# exomars 2016

## → EUROPE'S NEW ERA OF MARS EXPLORATION

European Space Agency

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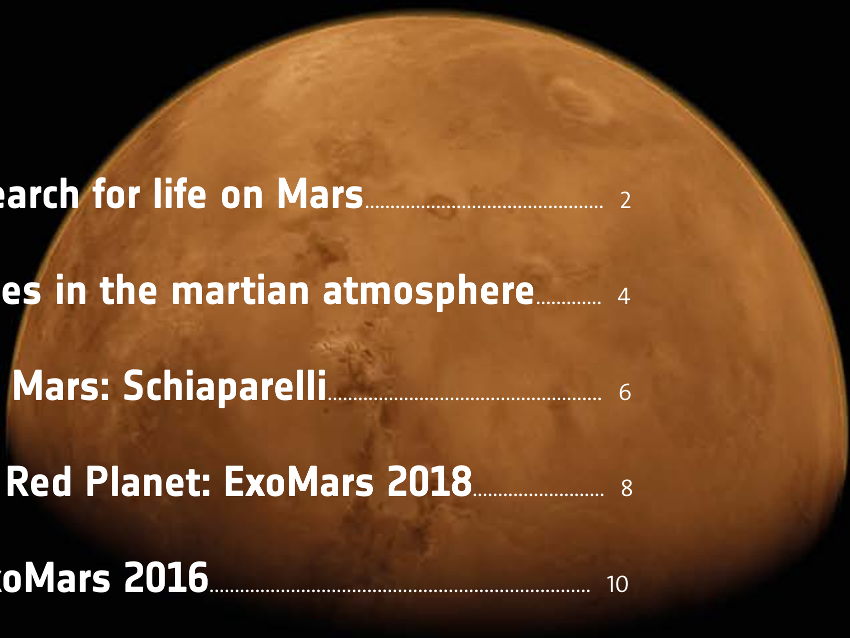
# EXOMARS 2016
# EUROPE'S NEW ERA OF MARS EXPLORATION



CONTENTS



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# → EUROPE'S SEARCH FOR LIFE ON MARS


Kasei Valles section, one of the largest outflow channel systems on Mars, imaged by ESA's Mars Express

Mars has captured the imagination of humankind for millennia, from artists and writers to scientists and astronomers alike. People often speculated that our neighbouring planet might host intelligent extraterrestrial life – a fantasy strengthened by 19th century Italian astronomer Giovanni Schiaparelli (for whom the ExoMars entry, descent and landing demonstrator module is named), who observed bright and dark straight-line features that he called 'canali'. This term was mistakenly translated into English as 'canal' instead of 'channel', conjuring up images of vast irrigation networks constructed by intelligent beings living on Mars. The controversy ended in the early 20th century, thanks to better telescopes offering a clearer view of the planet.

With the dawn of the space age in the latter half of the century, scientists instead began to look for evidence of the presence of water – an essential element for the emergence of life as we know it. Water is now known to have played an important role in the Red Planet's history, with numerous ancient dried-out riverbeds, channels and gullies observed by the fleet of spacecraft orbiting the planet and, more recently, evidence found of brief flows of briny water. But establishing whether life ever existed on Mars, even at a microbial level, remains one of the outstanding scientific questions of our time.


Mars, by the NASA/ESA Hubble Space Telescope

The present-day surface of Mars, dry and subject to harsh radiation, is too hostile for living organisms to survive. However, primitive life may have gained a foothold when the climate was warmer and wetter, more than 3.5 billion years ago, potentially leaving traces of early lifeforms still to be discovered below the surface.

## Europe to Mars

Mars exploration began in the 1960s, and over 40 spacecraft have attempted to reach the Red Planet to date, with varying degrees of success. European countries have participated in US-, Soviet- and Japanese-led missions through scientific collaboration and the contribution of instruments since the early 1970s. In particular, European instruments have flown on NASA's Mars orbiters, landers and rovers since 1992.

Possibilities for ESA-led Mars missions were studied from the early 1980s onwards, with the first, Mars Express, initiated following the loss of the Russian-led Mars 96. Mars Express was launched in 2003 with a suite of instruments and the Beagle-2 lander. The orbiter continues to yield world-class scientific data 12 years later, although the lander did not operate. The instruments on Mars Express provide extraordinary views of the planet and its environment. One unsolved question raised by the mission was the intriguing detection of atmospheric methane. On Earth, methane is produced almost exclusively by biological processes, with a small fraction due to volcanic or hydrothermal activity. Determining whether Mars is 'alive' today is at the heart of ESA's ExoMars programme.


Trace Gas Orbiter, Schiaparelli and the ExoMars rover

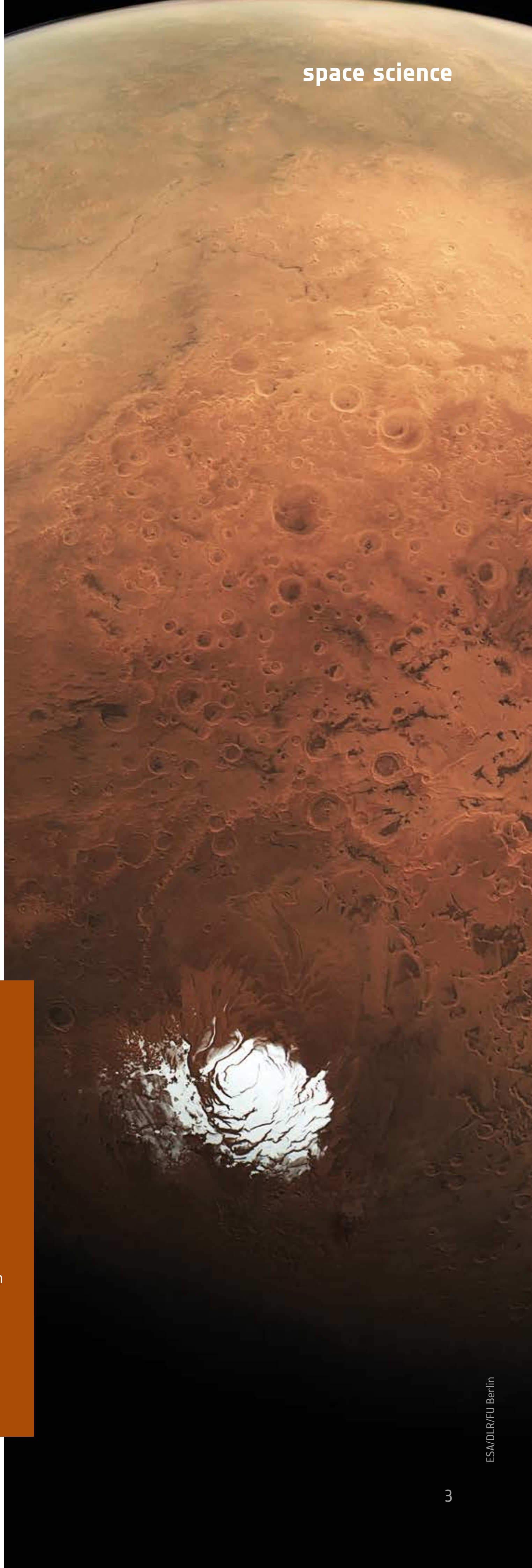
ExoMars is a cooperation between ESA and the Russian space agency, Roscosmos, and comprises two missions. The first, being launched in 2016, is made up of the Trace Gas Orbiter (TGO), which will carry out investigations to try to determine the biological or geological origin of important trace gases on Mars, plus Schiaparelli, an entry, descent and landing demonstrator module. Schiaparelli will test key landing technologies for ESA's contributions to subsequent missions to Mars.

