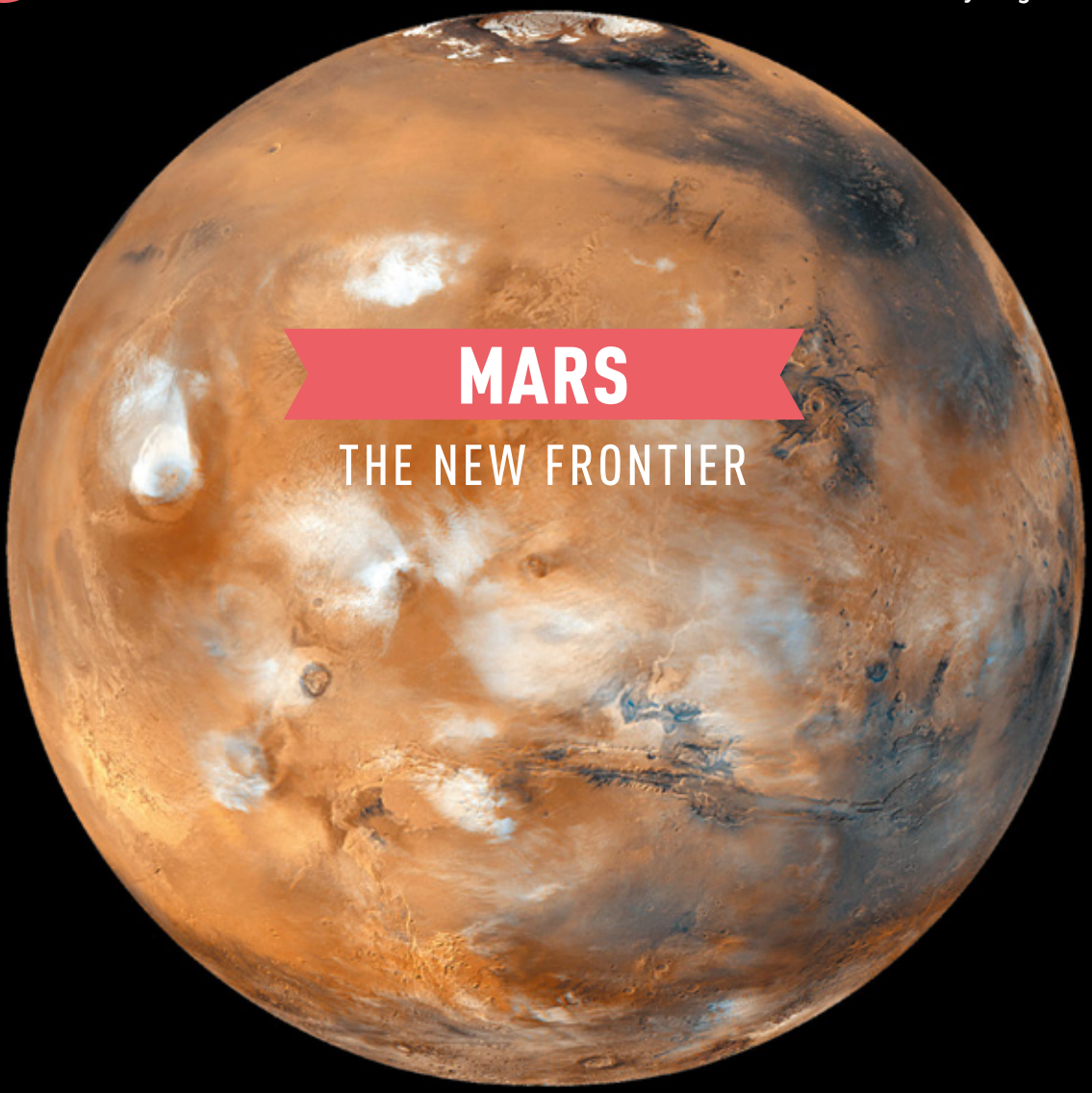
CNES MAG

EN FR

SPACE ● INNOVATION ● SOCIETY

#69
July-August 2016

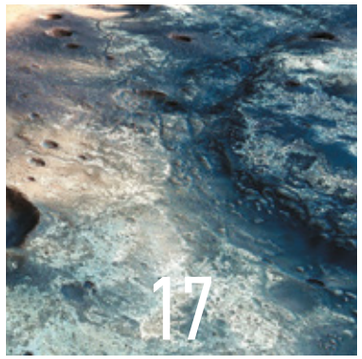


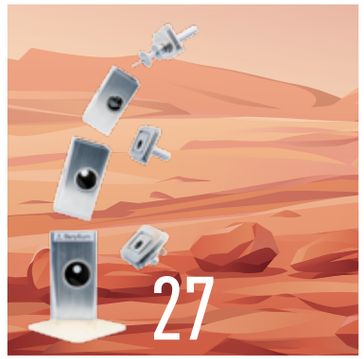
MARS

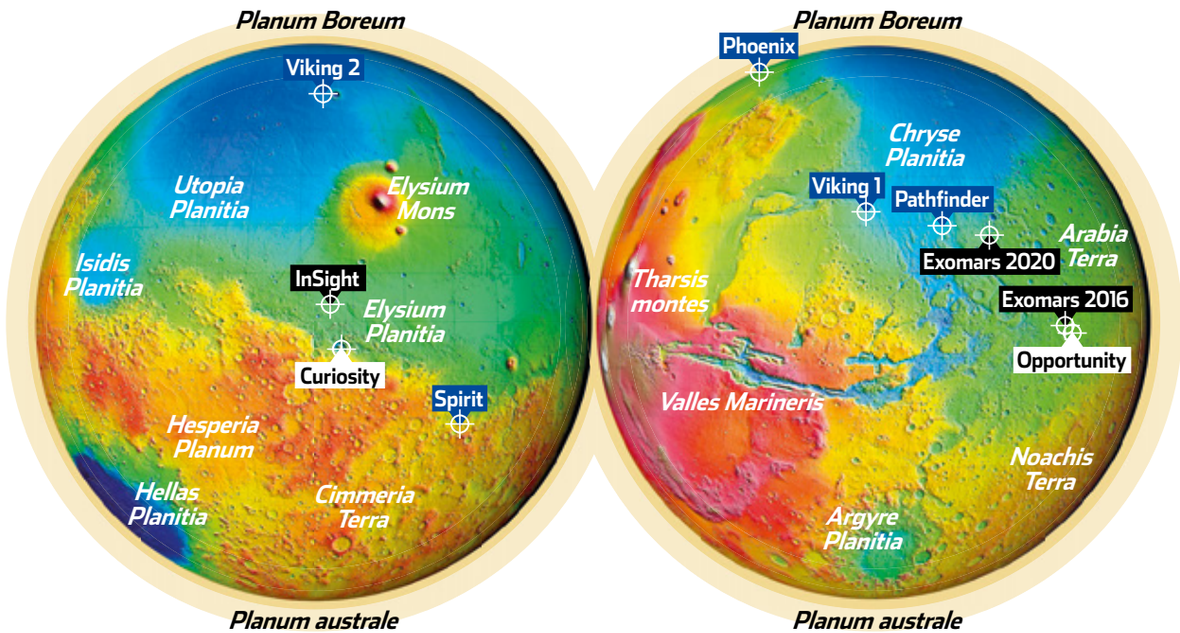
THE NEW FRONTIER

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

INSIDE







TOPOGRAPHIC MAP OF MARS

obtained by the Mars Orbiter Laser Altimeter (MOLA) on the U.S. Mars Global Surveyor mission (MGS) showing the main surface features and the position of past (white on blue) and future (black on white) mission landing sites.

PARTNERS

Mentioned in this issue: p.07 Novespace, the firm specializing in parabolic flights, microgravity and technology spinoff; p.10 The MEDES space medicine clinic; p.14/24/31 The IPGP global physics institute in Paris; p.20/24 CNRS-INSU, the national institute for universe sciences; p.36 the IRAP astrophysics and planetology research institute; p.30 The IAS space astrophysics institute, Orsay, and all of the space agencies contributing to the Mars adventure.

[+] WWW.CNES.FR
View additional content on our website wherever you see this sign.

Cover: © NASA/IPL/MSSS

CONTRIBUTORS

FABIENNE CASOLI

Qualified astrophysicist Fabienne Casoli has held various managerial positions at the Observatoire de Paris, CNRS's INSU universe sciences institute and the IAS space astrophysics institute in Orsay. So exploration of the Universe holds no secrets for her. With CNES since 2007, she is currently Deputy Head of the Directorate of Innovation, Applications and Science (DIA), where she is supporting French research work.

MICHEL VISO

Exobiology is just one of Michel Viso's hats at CNES, where he is managing French contributions to forthcoming missions that will be hunting for signs of life on Mars. Through his involvement in drafting international planetary protection recommendations to avert contamination of the solar system's planets by terrestrial micro-organisms, he is laying the groundwork for future Mars sample return missions.

ROBIN SARIAN

Infographics designer Robin Sarian, currently with press agency Idé, has been creating illustrations and artwork for 27 years. He is now combining his passions for science, technologies and the cosmos in Cnesmag's Timeline feature. This talented self-taught man believes the important thing is to always keep your sense of curiosity and wonderment.

FRÉDÉRIC MALIGNE

After obtaining his degree in history and economics, Frederic Maligne developed a feel for light at Studios Harcourt. His preferred medium of expression is portrait photos. For him, each shoot opens new avenues and possibilities, as was the case with Sylvestre Maurice for this issue's Q&A feature.

