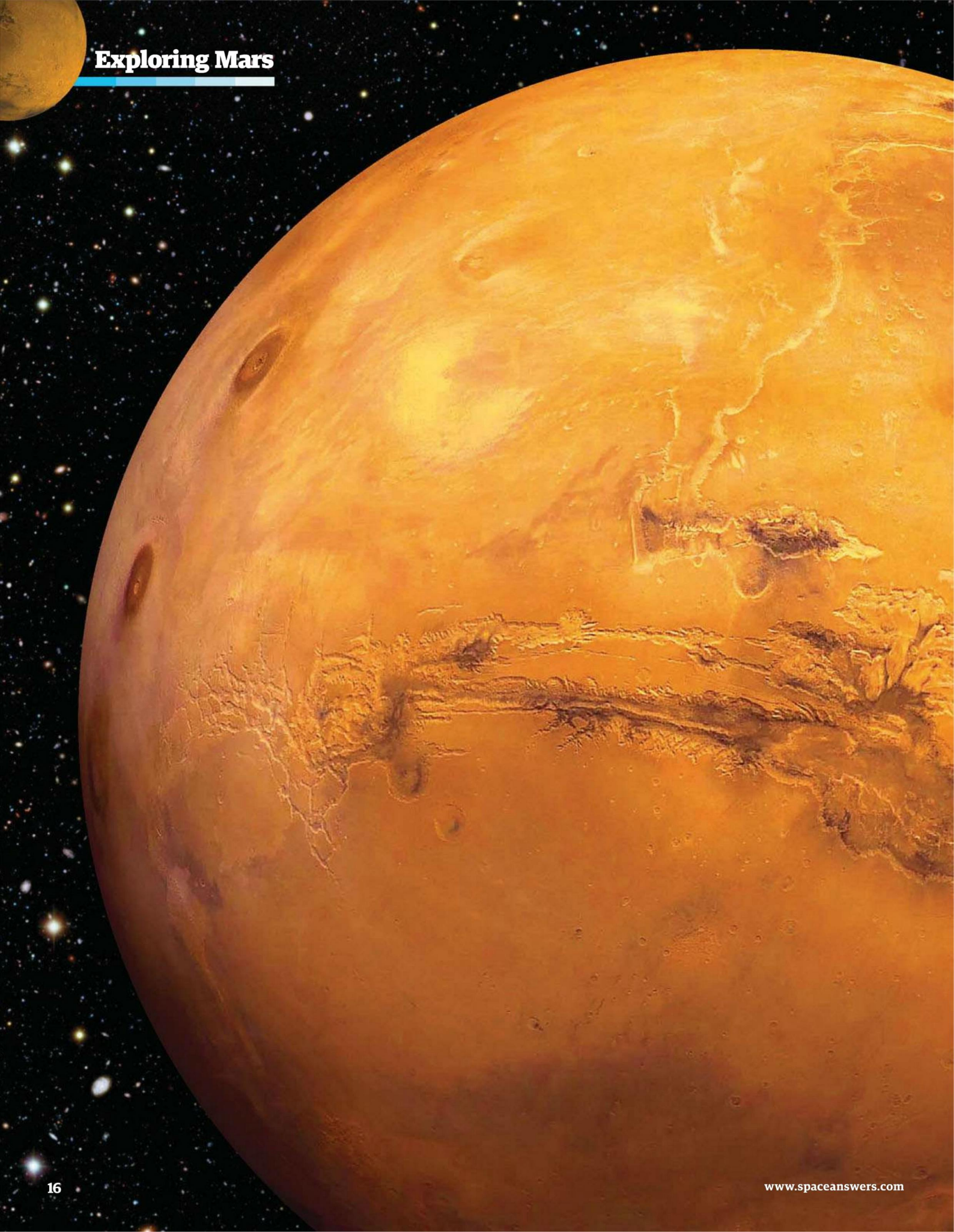


Exploring Mars

The Mars Science Laboratory will be the greatest mission to ever explore another world. It'll probe the Red Planet's ferocious past, uncover its mysterious present and, through the search for life, it may be a precursor to future manned missions

Written by Jonathan O'Callaghan

The Mars Science Laboratory (MSL), also known as the Curiosity rover, is NASA's most ambitious robotic mission to date. It will be the largest and most sophisticated machine to ever land on another world, and its ultimate objective is driven by the fact that life is thought to have once existed, or perhaps still does, on the Red Planet. Mars has been the subject of numerous missions over the past four decades but Curiosity is set to rove its surface like never before.

The rover is huge and complex, with ten different instruments on board that will probe the surface of Mars in unprecedented detail. "It's our most ambitious robotic mission," says Michael Meyer, program scientist for the MSL mission and lead scientist for the Mars Exploration Program, when we spoke to him. "This is the most complicated mission we've done and it's designed to last for [at least] a Mars year, so we're going to take it slow and make sure we don't break anything in our rush to get data."

Curiosity will be the largest landing vehicle ever to operate outside the confines of Earth, a behemoth of a machine almost 1,000 kilograms (2,200 pounds) in weight and the size of a car that will revolutionise our


Curiosity dwarfs the other Mars rovers by quite a margin

understanding of Mars when it lands on 6 August 2012. With a multitude of sample analysis instruments, cameras and even a hi-tech laser it is absolutely unmatched in its design.

The mission is designed to last 686 Earth days, approximately one Martian year. During this time Curiosity will carry out some groundbreaking science on the surface in addition to testing out new technologies and methodologies. The rover is somewhat autonomous, possessing the ability to move between two points while avoiding obstacles. However, to do so requires extensive daily input from the ground. "The challenge of [MSL] is that you can't just program it and collect your data in two weeks to see how it's going. You actually have to tell it what to do every day. That's what's going to pose a real challenge.

