→ EXOMARS

ESA's next step in Mars exploration

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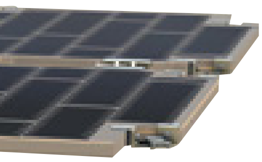


Establishing if life ever existed on Mars is one of the outstanding scientific questions of our time. To do this, ESA is launching two missions to Mars, in 2016 and 2018.

ESA and Russia's space agency Roscosmos have signed an agreement to work in partnership to develop and launch two ExoMars missions. The first mission will study Mars' atmospheric composition and deliver a lander. The second mission will land, operate a static surface platform and put a large rover on the surface with the objective of searching for signs of life.

Both missions will use novel technologies needed to accomplish their goals and extend Europe and Russia's planetary exploration capabilities.

The missions

The first ExoMars mission consists of two elements: the Trace Gas Orbiter (TGO) and the Entry, descent, and landing Demonstrator Module (EDM). The TGO will first deliver the EDM, which will land on Mars to validate key technologies for the 2018 mission. The orbiter will then begin an aerobraking

↑ The 2016 ExoMars Trace Gas Orbiter

campaign. On reaching its science orbit, the TGO will search for evidence of methane and other atmospheric gases and investigate the surface, looking for possible active geological or biological processes. The TGO will also serve as a data relay for surface missions until the end of 2022.

The second mission will deliver the ExoMars rover and a platform to the surface of Mars. The rover will search for signs of life, past and present. It will have the capability to drill to depths of 2 m to collect and analyse samples that have been shielded from the harsh conditions prevailing on the surface, where radiation and oxidants can destroy organic materials. The surface platform will be equipped with instruments to study the martian environment.

ESA and Roscosmos have agreed a well-balanced share of responsibilities for the different mission elements. ESA will provide the TGO and EDM in 2016, and the Carrier Module and rover in 2018. Roscosmos will be in charge of the 2018 Descent Module (DM), will furnish launchers for the two missions and Radioactive Heating Units for the rover. Both agencies will contribute scientific instruments. NASA will also deliver important elements to ExoMars, including the Electra Ultra-High Frequency radio package for TGO and Mars surface proximity link communications, engineering support to EDM, and a major part of MOMA, the organic molecule instrument on the rover.

Establishing whether life ever existed on Mars is one of the outstanding scientific objectives of our time and constitutes the highest scientific priority of the ExoMars programme.

The 2016 ExoMars Mission

The 2016 mission has the science objectives to study martian atmospheric trace gases and their sources, and to contribute to the search for signs of possible present life on Mars. The latter will be pursued through a careful analysis of the association among minor atmospheric constituents and isotope ratios. This mission will also achieve the first of the programme's technological objectives with the EDM – to land on Mars.

There are four TGO investigations. NOMAD groups two infrared and one ultraviolet channel, while ACS has three infrared channels. Combined, these two instruments will provide the most extensive spectral coverage of martian atmospheric processes so far. To achieve the very high sensitivity required to allow NOMAD and ACS to detect species existing in very minute abundances, these instruments need to operate in 'Solar Occultation' mode.

Twice per orbit, at local sunrise and sunset, they are able observe the Sun as it shines through the atmosphere. In other words, they use our star as a very bright infrared lamp. The Sun is so luminous that the signal-to-noise ratio is very high. Detection of atmospheric trace species at parts-per-billion level will be possible.

NOMAD and ACS can also operate in 'Limb Scanning' mode and in 'Nadir Pointing' mode. The latter mode is interesting, but very challenging. The instruments can look directly down at the planet. However, here they must observe infrared light reflected off the surface as it shines through the atmosphere. In this case, the signal is very weak. The strategy to achieve an acceptable signal-to-noise level is to reduce the noise. This requires cooling the detector and some of the optics, which is the difficult part. On the other hand, this mode allows the study of the atmosphere draped over the surface, and hopefully it will help to identify sources and sinks for interesting species.

One gas species that has elicited much interest is methane (CH_4). On Earth, it is methanogenic bacteria that produce most of our methane. Alternatively, it can be exhaled as the result of certain subsurface hydrothermal processes. The PFS instrument on Mars Express made a first possible detection in 2004.

Contemporary observations from Earth, using infrared spectrometers in association with ground telescopes, have provided similar information.

But because the Mars Express result was close to the detection limits of the instrument, and since the ground observations were obtained looking at Mars through Earth's atmosphere, which itself has a sizeable methane component, the scientific community would like to see this methane signature verified.

Recently, NASA's Mars Science Laboratory/Curiosity searched for a methane signal with its SAM instrument, but did not find any. It could be that Curiosity is not in the right location, or it is the wrong season, or that methane is not present on the ground but higher up in the atmosphere. With NOMAD and ACS, the TGO will be able to conduct a planet-wide observation campaign across a full martian year. It will be possible to detect methane and many other hydrocarbon species.