CNESMAG

Cnesmag, the magazine of the Centre National d'Etudes Spatiales, 2 place Maurice Quentin, 75039 Paris cedex 01. For all correspondence, write to: 18 avenue Edouard Belin, 31401 Toulouse cedex 9. Tel.: +33 (0)5 61 28 33 90. Internet: http://www.cnes.fr. This review is a member of *Communication&Entreprises*. Subscriptions: cnesmag@cnes.fr

Publication director: Jean-Yves Le Gall. **Editorial director:** Marie-Claude Salomé. **Editor-in-chief:** Brigitte Alonzo-Thomas. **Proofreading:** Céline Arnaud. **Writers:** Liliane Feuillerac, Didier Jamet, Marie-Claude Siron, Brigitte Alonzo-Thomas. **Photos and iconography:** Marie-Claire Fontebasso. **Photo credits:** © CNES/O.Pascaud - H.Piraud - R.Sarian - F.Maligne (p.4); CNES/O.Pascaud (p.5); TM & Twentieth Century Fox Film Corporation/Aidan Monaghan, 2015 (p.6); NASA/B.Stafford/ISC (p.7); NASA/JPL Caltech (p.8); ESA/DLR/FU Berlin & NASA MGS MOLA Science Team (p.9); CNES/IMBP (p.10 top); CNES/E.Grimault (p.10 bottom); S.Gifford (p.11 top); CNES/F.Maligne (p.11 middle); NASA/JPL-Caltech (p.11 bottom); CNES/F.Maligne (p.13-15); NASA/JPL/University of Arizona (p.16-17); NASA/U.S. Geological Survey (p.18); ESA/DLR/FU BERLIN (p.19); NASA/JPL-Caltech/MSSS (p.20); NASA/JPL-Caltech/ESA/DLR/FU Berlin/MSSS (p.21); NASA/JPL-Caltech/MSSS (p.22 left); CNES/E.Grimault (p.22 right); NASA/JPL-Caltech/Lockheed Martin (p.23); SA/ATG Medialab (p.24 and p.25 left); ESA-Stephane Corvaja (p.25 right); David Richalet (p.27); CNES/E.Grimault (p.33); CNES/D.Sarraute (p.36). **Illustrations:** François Foyard (p.07/26), Robin Sarian (IDE) (p.28/29), Jean-Marc Pau (p.30-32). **Webmaster:** Sylvain Charrier. **English text:** Boyd Vincent. **Design and pre-press:** Citizen Press – Camille Aulas, Stéphane Boumendil, David Corvaisier, Alexandra Roy, Aurélien Saublet. **Printing:** Ménard. ISSN 1283-9817. **Thanks to:** Laurence Amen, Karol Barthely, Guilhem Boyer (social networks), Fabienne Casoli, Sylvain Charrier (webmaster), Philippe Collot, Chantal Delabarre, Emline Deseez, Romain Desplats, Alain Gaboriaud, Guillemette Gauquelin-Koch, Séverine Klein, Patrick Landrodie, Didier Lapierre, Amélie Proust, Francis Rocard, Laurent Rastel, Muriel Saccoccio, Mathilde Savreux, Florence Serroussi, Marie-Claude Siron (digital Cnesmag), François Spiero, Michel Viso.

PEFC 10-31-2690

IMPRIM'VERT®

EDITORIAL

The current revolution in the space sector, driven by innovation for applications, could have the unexpected effect of stepping up the pace of Mars exploration. Slated for 2040-2050 only six months ago, launch of the first crewed mission to Mars is seemingly getting closer by the day, with proponents now talking about 2030 or even 2025. Why? Because we are starting to see the benefits of the spectacular cost reductions in satellites and space launches made possible by a series of projects and increased launch and production rates. As a result, what was previously just a concept to send a spacecraft to Mars capable of supporting a four-to-six-person crew in space for two years is now on the verge of becoming reality. Drawing on the in-depth knowledge of Mars gleaned from the exceptional Mars Express, Curiosity, MAVEN, ExoMars, InSight and Mars 2020 missions, France, CNES and our scientific community will be at the forefront of this new saga of the modern age—to conquer what is fast becoming THE new frontier for all of humankind.

JEAN-YVES LE GALL
CNES PRESIDENT

CINEMA

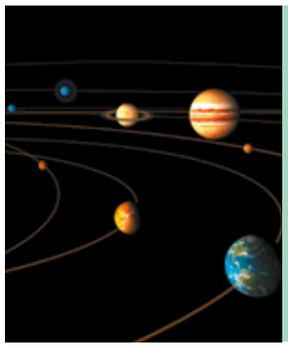
The Martian: CNES gets in on the act

The dubbed French version of The Martian has been widely praised, and a lot of the credit for that must go to CNES and its expertise. Thierry Vallée, who conducted 15 launches as Director of Operations at the Guiana Space Centre, helped with the adaptation by checking translations of the technical jargon that permeates the film. *"The challenge was twofold: to adapt the dialogue to the layman without denaturing the technical content, and to make the translations tight enough to sync with the actors' lip movements,"* he explains. This exciting experience has sown the seeds of a new dream for him: *"If one day a crewed Mars mission lifts off from French Guiana, I'd like to be there to direct the launch!"*

DEMONSTRATOR

MOXIE BRINGS A BREATH OF FRESH AIR TO MARS

More than 95% carbon dioxide, the atmosphere on Mars is unbreathable. However, as its chemical formula (CO_2) indicates, each carbon dioxide molecule contains two precious atoms of oxygen. To pave the way for future crewed missions to the red planet, Mars 2020 will be carrying a demonstrator called MOXIE (Mars OXygen In-situ resource utilization Experiment), which will break down CO_2 molecules on Mars by electrolysis to extract their oxygen. The mission will be considered conclusive if MOXIE is able to generate 22 grams of oxygen per hour for 50 Mars days, enough to keep a human alive for 10 days.



22 MINUTES

and 13 seconds is the maximum time a radio message takes to reach Earth from Mars when the two planets are on opposite sides of the Sun. When they are closest, it takes just over 3 minutes. So we won't be watching Man's first steps on Mars live.

VIDEO

Thomas Pesquet gives his take on *The Martian* from Houston

EYEWITNESS

THOMAS PESQUET HAS THE RIGHT STUFF TO BE A MARTIAN

As he prepares to fly to the International Space Station for a six-month mission in November, Thomas Pesquet is well placed to give a considered opinion of the film The Martian. *"This adventure of a human all alone in a strange land really resonated with me. All astronauts are explorers at heart!"* In fact, Thomas Pesquet has already been in a situation similar to what the hero of the film experiences, on parabolic flights organized by CNES subsidiary Novespace. *"We recreated Martian gravity conditions on some of these flights,"* he explains. *"Our astronaut training includes survival techniques for the event that our capsule doesn't land where expected on returning to Earth. We're taught to stay positive and not let ourselves get down, which is exactly what we see in the film."* This is also a lesson CNES has learned well over more than 30 years working tirelessly with the French scientific community on the long road to exploring Mars.

The ChemCam instrument's laser enables the mission science team to analyse the elemental composition of rocks and soil in the rover's vicinity.

TECHNOLOGY

CNES MAKES DREAMS COME TRUE

While the world of science-fiction abounds with warriors toting multicolour lasers, in real life things are a little more complex. Take for example the ChemCam laser used by the Curiosity rover to probe Mars' geology on the MSL mission. At the start of the 2000s, astrophysicist Sylvestre Maurice began to dream of fielding such a tool on Mars that would remotely reveal the composition of nearby rocks. But the only one meeting his specifications was a laser weighing 20 kilograms, the size of a desk, consuming several kilowatts and sensitive to shocks. In other words, it had no chance of being sent into space. The scientist therefore turned to CNES and Muriel Saccoccio, the development engineer at the agency's Toulouse Space Centre. Specializing in lasers and space applications, she helped the manufacturer, Thales Laser, to make the right technology choices. The resulting ChemCam laser weighs just 600 grams, is no larger than a soft drink can and has already fired 337,000 times. In fact, it has proved such a success that the Mars 2020 mission is set to carry an enhanced version of ChemCam called SuperCam, for which another CNES engineer, Benoît Faure, is developing the laser.

50 YEARS OF MARS EXPLORATION

1965

Mariner 4, USA. First flyby and images of the surface of Mars, which turns out to be a vast frozen desert.

1971

Mariner 9, USA. First satellite in orbit around a planet other than Earth. Discovers the Olympus Mons volcano and Valles Marineris canyon.

1976

Viking 1 and 2, USA. First successful landing and in-situ experiments to search for life on Mars. No traces are found.

1996

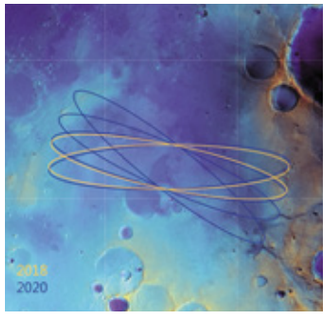
Mars 96. Ambitious Russian mission carrying more than 40 experiments, 11 from Europe. The mission is lost on launch, but replicas of the European instruments will fly on later missions. *Mars Pathfinder.* U.S. technology mission, the first to land a rover (Sojourner) on Mars.

VIDEO

Is Oxia Planum the ideal location on Mars?

LANDING

EXOMARS 2020 COULD HEAD FOR OXIA PLANUM



Oxia Planum was selected as the primary landing site for the ExoMars 2018 rover mission. Of the four candidates, the site was judged to offer the best compromise between science return and engineering constraints. Lying inside the landing ellipse of the descent module, Oxia Planum contains thin layers of clay that could hold traces of past microscopic life. Oxia Planum is also the least elevated of the sites, at three kilometres below the mean elevation of Mars. This lower altitude will mean the lander is able to brake for longer in Mars' tenuous atmosphere, thus reducing its terminal landing speed. As it will not be launching until 2020, the mission's scientists are working to analyse new possible trajectories and alternative landing sites could be considered, even if Oxia Planum remains for now the first choice.

200

BTS vocational diploma students from 22 schools in the Toulouse district who worked for two years on Elysium, a full-scale replica of the InSight mission's rover. This kind of learning experience initiated by CNES can be a passport to a career in science and engineering.

100 GRAMS

That's how much of Mars' atmosphere is stripped away by the solar wind every second, which explains how over billions of years the planet has lost most of it. On the strength of this discovery, the French-U.S. MAVEN mission has been extended until at least the end of this year.

[+] **MORE INFORMATION:** MAVEN.CNES.FR

5 KM/S

The theoretical speed a spacecraft lifting off from Mars needs to attain to escape the planet's gravity, only half that when escaping Earth (11.2 km/s).

2003

Mars Express, Europe. Still operating today, this hugely successful mission discovers the first clay deposits on Mars, a tantalizing prospect for exobiologists.

