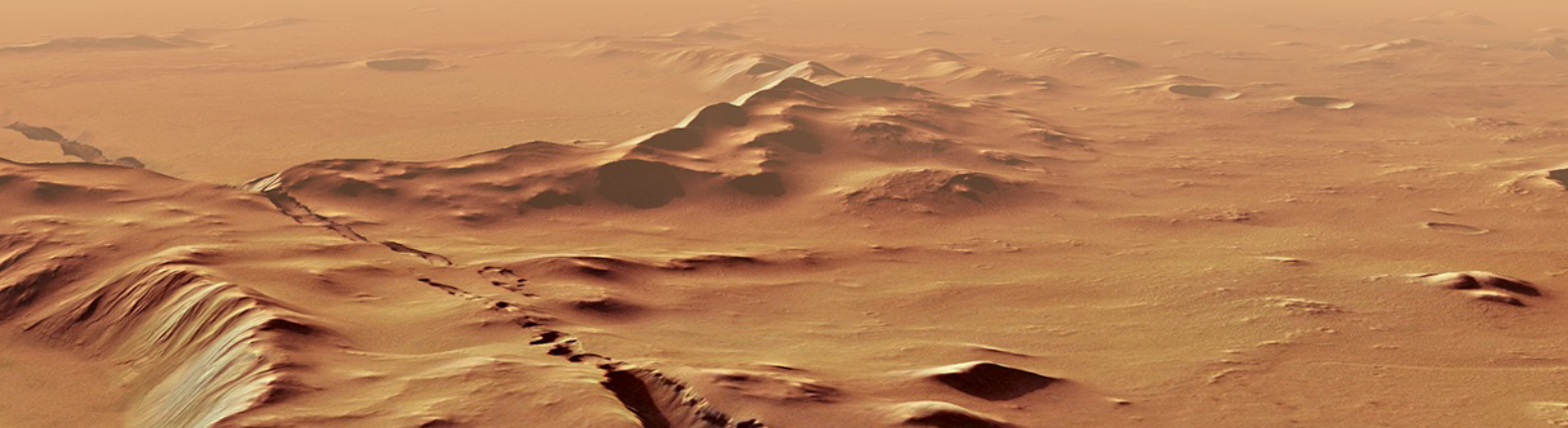
All About Space

SURVIVING ON MARS

By Gemma Lavender



SURVIVING ON MARS

Barren, cold and uninhabitable – will mankind be able to make a home out of the Red Planet?

Written by Gemma Lavender

Stranded on Mars. That's the fate that befalls one unfortunate astronaut in Ridley Scott's film *The Martian*, based on the novel by Andy Weir. With no way to contact home, he must rely on his skills and the equipment available to stay alive in the face of deadly Martian elements.

While the film and book are both works of fiction, it is true that going to Mars will be the most dangerous crewed space mission ever attempted. There are dust storms, radiation, an unbreathable atmosphere, fierce coldness and low gravity to contend with, while the astronauts themselves will have to constantly be in top physical and mental condition in the most challenging of environments. Should anything go wrong, it is an 18-month wait for a new launch back home, and then a further eight months travel time. The first astronauts to step foot on Mars will have to look after themselves.

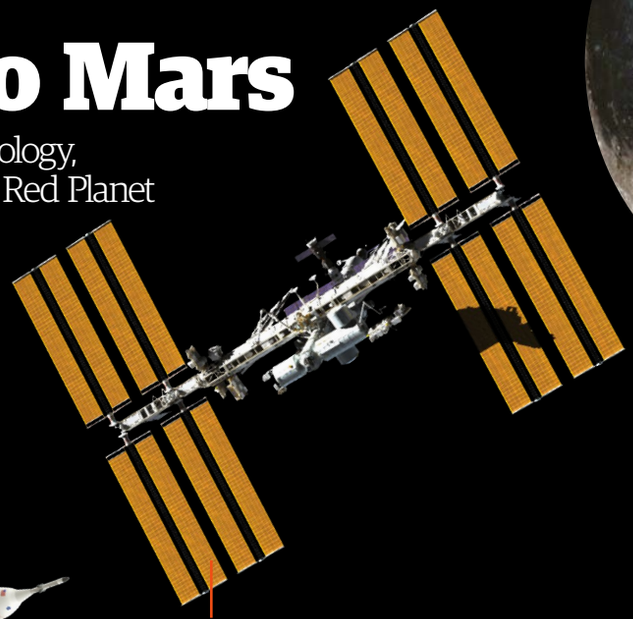
The motto for a future Mars mission might read 'be prepared'. Knowing that astronauts will be on Mars by themselves for a long time, any mission will require all the equipment they could conceivably need to survive, plus back-ups and spares for when things inevitably break. Carrying all this cargo at once would need a big ship, requiring a large amount of fuel. Instead, the idea is to send as much as possible to Mars ahead of the astronauts in the form of pre-cursor missions, so that supplies and a

