New Scientist

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SPECIAL REPORT

PUTTING HUMANS ON MARS

The long trip, surviving the surface, and how to get back alive

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The surprising new answer rooted in human evolution

(Spoiler alert: it's not 10,000 steps)

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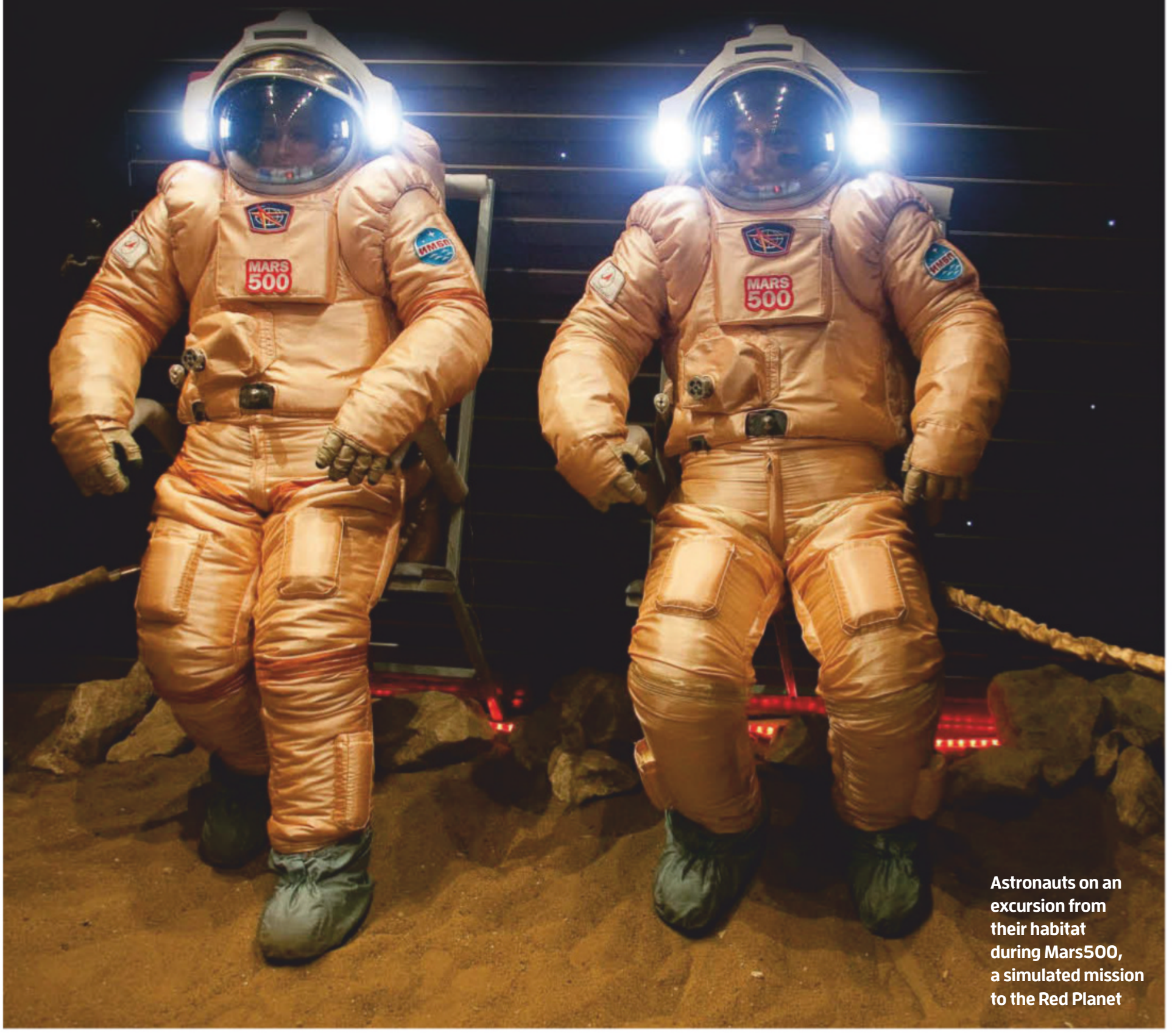
Destination: MARS

Leah Crane has your definitive guide to reaching our neighbouring planet and getting home in one piece



Astronauts on an excursion from their habitat during Mars500, a simulated mission to the Red Planet

IBMP, OLEG VOLOSHIN / EUROPEAN SPACE AGENCY/SPL

AS RUST-coloured dust blows across the empty plains and deep craters of Mars, it just occasionally dances over something made by human hands – perhaps the solar panel of a lander, or the wheel of a rover. The robots we have sent to our neighbouring planet have taught us plenty about it. It hosts the highest mountain in the solar system and probably has underground lakes of liquid water. Long ago it wasn't a freezing desert as it is now, but a warm, wet place. Yet we have never set foot there ourselves.