2004

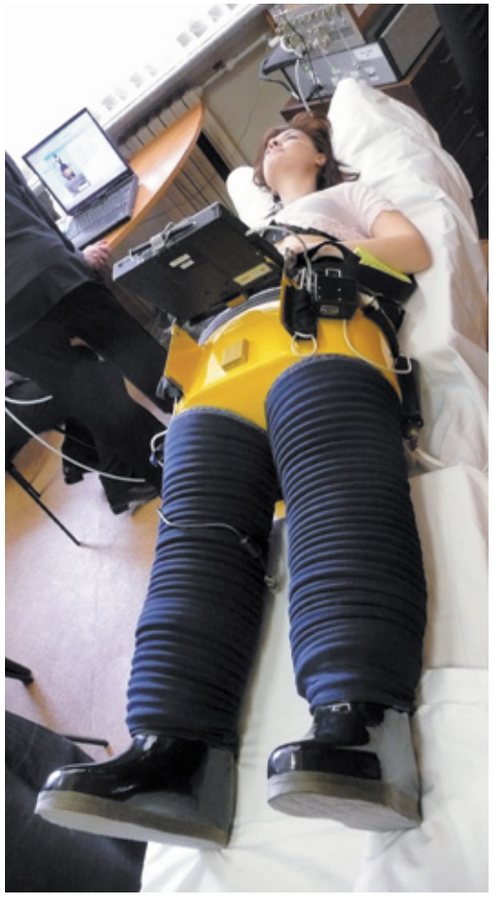
Mars Exploration Rover, USA. The twin rovers Spirit and Opportunity confirm the science value of operating a mobile platform on Mars. Opportunity is still working.

2012

Mars Science Laboratory (MSL), USA, with a major contribution from France. MSL confirms that Mars was once habitable in its ancient past. The Curiosity rover is pursuing its trek towards Mount Sharp.

2016

ExoMars 2016, Europe/Russia. This mission comprises the Trace Gas Orbiter (TGO) and Schiaparelli lander designed to validate technologies for landing on Mars. TGO will look for trace quantities of gas in the atmosphere.



TRAINING

READYING FOR LONG-DURATION FLIGHTS

The exploration of Mars is currently the preserve of satellites and rovers, but CNES is already preparing for crewed missions to the red planet. "*We're striving to sustain the key skills needed to prepare astronauts for long-duration flights*," confirms François Spiero, CNES's head of human spaceflight. At the Toulouse Space Centre, the CADMOS centre for the development of microgravity applications and space operations is conducting a range of human physiology experiments on the International Space Station (ISS). For example, it is preparing 12 instruments and technology demonstrators for the Proxima mission in which Thomas Pesquet will be taking part, set to start in November. Over the last 20 years, CNES has developed solid expertise in cardiovascular monitoring of space travellers with Cardiolab (ISS) and Cardiomed (Russian module of the ISS), and is poised to operate Cardiospace on China's TianGong 2 space station. "*This specialization is the result of the real problems that astronauts' cardiovascular systems face during long stays in space, but also of the expected benefits for public healthcare here on Earth*," explains Guillemette Gauquelin-Koch, head of life sciences at CNES. Another benefit of these preparations for long-duration missions is the prolonged bedrest experiments conducted at MEDES, CNES's space clinic subsidiary, to test countermeasures to the negative effects of microgravity.

CONFINEMENT

EXPERIMENT IN CHINA

The first human missions to Mars will probably be international cooperation efforts with multicultural crews who will have to learn to live together within a confined space for many months. Hence the CELSS[1] confinement experiment that CNES is partnering, which has just started in Shenzhen, China. Planned to last six months, CELSS will also be trialling a first version of Cardiospace before it flies in space.

1. Confined Ecological Life Support System

MARS ANALOGUE

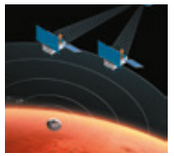
THE HAWAIIAN

Since 28 August 2015, 25-year-old French biologist Cyprien Verseux has been taking part in NASA's HI-SEAS[1] IV confinement experiment. With five other volunteers, he will be spending 365 days inside an 11-metre-diameter white dome designed as an analogue of the Martian habitat on the arid slopes of Mauna Loa, the volcano on Hawaii reminiscent of the red planet. Cyprien isn't living in total reclusion, however, since he alternates spacesuited sorties outside the dome with scientific work indoors. As a biologist, his mission is to create a Martian ecosystem from which the crew could partially subsist, while keeping tabs on any bacterial pathogens inside their living quarters.

1. Hawaii Space Exploration Analog and Simulation

SATELLITES

SENDING NANOSATS TO MARS



Once it enters Mars' atmosphere and reaches the surface after a six-and-a-half-month journey, the InSight mission will be able to count on the aid of two nanosatellites to relay the good news back to Earth. Dubbed MarCO (Mars Cube One), at 37.6 x 24 x 12 centimetres these satellites are no bigger than a shoebox—tiny for an interplanetary mission. If the experiment proves conclusive, this first use of nanosatellites for this kind of mission will open up new and interesting prospects.

WEB DOC

Why are we looking for life on Mars?

EXOMARS 2020

CONCLUSIVE FIRST TEST

As part of preparations for ExoMars, ESA began tests at the end of October last year to put its Mars rover demonstrator through its paces at the Toulouse Space Centre's SEROM[1] proving ground. Covering an area of 4,000 sq.m. laid with volcanic gravel, this very representative replica of driving conditions on Mars features many obstacles of various sizes, making it possible to create a wide range of environments. This first series of tests simulated initial operations on the surface of Mars, to determine on which side the rover should roll off using images from its camera to gauge the slope of the terrain and obstacles in the way. Everything went according to plan for this first 'sortie' of ESA's ExoMars team at SEROM. Technologies still in development, like an unmanned aerial system to simulate satellite imaging, were even used for the occasion, showcasing the full palette of services that CNES's robotics team is able to offer its partners. More tests are underway and planned in the months ahead.

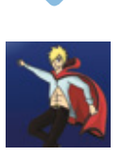
1. Site d'Essais des RObots Mobiles

#COMMUNITY

Every day, CNES engages with you on social networks and you share your thoughts and questions with us. Join the conversation!

@ EN DIRECT DU LABO
Pour la semaine du 6 juin, @_adam_amara_, Doctorant en biologie synthétique et systémique, au Manchester Institute of Biotechnology

The sequences for #SAM have been delivered to @MarsCuriosity. The #FIMOC team at @CNES is overjoyed ;)



@ VAMOS
Fan de @Unsterbliicher et @WankilStudio | Cumberbiatch | Pro-player sur Mario Kart | GLaDOS la patate | #TeamIronMan | Star Trek | Streamer à ses heures perdues

Today a CNES engineer did a talk in our school; he's driving Curiosity on Mars and firing holes in rocks with a laser!

@ EMILY LAKDAWALLA
Senior Editor & Planetary Evangelist, The Planetary Society. Planetary scientist, writer, public speaker. Writing a book on Curiosity mission. Asteroid 274860.

I love this Curiosity 2-Mars-year birthday cake made by the @CNES science team :)

@ EN DIRECT DU LABO
Pour la semaine du 6 juin, @_adam_amara_, Doctorant en biologie synthétique et systémique, au Manchester Institute of Biotechnology

With @MarsCuriosity, we've proved Mars was once habitable.

RAV THERADD
17 October 2015, 7:15 pm

We can't afford to miss out on Mars, it's the cornerstone of any space programme. All ambitious programmes are headed there. The more of us go, the more headway we'll make. Humankind aims to set foot on the planet some day, so it's pretty important.

FLORIAN CABOT
17 July 2015, 9 pm

We've come a long way in 50 years with the selfie of Curiosity :) The pace of technological progress is phenomenal!

CNESfrance @CNES YouTube CNES

Q & A

SYLVESTRE MAURICE

A SPECIALIST IN SOLAR SYSTEM EXPLORATION, ASTROPHYSICIST AND PLANETOLOGIST
Sylvestre Maurice oversaw construction of ChemCam, the chemical camera on the Curiosity rover operating on the surface of the red planet since the summer of 2012. For Cnesmag, he casts his eager eye over the human and scientific aspects of the Mars adventure.

VIDEO

Why send humans to Mars?

WHY DO YOU THINK MARS STILL HOLDS SUCH A FASCINATION FOR US?

Sylvestre Maurice: Right now, we're in a golden age for Mars. Two rovers, the venerable Opportunity and the more recent Curiosity, are currently on the surface and five orbiters are circling the planet, making seven spacecraft in all. Two more are set to join them this year for the European ExoMars 2016 mission. So it's quite logical that there's been a series of headline-making discoveries.

AT THE END OF LAST YEAR, NASA ANNOUNCED THE DISCOVERY OF BRINY WATER ON MARS. HOW DOES THIS CHANGE WHAT WE KNOW ABOUT THE PLANET?

S. M.: The brine discovery concerns present-day Mars, whereas most of the time our attention is focused on ancient Mars. More than three billion years ago, Mars had a dense atmosphere and liquid water flowing on its surface. Today, it's an extremely cold and arid planet. However, its atmosphere contains small quantities of water vapour, its soil contains ice, and we can now say that briny water flows intermittently.

YOU OVERSAW CONSTRUCTION OF THE CURIOSITY ROVER'S CHEMCAM CAMERA. WHAT NEW KNOWLEDGE HAVE WE GAINED FROM THE DATA GATHERED SINCE 2012?

S. M.: Curiosity is the first roving robotic geologist. The French scientific community, working with CNES, was fortunate to be involved in building part of the ChemCam and SAM instruments, which have shown with the rest of the rover's payload that Mars was once habitable. We're now striving to find out exactly when and for how long, but this discovery has already changed how we see the cosmos: if we once had two habitable planets out of eight in our solar system among the billions of billions of planets out there orbiting other stars, how many more might be habitable? In May this year Curiosity reached the milestone of two Mars years spent in Gale Crater. ChemCam has fired its power laser more than 337,000 times at more than 1,350 targets, revealing an unexpectedly diverse array of magmatic and sedimentary rocks. Its measurements have shown that some of these rocks are comparable to the Archeozoic formations composing Earth's primitive crust, completely changing our view of Mars' surface. ChemCam has also detected minerals that formed at a later stage through precipitation of phosphates, sulphates, calcium and manganese.

WHAT ARE THE BROAD SCIENCE OBJECTIVES OF THE MARS PROGRAMME?

S. M.: In the 1990s, the mantra of scientific exploration on Mars was to 'follow the water'. With Curiosity, we've reached a new milestone as we seek to characterize physical and chemical properties likely to support life, in other words, habitability. Tomorrow, we're going to start hunting for traces of life. We tried to do this in the 1970s with the Viking probes, without success. Now, we're going back with much better instruments.

THIS YEAR EUROPE IS PURSUING ITS MARS ADVENTURE. WHAT ARE THE CHALLENGES FACING THE MISSIONS AHEAD?