"One of the things that really makes this mission pretty exciting is that the amount of information that we have about the landing site from our orbital assets is phenomenal," says Meyer. "We've already plotted out likely pathways of where to go, and it's great to approach it with that sort of prior knowledge because when we find something that's different it's a real 'aha!' moment."

Curiosity will be the fourth rover to land on Mars, succeeding Sojourner, Spirit and Opportunity, and NASA has made sure to learn from the previous missions to optimise the data returned from this one. "Certainly we have greatly improved operations, and we have a much better sense of the kind of realistic timing for what we can do and what we can ask the rover to do." Indeed, as previously mentioned, one of Curiosity's greatest advancements on its predecessors is a greater degree of autonomous navigation. "On any of the runs where the rover goes more than 30 metres [100 feet], it can be done autonomously because we'll have enough data to plot out a good path," explains Meyer. "If we don't have enough information [about the topography] the rover can decide if it has an obstacle in the way and avoid it. The big science driver for this mission is not within the landing area, it's actually going up Mount Sharp, so because of that there'll be a fair amount of driving to get to the minerals we're most interested in early on in the mission." The rover, however, won't be speeding along the Martian landscape. It will take its time, going very slowly indeed. "To go 100 metres [330 feet] is doable in a day," says Meyer. "In theory you could maybe go 150 to 200 metres [490 to 650 feet]. Part of that is the wheels don't roll that fast, and the other part is that after a certain distance it has to stop and reassess its environment."

The Mars Science Laboratory will be landing in an area known as the Gale Crater, a 3.8-billion-year-old crater 154 kilometres (96 miles) in diameter. At its centre is the aforementioned Mount Sharp, towering 5,500 metres (18,000 feet) high. It was one of four candidates for a landing site and ultimately received the nod, but why was it picked? "All four [proposed] landing sites were pretty compelling," explains Meyer. "All four sites give you evidence of a place that has had water in the past, so they all met our criteria of a place that we think could have been habitable at one point. Any one of them would have been fantastic, but Gale has evidence of water in its past and it has two major minerals that we think are indicative of different periods of time on Mars: clays and sulphates. There's also layering there, which we think will give a somewhat ordered history of Mars. Gale has sedimentary deposits that we think traverse a period of time when Mars went from being relatively warm and wet to what it is now: cold and dry."

The most interesting thing about Gale, though, is that it has the possibility of organics or, in other words, past or present signs of alien life. This ties in directly with one of the key goals of Curiosity's mission, namely discerning whether Mars was or is habitable, a question that no other mission has yet been able to definitively answer. "With any sedimentary deposit you have the potential for preservation of organic material," says Meyer. "One of the surprises of the Viking probe was actually that they didn't find organics. You would expect to find some because you get them from meteorites and the like. So the big science revelation [from Viking] was that something's happening on Mars that destroyed the organics, at least on the surface. So we're hoping that by going to a place where you have these deposits laid out, that something buried may be preserved."

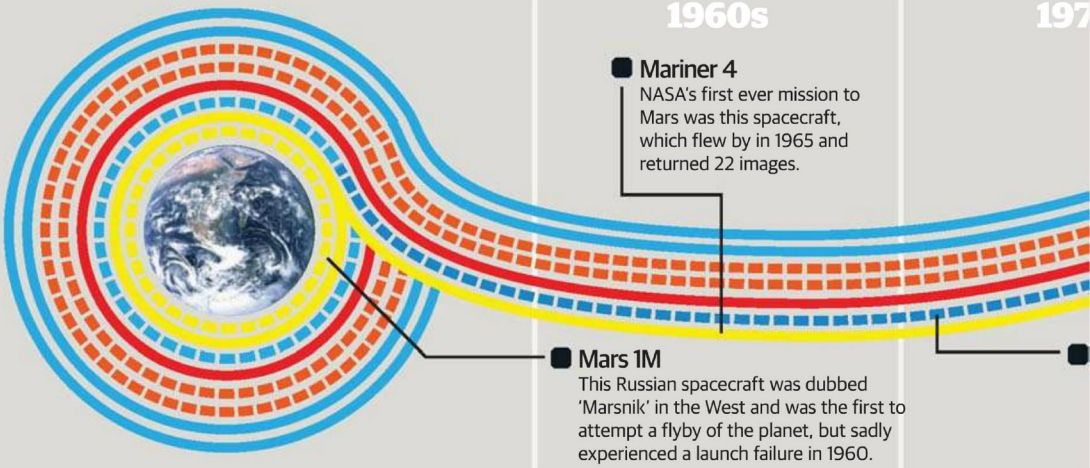
To find these hidden clues to the Martian past, Curiosity has a variety of hi-tech instruments on board. These include ChemCam, a laser that will vaporise areas of rock for Curiosity to analyse, and SAM (Sample Analysis at Mars), an instrument suite that will discern the molecular and elemental chemistry of soil samples collected by a drill on Curiosity's extendable arm. Meyer is fairly confident that Curiosity would be the mission that would find signs of habitability. "We expect to find organics from meteorite impacts, brought in from outer space. We also expect to find organics that were made on the planet, so this is a great lead into that. And then of course the million dollar question is: are there organics made by Martian life?"

So, will MSL be able to answer that question? "Definitively, no," says Meyer, "but there is a possibility, there is always a possibility. Carl Sagan [the American astronomer] said that even a camera is a life-detection instrument. If something hops in front of the camera then you know it's alive. But the camera was not designed to specifically look for things to hop in front of it. MSL is designed to understand the environment in which it lands."

