999). H_2O has been measured by Mariner 9, Viking, Mars Global Surveyor and Mars Express orbiters; condensation clouds have been monitored with imaging from various orbiters. No H_2O measurements have been made on the surface, however. The major source of H_2O is the northern permanent polar cap and according to recent observations the southern cap is a H_2O source as well (Titus et al, 2003; Bibring et al, 2004). The H_2O content varies by latitude and season with hemispherical asymmetry, the peak occurring in the northern polar region in the spring. Mars Odyssey GRS has also observed H (most likely H_2O) in the regolith (Boynton et al, 2004). The role of surface-atmosphere H_2O exchange is not well understood, as no surface humidity observations have been made.

Dust is the dominant aerosol species and its source is the surface, which has a temporally and spatially varying dust cover. Dust is lifted into the atmosphere by different processes resulting in dust storm activity in widely varying spatial and temporal scales (ranging from short-lived dust devils through regional dust storms of days to weeks duration to hemispherical, even global dust storms lasting up to several months). Consequently suspended dust is a ubiquitous component of the Martian atmosphere. Observations and models indicate favoured seasons and (smaller-scale) areas of dust storm activity, which points to regional or mesoscale characteristics as well. Hellas impact basin and the polar cap edges are among the areas that exhibit frequent dust storm activity. The dust optical thickness τ has an approximate lower limit of 0.2, but during dust storms $\tau \simeq 5$ or even more (Kahn et al, 1992). The dust effects on solar and thermal radiation (in turn highly dependent on the dust radiative characteristics) alter drastically the atmospheric thermal structure and consequently the circulation patterns.

Due to the low temperatures and the composition of the atmosphere, CO_2 is exchanged between the seasonal polar ice caps and the atmosphere: CO_2 condenses to the winter hemisphere polar cap and is sublimated from the summer hemisphere cap. This results in atmospheric mass being cycled between the caps and in variation of the mass of the atmosphere. Both of these processes are visible in, *e.g.*, surface pressure observations, as demonstrated already by the Viking landers. The condensation/sublimation flow (Figure 1) is hence also a manifestation of the CO_2 cycle.

Mesoscale phenomena

The Viking landers observed summertime slope winds (Hess et al, 1977), modelled by, *e.g.*, Blumsack et al (1973), Ye et al (1990), and Savijärvi and Siili (1993). Modelling indicates 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 combinations of surface variations (Siili et al, 1999); air mass modifications are also indicated (Segal et al, 1997). Observational confirmation on a number of possible mesoscale phenomena is yet missing.

The planetary boundary layer and surface-atmosphere interactions

The Martian planetary boundary layer (PBL) has been observed by altogether five landers (the Viking landers, the Mars Pathfinder and the Mars Exploration Rovers) and modelled quite extensively. *In situ* measurements of atmospheric temperature (at single or few levels), wind and pressure as well as surface-based remotely sensed observations of vertical profiles (the MER Mini-TES instruments) have given us an initial characterisation of the PBL. The strong diurnal variations of the PBL thickness, changes caused by dust storms and estimates of the heat and momentum fluxes between the surface and the atmosphere are among the features we currently are aware of and understand to a degree. Neither *in situ* measurements of H_2O nor of soil vertical thermal structure have, however, been made and consequently H_2O exchange and to a degree heat exchange between the surface and the atmosphere are less than satisfactorily understood.

Atmospheric vertical structure

Martian atmospheric vertical structure has been observed *in situ* with three landers (the Viking Landers and the Mars Pathfinder) during their descents, with the Mini-TES instruments on board the Mars Exploration Rovers and by several orbiters by means of, *e.g.*, infrared sounders, stellar and solar occultation as well as radio wave propagation. The structure exhibits diurnal, seasonal and spatial variations, wave phenomena and aerosol (ices and dust) layers.

2.2 Definition of science objectives

2.2.1 Overview of the science objectives

An itemised breakdown of the primary science objectives of the MetNet mission is the following:

A-1 characterise the spatial and temporal (from diurnal to interannual scales) characteristics and variations of the general circulation and the climatological cycles of CO_2, H_2O and dust
A-2 characterise the surface-atmosphere interactions (exchanges of momentum and mass) and the atmospheric planetary boundary layer at a wide variety of terrain types and spanning all seasons
A-3 observe *in situ* and from orbit the atmospheric vertical structure
A-4 monitor and characterise condensation clouds at multiple locations and all seasons jointly from surface and orbit
A-5 Characterization of the Martian internal structure and composition via magnetic and seismic observation

Additional science and programmatic objectives include:

B-1 characterise a selected set of mesoscale or regional phenomena
B-2 develop methods and procedures for provision of high-resolution and high-reliability weather forecasts for high-value and high-risk landed missions such as automated sample return and crewed missions
B-3 provide ground truth for orbital observations

Since many meteorological and climatological phenomena have both temporal and spatial variations in scales ranging from local to global and from sub-diurnal to multi-annual, characterisation of such phenomena require ideally simultaneous observations at multiple and different locations and over a sufficiently long period of time. Hence a *surface network* combined with an orbiting sounder is the preferred and closest-to-ideal means of observation. The spatial coverage and distribution of the network as well as the types, temporal durations and resolutions of the instruments and observations need to be commensurate with the characteristic spatial and temporal scales of the phenomena being observed. The need for such a mission concept has been obvious for a long time and several surface networks of varying coverage and complexity have been proposed in different contexts (Haberle and Catling, 1996; Barnes et al, 1993; Squyres, 1995; Harri et al, 1999). No Martian surface network has been deployed to date, however.

The number of the *in situ* payloads and their locations on the planetary surface play an essential role in the mission planning process, as documented by, *e.g.* Grant et al (2004). When addressing local and regional scale atmospheric behavior with one or few surface payloads, the observation posts should be located on areas with, *e.g.* variable types of geography, terrain, thermal inertia, altitude, as well as surface materials and albedo. Capturing synoptic and large-scale atmospheric flows and global circulation phenomena requires a number of simultaneously operating observation posts located around the planetary surface. At least of the order of ten to twenty observation posts are required to address planet-wide atmospheric phenomena as also pointed out by *e.g.* Haberle and Catling (1996). The MetNet Mission will be fit in nicely in this mission category.

The MetNet mission goal is to comprehensively address the objectives outlined above by means of deploying a primarily global-scale, multi-point surface observation network supplemented by an orbiting atmospheric remote sounder operating at least for two Martian years.

2.2.2 Objective A-1: general circulation and climatological cycles

For general or global circulation and climate related observations the main measured variable is pressure, supplemented by the temperature, wind, relative humidity and optical thickness observations. The pressure observations provide ground truth for the orbiting atmospheric sounder's observations for derivation of a 4-D image of the atmospheric state. As wide latitudinal coverage as possible on both hemispheres and at different terrains is required to sample a wide spectrum of phenomena and to provide good ground truth observations. As an example of identification of a class of general circulation phenomena, mid-latitude baroclinic eddies were observed by the Viking Lander spacecraft in the north, the models agree and predict their occurrence also in the south, but their existence there remains observationally unconfirmed *in situ* (Barnes et al, 1993). Longitudinal site coverage in turn can account for the effect of large topography features and resolve atmospheric waves extending over many longitudes.

Comprehensive global coverage will shed light into such features as characteristics of the CO_2 sublimation-condensation cycle and — with the inclusion of H_2O observations — into the global H_2O cycle. Multiple sensors of the lander payload will provide data relevant to initiation and evolution of the dust-related processes: optical thickness, LIDAR, temperature (reduced near-surface air temperatures during dust storms), and pressure (normal modes and their role in dust storm initialisation, passage of dust devils; Tillman (1988); Schofield et al (1997). Selection of a landing sites 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.

2.2.3 Objective A-2: planetary boundary layer and surface-atmosphere interactions

Surface *in situ* observations characterise the PBL phenomena and the surface-atmosphere interactions at the landing sites. The large number of landers and global coverage allow for selection of landing sites with widely varying surface characteristics. Consequently coarse mapping of on the dependence of the PBL on the surface characteristics can be obtained. 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_2O between the atmosphere and the regolith. Dust devils and their role in dust lifting are monitored through pressure observations and correlating them with imaging as well as LIDAR results.

2.2.4 Objective A-3: atmospheric vertical structure

The MetNet probes will measure their 3-axis accelerations as well as pressure and temperature during entry, descent and landing and hence provide additional sets of *in situ* and high spatial (vertical and horizontal) resolution vertical profiles of the atmospheric pressure, temperature, density and possibly also H_2O. The orbiting atmospheric sounder will in turn provide a coarser resolution but more continuous and longer-term data on the atmospheric vertical structure.

2.2.5 Objective A-4: condensation clouds

The panoramic camera, LIDAR and optical thickness instruments together with the good global distribution of the landers and multi-annual observations provide unprecedented surface data on the distribution, temporal variations (diurnal and seasonal) and other characteristics of condensation clouds.