S. M.: This year we're going to enter the first phase of the European ExoMars programme with an entry, descent and landing demonstrator module and a Trace Gas Orbiter (TGO). The second phase will begin in 2020 with an ambitious rover carrying the Pasteur payload to which France is making a big contribution. And in 2018 there will be an absolutely amazing U.S. mission called InSight that is going to sound Mars' beating heart for the first time. A seismometer for which the IPGP global physics institute in Paris is science lead will measure seismic waves propagating through the planet's insides to help us understand its interior structure.

AND LOOKING FURTHER AHEAD...

S. M.: Longer term, the U.S. is planning to return to Mars in 2020 with an enhanced version of Curiosity to look for traces of life. The SuperCam instrument, the successor to ChemCam, is part of the payload on this mission provisionally called Mars 2020. As well as measuring chemical composition it will be probing the planet's mineralogy using Raman[1] and infrared spectrometry. This instrument is already being built in French laboratories attached to the national scientific research centre CNRS and to several

SYLVESTRE MAURICE

ASTROPHYSICIST AND PLANETOLOGIST

"LET'S NOT KID OURSELVES [...], THERE'S NO OTHER PLACE THAN EARTH IN OUR SOLAR SYSTEM WITH A FUTURE FOR HUMANKIND."

universities (IRAP, LESIA, OMP, LAB, LATMOS and IAS) in collaboration with CNES.

HOW WILL MARS 2020 BE AN EXCEPTIONAL MISSION?

S. M.: For 20 years now, the 'holy grail' has been to bring back a piece of Mars for analysis in the lab. Mars 2020 will be the first step towards that. The idea is to find a rock, study it in situ, put it in a little 'rucksack' and later return it to Earth. We don't yet know how to land a rocket on Mars and then lift off again, but space agencies are working on it. So it's up to us to prove the value of going to get samples! Working with other instruments, SuperCam will therefore have the crucial task of selecting these samples and characterizing them. But the other goal underlying our search for traces of life, water and habitability is to put humans on Mars. Each mission from now on must develop an instrument with this goal in mind. Curiosity carried an instrument to measure radiation levels to help us gauge how to protect the crew during the cruise phase; Mars 2020 will be setting up an entire oxygen factory on the surface.

THE PROSPECT OF CREWED MISSIONS TO MARS HAS FIRED THE PUBLIC'S IMAGINATION. WHAT DO YOU THINK? WHAT COULD HUMANKIND GAIN FROM THEM?

S. M.: The world seems to want to extend exploration beyond Earth. This urge translates a need to push back boundaries, to dream. But let's not kid ourselves here, we're not talking about colonizing Mars: there's no other place in our solar system with a future for humankind. We're all adapted to life on Earth and no other planet. We have no choice but to stay here. There is no plan B! So we're going there with rovers as our scouts. Indeed, Curiosity is the first non-human to be made a member of an international association of geologists, and through it some 450 scientists are exploring Mars.

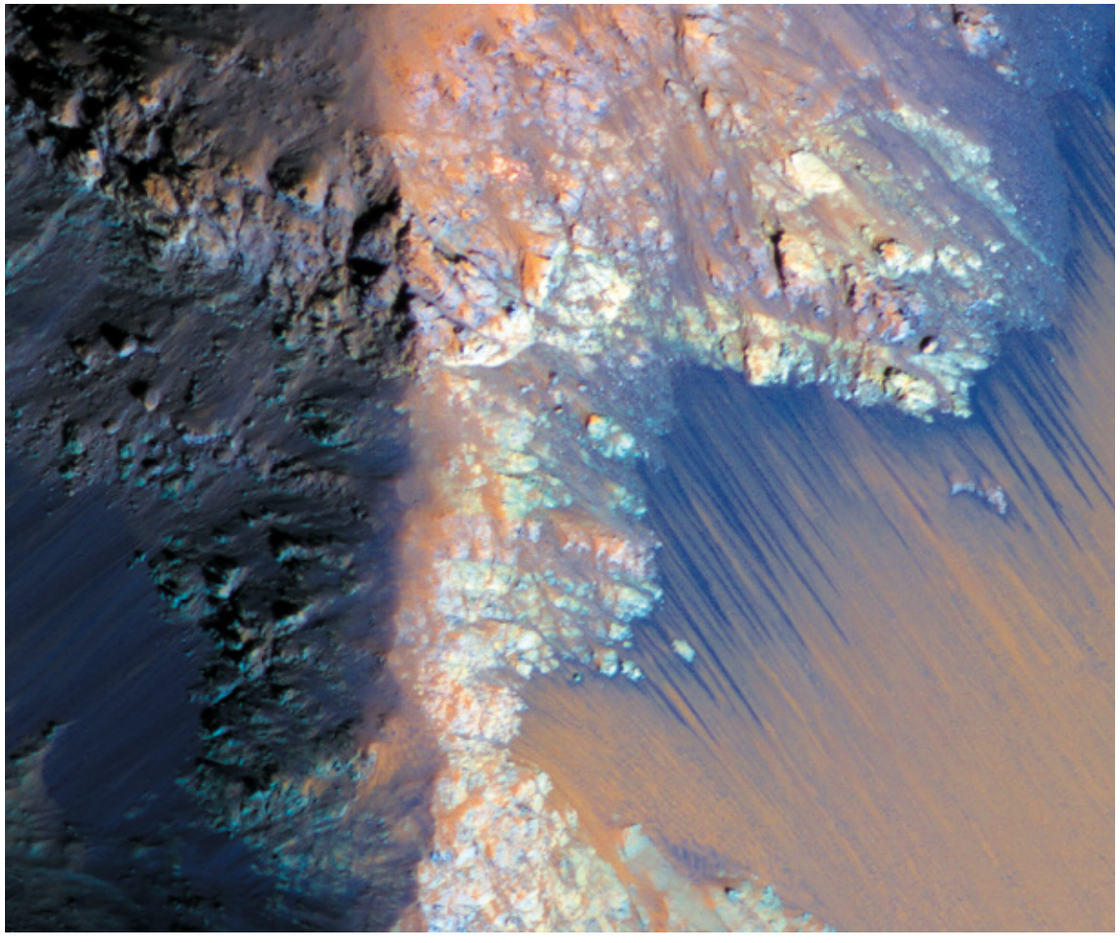
WHAT IS CNES'S ROLE IN THIS CONTEXT?

S. M.: As the agency overseeing the programme, CNES is responsible for delivering our instruments and is providing technical input during their construction. It has experts in components, quality assurance and planetary protection, and top engineers in optics, thermal management, mechanics and so on. It is also conducting operations on Mars with SAM and ChemCam from the French Instruments Mars Operations Centre (FIMOC) at the Toulouse Space Centre. Research scientists and CNES's engineers often work together in joint teams. Many of our international colleagues envy the way we work, including in the United States.

1. Non-destructive method of observing and characterizing materials.

Profile

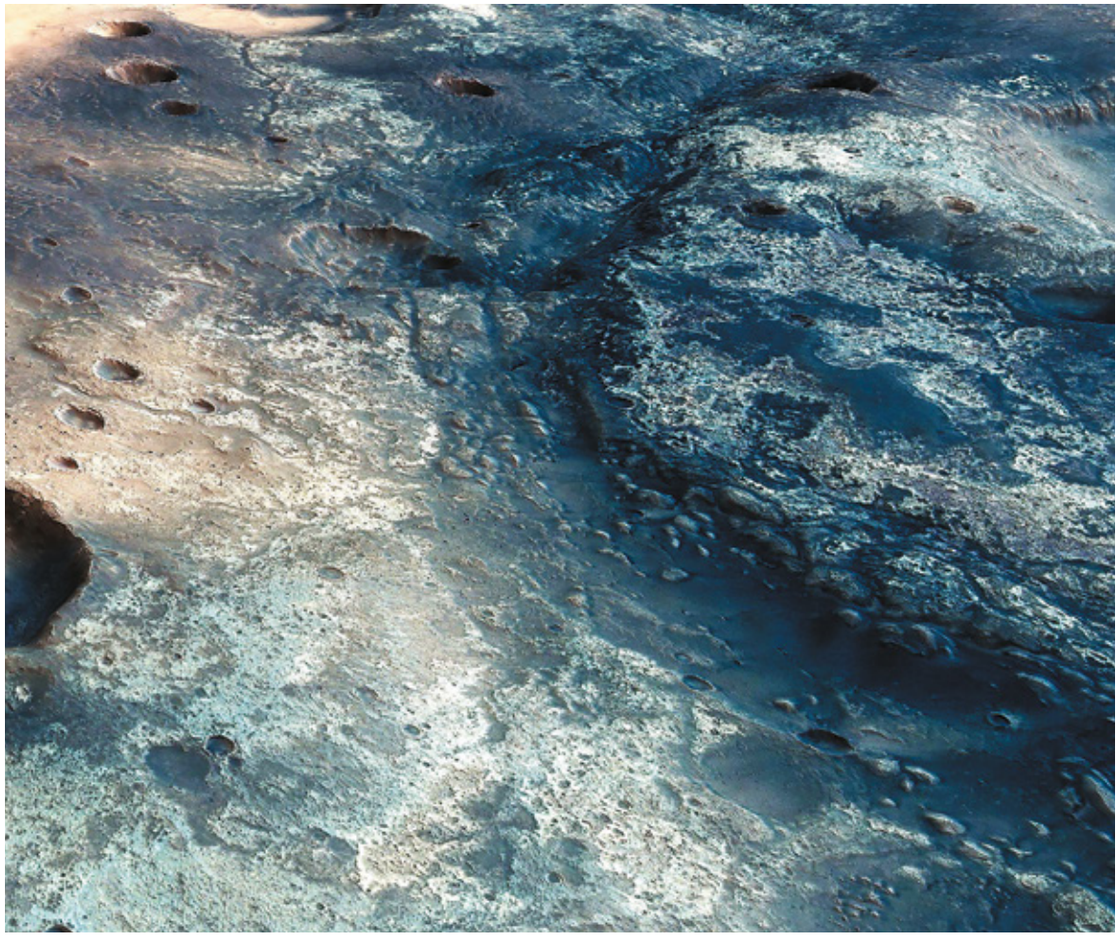
2014
Proposes the SuperCam instrument for the Mars 2020 rover with Roger Wiens from Los Alamos National Laboratory.
2011
Helps to discover water at the poles of Mercury (Messenger mission).
2005
Proposes the ChemCam instrument for the Curiosity rover with Roger Wiens from Los Alamos National Laboratory (United States).
2004
Helps to discover water on Mars (Mars Odyssey mission) and proposes the Raman instrument for the ExoMars mission with Fernando Rull from the University of Valladolid.
1998
Helps to discover water at the Moon's poles (Lunar Prospector mission).