One of the most fascinating features of this Mars mission, and one that scientists hope might be used in future Mars missions, is the

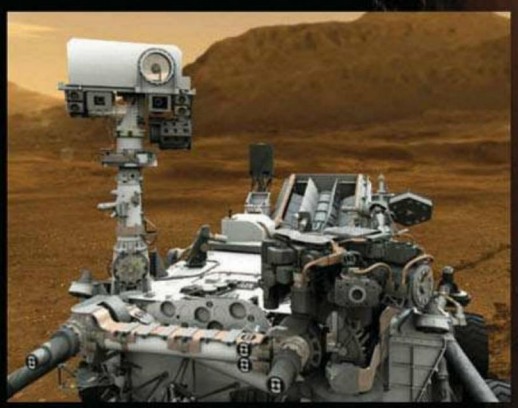
Mars mission history

Dozens of robotic spacecraft have made the hazardous journey to the Red Planet since the Sixties, with mixed results...



4 goals of going to Mars

The Mars Science Laboratory has four primary scientific goals that it will be looking to fulfil in its time on the surface of Mars. While it will perform other research as well, it is these goals that pose the greatest unanswered questions about the Red Planet



Curiosity will be able to return high-resolution images and video from the surface of Mars thanks to its on-board cameras

Is, or was, Mars habitable?

One of the strangest things about Mars, surprisingly, is that life has not yet been found. The planet has been pummelled by meteorite impacts, thanks largely to its thin atmosphere, and therefore we would expect to find organics of some kind. Curiosity will tackle this problem head-on, studying the mineralogical composition of the surface to discover what mysterious past this planet is hiding.

What is Mars's climate like?

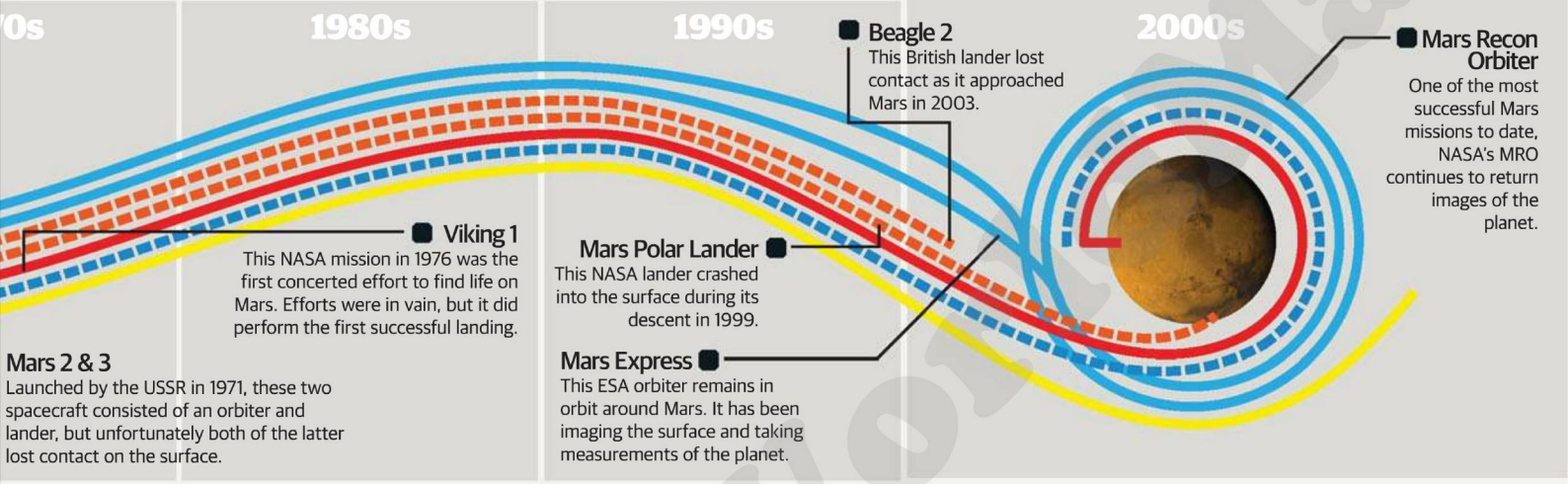
It is thought that in the past Mars may have been warmer and therefore had a thicker and wetter atmosphere compared to the thin, cold atmosphere it has now. The determination of whether water exists underground or once gouged the surface is imperative as life as we know it cannot exist without water. By measuring elements such as carbon, Curiosity will look for abrupt changes in the abundance of certain elements that could be associated to life forms.

Does Mars have a volatile history?

It is generally accepted that Mars is a much different world to what it was a few hundred million years ago, but what caused this change is still unknown. Of great interest to Curiosity will be Mount Sharp, in the Gale Crater. This mountain could have layers of sedimentary deposits of Martian history, similar to the layers of deposits we see on Earth. By studying various rocks and soils on Mars, Curiosity will be able to understand some of the geological processes that sculpted Mars.

Could we launch a human mission to Mars?

The Sky Crane is the only current landing method that can land 1,000kg (2,200lb) on the surface of another world, a necessity for a manned mission. By demonstrating that the Sky Crane works, Curiosity will pave the way for human explorers to use the same design to land on Mars. In addition, Curiosity will also study the levels of radiation to unearth any potential hazards that might face future explorers.



revolutionary Sky Crane concept that will land Curiosity in the Gale Crater. We were keen to find out why this design had been picked. "It wasn't just the desire to have something that looked like a Rube Goldberg device," explains Meyer. "When it came to Curiosity we wanted to build a system that we could use not only for this mission but also for future missions. We needed to find out how we could get a metric ton to the surface. With Sky Crane, we can do that."