The second mission, planned for launch in 2018, comprises a European rover and a stationary Russian surface science platform. The rover will be the first mission to combine the capability of moving across the surface with the ability to drill down to two metres below the surface, in order to retrieve and analyse samples using the Pasteur payload of sophisticated instruments.

ExoMars is thus set to open a new era for Europe: moving from remote observation to surface and subsurface exploration of Mars.

## Meet Mars

**Diameter:** 6794 km (about half the diameter of Earth)
**Surface area:** 145 million sq km (about the same as the land area of Earth)
**Gravity:** 3.711 $m/s^2$ (about one third of Earth's gravity)
**Density:** 3.93 $g/cm^3$ (Earth: 5.51 $g/cm^3$)
**Average distance from the Sun:** 227 940 000 km (1.52 times that of Earth)
**Martian day (a 'sol'):** 24 hours 37 minutes
**Martian year:** 669 sols or 687 Earth days
**Average temperature:** –55°C (from –133°C at the winter pole to +27°C during summer)
**Atmosphere:** 95.32% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.13% oxygen
**Atmospheric pressure at the surface:** 6.35 mbar (less than one hundredth of Earth's atmospheric pressure)
**Moons:** **Phobos:** 27 x 22 x 18 km; ~6000 km from the surface
**Deimos:** 15 x 12 x 11 km; ~20 000 km from the surface




Looking over the south polar ice cap and across its ancient cratered highlands

# → TRACING GASES IN THE MARTIAN ATMOSPHERE

The ExoMars 2016 mission, comprising the Trace Gas Orbiter (TGO) and Schiaparelli, will be launched on a Russian Proton rocket in March 2016 and arrive at Mars in October 2016. After releasing Schiaparelli, TGO will enter an elliptical orbit and use the atmosphere to slow itself down – aerobrake – in order to arrive at its final circular 400 km altitude orbit. It is expected to begin scientific investigations from this orbit in the latter part of 2017.

TGO includes state-of-the-art instruments designed to take a detailed inventory of Mars' atmospheric gases. Emphasis will be placed on analysing gases such as methane, water vapour, nitrogen dioxide and acetylene, which could point to active biological or geological processes, even though they are only present in small concentrations – less than 1% of the atmospheric inventory. To complement these measurements, TGO will also image and characterise features on the surface that may be related to trace-gas sources such as volcanoes.

Understanding the source of methane is of particular interest. Previous investigations have shown, for example, that the amount of methane can vary with location and time. Methane is short-lived on geological timescales, so its presence implies the existence of an active, current source. Data collected by TGO will be used to help assess the nature and origin of the methane.

The orbiter will monitor seasonal changes in the atmosphere's composition and temperature in order to create detailed atmospheric models. It will also map hydrogen on the surface and to a depth of a metre beneath, with improved spatial resolution compared with previous measurements. This could reveal deposits of water-ice hidden just below the surface, which, along with locations identified as sources of the trace gases, could influence the choice of landing sites of future missions.

As well as carrying Schiaparelli, TGO will serve as a data relay for the ExoMars 2018 rover mission.


TGO with Schiaparelli attached

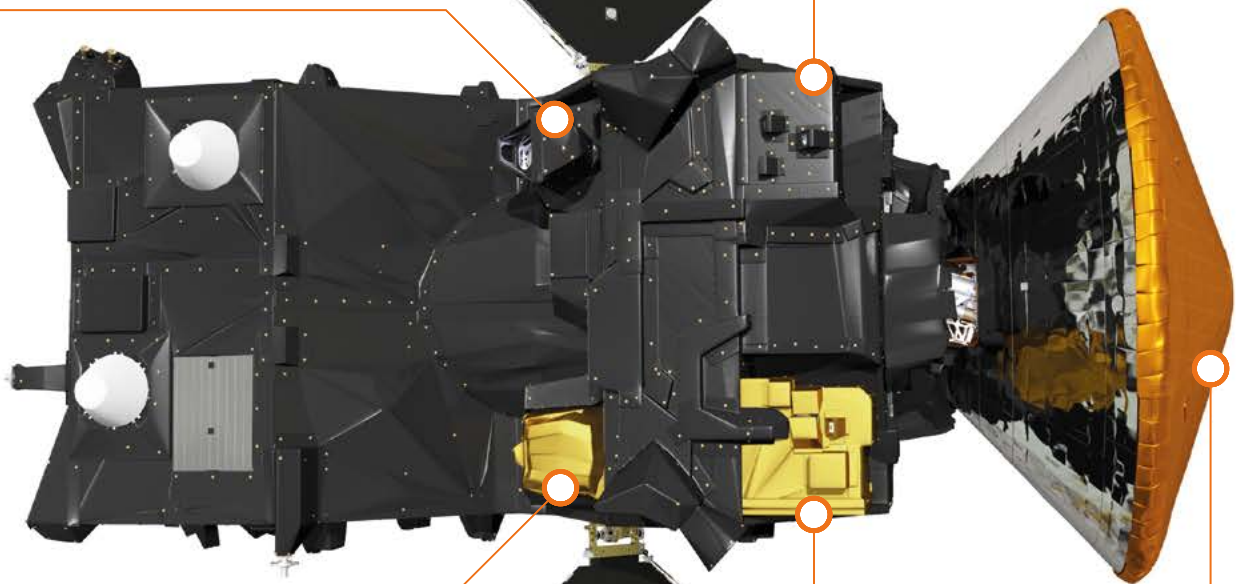
### What is a trace gas?

A trace gas makes up less than 1% by volume of a planet's atmosphere. Trace gases in the martian atmosphere include methane, water vapour, nitrogen dioxide and acetylene.

## TGO's instruments

**CaSSIS: Colour and Stereo Surface Imaging System**
This high-resolution camera (5 m per pixel) will obtain colour and stereo images of the surface covering a wide swath. It will provide the geological and dynamic context for sources of trace gases detected by NOMAD and ACS.
Principal Investigator: Nicolas Thomas, University of Bern, Switzerland.

**NOMAD: Nadir and Occultation for Mars Discovery**
NOMAD combines three spectrometers, two infrared and one ultraviolet, to perform high-sensitivity orbital identification of atmospheric components, including methane and many other species, via both solar occultation and direct reflected-light nadir observations.
Principal Investigator: Ann Carine Vandaele, Belgian Institute for Space Aeronomy, Brussels, Belgium.



