DESTINATION
MARS

GUIDEBOOK N°3

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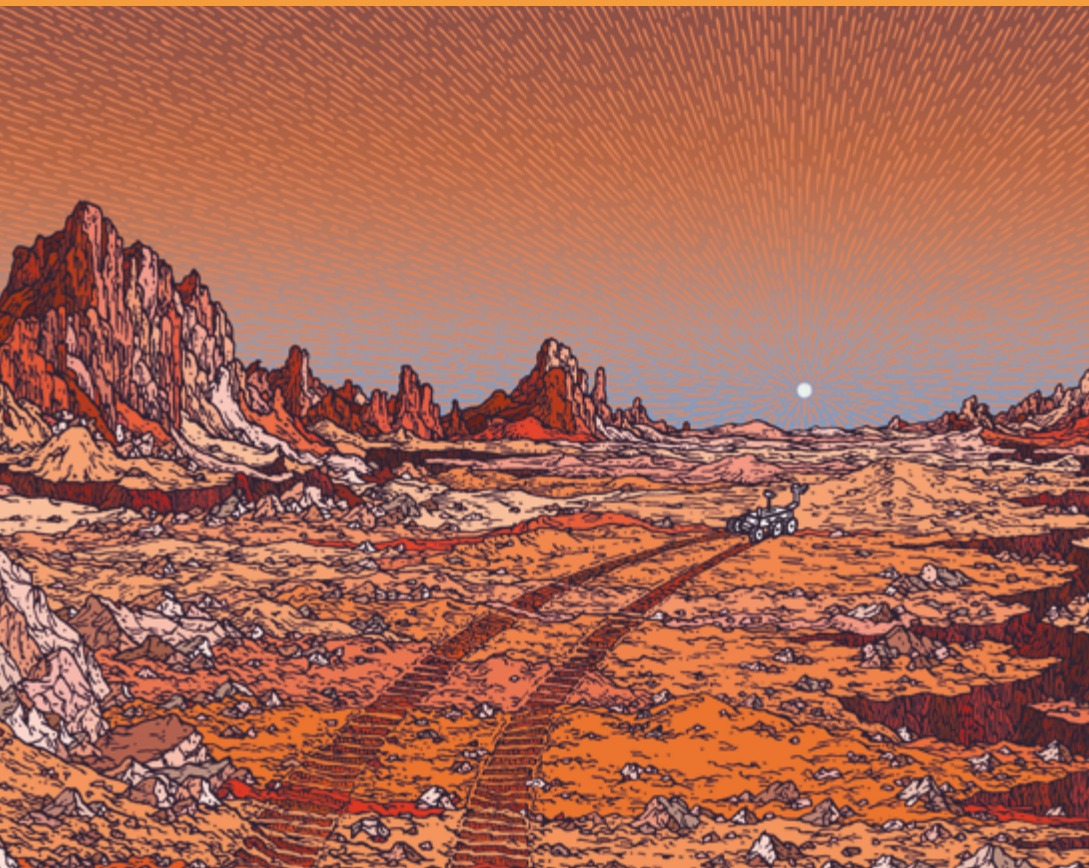

“Somewhere, something
incredible is waiting
to be known.”

Carl Sagan, astronomer

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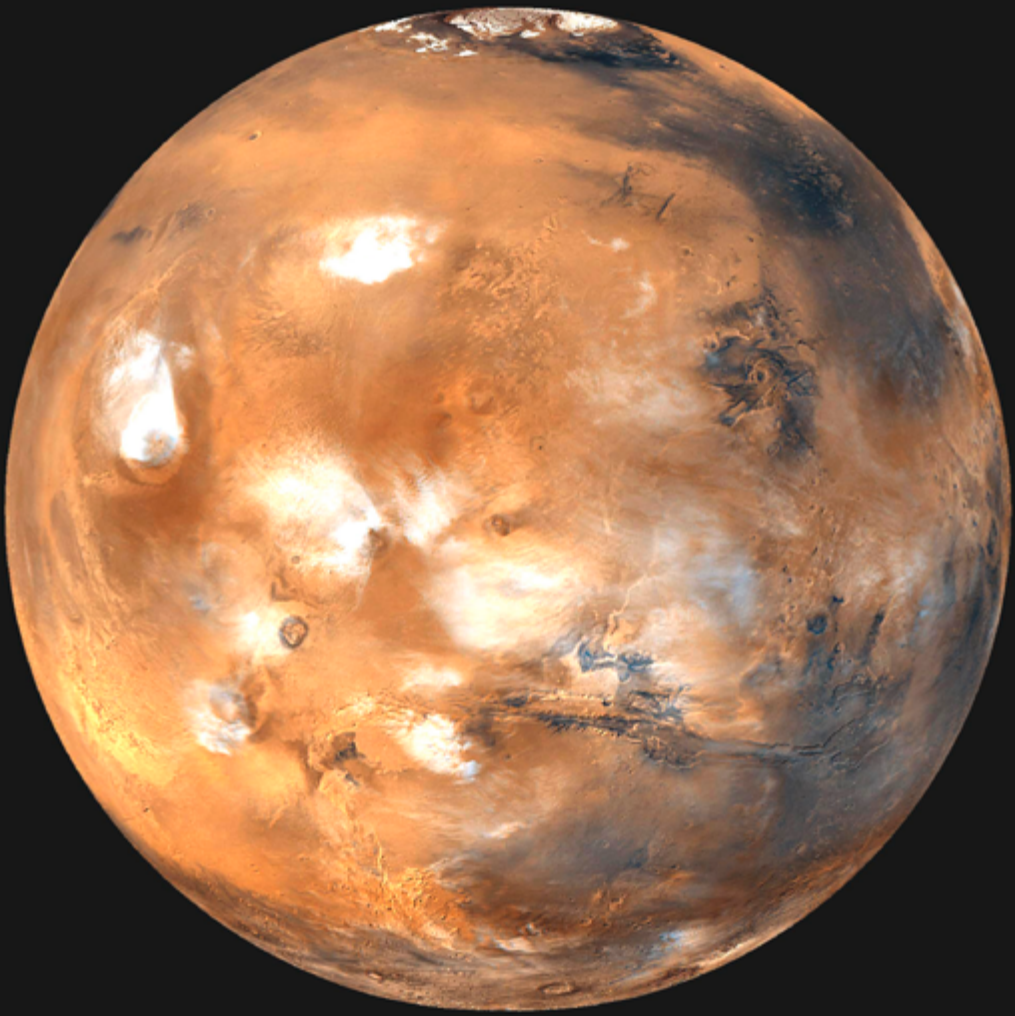


BEFORE YOU GO

Once no more than a faint orange dot in the sky, in the space of less than a century Mars has become a keen focus of study. Its ancient river beds, outflow channels and giant volcanoes appeal to the explorer in us. It's easy to imagine it as Earth's twin billions of years ago. Feeling adventurous? If so, we invite you on a voyage of discovery to mighty and majestic places that may once have harboured life... and where we dream of one day setting foot.

