DESTINATION: MARS

This winter, two events are bringing humankind ever closer to landing on the Red Planet: the end of the longest isolation study in history and the launch of NASA's most ambitious Mars rover, *Curiosity*

FACTFILE: MARS IN 60 SECONDS

NAME: Mars (for the Roman god of war)
DISCOVERER: Unknown
DISCOVERY DATE: Prehistoric

DISTANCE FROM EARTH: min 55.7 million km, max 401.3 million km
DISTANCE FROM SUN: min 207 million km, max 249 million km
LENGTH OF MARTIAN YEAR: 687 Earth days (669 sols, or Martian days)
AVERAGE ORBITAL SPEED: 24km/s

TYPE OF PLANET: Rocky (terrestrial)
CORE: Iron (mostly) and sulphur
SURFACE: Mostly silica-rich basalt. Much of the surface is deeply covered by fine iron oxide dust, which gives its reddish appearance (and its nickname)
NUMBER OF MOONS: 2 (Phobos and Deimos)

DIAMETER: 6792km (about half that of Earth)
MASS: 6.4185×10^{23}kg (about a tenth that of Earth)
SURFACE AREA: 144,798,500km^2 (about a fifth that of Earth)
SURFACE TEMPERATURE: min -87°C, average -63°C, max +20°C
SURFACE GRAVITY: 3.7 m/s^2 (about a third that of Earth)
SURFACE PRESSURE: 0.1 bar (about a hundredth that of Earth)

ATMOSPHERE: Mainly carbon (95.3%), nitrogen (2.7%) and argon (1.6%). Traces of other elements and compounds, including oxygen, water, carbon monoxide and methane.

ALAMY, CORBIS, ESA X2

MARS500 *p38*

Take six men, lock them away for 520 days to simulate a mission to Mars – and observe

CURIOUSER AND CURIOUSER *p42*

NASA's audacious plans for landing its most sophisticated rover ever in a crater on Mars

SHOULD WE GO? *p46*

Britain's Astronomer Royal, Lord Martin Rees, ponders the ethics behind missions to Mars

MARS500

Six men have been locked inside a small suite of rooms on a simulated mission to Mars since June 2010. As the experiment draws to a close in November, **Sally Palmer** asks whether it has shown if the human mind could tolerate the real trip

Moscow, 3 June 2010. Six men step into a silent, windowless suite of rooms. Amid a flurry of media interest and popping flashbulbs, the heavy metal door is sealed. Apart from the whirring of the ventilator, there is silence.

At first, the men are excited. They keep busy, performing scientific experiments, tending the plants in their greenhouse. Free time is spent reading, watching films, chatting. Visiting dignitaries come and stare at them and talk via video link. "Everything OK?" "How are you feeling?"

As the days pass, the men's communication with the outside world becomes fragmented. Phone conversations are no longer possible and emails arrive only after long time delays. The men keep their capsule clean and tidy. A week has no meaning: they devise a system of working in 10-day stints. Three of these makes a 'month'. Showers are only allowed every 10 days.

Hallowe'en arrives, then Christmas. The men – three Russians, two Europeans and a Chinese – share in each other's cultural celebrations with fervour. Birthdays arrive, complete with gifts carefully hoarded for each special day.

February 2011. The men pretend they've travelled to Mars. One uses his computer programming skills to create a 'window' as they approach their destination. The planet grows from a speck in the distance to a magnificent vista that fills the screen. Three of them don space suits and plant flags in a sandpit. Then they climb back into their capsule with the others and begin an imaginary journey home.

It's June. A year has gone by and the men are still in their box. Days feel longer and more monotonous. The men occupy themselves with ever-smaller tasks to keep their minds busy. The food is good but dull. They've missed the Arab Spring.

Now, their ordeal is finally coming to an end. On 4 November 2011, after 520 days, the imaginary spaceship will 'land' on Earth and the men will come out. They'll have to handle the glare of the media – and then they'll be back to being ordinary citizens who have never in fact been to Mars. How on Earth will they cope with that?