**Schiaparelli**

**FREND: Fine Resolution Epithermal Neutron Detector**
This neutron detector will map hydrogen on the surface down to a metre deep, revealing deposits of water-ice near the surface. FREND's mapping of shallow subsurface water-ice will be up to 10 times better than existing measurements.
Principal Investigator: Igor Mitrofanov, Space Research Institute, Moscow, Russia.

**ACS: Atmospheric Chemistry Suite**
ACS is a suite of three infrared spectrometers to investigate the chemistry, aerosols, and structure of the atmosphere. ACS will complement NOMAD by extending the coverage at infrared wavelengths.
Principal Investigator: Oleg Korablev, Space Research Institute, Moscow, Russia.

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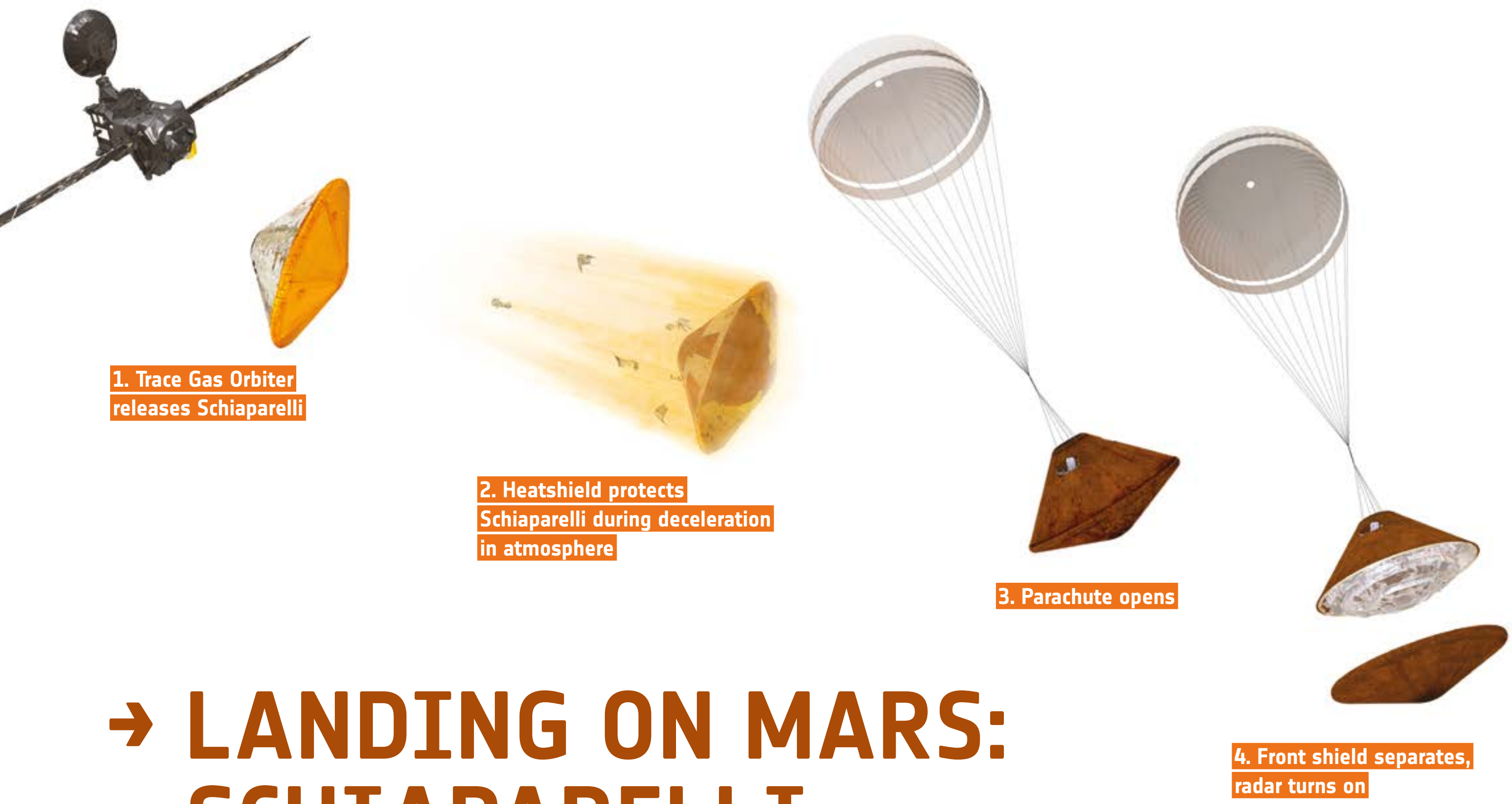
### Trace Gas Orbiter vital statistics

**Spacecraft:** 3.5 x 2 x 2 m, with solar wings spanning 17.5 m providing about 2000 W of power
**Launch mass:** 4332 kg (including 135.6 kg science payload plus the 600 kg Schiaparelli)
**Propulsion:** bipropellant, with a 424 N main engine for Mars orbit insertion and major manoeuvres
**Power:** in addition to solar power, 2 lithium-ion batteries to cover eclipses, with ~5100 Wh total capacity
**Communication:** 2.2 m-diameter X-band 65 W high-gain antenna for communication with Earth; UHF band transceivers (provided by NASA) with a single helix antenna for communication with surface rovers and landers
**Science:** 4 instrument packages
**Nominal mission end:** 2022




# → LANDING ON MARS: SCHIAPARELLI

Despite a number of prominent US successes since the 1970s, landing on Mars remains a significant challenge. As part of the ExoMars programme, a range of technologies has been developed to enable a controlled landing. These include a special material for thermal protection, a parachute system, a radar altimeter system, and a final braking system controlled by liquid-propellant retrorockets. Schiaparelli is designed to test and demonstrate these technologies, in preparation for future missions.

Three days before reaching Mars, Schiaparelli will separate from TGO and coast towards the planet in hibernation mode, to reduce its power consumption. It will be activated a few hours before entering the atmosphere at an altitude of 122.5 km and at a speed of 21 000 km/h. An aerodynamic heatshield will slow the lander down such that at an altitude of about 11 km, when the parachute is deployed, it will be travelling at around 1650 km/h.

Schiaparelli will release its front heat shield at an altitude of about 7 km and turn on its radar altimeter, which can measure the distance to the ground and its velocity across the surface. This information is used to activate and command the liquid propulsion system once the rear heatshield and parachute has been jettisoned 1.3 km above the surface. At this point, Schiaparelli will still be travelling at nearly 270 km/h, but the engines will slow it to less than 2 km/h by the time it is 2 m above the surface. At that moment, the engines will be switched off and Schiaparelli will freefall to the ground, where the final impact, at just under 11 km/h, will be cushioned by a crushable structure on the base of the lander.