There's a good reason for that: getting to Mars is hard. Since 1971 there have been 18 attempts to land robots on Mars and 11 of these either crashed, fatally malfunctioned soon after landing or missed the planet altogether. If human lives are at stake, we need better odds of success.

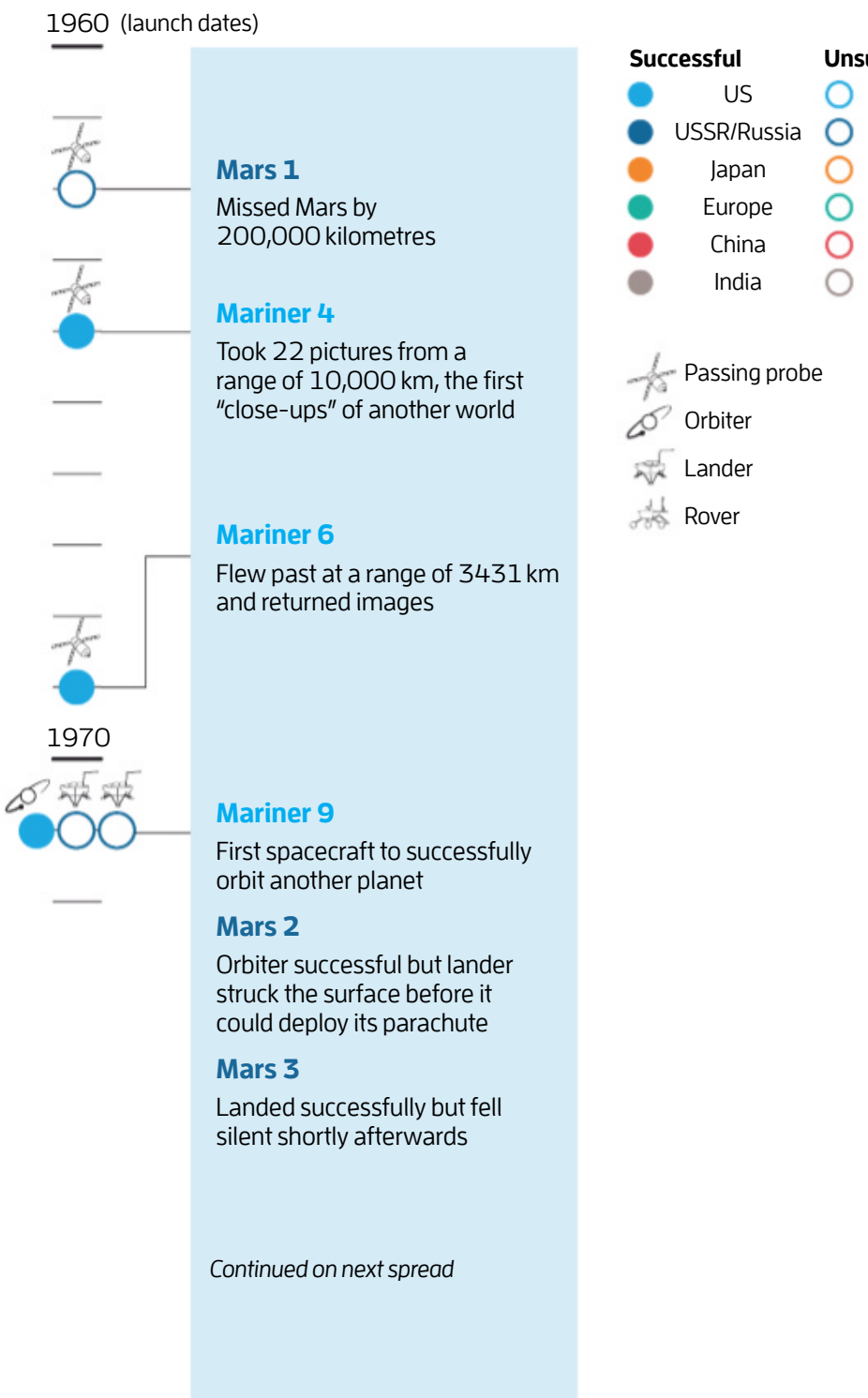
Putting humans on Mars is far from impossible. Doing so is a major goal for NASA, which aims to pull it off in a little over a decade. Elon Musk, the founder of SpaceX, has long said that he wants to build settlements on Mars. China, Russia and India all have their sights set on the planet too.