Endurance test

Mars500 is a psychological experiment intended to discover whether humans could manage a journey to the Red Planet or fall apart in the process. Jointly organised by the European Space Agency (ESA) and Russia's Institute of Biomedical Problems, its purpose has been to gather information, knowledge and understanding about how a carefully selected group of people behave when they are cooped up in cramped conditions for a protracted period of time.

What's the purpose of such an elaborate charade? In September 2010, President Obama authorised NASA to abandon the Bush administration's goal to have humankind return to the Moon by 2020. Instead, the agency

IBMP/HAIDER HOBIHOZIN, ESA X9, ALAMY

The six-man crew is all smiles at the start of the 'mission'. Once sealed, the door remains closed until 4 November 2011 – a total of 520 days

In place of windows, Diego devised a simulation of Mars drawing closer

Romain at Christmas. The different cultural celebrations added interest

INSIDE THE MARS500 MODULES

MARS LANDING MODULE
(6.3 x 6.17m/20.6 x 20.2ft)
This was only used during the 30-day 'Mars orbiting' phase. It includes three bunk beds and a sewerage system.

MARS SURFACE SIMULATOR
Between 14 and 22 February 2011, Russian Alexandr Smoleevskiy, Italian Diego Urbina and Chinese Wang Yue performed extra-vehicular activities on the surface of 'Mars'.

UTILITY MODULE (3.9 x 24m/12.8 x 78.7ft)
This houses the fridges and dry food storage, the gym, bathroom and sauna, and the experimental greenhouse – home to the only living organisms on board other than the men themselves.

HABITABLE MODULE (3.6 x 20m/11.8 x 65.6ft)
The six bedroom compartments each measure 2.8-3.2m² and have a bed, desk, chair and shelves. The module also contains the community kitchen/dining room, a living room, the main control room and a toilet.

MEDICAL MODULE
(3.2 x 11.9m/10.5 x 39ft)
Telemedical, laboratory and diagnostic medical investigations are carried out here, as well as routine medical examinations.

will aim to send explorers to an asteroid by 2025 and to Mars in the 2030s. It sounds exciting, but the reality of such journeys will involve mind-numbing tedium – and that's where Mars500 comes in.

The crew is entirely male, although Patrik Sundblad, the Mars500 project manager with responsibility for selecting the team from over 6,000 applicants, says the initial call for candidates did not limit participation to men. "We got a sizeable amount of female candidates who did not make it to the final round of selection," he says. "Had they done so, we would certainly have considered a mixed crew. We selected people who are physically and psychologically fit, with different types of skills – technical, medical... Then, from among very good specialists, we chose psychologically stable people able to work in a team."

The Mars500 experiment does not consider other key problems of long-duration spaceflight, such as radiation and weightlessness – these are being studied on the International Space Station (ISS) – but it is generating unique data about isolation. No-one has been isolated from the natural world for as long as these six men. The previous record was 438 days, by cosmonaut Valeri Polyakov while aboard Russia's Mir space station in 1994-95. That milestone was passed in mid-August by the Mars500 team, and when they leave their module on 4 November they will have been in isolation for 520 days.

The men will 'land' on Earth – and then they'll be back to being ordinary citizens

The set of four hermetically sealed, interconnected capsules where they have been living ▷

▷ simulates the confines of a space ship. According to Raymond Catchpole, Chair of the Feng Shui Society, it isn't easy for humans to function for a long time in such cramped conditions. "Would you like to go to Mars in what looks like a cross between a Scout hut and a launderette?" he asks.

Catchpole says there are small ways to make the journey less daunting, such as adding colour. "There is plenty of wood and metal here, but nothing of the other elements. Bright red will keep up energy levels and keep the crew motivated. Yellow will be supportive and introduce the earth element, very necessary all those miles away from Earth itself. Water can be introduced through using blue and black, and flowing lines in the designs of the structure and equipment. Sharp angles and corners should be avoided at all costs."