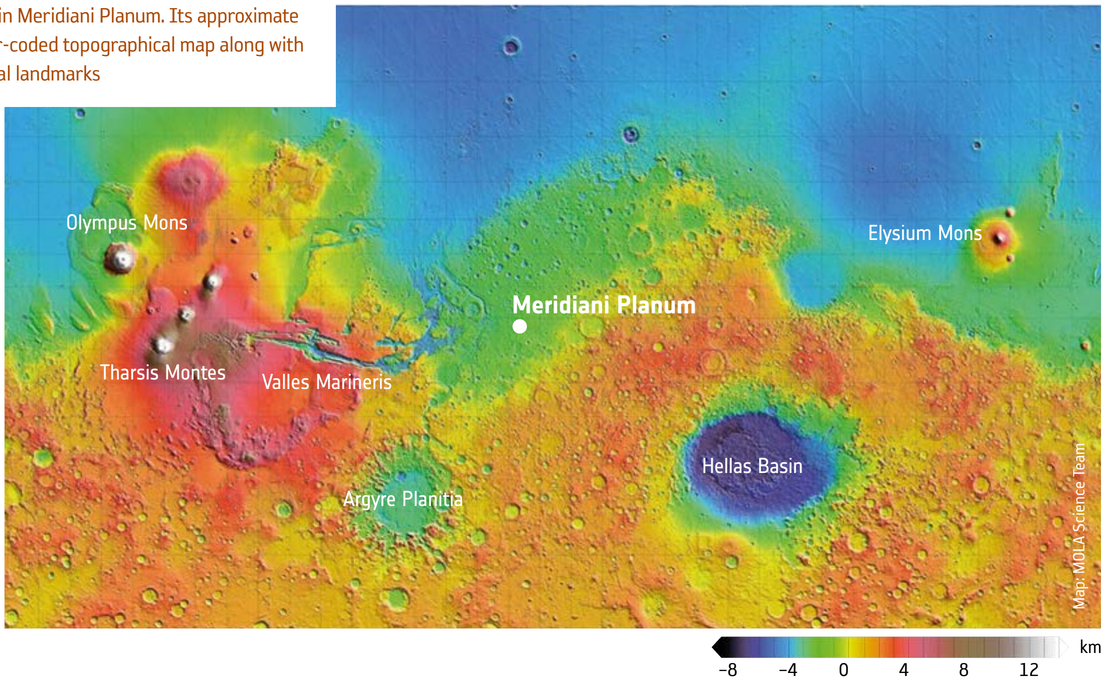
Although Schiaparelli will target the plain known as Meridiani Planum in a controlled landing, it is not guided, and the module has no obstacle-avoidance capability. It has, however, been designed to cope with landing on a terrain with rocks as tall as 40 cm and slopes as steep as 12.5°.

Because Schiaparelli is primarily demonstrating technologies needed for landing, it does not have a long scientific mission lifetime: it is intended to survive on the surface for just a few days by using the excess energy capacity of its batteries. However, a set of scientific sensors will analyse the local environment during descent and after landing, including performing the first measurements of atmospheric particle charging effects, to help understand how global dust storms get started on Mars. A communication link with TGO will provide realtime transmission of the most important operational data measured by Schiaparelli during its descent. Shortly after Schiaparelli lands, TGO will start a main engine burn and will return over the landing site only four sols later. In the meantime, the remainder of the entry, descent and landing data, along with some of the science instrument data, will be sent to Earth via ESA's Mars Express and NASA satellites already at Mars.

## Schiaparelli vital statistics

**Mass:** 600 kg
**Diameter:** 1.65 m
**Parachute diameter:** 12 m
**Propulsion:** 9 hydrazine engines in 3 triplet clusters
**Lifetime:** several days

Schiaparelli will target a region in Meridiani Planum. Its approximate location is labelled in this colour-coded topographical map along with some other prominent geological landmarks



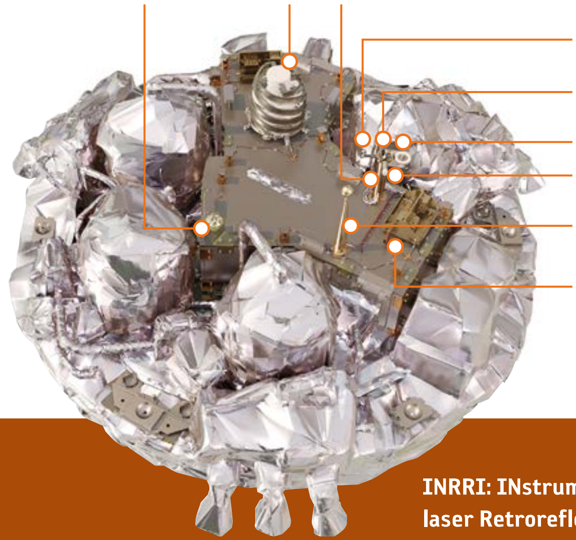





## Schiaparelli's instruments

**DREAMS: Dust Characterisation, Risk Assessment, and Environment Analyser on the Martian Surface**
The surface payload, consisting of a suite of sensors to measure local wind speed and direction (MetWind), humidity (DREAMS-H), pressure (DREAMS-P), atmospheric temperature close to the surface (MarsTem), transparency of the atmosphere (Solar Irradiance Sensor, SIS), and atmospheric electric fields (Atmospheric Radiation and Electricity Sensor, MicroARES).
Principal Investigator: Francesca Esposito, INAF – Osservatorio Astronomico di Capodimonte, Naples, Italy; Co-Principal Investigator: Stefano Debei, CISAS – Università di Padova, Italy.

**AMELIA: Atmospheric Mars Entry and Landing Investigation and Analysis**
To collect entry and descent science data using the spacecraft engineering sensors.
Principal Investigator: Francesca Ferri, Università degli Studi di Padova, Italy.