RECENT TRACES OF LIQUID WATER

On the steep slopes of Coprates Chasma, part of the giant Valles Marineris canyon, thin dark streaks appear seasonally as temperatures rise. The high-resolution CRISM spectrometer on the U.S. Mars Reconnaissance Orbiter (MRO) has detected hydrated salts there. These dark streaks were probably formed by very briny liquid water wicking from rocky outcrops and then flowing down the slopes before evaporating. This is because the low atmospheric pressure on the surface of present-day Mars makes it impossible to sustain liquid water.

IN PICTURES



PRECIOUS CLAYS

On both sides of a very ancient and now dry valley, the OMEGA instrument, one of the main French contributions to the European Mars Express mission, detected clays (light-coloured rocks in the image). Clays are sedimentary deposits formed by the slow alteration of volcanic rocks in the presence of liquid water. Sometimes hundreds of metres thick, these strata reveal a process that took place over hundreds of millions of years. If life once existed on Mars, and if it appeared as quickly as it did on Earth, it could have left traces in these layers of clay, each one a chapter in the red planet's history.

6,792 km

The diameter of Mars at its equator, just over half that of Earth's (12,756 km). What's more, the red planet is only 10% as massive as Earth, which explains its weaker gravity (38% of Earth's). Both these features have undoubtedly contributed to the disappearance of Mars' atmosphere, as it escapes more easily into space.

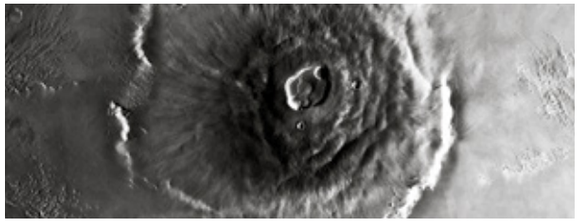
145 million sq.km

THE TOTAL SURFACE AREA OF MARS, 5 million sq.km less than Earth's land surfaces–a sizeable playground for future Martian explorers nevertheless!

44

MISSIONS LAUNCHED TO MARS since the start of space exploration as of end 2015. Of these, less than half have been successful and only seven landers or robots have made it to the planet's surface. These figures are improving, but getting to Mars remains a tough technological challenge.

ELEVATION



28,381 metres is the difference in elevation between Mars' highest (the Olympus Mons volcano) and lowest (the Hellas Planitia crater) points. On Earth, Mount Everest is only 19,759 metres above the Mariana Trench.

173 °C

amplitude. The mean temperature in degrees Celsius on the surface of Mars is −55°C. In fact, it ranges from −153°C at the poles in winter to +20°C at the equator at midday, in summer.

MARS YEAR

It takes the red planet 686.96 Earth days to complete a full revolution of the Sun. This amounts to a little under two Earth years. Because its axis of rotation is inclined 25.2° to the vertical (compared to 23.4° for Earth), Mars also has seasons in each of its hemispheres.

24 hours 39 minutes

AND 35 SECONDS... that's the length of a Mars solar day, about 40 minutes longer than a day here on Earth.

DESTINATION MARS!

MORE THAN 40 MISSIONS HAVE BEEN LAUNCHED TO MARS SINCE THE 1960S. WORKING ALONGSIDE THE FRENCH SCIENTIFIC COMMUNITY, CNES INTENDS TO PLAY AN INCREASING ROLE IN THIS CONTINUING ADVENTURE. THE FIRST MISSION OF THE EXOMARS PROGRAMME, A KEY MILESTONE ON THE ROAD TO THE RED PLANET, WAS LAUNCHED ON 14 MARCH.

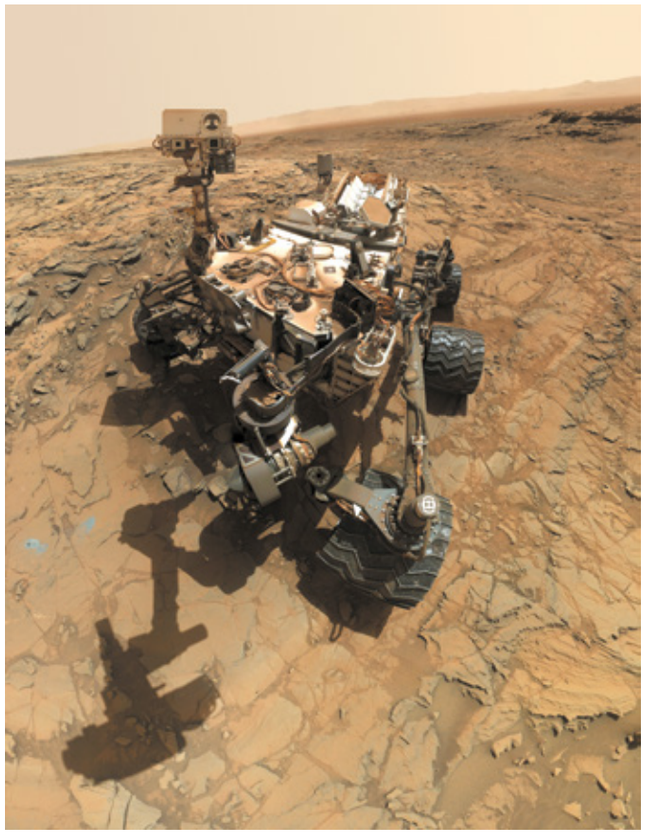
Mars pictured during the Martian summer from less than 10,000 km above its surface by Europe's Mars Express spacecraft. The ice cap (in white) at its south pole consists of water and carbon dioxide ice.

Ideally, the first samples of Martian soil should already have been brought back to Earth in a French spacecraft. Such was the ambition of the Mars Premier mission (for *Programme de Retour d'Echantillons Martiens et Installation d'Expériences en Réseau*). From 1998 to 2002, France nurtured the hope of conducting this mission jointly with the United States. Planned to launch on an Ariane 5, Mars Premier was to rendezvous in Mars orbit with a U.S. spacecraft that would have collected samples from the planet's surface. Once recovered, the sample container was to be returned to Earth inside an atmospheric re-entry capsule. Unfortunately, the cost and complexity of the mission put paid to this great idea, which would have required no fewer than three launches, and the project was wound down in 2002.

26

Months

between two launch windows to Mars, the time it takes for Earth and the red planet to be aligned to reduce the trip time to a minimum.



Selfie of the Curiosity rover on Mars.

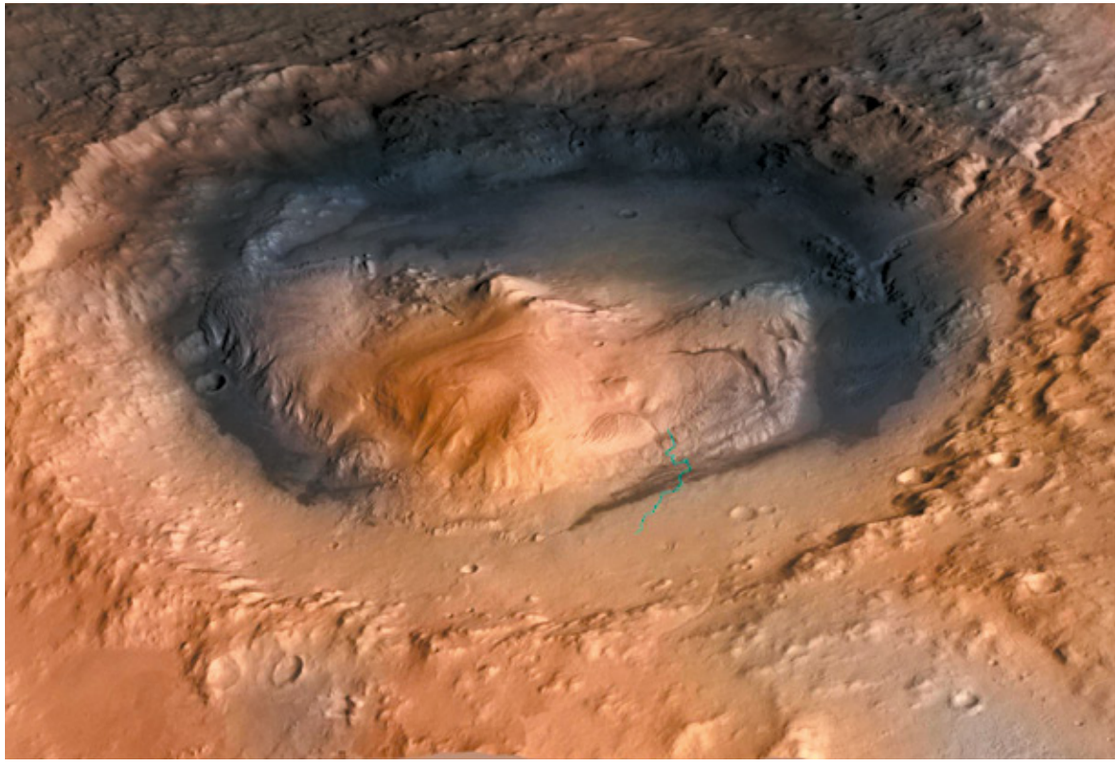
DOWN BUT NOT OUT

But this cruel blow did not mark the end of the Mars adventure for the French space community; far from it, in fact. From 2003 onwards, CNES got back to work supporting its partner research laboratories, building on the lessons that had been learned. "*We invested a lot of time, effort and money in the OMEGA and SPICAM instruments, and the spare models that eventually flew on Mars Express were hugely successful*," recalls Francis Rocard, in charge of CNES's solar system exploration programme. The OPTIMISM seismometer rose from the ashes in the form of SEIS, now the main instrument on the InSight mission. "*When you decide to explore Mars, you know you're in it for the long haul*," adds Fabienne Casoli, Deputy Director of Innovation, Applications and Science. "*CNES has long supported French planetology and robotic exploration of the solar system in partnership with INSU, the national institute for universe sciences at the French scientific research centre CNRS, and with other research bodies. If the French planetary science community is second in the world behind the United States, it's in no small measure down to our agency's efforts.*"

CRUCIAL EXPERTISE

CNES is contributing much more than just funding to this endeavour. It is a key link between research scientists and the space industry, grasping every opportunity to fly French experiments in space. Moreover, in an increasingly competitive context the support it offers scientists gives their projects the best chance of being selected.

CNES IN ACTION



The 154-kilometre wide Gale Crater, the landing site of the Curiosity rover.