However, as incredible as the Sky Crane concept looks there's still a significant chance of failure, especially as the whole routine is handled autonomously. "If you just look at statistics, like the percentage success rate of going to Mars, the odds aren't very good. We've been lucky in our US landed missions, we've been very successful. We are confident in that we're well over a probability of 90 per cent for landing but it's a tough one where one rock can do you in. You can do everything right and be unlucky. That's kind of why I would prefer to go somewhere else [during the landing] and find out a couple of days later if we actually made it, so I don't have to go through all that anxiety!"

While Curiosity will probe the Red Planet in an unprecedented manner, it's not too soon to consider what missions might come next. Of course, human exploration is one of the ultimate goals, but Meyer has some other thoughts on what would be best for the future. While orbiters like NASA's Mars Reconnaissance Orbiter will continue to play a role, he asserts that landing on Mars is the real driver for future missions. "I really think the science is on the surface. I think what will happen is that we'll have small rovers with different and more sophisticated instruments, and they might not be quite so ambitious in terms of the number of instruments [like MSL]. The expectation is that we'll have these things that are smaller and work just as well. And I think we ultimately need to work towards sample return, because there's so much we can do with a sample when we bring it back to Earth."

But does Meyer think sample return would be best done by humans or robots? "I think the first time we go and get samples on Mars, we want to do it robotically," he says. "Part of the reason is you can make a robot a lot cleaner than an astronaut! And there's also an issue with astronaut safety and that sort of thing. How you actually bring it back can be done robotically or you can have astronauts orbit Mars and pick it up."

There's little doubt, then, that the Mars Science Laboratory will be set to change Mars exploration completely, increasing our understanding of the past and present and leading the way to future missions.

At the time of going to print there's still the chance the landing will be unsuccessful, but NASA is confident and we'll certainly be sitting with fingers crossed as it descends to the surface. Through this incredible mission we will be able to answer some mysterious questions about Mars and maybe, finally, discover if it was or is a truly habitable world. ●

Is this the most ambitious space exploration mission of all time? @spaceanswers #GreatestMission

"You can't just program it and collect your data in two weeks and see how it's going. You actually have to tell it what to do every day. That's what's going to pose a real challenge"

Michael Meyer, lead scientist for NASA's Mars Exploration Program

Building the Mars Science Laboratory

The key steps in the development of this incredible rover

1. Mars heat shield constructed
2. Parts assembled
3. Wheels tested
4. Core of Curiosity assembled
5. Arm tested
6. Obstacle avoidance
7. Further testing
8. Instruments adjusted
9. Vacuum test
10. Sky Crane attached
11. MSL enters capsule
12. MSL readied for final assembly
13. Heat shield and capsule aligned
14. Mars spacecraft sealed
15. Inside the Atlas V payload fairing
16. MSL prepared for enclosure
17. Protective payload fairing sealed
18. MSL prepped for Atlas V
19. Atlas V launches on 26 Nov 2011
20. MSL begins surface operations

How Curiosity measures up

The Mars rovers that led the way for Curiosity

Sojourner

Size: 0.63 x 0.48 x 0.28m
Weight: 10.5kg

The first rover to operate on another planet was this tiny NASA vehicle, the size of just one wheel of Curiosity, which landed on 4 July 1997 near the Martian equator and lasted until 27 September 1997.

Spirit

Size: 1.6 x 2.3 x 1.5m
Weight: 174kg

Spirit, the first of the two Mars Exploration Rovers, landed at the Gusev Crater on 4 January 2004. It operated until May 2009 when it got stuck in soft soil and succumbed to the Martian weather.

Opportunity

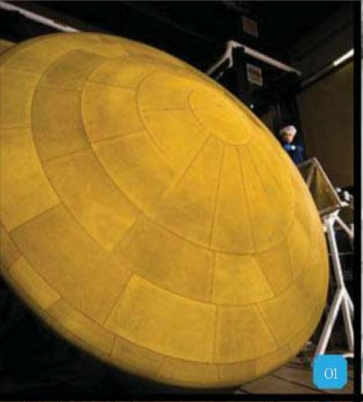
Size: 1.6 x 2.3 x 1.5m
Weight: 174kg

Opportunity landed on 24 January 2004 at Meridiani Planum, three weeks after its sister rover. Until the arrival of Curiosity it is the only vehicle currently operational on the surface of Mars.