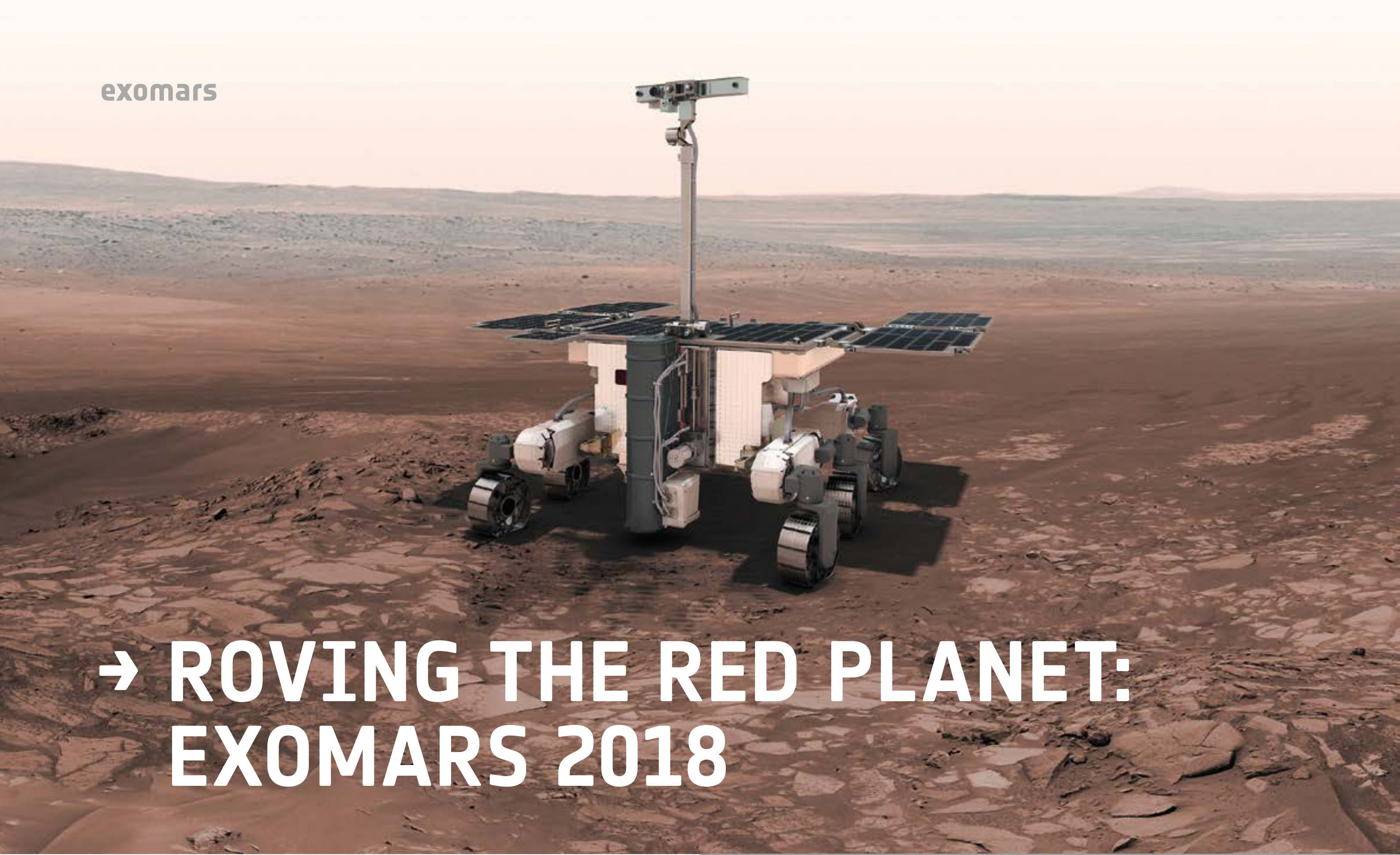



Schiaparelli's surface payload and key structural components

**COMARS+: Combined Aerothermal and Radiometer Sensors instrumentation package**
To monitor the heat flux on the back cover of Schiaparelli as it passes through the atmosphere.
Team leader: Ali Gülhan, DLR, Cologne, Germany.

**INRRI: INstrument for landing-Roving laser Retroreflector Investigations**
Team leader: Simone Dell'Agnello, INFN-LNF, Frascati, Italy.

**DECA: Descent Camera**
Will record several images during descent, but will not be able to take any images of the surface after landing.
Team leader: Detlef Koschny, ESA Science Support Office.



# → ROVING THE RED PLANET: EXOMARS 2018

Like its predecessor, the 2018 mission of a European rover and a Russian surface platform will also be launched on a Russian Proton rocket. During the launch and nine-month cruise to Mars, a carrier module (provided by ESA) will house the surface platform and the rover within a single protective aeroshell. A descent module (provided by Roscosmos with some contributions by ESA) will separate from the carrier shortly before reaching the martian atmosphere. During the descent, a heatshield will protect the payload as it passes through the atmosphere. Parachutes, thrusters and damping systems will reduce the speed, allowing a controlled landing.

After landing, the rover, which is about the size of a golf buggy, will leave the platform to start its science mission. The primary objective is to search for well-preserved organic material, particularly from the early history of the planet. With its suite of nine scientific instruments, collectively known as Pasteur, the rover will study the geology of the landing site and establish the physical and chemical properties of the samples, mainly from the subsurface. Underground samples are more likely to include ancient biosignatures in a good state of preservation since the tenuous atmosphere of today offers little protection from space radiation and surface photochemistry.

The rover is fitted with a drill – a first in Mars exploration – to extract samples from various depths, down to a maximum of two metres. Once collected, each sample is delivered to a number of instruments in the rover's next-generation analytical laboratory, which will perform investigations to determine the sample's mineralogy and chemistry.

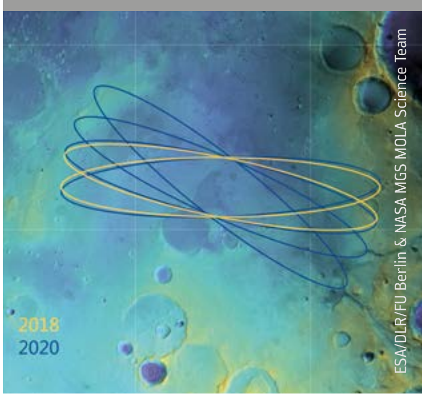
The rover is expected to travel several kilometres during its mission, collecting samples from a variety of locations.

## Choosing a landing site

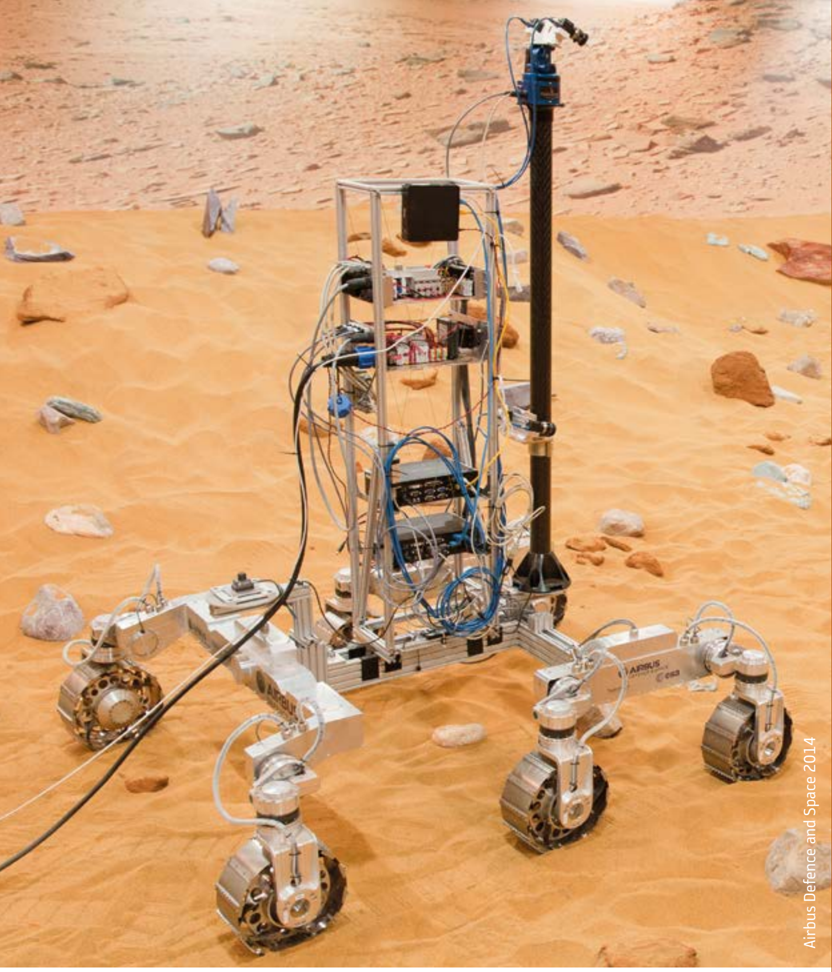
The surface area of Mars is some 145 million square kilometres, almost the same area as Earth's land masses. Fortunately, thanks to the fleet of spacecraft that has been studying Mars for over 50 years, a wealth of detailed information already exists about the surface, making the search for a suitable landing site less challenging than it was for the first missions that landed on the planet.