BBC Knowledge Magazine put his opinion to Diego Urbain and Romain Charles, the two European Mars500 crew members. They were still experiencing some delay in their email communications as part of the simulation, but when their answer came back, both agreed the idea had merit.

"We used our common sense to decorate and personalise the modules and our rooms," says Romain. "For example, my room is filled with photos and posters where the colour blue is dominant. Hard to say if I have an unconscious need of water or if it is a coincidence!"

"We have seen some videos of how this facility looked in the 90s when they were rehearsing flights to the ISS," adds Diego. "It was covered with some sort of white layer of foam or plastic that I would have had a hard time looking at for long, it was awful! [The psychologists] assessed that wood would be a more familiar material – at the beginning, I didn't see the point but later I acknowledged that it does feel warm compared with the module that doesn't have it."

The most dramatic event to have broken the monotony was a power cut

The crew's main coping strategy seems to have been to keep busy. They have been working in shifts based on the schedule of the ISS: eight hours' work, eight hours' recreation and eight hours' sleep, with one person on night shifts. During their working hours, they have been performing a battery of experiments for the scientists, ranging from fitness tests to wearing red glasses and having UV lights sited round the modules to simulate daylight.

"The absence of sunshine was compensated by strict planning of work and rest, daily medical checks in the mornings and evenings, and planning of scientific experiments, physical exercise and meals," says Elena Feichtinger, ESA psychologist and the daily contact point for the crew. "However, psychologically I think the absence of social contacts has had a more serious impact on the crew than the absence of sunshine."

Feichtinger thinks the current period, near the end of the mission, must be the most difficult for the crew. The 'purpose' of the mission – the landing on Mars – was now more than six months ago. "For the Mars landing, everybody understood that it was not real, but we monitored that the crew experienced quite some excitement, with their heart rates reaching almost double the normal value just before exiting onto the 'Mars' surface."

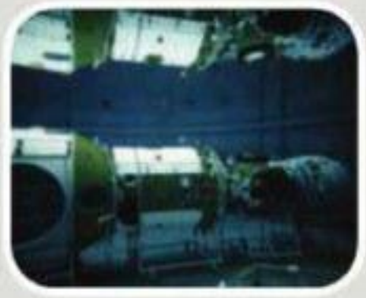
Since then, the most dramatic event to have broken their monotony was a power cut. "You have to imagine an 'end of the world' scene," wrote Romain on the Mars500 blog. "We were … six crewmembers lost in black modules with a thick silence around us. The friendly

HOUSTON, WE HAVE A PROBLEM

Past studies show that tension runs high when humans are confined

▲ IBEA, 1977
Twelve people of different backgrounds and nationalities were sent to Antarctica in a groundbreaking study. After 14 days, relations became so bad that several refused to participate in follow-up tests on their return.

▲ BIOSPHERE 2 MISSION 1, 1991-93
This vast structure in Arizona's Sonoran Desert was meant to sustain its crew without outside supplies. Eight people were sealed in for two years. One wrote: "We suffocated, starved and went mad."



▲ HUBES, 1996
A 135-day, Moscow-based experiment aimed to measure the psychological effects of close-quarter living in isolation. There was leadership competition, a breakdown in group dynamics and resentment of mission control.

▲ SFINCSS-99, Jul 1999-Mar 2000
One Japanese volunteer walked out of this Moscow-based group conflict study after witnessing a violent, alcohol-fuelled New Year's Eve episode, while a Canadian woman reported an incident of sexual harassment.

ESA X4, ALAMY X2, CORBIS

Wang Yue whiles away the time during the 27-hour power blackout

Alexandr and Diego take a 'Marswalk' on the simulated Martian terrain

humming of the ventilation disappeared at the same time as the electricity. We couldn't even get more than two litres from the tap because the pressure given by the pumps inside the water system had fallen too."