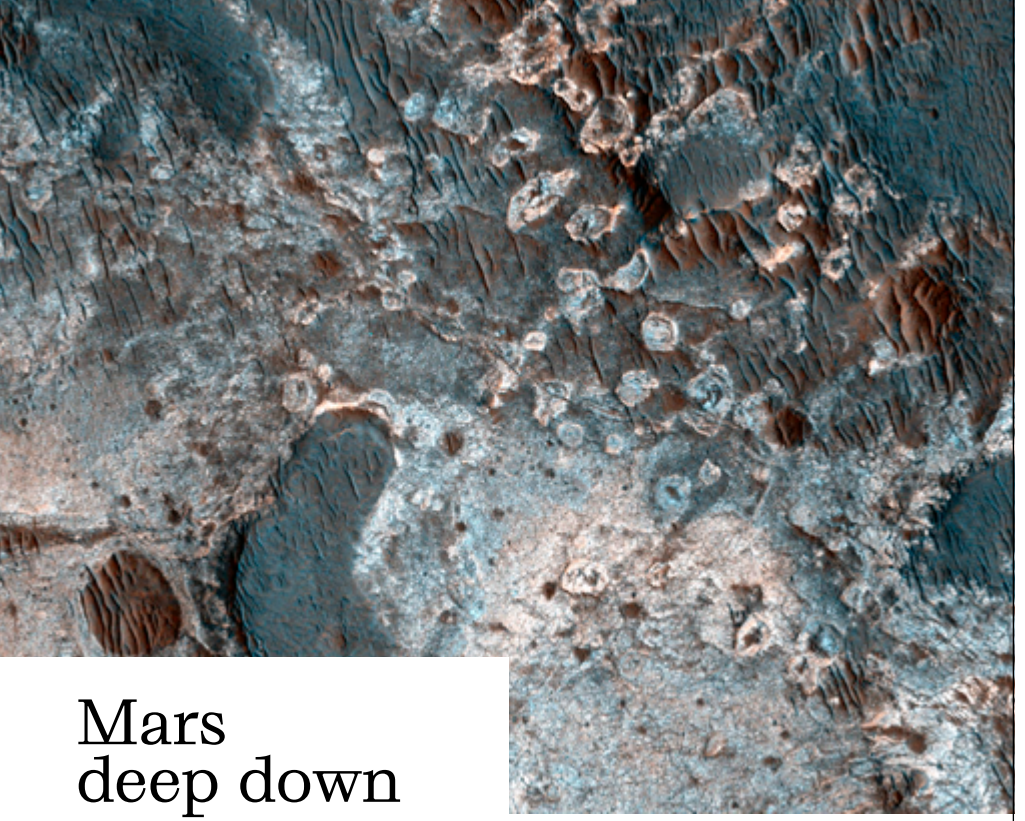
SNEAK PEEK

See a golden flash pierce the thin layer of cloud, and then a huge parachute plummeting towards the surface. All is quiet in the wide crater that was a broad marshy river delta several billions of years ago. The cloud of dust clears and our rover is ready to go... Another mission has made it to Mars. Now standing on the frozen clay soil, the rover is poised to unlock the secrets of the fourth planet from our Sun and our nearest neighbour after Venus. Capturing new pictures of the planet's geology, sounding its atmosphere and probing the surface to reveal its past, the rover will collect a wealth of precious data for transmission to our teams here on Earth, millions of kilometres away. Watch the rover as it traverses the red planet with its suite of instruments developed by decades of research, seeking to unveil parts of the solar system's history, preserved in the soil. With the rover, we are working tirelessly to bring back a tiny piece of Mars—a crucial step before one day taking humans to cross its frigid deserts.

Photo: Mars viewed by Mars Global Surveyor

WHAT YOU NEED TO KNOW

We have sent more missions to study these red sandy soils than to any other planet. For the rocks and layers you see hold the secrets of the past billions of years... Will you hear them? Key clues could be hiding in the slightest detail!



Mars deep down

STAR TURN

Taking the pulse of Mars

22 May 2019, the ground begins to tremble in the Cerberus Fossae fault system. From its station 1,600 kilometres away, the French SEIS precision seismometer on the InSight mission detects the weak but clear 'quake', the first ever seismic signal identified on Mars! Another step towards better understanding its interior structure and core, and ultimately how it formed.

The breezes that blow across the vast plains of Mars are so slight they barely trouble our most precise instruments. Have you listened to them? Over the last 40 years, we have mapped canyons and dreamed before blue-tinged sunsets. But our challenge at CNES is to find out how the past four billion years have made Mars the red planet it is today. The Mars Global Surveyor mission has revealed erosion; Mars Odyssey has detected signs of water and hydrogen; and Mars Express has helped us to understand its geology and how its clay deposits formed. Can you imagine that in calmer times a river once flowed here? And that a lake and oceans once stood over there? It's to study this ancient past that today we are sending rovers to scout the desert and analyse its rocky outcrops.

Photo: Clay signatures south of Coprates Chasma viewed by MRO.

STAR TURN

Rover in the driving seat

As it traverses the terrain of Oxia Planum for the ExoMars mission in 2023, Europe's Rosalind Franklin rover will be capable not only of drilling and analysing, but also of planning its next drive. Our algorithms will enable it to safely chart its course all alone without the intervention of teams here on Earth. Full steam ahead!

Was Mars once habitable?

Now look at the rows of tiny black dots on the ground, the impacts generated by the ChemCam instrument's laser. A few hours ago, our teams commanded the Curiosity rover to power up the laser and fire it at a rock to analyse its composition. Each day holds a new challenge for these small roving or stationary laboratories as they take pictures, analyse, drill, record temperatures and measure the atmosphere.

Soon, our European Rosalind Franklin rover on the ExoMars mission with Russia will drill down to more than two metres in search of molecules that might have been preserved from cosmic rays.

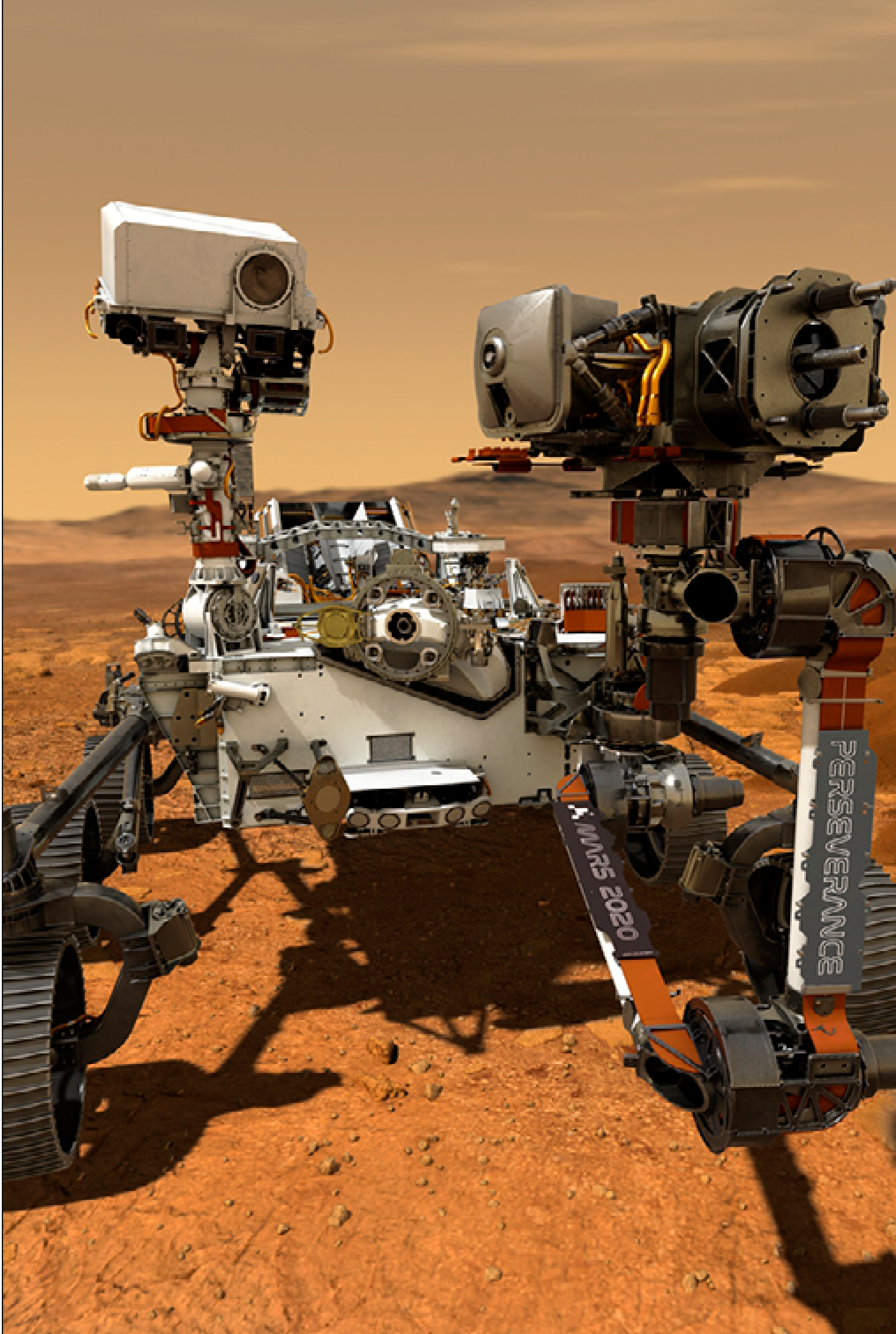
Since the first shaky images of orange-tinted rocks beamed back by the Viking landers, and since the Opportunity and Spirit rovers set out to "follow the water", the same question is on everyone's lips: did Mars once harbour life? And could there still be life on the red planet today?

