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Nasa rides 'bucking bronco' to Mars

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How to put a science lab on Mars

It weighs almost a tonne, has cost more than $2bn and, in 2013, it will be lowered on to the surface of Mars with a landing system that has never been tried before.

The Mars Science Laboratory will "revolutionise investigations in science on other planets", says Doug McCuistion, director of Nasa's Mars exploration programme.

It will, he says, lay the foundations for future missions that will eventually bring pieces of the Red Planet back home to Earth.

"The ability to put a metric tonne on the surface... gives us the capability to undertake sample collection," says Dr McCuistion. "To collect and launch samples back into orbit will require that size of a vehicle."

> **“It behoves us to plan our steps on Mars carefully”**
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> Adrian Brown, Seti Institute

But it has been a rather bumpy road to revolution.

The project has been struggling with technical challenges for several years, but Jim Green, the director of Nasa's planetary science division, recently announced to the planetary science subcommittee that the project had finally turned the corner.

Adrian Brown, a planetary scientist from the Seti Institute in California, has been watching the project's progress closely. He says that MSL managers have been riding a "bucking bronco" since it was first proposed.

The first official cost estimate for MSL's budget was set out in 2003. It was to be a "lander to carry out sophisticated surface observations and to validate sample return technologies". It would be a "medium cost" project.

So stated a document published by the National Research Council (NRC), which said that projects in this medium price bracket would come in at under $650m (£412m).

MSL is described as "Mini Cooper-sized"

But, at this point, the extent of the technology aboard MSL had been sketched out in only the most

general terms. NRC's estimate was very modest.

In 2006, the US Congress approved a figure of $1.63bn for the mission. This was the estimate from Nasa's Jet Propulsion Laboratory (JPL), whose engineers would build the mobile laboratory, as well as an audacious "sky crane" system to land it safely on Mars.

The most recent estimate for the total cost is just under $2.4bn (£1.5bn).

This discrepancy led some scientists to criticise JPL for poor management. And many feel that the project is bigger than it needs to be.

Dr Brown points out that we could have learned more about Mars by "going to a variety of landing sites with smaller robots but more accurate landing systems, so we could get on to challenging terrains".

"MSL is a fantastically capable vehicle, and should provide some great science," he says. "But it behoves us to plan our steps on Mars carefully and deliver on the public expectations of a cool and exciting, but well planned, robotic exploration of the planet."

Dr McCuistion argues that the budget "has not slipped dramatically" and stresses that MSL will indeed be worth it.

"This is completely the next step," he says. "We're essentially taking a small chemistry lab and compressing it into a rover."

Launch delay

The technical problems that plagued MSL - also known as "Curiosity" rover - eventually led Nasa, in 2008, to postpone the launch date by two years to 2011 - a delay estimated to have cost $200m.

Dr Brown says that the decision to make the rover so large turned it into something that JPL's engineers could not accomplish before the 2009 initial launch date.

Nasa plans to launch MSL to the Red Planet in 2011

The problems were mainly in two areas, says Dr McCuistion.

"The first was the avionics," he explains. "They were brand new… and much more challenging to build than expected.

"The other thing was the actuators. These are motors, each with a transmission built into one integral unit."

The sheer size and weight of MSL made these motors extremely complicated. In the largest of the rover's 50 actuators, there are up to 600 parts.

"They're designed to operate at very low voltage but create very high torque levels - to be able to move this 900kg rover, and they have to operate over an extreme range of temperatures," says Dr McCuistion.

The motors will drive the "Mini Cooper-sized rover" as well as move robotic arms that will reach out and grab samples from the surface of Mars for analysis by its on-board scientific instruments.

Putting these huge technical challenges aside, there was one nasty shock for Nasa that contributed to the delay. The agency unwittingly used a "bad batch" of titanium to build more than 1,000 parts on MSL.

Nasa purchased what it believed was military grade titanium from California-based Western Titanium.

"Someone [at that company] made a mistake," says Dr Green. "They certified that the titanium they were selling us, and that we were using, had a certain capability. It didn't."

This has meant painstaking verification of all of the titanium parts - to check they have the structural strength to withstand the launch.

"We're not quite done with that," says Dr Green. "But it doesn't look like it will be a show-stopper."

Back on track

With the budget settling down and the technical problems being gradually ticked off the list, Nasa now has to decide where to land its precious roving laboratory.

The planetary sciences advisory panel has looked at more than 50 possible landing sites and whittled those down to four finalists. The ultimate aim is to set MSL down safely (and softly), close to an area that looks scientifically interesting.

> **"We're looking at habitat potential - indicators of life rather than life itself"**
>
> Doug McCuistion, Nasa

"All four of the finalists are very high science merit and it's unclear which one will emerge as the winner," says John Grant, a scientist from the Smithsonian Institution in Washington DC, and a member of the advisory panel.