If the presence of methane is confirmed, its association with other gases, as well as a careful analysis of isotopic ratios, will help us to determine whether its origin is biological or geological, or perhaps a combination. In either case, this would indicate that Mars remains an active planet.

Two other instruments will also be observing the martian surface. CaSSIS is a high-resolution (4.5 m/pixel), colour stereo camera. Its innovative design allows obtaining co-registered image pairs, such that every photograph is stereo. This is very important for building accurate digital elevation models of the martian surface. CaSSIS will be used to study geological formations that may be associated with trace gas detections of interest. It will also be an important tool for characterising candidate landing site locations for future missions.

Finally, FREND is a neutron detector that can provide information on the presence of hydrogen, in the form of water or hydrated minerals, in the top metre layer of the martian surface. A similar instrument flew on NASA's 2001 Odyssey mission, providing a first map of global surface water distribution. FREND will be capable of improving significantly the ground coverage resolution of the existing subsurface water map.

Following the release of the EDM from the hyperbolic Mars arrival trajectory, the TGO will first settle into an intermediate orbit. From there it will conduct a roughly nine-month aerobraking campaign to achieve its science orbit: approximately circular, altitude about 400 km and 74° inclination. The orbit's inclination has been selected to maximise the number of Sun occultations during the mission, while still providing a good seasonal and latitude coverage. The EDM has been conceived as a technology demonstration platform, with the objective of achieving Europe's first landing on Mars. It will enter the martian atmosphere from the hyperbolic arrival trajectory and use its heatshield to slow down sufficiently to deploy a supersonic parachute.

> **"Establishing whether life ever existed on Mars is one of the outstanding scientific objectives of our time and constitutes the highest scientific priority of the ExoMars programme."**

↑ ExoMars Entry, descent, and landing Demonstrator Module being prepared for vibration tests at ESTEC in March 2013

The final stages of the landing will be performed using pulse-firing liquid-fuel engines. About a metre above ground, the engines will turn off. The platform will land on a crushable structure, designed to deform and absorb the final touchdown impact. Throughout the descent, the Entry and Descent Science Team will perform investigations using various ensors to recover a number of atmospheric parameters, including density.

The EDM will land during the statistical 'dust storm' season. No entry profiles yet exist obtained during this time of the year when Mars' atmosphere is dust loaded. This will be very important information for designing future landed missions. Finally, the EDM also includes a small environmental station, DREAMS, that will operate for a few days using battery electrical energy. DREAMS will measure a number of atmospheric parameters:

ExoMars 2016 mission information

Spacecraft	Trace Gas Orbiter / Entry, descent and landing Demonstrator Module
Launch	January 2016, from Baikonur, Kazakhstan
Launcher	Proton M
Mars arrival	October 2016
Wet mass	4332 kg, including 600 kg EDM
TGO orbit	Circular, 400 km altitude, 74° inclination, approx. 30-sol repeat pattern (achieved after aerobraking by November 2017
EDM landing	Direct entry, Meridiani Planum (1.82° S, 6.15° W), uncertainty ellipse 100 x 15 km
Lifetime	TGO: until end 2022 (nominal science lifetime is 1 martian year). EDM: 2–3 days

temperature, pressure, wind speed and direction, optical depth and, for the first time, atmospheric electrical charging. The EDM will also include a camera.

The 2018 ExoMars Mission

The 2018 mission will address the programme's two top science objectives. The ExoMars rover will carry a comprehensive suite of instruments dedicated to exobiology and geology research named after Louis Pasteur. The rover will be able to travel several kilometres searching for traces of past and present signs of life. It will do this by collecting and analysing samples from within rocky outcrops and from the subsurface – down to 2 m depth. The very powerful combination of mobility with the ability to access locations where organic molecules could be well preserved is unique to this mission. It is also planned to include instruments on the landing platform with the goal of studying the martian surface environment. However, these sensors have not been selected yet.

The search for life

The term 'exobiology', in its broadest definition, denotes the study of the origin, evolution and distribution of life in the Universe. It is well established that life arose very early on the young Earth. From the analysis of fossil records, we know that by 3.5 billion years ago life had attained a large degree of biological sophistication. Since then, it has proven extremely adaptable, colonising the most disparate ecological habitats, from the very cold to the very hot, spanning a wide range of pressure and chemical conditions.

Today, Mars is cold and dry. Its surface is highly oxidised and exposed to sterilising/degrading ultraviolet light and ionising radiation. Low ambient temperature and pressure preclude the existence of liquid water, except in very localised environments, and then only episodically. Nevertheless, numerous features such as large channels, dendritic valley networks and sedimentary rock formations signal the past action of surface liquid water on Mars: lots of it.