The most important driver for this Mars rush may be the prestige, but there are good scientific motivations too. While rovers can do marvellous things, they don't have the dexterity, knowledge or intuition that a human would bring to bear on one of the biggest questions our species has asked: are we alone in the universe? Mars is the best place to answer that, says NASA scientist Jennifer Heldmann. "And if you want to really learn about Mars, to answer those fundamental questions, you have to send humans."

To get there we will need to blast off from Earth with more supplies than we have ever put in space before, traverse millions of kilometres of deadly interplanetary nothingness, and land safely at the other end. It is daunting, but it isn't out of the question. Here is our step-by-step guide.

Mars missions

Humans have launched many spacecraft to Mars since the 1960s – whether to pass by, orbit, land on the surface or more recently to rove around – with varying success



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1. LEAVING EARTH

When Earth and Mars are at their closest, they are about 55 million kilometres apart. That sounds like a lot. But purely in terms of the propulsion systems needed, travelling that distance through space isn't actually too big an ask of our existing rocket technology.

Once you are far enough from Earth, its pull drops considerably and you could cruise to Mars using a reduced thrust. The journey would take about nine months, a little longer than an astronaut's standard six-month stint on the International Space Station (ISS). We don't need to dream up new types of engines or worry about things like solar sails, which accelerate very slowly. All we need is a big rocket pointed in the right direction.

Decades of space exploration have taught us a few things, chief among them being how to build big rockets. There are seven types of rocket in operation that could make it to Mars. The most powerful of these, SpaceX's Falcon Heavy, could shuttle about 18.5 tonnes there. That is more than enough for any lander or rover, but a human mission will be heavier. A crew of six along with food and water to last their journey there and back weighs in at a minimum of 20 tonnes. In 2017, a NASA report estimated that once you factor in scientific equipment and the kit needed to keep explorers alive on the surface – like a power generator and a place to live – a more realistic figure would be about 100 tonnes.

That's not unthinkable. Two rockets that are in development, NASA's Space Launch System (SLS) and SpaceX's Big Falcon Rocket (BFR), are planned to be more powerful than anything that has been launched before. SLS should be able to carry at least 45 tonnes of cargo to Mars, and BFR is expected to haul more than 100 tonnes. ›

New Scientist: The new quest for space

Next week, read how we are grappling to understand the solar system's mysterious evil twins, Mercury and Venus

In other words, building bigger, better rockets is something we know how to do. And we could always lighten the load by sending some equipment ahead of the humans. "Everything else is the hard part," says Bruce Jakosky at the University of Colorado, Boulder.

2. IN TRANSIT

It might seem as though humans have got to grips with surviving off-planet. After all, the ISS is permanently crewed. But as space exploration goes, visiting the space station is like camping in your back garden. You might feel like you are away from home, but your parents are still bringing you sandwiches. If you are going to Mars, you need to take your own sandwiches.

Except it isn't just food you have got to worry about. If the spacecraft breaks, you must have the spare parts and tools to fix it. If you get sick, you need the right medicine. But packing for every eventuality isn't possible, given that extra weight means more fuel and more expense. What do you do?

Part of the solution will be to take 3D printers that can produce parts on demand. The ISS already has one on board and NASA has been experimenting with it. So a Mars trip could pack a printer and raw material, rather than a bunch of parts that might not be needed.