Photo: ice cap at Mars' South Pole viewed by Mars Express.

Exobiology searching for signs of life

MICHEL VISO
Head of Exobiology, Exoplanets and Planetary Protection

"The chemical composition of life is among the simplest and most widespread in the universe, made up of atoms of hydrogen, nitrogen, oxygen and carbon compounds. But for life to appear in the first place, the right conditions and energy are required to transform that chemistry into biology. Searching for forms and traces of extraterrestrial life and seeking to understand the mechanisms that enabled life to emerge in our solar system are what exobiology is all about! Mars is like 'frozen' in time and has dried out since those conditions disappeared from its surface, yet this is one of the best places to look for signs of life. We're not expecting to find E.T. or a fossil on the ground, of course. If we do discover traces of life one day, it will take time to interpret the data and reach a scientific consensus, because our observations are indirect; they're only clues, after all. So bringing back samples will be the biggest step I can imagine towards investigating further. Exobiology also poses the question of how we would live or survive on another planet. On Mars, the atmosphere is composed mostly of CO_2, whereas humans need large quantities of oxygen. So to go to the red planet, we'll need to learn how to convert its resources! That's the goal of the MOXIE experiment to be run on Mars in 2021—a small-scale experiment serving the larger challenge of paving the way for crewed missions to Mars."


MARS 2020
PERSEVERANCE

Bringing Mars back to Earth

Photo: Perseverance

Take a seat and make yourself comfortable. Look around and you will see mission planners, programme managers, engineers and research scientists from all over the world working on one of the most eagerly awaited science endeavours of Mars exploration: sample return! In fact, the succinctly named Mars Sample Return mission has already begun. The Perseverance rover on the Mars 2020 mission set to land in February 2021 will collect and cache samples in metal tubes and then leave them on the surface along the way.

But the hardest part will be bringing them back to Earth… and what a journey that will be. Another small rover will fetch them, an ascent vehicle will loft them into Mars orbit and a return orbiter will retrieve them for the journey to Earth. This adventure will call for collaboration between several space agencies, while research laboratories are already working to ready the instruments needed to analyse the precious grams of material.

DID YOU KNOW?

Come in Mars, this is FOCSE!

Our engineers and scientists communicate with our rovers on the surface of Mars via FOCSE[1], the operations centre that manages exploration missions. This is where rovers' work plans are drawn up daily, received data are processed and the next measurements are planned, in coordination with teams from other countries.

[1] French Operations Centre for Science and Exploration

POINTER

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The maximum number of sealed tubes the Perseverance rover will fill with samples.

WHAT TO LOOK OUT FOR

MARS KEY FACTS

Diameter:

≈ 6,800 km

Length of Mars day or 'sol':

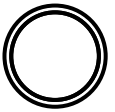
24 hrs 40 min

Length of Mars year:

687 Earth days

Mars-Sun distance:

228 million km on average



Tenuous atmosphere:

CO_2 (96%)
Argon (1.9%)
Dinitrogen (1.9%)

Largest volcano (and mountain) in the solar system:

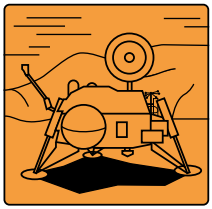
Olympus Mons (Mount Olympus), 22,500 m

Average surface temperature:

- 63°C

It never rains on Mars, but clouds and dust storms sometimes completely blanket the planet.

Mars may seem relatively easy to reach, but sending spacecraft and rovers there is fraught with difficulty. In 60 years, almost half the missions sent to Mars have ended in failure. Some landmark dates...



1960 **MARS 1M N°1,** first mission to Mars (Soviet Union). Fails.

1965 **MARINER 4,** first successful flyby (United States).

1971 **MARS 3,** first lander (Soviet Union). Transmissions cease after landing.

1971 **MARINER 9,** first probe to orbit another planet (United States).

1975 **VIKING 1 AND VIKING 2**

1996 **MARS 96**

1997 **SOJOURNER** becomes the first wheeled rover to drive on Mars (and on another planet), covering 104 metres in total (United States).

2004-2018 **THE OPPORTUNITY ROVER** on the Mars Exploration Rover (MER) mission drives more than 45 kilometres across the planet's surface (United States).

2004 **MARS EXPRESS**

2012 **THE CURIOSITY ROVER** on the Mars Science Laboratory mission (MSL) is set down on the surface of Mars using a 'sky crane' system (United States).

2016 **THE EUROPEAN EXOMARS TGO SPACECRAFT**

2018 **INSIGHT** is the first mission designed to probe the interior structure of Mars (United States).

2020 In 2020, three missions are setting out for the red planet: NASA's Mars 2020 mission with **Perseverance,** the United Arab Emirates' Hope spacecraft and China's **Tianwen-1** mission featuring an orbiter, a lander and a small wheeled rover. In 2022, the Pasteur rover will lift off for the **ExoMars** mission.

VIKING 1 AND 2

These two U.S. missions are the first to successfully land and beam back pictures from the surface of Mars, revealing a strange orange-hued desert.

MARS 96

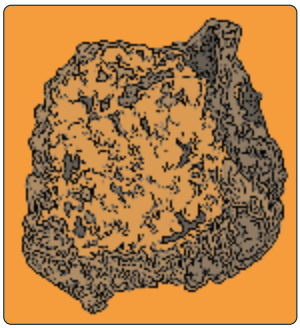
The most ambitious Mars mission of its generation fails to escape Earth orbit. This Russian craft weighed more than 6 tonnes and was carrying international instruments, as well as two small stations and two penetrators designed to measure soil properties.

MARS EXPRESS

The first Mars mission undertaken by the European Space Agency (ESA) is still operating in orbit 17 years after it was launched! It is seeking to trace the history of water on Mars. In 2005, it identifies sedimentary rocks (sulphates and clays), proving that water once flowed on the red planet. In 2018, its radar confirms the presence of an underground water lake near the South Pole.

THE EUROPEAN EXOMARS TGO SPACECRAFT

TGO arrives in Mars orbit to study rare compounds in its atmosphere and traces of methane. Thanks to its antenna, it also serves as a relay for rovers on the surface. On arrival, it releases the Schiaparelli lander, which fails to set down.