Curiosity

Size: 3.0 x 2.8 x 2.1m
Weight: 900kg

More than twice the weight of all the other Mars rovers combined, the MSL is a monster. Eight years in the making, its hi-tech instruments will probe the fourth planet from the Sun like never before.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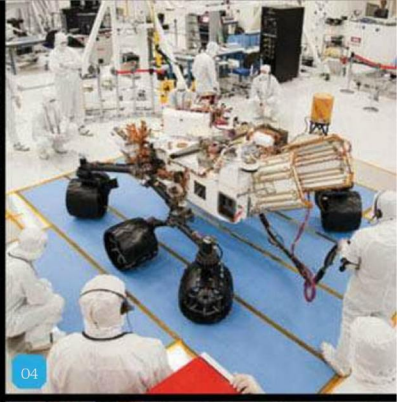
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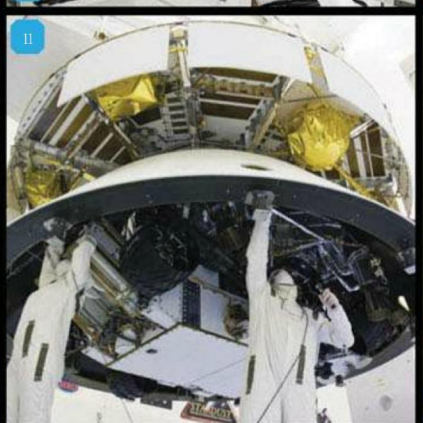
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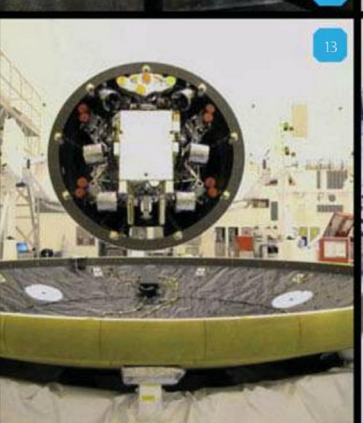
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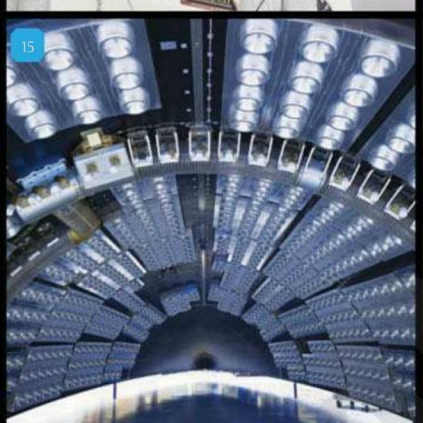
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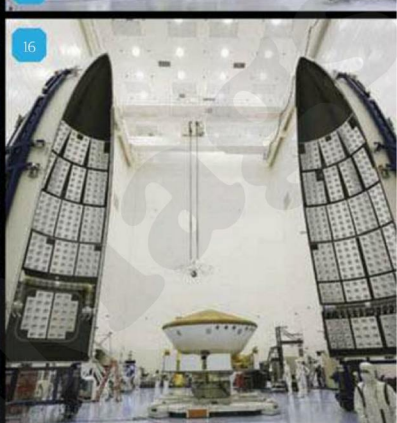
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"Seven minutes of terror"

How do you slow a spacecraft down from 13,000mph to zero in just over 400 seconds?

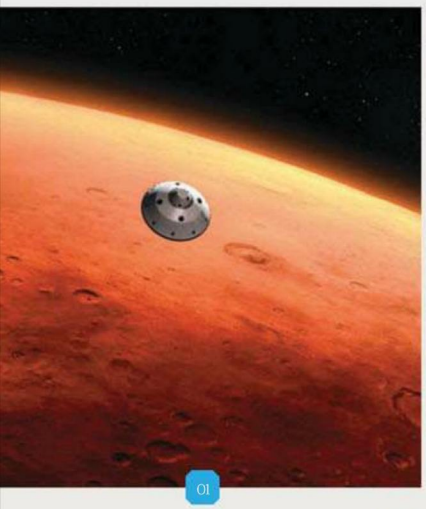
Set to land on 6 August 2012, MSL's groundbreaking Sky Crane will enable the craft to traverse Mars's atmosphere before its make-or-break touchdown on the planet's surface in a descent which NASA has described as "seven minutes of terror".

A landing mechanism that is as thrilling as it is terrifying, the Sky Crane could revolutionise how we land on other worlds. Previously, it was thought that air bags would be the only option to land on a planet such as Mars, but now it's widely believed that future off-Earth landings will use a Sky Crane design to lower vehicles to the surface.

Curiosity will have a much greater degree of control as it plummets through the Martian atmosphere than any mission before it. As it descends it will jettison some weights, putting the centre of mass of the descent capsule off balance and allowing the craft to manoeuvre through the atmosphere.

Such is the accuracy of the descent that NASA has been able to pinpoint a fairly precise area in which it expects Curiosity to land. The landing culminates with a rocket-powered descent after the parachute phase.

One of the benefits of this landing design is that Curiosity is placed straight down onto the surface rather than rolling off a ramped platform like Sojourner, Spirit and Opportunity. While alleviating some hazards, such as the ramp getting stuck, Curiosity might still encounter problems. If it lands on top of a rock engineers will need to carefully manoeuvre it to a safer position. Mission controllers must make sure there are no hazards immediately around the vehicle, such as rocks or an uneven surface, before it can begin scientific operations.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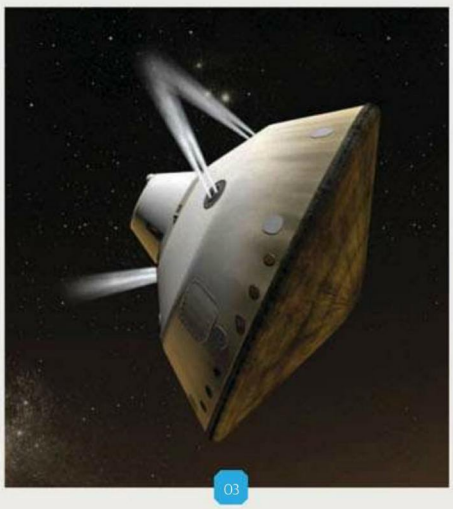
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1st minute: Dead or alive

Curiosity encounters the Martian atmosphere travelling at 21,000kph (13,000mph), more than 17 times faster than the speed of sound on Earth. The whole landing lasts seven minutes but it takes 14 minutes for Curiosity to communicate with Earth, so when ground control receives word that the rover has hit the atmosphere, it will have been alive or dead on the surface for seven minutes.