The size of martian outflow channels implies immense discharges, exceeding any known flood flows on Earth. Mars' observable geological record spans approximately 4.5 billion years. From the number of superposed craters, the oldest terrain is believed to be about 4 billion years old, and the youngest possibly less than 100 million years of age. Most river valley networks are ancient (3.5–4 billion years old). Presently, water on Mars is only stable as ice, either at the poles as permafrost, or widespread underground deposits or in trace amounts in the atmosphere.

From a biological perspective, the existence of past liquid water in itself motivates the question of life on Mars: though the planet as a whole may have been prevalently cold, during its first 500 million years some surface environments were warm and wet. Perhaps life may have independently arisen on Mars, more or less at the same time as it did on Earth.

An alternative pathway may have been through the transport of terrestrial organisms, embedded in meteoroids, delivered from Earth to Mars. Yet another hypothesis is that life may have developed within a warm, wet subterranean environment. In fact, given the discovery of a flourishing biosphere a kilometre below Earth's surface, a similar vast microbial community may be active on Mars, having long ago retreated into that ecological niche, following the disappearance of a more benign surface environment.

The possibility that life may have evolved on Mars during an earlier period when water existed on its surface, and that organisms may still exist underground, marks the planet as a prime candidate to search for life beyond Earth.

If life ever arose on Mars, it probably did so during the planet's first half to one billion years. Conditions then were similar to those on early Earth: active volcanism and hydrothermal activity, meteoritic impacts, large bodies of liquid water (which may have been largely ice covered) and a mildly reducing atmosphere. Nevertheless, there is inevitably a large measure of chance involved in finding convincing evidence of ancient, microscopic life forms.

↑ View of Mars from NASA's 1976 Viking mission

On our planet's surface, the permanent presence of running water, solar ultraviolet radiation, atmospheric oxygen and life itself quickly erases all traces of any exposed, dead organisms. The only opportunity to detect them is to find their biosignatures encased in a protective environment – for example, within a suitable rock horizon. However, since high-temperature metamorphic processes and plate tectonics have resulted in the reforming of most ancient terrains, it is very difficult to find rocks on Earth older than three billion years in good condition.

Mars, on the other hand, has not experienced widespread tectonic activity like Earth. This means that rock formations from the earliest period in martian history exist, that have not been exposed to high-temperature recycling. Consequently, well-preserved ancient biomarkers may still be accessible for analysis. So why have we not found them yet? Possible answers to this question lie on where and how we have explored Mars.

In 1976, the twin Viking landers conducted the first in situ measurements focusing on the detection of organic compounds and life on Mars. The Viking biology package contained three experiments, all looking for signs of metabolism in soil samples. One of them, the labelled-release experiment, produced very provocative results. If other information had not been also available, these data could have been interpreted as proof of biological activity. However, theoretical modelling of the martian atmosphere and regolith chemistry hinted at the existence of powerful oxidants, which could more-or-less account for the results of the three biology package experiments.

The biggest blow was the failure of the Viking gas chromatographer mass spectrometer to find evidence of organic molecules at the parts-per-billion level. With few exceptions, the majority of the scientific community concluded that the Viking results did not demonstrate the presence of life. Numerous attempts were made in the laboratory to simulate the reactions observed by the Viking biological package. While some have reproduced certain aspects of the data, none succeeded entirely.

The next incremental step in our understanding of the martian surface was entirely unexpected. It came as a result of measurements conducted by the 2009 Phoenix lander in the northern subpolar plains. Phoenix included, for the first time, a wet chemistry analysis instrument that detected the presence of the perchlorate anion in soil samples collected by the robotic arm. Perchlorates are interesting molecules. For example, ammonium perchlorate is regularly used as a powerful rocket fuel oxidiser. Its salts are chemically inert at room temperature, but when heated beyond a few hundred degrees, the four oxygen atoms are released, becoming very reactive oxidation vectors.

↑ The rover and drill on the surface of Mars. The Rover will monitor and control torque, penetration depth and temperature of the drill bit. The drill's full 2 m extension is achieved by assembling four sections: one drill tool rod, with an internal shutter and sampling collection capability, plus three extension rods

It did not take long for investigators to recall that Viking had relied on thermal volatilisation (in other words, heat) to release organics from soil samples. If perchlorate had been present in the soil at the two Viking lander locations, perhaps heating could explain the results obtained? A review of the Viking findings showed that some simple chlorinated organic molecules had been detected. At the time, these compounds were interpreted to be remnants of a cleaning agent used to prepare the spacecraft.

More recently, the 2011 Mars Science Laboratory has looked for organic molecules on samples drilled out of surface rocks. They have obtained the same chlorinated compounds as Viking. Hence, also the MSL results are consistent with the presence of perchlorate. We must take these results into account for preparing our mission.

The need for subsurface exploration

For organisms to have emerged and evolved, liquid water must have been present on Mars. Without it, most cellular metabolic processes would not be possible. In the absence of water, life either ceases or slips into a quiescent mode. Hence, the search for extinct or extant life automatically translates into a search for long-standing water-rich environments, past or present.