Our path to Mars

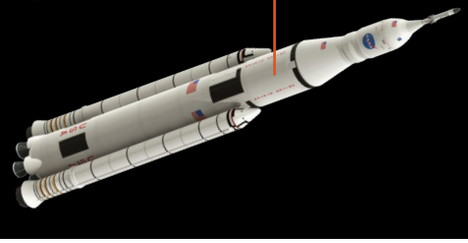
Steadily, and with the right technology, we're hoping to land man on the Red Planet

Relying on Earth

Mission length: 6-12 months
Time to return to Earth: hours



Humans in orbit
Rockets have allowed astronauts to gain access to space via low-Earth orbit.



International Space Station
We've managed to master the very basics of getting to Mars on the International Space Station.

power source is waiting for them when they arrive. One of these pre-cursor flights will also act as the astronauts' return vehicle. It will make its own rocket fuel by reacting a small amount of hydrogen that it carries with the plentiful carbon dioxide in the Red Planet's atmosphere. This chemical reaction produces oxygen that can be used as rocket propellant. So, if anything does go wrong when the astronauts first touch down on Mars, there will be a ship there ready and waiting, guaranteed to be able to bring them home. Their landing craft will also double up as a habitation module, or at least part of one – a place for them to live and work. When the crew is ready to return to Earth, the habitation module is left behind for the next mission to use. An additional habitation module is left behind with each mission, gradually forming the beginnings of a permanent base on Mars.

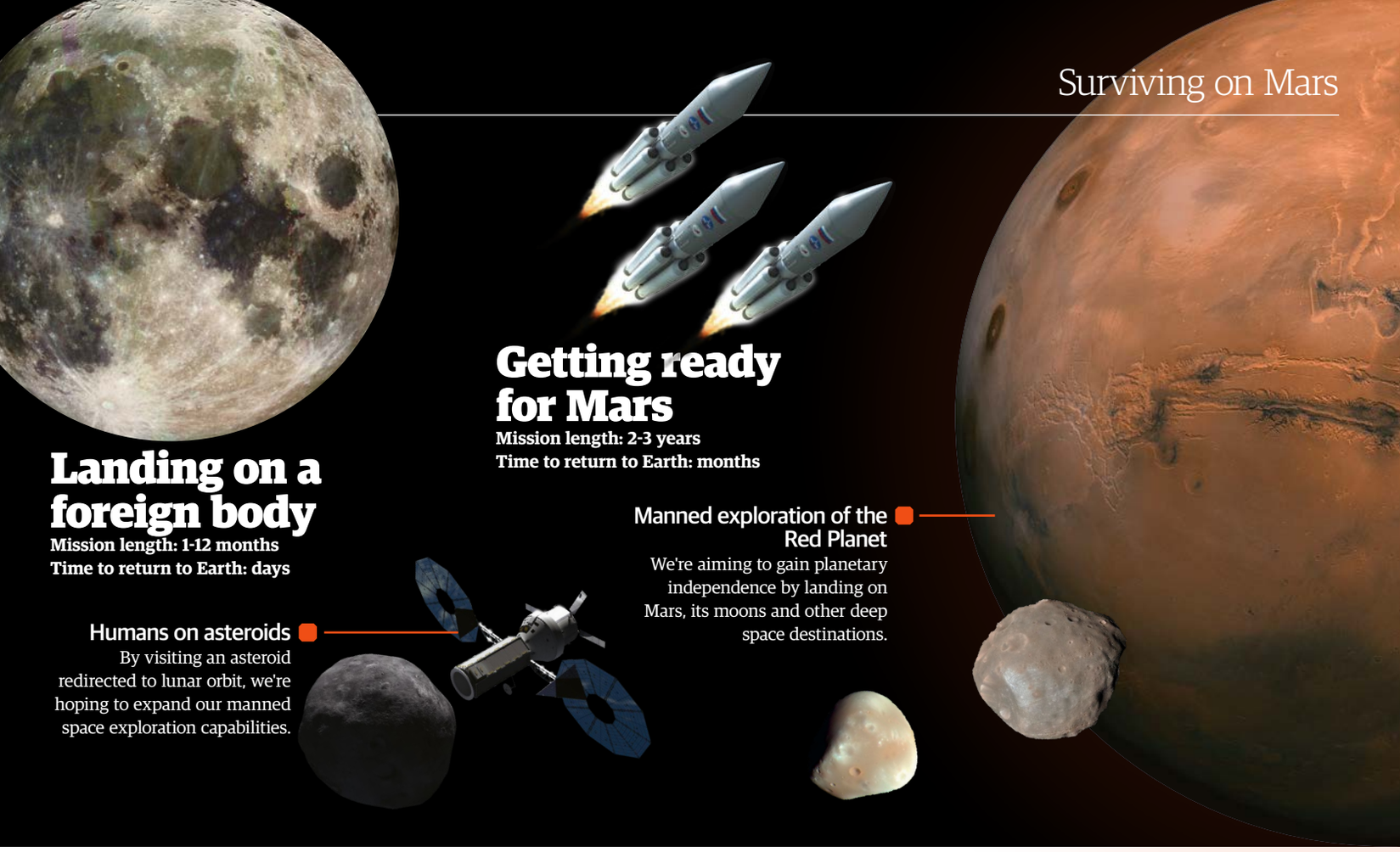
An advocate of this mission plan is Kevin Nolan, author of the book, *Mars: A Cosmic Stepping Stone*. He highlights that giving astronauts a decent chance of succeeding and surviving in their mission is going to take patience – rushing to Mars would make the astronauts unlikely to come home again.

