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Opportunity of a lifetime: NASA's 4,000 days roving Mars

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The rover that could, and still is, running scientific marathons on Mars. NASA/JPL/Cornell/Maas Digital LLC

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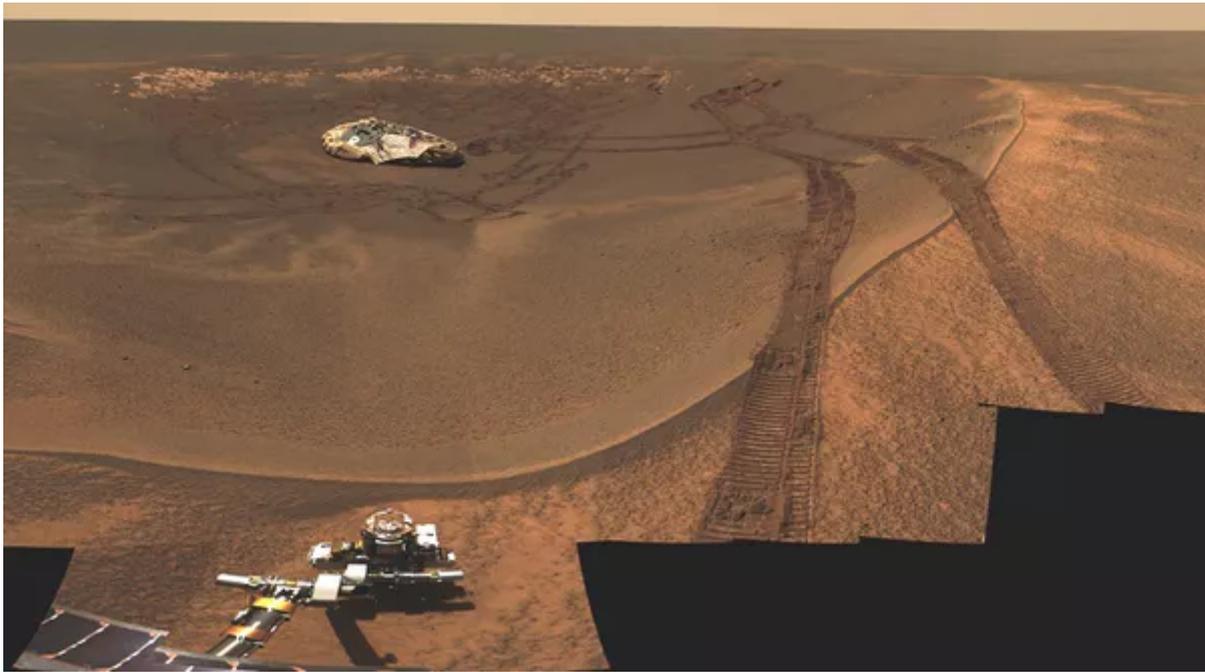
NASA's exploration rover **Opportunity** landed on Mars more than 11 years ago, in January 2004, with what then seemed like ambitious goals: to survive 90 Martian days and drive 600 metres.

Opportunity has since driven the first off-Earth marathon (42.2 kilometres, or just over 26 miles) and just passed through its 4,000th Martian day – known as a sol on the Red Planet, lasting 40 minutes longer than on Earth.

I've been fortunate to have been involved with the project from the start, but never would I have thought that besides my wife's companionship, the other constant in my life would be a robotic rover

roaming across the surface of a planet hundreds of millions of kilometres away. To put this in perspective, since Opportunity landed I finished my PhD, started a family, and worked at six institutions in three different countries.

Opportunity found fame and fortune early on. Right where it landed, finely-layered sedimentary rocks revealed evidence that liquid water had once pooled on the Martian surface. Mars is a prime location for the search for life outside our own planet, and water is the most important prerequisite for life. That discovery was hailed as the scientific breakthrough of 2004 by the journal *Science*.



Looking back at the landing module in Eagle crater, where Opportunity found water. NASA/JPL-Caltech/Cornell/USGS/ASU

Opportunity then had to become more daring. As only impact craters reveal what is hidden below the sand that covers most of Meridiani Planum where the rover had landed, the exploration strategy adopted was to hop between craters.

Crater-hopping on Mars

From 20-metre-wide Eagle crater via the 150-metre Endurance crater and 800-metre Victoria crater eventually to the 22km-wide Endeavour crater: with each successive crater the next seemed always beyond reach – or so it seemed to us, so far away. It took more than 600 sols to traverse roughly 6km between Endurance and Victoria – and more than 1,000 sols to cover the 21km from Victoria to Endeavour.



A 26-mile Martian marathon, and counting, for the 11-year-old rover. NASA/JPL-Caltech/Cornell/USGS/ASU

Opportunity drove in and out of Endurance and Victoria craters – a dangerous, potentially mission-ending undertaking that had to be cleared by NASA headquarters in advance. In the process it took images of and investigated spectacular cliffs of layered sandstone within the craters. More water was discovered at Endeavour, but unlike the previous discovery, this time it was from an earlier Martian eon and was non-acidic and more friendly towards life.

Between craters, Opportunity could investigate rock fragments that had landed on top of the sand sheet and in doing so discovered meteorites among the rubble. Opportunity's twin rover Spirit and, more recently, NASA's Mars Science Laboratory rover, Curiosity, had already observed iron meteorites from a distance. After all, chunks of iron metal glinting in the sun appear otherworldly – even on another world. But only Opportunity was able to take a detailed sample of their composition – and only Opportunity discovered stony meteorites. While the fragments were discovered several kilometres apart, they seem to part of a larger whole – possibly the massive impact that created the Victoria crater.



Opportunity's view from the top of Cape Tribulation into the Endeavour crater. NASA/JPL-Caltech/Cornell/ASU

Danger everywhere

There were occasions where it was touch and go whether Opportunity would be able to continue its journey. En route to Victoria crater, the rover got stuck in a sand dune – subsequently dubbed Purgatory – and it took 38 sols to free itself. On another occasion, one of the notorious Martian dust storms that extend across entire regions blocked out much of the sunlight for days on end, threatening to permanently shut down the solar-powered rover.

However, perhaps the greatest threat to its continued mission is man-made: NASA's latest budget proposal is not sufficient to continue Opportunity's operations. While our rover certainly now shows signs age and wear, Opportunity has gathered many friends and admirers during its long journey and there is realistic hope that funding for another mission extension can be found.



After 4,000 days, looking out to a rocky spire in Mars' Spirit of St Louis crater. NASA/JPL-Caltech/Cornell/ASU

So, how did Opportunity celebrate its 4,000 days? She drove five meters onto an outcrop peninsula inside Spirit of St. Louis crater, a small crater among the rocks marking the rim of the much larger Endeavour Crater and sniffed the air with her Alpha Particle X-ray Spectrometer. True to her name, Opportunity is still more than capable of making important new discoveries, generating new records with each passing day. It's been a pleasure working with Opportunity so far, and I hope that she'll remain part of my life for a while yet.

 Mars  Curiosity  Opportunity rover

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