A new NASA rover is about to go to Mars. What are its objectives and what are the news compared to previous missions?
A new NASA mission for the exploration of Mars will begin between July 17 and August 5, 2020. In the past two decades, probes and rover have confirmed that the Red Planet in the past was very different from the cold and dry world we know today. Not only were there environments that could have hosted life but the conditions of habitability would last long enough to support it. NASA's new mission, Mars 2020, will send a rover, Perseverance, to Mars to better understand the history of the planet and look for traces of that past biology that could have developed.
The main scientific objectives are:
1. Search for habitability, identify past environments that could have supported microbial life;
2. Search for biosignatures, look for signs of possible microbial life spent in the habitable environments identified, in particular those types of rocks already known on Earth for their ability to preserve fossil traces;
3. Caching Samples, that is to collect samples of soil and Martian rocks and keep them for a future return to Earth with a sample return mission;
4. Preparation for human exploration, demonstrate new technologies for the next robotic and manned missions.

The selected landing site is one of the most intriguing and promising places on Mars, the Jezero crater, located at 18.38 ° N and 77.58 ° E.
The landing site
Jezero is a crater about 45 kilometers in diameter located on the western side of Isidis Planitia.

Scientists believe that in the past it hosted a large lake. The orbital images show ancient carved canals, deltas and sediments dating back to around 3.5 billion years ago.
In this frame, taken from a NASA video, a three-dimensional aerial view of the Jezero crater is shown: the ellipse is the landing area; the white line is the path that the rover could follow in the first two years of the main mission. Credits: NASA.
The team wants to land Perseverance right near the ancient fan-shaped river deposits because on Earth the sedimentary accumulations at the mouth of the rivers are an excellent place to look for traces of present and past life. The deltas are formed when the waterways convey the sediments collected along the way into large stable water bodies, such as lakes, seas or oceans. These are generally areas that are teeming with biological activity on our planet and, perhaps, the same thing happened on Mars.
Subsequently, the rover will move to the edge of the basin where the impact that occurred billions of years ago dug and exposed the Martian crust. It is hypothesized that those rocks remained hot for some time after the formation of the crater, favoring the birth of hydrothermal springs.
The entire area has been mapped and divided into 1.2 x1.2 km dials. For the 342 panels that include and surround the landing ellipse, the various geological units have been defined in broad terms, obtaining data from the various orbital missions that have worked on the Red Planet so far.
Credits: Williams et al. (2020)

The Jezero crater, of the Noachian age, is the only known location on Mars where the signature of carbonates was clearly detected in the vicinity of evident river and lake elements that indicate the past presence of a

paleolago. On earth, carbonates aid the formation of structures strong enough to survive fossil forms, such as shells, corals and stromatolites, for billions of years. Carbonate minerals are formed by the interactions between carbon dioxide and water, recording their subtle changes over time. So the Martian deposits will also be able to provide a lot of useful information on the atmospheric evolution of the planet.

According to a recent study, the water stayed long enough in the Jezero crater to sustain life and just as long was the sedimentation process, necessary to capture life in fossil forms.
The rover
Perseverance - artistic representation Credits: NASA / JPL-Caltech
Perseverance follows the dimensions and structure of Curiosity which has been successfully exploring Mars since 2012. It is about 3 meters long, 2.7 meters wide and 2.2 meters high but with a weight of 1,025 kilograms, it weighs 126 kilograms in more than Curiosity. The power supply is always based on the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), a generator that converts the heat generated by the radioactive decay of plutonium into electricity. But the rover also has many new features on board and will test new technologies.
A series of systems have been specifically designed to improve entry into the atmosphere, descent and landing:
• Range Trigger, is a technology that will allow the team to reduce the size of the landing ellipse by more than 50%, reaching the main target with greater precision. This will save valuable time on the surface of Mars, which would otherwise have to be used to drive to the primary destination. In practice, the Range Trigger is a solution that will allow you to adjust the deployment of the parachute, anticipating or postponing it according to the distance from the target. In previous missions, however, the parachute was opened when a certain predetermined speed was reached.
• Terrain-Relative Navigation, is a technology that will allow the rover to land safely. The on-board computer will monitor the landing area practically in real time, comparing the images taken during the descent with the best map of the area preloaded in the internal memory. If the area proves too dangerous, the system can autonomously move the landing site within a radius of 300 meters.
The demonstration of Terrain-Relative Navigation will be crucial for future missions because many of the most interesting places on Mars are where the ground conditions are more difficult and, so far, it has not been possible to reach them. Curiosity has already experimented with similar technology: an autonomous driving system to avoid obstacles and drive safely.
• MEDLI2, is a suite of sensors that will help improve the atmospheric models of Mars for the next missions. During the entry into the atmosphere, the descent and landing phase will be active: it will collect data such as pressure and atmospheric temperature and the heat shield. The first version, MEDLI (MSL Entry, Descent and Landing Instrumentation), had flown with Curiosity.