False alarm

Sleep that night was in dark, silent and gradually warming cells. It was a full 27 hours before the power came back and the team were finally advised that the event had been a drill. "We enjoyed this unexpected event. It was a new situation breaking our monotonous days," wrote Romain.

Nick Kanas MD, Professor in Residence at the University of California, San Francisco, is a psychologist who specialises in long-term spaceflight. He thinks that Romain's reaction would have been far less positive had he been on a real space ship. In 1997, there was a fire on board Mir. "The Mir crew was literally ready to evacuate before they got things under control," says Kanas. "Romain was reacting more to the novelty than the actual stress itself. There are other comments about how everybody was calm, and they were not reacting with a great deal of stress. But in real space missions, it's very scary."

On 4 November 2011, the men will finally conclude their ordeal. Although they never actually left Earth, their work will stand as a milestone on humankind's path to other planets just as surely as that of those pioneers who first walked on the Moon. They can feel secure in the knowledge that they have brought humanity's chances of exploring beyond our current horizons that little bit closer.

Sally Palmer is a science journalist and editor. She is the Editor of *BBC Knowledge Magazine*.

FIND OUT MORE

▶ **www.esa.int/esaMI/Mars500/index.html**

The home page of the Mars500 project, complete with video diaries and blogs from Diego and Romain

WHAT DO YOU THINK?

Is Mars500 an invaluable learning process or an expensive waste of time?

email: **editor@bbcknowledge.com**

FROM THE INSIDE

Diego Urbina and Romain Charles answered questions for *BBC Knowledge Magazine* from inside their module, just before arriving 'home'

How are you coping with feeling bored or lonely?

Diego: The important thing is what you do to fix these moods. I have my Twitter account (@diegou), but I don't find any use in rambling about personal problems there or on a blog post. Instead I use them to have some positive input from people following the mission. I do things to help improve the situation that I am in.

Romain: If you ask me how I feel today, I'd answer "good", and it would have been the same answer every day for the past 15 months because I really feel that way. I don't have any pain and the ambience is good among our crew. I've been training myself to only plan my activities one week ahead. This has helped me to get through this very long isolation without any problem. Now the end of the mission is close, but I'm not abandoning my coping strategy. My days still feel the same, but I'm sure that one week before our egress, they will feel much longer.

Q: Once the mission ends and you are a 'normal' citizen once more, how will you adjust?

Diego: Before the mission, I was involved with spaceflight and afterwards I plan to continue. My plans are taking us to Mars for real, be it as a crew or in some other equally useful ground role. This mission is not just one remarkable insular achievement, but a unique personal learning step.

Romain: My main objective was to enter the space industry. The last two years gave me the experience and connections which should allow me to continue in this field. When the media interest dies down, I'll cope by remembering I'm now part of this space 'world' and I'm working to make a reality of our simulation.

What are you looking forward to doing the most when you come out?

Diego: Besides sun and a bath, and meeting my family and friends, I want to ride on a rollercoaster and fly a small plane.

Romain: I'd love to walk through a nice park on a sunny day to join some friends on the terrace of a café and to enjoy a fresh beer chatting with them.

Diego and Romain prepare an 'on-board' experiment (*top*), a welcome distraction from the crew's many hours of relaxation (*above*)

CURIOUSER AND CURIOUSER

Sometime between 25 November and 18 December, NASA scientists will send *Curiosity*, their most ambitious rover yet, to Mars. **Will Gater** takes a look at how they aim to land a science lab the size of a small car on the Red Planet

Over the course of a few tumultuous minutes next August, the rock-strewn Martian plains will go from a quiet desert to a spectacular scene of noise and activity as a robot the size of a family car is lowered onto the surface by a rocket-powered crane.

After months of travelling through space, the Mars Science Laboratory (MSL)'s *Curiosity*, a 2.7m (8.9ft)-long, 850kg (1874lb) robotic rover, will touch down in what is arguably NASA's most technologically advanced landing to date. If the rover lands safely, we'll be in for a Martian adventure like nothing on Earth.