"If we're to set people on the surface of Mars then it most likely cannot happen before 2040," Nolan says. "The notion of placing people on the surface for a required 500-day stay there requires significant resources such as supply missions two years in advance, landing miniature nuclear power stations on the surface, and providing a facility to manufacture the fuel to be able to return home. All of these are decades away – so this time period is the most likely for actual human missions to the surface."

The dangers of living on Mars are environmental. The atmosphere is 95 per cent carbon dioxide with the remaining five percent being made up of nitrogen and argon, and a measly 0.1 per cent of the atmosphere being oxygen. Contrast that with Earth's friendly atmosphere, which contains a breathable 21 per cent oxygen and 78 per cent nitrogen.

> "Under such low pressure your blood would boil, so a spacesuit is essential to surviving on Mars"

The Red Planet is an extremely barren place



Landing on a foreign body

Mission length: 1-12 months
Time to return to Earth: days

Humans on asteroids

By visiting an asteroid redirected to lunar orbit, we're hoping to expand our manned space exploration capabilities.

Getting ready for Mars

Mission length: 2-3 years
Time to return to Earth: months

Manned exploration of the Red Planet

We're aiming to gain planetary independence by landing on Mars, its moons and other deep space destinations.

The temperature on Mars varies wildly. In the summer, near the equator, temperatures can actually reach above the freezing point of water, but the air pressure is so low (just 0.6 per cent of Earth's surface pressure) that water still cannot exist as a liquid, and it wouldn't feel very warm. In winter, at the poles, the temperature can plummet as low as -125 degrees Celsius (-193 degrees Fahrenheit).