2.2.6 Objective A-5: Martian internal structure and composition

Our present understanding of the internal structure of Mars is principally based on interpretation of gravity data, analysis of SNC meteoroids, and on extrapolation of the Earth2̆019s internal structure to the lower pressures of Mars interior. Mars is a one-plate planet and hence the strong seismicity associated with active plate-tectonics is very likely absent. Modeling efforts show that seismic activity is taking place at Mars based on the thermo-elastic cooling of the one-plate planet, as well as the re-equilibration of the high-topography volcanic complexes. Therefore, seismological and magnetic observations onboard the MetNet Landers will shed light on the internal structure and composition of Mars. (Anderson et al, 1977; Banerdt and Smrekar, 2007; Lognonné, 2005)

2.2.7 Objectives B-1 and B-2: Mesoscale phenomena and future missions

A landing site in sloped terrain or in the proximity of a seasonal CO_2 cap edge would allow for detection and characterisation of cap edge circulations or slope winds. The ability of the MetNet mission to characterise such *mesoscale* phenomena depends crucially on the location and characteristics of chosen landing sites. Deployment constraints permitting, the large total number of landers may allow for choice of some landing sites with mesoscale phenomenon characterisation as a priority. It may even be feasible to deploy a part of the network as a regional or mesoscale subnetwork at a high-interest area — either from atmospheric science or from a future programmatic perspective (a likely landing site of a future mission).

2.2.8 Objective B-3: ground truth for other missions

For instance observations of surface pressure have the potential of improving the accuracy of surface-based remote sensing observations (such as the Mini-TES) or certain geochemical observations. The wide-coverage surface observations coupled with the orbiter observations and advanced data assimilation will permit improved pressure data to be provided for interpretation of observations of other types of Mars landers and their instruments.

3 Mission Profile

3.1 Mission requirements

The MetNet Mars Mission consists of 16 scientific observation posts on the Martian surface accompanied by an atmospheric sounder and data relay onboard an the MetNet Orbiter. The nominal mission lifetime is two Martian years with a possible extended period of operations for another two Martian years. The surface stations will carry out science observations simultaneously all around the Martian surface, and at the same time the atmospheric sounder will measure the atmospheric temperature, pressure and other key parameters from the orbit. The data relay onboard the MetNet Orbiter should communicate with the surface stations once in few days to acquire the accumulated data and to provide new sets of control orders.

The scientific and data relay functions of the MetNet Orbiter require an orbit that is suitable for atmospheric sounding as well as frequent contact with the landers. The optimal orbit for this would be a circular polar orbit, but the objectives can also be obtained with a high-inclination elliptic orbit which requires much less fuel to achieve. The orbital period is chosen to give low-altitude flyovers of the entire planet within a short time.

To meet the scientific objectives the surface stations should land on varying latitudinal locations and different types of terrain, altitude and other places of interest to the atmospheric science, e.g. vicinity of the poles, Hellas Valley and the Tharsis area. Also, surface stations should also be directed to the locations, where observations were previously performed by the Viking Landers and the Mars Pathfinder. This would enable us to compare the current atmosphere at those sites to the atmospheric conditions prevailing earlier. This would be especially interesting at the Viking Lander sites, where observation records of several Martian years are available. Repeating atmospheric observations at those sites now will facilitate climatological investigations. The requirements on the surface station locations can be summarised as:

- Global latitudinal coverage (as close to the poles as feasible)
- Locations with differing type of terrain, albedo, altitude and thermal inertia
- Landings at sites of special meteorological interest (e.g. Hellas Valley and Tharsis, vicinity of the poles)
- A few surface stations should be located such that they would create a limited area network. This implies that within an area of about 1/5 of the Martian surface there would be at least 5 operational surface stations. These observations would be supported by simultaneous simulation runs of the Mars Limited Area Model (MLAM).

Most of the MetNet Landers will be deployed to the Martian surface from the interplanetary trajectory prior to the arrival to Mars. Four MetNet Landers will stay onboard and will be deployed from the orbit around Mars to enable the supplementing of the network based on the early data transmissions. The rough order action requirements during the deployment procedure run as follows: (Harri et al, 2003):

- Spacecraft is targeted and the MNL is separated when still on the approaching path to Mars; this is more economical than jettisoning the MNL from Martian orbit.

- Autonomous flight to Mars (from a few days up to some weeks).

- Entry into the Martian atmosphere. The inflatable heat shield is deployed at the Mach number (M) of approximately 29. At this phase the MNL speed is reduced from supersonic speed to subsonic speed.

- The additional inflatable deceleration structure is deployed when the speed is reduced to

$M \cong 0.8$. By means of this device the speed of the landers is reduced to about 70 m/s by the time the MetNet Lander reaches the Martian surface.

- Impact onto the Martian surface (maximal deceleration 500g over the time of 50 ms) and penetration into the soil thus obtaining a proper operating attitude.
- Systems start-up and checkout.
- Scientific investigations program.

3.2 Proposed mission scenario

The MetNet landers will travel to Mars aboard the carrier and orbiter spacecraft. A Soyuz-Fregat 2B, launched during the 2016 launch window from the launch facilities in Baikonur Cosmodrome[1], Kazakhstan, will place the spacecraft on a Hofmann transfer orbit. During the cruise phase of about 7 months the spacecraft systems and scientific payload will be woken up every few weeks for regular health-check tests.

Most landers will be released from the carrier on a hyperbolic trajectory. The carrier will release the first lander about 2 weeks before Mars arrival, after which time it will begin to decelerate and release the landers at different velocities. Each lander will be individually targeted by maneuvering the carrier spacecraft. The carrier makes small adjustments to its trajectory in order to select the landing site, and its attitude is adjusted to ensure a proper entry orientation for the landers. The deceleration will result in a total delay of about one Martian day to the arrival of the landers, allowing them to be deployed to cover the entire surface of Mars.

With the landers released, the carrier will shift its course to avoid the atmosphere of Mars, cruise the remaining distance and execute an orbit insertion burn to place itself on an initial highly elliptic orbit. Over the following months, it will adjust its orbit to be better suitable for telecommunications and orbital observations.

On the first few orbits, the carrier will establish contact to the landers and determine their condition and location. The carrier contacts the landers by transmitting a call signal which can be received by all landers. The probes will answer the call with individual response signals, which allows the carrier to identify the landers. The carrier then selects the lander to connect to, and asks the lander to uplink data. Co-operation with other orbiters at Mars at the time, such as the ExoMars orbiter and the Mars Reconnaissance Orbiter (MRO), will be useful for the communications. The MRO HiRISE or an equivalent orbital camera can be used to pinpoint the locations of the landers.

After landing on the Martian surface each MetNet Lander will firstly inspect the status of its internal systems, and will packetise the observations performed during the entry, descent and landing phases. Secondly, it will deploy the instrument boom carrying also the antenna, and will start listening to the orbiter and eventually will transmit the health check results and the first observations. Thirdly it will deploy the soil probe and the magnetometer. The actual science operations will start by gathering context information with the panoramic camera. Routine science operations with the entire payload will be started within 1-3 weeks from the landing, after the commissioning phase described above is complete.

[1]The use of Russian RTG power sources is likely to restrict the launch site to Russian facilities.

4 Proposed Payload

4.1 Overview

The scientific payload of the MetNet Mission encompasses separate instrument packages for the atmospheric entry and descent phase and for the surface operation phase, as well as the MetNet Orbiting Platform that orbits Mars with atmospheric sounding instrumentation.

During the descent phase, acceleration, pressure and temperature are followed to record at-

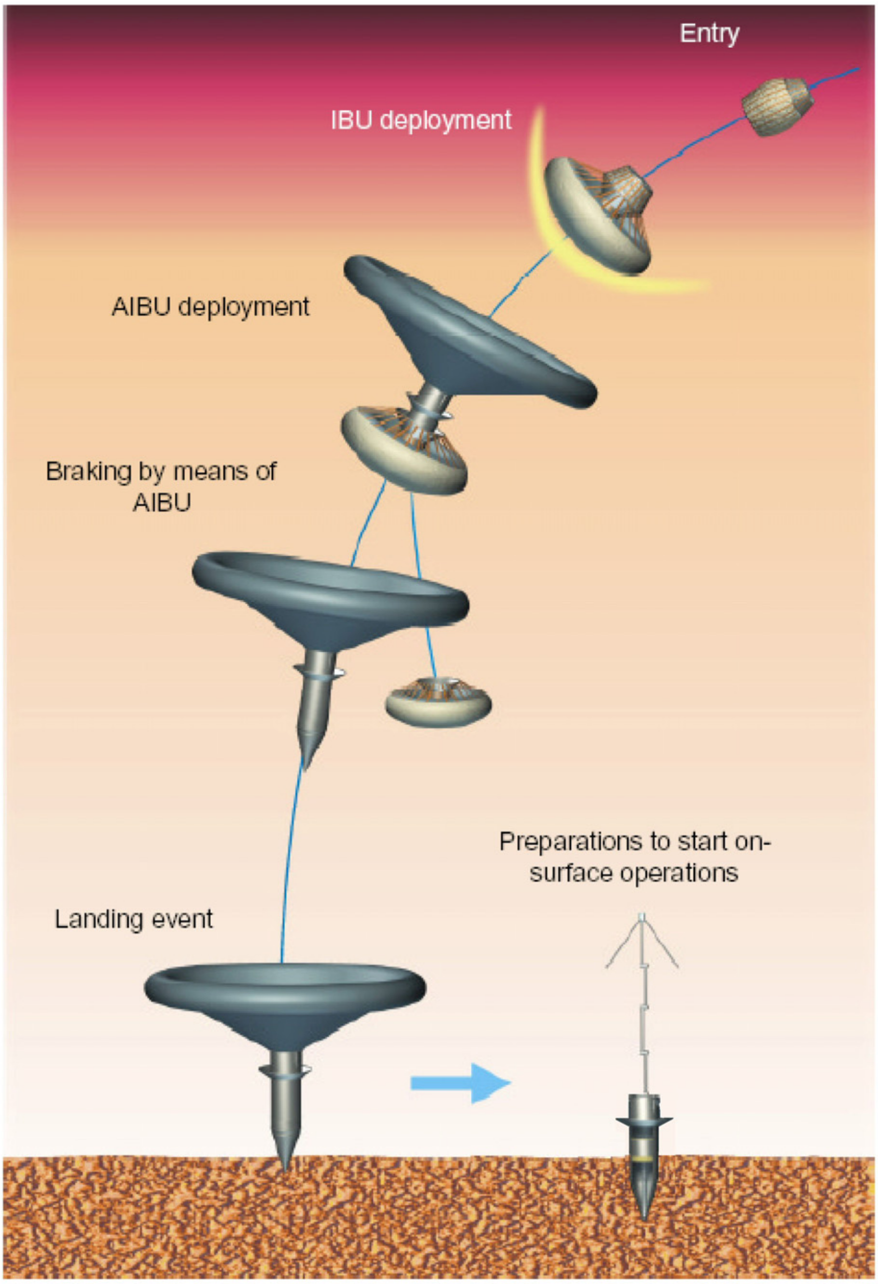


Figure 2: The entry, descent and landing scenario of the MetNet Lander based on inflatable structures. The specified maximum impact shock on the Martian surface is 500 g. MNL obtains proper operations attitude through penetrating into the Martian soil, which also serves as one deceleration mechanism (Harri et al, 2003).