"The single objective of MSL is habitability," he says. "That entails looking at geologic environments that may not only have been habitable but where signals associated with that habitability have been preserved."

Dr Grant avoids using what he calls the "four letter word". MSL, he says, is not a life detection mission.

Doug McCuistion says: "We're looking at habitat potential - indicators of life rather than life itself."

Three orbiters currently keeping a close eye on Mars from space, have pointed Nasa to the most scientifically enticing sites.

"We have seen clays on the surface from the Mars Reconnaissance Orbiter (MRO), which is extremely exciting," says Dr McCuistion. "That shows us long periods of water."

MRO's camera can also identify potential dangers - showing the scientists boulders as small as 1m across that might damage the valuable rover.

Nasa scientists want to find an area where the geology could have preserved signals of life. They hope to set down on a flat landscape within reach of rocky minerals, such as sulphates and phyllosilicates, which, at least on Earth, are associated with the preservation of fossils.

The team will make its final landing site recommendation to Nasa early in 2011.

Where will MSL land?

Enlarge Image

Gently does it

And how do you go about guiding and landing a tonne of scientific equipment on to the surface of a planet more than 55 million kilometres away?

For this, JPL's engineers have come up with a new system - the sky crane.

"You can think of it as a rocket-powered helicopter that will hover and then lower MSL to the surface on a harness called a bridle," says Doug McCuistion.

"It lands on its wheels and as soon as it puts its mast up, it's ready to go."

Once this system has safely delivered MSL to Mars' surface, it will be used for other large rovers and platforms for sample return missions that Nasa plans to embark upon after 2020.

MSL's parachute was tested in the world's largest wind tunnel

But this mission remains the sky crane's first and only test.

"The only place you can test it end-to-end is on Mars, so it carries a certain risk," says Dr McCuistion. "Setting down MSL is definitely the most nerve-wracking part. It's hard to hold your breath for six minutes."

If all goes well, Nasa says the stage will be set for the next big step forward - bringing samples back from Mars.

This is something that Nasa and the European Space Agency (Esa) were planning to work on collaboratively. This mission's creeping budget, however, brought the two agencies together early to work on an orbiter set for launch in 2016.

This has meant a reprieve for the orbiter.

"We had [made the decision to go] from a lander, because of MSL's budget needs, to a small orbiter mission," explains Dr McCuistion.

> **“It's only one rover and it's only going to be looking at one spot on Mars”**
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"That did dramatically limit the science we could do in 2016. But partnership with Esa allowed us to go back to a full-sized orbiter, with full science complement and telecommunications capability.

"It came at a very advantageous time."

But Dr Brown says this Nasa-Esa mission has only come about because of "the unexpected growth of MSL" and that, without the motivation of another lander project, JPL might struggle to keep its engineers interested.

"It will be an exciting mission to look for methane in the atmosphere," he says.

"Missing the opportunity to put a rover on the surface in 2016 and 2018 will seriously strain Nasa's ability to keep rover engineers at JPL on staff and ready for the Mars sample return mission around 2020."

Shrinking back

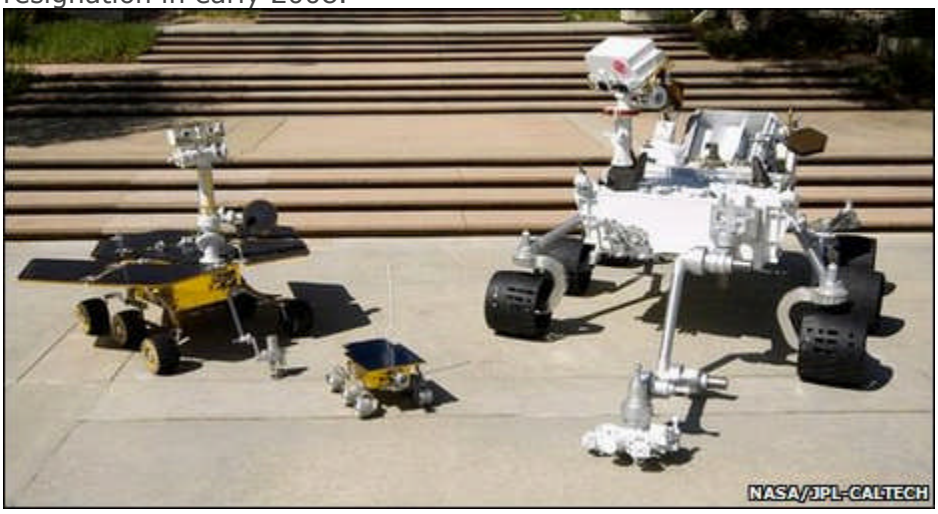
Dr Brown warns that Nasa could be putting all of its eggs in one very expensive basket.