The strategy to find traces of past biological activity rests on the assumption that any surviving signatures of interest will be preserved in the geological record, in the form of buried or encased remains, organic materials and fossil communities. Similarly, because current martian surface conditions are hostile to most known organisms, also when looking for signs of extant life, the search methodology should focus on investigations in protected niches: in the subsurface and within surface outcrops.

The same sampling device and instrumentation can adequately serve both types of studies. The ExoMars rover's surface mobility and the 2 m vertical reach of its drill are both crucial for the scientific success of the mission.

The rover will search for two types of life-related signatures: morphological and chemical. This will be complemented by an accurate determination of the geological context. Morphological information related to biological processes may be preserved on the surface of rocks. Possible examples include the microbially mediated deposition of sediments, fossilised bacterial mats or stromatolitic mounds. Such studies can only be accomplished with mobility and an imaging system capable of covering from the metre scale down to submillimetre resolution (to discern microtextural information in rocks).

Effective chemical identification of biosignatures requires access to well-preserved organic molecules. Because the martian atmosphere is more tenuous than Earth's, three important physical agents reach the surface of Mars with adverse effects for the long-term preservation of biomarkers:

1. The ultraviolet (UV) radiation dose is higher than on our planet and will quickly damage potential exposed organisms or biomolecules.

2. UV-induced photochemistry is responsible for the production of reactive oxidant species (like the perchlorates mentioned earlier) that, when activated, can also destroy biomarkers; the diffusion of oxidants

→ Mission strategy to achieve ExoMars rover scientific objectives

1. To land on an ancient location possessing high exobiological interest for past (and/or present) life signatures, i.e. access to the appropriate geological environment.

2. To collect well preserved scientific samples (free from radiation damage and surface oxidation) at different sites with a rover equipped with a drill capable of reaching well into the soil and surface rocks. This requires mobility and access to the subsurface.

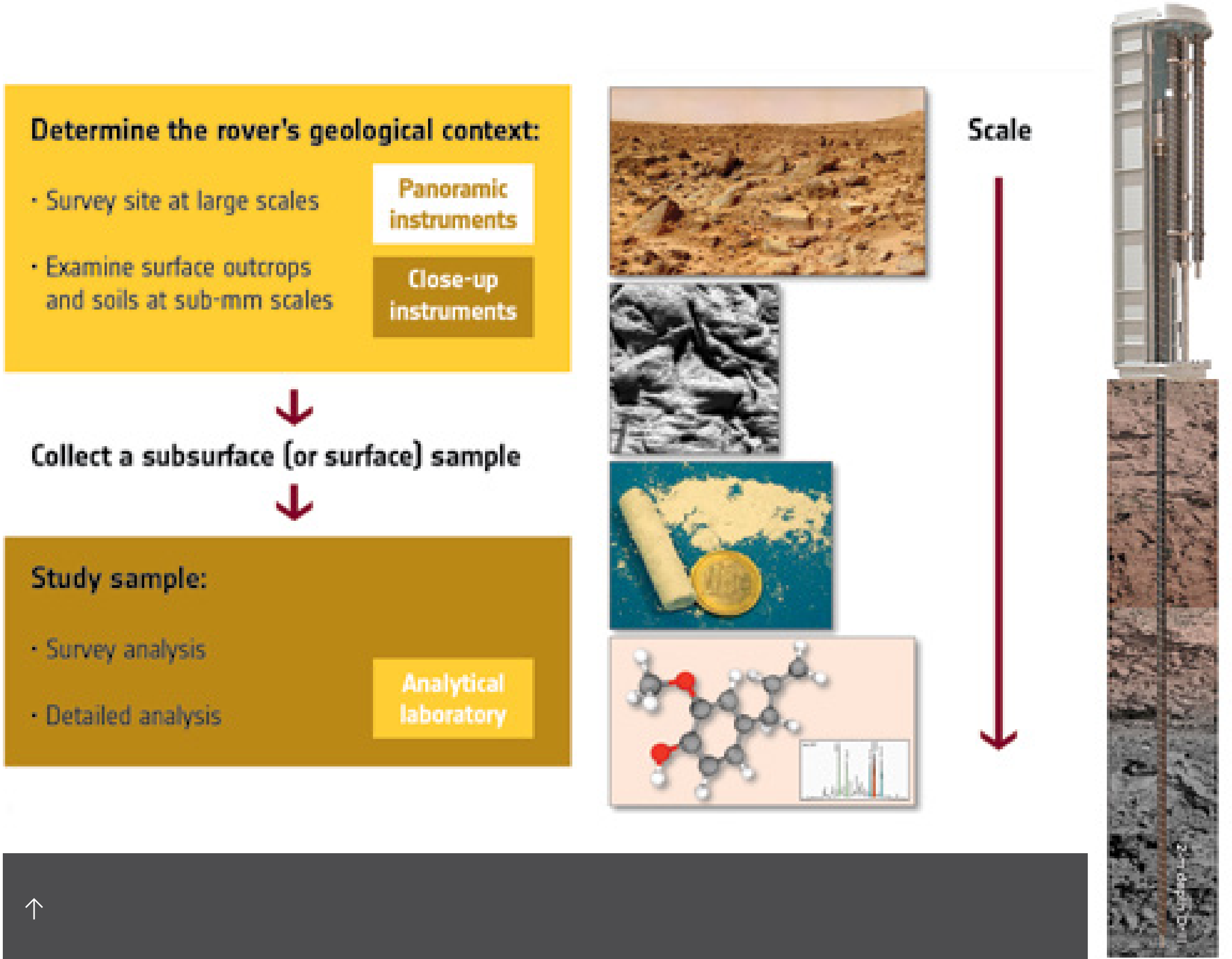
3. At each site, to conduct an integral set of measurements at multiple scales to achieve a coherent understanding of the geological context and thus inform the search for biosignatures: beginning with a panoramic assessment of the geological environment, the rover must progress to smaller-scale investigations of surface rock textures, and culminate with the collection of well-selected samples to be studied in its analytical laboratory.