• Cameras and microphones will document EDL (Entry, Descent, Landing) as never before. The microphones are a great novelty compared to Curiosity and Perseverance has two, one for recording sounds during the descent, the other is part of the SuperCam kit, one of the seven instruments we will talk about shortly.
It may seem strange but this device, so common, has been included very few times in missions to Mars. Of course not for a matter of cost or weight but it seems that, simply,

has never aroused too much scientific interest. On the contrary, listening to sounds from other planets fascinates the audience. One was provided by the Planetary Society for NASA's Mars Polar Lander mission in 1999 but unfortunately the spacecraft crashed on the surface of the Red Planet. In 2007, another was included in the Phoenix lander descent camera but was never turned on due to a potential electronic problem. We hope that Perseverance will have better luck!

Another novelty concerns the wheels which, compared to Curiosity, have been revised.

There are always six in total, three on each side, each controlled by its own motor. The two front and two rear also have autonomous steering motors to allow the rover to rotate on itself 360 degrees.

Like Curiosity, the Mars Exploration Rovers Spirit and Opportunity and Pathfinder, Perseverance uses the rocker-bogie system that allows the rover to roll over large rocks and hollows without tipping over. The term "rocker", rocking, derives from the design of the differential (the horizontal bar above the back of the rover) which actually has the appearance of a rocker connected to the lateral suspension mechanism. The term "bogie", trolley, derives from the old railway systems and refers to the connections at the end of the driving wheel.

The rocker-bogie design has neither springs nor axle shafts. While driving on uneven terrain, the suspension system maintains a relatively constant weight on each of the rover's wheels and minimizes its tilt, keeping it stable. Perseverance is designed to withstand an inclination of 45 degrees in any direction without tipping over but the team will always keep well within the parameters.

Credits: NASA / JPL-Caltech

The substantial difference between the two rovers concerns the design of the aluminum cladding which on Curiosity started to give problems after only 60 mission sols. Slightly larger in diameter (52.6cm versus 50.8cm) and narrower, the Perseverance wheels have twice the tread, are slightly curved with a different pattern of ribs.

The instruments

The rover has 7 main tools and interesting features such as 23 cameras in total (7 scientific, 9 to support operations, 7 to monitor the various stages of landing) and a drone helicopter attached under the belly.

The main tools are:

• Mastcam-Z, the eyes of Perseverance. It is an imaging system mounted on the rover shaft and is very similar to the Curiosity Mastcam. Like the latter, it is about 2 meters high to simulate a person's point of view but, compared to the previous version, it has a zoom. It can take photos at high speed (4 frames per second at maximum resolution) and 3D (the two cameras that compose it are installed at a distance of 24.2 centimeters from each other to obtain a stereoscopic view). It is capable of resolving from 150 microns per pixel to 7.4 millimeters per pixel depending on the distance. It will return 1600x1200 pixel images with 2 megapixel color quality. It is a multispectral stereoscopic imaging instrument also equipped with band-pass filters (from 400 to 1000 nanometers) which will be used to distinguish the materials and provide important insights on the mineralogy of silicates, oxides, hydroxides and mineral hydrates. A pair of sunscreens will allow direct recovery of the sun.

• MEDA (Mars Environmental Dynamics Analyzer), will perform meteorological measurements and study the dust present in the Martian atmosphere. It is a suite of environmental sensors designed to record the properties of dust particles and six atmospheric parameters: speed / direction of the

wind, pressure, relative humidity, air temperature, soil temperature and radiation in the UV, visible and IR range of the spectrum.