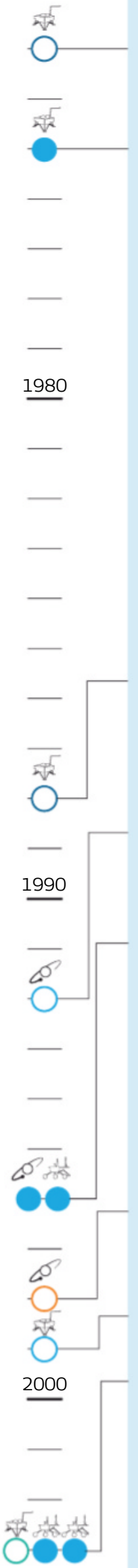
Stocking the medicine cabinet is more tricky. Our experience on the space station shows germs can thrive in spacecraft. And studies have shown that bacteria growing in simulated microgravity can develop resistance to a broad-spectrum antibiotic, and they retain that resistance for longer than they would on Earth. There are projects in the works to mitigate this, including antibacterial coatings for surfaces that might get dirty, like toilet doors. There is also a suggestion that astronauts could bring along raw pharmaceutical ingredients instead of fully-formulated medications and manufacture their own drugs on demand. A prototype system for automatically synthesising simple medicines has already been tested in space.

Whether or not astronauts get sick, they will definitely feel the physical effects of space travel. Without the pull of gravity to contend with, muscles and bones start to waste away. Studies show that astronauts can lose up to 20 per cent of their muscle mass in under a fortnight, even with daily workouts. The good news is that this may not matter much on Mars because its gravity is so much lower than Earth's – walking on the Red Planet would be far easier. Still, we would want to counteract the effects as much as possible, and astronauts would probably be tasked with hours of daily exercise and special diets. They might also have to wear muscle-compression suits.

As well as missing Earth's gravity, astronauts won't be shielded by its magnetic field, which diverts harmful cosmic radiation. NASA limits radiation exposure for male astronauts to

SPACE X

SpaceX's Falcon Heavy rocket is powerful enough to reach Mars, but it could not carry all the supplies a human mission would need



Mars 6
Struck the surface travelling at 600 metres per second

Viking 1 and 2
Landed safely with instruments to measure water, heat and soil chemistry, bringing the first comprehensive information from Mars's surface

Phobos 2
Designed to explore Mars's two moons, Phobos and Deimos, and land on Phobos, it snapped 37 pictures of Phobos before it stopped transmitting

Mars Observer
Built to measure Mars's atmosphere and magnetic field, it fell silent before entering orbit

Mars Global Surveyor
Mapped the whole surface and the thermal structure of the atmosphere until 2006

Mars Pathfinder/ Sojourner
First successful Mars rover, driving about 100 metres

Nozomi
Intended to orbit, but flew past the planet at a range of 1000 km

Mars Polar Lander
Communication lost on landing

Beagle 2
Landed, but failed to unfold its solar panels

Spirit
Roved for 7.7 km before getting stuck in some dirt in 2010

Opportunity
The record-breaking rover covered over 45 km before contact was finally lost in 2018

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MARS WALK

There are lots of impressive geological features to explore on the surface of the Red Planet

A The northern hemisphere of Mars is dominated by vast and largely featureless plains such as the Vastitas Borealis. This huge flat area around its north pole is about 4 or 5 kilometres lower than the planet's average elevation.

B Mars's southern hemisphere contains heavily cratered areas like Terra Sirenum. It is a mystery why the northern and southern hemispheres are so starkly different, a characteristic not seen on any other planet.