The rover's Pasteur payload must produce self-consistent sets of measurements capable to provide reliable evidence, for or against, the existence of a range of biosignatures at each search location.

For the ExoMars rover to achieve high-quality scientific results regarding the possible existence of biosignatures, the rover must be delivered safely to a scientifically appropriate setting: ancient (older than 3.6 billion years, dating from Mars' early, more life-friendly period), having abundant morphological and mineral evidence for long-term water activity, including numerous outcrop targets distributed in the landing ellipse (to be sure the rover can get at least to some of them), and with little dust coverage.

ExoMars 2018 mission information

Spacecraft	Carrier Module and Descent Module (including Rover and Surface Platform). Data relay function to be provided by TGO
Launch	May 2018, from Baikonur, Kazakhstan
Launcher	Proton M (back-up in Aug 2020)
Mars arrival	Jan 2019 (back-up in Apr 2021)
Landing	Direct entry, from hyperbolic trajectory, after the dust storm season Landing site to be defined: must be safe/appropriate for 'search for life' science objectives. Latitudes between 5°S and 25°N, all longitudes. Uncertainty ellipse: 100 x 15 km.
Rover mass	310 kg, including drill/SPDS and instruments
Lifetime	220 sols (solar days on Mars)



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The ExoMars rover surface exploration scenario. The rover will conduct measurements at multiple scales. Starting with a panoramic assessment of the geological environment in its vicinity, it will then perform more detailed investigations of surface rock textures to try to decipher their depositional history and search for biosignatures. The rover will also scrutinise the subsurface to complete the geological picture, and to help decide where to drill. Samples can be collected from outcrops or from the subsurface (0–2m depth). Once a sample has been obtained, it will be imaged and analysed further, at mineral grain and molecular scales, in the analytical laboratory

into the subsurface is not well characterised and constitutes an important measurement that the mission must perform.

3. Ionising radiation penetrates into the uppermost metres of the planet's subsurface. This causes a slow degradation process that, over many millions of years, can alter organic molecules beyond the detection sensitivity of analytical instruments. Note that the ionising radiation effects are depth dependent: the material closer to the surface is exposed to a higher dose than that buried deeper.

The best opportunity for life to have gained a foothold on Mars was during the planet's very young history, when water was more abundant. It is therefore imperative that the rover is able to land in an ancient region (older than 3.5 billion years) that includes water-related deposits. However, the record of early martian life, if it ever existed, is likely to have escaped radiation and chemical damage only if trapped in the subsurface for long periods. Studies show that a subsurface penetration in the range of 2 m is necessary to recover well-preserved organics from the very early history of Mars.

Additionally, it is essential to avoid loose dust deposits distributed by the wind. While driven by the wind, this material has been processed by UV radiation, ionising radiation and potential oxidants in the atmosphere and on the surface of Mars. Any organic biomarkers would be highly degraded in these samples.

For all these reasons, the ExoMars drill will be able to penetrate and obtain samples from well-consolidated (hard) formations, such as sedimentary rocks and evaporitic deposits, at various depths from zero down to 2 m. The drill's infrared spectrometer will conduct mineralogy studies inside the borehole.

On Earth, microbial life quickly became a global phenomenon. If a similar explosive process occurred in the early history of Mars, then the chances of finding evidence of past life may be good. Even more interesting would be the discovery and study of life forms that have successfully adapted to modern Mars. However, this presupposes the prior identification of geologically suitable, life-friendly locations where it can be demonstrated that liquid water still exists – at least episodically throughout the year. None have been identified so far.

For these reasons, the ESA Exobiology advisory team recommended that ESA focus mainly on the detection of extinct life; but also, build enough flexibility into the mission design to allow identifying present life.