Since the objective of the ExoMars rover is to seek out signs of life, the candidate landing sites must show evidence for the past presence of abundant liquid water. At the same time, the sites have to satisfy a number of technological constraints.

Four sites have been under discussion: Mawrth Vallis (one of the oldest outflow channels with exposures of clay-rich rocks), Oxia Planum (one of the largest exposures of layered clay-rich rocks), Hypanis Vallis (the remnant of an ancient river delta) and Aram Dorsum (home to alluvial sediments associated with a channel running through the site). While Oxia Planum has been recommended by the Landing Site Selection Working Group as the primary focus for further detailed evaluation for the 2018 mission, the final decision will be made by ESA and Roscosmos during 2017.




Oxia Planum landing ellipses under evaluation, each covering an area 104 x 19 km. The orientation of the landing ellipse depends on when the launch takes place within a given launch window – they have to be compliant with launch in 2018 and the backup launch window in 2020.




The Stevenage site of Airbus Defence and Space in the UK and ESA's European Space Research and Technology Centre (ESTEC) in the Netherlands both have 'Mars Yards' to provide realistic training grounds for developing the locomotion and navigation systems for prototype planetary rovers (above and below, respectively)


## Rover instruments

**PanCam: Panoramic Camera**
Three cameras – a stereo pair and a high-resolution camera – will image in colour the rover's surroundings, perform digital terrain mapping, and help to decide where the rover should go and which targets it should explore.
Principal Investigator: Andrew John Coates, MSSL/University College London, London, UK.

**ISEM: Infrared Spectrometer for ExoMars**
ISEM will assess the mineralogical composition of surface targets. Working with PanCam, it will contribute to the selection of targets for further analysis by the other instruments.
Principal Investigator: Oleg Korablev, Space Research Institute, Moscow, Russia.

**CLUPI: Close-UP Imager**
This camera system will acquire high-resolution, colour, close-up images of rocks, outcrops, and drill core samples.
Principal Investigator: Jean-Luc Josset, Space Exploration Institute, Neuchâtel, Switzerland.

**WISDOM: Water-Ice and Subsurface Deposit Observation On Mars**
WISDOM is a ground-penetrating radar to characterise the stratigraphy under the rover. It will be used with Adron, which can provide information on subsurface water content, to decide where to collect subsurface samples for analysis.
Principal Investigator: Valérie Ciarletti, LATMOS, France.

**Adron**
Adron, a neutron spectrometer, will search for subsurface water and hydrated minerals. It will be used in combination with WISDOM to study the subsurface beneath the rover and to search for suitable areas for drilling and sample collection.
Principal Investigator: Igor Mitrofanov, Space Research Institute, Moscow, Russia.

**Ma_MISS: Mars Multispectral Imager for Subsurface Studies**
Located inside the drill, Ma_MISS will contribute to the study of mineralogy and rock formation.
Principal Investigator: Maria Cristina De Sanctis, Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF), INAF, Rome, Italy.

**MicrOmega**
This is a visible plus infrared imaging spectrometer for mineralogy studies of samples.
Principal Investigator: Jean-Pierre Bibring, Institut d'Astrophysique Spatiale, Orsay, France.

**RLS: Raman Laser Spectrometer**
RLS will establish the mineralogical composition and identify organic pigments.
Principal Investigator: Fernando Rull Perez, Centro de Astrobiología, Unidad Asociada (CSIC-UVA), Spain.

**MOMA: Mars Organic Molecule Analyser**
MOMA will target biomarkers in order to answer questions related to the potential origin, evolution and distribution of life on Mars.
Principal Investigator: Fred Goesmann, Max Planck Institute for Solar System Research, Göttingen, Germany.

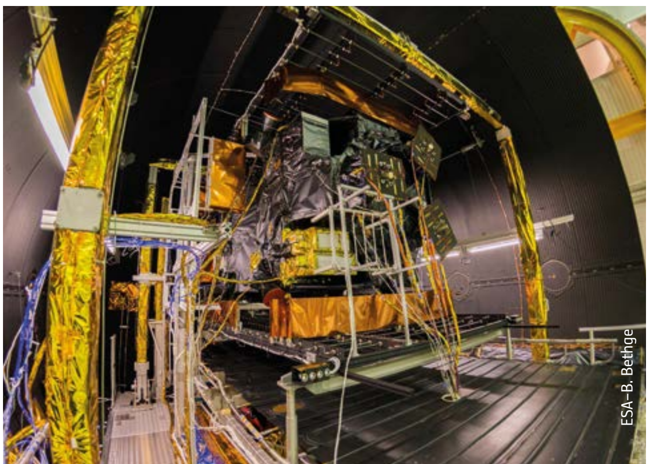
# → BUILDING AND TESTING EXOMARS 2016

TGO and Schiaparelli are put through their paces to test they can survive the violent shaking encountered during launch, the harsh radiation environment of space, and operations at Mars.