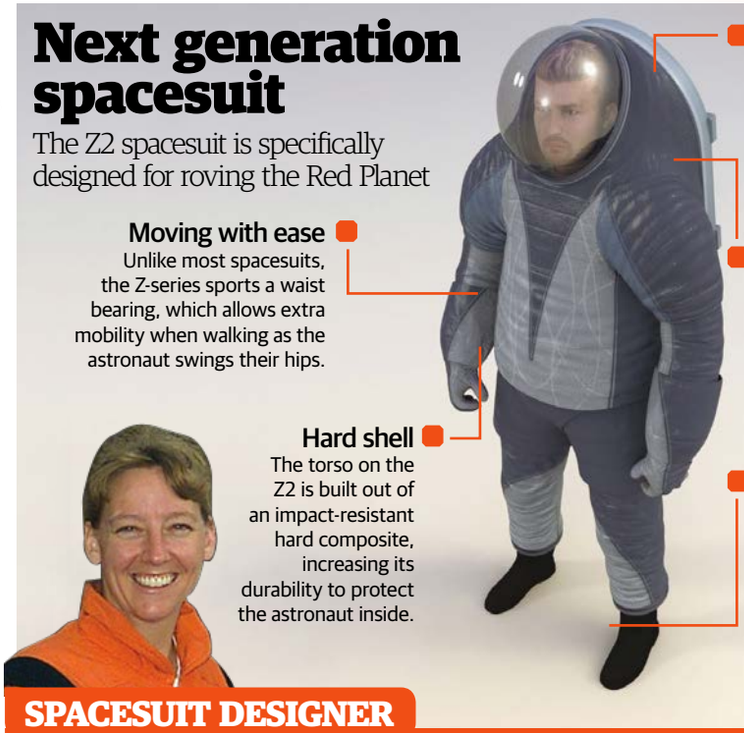
So Mars' atmosphere is not a mixture that you can breathe, and the temperatures mean that you would freeze. Not only that, under such low pressure your blood would boil, meaning a spacesuit is essential to survive on Mars. Specially designed suits are in development that will transform any budding space adventurer into Buzz Lightyear.

NASA's new Z-series of spacesuits are prototypes of what men and women may one day wear when they are trudging around the surface of the Red Planet. The key difference between the Z-series and other spacesuits is that they will be designed to make walking easier, which astronauts haven't really needed to do when floating in space. Even when the Apollo astronauts ventured to the Moon, they only had to put up with an ungainly gait for short excursions onto the surface. When spending 500 days on Mars, the astronauts are going to want to wear something that is practical and flexible, and not as stressful on the human body. The Z-series achieves this by having bearings in the shoulders, waist, upper legs and ankles that allow greater freedom of leg movement and firmer footing. The upper torso of the latest version of the suit - the Z2 - is a hard shell, so if an astronaut tumbles, they are less likely to damage or rip the suit. In Mars' cold, low pressure, unbreathable air, that would be deadly.

The Z-series spacesuits will essentially be life-support systems for the Mars dwellers. Not

Next generation spacesuit

The Z2 spacesuit is specifically designed for roving the Red Planet



Docking port

The Z-series of spacesuits are unique in that they feature a docking port on the back that allows the suit to connect with airlocks on vehicles and habitats.

Moving with ease

Unlike most spacesuits, the Z-series sports a waist bearing, which allows extra mobility when walking as the astronaut swings their hips.

Life support

The advanced Portable Life Support System contains batteries, a carbon dioxide remover, humidity monitors, oxygen and suit pressure controls.

Hard shell

The torso on the Z2 is built out of an impact-resistant hard composite, increasing its durability to protect the astronaut inside.

Sure footed

An ankle bearing in the suit's boots allows the user to step sure-footed over rough terrain.

SPACESUIT DESIGNER

Amy Ross, NASA

"The Z-series spacesuit is designed with very good walking capabilities. I participated in the spacesuit field-testing, where we wanted to understand what a suit that we built for the Moon or Mars would be like doing its job, and the only way to do that is to go out and see. How does the subject in the suit do geology for instance? We monitor how well the suit allows them or doesn't allow them to do that job, and what features we need to focus on for further development. The strategy we're taking right now is looking at what the most challenging aspect is. For mobility on Mars, it is being able to walk on the surface. We try to design so that we're capable of that, so when we have to build a suit for one specific mission, we already have the information and capability to build a spacesuit that's going to work."

only do they offer protection against the cold and the poisonous atmosphere, they also provide air, water and even food, and monitor the astronaut's health. Scientists at NASA's Johnson Space Center are currently working on an advanced Portable Life Support System (PLSS) that will attach to the Z-series suit. The PLSS will control the suit's pressurisation, as well as remove poisonous carbon dioxide that has been exhaled by the astronaut, which would otherwise build up in the suit's air recycling system.