mospheric density and temperature profiles. Descent phase pressure and temperature sensors will be destroyed in the landing and are thus not usable afterwards. The accelerometer will be used after the landing as an inclinometer for determining lander attitude. The descent phase camera is used to identify the landing area landscape.

At the Martian surface the MetNet stations will take panoramic pictures, and perform measurements of pressure, temperature, humidity, wind direction and speed, as well as atmospheric optical depth. A water detection device and thermal conductivity sensors are attached in the probe that will penetrate the Martian ground during the landing phase. Additionally, a lightweight LIDAR operates on the platform and a magnetometer is deployed in the side of the MetNet Lander. (Harri et al, 1995)

The schematic drawing of the MetNet surface payload is illustrated in Figure 3. The current payload has already been prototyped in real dimensions, and fit checked with the payload compartment, as depicted in Figure 4.

The electronics, system devices and instruments are accommodated inside the Equipment Module (except the Water Detector and the Ground Temperature instruments which are in the Body Cone section). The Equipment Module is divided into two parts which are the Payload System Compartment and the Lander Deck Compartment.

4.2 Payload accommodation

4.2.1 Payload System Compartment

The Payload System Compartment (PSC) is a thermally insulated and temperature controlled compartment on the lander body. PSC accommodates instrument and system electronics and other system devices. The system electronics and devices in the PSC include the Central Data Management System (CDMS), power subsystem, pyro interface, telecommunications system,

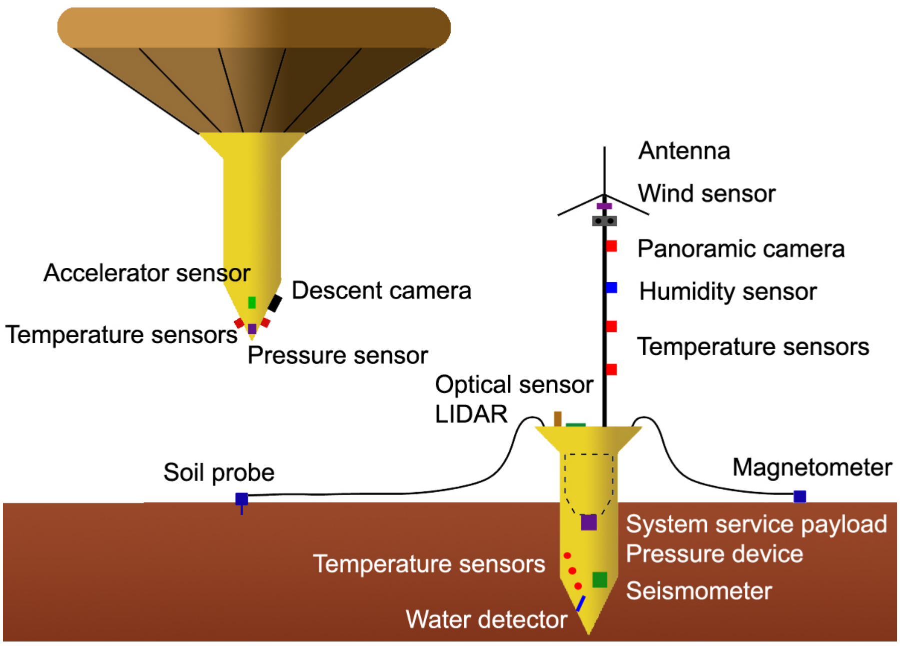


Figure 3: A sketch of the surface payload of the MetNet Lander. The sensor boom will also carry the UHF communications antenna.

Radioisotope Thermoelectric Generators (RTG) and the battery. The communication between devices in the PSC is handled by the Optical Wireless Link System (OWLS).

4.2.2 Lander Deck Compartment

The Lander Deck Compartment is located on the top of the PSC box and it supports and accommodates instruments which must have access to ambient environment. These are the optical sensor, the LIDAR, the Met Boom with the temperature, wind and humidity sensors, and the soil probe with the magnetometer, temperature and humidity sensors. The Met Boom also supports the panoramic camera and the telecommunications antenna.

Deployables, Met Boom, Soil Probe and Magnetometer sensor head, are stowed on the Lander Deck Compartment. Met Boom is a telescopic boom stowed in an 80x80x230 mm container and actuated by an electric motor. Soil Probe and Magnetometer are ejected by spring operated ejectors to 1-1.5 m distance from the lander.

4.3 Sensor systems

4.3.1 Pressure sensor

The pressure sensor unit consists of Barocap absolute pressure sensor heads and their transducer electronics. The unit is based on similar devices flown on the Mars-96, Huygens, Beagle 2 and Mars Polar Lander. These devices will also fly on the Phoenix, Mars Science Laboratory and ExoMars missions.

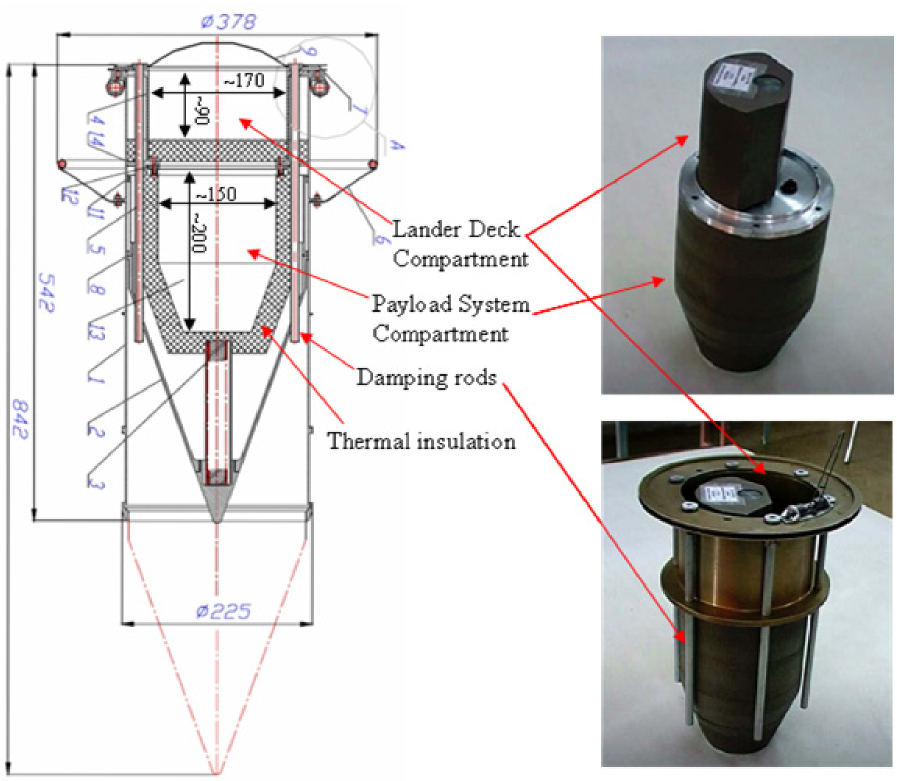


Figure 4: The MetNet lander payload compartments. On the right PL compartment is shown in its current engineering model state with prototype payload inside.

Table 1: An overview of the power requirements and data rates of the MetNet surface payload.