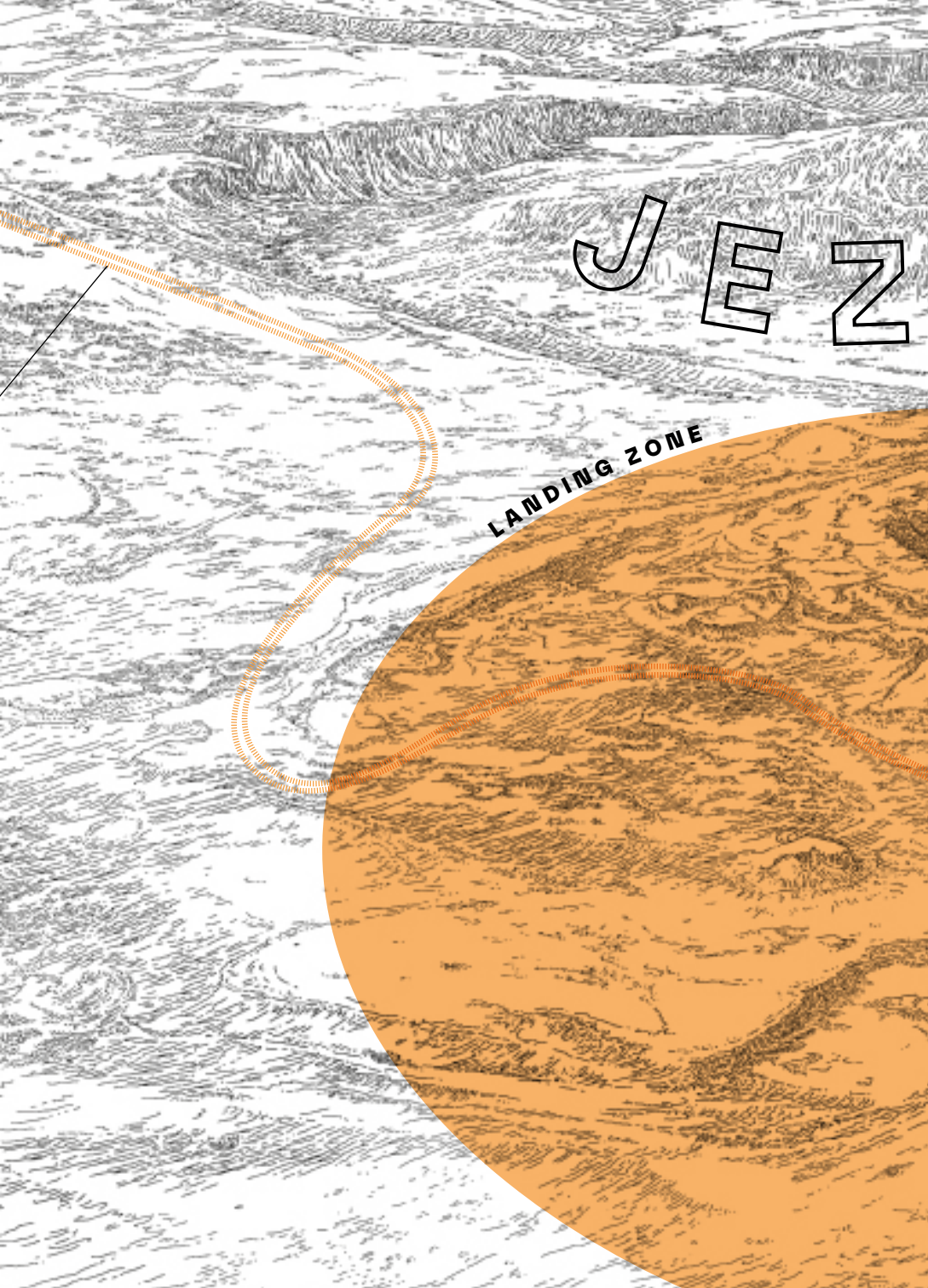
3. Midway minerals

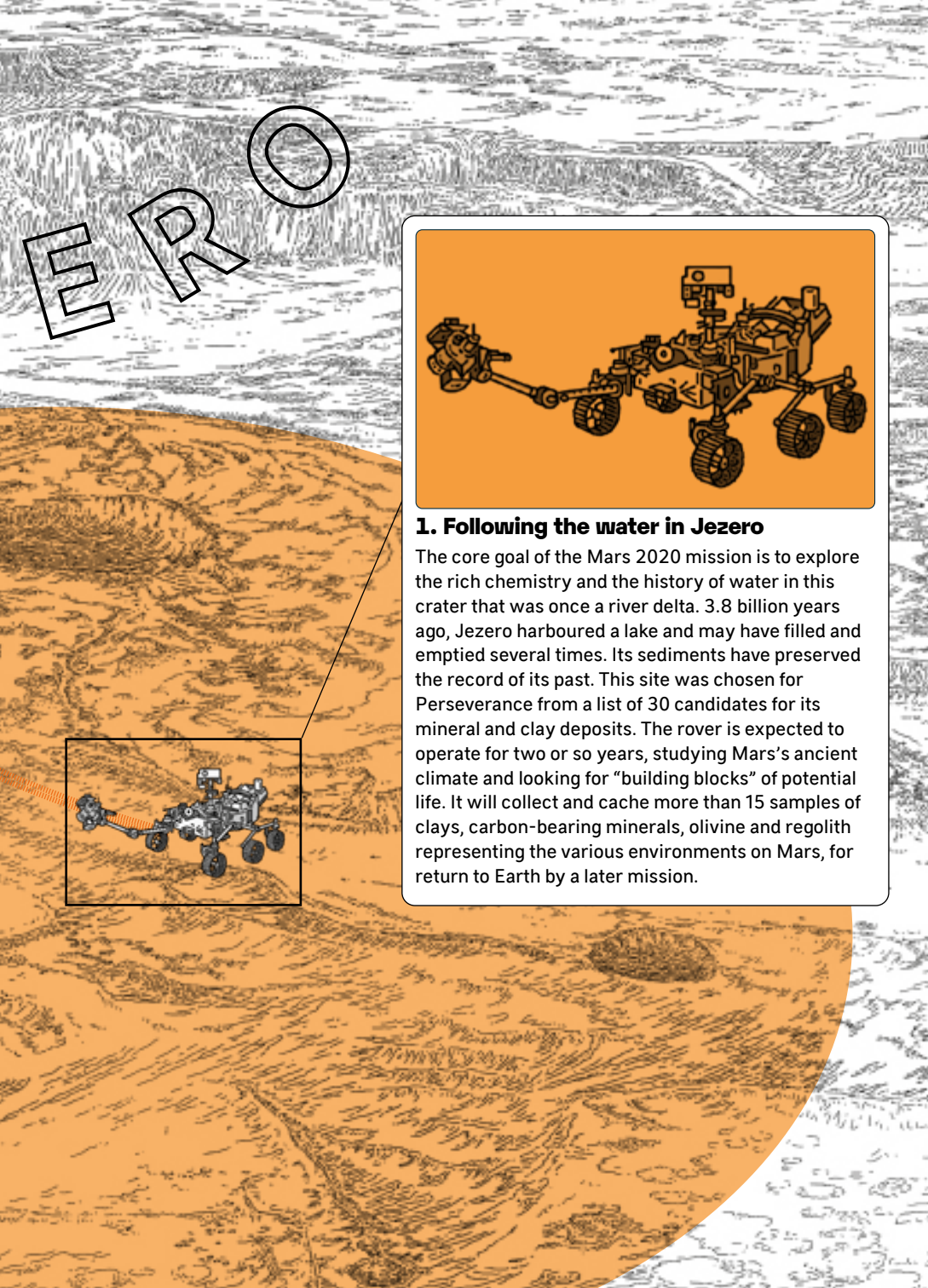
If Perseverance undertakes this trek, Midway will be its final destination, which it won't reach in all probability before 2027. This region will be a good place to observe the surface crust and its evolution over time, as well as how changes in climate have shaped Martian rocks. The surface minerals and rocks there would complement the different samples collected and studied in Jezero earlier in the mission. But questions remain: Will the rover be able to make it to Midway and collect samples? What about those collected in Jezero? Will it have to leave them behind for future missions to retrieve before embarking on its journey? What's for sure is that mission teams will have plenty to ponder...

TO MIDWAY

2. Traversing the terrain

Once Perseverance reaches the end of the first main phase of its mission, teams will decide whether or not to embark on the long trek to Midway, another key site of interest. This choice will have far-reaching consequences, taking the rover on a 28-kilometre trail over nearly two years, through rocks and dunes, and sometimes up steep inclines. It will be a long, tough trip with no turning back. In comparison, Curiosity has driven no more than 23 kilometres in close to eight years. But the terrain to be traversed appears promising and the rover could collect samples of minerals not found in Jezero.


JEZ
LANDING ZONE



1. Following the water in Jezero

The core goal of the Mars 2020 mission is to explore the rich chemistry and the history of water in this crater that was once a river delta. 3.8 billion years ago, Jezero harboured a lake and may have filled and emptied several times. Its sediments have preserved the record of its past. This site was chosen for Perseverance from a list of 30 candidates for its mineral and clay deposits. The rover is expected to operate for two or so years, studying Mars's ancient climate and looking for "building blocks" of potential life. It will collect and cache more than 15 samples of clays, carbon-bearing minerals, olivine and regolith representing the various environments on Mars, for return to Earth by a later mission.

Planning the Mars 2020 mission

The Perseverance rover will set down in Jezero Crater in February 2021 and embark on a science mission of discovery. At CNES, we've been involved in charting the course of this roving laboratory for a number of years. Of course, there might be some surprises in store when it gets there...