"*Most U.S. planetary missions today select their instruments through calls for proposals*," explains Fabienne Casoli. "*So our scientists are competing with tens of others from around the world. CNES therefore has to quickly set up project teams to lend extra credibility to laboratories' and manufacturers' proposals.*"

PERSEVERANCE IS THE KEY

One of the best illustrations of the value of this approach is undoubtedly the Mars Science Laboratory (MSL) mission and its Curiosity rover, which is carrying SAM and ChemCam, two instruments with a strong French contribution, notably the first laser ever to be fired on Mars. Another is SEIS, the main instrument on the future InSight mission, and SuperCam on Mars 2020. "*It's a virtuous circle*," says Fabienne Casoli. "*CNES is driving innovation by nurturing research scientists' ideas and helping industry to build them. This broad expertise helps to make French research more credible in the eyes of our international partners and encourages our scientists to envision ever-more-ambitious projects*," like a Mars sample return mission. If a new opportunity were to present itself, CNES would no doubt be ready once more to step into the breach.

567

Million kilometres

covered between Earth and Mars by Curiosity, 10 times the shortest distance between the two planets. This is because Mars trajectories are elliptical arcs, not straight lines.

[+] MORE INFORMATION: MARS-EXPRESS.CNES.FR

Clay formation in Yellowknife Bay (Curiosity).

The FIMOC team monitors and programs the instruments and retrieves and processes science data for the MSL mission. From left: Eric Lorigny (FIMOC), Samuel Teinturier (LATMOS), Arnaud Buch (ECP).

CURIOSITY
EN ROUTE FOR AEOLIS MONS

The Curiosity rover has been exploring Mars since August 2012 and is pursuing its trek towards Aeolis Mons, the mountain in the middle of Gale Crater. Its instruments have already revealed much about the planet's past.

337,000

Number of firings
by ChemCam's laser since arriving on Mars in August 2012. Each firing lasts no longer than a few nanoseconds.

Rising up 5,500 metres in the centre of Gale Crater, Aeolis Mons is the Curiosity rover's ultimate destination. "*Curiosity should be getting there before next summer*," reckons Francis Rocard, in charge of solar system exploration at CNES. It is in the foothills of this mountain that the most interesting geological strata lie. The thin layers of clay stripped from the surrounding rocks by erosion and transported by the water that once filled this crater might have preserved the traces of primitive lifeforms in the shape of organic molecules, much like the herbaria of our childhood.

MARS' HABITABILITY CONFIRMED

While it is taking longer to reach these clay sediments than planned due to a long sand dune that the driving teams thought best to skirt around, Curiosity has been kept busy in transit. Its ChemCam instrument has remotely revealed the composition of rocks within a radius of seven metres around the rover. Above all, it has also discovered that Mars was indeed once habitable in its ancient past. This confirmation came from an area on the crater floor that has been named Yellowknife Bay. "*Curiosity's drill revealed that in the first centimetre of the subsoil, the colour of the rock changed from red to blue-grey, which is the sign that it was not oxidized. Subsequent analyses by the SAM instrument on the dust extracted showed that this ancient lakebed environment could have been habitable for bacteria*," says Francis Rocard. And what is true now was equally true four billion years ago.

FIMOC WORKING ON U.S. TIME

SAM and ChemCam are operated alternate weeks from the French Instruments Mars Operations Centre (FIMOC) in Toulouse. "*This is the first time Europe has been involved in operating a roving laboratory exploring another planet, and it's happening here in France*," says the FIMOC manager Eric Lorigny proudly. But along with this sense of pride come some big constraints. "*We're living on California time with JPL. When their day starts at 8 in the morning, it's 5 in the afternoon here in France and our 'day' doesn't end until 3 in the morning.*" But the teams' motivation is as strong as ever. "*There's something magic about it*," says Lorigny. "*Even if it's a rover doing the drilling, us French guys are among the first pioneers to dig down into the surface of Mars!*" And with the rover's mission now extended until at least this summer to reach the eagerly awaited clay-bearing layers, the FIMOC's operators will continue to dream while burning the midnight oil.

MORE INFORMATION: MSL-CURIOSITY.CNES.FR

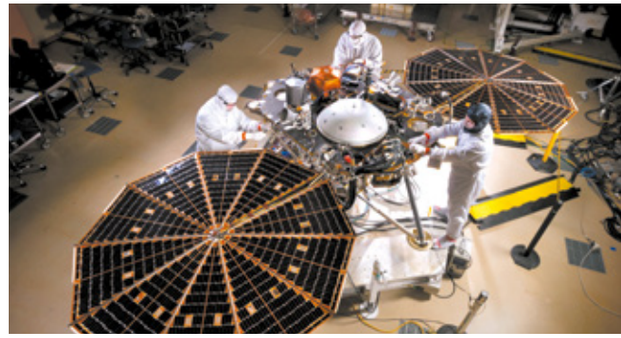
INSIGHT
JOURNEY TO THE CENTRE OF THE RED PLANET

In 2018, the InSight mission will attempt to unlock the secrets of Mars' interior structure in an effort to better understand the formation and evolution of rocky planets like our own Earth.

While the goal of the InSight exploration mission that NASA plans to send to Mars in 2018 is to reveal its inner composition, it also stands to bring new insights into Earth. Determining how Mars' interior structure might have shaped its evolution would tell us a great deal about the future habitability of our own planet.

A REVOLUTIONARY INSTRUMENT

The InSight adventure first took shape back in 2010, when the U.S. space agency issued a call for proposals for a planetology mission



InSight's solar panels undergo testing in a clean room at Lockheed Martin Space Systems, Denver (USA), April 2015.

for its Discovery programme. Scientists immediately saw the opportunity to propose a unique instrument, starting with the French research team at the IPGP global physics institute in Paris who have been working for several years now on the SEIS seismometer (Seismic Experiment for Interior Structures), a revolutionary instrument concept. "*What sets SEIS apart is its extreme sensitivity*," explains Philippe Laudet, the instrument's project leader at CNES. "*It's a bit like a stethoscope that we'll use to listen to Mars' beating heart for at least two years.*" And so it was that NASA selected for one of its future Mars missions a French instrument that is the result of an exemplary partnership between IPGP and CNES.

MEASURING TEMPERATURE EXCHANGES

SEIS, whose ancestor OPTIMISM was already on the Mars 96 mission, is so much more sensitive than terrestrial seismometers for the simple reason that the signals it is designed to detect are much fainter than those on Earth. There is likely very little seismic activity on Mars. Fortunately for us, Mars' tenuous atmosphere lets through most of the celestial voyagers that cross its path every day. SEIS will be capable of detecting how the waves caused by such meteorites hitting the planet's surface propagate, and thus of deducing its interior structure. Another formidable ally in this task will be Phobos, the largest of Mars' two moons. As it approaches to within less than 6,000 kilometres of the surface, Phobos triggers solid tides on Mars likely to cause cracking and creaking that SEIS will be able to measure. Alongside SEIS, the HP3 instrument (Heat Flow and Physical Properties Package) supplied by the German space agency DLR will penetrate five metres down to determine temperature exchanges between the surface and subsurface. The InSight mission therefore expects to yield precious data for the study of Mars' geophysical characteristics.

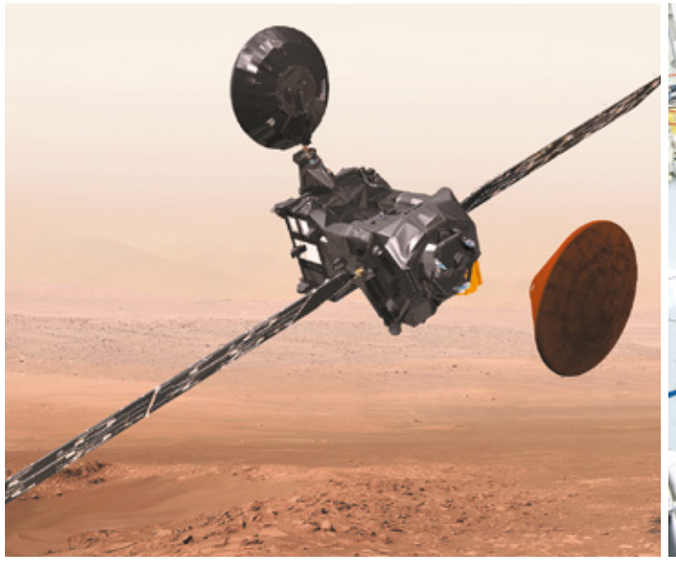
MORE INFORMATION: INSIGHT.CNES.FR

EXOMARS
EUROPE GOES IN SEARCH OF LIFE ON MARS

Did the red planet once harbour life? This is the fundamental question the 2016 and 2020 missions of the European-Russian ExoMars programme seeks to answer. They will also give Europe the opportunity to demonstrate its ability to operate on the surface of Mars.

Exploring Mars is a long trek on which each step is a little more than two years apart, the time between launch windows as a result of the red planet's rotation. For ExoMars, the first step came in March with the launch of a Russian Proton rocket from Baikonur, which inserted a duo composed of the Trace Gas Orbiter (TGO) spacecraft and the Schiaparelli lander into a Mars trajectory. While TGO will circle the planet to study its atmosphere, Schiaparelli is first and foremost a demonstrator. "*Schiaparelli will serve as a testbed for technologies to be developed for a Mars landing*," says Michel Viso, in charge of exobiology programmes at CNES.

Artist's impression of the ExoMars 2020 rover.



Left: the ExoMars 2016 mission's Trace Gas Orbiter (TGO) and Schiaparelli lander / Right: the Schiaparelli lander being mounted on the orbiter at Thales Alenia Space in Cannes.

SIGNS OF LIFE

The second phase of the mission, ExoMars 2020, will build on the lessons learned from ExoMars 2016 to go one step further and land a rover with a payload, Pasteur, designed to hunt for signs of life. "*Pasteur will look for complex organic molecules that could be the signatures of past life*," explains Michel Viso. Life as we know it transforms simple elements like amino acids into more complex protein molecules. As such proteins are destroyed by the extremely hostile conditions on the surface of Mars, the ExoMars 2020 rover will be equipped with a drill able to extract samples below the surface. These samples will then be analysed by the Pasteur instrument suite and results relayed to Earth by the TGO spacecraft.

1,500

Degrees Celsius

is the temperature Schiaparelli's heatshield will have to withstand as it flies through Mars' atmosphere.