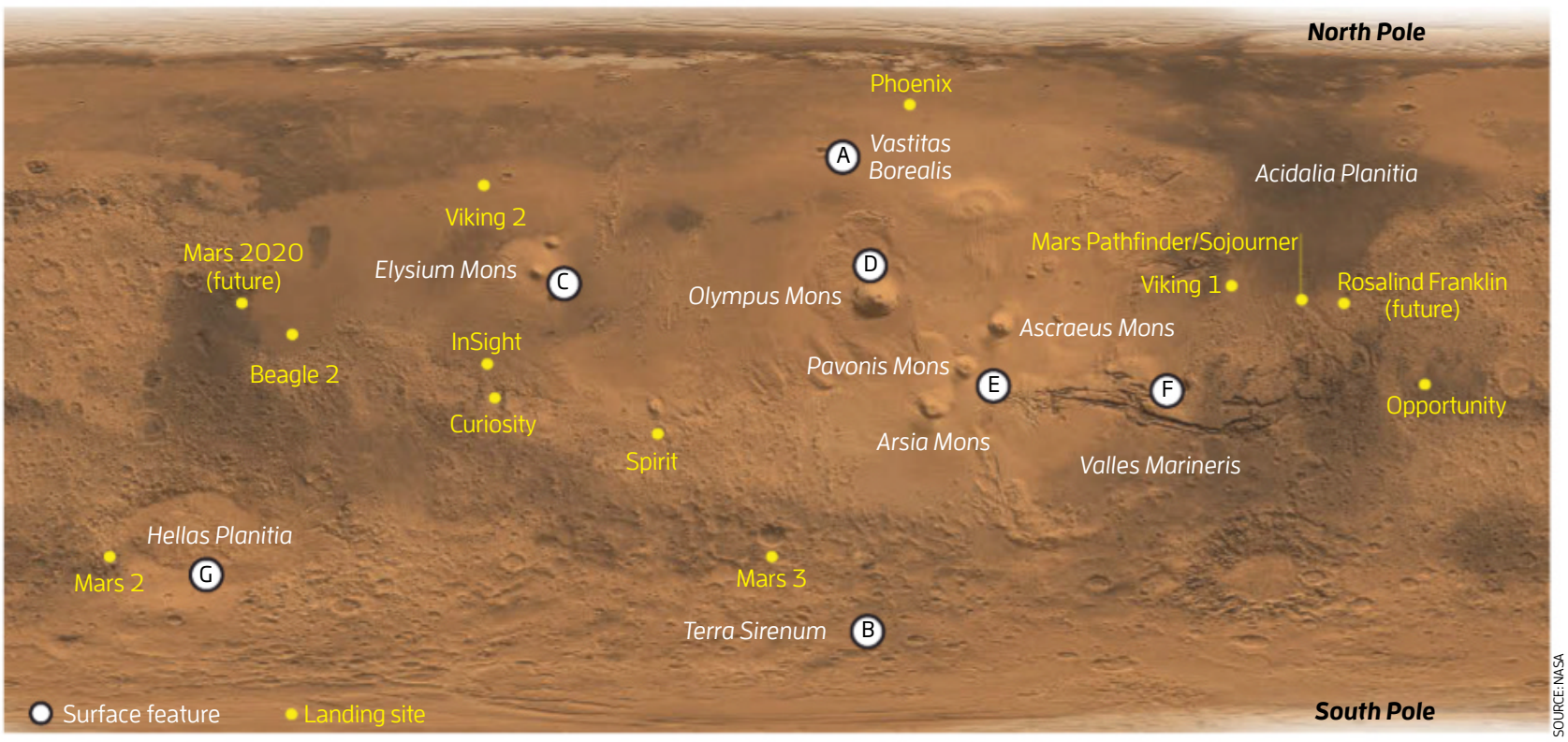
C Standing almost 13 kilometres high, Elysium Mons is the fourth highest mountain on Mars.

D Olympus Mons is the tallest known mountain in the solar system. Standing nearly 22 kilometres high, it is about two and a half times the height of Everest.

E To the south-east of Olympus Mons are three vast extinct volcanoes, including Pavonis Mons. Hundreds of kilometres wide, the tallest of them peaks at more than 18 kilometres.

F The Valles Marineris is a huge and intricate system of canyons that is more than 4000 kilometres long and up to 7 kilometres deep. Most scientists think this feature is essentially a crack in the planet's crust, which may have formed through plate tectonics.

G Hellas Planitia is an impact basin 3 kilometres deep. It is thought to have formed about 4 billion years ago when a huge asteroid struck Mars.



SOURCE: NASA

about the equivalent of 286,000 chest X-rays, and around 20 per cent less than this for women, whose bodies may be more susceptible to radiation damage. Astronauts on a Mars mission would hit 60 per cent of that limit on the shortest possible return journey, without taking into account time on the surface. "As it stands right now, every single mission would have to evaluate whether its goals are worth violating the astronaut health standards," says Lucianne Walkowicz at the Adler Planetarium in Chicago. "There's no way to meet the current ones on long-range missions, and there's no way to run the experiment to find out exactly what the risks are without actually doing the mission."

That goes for the mental health risks, too. Being so far from Earth – far enough that home becomes just another point of light in the sky – could be psychologically challenging, says retired NASA astronaut Nicole Stott. "Everything we've done so far, we have had the view of Earth out our window, right there," she says. "It's not just pretty. You have a connection to that place. As long as you can see it present with you, you can maintain that connection." You need a special type of person to cope without it.