Perseverance in the tracks of Curiosity

By the time the Mars 2020 mission departs, the Curiosity rover will have been scaling the foothills of Mount Sharp, in the middle of the 90-kilometre-wide Gale Crater, for almost eight years. While the two rovers may look the same, Perseverance features a host of improvements, like the SuperCam optical instrument in place of ChemCam. The rover will even be carrying a piece of a meteorite from Mars, found in the Sahara in 2011, which previously spent time in orbit during Thomas Pesquet's stay aboard the International Space Station (ISS) in 2016. With Perseverance, it will be returning to its roots.

PERSEVERANCE BY THE NUMBERS

23

That's how many cameras the Mars 2020 mission will be carrying. Seven of them will be switched on just to film the landing sequence.

50
centimetres

The diameter of Perseverance's wheels. The rover is the size of a small car, 3 metres long and 2.7 metres wide.

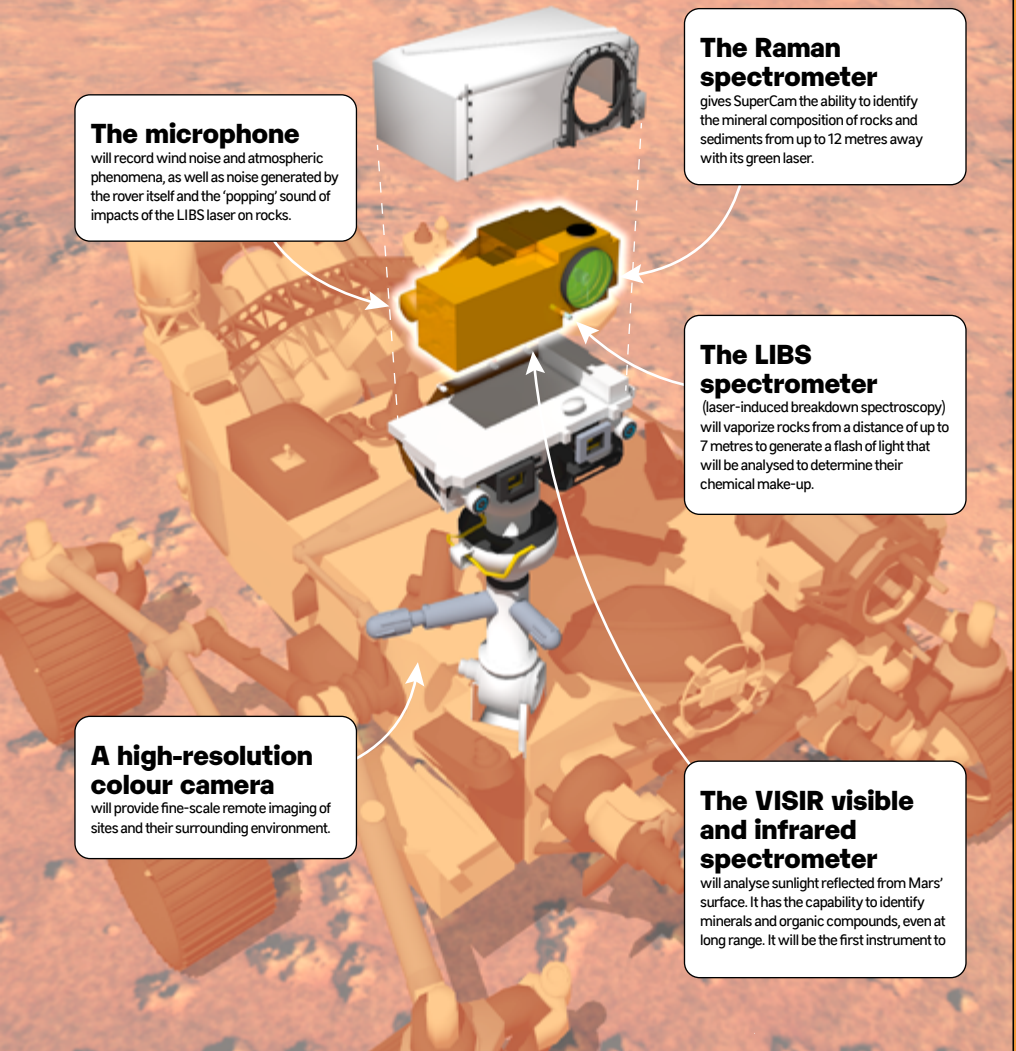
3
minutes

The flight time for each sortie of Ingenuity, a small dual-rotor helicopter demonstrator riding to Mars on Perseverance's belly. This will mark the first time an instrument has taken off from the surface of Mars to survey its surroundings.

SUPERCAM

A French-U.S. Swiss Army knife

SuperCam is a suite of instruments perched atop Perseverance's mast, giving it the ability to survey Mars from head height with unrivalled precision. This optical unit is a superb feat of technology, built in partnership by teams at CNES and the IRAP astrophysics and planetology research institute in Toulouse, French universities and research laboratories affiliated to the national scientific research centre CNRS.



The microphone
will record wind noise and atmospheric phenomena, as well as noise generated by the rover itself and the 'popping' sound of impacts of the LIBS laser on rocks.

The Raman spectrometer
gives SuperCam the ability to identify the mineral composition of rocks and sediments from up to 12 metres away with its green laser.

The LIBS spectrometer
(laser-induced breakdown spectroscopy) will vaporize rocks from a distance of up to 7 metres to generate a flash of light that will be analysed to determine their chemical make-up.

A high-resolution colour camera
will provide fine-scale remote imaging of sites and their surrounding environment.

The VISIR visible and infrared spectrometer
will analyse sunlight reflected from Mars' surface. It has the capability to identify minerals and organic compounds, even at long range. It will be the first instrument to

RETURN TO EARTH

We have to go there to discover Mars, but it's here on Earth that our laboratories are working to reveal its secrets. The rovers operating 200 million kilometres away are both the tool and pride of our research scientists and engineers. Time to meet them...

Our innovations

How to condense a 20-kilogram desk-size laser into an instrument weighing no more than 600 grams? That's one of the challenges of Mars exploration, which calls for new instruments to observe it more closely. Forty French research laboratories are working with CNES to explore the solar system. Can you imagine lying down all day? At our MEDES space clinic, teams are testing bedrest protocols to prepare for long-duration crewed missions lasting more than six months in space. And at our SEROM rover proving ground at the Toulouse Space Centre, others are training rovers to drive over a 4,000-sq.m. simulated Martian terrain...

Photo: SuperCam instrument being integrated at IRAP.

Our limits

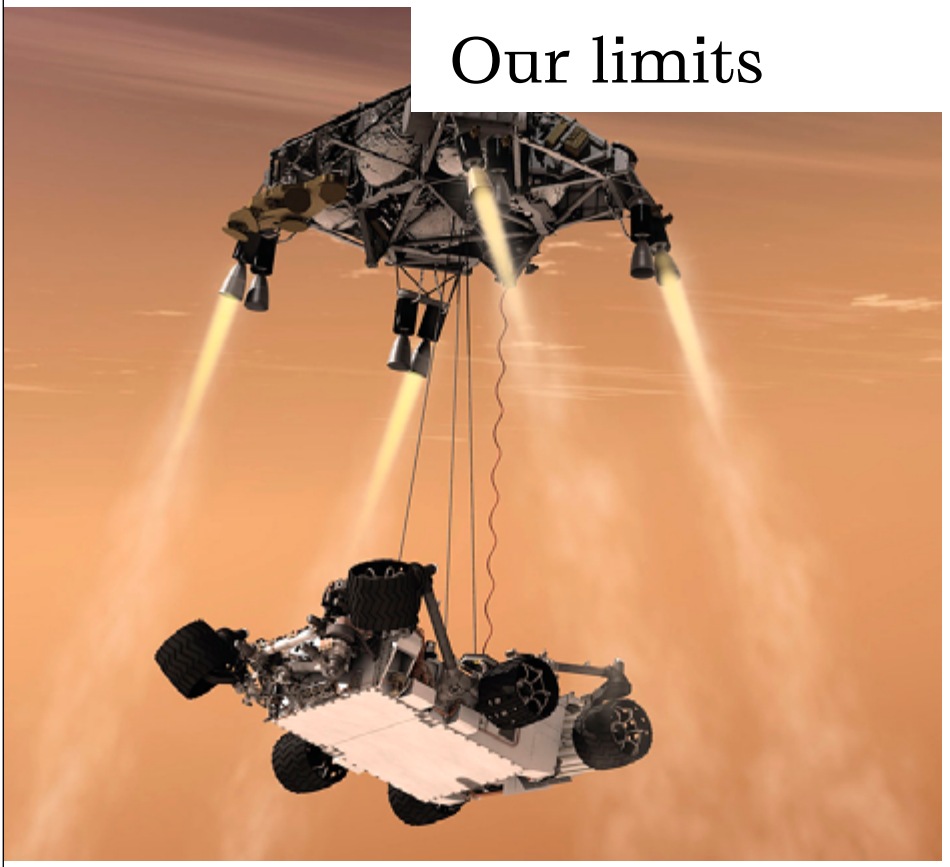


Photo: The MSL mission's Curiosity rover descends to the surface.