The importance of a safe spacesuit becomes clear once you look at what would happen should you become exposed to the Martian air. Imagine you are on that first human mission to Mars. You open the airlock, climb down the ladder and put that first booted footprint into the Martian dust. You step out and go for a short walk around the landing site. Unfortunately you have landed close to a gorge. Unaccustomed to the low gravity, you fall in, smashing your helmet's visor on a rock (in reality, a spacesuit's visor is extremely tough and would be hard to break). The oxygen in your helmet quickly leaks out and within 15 seconds you lose consciousness from the lack of oxygen. The low pressure causes your blood to boil, making your skin and organs expand. Your body becomes swollen, but your blood does not evaporate – instead as it boils it sheds heat quickly and, in the cold temperatures of Mars, actually freezes. The low pressure and lack of oxygen will kill you in less than a minute.

Another scenario is that one of your suit's air valves might develop a small but deadly leak. You probably won't hear the air whistling out through the hole, as the thin atmosphere muffles sound, but the PLSS on your back will alert you to the fact that your oxygen and pressure is decreasing, while carbon dioxide leaking in from outside is building up, slowly suffocating you. Fortunately, air valves, tubes and other life support fittings will be standardised not only on the suit, but where possible in the habitat and any vehicles, making repairs relatively simple.

A nifty feature of the Z-series suit is that the astronaut enters the suit through a port at the back – that same port can be used to 'dock' with vehicles or even habitat buildings and allow safe passage inside from the suit. In many ways, a Mars habitat will be an extension of the life support system of the spacesuit. It will need to keep the astronauts safe and comfortable for 500 or more days without being resupplied, and with only limited repairs possible should damage be incurred. The habitat could be hit by dust storms or even a meteorite fall – as the atmosphere is so thin on Mars, more meteors are able to reach the surface intact than on Earth.

As discussed earlier, the habitat is likely to be made from crew modules that landed on the surface during the pre-cursor flights. However, an alternative method would be to print and assemble a habitat on Mars using a 3D printer. NASA has commissioned dozens of plans and designs of habitats in the past for use on both Mars and the Moon. For example, scientists in the Aerospace Engineering Sciences Department at the University of Colorado produced a report on the engineering design of a proposed Mars habitat, highlighting that each life support system needs several layers of redundancy. For example, if the water recycling system or the power generator

Living on another world

Turning the Red Planet into our home will involve many adaptations and alterations

Hidden danger
The pink sky on Mars looks calm and serene, but with the onset of Martian summer, huge dust storms can blow up that turn the sky dark and cover solar panels.

Phoning home
Talking with mission control or loved ones back home will be difficult for Mars astronauts. Because our two planets are so far away from each other, a signal will take up to 20 minutes to reach from one planet to the other.

Return vehicle
The way home will already be set up on Mars when the astronauts arrive. Early pre-cursor missions will deploy habitats, equipment and a spacecraft to fly the crew home prior to the astronauts' arrival.

Low gravity
The gravity on Mars is just 38 per cent of the gravity on Earth. Astronauts will have to get used to living and working in this low gravity for months on end.

Spacesuit
The astronauts' space suits are mobile life support systems that keep the wearers alive despite the cold and low pressure on the surface of Mars.

MARS EXPERT

Bob Zubrin, Mars Society

"The basic idea is to explore Mars with a 'travel-light' philosophy, so rather than building giant spaceships in orbit loaded with all of the food, water, air, fuel and oxygen required for a round-trip mission, we try to make the most important of these on Mars. First you'd send a Mars return vehicle with no one in it. That lands on Mars and reacts a small amount of hydrogen that it brought from Earth with carbon dioxide in the Martian atmosphere to produce a large supply of methane, oxygen rocket propellant and oxidiser. So now you have a fully fuelled Earth-return vehicle sitting on the Martian surface. Then you shoot the crew out to Mars in a habitation module that they use as their house while they are on Mars exploring. Then after 18 months of exploration they get in the Earth-return vehicle and fly back, leaving the habitation module on Mars. Each time you do this you add another habitat to the base and before you know it, you have the first human settlement on another world."

