Three missions to Mars are now under way

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With yesterday's launch of NASA's Perseverance Mars rover, the three Mars missions being attempted in this year's "window" of efficient access to the red planet are off successfully. Perseverance joins the Chinese Tianwen-1 orbiter/lander/rover mission, launched on July 23, and the United Arab Emirates/US Hope orbiter, launched July 19.

Mars presents favorable circumstances about every 26 months for missions from the Earth. This is the same interval as between "oppositions," where the two planets reach their closest approaches, Mars in a near line outwards from the Sun to the Earth. Launch windows occur about two months before the close approaches, with travel time about 8.5 months before spacecraft reach Mars.

It has been 60 years since the first exploited launch window, in 1960, saw a pair of Soviet spacecraft sent on their way. Around 50 missions have used the 27 subsequent launch windows until the present one. Only in the last two decades have successes overtaken failures: more than half of attempts to reach Mars to date have failed.

Prior to the spacecraft age, each Martian opposition was the source of intense Earth-based telescopic exploration. Even at these close approaches, however, Mars is 150 times the distance of our own Moon, and the features easily visible through a telescope on the Moon, its mountain chains and craters, were invisible from Earth-bound telescopes. As a result, much of what we now know about Mars is the product of the past 60 years of "up close" exploration with our robotic probes.

What was known within the first century after Galileo turned the telescope into an astronomer's instrument was that Mars had bright white spots that appeared at its poles, correctly interpreted as icy polar caps (that the ice is substantially carbon dioxide would not be suspected until much later). While several wealthy amateurs in the late 19th century would begin several decades of feverish promotion of the idea that Mars had a system of "canals," supposedly visible through the telescope and representing signs of a civilization, sober scientists deployed new technologies as they became available and, laboring largely in public obscurity, laid the groundwork for the Mars science of today.

Thus by the turn of the 20th century the astronomical spectroscope suggested a closer similarity of Mars to the Moon rather than the Earth, 1920s measurements of radiated heat showed very cold (-85C–7C) surface temperatures, and 1930s measurements showed that oxygen, if present, could not be more than one percent of Earth levels. An early 1970s measurement from a high-flying plane, above most of Earth's atmosphere, also recorded the signature of chemically-bound water on the Martian surface, suggesting a different and wetter past.

Only with the first successful Mars spacecraft, the July 1965 flyby of Mariner 4, was the heavily cratered surface of Mars revealed, and the entire surface was finally mapped by Mars' first successful orbiter, Mariner 9, in 1971.

Generations of spacecraft since have derived their design from scientific questions raised by the results of prior missions, together with the immense growth of technology over the last half century.

The first missions largely carried out basic mapping, using crude television technology, and measurements of the Martian atmosphere and surface conditions over the considerable vertical relief of the planet. With the two Viking landers of 1976, the first detailed images of the Martian surface were returned, and chemical measurements of the Martian soil were made, including a crude attempt to detect a signature of possible life.

More than five launch windows passed without a mission until attempts resumed in 1988. The thrust of the following decade was to prepare far more detailed studies of the surface from orbit, and to begin testing new technology for landers on the surface, including roving capability.

In the last twenty years, both of these areas have been revolutionized, with stunning imagery from orbit suggesting a rich geological history, including wind- and water-shaped terrain, and from an increasingly sophisticated series of roving explorers on the surface, filling in the details of this picture from geological exploration of rocks and exposed cliff faces from meteoritic impacts.

With the geology now firmly in hand, confirming that Mars had for some sustained early part of its history a warmer surface with flowing water—conditions with parallels to those that spawned life on our own planet—more recent missions have focused on addressing the extraordinary question raised by that parallel.

Of the three missions on their way (a fourth European mission which was to have joined them has been deferred until the next launch window in 2022), the first launched is a relatively modest mission jointly undertaken by the United Arab Emirates in collaboration with three American universities, the University of California, Berkeley, the University of Colorado, Boulder and Arizona State University.

The "Hope" orbiter, launched from a Japanese H-IIA rocket in Tanegashima, Japan, has been described as Mars' "first true weather satellite," though it is adapted toward the very different variations displayed by the Martian atmosphere as compared to Earth's. In particular, it carries scientific instruments which can study the process by which Mars loses atmosphere to space, a process which, thanks to Mars' lower gravity and lack of a substantial magnetic field, is much more rapid than Earth's loss, and also thought to be more complex.