The ExoMars Rover

The ExoMars rover will have a lifetime of 220 sols (around six months). During this period, it will ensure a regional mobility of several kilometres, relying on electrical power from solar arrays. The Pasteur payload contains: panoramic instruments (cameras, an infrared spectrometer, a ground-penetrating radar and a neutron spectrometer); contact instruments for studying rocks and collected samples (a close-up imager and an infrared spectrometer in the drill head); a subsurface drill capable of reaching a depth of 2 m and to obtain specimens from bedrock; a sample preparation and distribution system (SPDS); and the analytical laboratory (a visual/infrared imaging spectrometer, a Raman spectrometer and a Laser Desorption, Thermal Volatilisation Gas Chromatograph Mass Spectrometer).

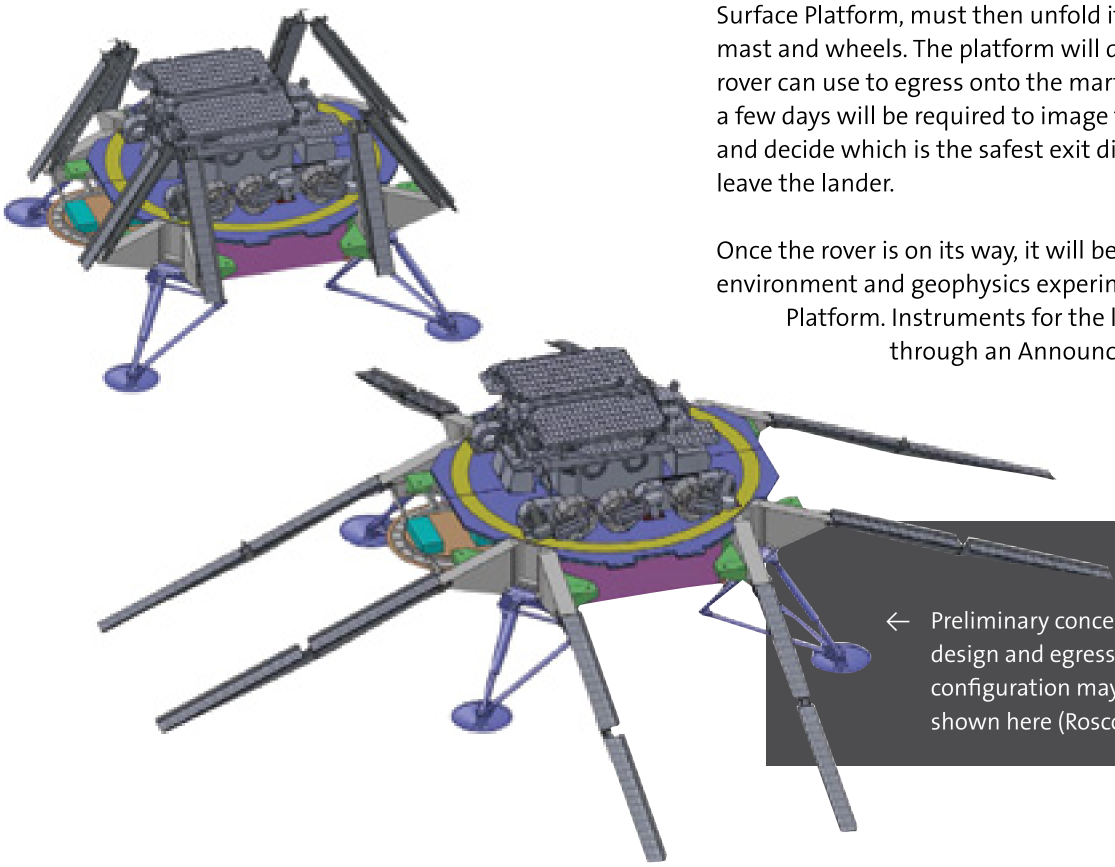
The ExoMars lander

The ExoMars Descent Module (DM) is the part of the spacecraft composite that enters the atmosphere to achieve a controlled descent and landing. The Carrier Module (CM) will take the DM to Mars and deliver with a very precise entry angle. The DM will hit the top of the martian atmosphere at approximately 20 000 km/h. A thermal shield at the bottom of the capsule will be used to decelerate to roughly twice the speed of sound. Thereafter, the parachute system will take over.

However, even after the main parachute has reached its terminal speed, the DM will be still travelling at more than 300 km/h. The last stage will involve using of throttled liquid-fuel engines. A multibeam radar will measure the distance to ground and the horizontal speed over the terrain. The DM's computer will receive this information and combine it with its knowledge of the DM's attitude to decide how to fire the engines and achieve a controlled landing. Legs will be used for the final touchdown.

If all goes according to plan, the rover, sitting on top of the Surface Platform, must then unfold its solar panels, camera mast and wheels. The platform will deploy ramps that the rover can use to egress onto the martian surface. Most likely, a few days will be required to image the lander surroundings and decide which is the safest exit direction for the rover to leave the lander.