2nd minute: Into the frying pan

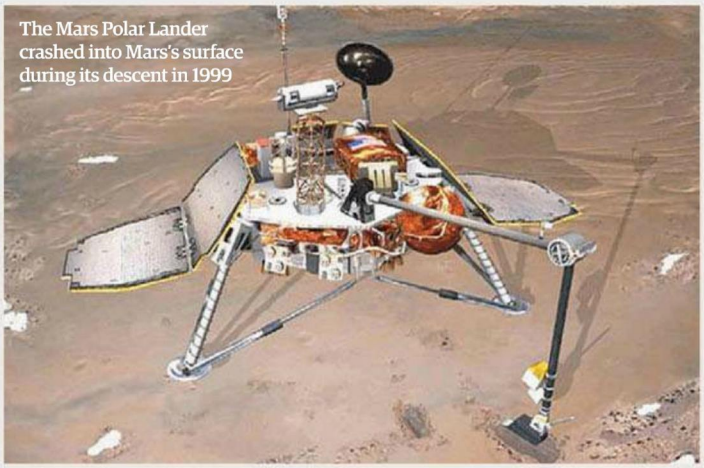
The atmosphere of Mars is 100 times thinner than Earth's. However, while it is not too thin to slow a spacecraft down completely, it is thick enough to tear an unprotected spacecraft apart. Therefore, as the capsule slams into the atmosphere, its heat shield bears the brunt of a 1,600°C (2,900°F) heat from atmospheric drag, glowing like the surface of the Sun.

3rd minute: Steering through the fire

As MSL makes its way through the atmosphere it is constantly steering itself with reaction thrusters, guiding itself like an aeroplane so that it can land in a precise area. In fact, it can manoeuvre so much that it could even perform an 'S' turn in the air.

4th minute: Chute for glory

After exiting the atmosphere the capsule will still be travelling at 1,600kph (1,000mph). To continue the deceleration, the largest and strongest supersonic parachute that has ever been built is deployed, snapping open at an incredible 5gs. Weighing just 100 pounds, it must withstand a force of 29,500kg (65,000 pounds) as it slows down the rover.



The Mars Polar Lander crashed into Mars's surface during its descent in 1999

What could go wrong?

At the time of going to print, Curiosity is still on its way to Mars. Therefore, by the time you're reading this, you might know already if it has made it safely to the surface or not. If it has, great! But if it hasn't, what might have gone wrong? As this is such a precise mission there is so much that could fail. During the intricately choreographed process every single aspect must work perfectly for the rover's seven-minute landing procedure to be a success. For example, if the parachute deploys too early it will be ripped to shreds. If the Sky Crane fails to disconnect it will pull the rover back into the sky before coming back to collide with Mars. Or, the mission could work flawlessly, but MSL could accidentally land on a large rock or loose sand, leaving it stuck on the surface.

However, NASA is optimistic. Not only has every eventuality been hopefully accounted for, but it has successfully completed a rocket landing before. Its Phoenix lander, in 2008, used rocket propulsion to lower itself to the surface of Mars's North Pole, although it didn't employ the same Sky Crane winch concept as Curiosity. There's no doubt, though, that if the rover lands it will be one of the greatest space exploration accomplishments of all time.

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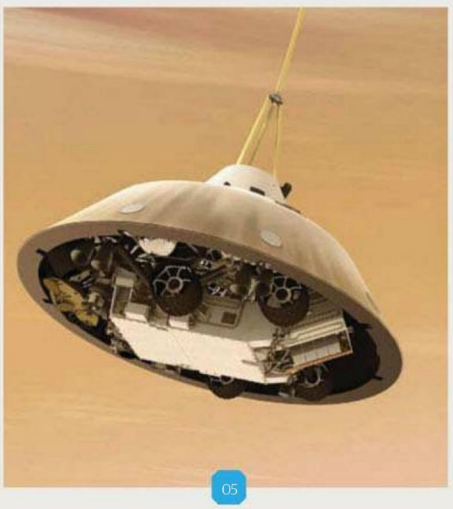

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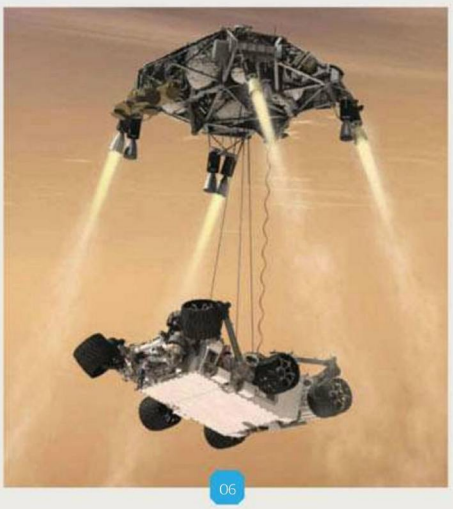

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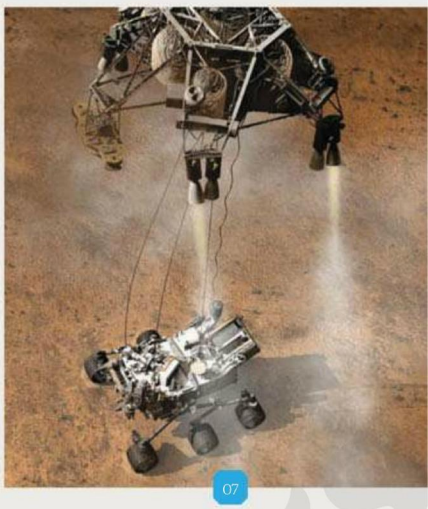

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6th minute: Sky Crane

Eight rockets on the Sky Crane suddenly spring into action, taking the rover off to the side to avoid the parachute overhead. This mechanism must then kill the horizontal and vertical velocity of the spacecraft and head for the planned landing site at the bottom of Gale Crater, right beside the 5.5km (3.4-mile) high Mount Sharp.