3. WHO DO WE SEND?

The people we send to Mars will have to meet all the requirements that astronauts do now, including passing strenuous physical and psychological tests. But their skills will have to go beyond that. On the way to Mars, nobody can quit the team and nobody can be added. The handful of people on board will be totally responsible for keeping the mission aloft.

Certain roles like engineers, doctors and scientists will be indispensable. But it won't make sense to look for perfect astronauts, rather the perfect team of astronauts. "You're trying to put together a toolbox, and you wouldn't fill a toolbox with hammers even if they're all the best hammers in the world," says Kim Binsted at the University of Hawaii.

Binsted knows what she's talking about, as chief of the Hawaii Space Exploration Analog and Simulation, in which crews of four to six people live as if they are on Mars. Participants stay for months at a time, donning mock spacesuits when they go outside and enduring a 20-minute communication lag with "Earth".

One thing that consistently causes conflict, says Binsted, is when one or two team members feel different from the others. It could be differences in gender, nationality or even music preference. A crew with three men and one woman, or one person who wants to blast Metallica at all hours, might crumble because the team don't feel like they are all on the same footing. "Given that you're going to have some diversity, you want as much as possible," says Binsted.

Getting a team mission ready will probably involve more intensive group training than ›

Can we make it to Mars?
Hear space psychologist Iya Whiteley speak at New Scientist Live
newscientist.com/iya-whiteley

astronauts undergo now. The crew will have to learn to deal with each other's personality quirks to defuse even small interpersonal conflicts. "Molehills become mountains in austere environments over time," says NASA psychologist James Picano. "They will have to train as a crew, live together as a crew, simulate those kinds of conditions."

4. LANDING AND LIVING ON MARS

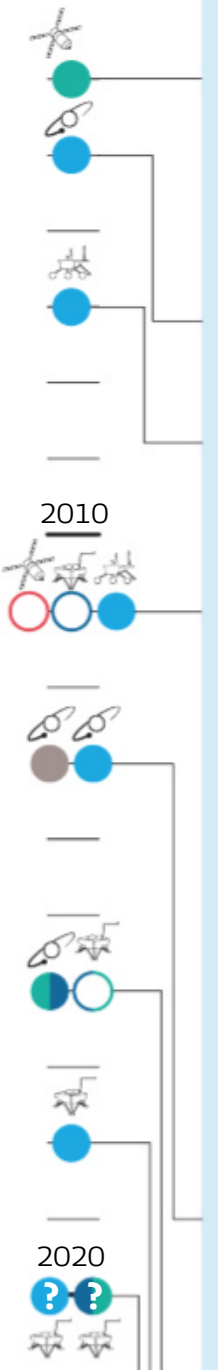
With nine months of empty space and avoided arguments behind them, the travellers are about to face the most dangerous part of their journey. The trouble with landing on Mars is that its atmosphere is almost non-existent – it is 160 times less dense than Earth's, on average. This means that parachutes don't create enough drag to slow down spacecraft, as they do when landing on Earth. We could use boosters to slow down, like the Apollo astronauts did when they landed on the moon. But because gravity on Mars is stronger than that on the moon, we would need a lot more boosters. This means we will probably need a combination of boosters and something to create drag.

This approach has succeeded for a 1-tonne robot, but it won't be so easy for a heavier craft, which is why researchers are working on finding improved ways to land.

One is NASA's Hypersonic Inflatable Aerodynamic Decelerators, a series of landing devices that use fabric strengthened with Kevlar to form a blow-up structure that is more rigid than a parachute and so creates more drag. The agency has tested small scale models of it on Earth.

Yet the really difficult question isn't how we land, but where. A site near either of the poles would seem the obvious choice because this is where we know there is underground water ice – and possibly an underground lake of liquid water – which would serve as a crucial resource. Humans use a lot of water and it is very heavy, so the amount we could take to Mars would be limited. Plus, many proposed Mars missions involve using water to make rocket fuel to get the explorers home.