Metnet Surface Science Instrument P/L

Assembly	Instrument & function	Power Average mW	Power Peak mW	Nature of operation Cont./Periodic/Few 2)	Data rate / Sol KByte/sol (raw)	Interface to	Energy /sol mWh
Met Boom	Met Boom	N/A	N/A	N/A	N/A	N/A	N/A
	T sensors on Met Boom	on T-electr.			4)	T sens. electr.	4)
	H sensors on Met Boom	15	15	Periodic	34	CDMS	25
	W sensor on Met Boom	on W-electr.		Periodic	4)	W sens. electr.	4)
	Pancam camera	see text		Few	2)	CDMS	2)
Soil probe	Soil Probe	N/A	N/A	N/A	N/A	N/A	N/A
	Ta sensor on Soil Probe	N/A			4)	T sens. electr.	4)
	Ts sensor on Soil Probe	N/A			4)	T sens. electr.	4)
	H sensor on Soil Probe	15	15	Periodic	34	CDMS	25
Magnetometer	Magnetometer	10	200	Continuous	200	M electronics	5)
Seismometer	Seismometer	100	100	TBD	TBD	CDMS	TBD
Instr. in electronics compartment	T sensor electronics	65	65		336	CDMS	500
	W-sensor electronics	90	90		100	CDMS	600
	Lidar & Pancam electronics	SeeLid. & PC	SeeLid. & PC	Periodic	3)	CDMS	3)
	Opt. & M sensor electr.	50	80			CDMS	500
	Pressure sensor	15	15	Continuous	100	CDMS	100
On the deck	Optical Depth sensor	on Opt.electr.	on Opt.electr.	Continuous	9	Optical sens. El.	5)
	Lidar transceiver	4000	4000	few	3)	Lidar Electr.	3)
On the body cone	Ground temperature	20	20	Periodic	5	CDMS	20
	Water detector	100	5000	Few	2)	CDMS	
Total for daily operated instruments (rest of the energy & link budget for campaign operations):					818		1745
Available for dedicated observation campaigns:							3255

T Temperature
W Wind
H Humidity
Ta Air temperature (in Soil Probe)
Ts Soil Temperature (in Soil Probe
M Magnetomer

1) Continous: Observations 1%...10% of sol
Periodic: Fewer than continuous operations but at least once per sol or more
Few: Observations in the beg. of mission, later on less frequent (like camera)
Observations maybe also "event triggered" or run "campaign style"
2) Only few operations during the mission
3) Used only campaign style due to high power & data rate
4) Data and energy on W- and T-electronics

System device	Function	Power Average mW	Power Peak mW	Nature of operation	Energy / Sol mWh	Note
CDMS	Operates lander & instruments	700	2500	Sleep / Idle / Operating	4000	6 hours on/Sol
Telecomms	Telecommunication		4000 rx/300 tx	Idle / Listen / Transmit	1000	max 256 kb/s rx

Descent Phase Science Instruments

Assembly	Instrument & function	Power Average mW	Power Peak mW	Nature of operation	Cumulated data Kbyte (raw)	Interface to	Energy mWh
Descent pressure	Pressure profile	15	15	Continuously on	15	CDMS	2.5
Descent temperature	Temperature profile	65	65	Continuously on	4	T-electronics	11
Descent Camera	Landing area pictures	1500	1500	2 pictures/second	100000	CDMS	100
Accelerometer	Accelerometer	250	250	Continuously on	72	CDMS	100
Total			**1830**		**100091**		**213.5**

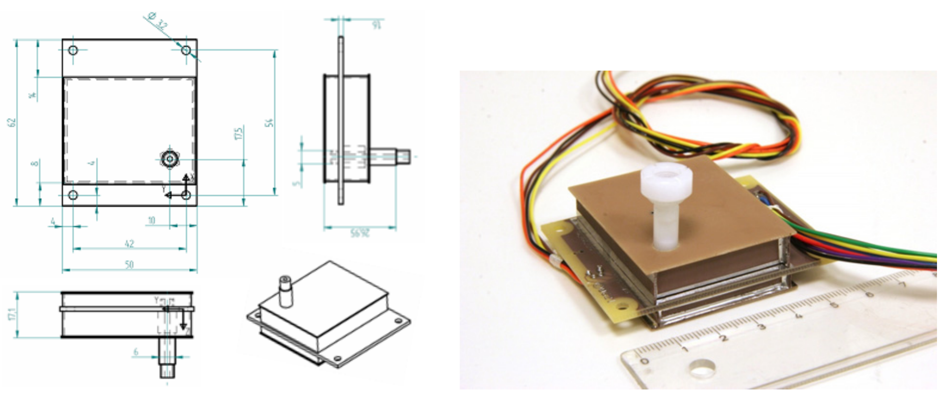


Figure 5: A schematic and a photograph of the pressure sensor.

Table 2: An overview of the mass and volume of the MetNet surface payload.

Metnet Surface Science Instrument P/L

Assembly	Instrument & function	Mass g	Assembly g	Dimensions cm	Volume cm3	Assembly cm3	Technology readyness
Met Boom	-Supports T, H, W sensors	350		8x8x23 1)	1472		4
	T sensors on Met Boom (3 pc	10		5x5x0.3x 3pcs	25		7
	H sensors on Met Boom	15		Ø1.5 x 4.5	10		7
	W sensor on Met Boom	20		Ø2.5 x 5	25		7
	Pancam camera	150		4x3x8	96		6
	Antenna	27		Ø18 x 18	50		
	Cables & connectors	50	622			1472	
Soil probe	- Supports soil surface	100		5x5x12 1)	300		5
	Ta sensor on Soil Probe	3		5x5x0.3	8		7
	Ts sensor on Soil Probe	5		Ø0.5 x 5	1		7
	H sensor on Soil Probe	15		Ø1.5 x 4	10		7
	Cables & connectors	30	153			300	
Magnetometer	and ejection mechanism	200	200	5x5x10 1)	250	250	4
Seismometer	Seismometer	200	200	< 3x3x4	< 36	< 36	4
	T sensor electronics	60		8x7x1	56		7
Instr. in electronics	W-sensor electronics	60		8x7x1	56		7
compartment	Lidar & Camera electronics	150		10x8x1,5	120		4
	Opt. & M sensor electr.	180		10x8x2,5	200		6
	Pressure sensor	45		2x6.2x5.5	70		8
	Cables & connectors int. & ex	150	645			502	
On the deck	Optical Depth sensor	70		12x5x5	300		6
	Lidar transceiver	50	120	3x5x5	75	375	4
On the body cone	Water Detector	100		Ø3 x 10	50		7
	Ground temperature	50	150	Ø1x1x 3 pcs	5	55	7
Total			2090			2954	

T Temperature
W Wind
H Humidity
Ta Air temperature (in Soil Probe)
Ts Soil Temperature (in Soil Probe)
M Magnetomer
S Seismometer

1) Dimension and volume in stowed configuration

Assembly	Device & Function	Mass g	Assembly g	Dimensions cm	Volume cm3	Assembly cm3	Technology readyness
CDMS	Central Data Management	120		12x12x1	144		
Power System	Power subsystem, swithches	120		12x12x1	144		
Telecomss	Telecommunication	100		10x8x1,5	120		
Accelerometer	Descent science, landing timi	200		8x8x4	256		
Connector & cables		50	590			664	
RTG	Power source	400		Ø7x12	460		
Batteries	Battery	260	660	8x3,5x3,5	98	558	
Thermal system	Insulation, heat pipes, radiato	610	610		300	300	
Equipment module	Construction of the equip. Mo	1150	1150				
Total			3010			1522	

Descent Phase science instruments

Assembly	Device & Function	Mass g	Assembly g	Dimensions cm	Volume cm3	Assembly cm3	Technology readyness
Descent pressure	Pressure profile	60		7x6x2	84		8

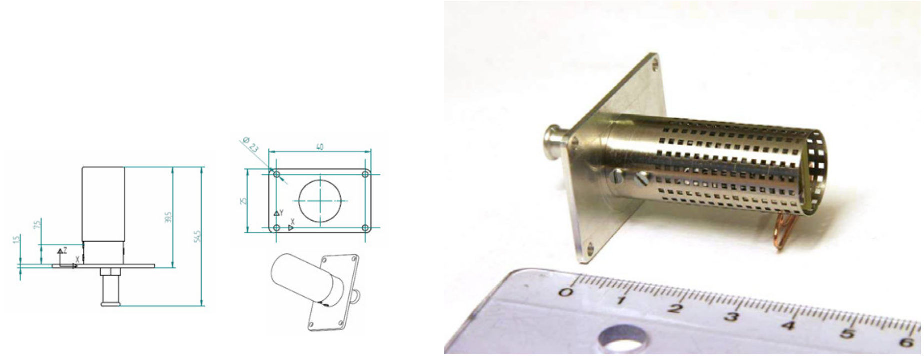


Figure 6: A schematic and a photograph of the humidity sensor.

The descent phase pressure sensor system is similar to surface phase pressure sensor. The Barocap pressure sensor heads are selected to optimise low end pressure measurements. The pressure sensor is located at the lander cone section, where the pressure is sampled from the lander front tip and led by piping to the pressure sensor.

Pressure sensor characteristics and performance

Mass:	45 g (excluding wires, connectors and pressure lead-in piping)
Dimensions:	20 mm × 62 mm × 55 mm
Power:	3 mA / +5 V, 15 mW
Resolution:	0.2 Pa
Time resolution:	2 samples / second
Accuracy BoL:	10 Pa
Accuracy EoL:	15 Pa

Pressure sensor interface requirements

I/F:	CMOS level 0/+5V digital Input: Two digital inputs for resetting and stepping the sensor multiplexer Output: Frequency in the range 3-18 kHz, 24 bit frequency counter with min. 8 Mhz reference clock required.
Mechanics:	Located inside the electronics compartment. Pressure lead in piping with a dust filter required.

Pressure sensor data and observations

Data output:	24 Byte / s raw data 6 Byte / s preprocessed data
”Continuous” observations five percent of time	Few seconds once a minute or few minutes per hour or ≈ 1.5 hours true continuous per sol
Data output:	100 kB raw data, 25 kB preprocessed data
Energy:	< 20 mWh / sol

4.3.2 Humidity sensor

The humidity sensor unit contains Humicap relative humidity sensors and their transducer electronics. An earlier version flew on Mars-96. The current version will fly in the Mars Science Laboratory and ExoMars.