Once the rover is on its way, it will be possible to conduct environment and geophysics experiments from the Surface Platform. Instruments for the lander will be selected through an Announcement of Opportunity.

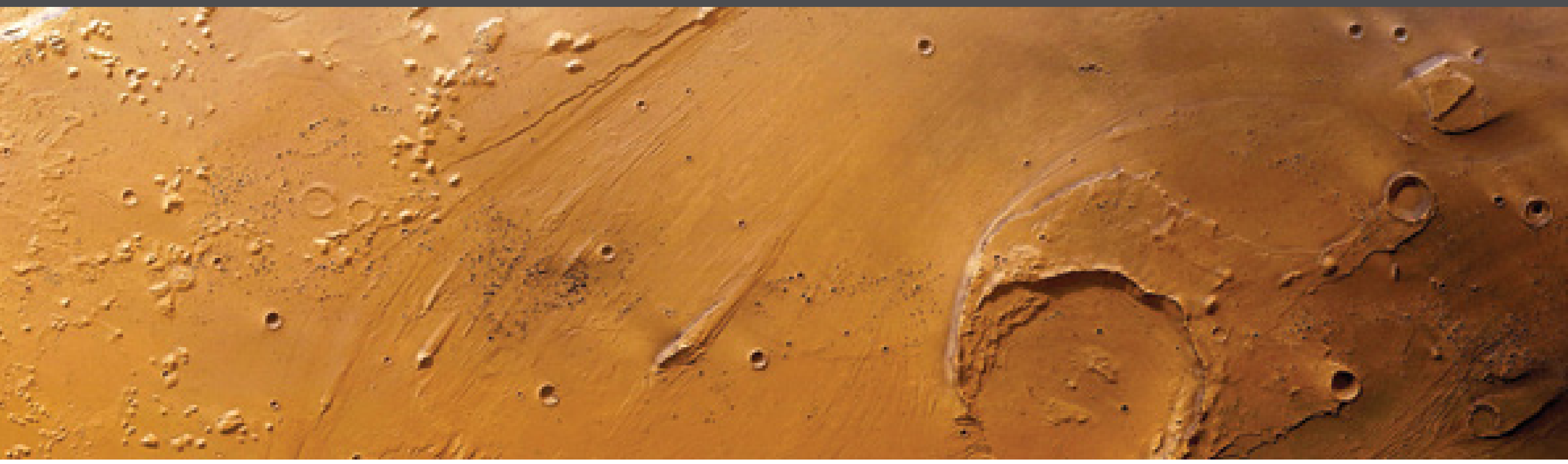


← Preliminary concept for the rover platform design and egress system. The final configuration may differ from the one shown here (Roscosmos/Lavochkin)

ExoMars Rover Pasteur exobiology instruments

Instrument	Scientific rationale
Panoramic instruments	**To characterise the rover's geological context, both on the surface and on the subsurface. Typical scales span from panoramic to 10 m, with a resolution of approx. 1 cm for close targets.**
PanCam	Panoramic camera system with two wide-angle stereo cameras and a high-resolution camera; to characterise the rover's environment and its geology. Very important for target selection.
ISEM	Infrared Spectrometer, for bulk mineralogy characterisation, remote identification of water-related minerals and for aiding PanCam with target selection.
WISDOM	Ground Penetrating Radar, to establish subsurface stratigraphy down to 3 m depth and to help plan the drilling strategy.
ADRON	Neutron Spectrometer, to determine the level of subsurface hydration, and the possible presence of ice.
Contact instruments	**To investigate outcrops, surface rocks, and soils. Among the scientific interests at this scale are: macroscopic textures, structure and layering. This information will be fundamental to understand the local depositional environment and to search for morphological biosignatures on rocks.**
CLUPI	Close-Up Imager, to visually study rock targets at close range (50 cm) with sub-mm resolution. This instrument will also investigate the fines produced during drilling operations, and image samples collected by the drill. The close-up imager has variable focusing and can obtain high-resolution images at longer distances.
Ma_MISS	IR spectrometer in drill, for conducting mineralogical studies in the drill borehole's walls.
Support subsystems	**These essential devices are devoted to the acquisition and preparation of samples for detail investigations in the analytical laboratory. The mission's ability to break new scientific ground, particularly for 'signs of life' investigations, depends on these two subsystems.**
Subsurface drill	Capable of obtaining samples from 0–2 m depth, where organic molecules can be well preserved from radiation and oxidation damage. It contains temperature sensors and an infrared spectrometer.
SPDS	Sample Preparation and Distribution System, receives a sample from the drill system, prepares it for scientific analysis, and presents it to all analytical laboratory instruments. A very important function is to produce particulate material while preserving the organic and water content fractions.
Analytical laboratory	**To conduct a detailed analysis of each collected sample. Following crushing of the sample, the first step is a visual and spectroscopic investigation. Thereafter follows a first search for organic molecules. In case interesting results are found, the instruments are able to perform more detailed analyses.**
MicrOmega	Visual/IR Imaging Spectrometer, will examine the crushed sample material to characterise structure and composition at grain-size level. These measurements will also be used to help point the laser-based instruments, Raman and MOMA.
RLS	Raman Laser Spectrometer, to determine the geochemistry/organic content of minerals in the crushed sample material.
MOMA	Mars Organic Molecule Analyser, the rover's largest instrument. Its goal is to conduct a broad-range, very-high sensitivity search for organic molecules in the collected sample. It incudes two different ways for extracting organics: Laser Desorption and Thermal Volatilisation with or without derivatisation (Der) agents, followed by separation using four gas chromatograph columns. The identification of the evolved organic molecules is performed with an ion trap mass spectrometer.