• MOXIE (Mars Oxygen In-Situ Resource Utilization Experiment), is an experiment that will allow NASA to test the production of oxygen from the atmosphere of Mars as a vital and propellant support for future astronauts. It will also characterize the size and morphology of atmospheric dust to understand its effects on the functioning of surface systems.

• RIMFAX (Radar Imager for Mars' Subsurface Experiment), is a GPR (Ground Penetrating Radar) radar for exploring the subsoil. It is the first radar that will work directly from the surface of Mars to produce high definition stratigraphic images. Its ultra broadband design works from 150 MHz to 1.2 GHz.

• SuperCam, is a camera equipped with lasers and spectrometers that will be used to determine the mineralogy, the chemistry and the atomic and molecular composition of the samples on a microscopic scale. It combines several instruments: a Laser Induced Breakdown Spectroscopy (LIBS), Raman spectroscopy (at 532 nm to study objectives up to 12 meters away from the rover), Time-Resolved Fluorescence (TRF) spectroscopy, Visible and InfraRed reflectance spectroscopy (VISIR) (400 - 900 nm, 1.3 - 2.6 μm). Finally, it can acquire high resolution images of the samples being studied using a color microimager (MRI).

• PIXL (Planetary Instrument for X-ray Lithochemistry), is an X-ray spectrometer with camera to identify small-scale chemical elements and take close-up pictures of the ground and rocks. It is a microfocus X-ray fluorescence instrument that quickly measures elemental chemistry on sub-millimeter scales, focusing X-rays on a small target and analyzing induced fluorescence. This is a technique that is mainly applied for the identification of inorganic materials and PIXL can detect elements such as: Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Br, Rb, Sr, Y, Ga, Ge, As and Zr, with important trace elements such as Rb, Sr, Y and Zr also present in small quantities (10 ppm)

• SHERLOC (Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals), is the first Raman UV spectrometer to land on the surface of Mars. He will look for organic and mineral substances that may contain signs of past life. It is the cutting edge of Perseverance tools: it combines imaging with UV Raman resonance and native UV fluorescence spectroscopy, using a 248.6 nanometer laser with a beam size of less than 100 microns. SHERLOC allows the detection and characterization without contact (and therefore without interacting and / or destroying the sample) of biosignatures, working on an area of 7 × 7

millimeters. In combination with the auto focus mechanisms of a service camera, Autofocuing Contextual Imager (ACI), can be positioned 48mm above natural or abraded surfaces.
WATSON (Wide Angle Topographic Sensor for Operations and Engineering), the camera placed on the rover's robotic arm (like the Curiosity MAHLI) will help SHERLOC's work by taking close-up photos of the targets (and selfies at Perseverance). It is a color camera with a wide range of resolutions (from infinite to 13.1 microns / pixel) and can support the work of different instruments such as the PIXL X-ray spectrometer.
SHERLOC also has a unique calibration set that includes six round and four square targets.
To calibrate the instrument, inevitably subject to significant temperature fluctuations, radiation and cosmic rays, the team has ten accessories including a sample of a Martian meteorite that arrived on Earth and was found in the Oman desert in 1999 (known as Sayh al Uhaymir 008 -

SAU008). This will in fact be the first piece of Mars that will be brought home. Before Perseverance, another meteorite, known as Zagami, had traveled to Mars aboard the Mars Global Surveyor spacecraft, which is still floating, defunct, around the Red Planet today. Next to the Martian meteorite are five space suit fabric samples and visor material developed by NASA's Johnson Space Center. SHERLOC will periodically check the status of these materials during the mission, providing designers with a complete picture of how they degrade over time subjected to the elements of Mars. When the first astronauts arrive on the Red Planet, they will probably have to thank SHERLOC if their suit will keep them safe.
Perseverance will not be alone on a mission: the Ingenuity helicopter will accompany him during the journey and stay on the Red Planet. The dual rotor and solar powered drone weighs 1.8 kilograms on Earth which will become 650 grams on Mars due to reduced gravity. Once on the Red Planet it will deploy with a wingspan of 1.2 meters: each flight should last no more than three minutes, at altitudes between 3 and 10 meters above the ground. He will be able to navigate independently and communicate with the rover.
Raman UV spectroscopy
The SHERLOC investigation combines two spectral phenomena: native fluorescence and Raman scattering pre-resonance / resonance. The latter is a spectroscopic technique that takes its name from the Indian physicist C.V. Raman who first experienced it in the 1920s.
Such events occur when a high brightness laser source illuminates the sample. The organic products present therefore absorb the incident photon and re-emit radiation at a higher wavelength. The difference between the excitation wavelength and the emission wavelength indicates the number of electronic transitions, which increases with increasing aromatic structures (i.e. with the number of aromatic rings).
The native UV-induced fluorescence is very sensitive to condensed carbon and aromatic organic compounds; while, SHERLOC Raman resonance allows the detection and classification of aromatic and aliphatic organic substances, as well as the detection and classification of those minerals involved in chemical processes that include water. On the other hand, organic substances can also form with abiotic processes, so it remains essential to demonstrate the past habitability of the environment in which the sample was taken. Then, through the use of imaging, SHERLOC will be able to correlate the classes of organic substances detected with the