POINTERS

13

Years that Europe thought the tiny Beagle 2 Mars lander had crashed on arrival on 25 December 2003. Research scientists eventually found it in pictures acquired from orbit in 2015. Its antenna had never deployed.

20,000

orbits!

The extraordinary longevity of the Mars Express mission, still going strong after 17 years.

Today, landing on Mars is challenging. Our rovers have to do it on their own, as we can't guide them down given the distance from Earth: any commands we sent simply wouldn't reach them quickly enough. On landing day, teams wait just like us with bated breath through "seven minutes of terror". By the time we receive the first signals back from our precious missions, their fate is already sealed! Conceiving such an adventure would also be impossible alone: to explore Mars, centres of excellence from around the world are working together. CNES's instruments are flying to Mars on European, American, Japanese, Russian and maybe soon Chinese spacecraft. And we're paying particular attention to planetary protection to avoid contaminating Mars' preserved environment—and Earth's—at all costs.

Our fantasies

Will humans be able to resist the temptation of setting foot on Mars? Getting there will be a titanic effort. In terms of technology first of all, for it will require a spacecraft capable of ferrying a crew, landing on the planet and returning into orbit for the journey back to Earth. The crew will also have to stay on Mars for a long period, maybe 18 months. It will be a medical and psychological challenge too, as the entire mission could last two to three years, exposing crew members to high doses of radiation. Still tempted? One day, men and women will no doubt embark on this adventure, which will be a whole lot more complex and costly than setting foot on the Moon. Some even dream of colonizing Mars. Not only is that currently impossible, but it could also hold back scientific research.

Up to 400 million kilometres from our laboratory!

CAROLINE FREISSINET
CNRS research scientist
at the LATMOS laboratory

"'Building blocks of life', in other words molecules that would prove Mars was once habitable, is what we're looking for with SAM[1], our instrument on the Curiosity rover. SAM analyses Mars' atmosphere and the composition of its soil. This week, Curiosity succeeded in drilling a new hole in the surface of Gale Crater. It then excavated some material and transferred it with its robotic arm to SAM, to analyse its composition. This is only the 26th hole drilled in eight years! SAM is a power-hungry instrument, so much so that when it's functioning, Curiosity can't drive or operate its other instruments. Working at three laboratories in France—the LATMOS[2] atmospheres, environments and space observations laboratory, the LISA[3] inter-university laboratory for the study of atmospheric systems and the CentraleSupelec engineering school—we wait patiently for analyses to arrive. Together, every four weeks, we guide operations from Toulouse with the other groups based in California. Taking care of SAM is a team effort!"

1 Sample Analysis at Mars
2 Laboratoire atmosphères, milieux, observations spatiales
3 Laboratoire interuniversitaire des systèmes atmosphériques

IN THE TRACKS OF...

Mars is a fascinating, astonishing place that inspires literature. Mixing science with fantasy, author Éric Pessan draws on CNES research to take it further in fiction.

ÉRIC PESSAN

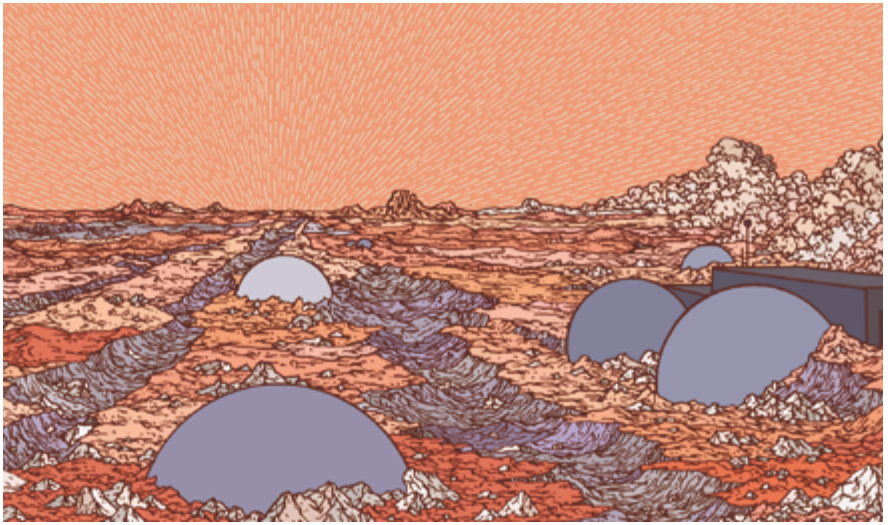
Born 3 January 1970, Éric Pessan is a prizewinning novelist, playwright and author of articles. This active and inspired resident of CNES's Observatoire de l'espace cultural laboratory is putting the finishing touches to a novel whose protagonists will leave their home planet Earth. A first space story reflecting what we're doing on Mars in a special light.

In the literary world, Mars exploration occupies an important, almost central role. The planet inspires fascination and is the scene for science-fiction novels and other scientific literature.

For me, our perception of Mars through the centuries is a wonderful source of inspiration. I'm especially fond of the era when big names like Flammarion or Victor Hugo were convinced there was life on Mars; it was almost an established fact. In the 18th and 19th centuries, we thought we'd found channels on its surface and we anticipated one day meeting Martians. Psychic mediums even purported to be able to communicate with them! That all seems so far gone to us now.

Philosophers and astronomers have always searched for other habitable worlds. Today, exoplanets are the object of our attention and fantasies.

Mars is a great fictional storehouse!

