MISSIONS TO MARS

'It is pretty special to get new views of martian vistas—it truly feels like exploration.'

A self-portrait of NASA's Curiosity rover taken on Sol 2082 (June 15, 2018). A Martian dust storm has reduced sunlight and visibility at the rover's location in Gale Crater. Credit: NASA/JPL-Caltech/MSSS

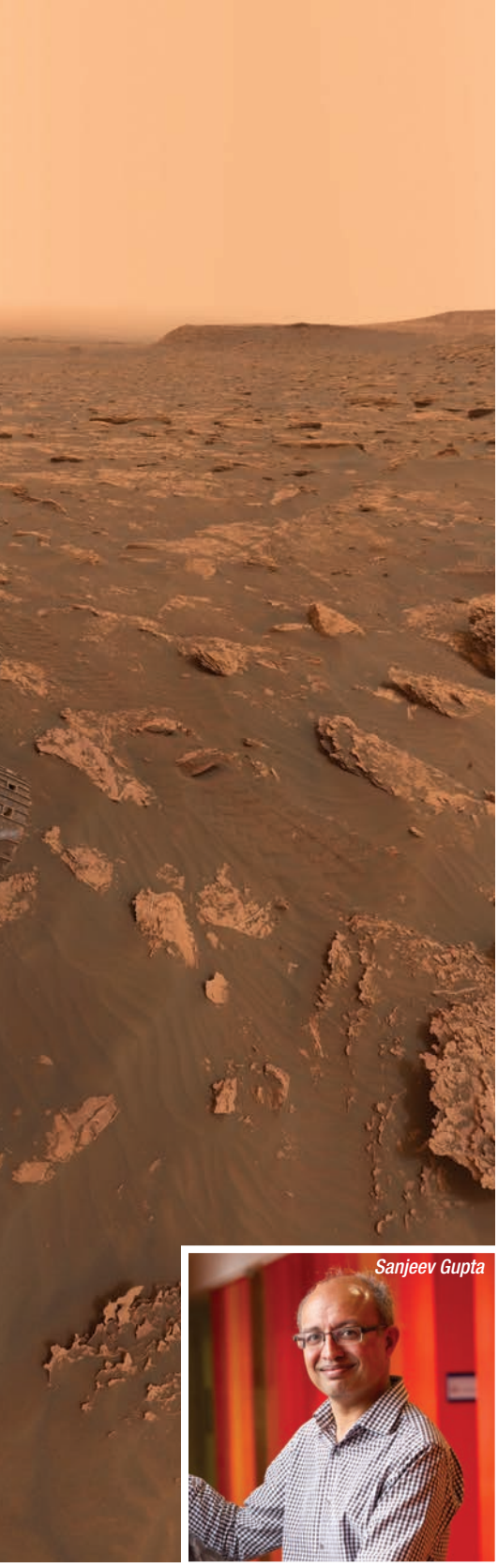
In August 2012, NASA's *Curiosity* rover touched down in Gale crater, Mars, after a 350-million-mile journey lasting more than 8 months. Sanjeev Gupta, Professor of Earth Sciences at Imperial College London, is an Earth and planetary scientist who researches modern and ancient environmental change on Earth's surface and on Mars. He is one of the scientists working on the *Curiosity* rover mission—still active after 8 years on Mars.

'On the *Curiosity* mission, I have two roles. Firstly, I am one of the sedimentologists and stratigraphers on the mission, and my job is to work with other team members in reconstructing the ancient palaeoenvironments from Gale crater strata and to determine the habitability of early Mars.

'I am also one of the strategic planners for the mission, what we call a Long Term Planner. For this role I integrate between the science team and engineers in building strategic plans for exploration and scientific observations and experiments.'

Exploration

Since the 1960s, humans have been exploring Mars with an increasingly sophisticated series of probes, landers and rovers. In that time, we've learned a huge amount about the planet's geological history, composition and potential for life. Among the missions currently operating alongside *Curiosity* are NASA's InSIGHT (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) lander, which is studying the interior of Mars, and MAVEN (Mars Atmospheric and Volatile EvolutioN), an



Sanjeev Gupta

orbiter studying the Martian atmosphere.