↓ A Mars Express image of the Ares Vallis region, showing evidence of ancient and vast water discharges. This immense channel — 1400 km long — empties into Chryse Planitia, where the Mars Pathfinder mission landed in 1997 (ESA/DLR/FU Berlin)



ExoMars TGO instruments

Instrument	Scientific rationale
Trace gases	**To provide a detailed characterisation of the martian atmospheric composition, including trace species at parts per billion level. Map the distribution of trace gases, identifying sources and sinks, and study geographical distribution and temporal variability. These two instrument suites will work in partnership to maximise the science results.**
NOMAD	Suite of two IR and one UV spectrometers The two IR channels cover the 2.2–4.3 µm band (for trace gases and atmospheric escape), whereas the UV and visible channel spans the 0.20–0.65 µm range (to investigate aerosols, ozone and sulphuric acid).
ACS	Cluster of three IR spectrometers covering respectively the bands 0.7–1.7 µm, 2.3–4.6 µm and 1.7–17.0 µm. ACS will study trace gases, profile isotope ratios and contribute to atmospheric escape studies.
Camera	**To perform photo-geological investigations on zones deemed interesting as possible sources of important trace gases. To characterise candidate landing sites for future missions.**
CaSSIS	High-resolution stereo camera (4.5 m/pixel), capable of obtaining coregistered colour, stereo image pairs.
Subsurface	**To obtain improved coverage of subsurface water and hydrated minerals in the top 1 m layer of the martian surface with the objective to achieve ten times better resolution than previous measurements.**
FREND	Neutron Spectrometer with a collimation module to significantly narrow the instrument's field of view, thus allowing the creation of higher resolution maps of hydrogen distribution.

ExoMars EDM investigations

Investigation	Scientific rationale
Descent science	**To study the martian atmosphere and obtain images throughout the EDM's descent.**
AMELIA	Utilising the EDM's engineering data (accelerometers and heatshield sensors) to reconstruct its trajectory and determine atmospheric conditions, such as density and wind, from a high altitude to the surface. Use the results to improve atmospheric models.
Surface science	**To characterise the surface environment in the presence of a dust-rich atmosphere.**
DREAMS	Environmental station that will conduct a series of short observations to establish temperature, pressure, wind speed and direction, optical opacity (dust loading), and atmospheric charging (electric fields) at the EDM's landing location.

Great expectations

The TGO mission will provide fundamental new science about the martian atmosphere. By measuring trace gases with unprecedented sensitivity, this mission will help scientists to determine whether Mars is still alive today – either from a geological or biological perspective.

NASA's very successful 2004 Mars Exploration Rovers were conceived as robotic geologists. They have demonstrated the past existence of wet environments on Mars. In 2009, Phoenix provided important new results about the oxidation environment. But perhaps it is ESA's Mars Express together with NASA's Mars Reconnaissance Orbiter mission of 2005 that have advanced most our understanding of past Mars. They revealed multiple, ancient deposits containing clay minerals that can only have formed in the presence of liquid water. This reinforces the hypothesis that ancient Mars may have been wetter than it is today. Mars Science Laboratory is studying geology and seeking organics on the martian surface with the goal to identify habitable environments. The ExoMars rover constitutes the next logical step.

ExoMars will have instruments to investigate whether life ever arose on the Red Planet. It will also be the first mission combining mobility with the capability to access locations where organic molecules can be well-preserved, thus allowing, for the first time, the investigation in situ of Mars' third dimension: depth. This alone is a guarantee that the mission will be able to break new scientific ground. The rover results will be complemented by those obtained with the Surface Platform instruments.

With a longer-term perspective, understanding the scientific importance of subsurface material is fundamental prior to deciding which types of samples to return to Earth for further analyses. The ESA and Roscosmos ExoMars rover's findings constitute a key milestone for a future international Mars Sample Return campaign.

Following on the accomplishments of Huygens and Mars Express, ExoMars provides Europe and Russia with a new challenge, and a new opportunity to demonstrate their capacity to perform world-class planetary exploration science. ■