The mission, which will last for one Mars year (nearly two Earth years), was originally scheduled for 2009 but its launch date was delayed until this year, in part because of the huge technical challenges of getting a rover that weighs close to a tonne safely onto the surface. To give it the best chance, NASA scientists have spent five years selecting the most scientifically interesting and safe landing spot from information sent from spacecraft currently in orbit around Mars.

Happy landings

From an initial 60 sites, they narrowed the list of candidates down to four – three craters and a valley. In July, they announced they had chosen Gale Crater, named after the 19th-century astronomer Walter Frederick Gale. Gale Crater offers the NASA scientists a crucial window into Mars's past, as it is thought to be between 3.5 and 3.8 billion years old. At its heart, a vast mountain of layered rock reaches into the Martian sky. When *Curiosity* touches down within the northern part of the crater it will be in a prime position to study these layers as well as the other interesting features – probably created by water – that the NASA team has identified.

The choice of landing site is crucial if the goals that scientists have set for *Curiosity* are to be met. These include continuing the investigation into whether there was ever any life on Mars's surface, exploring the planet's complex geology and learning more about its varying climate.

Heavy cargo

Another aim is to give scientists and engineers the experience of landing a heavy object on Mars. *Curiosity* should provide NASA engineers with a taste of what might be needed to safely transport a large, manned spacecraft to precisely the right place on the Martian surface.

That may seem like a daunting series of tasks, but *Curiosity* is more than up to

HOW *CURIOSITY* WILL LAND ON MARS

The ambitious descent will involve the largest parachute ever used, retro-rockets and a crane...

1: FIRST SIGHTING
Curiosity punches through the atmosphere, housed in an aeroshell

2: SLOW DOWN
A huge parachute deploys, dramatically decelerating down the craft

3: ABANDON SHIELD
As the rover and Skycrane slow, the heat shield is jettisoned

4: PREPARE FOR LANDING
The rover deploys its 'legs' and the Skycrane's rockets fire up

NASA X10

The construction of *Curiosity* at NASA's Jet Propulsion Laboratory in California

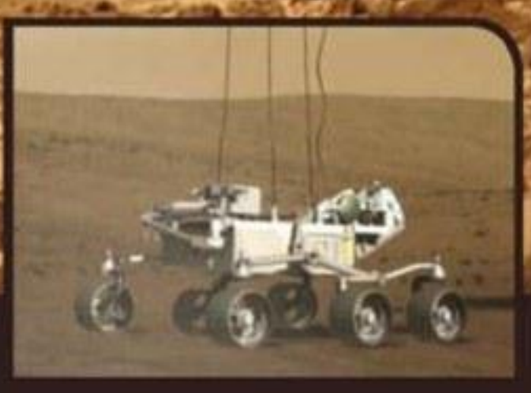
the challenge. With its 80kg (176lb) payload of science instruments, including cameras, spectrometers, miniature chemical laboratories and even a vaporising laser, it will be able to study the Martian environment in unprecedented detail. It inherited some of its design elements from the 2003 *Spirit* and *Opportunity* rovers, including six-wheel drive and the suspension system. Unlike those earlier NASA rovers, it will also carry a navigation camera and hazard-avoidance cameras, as well as tools to remove dust from rock surfaces, scoop up soil, drill into rocks and collect powdered samples, sort samples by particle size with sieves, and deliver samples to laboratory instruments.

When *Curiosity* reaches Mars, the first thing it will have to deal with is the Martian atmosphere. Protected by a heat shield and an outer casing known as the aeroshell, it will make a fast and fiery descent. Moments after it breaches the atmosphere, miniature rockets at the back of the aeroshell will kick into life, steering and tweaking the craft's descent.