7th minute: Touchdown

The last minute of the mission is the riskiest. At this point the Sky Crane lowers the rover down from a height of 20 metres (65 feet) on four cables that are each 6.4 metres (21 feet) long. Slowly, the rover is touched down on the surface, the cables are released from the rover and the Sky Crane flies off to crash in the distance so that it does not land on the rover. Seven minutes later, ground control will receive a signal from the rover confirming it has made it to the surface, and the crux of the mission can begin.

5th minute: Cut off point

The parachute slows the craft down to 320kph (200mph), but this is not slow enough to land. The lower heat shield is no longer needed, so this is jettisoned, and then the upper portion of the parachute flies off, leaving the rover and its Sky Crane in freefall.

Landing Zone at Gale Crater

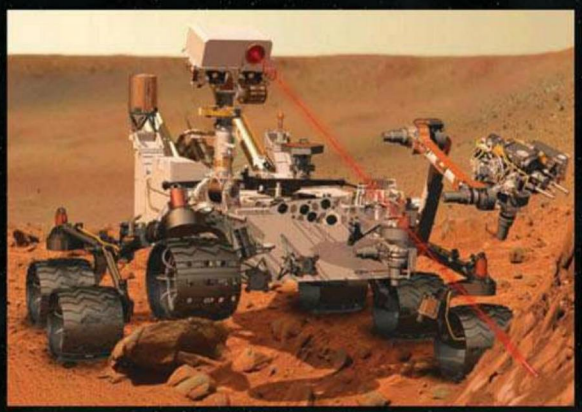
A year on Mars

What will Curiosity do once it has landed?

After landing, Curiosity enters the first drive phase, when engineers will conduct tests on the rover for five days to ensure it is in a "safe state" before moving it for the first time.

During the first five days several instruments will be deployed and tested, including the High Gain Antenna for communications with Earth and the sampling system. Once this has been completed, the rover will then run through some further checks before it is ready to move into uncharted Martian terrain for the first time.

Curiosity has a primary mission time of one Martian year, about 686 Earth days. It will travel up to 20km (12 miles) from its landing site and is expected to analyse about 70 samples of soil and rock throughout its primary mission. It is likely that Curiosity's operations on Mars will be extended if the primary mission is successful.



The ChemCam laser will allow Curiosity to examine the composition of rocks and soil on Mars

Curiosity's technologies

What's on board the rover?

Autonomous
It can take up to 40 minutes for a signal to be sent to Curiosity and a response received, so planning what the rover will do is of utmost importance. While Curiosity is somewhat autonomous, allowing itself to dodge rocks and other obstacles, it largely relies on input from the ground to carry out a task. This can be a very long process, from several days to weeks.

Sample Analysis at Mars
This instrument uses a sophisticated chemical lab to analyse samples from the Martian surface. A robotic arm will pick up samples and place them in the chamber to be investigated.

Cameras
The MastCam will take true colour images at 1,200 x 1,200 pixels and 720p video. Another camera, the Mars Hand Lens Imager (MAHLI), on the end of the robotic arm will be used for microscopic images of rock and soil.

ChemCam
Curiosity's ChemCam laser will be able to vaporise rocks from a distance of seven metres (23 feet), allowing Curiosity to study the resultant gas for signs of organics.

Drill
The drill produces a fine powder that can be sampled by one of several instruments on board.

Mars is strewn with interesting rocks that could provide clues to its possibly wet past

Mission destination

Curiosity is scheduled to last for 668 Martian sols, which is equivalent to 686 Earth days. At this point it will have reached a significant distance up Mount Sharp, but the rover is actually expected to last for many years after this just as Opportunity has done.

Mission destination

Mount Sharp

The crux of Curiosity's mission revolves around the geologically fascinating Mount Sharp. After driving across the flats of Gale Crater, the rover will make its way up the mountain, gleaning insights into Martian history along the way.

Landing Zone

Revised landing zone

NASA has been able to revise the landing zone as Curiosity approaches, allowing for a more precise ellipse 6km (four miles) wide and 19km (12 miles) long. This will shave months off its journey time to Mount Sharp if the landing is as precise as anticipated.

Original landing zone

As impressive as the Sky Crane is, it isn't able to perform a completely exact landing. In fact, the target area for Curiosity's landing was originally 19km (12 miles) wide and 26km (16 miles) long.

Observations

Studying an interesting rock will be no easy feat. Curiosity will approach the rock, and ground control will then discuss what sort of work they wanted to do on the rock. After debating which instrument to use, the rover would then bring that instrument into contact with the rock (in the case of the arm or the ChemCam laser) and slowly extract a sample to study, but only when the weather permits as otherwise Martian wind could blow away the sample. This whole process can actually take up to a month, so excessive planning must be done in advance.

"The first time we go and get samples on Mars, we want to do it robotically. Part of it is you can make a robot a lot cleaner than an astronaut"

Manned missions to Mars

When and how will humans land on the Red Planet?

The holy grail for Mars exploration has for many decades been to ultimately land humans on the Red Planet. After the Apollo missions in the Sixties and Seventies it was widely believed that Mars was the logical next step, but funding cuts left NASA in Earth orbit despite having a rocket, namely the Saturn V, that would have been capable of taking humans to the surface of Mars.

Therefore, for four decades the thought of human exploration of Mars was left by the wayside as a variety of spacecraft and space stations were launched into Earth orbit and beyond. Now, however, Mars is back on the space-exploration agenda, and getting there could be achievable with some upcoming technologies.