morphology of the site to determine if the microfossil candidates, such as stromatolytic strands or stratifications, are potentially biogenic.
Why was this technique chosen for Mars?
Because first of all it provides a powerful investigation tool: it can analyze solid, liquid and gaseous materials; it is not destructive; does not require sample preparation; it can be used in any place and / or at any time and gives quick answers. But building an instrument that respected all the engineering constraints dictated by space missions was a great challenge. Luther Beegle, principal researcher of SHERLOC, told us via email:
“There was a call [to present] Mars 2020 payload tools and SHERLOC was chosen after an extensive review process. SHERLOC is both a Raman laser and a fluorescence spectrometer. Raman identifies mineral and chemical footprints as IR spectroscopy but with more specificity (i.e. the peaks are narrower so that more information can be collected than with IR spectroscopy). Fluorescence identifies aromatic organic compounds and is 3-5 orders of magnitude more sensitive than Raman. Fluorescence does not have the selectivity of other techniques (i.e. I can say that there is a ringed molecule in the sample but I cannot say if it is tryptophan or benzene) but the sensitivity is exceptional. The two

observations carried out together result in a more sensitive measurement with high specificity for biological samples. We will also take the images of the samples at the highest resolution ever obtained on the planet and we will be able to map chemicals and materials in 100 micron points in the rocks that will provide clues to the sample and where it comes from ".

The collection of samples
Perseverance will collect samples from Martian rocks and soil using a rotary hammer drill, as Curiosity is doing. However, in this case, the rover will store the material in test tubes that will be left on the surface of Mars for a possible future mission, which should recover them and bring them to Earth for analysis. The whole process is called the "Sample Caching System".
There are three main steps in sample management:
1. Collection.
After careful selection work, the drill, positioned on the robotic arm of the rover, will perforate the ground, while in the front of Perseverance, another small robotic arm will act as a "laboratory assistant". This will take care of passing the drills and the tubes to be filled to the drill (43 in all). Each sample will contain approximately 15 grams of material.
2. Sealing and conservation.
The filled test tube will be transferred to the rover's belly from the assistant arm. Here, the samples will pass through the inspection and sealing stations. The hermetically sealed tubes will be stored in a unit within Perseverance, until the team decides to release them on the surface of Mars.
3. Deposit on the surface.
The samples will be deposited on the surface of the Red Planet in the places designated by the team. The positions will be well documented by local reference points and orbital coordinates.
So what can Perseverance offer us differently from previous missions?

Anyone who is following the space exploration will have the feeling that everything is going a little slow. We have now sent many probes and rovers to Mars and, if it is true that Perseverance will test some technological innovations, it is also true that it seems to do little more than the previous rover, Curiosity. And above all, there is still a big question that has not been answered since the days of the Viking missions: is there, or has there been, life on Mars? NASA has always been very skeptical about the results obtained by the Viking missions, so much so that, in the last 40 years, no biological experiments have been sent to the Red Planet. The landers, Viking 1 and Viking 2 which landed respectively in Chryse Planitia and Utopia Planitia in 1976, carried specific tests designed to find out if there was life on Mars, in addition to a gas chromatographer and mass spectrometer, two fundamental tools for astrobiology. However, biological experiments produced results so controversial that they still divide the scientific community today. They were based on a very simple concept: they assumed that Martian and terrestrial microorganisms would behave in the same way and therefore, feeding on organic substances present in the soil, they would release carbon dioxide or methane as a result. In one of the experiments, the collected Martian soil sample was then mixed with seven nutrient molecules "labeled" with a radioactive carbon isotope. If bacteria or other biological forms had metabolized these substances, they would have released methane or carbon dioxide also radiative, implicitly confirming the presence of forms

of life. For both Viking the results were positive only on the first application. When the test was repeated a week later there was no reaction and no evidence of organic molecules in the soil of Mars. For NASA, therefore, it was only a false positive because the data were probably distorted by a "non-biological property" of the Martian soil, an oxidant or more oxidizers not yet well identified.