To further slow it down, a huge 17m (55ft)-wide parachute will be deployed from the top of the aeroshell. Measuring some 50m (164ft) ▷

5: SEPARATION
Explosive bolts release the Skycrane and rover from the aeroshell

6: SWING LOW
The Skycrane slows the rover and lowers it on a long tether



7: TOUCH DOWN
The rover's wheels touch the surface and the tether is cut

8: FINAL THROES
The Skycrane fires its rockets to send it flying away from the rover to crash

MSL CURIOSITY

This latest rover will carry sophisticated science experiments designed by NASA and its international partners to study whether the landing site could, or has ever, supported microbial life

RAD (RADIATION ASSESSMENT DETECTOR)
RAD will examine the radiation environment at the surface of Mars – important for assessing the planet's ability to harbour life and to support future human exploration.

DAN (DYNAMIC ALBEDO OF NEUTRONS)
DAN measures subsurface hydrogen up to 1m (3.3ft) below the surface. Detections of hydrogen may indicate the presence of water in the form of ice or bound in minerals.

CHEMCAM (CHEMISTRY AND CAMERA INSTRUMENT)
This instrument uses infrared laser pulses to vaporise tiny regions of rocks or soil up to 9m (30ft) away. It includes a spectrometer to measure the small cloud of vaporised rock to determine its chemical composition.

MASTCAM (MAST CAMERA)
Mounted at about human eye height, this will photograph the rover's surroundings in high-resolution video and colour. It will also be used for viewing materials collected or treated by the arm.

REMS (ROVER ENVIRONMENTAL MONITORING STATION)
REMS measures atmospheric pressure, temperature, humidity, winds and UV radiation levels.

SAM (SAMPLE ANALYSIS AT MARS)
A suite of instruments will analyse samples of material – collected and delivered by the rover's arm – and atmospheric samples. It includes equipment to identify a wide range of organic compounds and determine the ratios of different isotopes of key elements. Isotope ratios are clues to understanding the history of Mars' atmosphere.

CHEMIN (CHEMISTRY AND MINEROLOGY INSTRUMENT)
An X-ray diffraction and fluorescence instrument designed to identify and quantify the minerals in samples gathered by the robotic arm.

MAHLI (MARS HAND LENS IMAGER)
Mounted on the arm, MAHLI will take extreme close-up pictures of rocks, soil and, if present, ice, revealing details smaller than the width of a human hair. It will also be able to focus on hard-to-reach objects more than an arm's length away.

APXS (ALPHA PARTICLE X-RAY SPECTROMETER)
Also on the arm, this will determine the relative abundances of different elements in rocks and soils.

ROBOT ARM
Has the agility of a human arm but is twice the size.

MARDI (MARS DESCENT IMAGER)
In the two minutes before landing, this will take colour video of the landing region.

VITAL STATISTICS
The MSL rover weighs 850kg (1874lb) and is 2.7m (8.9ft) long – about twice as long and five times as heavy as NASA's twin Mars Exploration Rovers, *Spirit* and *Opportunity*. It is powered by a plutonium electricity generator.

▷ in length, it is the biggest parachute of its kind. With the parachute straining above and the heat shield gone, the rover's systems will spring to life and the landing will suddenly become a little less orthodox.

About 1.5km (1 mile) above the Martian surface, the most crucial moments take place. With the aeroshell and parachute jettisoned, the rover races towards the surface, still attached to the last section of its landing gear – a device called a Skycrane. This takes over control of the descent, igniting its four descent rockets to slow the unit's fall.

Controlled descent

The Skycrane will constantly assess its own descent, making adjustments to get the rover down in precisely the right location – what's known as a closed-loop control system. It will slow the descent of the rover to an almost dead stop, until it is hovering just a few metres above the Red Planet's dusty surface.

Then, as the Skycrane's rockets deftly float the craft, the rover is gently lowered the final metres onto the surface while attached to the Skycrane by cords and a bridle. Once the rover is down, the Skycrane severs its umbilical link and briefly blasts its engines one last time to crash onto the surface about 150m (492ft) away from the rover.