Humidity sensor characteristics and performance

Mass:	15 g (excluding wires and connectors)
Dimensions:	∅15 mm × 40 mm
Power:	3 mA / +5 V, 15 mW
Resolution:	0.2 Pa
Time constant of sensors:	1 s /+20 °C, 20 s /-40 °C, 1000 s /-70 °C
Accuracy:	±1% RH at +20 °C, ±4% RH at -40 °C, ±5.5% RH at -70 °C

Humidity sensor interface requirements

I/F:	CMOS level 0/+5V digital
Input:	Two digital inputs for resetting and stepping the sensor multiplexer.
Output:	Frequency in the range 3-18 kHz, 24 bit frequency counter with min 8 Mhz reference clock required.
Heating:	5V heating voltage required for periodic defrosting/regeneration of the sensor.
Mechanics:	Unit 1 located on the Met Boom, Unit 2 located on the Soil Probe.

Humidity sensor data and observations

Data output:	24 Bytes / s raw data 7 Bytes / s preprocessed data
"Continuous" observations 1%/sol:	10 seconds once in 15 minutes or a minute in an hour
Data output:	20 kByte raw data, 6 kBytes preprocessed data
Energy:	<50 mWh / sol

4.3.3 Temperature sensors

The temperature sensors for the Met Boom, soil probe and descent phase temperature measurements are thin wire chromel-constantan thermocouples. There are three sensors on the Met Boom, two on the soil probe and two outside the lander front cone for the descent phase. The reference junctions of these temperature sensor thermocouples are on an isothermal block located on the Met Boom root. The temperature of the isothermal block is measured by a platinum sensor. The temperature sensor electronics are located on an electronics board inside the Payload System Compartment.

Thermocouple sensor characteristics

Sensor dimensions:	50 mm × 50 mm × 3 mm
Mass:	3 g
Time constant:	< 1 s
Accuracy:	0.5 °C
Resolution:	0.05 °C

The ground temperature sensors are located on the lander body cone. The sensor heads are on the surface of the cone and they are thermally isolated from the cone by an insulator. There are three sensor elements. The sensors are platinum thermoresistors operated directly by the CDMS.

Ground temperature sensor characteristics

Dimensions:	∅10 mm × 10 mm, 3 pieces
Mass:	< 10 g

4.3.4 Accelerometer

The accelerometer is located inside the Payload System Compartment. It is based on a three-axis capacitive sensor.

Accelerometer characteristics

Range:	± 200 m/s
Sensitivity:	0.00001 m/s
Sample rate:	< 10 Hz
Interface:	115 kBaud RS232
Input power:	0.25 W, 5-8 V
Temperature range:	-50°C-+50°C
Mass:	250 g

4.3.5 Wind sensor

The wind sensor is based on constant temperature difference. The sensor is composed of four co-planar ”hot” cubes made of silicon. The platinum resistors are located on the surface of the silicon chip, electrically isolated from the bulk and from each other. The geometric arrangement makes the relative output signal of the cubes sensitive to angle. There is a fifth cube, as reference or ”cold” cube. The electronic circuit is a closed thermal sigma-delta modulator loop consisting on a comparator and a bistable circuit which compares the temperature difference between hot and cold points with a pre-set value and provides power pulses to the heater accordingly.

The output of the converter is the count of the number of heating power pulses delivered to the hot point in a given time window, providing the value of the power required to keep delta T between hot and reference points. From the values of the average power and of the delta T, the thermal conductance from the hot point to the ambient is determined, and this is related to the wind speed by means of the Nusselt number. (Domínguez et al, 2002, 2005)

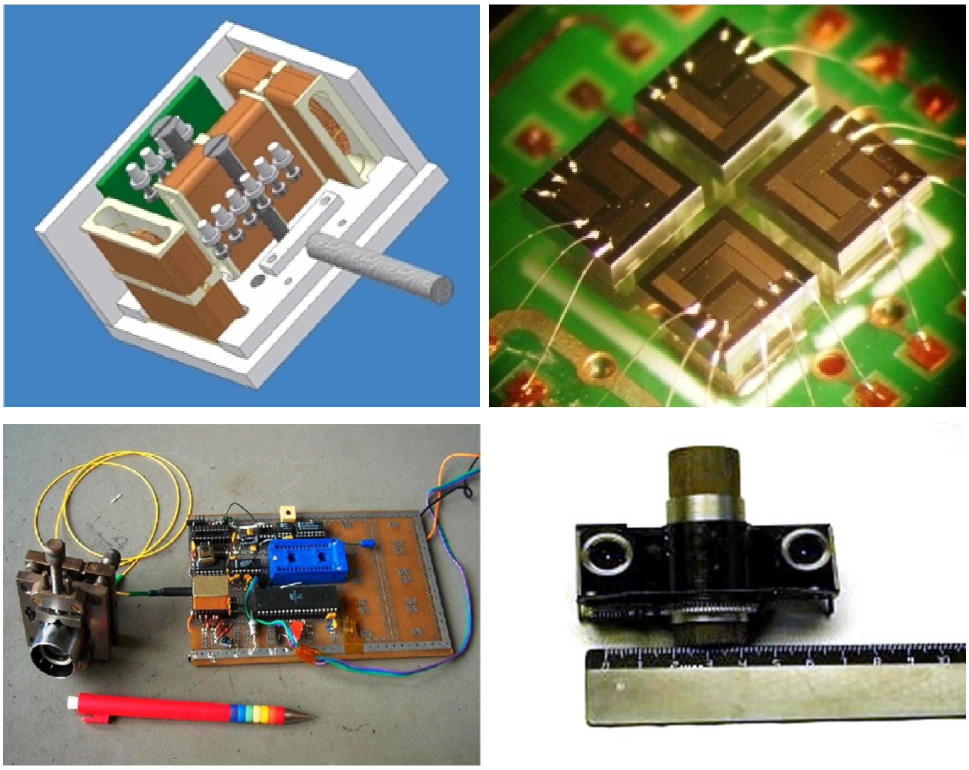


Figure 7: Payload images: the magnetometer (top left), the wind sensor (top right), the LIDAR (bottom left), and the camera (bottom right).

Wind sensor characteristics

Mass:	100 g (the mass of the assembled plate in Figure 7)
Plate dimensions:	3.5 × 1 cm^2
One silicon die dimensions:	1.5 × 1.5 × 0.5 mm^3
Power requirements:	90 mW (excluding front end electronics)
Dimensions:	Two
Speed range:	0-20 m/s or 0-70 m/s
Accuracy:	1 m/s, 20°
Resolution:	0,5 m/s, 10°
Measurement rate:	1 Hz

4.3.6 Optical sensor

The optical sensor measures direct solar irradiance and diffuse light on the Mars surface. The atmospheric optical depth is measured with the proposed sensor. The device is based on two different technologies to detect light: an array of large area photodiodes with response between 200 nm and 1000 nm (UV-VIS-near IR), and a set of fluorescent optical fibres for lateral detection of direct incident and diffuse light. It also will include a dust wiper to remove the dust on the array of photodiodes. The photodiode array has ten elements. Each photodiode of the array has interference band pass filters on it to be wavelength selective. The system will have a field of view over 120°. All the system will be on the deck of the lander, facing up to the Martian sky.

The fluorescent optical fibres are a solution to avoid the dust deposition on the photodiodes array, and also for measuring contribution of the atmospheric diffuse light. These are optical fibres whose cores have fluorescent molecules. Light photons are side collected and fluorescent molecules re-emit in all directions. Of these re-emitted photons, those that are below the critical angle of the optical fibre are then transmitted under total internal reflection conditions.

The accuracy of the photodiodes operating on the surface of Mars is affected by Martian dust deposition. A robotic dust wiper technology to clean the deposition of Martian dust on the irradiance sensor is proposed herein. The technology has been developed to clean surfaces from deposited micron-sized dust particles (aerosols). In particular, it has been designed and tested to clean the surface of optical sensors operating on the surface of Mars.

Optical sensor characteristics

Mass:	< 40 g
Dimensions:	Optical fibers: 6 cylinders of 20 cm × 0.5 cm (diam)
	Photodiodes: 10 cm × 5 × cm × 1 cm
Volume:	160 cm^3
Power Average:	< 80 mW
Power Peak:	< 80 mW
Resolution:	TBD
Accuracy:	TBD
Nature of Operation:	Continuous / Read every 5-10' (during the Martian day)
Data rate:	Low (TBD) - DC signal
I/F (Data and Power):	OWLS for Data Transmission and ±5 V
Assembly:	Photodiodes array on the Deck
	6 optical fibers on the MET Boom
TRL:	4-5

Dust wiper characteristics

Mass:	< 30 g
Power Consumption:	< 7 W, 2 s per wiping cycle
Dimension:	12 cm × 5 cm × 5 cm
Cleaning Efficiency:	> 95% under any dust accumulation

4.3.7 LIDAR

The LIDAR observes atmospheric dust, aerosols and water vapour columns above the lander up to 10000 m. It consists of an optical transceiver block located on the lander deck and an electronics board located inside the Payload System Compartment. The electronics include a power converter and a microprocessor.