The trouble is the pole areas get as cold as -195°C and are prone to storms that make landing even harder. "It's also not a very exciting place. The northern plains of Mars are pretty flat and boring," says Tanya Harrison at Arizona State University. The equatorial region mostly stays above -100°C and can reach 20°C. It also has more sunlight that astronauts could harvest for solar power, rarely gets storms and has all sorts of interesting terrain to explore. But it doesn't



Rosetta
Designed to rendezvous with a comet, the probe skimmed past Mars at range of 250 km

Mars Reconnaissance Orbiter
Still active

Phoenix
Made first successful landing in a polar region, active for five months

Yinghuo-1
Stranded in Earth orbit after thrusters failed to burn

Phobos-Grunt
Intended as a sample return mission to Phobos, it was launched with Yinghuo-1 and stranded with it in Earth orbit

Curiosity
Still active, this car-sized rover has driven more than 18 km on Mars, investigating its geology to see whether its past conditions could have supported life

Mangalyaan
A successful technology demonstration mission that made India the first Asian nation to reach Mars orbit

MAVEN
Designed to study evolution of Mars's atmosphere, still in orbit functioning as a communications relay

ExoMars Trace Gas Orbiter
Still in orbit, this European-Russian project was designed to measure methane and other gases in the atmosphere that could be signatures of life

Schiaparelli
Delivered by the Exomars orbiter, it crashed while attempting to land

InSight
Designed to study Mars's deep interior and seismic activity, successfully landed in November 2018

Mars 2020 Rosalind Franklin
Planned missions to assess the possibility that Mars once hosted life

Cosmic radiation is one of the biggest dangers astronauts would face on the way to Mars. This equipment at the Facility for Antiproton and Ion Research near Darmstadt in Germany is one place where such radiation is generated and its effects studied

seem to have much, if any, accessible water.

It is a tricky problem, but for the first missions, it may be simplest to land somewhere predictable, where rovers have already explored (see "Mars walk", page 41). Once they are down, the explorers will be sticking around for a while. Even if they aren't establishing a permanent settlement, they will have to wait months at a minimum for Earth and Mars to come into alignment again so they can travel home in a matter of months rather than years. There is no visiting Mars without setting up a base.

The base will have to deal with the variety of interesting ways in which Mars can kill you. Apart from the aforementioned gnawing cold, there is the constant risk of being hit by micrometeorites, which often don't burn up in the wispy atmosphere. Then there is the radiation from space, which isn't deflected away because Mars has no planet-wide magnetic field. And with so little atmosphere, the pressure is incredibly low, almost akin to deep space (see diagram, below).

The simplest protection from these risks may be the spacecraft that got our explorers here. But the landing craft itself would probably make for cramped quarters. Another option would be to bring their shelter or the materials to build it with them. NASA is running a competition to design 3D-printed

Leah Crane is a reporter for *New Scientist*. Follow her on Twitter @DownHereOnEarth

habitats, and there have been many entries. A number of them use pieces of the landing craft in their design, but they all also require other building materials, which adds weight to the launch craft. The entries get extra points if they use resources already on the Martian surface, which has inspired plans to make bricks of compressed Martian soil and build igloo-like shelters. NASA has given contracts to several groups studying the best way to make such bricks using precisely engineered replica Mars dust. But even so, building a home on Mars will probably require sending a few packages of building materials on ahead.

It might be possible to rope in the Martian crust itself as a natural radiation shield. One proposal would see humans setting up their habitats in the cylindrical caves created by ancient lava flows. We have seen the entrances to such caves on Mars in satellite images and studied similar structures here. On Earth, these caves are generally about 30 metres wide, but research suggests that on Mars, with its much lower gravity, they could be eight times wider and stretch for miles. One day they could accommodate a whole street of habitats.