"The Skycrane is a combination of sub-systems that have been used before, but as a system it is completely new," says Rob Manning, NASA's chief engineer for the MSL mission. Yet for all its intricacy, the NASA engineers are confident in the design. "While the Skycrane requires the additional complexity of a closed-loop control system and the bridle, its slow and precise touchdown system makes it much more robust when landing [a rover] on rough terrain and on steep slopes than any other landing system used to date," explains Manning. "We believe it is the safest robotic Mars lander yet."

Delayed response

If all goes to plan for *Curiosity* in the coming months, scientists at mission control will gradually receive the delayed signals sent by the spacecraft during its extraordinary descent. As each new signal comes in, the scientists will nervously relive what has already happened on Mars; they'll be powerless to help it at this stage, just hoping that each transmission from the spacecraft won't be its last.

It will be several minutes before the MSL scientists know if the landing has been successful and whether the Skycrane has done its job. If it has, the rover's wheels will settle on the dusty Martian regolith as it unpacks its sensors and opens its electronic eyes. Only then will *Curiosity*'s journey really begin.

[A version of this article first appeared in *Sky At Night Magazine*]

Will Gater is an astronomy journalist, author and News Editor of *Sky at Night Magazine*. He is also a columnist for *BBC Knowledge Magazine*

FIND OUT MORE

▶ **http://mars.jpl.nasa.gov/msl/**
All about MSL, including information on the Curiosity rover and MSL videos

▶ **http://msl-scicorner.jpl.nasa.gov/**
More detailed information on the science payload *Curiosity* will carry

WHAT DO YOU THINK?

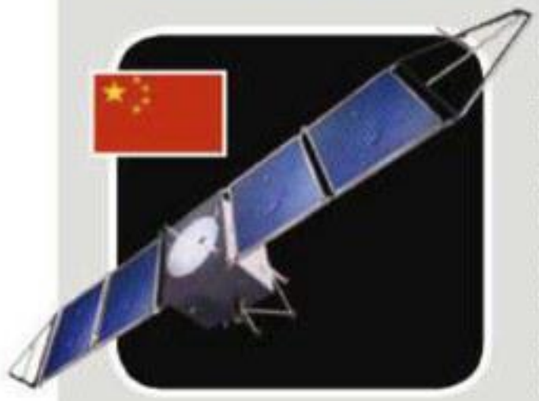
Will what we learn about Mars be worth the effort?

email: **editor@bbcknowledge.com**

IN THE PIPELINE

Curiosity is far from the only Mars mission on the table. Other imminent projects include:

NAME: Fobos-Grunt
AGENCY: Russian Federal Space Agency
MISSION TYPE: Orbiter, lander and sample return
LAUNCH DATE: November 2011
GOAL: The destination is Phobos, one of Mars's two small moons. Its goal is to study Mars from orbit and collect a sample from Phobos, returning to Earth by August 2014. It's the first Russian interplanetary mission since the failed 'Mars 96'.



NAME: Yinghuo-1
AGENCY: China National Space Administration
MISSION TYPE: Orbiter
LAUNCH DATE: November 2011
GOAL: *Firefly* will also orbit Mars, taking photographs and sending data and photographs back to Earth. It will conduct experiments on the Red Planet's space environment, particularly its magnetic field and ionosphere.

NAME: MetNet
AGENCY: Finnish Meteorological Institute
MISSION TYPE: Landers
LAUNCH DATE: tbc
GOAL: Although the initial goal is to send just one or two landers, Finland intends ultimately to send several (each intended to last for around seven years) to the Martian surface to establish an observation network about the atmosphere there.

NAME: Mars Atmosphere and Volatile EvolutioN (MAVEN)
AGENCY: NASA
MISSION TYPE: Orbiter
LAUNCH DATE: 2013
GOAL: MAVEN will collect critical measurements about Mars's atmosphere in order to help scientists better understand climate change on the Red Planet.