The TGO core module, consisting of the structure and the thermal control and propulsion systems

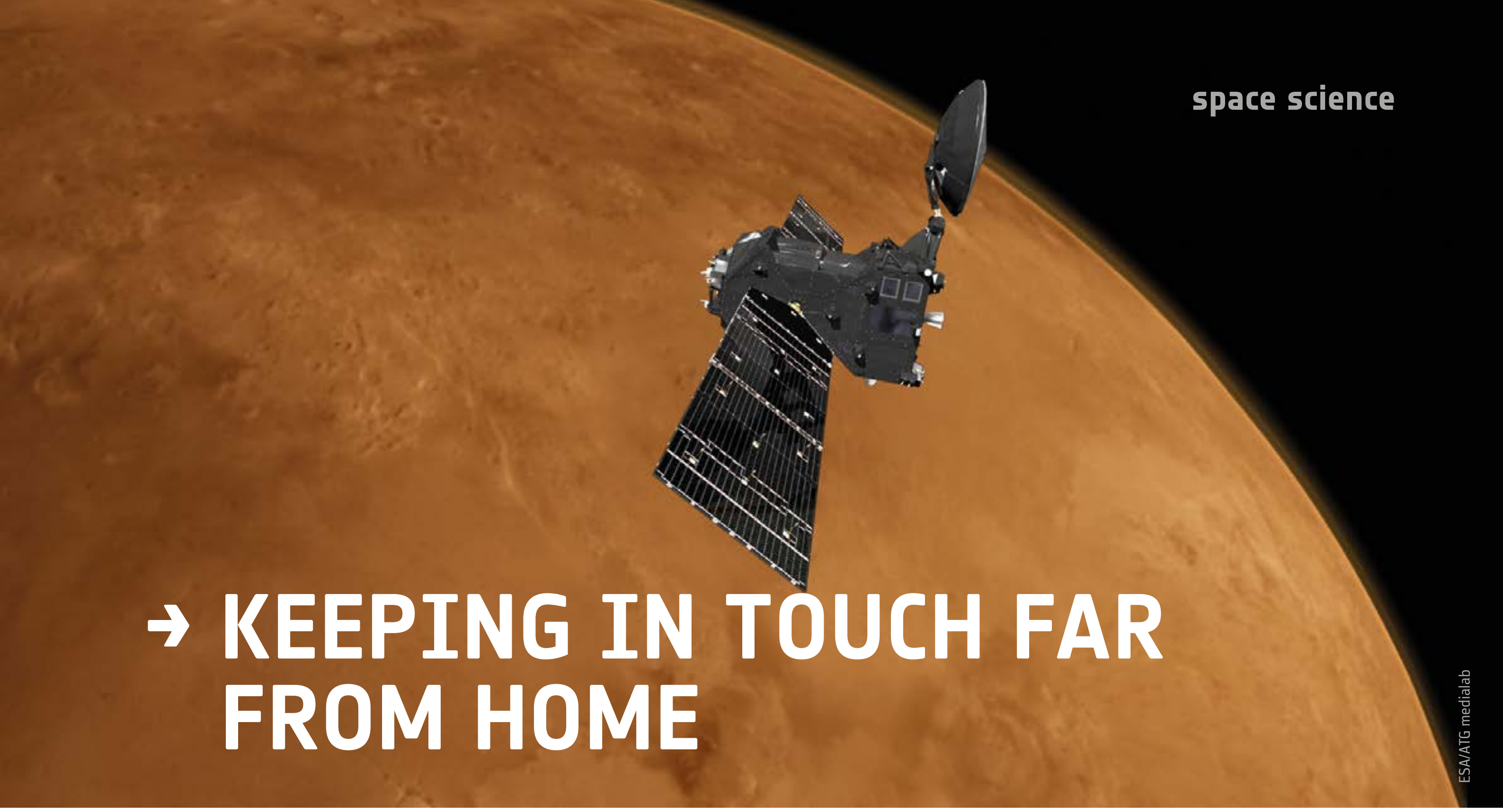

Schiaparelli being craned into position for mating with TGO in the Cannes facility of Thales Alenia Space (France)


Lowering the 600 kg structural model of Schiaparelli onto the Multishaker at ESA's ESTEC in Noordwijk, the Netherlands, for vibration testing




TGO during the large thermal vacuum test at Thales Alenia Space, in Cannes

TGO with Schiaparelli (top) during testing at Thales Alenia Space, in Cannes (the high-gain antenna is on the right)




# → KEEPING IN TOUCH FAR FROM HOME

TGO at Mars

Both TGO and Schiaparelli will be operated from ESA's European Space Operations Centre (ESOC), in Darmstadt, Germany, supported by ground stations worldwide, including ESA's Estrack network, NASA's Deep Space Network and – during TGO science operations – Roscosmos facilities.

After separation, TGO will monitor transmissions from Schiaparelli from its coast to Mars until landing. Earth-based communication arrays will also track the signal during the entry, descent and landing. ESA's Mars Express along with NASA orbiters will also provide data relay to and from Earth during Schiaparelli's surface operations.

The operations team at ESOC will control TGO during all phases of its mission, including insertion into Mars orbit, orbit control, aerobraking, science operations (planned by ESA's European Space Astronomy Centre, ESAC) and Mars communications operations.

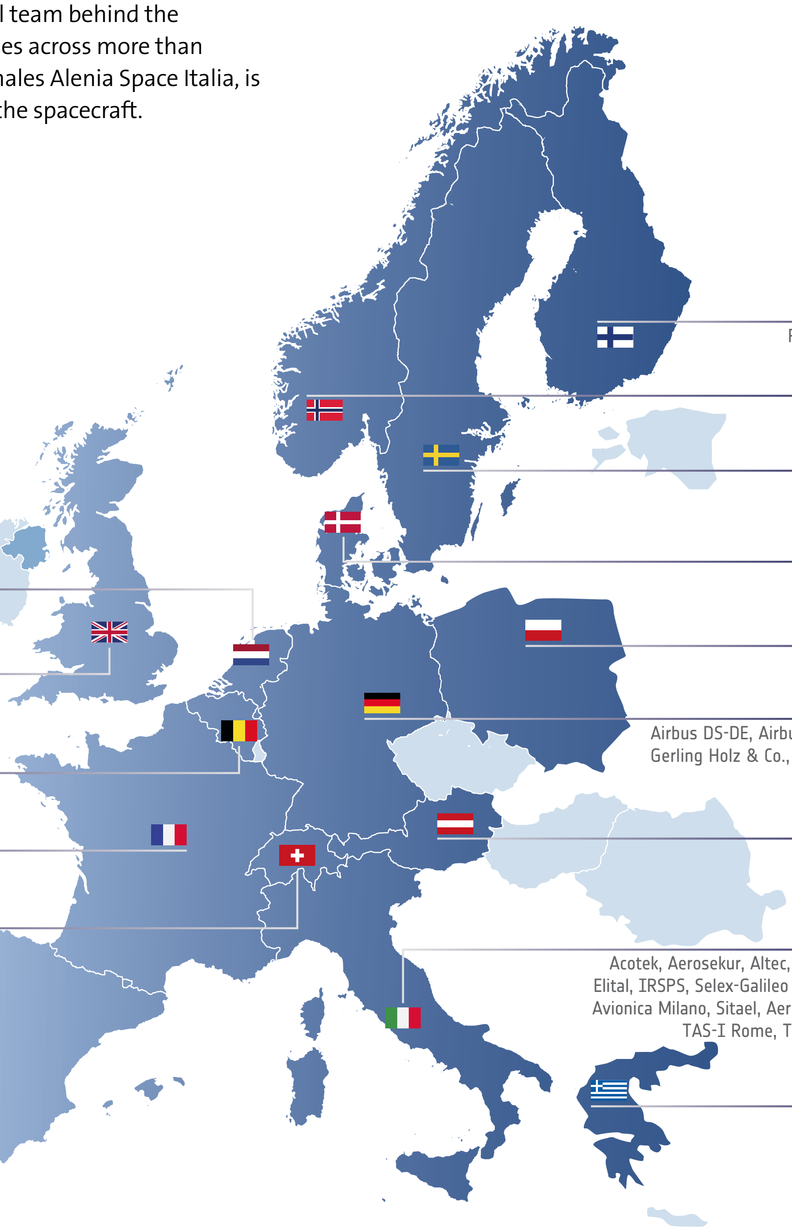
TGO will later provide communications with the 2018 ExoMars rover. The Rover Operations Control Centre will be located in Turin, Italy. Commands to the rover will be transmitted through TGO from ESOC, via the ground stations.