FRENCH TECHNOLOGY AND RESEARCH

French industry is closely involved in ExoMars. Thales Alenia Space's Cannes facility in southern France is supplying elements of the TGO spacecraft, among other things, while the Aquitaine branch of Airbus Defence & Space in southwest France is applying its unique know-how in Europe to make thermal protection. On ExoMars 2020, France will be the science lead on two scientific instruments: MicrOmega, a visible and infrared camera, and WISDOM, a radar designed to analyse the structure of the subsoil. Three other instruments, MOMA, RLS and CLUPI, are also being built with French involvement. As well as funding the French contribution, CNES is working with ESA on the atmospheric entry study for Schiaparelli and supplying navigation software for the ExoMars 2020 rover.

MORE INFORMATION: EXOMARS.CNES.FR

SUPERCAM **FOR MARS** 2020

In the summer of 2020, NASA will launch its own mission designed to look for traces of life on Mars—a mission that will pave the way for returning samples at a future date.

After the landing of its Mars Science Laboratory (MSL) in August 2012, NASA announced it would be launching a similar mission in 2020. But where MSL was focused on searching for signs of habitability, this new mission would look for signatures of life. CNES and its partners at the national scientific research centre CNRS and in academia will supply a key element of the mission, the mast unit for SuperCam, for which France is science and engineering co-lead. SuperCam is an enhanced version of ChemCam that will have the same goal of remotely detecting the composition of rocks and soil using its infrared laser, but it will also have other strings to its bow: Raman and infrared spectrometers that will analyse emissions from rocks stimulated by a green laser or the sunlight reflected from them. Both spectrometers are designed to help scientists probe their mineral composition and ascertain how atoms are bound together to form molecules, which might indicate the presence of organic chemistry. SuperCam will also have a very-high-definition colour camera capable of determining the texture and context of analysed targets. Once it has located areas likely to contain organic material, the rover will approach them and collect samples with its caching system. The decision to return samples to Earth for close analysis will be taken later on the strength of their quality and available funding. The instrument is in construction for delivery to Los Alamos National Laboratory (LANL) in 2018 and integration with the U.S. spectrometers, after which it will be mounted on the rover at the Jet Propulsion Laboratory (JPL).

MORE INFORMATION: SUPERCAM.CNES.FR

AN ULTRA-SECURE CANISTER

RETURNING SAMPLES FROM MARS IS NO LONGER PURELY THE REALM OF SCIENCE-FICTION. Plans being laid are making every effort to address the biological hazards they could pose. To avert all risks of contaminating Earth's biosphere, they will need to be transported securely for analysis in the lab. CNES has patented an ultra-secure transport method for samples, which will be stored inside pure silicon capillary tubes with ultra-thin walls (10 µm). These tubes will then be enclosed inside three sealed canisters with windows, nested like Russian dolls. Samples will be analysed safely in the lab through the canister windows, using X-ray, Raman and infrared techniques. This P4-class high-security mini-laboratory could also be used to transport and analyse toxic products.

WHAT'S AHEAD

PROPULSION

GETTING THERE... AND BACK

Propulsion is the key to getting to Mars: the shorter the journey, the lower the risk to the crew's health from solar and galactic radiation. While traditional launchers like Ariane will be needed to loft the large masses required for a crewed mission into space, the voyage from Earth orbit to Mars orbit would gain from using plasma thrusters that could cut the trip time from six months to six weeks. But such thrusters, which would have to take a mini nuclear power station with them into space, are still only at the small-scale prototype stage and not yet flight-proven.

LANDING

LANDING SAFELY

Mars has enough of an atmosphere for it to be a factor in landing, but not to effectively slow a spacecraft with a heatshield and parachute. Airbag systems of the kind used to land the 500-kg Spirit and Opportunity rovers are no longer adequate for masses approaching one tonne, like Curiosity. A controlled descent using retrorockets would demand a lot of fuel and therefore extra mass. Another solution could be to shuttle the crew down in a small reusable ascent vehicle and to ferry equipment, able to withstand more-sudden decelerations, with simpler systems.

HUMAN EXPLORATION OF MARS IS SET TO BE THE GREAT SPACE ADVENTURE OF THE 21ST CENTURY. BUT IT WON'T BE EASY. CNESMAG LOOKS AT THE MAIN CHALLENGES STILL AHEAD BEFORE MAKING THIS GIANT LEAP.

SURVIVAL

LIVING OFF THE LAND

The first explorers to set foot on Mars will need to subsist partly by making the best use of the planet's resources. While obtaining water from the frozen subsurface would appear possible, oxygen will also have to be produced either by extracting it from water by electrolysis or from carbon dioxide in the atmosphere. Fuel like methane will also have to be produced in situ for the ascent vehicle's engines. Growing vegetables like in The Martian will also be possible, only hydroponically[1] and not in contact with the soil, which is saturated with toxic perchlorates that would be very hard to remove.

1. With their roots suspended in a nutrient solution.

ENDURANCE

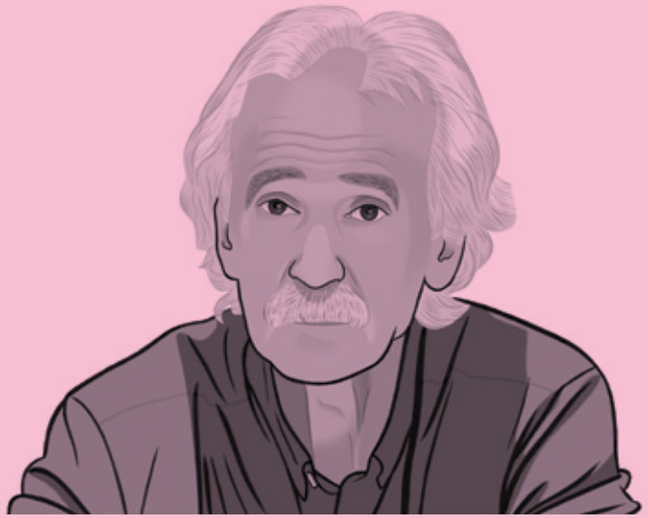
STAYING HEALTHY IN BODY AND MIND

The main dangers on the trip will come from the effects of microgravity—leading to bone loss and cardiovascular deconditioning—and potentially carcinogenic cosmic and solar radiation. Psychological aspects will also be a prime factor during the voyage, as without visual cues the crew will have the impression they're not moving. They will also be confined inside a small space and will not, due to the limited speed of electromagnetic waves, be able to communicate live with their loved ones back on Earth.

JEAN-PIERRE BIBRING

Astrophysicist at the IAS space astrophysics institute in Paris and Lead Scientist (France) for the Philae lander.

"Our generation is forging the era of Mars exploration..."



If Jean-Pierre Bibring had lived in the 16th century, he might have shared the same fate as Giordano Bruno, burned at the stake for heresy. Those days and the simplistic view of a *"unique Earth at the centre of everything"* are of course long gone. ***"How we understand Earth, space and time is continually evolving,"* says Bibring. And space technologies are key to that process.** In 2004, when he discovered clay on Mars, it was with the help of Europe's Mars Express mission and OMEGA spectrometer. That major finding showed that *"liquid water was present and stable on early Mars for long enough to create the same conditions that allowed life to emerge on Earth. Sites have been identified where the record of those conditions is still preserved.* ***The question is: When and how did Mars start to evolve differently from Earth? Mars holds the key."***

But this is just the start of the story. While water is the first requirement for life, the second is carbon. *"Comets aren't just made of ice, they also contain carbon grains, which may have played a key role,"* says Bibring. *"Philae has identified them, but hasn't fully characterized them yet."* As Lead Scientist for Philae, he notes that *"Mars and Rosetta are important milestones in our understanding of the solar system"*. But the scope of his investigations is taking him even further afield. *"The diversity of the solar system is reflected in the wider galaxy, where numerous other systems are being discovered, which are similar in some ways and very different in others."* **Passionate about this ongoing quest, he also has high praise for French public research.** *"France is noted for its space laboratories, which are prolific in their work, underpinning a unique partnership with CNES and the best in the space industry,"* he concludes—a way to explore space while keeping our feet firmly on the ground.

FRANCIS ROCARD

InSight programme manager at CNES.

"With the InSight project, we're opening a whole new chapter in our knowledge of Mars' interior."

For Francis Rocard, Mars is much more than just a red planet—it's the central thread running through his career. In 1988, he studied the mineral composition of Mars' surface as a young astrophysicist at the French scientific research centre CNRS, working with the Soviet PHOBOS 88 mission. On joining CNES in 1989, he broadened his research to the entire solar system. But he has always kept Mars in his sights, even writing and contributing to books on the subject[1]. *"For two decades now, Mars has been the subject of constant research, aided by advances in space technologies, which have had a fundamental impact on the work of planetologists,"* he says. Some Mars missions have been more successful than others, but Francis Rocard is upbeat: *"In space, you've got to be optimistic, even though progress isn't always as fast as we'd like..."*

With the InSight project, for which he has planning responsibility, he believes we're entering a *"fascinating new phase"*. What interests him most isn't the long-standing search for life on Mars. *"InSight is exciting because we'll be studying the planet's interior and looking for evidence of marsquakes, meteorite impacts and subsurface waves caused by tidal activity,"* he adds. *"We'll also be studying the origins of the Martian dichotomy between the northern and southern hemispheres and finding out whether Mars is a geologically dead planet."* The SEIS seismometer developed by CNES will be playing a key role in these investigations. *"We worked with the IPGP global physics institute in Paris to build the best space-rated seismometer in the world, confirmed by its selection for the NASA mission."* He concludes: ***"CNES is part of a U.S.-European consortium. In a project like this, coordination is a key factor and everything must run like clockwork."*** Achieving that may be a challenge, but the best is yet to come as InSight unlocks a little more of the Universe's mysteries.

1. *Planète rouge : dernières nouvelles de Mars (published by Dunod). He also contributed to Mars, une exploration photographique (Xavier Barral)*

HORIZONS

PHILIPPE LOGNONNÉ

Planetologist at the IPGP global physics institute in Paris and lecturer at Paris-Diderot University.

"Space research combines exact and experimental science."