'We have learnt enormous amounts about Mars in the light of recent missions, such as *Curiosity*, MAVEN and InSIGHT' says Sanjeev. '*Curiosity*'s big finding has been the discovery of 'smoking gun' evidence for active surface water flow on Mars—rivers transporting rounded pebbles and cobbles 3.5 billion years ago, and the presence of lakes in Gale crater at that time that likely existed for at least hundreds of thousands , if not millions of years. We have also discovered organic compounds in Martian mudstone samples.'

As well as the *Curiosity* rover, Sanjeev is also working on *Perseverance*, NASA's latest rover mission launched in July and expected to land in February next year, and the ExoMars *Rosalind Franklin* rover, a joint mission between the European and Russian space agencies, planned to launch in 2022. As one of the Long Term Planners for NASA's *Perseverance* mission to Jezero crater, he has been working with the science team to develop investigation strategies for exploring deltaic strata in the crater.

'The *Perseverance* rover will be coring and caching rock samples for future return to Earth. When analyzed in Earth laboratories, scientists will be able to look for chemical and textural evidence for past life. Moreover, investigation of the geochemistry and mineralogy of samples will tell us invaluable information about the geological and atmospheric evolution of Mars.

We also hope to be able to collect samples that could be age dated back on Earth so that we can begin to construct a robust timeline for Mars—something that is lacking. In the ESA/Roscosmos ExoMars mission, the *Rosalind Franklin* rover will drill up to 2 m into the martian subsurface, well below the radiation damage zone, to look for organics in martian rock samples.'

Martian vistas

Curiosity has become known for the incredible panoramic images of Mars it has captured, as well as for the first 'selfies' to be taken on Mars—created by stitching together numerous images taken by the handlens camera located at the end of its robotic arm. The panoramic images we've become used to seeing in the news are captured by the Mast Camera (Mastcam), which recently captured a mosaic made up of one hundred images that contained 1.8 billion pixels.

'Mastcam images are typically put together by a small group of people. When I dial into daily operations, I will look over a Navigation Camera panorama taken at the end of a drive the previous day. I and other team members will use this to identify and target areas, rock outcrops, landscape features etc., that we are interested in getting a photo mosaic of. We will make suggestions to the engineers of the Mastcam team, who will construct framework for a possible panorama to be taken by the Mastcam cameras based on individual image frames.

'Usually we have to decrease the size of the mosaic because of data volume constraints or issues with how long the mosaic will take in terms of time. When the image frames come down, one of the Mastcam engineers will put the images together into a mosaic, though this is often done automatically.

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Sample return

Alongside the incredible images and scientific data already being collected, Sanjeev is hopeful that, in time, it will be possible to bring samples from Mars back to Earth.

'This is the plan! The *Perseverance* rover is collecting and caching rock samples, which is the first step in the Mars Sample Return mission concept. The idea is that around 2026, a mission will be sent to Mars that will contain a Sample Fetch rover that will retrieve the cached samples, take them back to the lander and the samples will be launched into Mars orbit in a Mars Ascent Vehicle. Then, perhaps in 2030, a third mission will retrieve the samples from Mars orbit and bring them back to Earth!'

It wasn't until the final Apollo mission that a geologist was sent to the surface of the Moon--Apollo 17's Harrison Schmidt, who is now an Honorary Fellow of the Geological Society and was instrumental in sample collection and documentation during that mission. It may be some time yet before we can send humans to Mars, but Sanjeev believes that when we do, geologists may be at the front of the queue.

'I think it will definitely happen and perhaps the key scientists on that first mission will be geologists. Whilst we can do a lot with a rover on Mars, we really need geologist astronauts to explore the complexity of Mars's evolution.'

In the meantime, the scope of what can be achieved remotely is growing all the time, and the teamwork involved in planning missions is one of Sanjeev's favourite parts of the job.

'I really like doing rover operations and working with the science and engineering team in planning what we will do on Mars the following day and the next days ahead.

'We all know each other quite well now despite having worked predominantly online for the past 8 years. It's great working with such an amazing group of people!'

Interview by Sarah Day