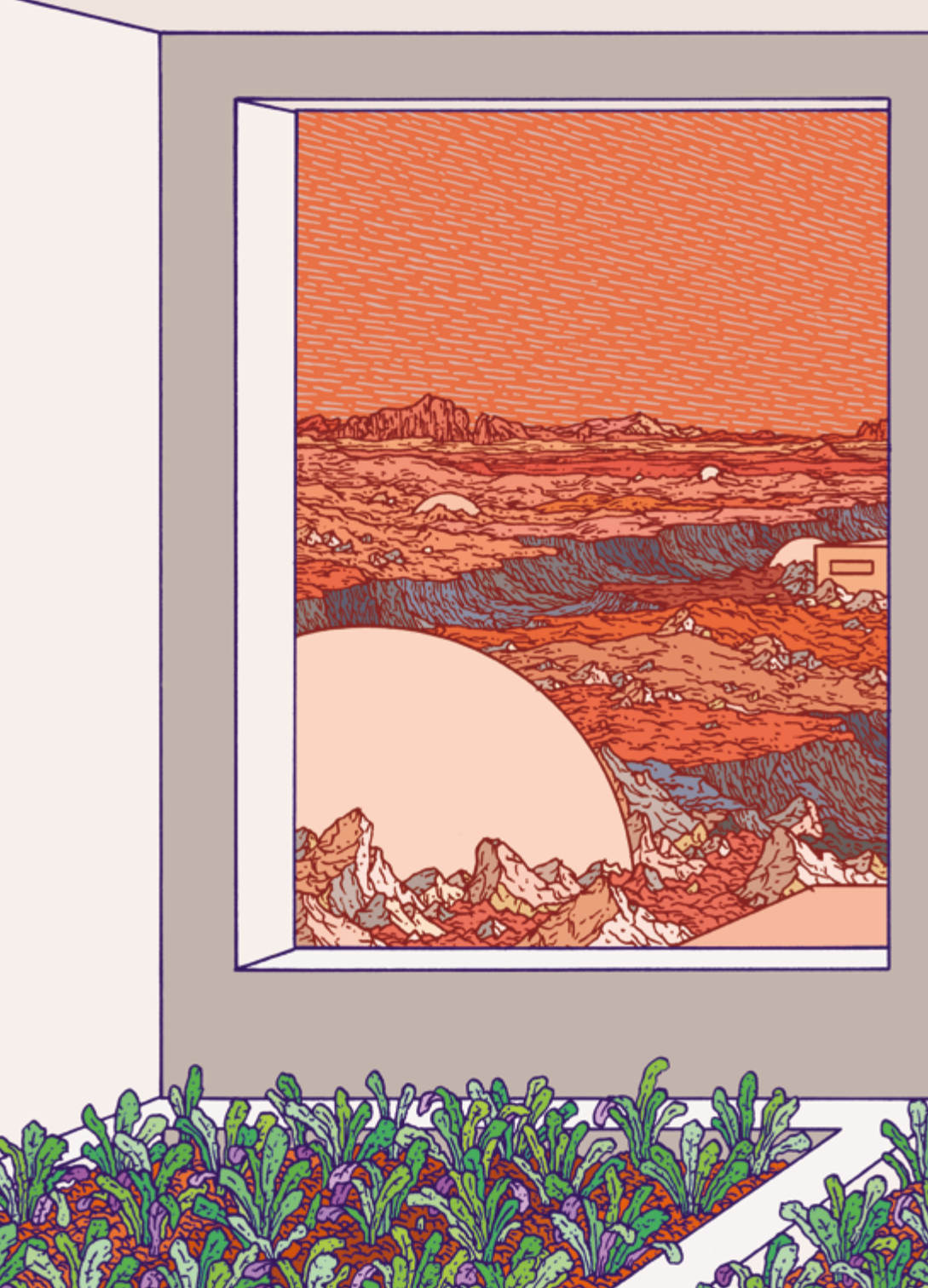


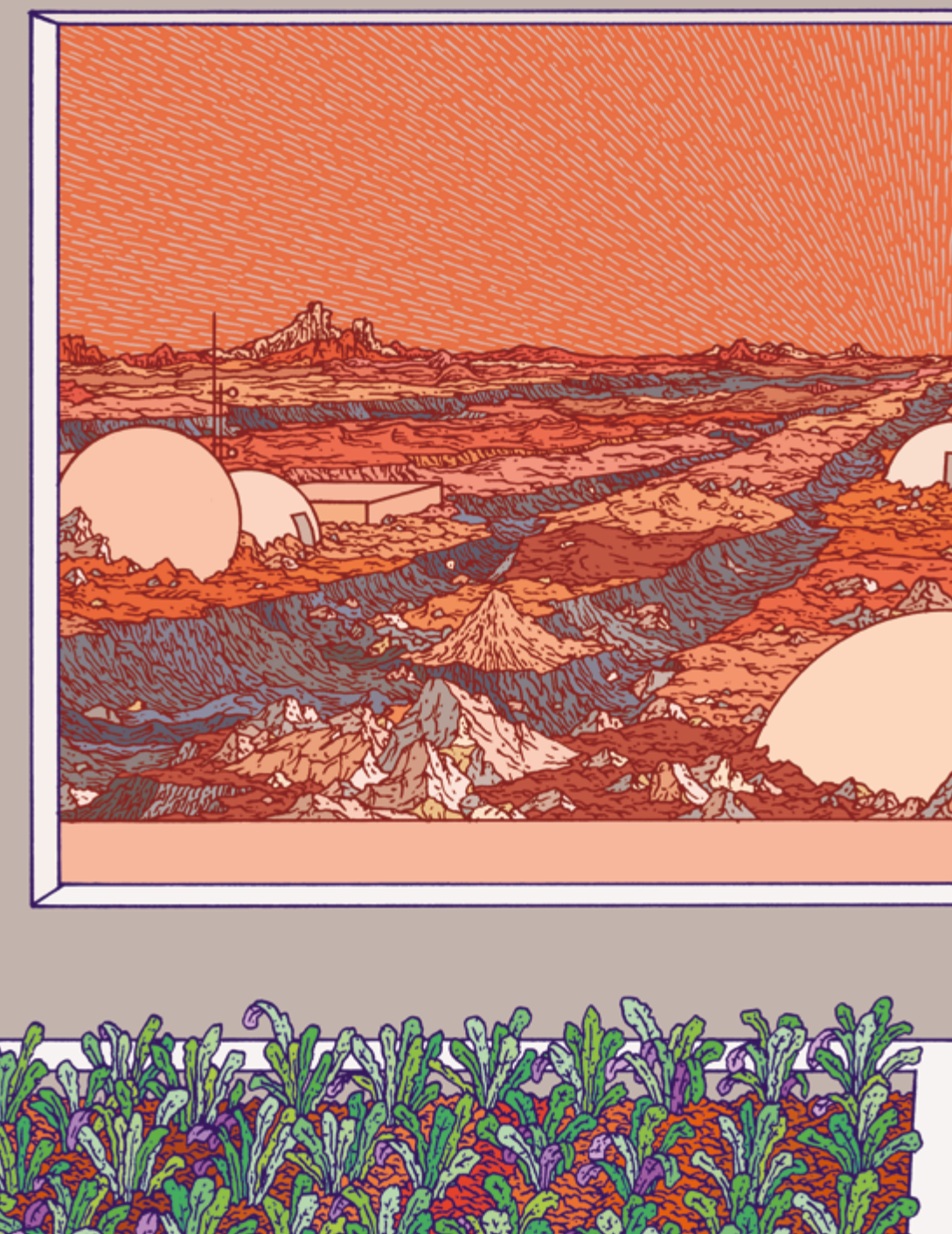
This obsession with discovery is central to the plot of my novel: having polluted and destroyed Earth, we really need to find a planet B.

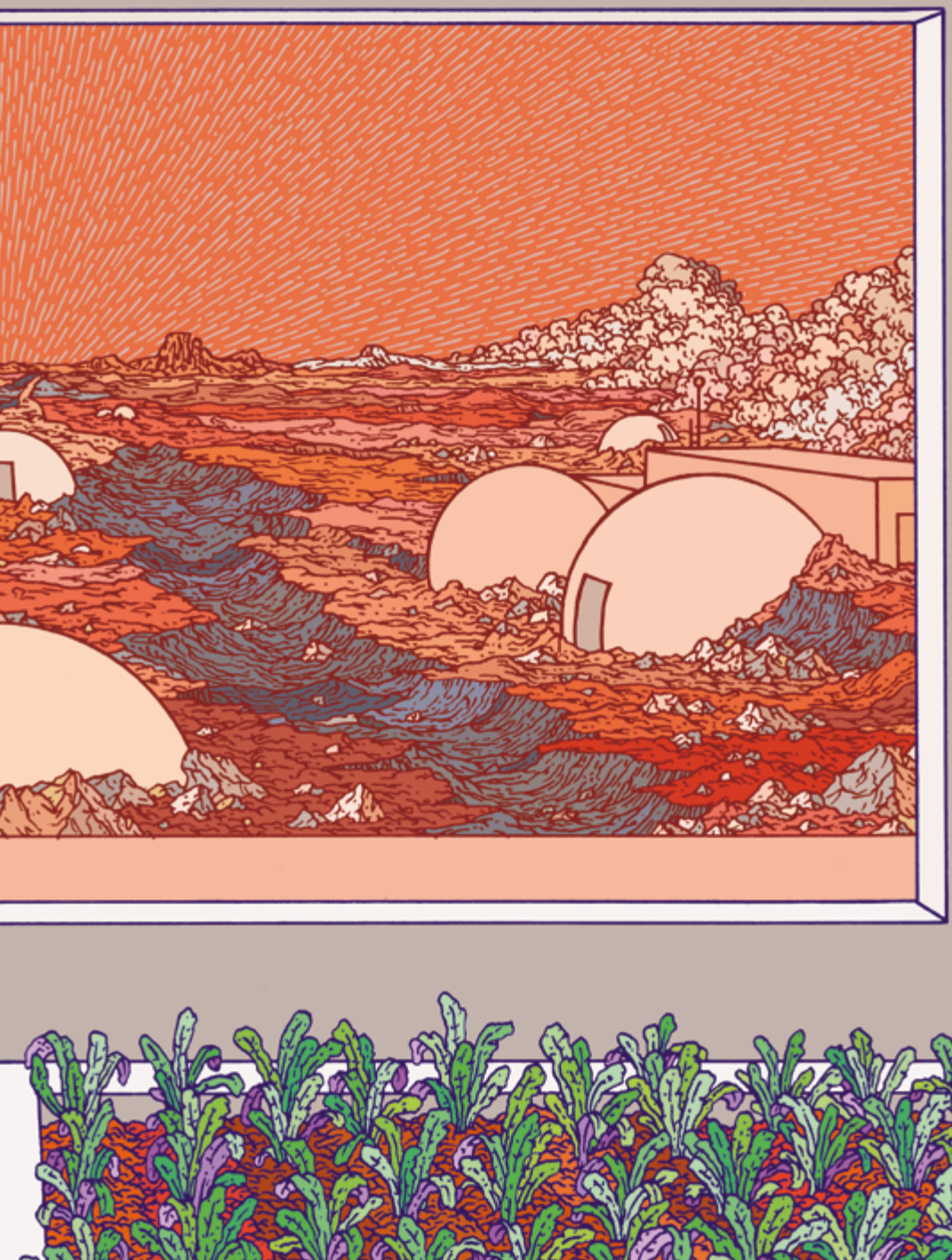
To entertain the idea of humans one day leaving Earth for good, I wanted a realistic technical and scientific vision, because obviously only science and engineering can make that journey possible. In this sense, my residency with the Observatoire de l'espace is performing a brainstorming role. It helps me to understand the present and future of Mars exploration, and the stakes involved.