The dr. Gilbert Levin, who followed the Viking experiments, never shared this position. As he recalled in a recent article, he was also a member of NASA's Planetary Quarantine Advisory Panel (PQAP). Therefore, its aim has always been to avoid planetary contamination for a threefold reason: ethical, so as not to interfere with the natural development of another planet; public health, so as not to endanger the Earth with alien pathogens and to prevent any invalidation of the life-tracking experiment on board the Viking (what then happened). Levin also recalls that the Viking were sterilized with a heat treatment at around 120 ° C, in addition to having undergone chemical sterilization treatments therefore, he underlines, "Viking data on Mars are the only uncontaminated data that we will ever see from the Red Planet".
The results generated by the Viking Labeled Release (LR) experiment have undergone dozens of abiotic reviews and explanations in recent years despite the subsequent missions, Curiosity in particular, have shown that there are essential elements to life on Mars, including sporadic (and discussed) appearances of liquid water on the surface.
The fact is that, since then, the perspective of the missions has changed: in addition to focusing on the study of the evolution of the planet and on the characterization of current geological and climatic processes, we have gone from looking for life forms to confirming potentially habitable past environments and now, looking for past life forms. With a more cautious and less direct approach.

Mars 2020 scientist from Arizona State University Jim Bell told the BBC "We can say that we have found a biosignature but it is not clear to me how many would believe it." This is why Perseverance will carry out preparatory work for the collection and storage of samples to be brought back to Earth so that "if extraordinary claims are made, they can be verified".
The carbonate rocks identified by the orbit in the Jezero crater seem to be one of the best places to look for past life on Mars. On Earth, they are formed mostly in marine environments and can be of chemical or biochemical origin, when animal and plant organisms also intervene. The most common fossil groups that make up marine carbonate rocks are: lamellibranchs, corals, echinoderms, foraminifera and calcareous algae, gastropods, etc.
It is difficult to say if Perseverance will find all this also on Mars but the rover, as we have seen, offers many more investigation possibilities than Curisosity which can carry out less refined analyzes and must necessarily crush the samples in order to analyze them.
If fossil traces on Mars are confirmed it will be a sensational but frustrating discovery: continuing to look to the past will never be the same thing as being able to confirm or deny that on the Red Planet there is microbial life today. Among other things, this should be a topic of great interest for the next manned missions: what kind of microbes could future astronauts meet and bring back to Earth? In a historical period in which almost the whole world is still trying to get out of the COVID-19 pandemic, this should be a more than legitimate and priority question.

But will Raman spectroscopy solve the dilemma?
According to Levin, "Raman UV spectroscopy suffers from the two problems that all biomarker detectors have in common. First, regardless of the molecules it detects, even DNA, it will always be said that it is easier for that molecule to have emerged abiotically than for life to have emerged to produce

this molecule. Secondly, even guaranteeing the detection of life, it is not possible to establish whether the detected life was alive or dead, "he told us by email.
However, Perseverance will offer some more chance.
We asked Beegle if SHERLOC will also be able to report the presence of living biological forms: "Yes, it could but we don't expect it" was the answer. In a document "The Cell and the Sum of Its Parts: Patterns of Complexity in Biosignatures as Revealed by Deep UV Raman Spectroscopy" (Frontiers in Microbiology - HM, J Razzell Hollis, R. Bhartia, LW Beegle, VJ Orphan, JP Amend - 2019) the team explored the results returned by SHERLOC by analyzing a living cell. Beegle added, "At its highest level, SHERLOC will look for" small carbon bags "that we can analyze to determine if it is a potential biosignature for the return of the sample. If we find a high concentration of carbon in the 100 micron spot, we could interpret it as such and therefore we will try to bring it back to Earth for further studies ".