NAME: ExoMars
AGENCY: ESA and NASA
MISSION TYPE: Orbiter, lander and rover
LAUNCH DATE: 2016 and 2018
GOAL: The first lander in this mission will be used to test out new landing technology. It will then be followed in 2018 by the European ExoMars rover, which will drill down into Mars to examine its subsurface geology.

▶▶ FURTHER AHEAD: With the addition of NASA's recently announced Space Launch System, it's possible that by the time these missions end humans will have already walked on the surface of Mars.

NASA X2, CNES, FINNISH METEOROLOGICAL INSTITUTE/HARRI HAUKKA, ESA

SHOULD WE GO?

It'll be a one-way ticket if we do, says **Lord Martin Rees**, Baron of Ludlow

I hope that some people now living will walk on Mars. But I don't think they will go there NASA-style. Indeed, there is little practical or scientific purpose for sending them. The kind of robots and fabricators that we'll have by mid-century will be able to do essentially everything that people could do – and at far less cost.

Until the very recent announcement about its plans for the heavy-lift launch vehicle Space Launch System, the US had downgraded the priority of manned space flight. The main impediment for NASA is that it is constrained by public and political opinion to be too risk-averse. The Space Shuttle has failed twice in more than 130 launches. This represents a level of risk that astronauts or test pilots would willingly accept, but the Shuttle had been promoted as a safe vehicle for civilians. Each failure caused a national trauma, and was followed by a hiatus in the programme, while costly efforts were made (with very limited effect) to reduce the risk still further.

Budget flights

I do not think future manned expeditions into 'deep space' will be politically and financially viable unless they are cut-price ventures, spearheaded by individuals prepared to accept high risks – perhaps even 'one-way tickets'. And these may have to be privately funded; no Western governmental agency would expose civilians to such a hazardous venture.

Mars offers an environment that's not even as clement as the Antarctic or the top of Everest

ALAMY, CORBIS

Privately financed spacecraft, like the Falcon 9 rocket, could be the future

The first people to land on Mars will be driven by the same motives as those who explored distant continents 500 years ago – the spirit that drives test pilots, round-the-world balloonists and the like.

It is now US policy to encourage private companies to undertake launches, rendering NASA more like an airport authority and less like an airline. The Falcon 9 rocket, developed by the Space X company led by the entrepreneur Elon Musk, has successfully launched a payload into orbit.

The involvement in space projects of Musk, Amazon founder Jeff Bezos and others in the high-tech community with credibility and resources is surely a positive step. And Google has offered a prize for whoever can build and launch a robotic lunar lander that can carry out specific tasks on the Moon. This is another stimulus – leveraging far more money than the prize itself offers. It is not unrealistic to envisage private sponsorship, spread over several years, exceeding the $10bn level. At present, that wouldn't even fund a one-way trip, but the cost will come down as technology advances.

It will be dangerous. Remember, Mars offers an environment not even as clement as the Antarctic or the top of Everest. It is foolish to claim, as some do, that emigration into space offers a long-term escape from Earth's problems.

A century or two from now, however, small groups of intrepid adventurers may be living on Mars. Whatever ethical constraints we impose here on the ground, we should surely wish such pioneers good luck in genetically modifying their progeny to adapt to alien environments. This might be the first step towards divergence into a new species: the post-human era would then begin. And machines of human intelligence could spread into the cold regions of the outer Solar System. Whether the longer-range future lies with organic post-humans or with intelligent machines is a matter for debate.

Moral dilemmas

Would it be appropriate to exploit Mars, as happened when the pioneers advanced westward across the United States? Should we send seeds for plants genetically-engineered to grow and reproduce there? Or should the Red Planet be preserved as a natural wilderness, like the Antarctic?

The answer surely depends on what the pristine state of Mars actually is. If there were any life there already – especially if it had different DNA that testified to quite separate origin from any life on Earth – then Mars should be preserved unpolluted. Long before the first people go, let's hope this scientific question has been settled by robotic probes.

WHAT DO YOU THINK?

Do you agree or disagree with Lord Rees?

email: **editor@bbcknowledge.com**