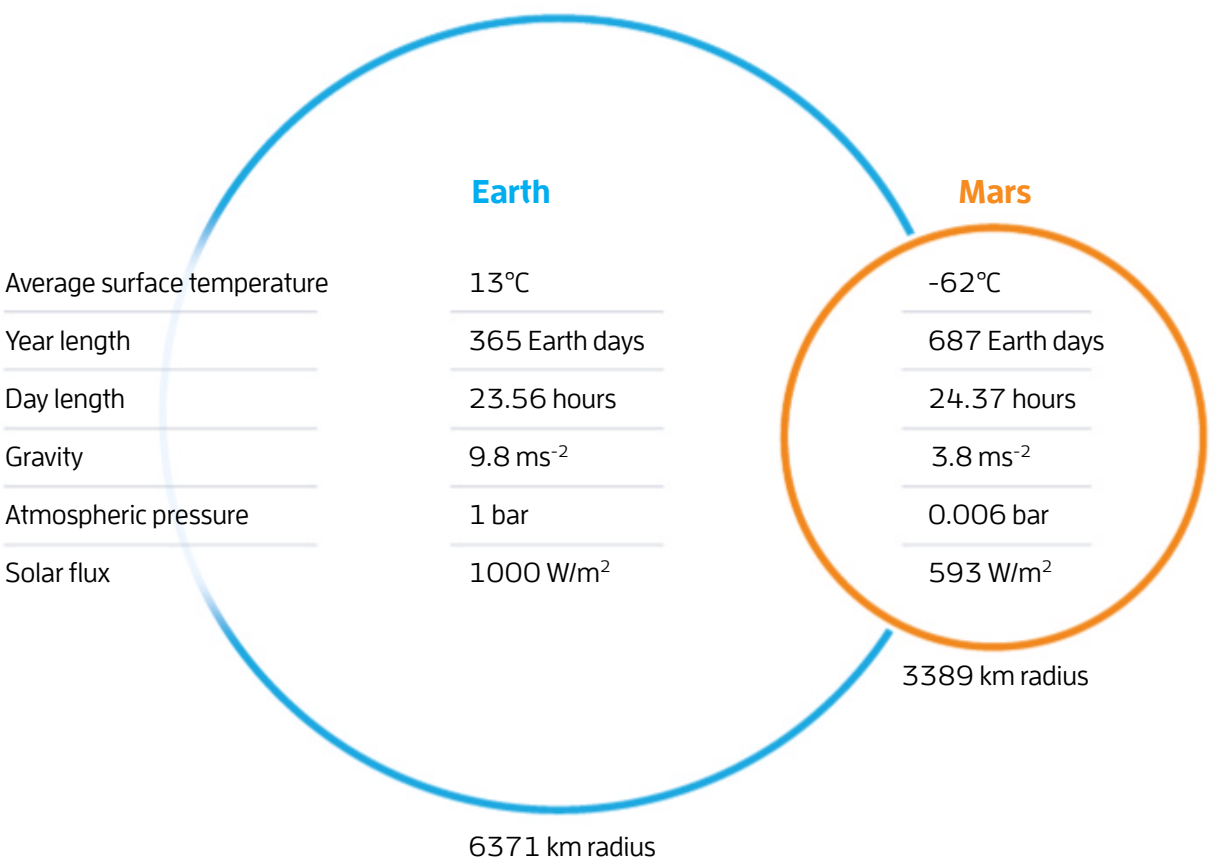
The intrepid astronauts will have other pressing needs to think about. Food can be freeze-dried, seeds can be packed, oxygen can be taken in tanks if it can't be scrubbed from the Martian atmosphere once there.

But water is less easy. Even if the astronauts have landed in a location with plenty of it beneath the surface, they will need to have brought heavy mining equipment to reach it. And there's no guarantee that it will be potable once it is out of the ground. "We don't know a lot about the ice that's there," says Harrison. "You don't want to hang your hat on assuming that what's there is all nice, drinkable water because we really don't know." Even if the water is safe to drink, it will be full of fine dust. So the astronauts will have to bring sophisticated filtration systems with them.

That goes for the spacesuits too: they will have to be excellent at keeping dust out, especially as Martian soil may be full of chemicals that can be deadly if inhaled or swallowed. NASA is already working on next-generation spacesuits and special coating materials that would counter the dust problem. "On Mars, there's no margin of error," says Harrison. "Everything has to be working or you die."

Worlds apart

Frigid temperatures and low pressures make life on Mars incredibly challenging. Plus, the years really drag



5. HOME TIME

Some people may be hoping that we will settle on Mars permanently in the long term. But all serious Mars mission plans currently involve bringing the explorers back. "It's a very harsh environment and I don't know why we would want to live there," says Jakosky. This means the astronauts need to endure another launch, another nine-month journey, another landing. Luckily, it will be easier the second time. Mars's thin atmosphere and its weaker gravity will mean getting into space won't be as tough. The journey itself will be equally long, but the familiar azure glow of our home world will grow stronger by the day. The landing will be simple, aided by parachutes and Earth's thick atmosphere.

When the explorers peek their heads out of their capsule, they will be splashed by the cool water of our abundant oceans and enveloped in the chatter of other people. They will be home. Back on Mars, the swirling dust will have already covered their footprints. But their habitat will still be standing, ready and waiting for the next visitors. ▮