MARS MISSION EXPERT

Steve Squyres, NASA

"Despite having devoted my career to exploring the Solar System with robots, I am a strong advocate of human exploration, particularly on Mars. Humans have an extraordinary ability to function in complex environments, to improvise, and to respond quickly to new discoveries. Robots, in contrast, do best when the environment is simple and well understood, and when the scientific tasks are well defined in advance. The capabilities of humans surpass those of robots in complex environments. And there is no planetary environment where humans can operate in the foreseeable future that is more complex than the Martian surface."

The Mars Curiosity rover (pictured) along with other spacecraft have allowed us to observe the Red Planet before stepping foot on its soil

breaks down, a back-up would be available to step in, and there would be a back-up for the back-up too, just in case.

A Mars habitat also needs to be capable of providing food. Surprisingly, scientists believe that Martian dirt would be suitable for growing crops in. Dutch scientists have tried this in their laboratory, by making their own 'Martian dirt', based on what the Mars rovers and the older Viking missions of the 1970s have taught us about its composition. The 14 species of plant grown in the Martian dirt replica flourished; they germinated, flowered and survived the 50 days that the experiment lasted. Dirt on Mars lacks nitrogen and liquid water, which plants need, but contains many other nutrients that plants can feed from. The introduction of bacteria into the dirt can provide a source of nitrogen, and the humble watering can will supply the water. Future Mars habitats will therefore have a greenhouse section where crops are grown. These will have to be artificially lit, as the daytime Sun on Mars is fainter than it is on Earth. Nevertheless, starvation should not be a problem for the Mars population.

Obtaining water should be a simple task too. Mars is a dry world, but there is plenty of water on it, in the form of ice. There are the ice caps at the poles, but there is also subsurface permafrost ice just below the surface, stretching down to the planet's mid-latitudes. So water could be obtained by melting this ice. Another option is to copy the stranded astronaut in *The Martian*, who burns hydrazine rocket fuel to release hydrogen, and combines this hydrogen with oxygen produced by his habitat's 'oxygenator', which splits oxygen from Mars' carbon dioxide atmosphere.

A habitat will also act as a shelter against the elements outside. Mars has no global magnetic field and a thin atmosphere, so it cannot deflect solar radiation. The habitat will contain a shielded room to protect from the radiation emitted by solar flares. Unfortunately, the astronauts will need to rely on fate or good luck to protect them from cosmic rays while out and about on Mars – prolonged exposure out in the open will increase the chances of the astronauts getting cancer from space radiation.

The biggest natural hazard on Mars is the wave of dust storms that blow up every Martian summer. The biggest ones can envelop the entire planet, coating solar panels with dust and concealing the Sun in the sky. Martian dust is made of very small particles, and the wind speeds are not very high in the thin atmosphere. So a habitat is not going to be blown over in a storm, but it is possible that the dust could find its way into the living area or into electronics, causing serious damage. However, the Mars rovers have survived many dust storms; up until Opportunity could take no more from the Martian elements the biggest problem they faced was a loss of power as their solar panels became covered in dust. Fortunately, astronauts can just wipe the panels clean.

The biggest obstacle to surviving on Mars may not be the lack of air, or the cold, radiation or planet-sized storms. The biggest killer could be loneliness. Even if you not stranded alone like the hero in *The Martian*, and you are with six to ten other astronauts, you are still 200 million kilometres (124 million miles) from your friends, family and everything you knew on Earth. Your calls to home will take 20 minutes to get there, and then another 20 minutes to be returned. Scientists are attempting to study how long-term exposure and isolation in space affects mental health – the year-long mission of NASA astronaut Scott Kelly on board the International Space Station was part of this research. Spending over two years in a challenging and alien environment will tax even the most mentally strong – unlike a mission to the Moon, you can't be back home in three days.

The initial wave of astronauts who will travel to explore Mars are going to need to be tough, both mentally and physically, and they and their ground teams will need to be extremely well prepared for the challenges that meet them during their extensive mission. However, with scientists and engineers back on Earth supporting the team, years of intensive training to help them, and a knack for ingenuity and adaptation, perhaps it will be possible to survive on Mars after all.

The team behind NASA's Mars Science Laboratory

A researcher performing simulated 'Martian' surface activities at the Mars Society Desert Research Station in Hanksville, Utah