Philippe Lognonné, Principal Investigator for the SEIS instrument on NASA's InSight mission, has followed a somewhat **unconventional career path that has made him cautious, but not sceptical.** In 1989, after completing his PhD at the IPGP institute, he worked on the OPTIMISM seismology experiment for the Russian Mars 94 mission. The institute was particularly interested in the deployment of two seismic stations on the red planet: *"Space wasn't a familiar field for the institute, but they trusted me,"* he says. The failure of the Russian mission in 1996 didn't dampen his enthusiasm. *"The value of space technologies for investigating the geophysics of new planets remained intact,"* he says. *"The launch was nominal, but at 4 a.m. the dream was dashed!"* **Lognonné has since contributed to ten Mars projects that were either deselected or cancelled, including NetLander with CNES and NASA, then Humbold, a project to carry a geophysical station on ESA's future ExoMars 2020 mission,** and now InSight, for which the chief objective is to deploy this much-awaited geophysical station, which has also been pushed back. But the planetologist sees the glass half full: *"A Mars mission is no mean feat, involving a lot of people, so you have to keep your contribution in perspective,"* he adds. *"Plus, as a lecturer-researcher, I have the satisfaction of sharing my dreams of exploration with my students."* **With InSight, Lognonné is confidently pursuing an "*extraordinary human adventure*".** *"The collaboration with the Jet Propulsion Laboratory (IPL) and all the partnerships have gone very smoothly, driven by a shared determination to succeed."* 25 years after his first steps toward Mars, he remains confident: *"Projects are often selected on the basis of what we know or can extrapolate,"* he concludes. *"InSight is uniquely exciting because it's focusing on the unexpected—what we've never seen before or even imagined!"*

Jacques Arnould, science historian and theologian, CNES ethics officer.

ETHICS CORNER

JACQUES **ARNOULD**

RED UTOPIA

Earth's near neighbour Mars has always fascinated humans, inspiring our imaginations and our dreams of another reality. This worthy pursuit must nonetheless be guided by reason.

Mars isn't Venus, yet its red-tinted mirror reflects many of our dreams and nightmares, our hopes and fears. We shouldn't try to hide these, least of all ignore them. On the contrary, we must give full expression to them in our sci-fi novels and movies, in the sober status reports of our science programmes and our madcap proposals for interplanetary travel. And we must keep reason as our guide.

Such was the endeavour of Thomas More when he coined the term 'utopia' in the title of a book published in 1516. The word has a dual etymology: 'eu-topos', meaning 'good place', and 'ou-topos', or 'nowhere'. The red planet is clearly, as far as we know, neither of these: scientists today have described the Martian landscape and its extreme conditions in great detail. But More was hardly concerned with the natural conditions of his fictional island. Only the human society he created there held his attention, with its fear of want and its collective economy. A way for More to critique the English society in which he lived, with its rampant individualism. In light of our achievements and Martian dreams, would we dare do likewise? Are we ready to admit the ambiguities, paradoxes and contradictions they conceal?

REASON, A NECESSARY PRECAUTION

What should we make of these colonization plans, which defy our current technological capabilities or anything likely in the near future, to give humanity the promise of a back-up planet? Do they not overlook the research undertaken on Mars to better understand its physical and chemical composition and search for evidence of life past or present? Do they not overlook the due caution with which scientists dispatch probes to Mars, drive them on the surface and, maybe one day, will bring back samples to Earth? Would it not be better to learn more about our red neighbour before plotting to conquer, colonize and escape to it?

All exploration betrays an element of utopia: humans have always dreamed of other realities, before venturing beyond the known world to confront the unknown. Such endeavours are never innocent, whether they end in colonization or a homecoming, "seasoned in the ways of men". What if we took the time to discover Mars and, through its inevitable and vital utopias, rediscover our own humanity?

EXHIBITION

ONE DREAM, MANY EXPLOITS

Since the dawn of time, people have dreamt of venturing into space in search of other planets. With L'espace, quelle histoire ! (Space, what a story!), learn about the ideas that inspired our ancestors and the major firsts of space exploration in their historical context. Anecdotes, artefacts, unlikely spacecraft and more—journey back 50 years at the Cité de l'espace in Toulouse and relive the excitement of this epic adventure.

CALCULATIONS

Pinning down North on Mars

As unlikely as it may seem, we still haven't found the geographic North on Mars. Despite scientists' best efforts, it has so far proved elusive. They are now turning to the gnomon, an instrument first used by the Babylonians in 2000 B.C. Mounted on top of the SEIS seismometer, a gnomon will cast a shadow like on a sundial that will move according to the time of day and the seismometer's geographic position on the surface of the red planet. *"We'll have three days to precisely determine the position of Mars' north pole,"* says Denis Savoie, in charge of science outreach for the Palais de la Découverte at the Cité des Sciences et de l'Industrie. He has already set aside three days in his diary in 2018 to perform his calculations.

BOOKS

#Solar system– *How did our solar system form? Are the orbits of planets the result of cosmic billiards? A book co-written by two CNES authors, astrophysicist Francis Rocard and planetologist Florence Chiavassa.*

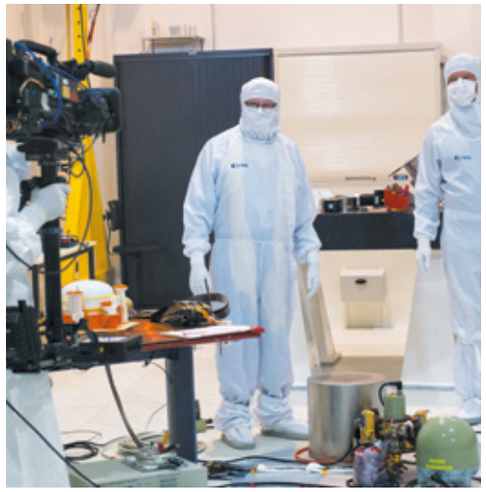
Quelle est la véritable histoire du système solaire ? By Francis Rocard and Florence Chiavassa, published by Le Pommier, 2014, 128 pages, €7.90

#Fiction – *At the very end of the 19th century, Marcel Moye, a member of France's science academy, wrote a fictional and visionary work. Jean-Michel Faidit has reworked this text as a contribution to the history of astronomy.*

À travers l'espace – Destination Mars, Marcel Moye, new preface by Jean-Michel Faidit, published by Les Presses du Midi, 2015, 213 pages, €19

TELEVISION

PHILAE **UPDATE**



France 3's *Carnets de Vol* TV series about air and space took a close interest in Philae's epic adventure in 2014. A year later, France 3 was back at CNES for an update. *"We wanted to give viewers the latest on Philae,"* says editor-in-chief Nicolas Albrand. Aired on 10 January, the show reported on the InSight mission and Curiosity, reflecting the Toulouse region's valuable role as an aerospace hub, and looked back at the Mars 500 confinement experiment. As well as Mars, the show included a slot on stratospheric balloons, their specific capabilities and applications—an area where CNES has unique expertise.

✚ WATCH THE SHOW ON THE FRANCE 3 WEBSITE: **HTTP://FRANCE3-REGIONS.FRANCETVINFO.FR/MIDI-PYRENEES/EMISSIONS/CARNETS-DE-VOL/FOCUS-SUR-LA-PLANETE-MARS-CE-DIMANCHE-10H45-DANS-CARNETS-DE-VOL.HTML**

PHOTOBOOK

RED PLANET IN BLACK AND WHITE

Valles Marineris, Arcadia Planitia and Elysium Mons are just three of the regions viewed by the U.S. Mars Reconnaissance Orbiter (MRO), launched in 2005 to study the planet's surface. From the thousands of images acquired at unprecedented resolution, Xavier Barral has selected 200 black-and-white photographs. Since the 1960s, numerous probes have returned images of Mars. Then in 2006, observations by MRO's HiRISE camera changed how we see the planet, revealing an unimaginable landscape with a level of detail never seen before. As Francis Rocard says in the book: *"Mars stands with Earth as the planet with the richest and most varied history."* To best appreciate the geological and mineralogical features of this mythical planet, the book maintains a uniform vantage point: each photograph covers an area 6 kilometres (3.7 miles) across, showing fields of black sand dunes, craters covered in volcanic dust, abyssal canyons and collapsed poles. An awe-inspiring 'visual atlas' of Mars.

Mars – Une exploration photographique, by Francis Rocard, Alfred S. McEwen, Xavier Barral – 2013 – Published by Xavier Barral – 272 pages – €79.

Planetary event

CALENDAR

4 JULY 2016
Juno goes into orbit around Jupiter

8 SEPTEMBER 2016
Launch of OSIRIS-REx mission

30 SEPTEMBER 2016
End of Rosetta mission, live from the Cité de l'espace

19 OCTOBER 2016
ExoMars 2016: arrival of Trace Gas Orbiter (TGO) and landing of Schiaparelli

OCTOBER 2016
Curiosity begins second extended mission

4 NOVEMBER 2016
ExoMars 2016: start of TGO aerobraking phase

END 2016
End of Mars Express extended mission

APRIL 2017
Cassini passes inside Saturn's rings

JUNE 2017
Delivery of flight model of SEIS for InSight

15 SEPTEMBER 2017
Cassini to burn up in Saturn's atmosphere

OCTOBER 2017
Juno to burn up in Jupiter's atmosphere

CHEMCAM

PROMISE OF APPLICATIONS CLOSER TO HOME

ChemCam's laser 'eye' has been performing miracles on Mars. Hailed for its robustness, it was designed and built by a joint team at CNES and the IRAP astrophysics and planetology research institute. A version of the instrument designed for an industrial application here on Earth could soon see the light of day.

metres
The sample targeting range of ChemCam's laser on Mars.

"*The compactness, robustness and low power consumption of the ChemCam laser-induced breakdown spectroscopy (LIBS) instrument pushed us to be innovative and clever,*" recounts Muriel Saccoccio, development project leader. And the solutions her team conceived could find applications in other fields. 'Terrestrial' replicas of ChemCam already exist, operating at low or room temperature, but the main obstacle to using the current model for an industrial application is its high cost. The space-rated version has to withstand severe vibration and radiation, and make do with the low amount of available power. However, a concept offering similar performance at an affordable cost could be tailored to operate in a less hostile environment. Such a spinoff is likely to spark interest in many sectors involving soil and rock investigation, like geology, precious mineralogy, mining, and oil and gas exploration. "*Users could conduct quick analyses without having to touch or prepare samples, and possibly without even having to retrieve them. They would thus save time and money with a genuine proximity laboratory,*" says Saccoccio. And with evolutions in unmanned aerial systems, an instrument like ChemCam could even be mounted on a vehicle "*for remotely controlled or autonomous exploration,*" she adds. "*That would be a great advantage in remote or hazardous areas.*" CNES has already filed two patents and discussions underway hold out the prospect of at least an industrial prototype being developed.