LIDAR characteristics

Range:	From 5 m to 1 km (range 1, day) / 10 km (range 2, night) / 300 m (range 3, humidity)
Sensitivity:	$2 \cdot 10^6$ m^{-1} / 10^6 m^{-1} / 10^{14} m^{-1}
Sample rate:	1.0 Hz / 0.1 Hz / 0.01 Hz
Interface:	115 kBaud RS232
Input power:	4 W, 5-8 V
Temperature range:	-55°C-+50°C
Mass:	150 g

4.3.8 Magnetometer

The tri-axial vector field magnetometer (FMAG) is originally developed for the CNES Mars NetLander mission and tested on stratospheric balloons and in Antarctica. The magnetometer consists of a tri-axial magnetic feedback sensor with three fluxgate elements, one printed circuit board (PCB) electronics unit and an interconnecting harness cable. The FMAG will be part of the miniaturisation development to be proven onboard the ESA PROBA 2 mission 2007 and the instruments approved for the 2010 ESA Swarm mapping mission.

The magnetometer sensor head is deployed about 1 meter away from the lander body by a mortar mechanism operated by a spring. The attitude of the sensor head is determined by a known magnetic signal given by sensor electronics after the deployment.

Magnetometer characteristics

Sensor mass:	50 g incl. mechanical fixture and passive thermal insulation.
Mortar mechanism:	50 g
Electronics board mass:	100 g
Harness cable:	30 g/m
Dynamic range:	±100 T to 0.048 nT LSB (using 22 bits of a 24 bit ADC)
Electronics noise:	60 pT RMS in the band 0.05-10 Hz (20 pT RMS/$\sqrt{\text{Hz}}$ at 1 Hz)
Sampling rate:	1 vector / 30 s (averaged), optional higher rate (TBD) in campaign mode.
Zero stability:	$<$ 0.3 nT (thermal and long term, in-orbit proven)
Sensor:	-150°C to +120∘C (operating and survival)
Electronics:	-20°C to +60∘C (operating), -40°C to +85°C (survival)

4.3.9 Seismometer

Seismometer is located on the tip of the MetNet lander cone to ensure the proper contact to the Martian ground. The tip of the cone is the best possible location for seismometer to ensure the optimum quality of the seismological observations. Seismometer mechanical structure and design is miniaturized, lightweight, low-power consumption designed and specially designed for planetary applications. The mass of the seismometer is approximately 200 grams and the dimensions are less than 3x3x4 cm. The power consumption of the sensor is about 100 mW. Similar type of seismometers has been proposed, qualified and selected for earlier missions (e.g. Rosetta Lander and NetLander). (Anderson et al, 1977; Banerdt and Smrekar, 2007; Lognonné, 2005)

4.3.10 Camera

The panoramic camera is located on the Met Boom. The camera is based on a 1280×1024 RGB-colour CCD matrix. The angle of view of a single frame is 90 degrees horizontal and 50 degrees vertical. The camera is rotated by an electric motor to get a full 360 degree view.

The descent phase camera is located in the lander front end cone section. It uses the same CCD as the panoramic camera, with the optics giving a 75° × 63° field of view.

Camera characteristics

Angular resolution:	2' (surface) / 4' (descent)
Exposure:	50 μs - 500 ms
Sensor dynamic range:	1000
Sharp focus range:	0.5 m - ∞
Interface:	2 kBaud RS232
Power consumption:	5 W (surface) / 1.5 W (descent)
Temperature range:	-55°C to +50°C
Mass:	150 g (surface) / 40 g (descent)
Input voltage:	4.5 V - 9 V

4.3.11 Water detector

The water detector instrument is located in the lander body cone compartment. The water detector takes a soil sample by an Archimedes screw based sampling mechanism. The sample is then heated and the water concentration is determined by calorimetric energy balance and by a humidity sensor (which is identical to meteorological humidity sensors of the lander). The instrument is used once.

Water detector characteristics

Mass:	50 g
Dimensions:	∅30 × 100 mm
Power:	5 W (Peak)
Flight heritage:	Deep Space 2 micropenetrators had equivalent instruments

4.4 Orbital payload

4.4.1 Mars Climate Sounder

Remote sensing of the vertical structure of atmospheric pressure, temperature dust and water content will be performed using a development of the Mars Climate Sounder instrument (MCS MCleese et al 2007) which is currently in operation on the NASA Mars Reconnaissance Orbiter. The MCS is, in turn, a development of the PMIRR experiment that was developed by the Jet Propulsion Laboratory and Oxford University but lost on Mars Observer and Mars Climate Orbiter.

The MCS exploits modern thermopyle detector technology to make high spatial resolution measurements of the atmospheric limb without the need for a cooled focal plane. These high vertical resolutions (5km) measurements are ideal for comparison with numerical models of the Martian atmosphere. The low mass of the instrument is possible because of the use of miniature (1 x 11 x 0.4mm) interference and mesh filters which have been developed by Reading and Cardiff Universities. The instrument has nine spectral channels covering wavelengths from 0.3 microns to 45 microns. The channels are optimised for measurement of atmospheric pressure, temperature, water and aerosols as well as measuring broad band reflected sunlight.

Observations of the surface are interleaved with the limb scanning so that the surface energy balance and thermal inertia can be investigated.

MCS can be used for measurements of heights from 85km down to 10km. This lower limit rises to 20km or above when observing during high atmospheric dust conditions. The combination of MCS measurements with in-situ measurements of the lower atmosphere provides an ideal way to obtain a complete 3 dimensional measurement of the state of the atmosphere at any time. Both sets of measurements can be continuously assimilated into Oxford's general circulation model to allow us to determine the atmospheric state most consistent with the full array of measurements.

Characteristics

Mass:	9 kg
Power:	11 W
Spectral range:	0.3 to 45.0 mm in nine spectral channels
Telescopes:	Two identical, 4 cm aperture, f/1.7 telescopes
Detectors:	Nine 21x1 arrays near 290 K
Detector IFOV:	3.6x6.2 mrad (5.0x8.6 km at limb)
Instrument IFOV:	75x75 mrad (105x105 km at limb)
Instrument articulation:	Two-axis azimuth/elevation
Range/resolution:	Azimuth: 270/0.1 degrees, Elevation: 270/0.1 degrees
Signal integration period:	2.048s
Observation strategy:	Limb Staring; limb, nadir and off-nadir scanning in-track, cross-track, and off-track viewing

5 Spacecraft Key Factors

5.1 Spacecraft configuration

The MetNet spacecraft include a carrier spacecraft and 16 identical compact landers. 10-12 of the landers will be released from the carrier prior to Mars arrival, after which the carrier will decelerate to Mars orbit. The remaining landers will be released from orbit, which allows for a more complete coverage of the surface and the ability to replace landers that failed to land successfully.

The MetNet carrier will be based on the three-axis stabilised Mars Express spacecraft bus that has also been used successfully with Venus Express. Six landers will be mounted on each of the empty sides (i.e. those not used by the solar panels, the main antenna or the main engine) of the bus, and additional four adjacent to the main engine.

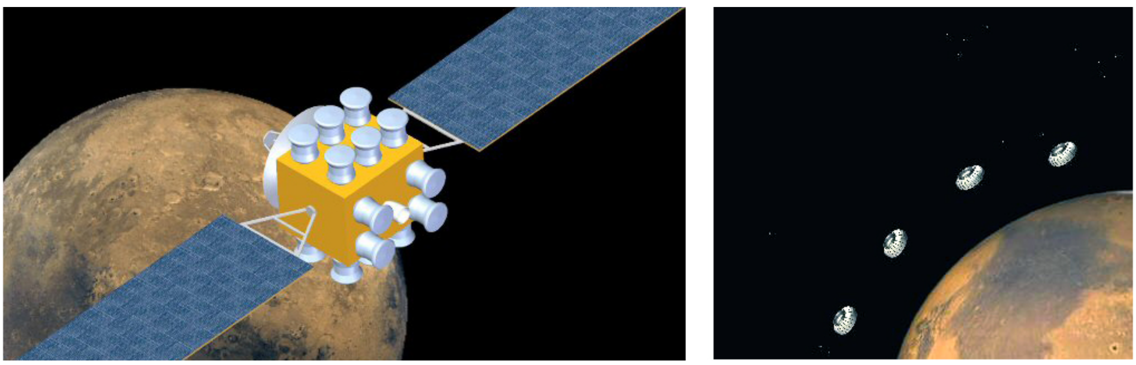


Figure 8: An illustration of the MetNet Mars mission deploying sixteen MetNet landers on the surface of Mars. They are accompanied with the MetNet Orbiter performing atmospheric soundings.

Figure 9: The left image shows the MetNet configured for descending. The middle image shows a flight test version with the heat shield fully inflated. The right shows the MetNet configured for landing. The circular tube-like structure above the MetNet station is a second stage inflatable for deceleration after the hypersonic entry phase.

Each lander is attached to an individual mount that will spin-stabilise and release it. As the landers are released several weeks before Mars arrival to ensure a complete coverage of the planet, precise targeting maneuvers are required by the orbiter. The level of accuracy achieved by Mars Express with the release of Beagle 2 will be sufficient for this purpose.

The MetNet landers are compact probes that optimise mass usage by utilising state-of-the-art entry and landing technologies. The entry phase Thermal Protection System (TPS) is provided by the 1.0 m diameter Main Inflatable Braking Unit (MIBU) which is inflated after the lander release from the carrier. After atmospheric entry at about 13° angle, the MIBU slows down the lander from the hypersonic entry velocity to a suitable velocity for the 1.8 m Additional Inflatable Braking Unit (AIBU). The AIBU deploys behind the lander to keep it aerodynamically stable and decrease its velocity further for the landing. The lander impacts the ground at about 45-55 m/s and penetrates to the ground. The Shock-Absorption System (SAS) limits the deceleration experienced by the payload to about 500 g by means of mechanical deformation. (Terterashvili et al, 2003; Pichkhadze et al, 2004)

5.2 Telecommunication

The MetNet landers will transmit to Earth via the MetNet Orbiter, which gathers the data from the landers and sends them to the Earth regularly.