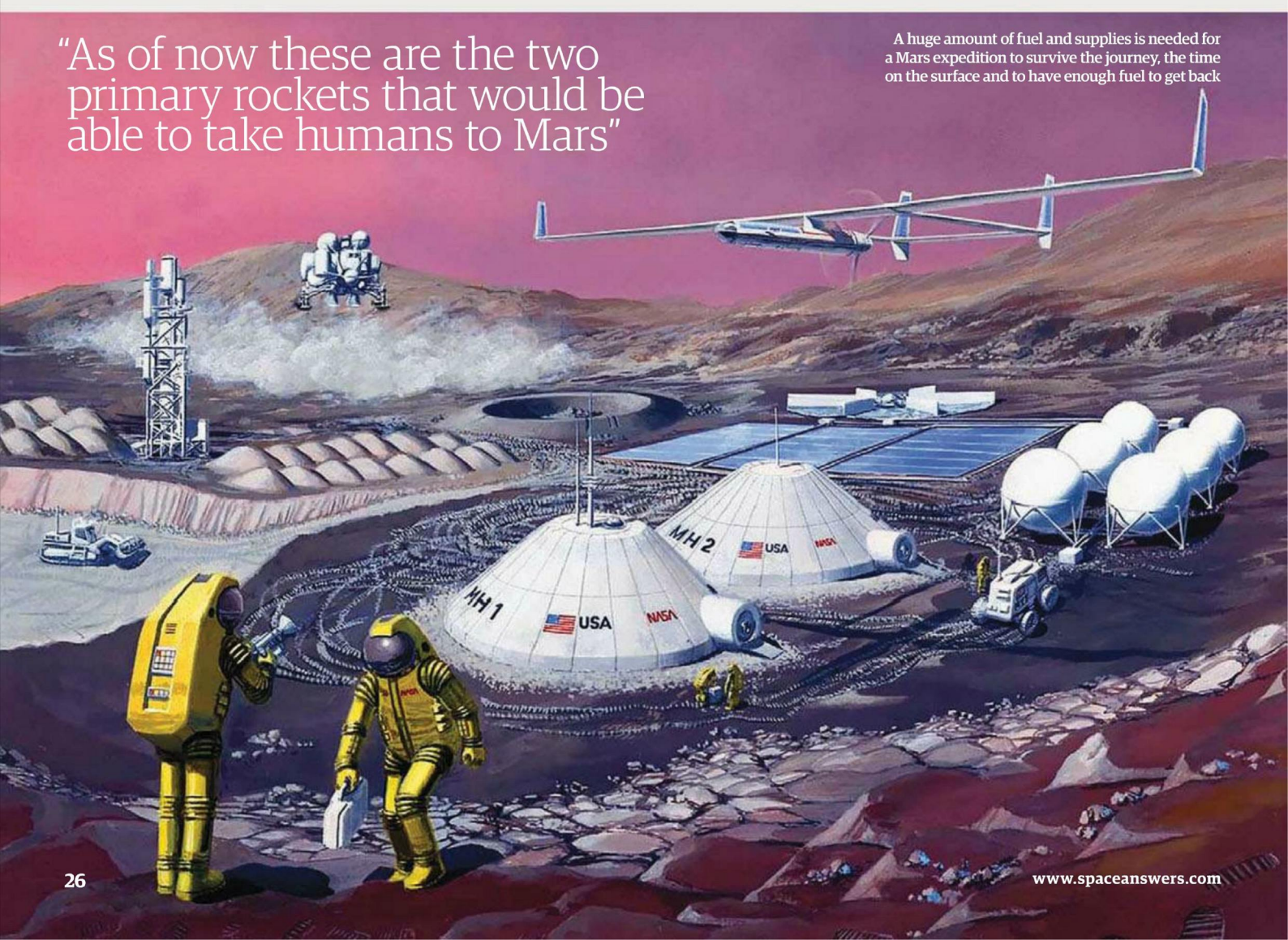
For starters, NASA is building its own successor to the Saturn V, known as the Space Launch System (SLS). Capable of carrying over 100,000 kilograms (220,000 pounds) into orbit, the SLS will have the capability to take humans to Mars, and indeed that appears to be NASA's ultimate goal. It is thought that, in the 2020s, the SLS will launch astronauts in an Orion capsule on trips to the Moon and a near-Earth asteroid. The next step will be to either land on one of Mars's moons, Phobos or Deimos, or head straight for the Martian surface by the 2030s.

The other rocket that could get us there is SpaceX's Falcon Heavy rocket. Employing three of the boosters already used on the successful Falcon 9 rocket, the Falcon Heavy will be able to take over 50,000 kilograms (110,000 pounds) to orbit. By combining several such launches it could be possible to launch a mission to the Red Planet. In addition, SpaceX is working on its own variant of its successful Dragon capsule that docked with the International Space Station in May, known as the Red Dragon, that could be able to land on and take off from the surface of Mars.

As of now these are the two primary rockets that would be able to take humans to Mars. It's likely, though, that over the next decade more agencies such as China will announce heavy lift rockets capable of taking the giant spacecraft that will be needed to mount a six-month journey to Mars. However, while the possibility of humans stepping on another planet will be ever present, it will likely require international collaboration to have any chance of success. ●

Will humans ever be able to land on Mars? @spaceanswers #HumansOnMars

"As of now these are the two primary rockets that would be able to take humans to Mars"



A huge amount of fuel and supplies is needed for a Mars expedition to survive the journey, the time on the surface and to have enough fuel to get back