"MSL is only one rover," he says, "and it's only going to be looking at one spot on Mars. It has meant that the Mars programme will be shrunk in the latter half of this decade."

Alan Stern, formerly associate administrator for Nasa's science mission directorate, has gone much further. In a 2008 article in the New York Times, he likened Nasa missions' inflated costs to a "cancer

overtaking our space agency".

He also said that he was admonished by Nasa executives when he attempted to curtail the cost increases associated with science missions, including MSL. These confrontations eventually led to his resignation in early 2008.



A scale model of MSL dwarfs the previous two generations of Nasa Mars rover

"The costs of badly run Nasa projects are paid for with cutbacks or delays in Nasa projects that didn't go over budget," he wrote. "Hence the guilty are rewarded and the innocent are punished."

But Dr McCuistion remains bullish about the budget and very positive about the science and engineering value of MSL.

He tells BBC News: "It has not taken money away from anything else. When we had to move the launch date, I had to pay for that with my 2016 budget.

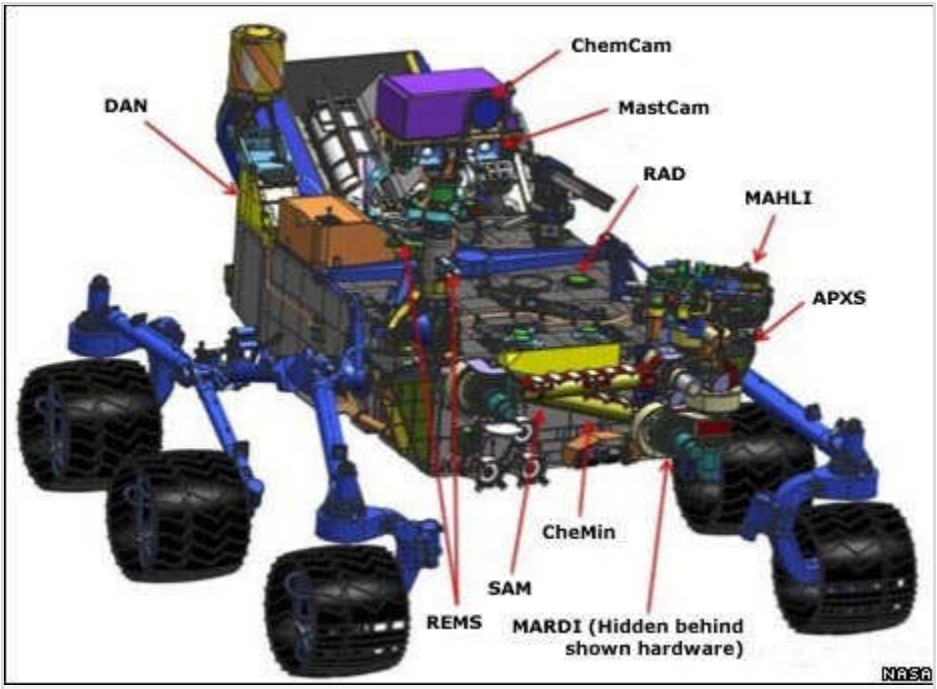
"MSL is the most capable system ever put on the surface of another planet," he continues. "It eclipses the Viking landers in its ability to do chemical analysis on the surface of Mars.

"It's also guided entry, so we will be able to access areas of the planet we never have before."

Dr Brown stresses that, should MSL succeed, it will indeed be a "great outcome".

"It will give us the capability to land all the components of a Mars sample return mission, hopefully around 2020," he says.

"But, to keep us on that path, JPL must openly review its overhead, planning and costs procedures, so that Mars sample return can become a reality."



The Mast Camera (Mastcam) will take images and video footage of the terrain
Mars Hand Lens Imager (MAHLI) will allow MSL to examine samples
Mars Descent Imager (MARDI) will take colour video during the rover's descent
Alpha Particle X-Ray Spectrometer (APXS) will measure chemical elements in rocks and soils by exposing material to alpha particles and X-rays
Chemistry & Camera (ChemCam) will fire a laser and analyze the composition of the materials it vaporises
Chemistry & Mineralogy X-Ray Diffraction/X-Ray Fluorescence Instrument (CheMin) will measure the abundances of various minerals
Sample Analysis at Mars (SAM) instrument suite will search for organic compounds that are associated with life
Radiation Assessment Detector (RAD) will prepare for future human exploration, measuring high-energy radiation on the planet's surface
Dynamic Albedo of Neutrons (DAN) will look for neutrons escaping from the planet's surface. If liquid or frozen water happens to be present, hydrogen atoms slow the neutrons down
Rover Environmental Monitoring Station (REMS) will monitor the weather on Mars