The communication from the Martian surface to the orbiting spacecraft uses the UHF band, as other current and future Mars lander missions. This ensures compatibility with other Mars-orbiting spacecraft such as the ExoMars Orbiter and the Mars Reconnaissance Orbiter. The carrier communicates to the Earth using the S-band and X-band links of the high gain antenna of the Mars Express bus. This allows it to downlink data to any ESA ground station (e.g. Villafranca, Perth or Kourou). The use of K_a-band communications is also possible.

The bandwidth of the UHF surface-to-orbit link is in the order of 16 kbps, while the orbiter is expected to downlink data to the Earth at the Mars Express rate of 262 kbps. The landers as well as the orbiter store data in the on-board solid state memory before transmission. The data products with high storage requirements such as images are compressed with the on board computers of the landers before transmission. The data will be transmitted using a fast, error-tolerant coding scheme.

The MetNet landers will be equipped with a carrier status signal system similar to that used by the NASA Mars Exploration Rovers. This system will enable the lander to indicate its status

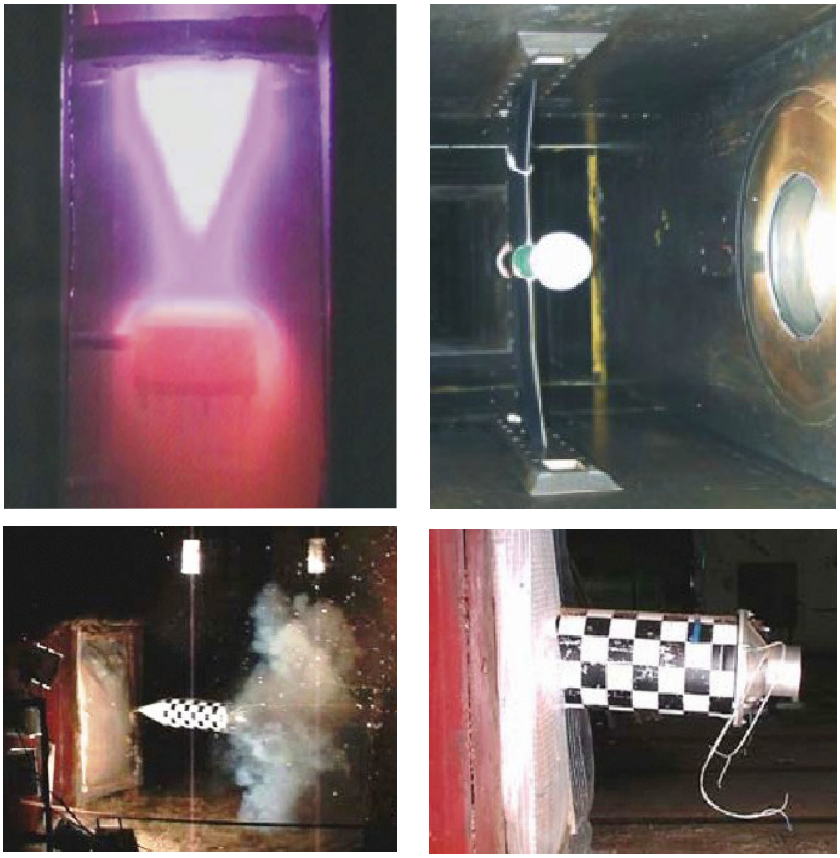


Figure 10: Testing of the EDLS under realistic flight and impact conditions. The top left image shows MetNet heat shield material models under the extreme thermal environment of entry into the Martian atmosphere. The top right image shows wind tunnel tests of the MetNet. The bottom images show a test of the MetNet landing. The projectile is fired into a simulated Martian regolith.

during the entry and landing by switching its carrier signal between slightly different frequencies. The frequency shift can be detected by the carrier or by Earth-based radio telescopes, providing information about the progress of the landing.

5.3 Mass requirements

With a spacecraft bus based on the Mars Express design, we can base the mass calculations on the same estimates. The mass of the Mars Express bus is approximately 500 kg, excluding the Beagle 2 lander. The required velocity change for the orbital insertion of Mars Express is stated as 2800 km/h or about 800 m/s, which requires in the order of 1/4 of the total mass of the spacecraft.

A proposed mass budget for the MetNet mission with 16 landers is presented in Table 3. Each lander is allocated 20 kg of mass, plus 10 kg for the spin/ejection mechanisms. The orbit insertion mass is calculated for only 4 landers left, with the carrier much lighter. These calculations place the mass estimate at 1600 kg, or the nominal capacity of the Soyuz-Fregat 2B to escape trajectory. The estimates are given with 10%-20% margins, and contingency mass can also be obtained from reducing the amount of orbital maneuvering fuel. In addition, according to Russian sources, the Soyuz-Fregat 2B can deliver up to 2000 kg to Mars during the 2016 or 2018 launch windows.

Table 3: The proposed mass budget for the MetNet mission.

Bus	500 kg
Landers	320 kg
Spin/ejection devices	160 kg
Orbital payload	10 kg
Total payload	490 kg
Lander targeting propellant	110 kg
Orbit insertion propellant	340 kg
Orbit maneuver propellant	140 kg
Propellant	590 kg
Total	1580 kg

5.4 Power requirements

The power requirements are mostly based on Mars Express mission requirements. The carrier power, provided by solar panels, is 650 W. The bus power requirement is at the maximum case about 500 W. The payload, including the MetNet landers (before the release) and the MCS instrument, requires about 50 W. This places the total power requirement at about 550 W. This is well within the power provided by the solar panels.

The lander power is provided with two Radioisotope Thermoelectric Generators (RTG) providing a total of approximately 0.5 W of electric power. The power output is clearly insufficient to operate all instruments simultaneously: it distributed to the instruments by operating them one at a time and using lithium batteries to output higher power temporarily.

5.5 Spacecraft environment

Mars poses an hostile and unwelcoming environment for lander missions. Temperature varies widely and abundant small grained dust sticks on surfaces and sneaks into joints and corners of the spacecraft. The humidity sensors and optical systems may also need protection from the Martian dust. However, these features of the operating environment of the MetNet mission are well understood from previous missions. Thus the spacecraft can rely on standard measures of protection against these conditions and furthermore the landers will be tested in analog Martian environment before launch.

Figure 11: Engineering model of the MetNet Lander being exposed to a set of mechanical tests.

The orbiter systems inherit their radiation and thermal protection from the Mars Express mission. Being probes in a planetary landing mission, the MetNet landers additionally require planetary protection measurements to prevent biological contamination of Mars. The COSPAR recommendations for planetary protection will be followed.

5.6 Current Heritage and Technology Readiness Level

The MetNet mission concept and key MetNet Lander technologies and critical subsystems have been qualified to meet the Martian environmental and functional conditions. The most demanding work of the MetNet Mars Mission, development and qualification of the new type of entry, descent and landing system, has been performed during the years 2002 - 2004. Prototyping of the payload instrumentation with final dimensions was carried out in 2003-2006. This development effort from conceptual design to space qualification of the critical systems has been fulfilled in collaboration between the Finnish Meteorological Institute (FMI), the Russian Lavoschkin Association (LA) and the Russian Space Research Institute (IKI) during the years 2001-2006.

Presently, an ongoing mission development is under way to send two MetNet Landers to Mars onboard the Russian Phobos Sample Return Mission in 2009/2011. This is called the MetNet Mars Precursor Mission, and it will demonstrate the performance of the MetNet concept. Also, a suborbital test launch is under preparation to take place in 2008 to perform a supplemental test of the MetNet Lander in the atmospheric entry environment it will meet when arriving in Mars. All the MetNet probe systems and payload benefit also from the heritage of successful Mars landing missions: Viking, Mars Pathfinder and the Mars Exploration Rovers. (Soffen, 1976)

While the MetNet landers are based on a new concept, many systems used in the mission are based on a long legacy of planetary and space missions. In particular, the bus based on Mars Express has been tested in space twice, and most of its systems can be used in this mission unmodified. Despite the failure of the Beagle 2 mission, the Mars Express bus has been used to successfully release landers, and a UHF communication system for Mars has already been designed for the bus.

The Technology Readiness Level of the new entry system is currently 4, while the landing system has been drop tested and can be considered TRL 6. Most other lander systems, including the release and spin clamps, are based on ones used successfully in space, being at TRL 6-9. Most of the orbiter systems are at TRL 9.

Figure 12: Two complete Flight Units of the MetNet Lander with all the entry, descent and landing systems have been manufactured. They will be used in the MetNet Mars Precursor Mission slated for launch in 2009/2011.

Figure 13: Two sets of Flight Unit payload bays are shown above with the end cone of the two MetNet Lander Flight Units also depicted in the preceding figure 12. The payload compartment will slide downwards during the impact and some of the mechanical energy is consumed by the metallic rods.

5.7 Proposed Procurement Approach and International Partners

The procurement approach will reflect the international participation and design heritage of this mission. Science instruments will be provided to ESA by the science teams as with the AO call. For the lander itself ESA will procure this by purchase order from Russian organizations, which have developed the novel entry, descent and landing system of the MetNet Mission. This will allow a modest cost compared to a program where ESA develops the lander itself. ESA will provide for the MNO and data relay system. The MNO is based on Mars Express development heritage and will also be of modest cost. This procurement approach enables the MetNet Mars Mission to meet the cost cap of the M-class mission within the framework of the Cosmic Vision Programme.