ESA's ground station at Malargüe, Argentina

# → AN INTERNATIONAL ENTERPRISE

ExoMars is a cooperation between ESA and the Russian space agency, Roscosmos. Roscosmos is providing the Proton rockets to deliver both missions to Mars, contributions to the scientific payload, the surface platform of the 2018 mission, and Russian ground station support. The technical team behind the ExoMars spacecraft involves companies across more than 20 countries. The prime contractor, Thales Alenia Space Italia, is leading the industrial team building the spacecraft.

The map highlights ESA Member and Cooperating States within Europe that are contributing to ExoMars. Participating countries outside Europe are indicated at top left.



**Russia**
Khrunichev, Lavochkin Association, TsENKI

**United States**
ATK-PSI, EMS, ERG, GD-OTS, Haigh-Farr, Honeywell, Mu Space

**Canada**
MDA, Neptec

**Israel**
Rafael

**Netherlands**
Bradford, TNO, TNO-TPD, SSBV, Airbus DS-NL

**United Kingdom**
ABSL, Airbus DS-UK, Fluid Gravity Engineering Ltd, Qinetiq, TAS, Tessella, Vorticity

**Belgium**
ASTEK, OHB-BE, Qinetiq, TAS-BE, Trasys

**France**
Airbus DS-FR, ETS, SAFT, Souriau, TAS-F Cannes

**Switzerland**
Almatech, APCO
Clemessey, Maxon, RUAG

**Portugal**
Active Space Technologies, Critical Software, Deimos, GMV, HPS, IST

**Spain**
Casa, Crisa, Deimos, GMV, Iberespacio, Rymsa, Sener, TAS-ES

**Finland**
Patria, Space Systems

**Norway**
Kongsberg

**Sweden**
RUAG

**Denmark**
Terma

**Poland**
Sener

**Germany**
Airbus DS-DE, Airbus DE, DLR, DSI, ETS, Gerling Holz & Co., Kayser-Threde, OHB, Rockwell Collins

**Austria**
RUAG, Siemens

**Italy**
Acotek, Aerosekur, Altec, Corista, D'Appollonia, Elital, IRSPS, Selex-Galileo Firenze, Selex-Galileo Avionica Milano, Sitael, Aerospace, TAS-I Torino, TAS-I Rome, Tecnomare, Telespazio

**Greece**
TEMMA

For more information, see:
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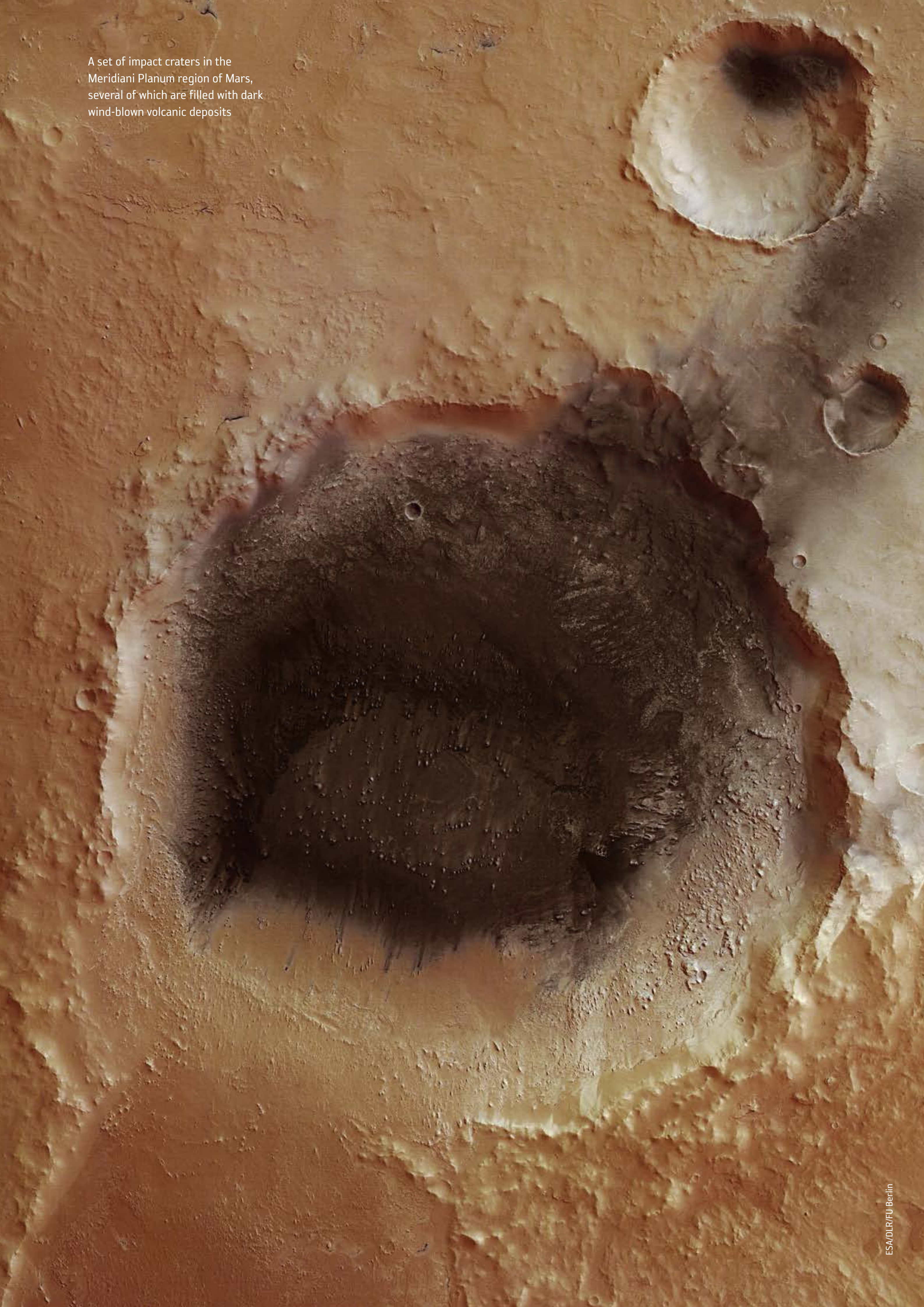

A set of impact craters in the Meridiani Planum region of Mars, several of which are filled with dark wind-blown volcanic deposits

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