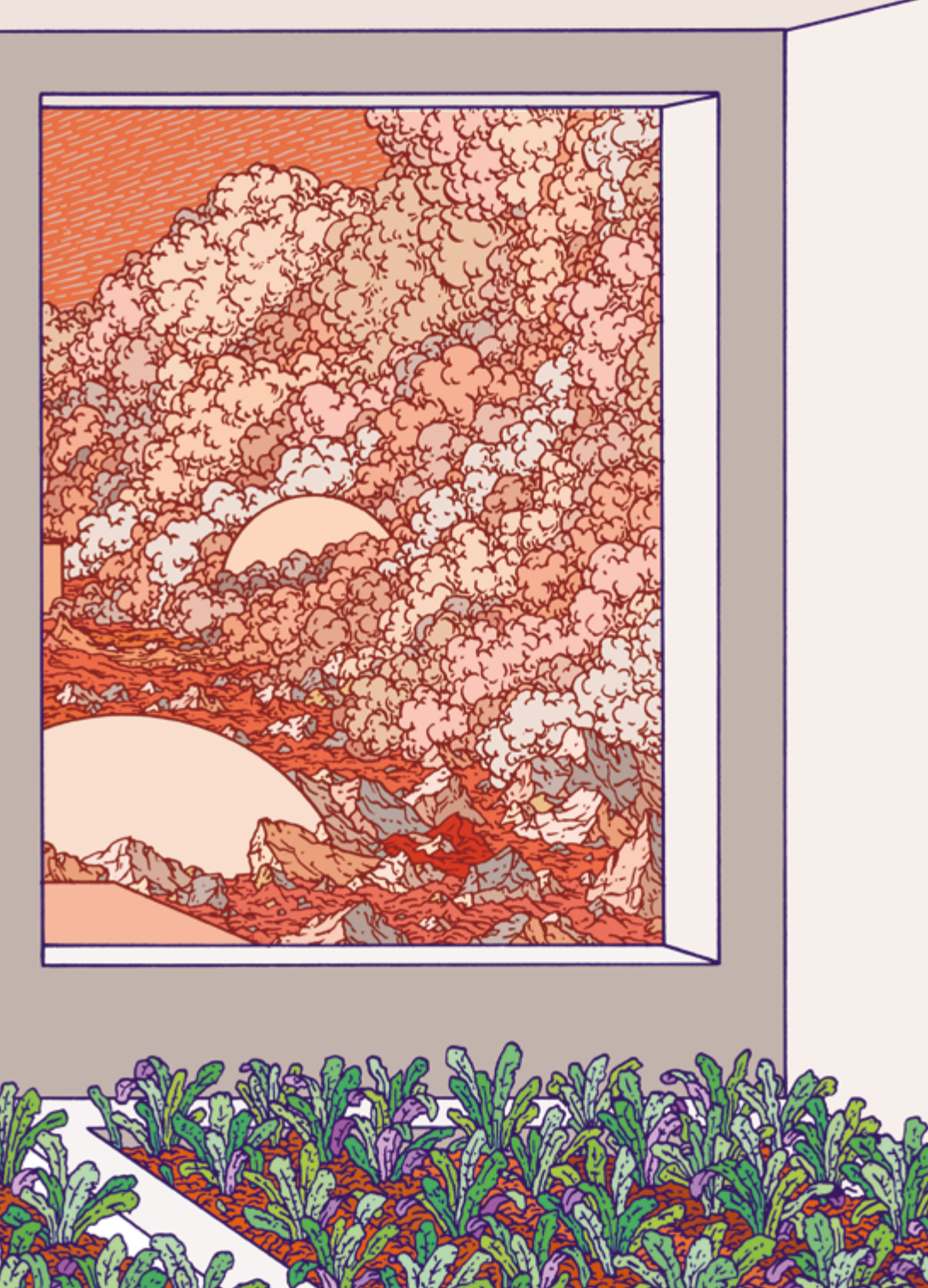
I'm also running a workshop with 20 high-school pupils to get them thinking and writing about the idea of departing for another world. It's an opportunity for self-introspection as well as reflecting on our society and the changes they would like to see. It seems to me that space exploration and the conquest of Mars are a metaphor for all our worldly concerns here on Earth. Today, we hear a handful of billionaires dreaming about "colonizing" Mars. To me, it's the reawakening of an old obsession that drives us to want to conquer new lands and protect ourselves from the masses.

So maybe space is a good mirror to look at ourselves.









MEMO

MARS GLOSSARY

Heatshield

To land on Mars, our spacecraft must first slow during its descent through the tenuous atmosphere. But at high speed, the friction imparted raises the spacecraft's temperature to almost 1,500°C! A very strong and light heatshield affords the required protection.

Dust devil

In the Martian desert, whirlwinds sometimes pick up fine grains of dust to form what we call dust devils. These formations, which have already been observed by rovers on the surface, can stretch for tens of kilometres and leave tracks visible from orbit.

Radioisotope thermoelectric generator (RTG)

The impressive Curiosity and Perseverance rovers are not powered by solar panels but rather by a nuclear battery or RTG. An RTG converts the waste heat generated by decaying pellets of plutonium into electricity.

Orbital window

Because Mars and Earth don't circle the Sun at the same speed, the distance between them varies from 54 million to as much as 400 million kilometres. So to send our missions there, we have to wait for the two planets to be as close as possible to each other to shorten the journey time. This conjunction is what's known as an "orbital window", which opens every 26 months and lasts about three weeks. Even then, the trip still takes at least seven months.

FURTHER READING

Dernières nouvelles de Mars, la mission du siècle
by Francis Rocard (Flammarion, 2020)

Mars Horizon
by Florence Porcel and Erwann Surcouf (Delcourt, 2017)

Embarquement pour Mars : 25 clés pour 25 défis à relever
by Richard Heidmann, Alain Souchier, Jean-François Pellerin and Pierre Brisson (A2C Medias, 2017)

The Martian
Andy Weir (novel, Crown, 2014)

NOTES

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GET READY TO DEPART WITH US ON A VOYAGE INTO SPACE

with our series of guidebooks. All aboard for the red planet!
More than ever before, CNES is on a mission to explore Mars.
Come with us to unveil the secrets of the desert landscapes
where we dream of one day setting foot. An adventure that starts today,
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