5.8 Critical issues and Redundancy

As the MetNet mission relies on well established principles of planetary missions, there are no critical issues beyond those of the usual risks of planetary and space exploration.

The most critical phases of the MetNet mission are the entry and the landing. While the aim is to deploy all 16 landers successfully, the landers that remain on the orbiter after the orbit insertion can be used to replace any failed units with minimal impact on the overall science return. The orbiter relies on the redundant components of the Mars Express bus.

6 Science Operations and Archiving

MetNet data received by ESOC via ground stations will be processed to PDS level 1a by ESA and distributed to the PIs via the MetNet Distribution System (MDS). PI teams will produce PDS-compliant datasets under co-ordination of the science team. Both uncalibrated and calibrated datasets will be produced. Some technical support will be required from the ESA archiving team. The ESA archiving team will then arrange the peer reviews and digest the datasets into the Planetary missions Science data Archive (PSA) system. The goal is that first data will be available in the PSA archive 6 months after the beginning of data collection with the support of the ESA archiving team.

We propose a virtual science operations centre that would allow remote science operations from instrument host institutes with advanced networking and teleconferencing with very light infrastructure at the central operations centre. Such an organisation could help reduce science team support from ESA. This will help minimise the impact of costs typically associated with long term mission and ease the transition into an extended missions if that should arise. Also there is inherent flexibility in such a distributed network that enables coordinated cooperation amongst the science team. This would result in a focused and targeted investigation of Mars increasing the scientific return.

The data would then be analysed in the following way. The payload PI groups and possible Participating Scientists will initially analyse the data as well as interpret and publish the results in conferences, generalised and mission-dedicated workshops, peer reviewed journals and other relevant scientific forums. After the 6-month data embargo the entire scientific community will have access to the data and will participate in the analyses. Due to the atmospheric science emphasis of the Mars MetNet Precursor Mission payload, groups involved in Martian meteorological, atmospheric circulation and climate modelling are expected to be highly interested in the data. Currently such groups with foci in global, meso-scale and microscale modelling exist in as least Europe (including Russia), Canada, USA and Japan. Since the Mars MetNet Precursor Mission does provide surface pressure observations a highly relevant boundary condition for orbital atmospheric observations dedicated observation campaigns combining surface and orbital observations with advanced modelling are foreseen and are expected to be scientifically highly profitable.

7 Key technology areas

Landing system of the MetNet lander is specially designed for the MetNet mission and it has been tested numerous times in laboratory and in Earth atmosphere. Brand new technology in MetNet landing system are the inflatable descent phase system, which has been already successfully demonstrated in Mars-96, and the landing phase systems. The penetrator type of landing has been earlier introduced, developed and qualified for Mars Polar Lander mission and therefore it has been proven to be a working solution as a landing concept for Mars. All the MetNet lander landing systems has been fully qualified for Martian environment and conditions during the developing and testing phase. The TRL of the landing system is currently 5-6.

All the MetNet landers payload elements consist of tight packed miniaturised instruments that are developed for the MetNet mission based on heritage of the earlier missions (e.g. Mars-96, Mars Polar Lander and Beagle 2). The OWLS, which is developed by INTA within the ESA technology Development program, is used in inboard communication. The OWLS has been tested in Earth orbit and found to be a workable method for inboard communication. The data management systems of the landers are physically and functionally in the vicinity of the payload elements and the integration between them will be developed based on the experiences of the previous missions.

The spacecraft will be based on well-proven Mars Express and Venus Express platforms. The orbit insertion of the 16 MetNet landers is challenging, but the basics of the such maneuver are well known and similar type of maneuvers are performed several times before (e.g. Beagle 2).

8 Preliminary Programmatics/Costs

The MetNet Mars Mission will deploy 16 MetNet Landers (MNLs) on the Martian surface using inflatable descent system structures accompanied by an atmospheric sounder and data relay onboard the MetNet Orbiter (MNO). The MNL will perform simultaneous *in situ* measurements on the Martian surface, and will communicate with the MNO to transmit data and to get new operational instructions . The Mission slated for launch in 2016 / 2018.

The Mission is to be managed according to the standards of ESA planetary missions. The scientific payload will be selected through the ESA AO process, and the instruments will be provided by PI-led science teams. The Mission will be operationally managed by the ESA Mission Manager and Mission Scientist.

The MetNet Mars Mission is to be implemented in collaboration with ESA, FMI, LA, IKI and the payload providing science teams. The mission leader responsibility would rest with ESA. The Immaterial Property Rights (IPR) of the entry descent and landing system of the MetNet Landers are of property of FMI, who will license the IPR for this mission. The LA and IKI would manufacture the entry, descent and landing systems of the MetNet Landers. This collaboration would considerably decrease the overall mission costs. Optionally, also the MetNet orbiter that in this proposal is nominally a derivative of the Mars Express platform, could be replaced by a derivative of the Russian Phobos-Grunt platform. This option would slightly add to the mission complexity but would also further decrease the mission costs.

The overall costs of the Mars MetNet Mission can be estimated, when taking into account the cost guidelines given in the Cosmic Vision Call Annex 4. The development of the MetNet Orbiter (MNO) and its service functions during the cruise phase as well as during the mission operations around Mars are relatively low, because the MNO is based on existing design the Mars Express and enus Express platforms. The MetNet Landers will be procured from Russia, where the actual development work already has been done. The Immaterial Property Rights (IPR) of the MetNet Landers will be licensed to the Mission by FMI. With these considerations the overall mission cost cap meet the M-class mission cost requirement.

An optional mission scenario includes the procurement of the MetNet Orbiter (MNO) from Russia, and then the MNO would be a derivative of the Phobos-Grunt platform. This would decrease the overall cost considerably even when taking into account the supplemental expenses caused by the added mission complexity.

Activity	**Cost to ESA**
Mission and industrial team kick-off	1 Meuro
MNO procurement	100 Meuro
MNL IPR (FMI)	0 Meuro
MNLs (16+4) w/o science payload	20 Meuro
Launch services from Baikonur (Soyuz Fregat-2B)	39 Meuro
Ground segment (MOC and SOC)	60 Meuro
ESA internal costs	30 Meuro
Cost margin	45 Meuro
Total	295 Meuro

Table 4: Summary of the MetNet Mars Mission costs

The cost of the science payload is born by the PI-led organizations providing the instruments. An approximate cost of all the payload including the instruments onboard the MetNet Landers and the atmospheric sounding instrument onboard the MetNet Orbiter is approximately 200

Meuro. This expense is covered by the payload providing organizations primarily located in the ESA member countries and in Russia.

There are no severe schedule drivers in this Mission. All the required technologies have already been qualified for planetary missions. The rough mission development time from the moment the industrial contracts are signed to the launch date is approximately 6 years.

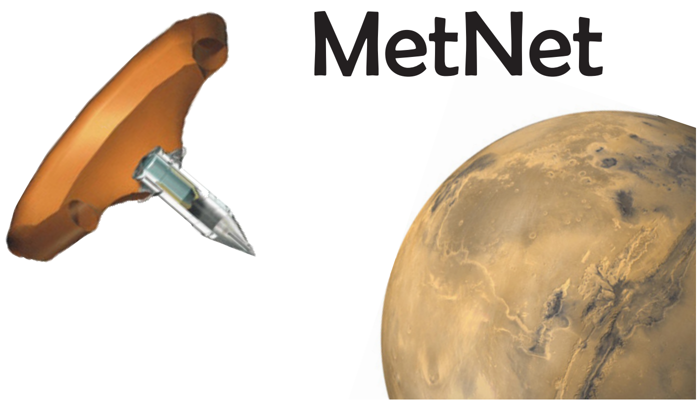
9 Communications and Outreach

Planetary missions are considered by public to be the most inspiring space missions. Within planetary exploration programs especially missions with landing components have shown to be most exhilarating and stimulating for curious people. Since the MetNet mission will provide on-site images from up to 16 new locations on Mars, it has great potential to increase the public interest in Mars exploration, and space activities in general, in Europe and beyond. This potential needs to be utilised with good press relations as well as by organising events of public interest such as live broadcasts of high-profile mission events like launch and landing.

It is challenging for human mind to grasp the vastness of the world we are living in. Following a planetary mission like this brings the solar system closer and yet demonstrates the great distances and effort it takes to get even the smallest and simplest landers on a surface of another planet. The feeling of a truly international co-operation accomplishing such a grand feat will further facilitate the international relations and lay foundations for further generations to continue on this road of co-operation and ever-continuing exploration.

Missions like this also provide scientific tools for teachers to introduce planetary system exploration and scientific principles in general. We will involve students of all the participating countries at all the levels of education in planning, construction and analyzing of the data produced by the mission. Graduate students will participate by doing research for their thesis on MetNet measurements, while kindergardeners will learn key facts of the solar system. The MetNet mission further demonstrates beautifully the power of simple ideas developed with care to reach complex aims.

The leading aspect of all the lander missions that remains in the minds of the public is the first images from the surface after the landing. The MetNet mission will produce 16 of these 'first glimpses' from highly varied locations. Large number of landers will also nicely correspond with some number of countries, which will be given or allocated "dedicated" landers for outreach purposes. Those landers will be monitored, even operated to some degree, by their "host" countries. The public will also participate by competitions in style of "name your country's own Mars lander".



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tel. (09) 19 291
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ISBN 978-951-697-625-2
ISSN 0782-6079
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Helsinki