A better understanding of this process will likely give a better understanding of the evolution of Mars' geology and how long conditions compatible with the genesis of life were sustained.

The second mission launched, China's Tianwen-1 ("heavenly questions"), is China's first independent interplanetary mission. It will both build an independent Chinese orbital capability to study the surface and relay radio communications from it, as well as land a rover modeled to some extent on, but with more contemporary technology than, the twin US Mars Exploration Rovers (MER) Spirit and Opportunity of 2003.

Unlike those missions, which did not include an orbiter component, Tianwen-1 will not proceed directly to a landing, but rather enter orbit and begin studies to select from several preliminary sites, and only then will the lander separate and make its way to the surface. Like the MER rovers, this one will use a combination of atmospheric braking, a large parachute, retrorockets, and finally a set of airbags to cushion its impact on the Martian surface. A likely landing site will be near the Viking 2 landing of 1976, Utopia Planitia, a low-elevation area thought to be reshaped by mud flows in the Martian watery past, where biosignatures may still survive from possible past life.

The most ambitious mission of this group is the US "Perseverance" rover, at $2.1 billion somewhat cheaper than its predecessor Mars Science Laboratory "Curiosity," only because its instrumentation is built upon a framework consisting of many spare parts from that former mission. Like its predecessor, it relies on nuclear power rather than solar, and will thus be immune to the dust storms and seasonal variations that played havoc with prior rover missions.

As an aside, much is being made in the American press of this second nuclear Mars mission being powered by "US-made" plutonium-238, production of which recently began again for the first time since 1988. But in fact, most of the plutonium onboard originates in the declining NASA reserve bought from Russia prior to it suspending sales in 2010, with American production still at low levels.

With 23 cameras and a wide suite of scientific instruments, Perseverance will be the most capable Mars rover to date in the capacity to undertake a broad study of Martian minerology, and in particular the study of organic or carbon-containing molecules that may indicate both the signature of past life and the tracers that conditions fertile to its formation were once present.

A key driver of the design of Perseverance's instruments has been to assess the inventory and environment of life-associated elements in the geology it will explore. Like its predecessor Curiosity, it can make observations at a distance by using a laser to vaporize a bit of rock the size of a period from more than 20 feet away, studying the light emitted in the flash to determine the composition and properties of the material. But it also has, for the first time on a rover, a device called a Raman spectrometer that can analyze the minerology and organic chemistry of individual grains on a rock reachable to the rover's robotic arm.

Perseverance will carry two other novelties: first, a small solar-powered helicopter, that can travel up to 2,000 feet per flight and image the possible driving route, and secondly, a ground-penetrating radar (a first also shared by the Tianwen-1 rover), to study what no lander yet has in detail, the depths beneath the Martian surface. Perseverance will also test from the Martian surface a technology to manufacture oxygen from the largely carbon dioxide atmosphere, a necessity for future hopes at human exploration or even for more efficient fueling of Mars return rockets from supplies generated locally, rather than brought from Earth.

And towards that end, Perseverance is also equipped to encapsulate up to 30 samples it retrieves from the surface, or cores it drills from the soil, and deposit them in caches along its route where a future mission might gather them and ship them to Earth. There, laboratories far more sophisticated than what can be packed in a Martian rover could mine them for clues. It is hoped that this may happen within a decade: the technology is not the limiting factor, as with most fundamental questions today, it's access to funding.

Perseverance will rely on the same "sky hook" concept for landing as Curiosity, the "seven minutes of terror" necessary for landing heavier items, in which a highly choreographed sequence takes place including the use of a parachute, and ending with the deployment of a hovering rocket platform from which the rover is literally winched to the surface on a cable and freed in the final seconds. This will take place directly on the arrival of Perseverance at Mars, its landing site already selected. That site, Jezero Crater, is another area which orbital imagery suggests was once a river delta into a shallow sea, fertile grounds for microbial life or more.

While Mars is much smaller than the Earth, its surface is only a little smaller than the total area of Earth's dry land, so only a tiny range of the diversity of the Martian surface has been reached from the ground. Both of these rovers and the European one to hopefully join them at the next launch window, together with the Chinese and Emirati orbiters, the suite of robotic explorers still at work in Martian orbit and the surface, will continue to tease out the detailed history of the red planet. From their results, and in particular from the questions raised by these, the next generations of exploration will be defined, first robotic, and eventually—human.