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NASA/JPL-CALTECH

An early image from Curiosity showed that the rover had landed facing the north flank of Mount Sharp.

PLANETARY SCIENCE

Mars rover sizes up the field

After a picture-perfect landing, Curiosity's science team ponders its first moves at Gale Crater.

BY ERIC HAND IN PASADENA

The mountain rises in the late-afternoon sun: a daunting challenge to the vehicle before it. In a photograph taken minutes after Curiosity landed on the surface of Mars, the rover's shadow already seems to be reaching for the distant slope that it was built to climb.

On 6 August, Curiosity — the rover for NASA's Mars Science Laboratory mission — arrived at its destination at the bottom of Gale Crater, a basin with the area of Lake Ontario. Its goal is to explore the ancient rocks of Mars for organic molecules and the remains of watery environments that could have provided a habitat for life. It will do that by climbing a

mountain that rises from the centre of the crater: Aeolis Mons — informally dubbed Mount Sharp by mission scientists — which contains 5.5 kilometres of layered rocks representing hundreds of millions of years of Martian history. As the 900-kilogram rover climbs those slopes, on a journey that could take a decade or more, it will carry not only the most extensive suite of instruments ever sent to Mars, but also the hopes and dreams of engineers and explorers who see the mission as a prelude to an eventual human presence on the planet.

"The wheels of Curiosity have begun to blaze a trail for human footprints on the surface of Mars," said NASA administrator Charles Bolden at an emotional briefing at the Jet Propulsion Laboratory (JPL) in Pasadena, California, shortly after the landing. For now, the 400-strong rover science team must work to ensure that their US\$2.5-billion mission exceeds the achievements of all previous excursions to the red planet.

Complicated technology was needed to drop the rover precisely between Mount Sharp and the walls of Gale Crater. Over 7 minutes, a combination of a heat shield, a parachute, retrorockets and a 'sky crane' decelerated the rover from 5,900 metres per second to less than 1 metre per second and set it down gently on the surface (see *Nature* 488, 16–17; 2012).

"Touchdown confirmed," said Allen Chen, the JPL's operations lead for entry, descent and landing, whose voice remained calm and steady throughout the tense sequence. His words triggered hugs, high-fives and tears of relief. Moments later, the first pictures from the rover's front and rear hazard-avoidance cameras were relayed to Earth by Mars Odyssey, an 11-year-old orbiter that was passing over the crater.

Doug McCuistion, director of the Mars exploration programme at NASA headquarters in Washington DC, doesn't want this new landing capability, developed over the course of a decade, to go to waste. A rover like Curiosity could be built more cheaply and quickly now, he says, because he directed the JPL to "treat this like we're going to build them again and again and again". If the mission were to be repeated, the rover might cost 500 million dollars less. But that is still beyond the budget of NASA's planetary science programme, which has no further Mars landings on the books for ▶

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TOUCHDOWN AT GALE CRATER

Early estimates suggest that the Mars rover Curiosity touched down just off centre of its projected landing ellipse, 6.5 kilometres northwest of the mound known as Mount Sharp.

Passing above the rover, NASA's Mars Reconnaissance Orbiter captured a photo of Curiosity parachuting down to the surface.

► now. However, the programme does have an opportunity for a Mars mission in 2018, costing between \$700 million and \$800 million; later this month, NASA science chief John Grunsfeld is scheduled to reveal the results of a study exploring the best use of this window.

While the descent team basked in the post-landing limelight, mission engineers set about testing the car-sized rover. During the vehicle's first hours on Mars, data arrived in a relative trickle. The following day, engineers commanded the rover to deploy a communications antenna that will increase the data rate. The unstowing of the rover's mast, which contains several cameras, is planned for the day after that, and should unleash a cascade of colour photos of the landing site later this week. It will be a further several days before a drive is attempted.

The rover is starting its exploration essentially where mission planners had hoped. The

day after the landing, Mike Malin, president of Malin Space Science Systems in San Diego, California, and principal investigator for a camera on the belly of the rover, unveiled a dramatic video showing the final 150 seconds of the rover's descent. By cross-checking those images with high-resolution photos from the Mars Reconnaissance Orbiter — which caught the spacecraft in the act of descending beneath its parachute — Malin was able to pinpoint the rover on a barren plain just 6.5 kilometres from Mount Sharp (see 'Touchdown at Gale Crater').

Now, project scientist John Grotzinger, a geologist at the California Institute of Technology in Pasadena, needs to decide on the direction of the rover's first foray. Should he turn Curiosity away from Mount Sharp and drive it towards an intriguing fan of material at the crater's rim? The feature, called an alluvial

fan, is thought to have been formed by water that swept sediments over the lip of the basin. An instrument on Odyssey has detected that materials in the fan retain heat longer than the surrounding soil in the cold Martian night. Grotzinger says that this could indicate that the materials in the fan are firmer and more consolidated than the rest. "That implicates water as one way to cement them together," he says.

Alternatively, Curiosity could travel in the opposite direction: towards the base of Mount Sharp, where rock beds contain water-altered clays and sulphates. Whichever direction he chooses, Grotzinger wants to explore the rocks near the landing site to learn how layers of sediment from the base of Mount Sharp interweave with layers from the alluvial fan, and find out which was laid down first. Answers might lie in small craters or other features that cut through the rock layers near the rover, so the mission team will create a route based on those objects. "We're going to try to string together as many pearls as we think we can identify from orbit, and then explore them as we drive along," says Grotzinger.

Curiosity is more powerful than NASA's previous Mars rovers, Spirit and Opportunity, and more efficient at exploring a three-dimensional area. And the strata of the crater and mountain offer an abundant view of the fourth dimension — time. Grotzinger notes that although Spirit and Opportunity have travelled more than 42 kilometres between them since they landed in 2004, they have crossed only tens of metres of strata. At Mount Sharp, Curiosity has 5,500 metres of strata to traverse.

Curiosity itself has time on its side. Its nuclear-powered energy source could sustain it for many years beyond its nominal two-year lifetime. So as tempting as it is to turn Curiosity into a mountain climber immediately, Grotzinger is happy to be patient. "If it takes a year to get there," he says, "that's okay." ■ SEE

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The Curiosity mission team celebrated after the rover touched down according to plan.