Marswalk One

First Steps on a New Planet

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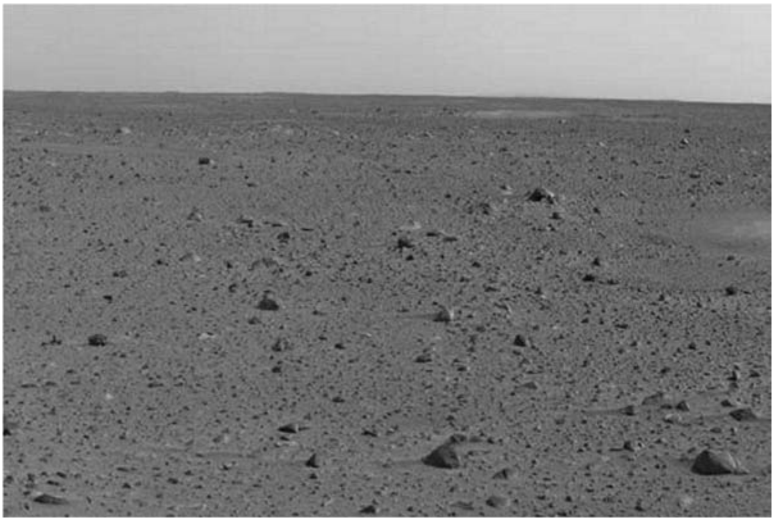
This book is dedicated to the lasting memory of
William H.J. Salmon (1924–1985)
and
Derek J. Shayler (1927–2002)



'Magnificent desolation' – a view of Mars' terrain and horizon, from Spirit, 2004

'Man's first step on Mars will be no less exciting than
Neil Armstrong's first step on the Moon'

Wernher von Braun, from his Manned Mars Landing presentation to the Space Task Group on 4 August 1969, two weeks after Neil Armstrong took his 'small step' on the Moon

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Table of contents

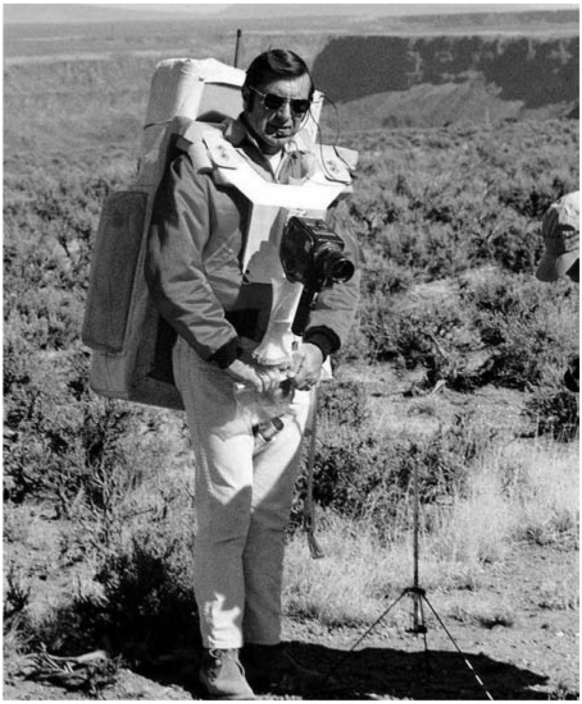
Foreword

On 14 January 2004, President George W. Bush appeared before employees at NASA headquarters and announced 'a new plan to explore space and extend a human presence across our Solar System.' This initiative energises and refocuses NASA on new goals that include manned missions to the Moon by 2015 and a permanent lunar base by 2020, with Mars as an ultimate objective. The President stated: 'We will build new ships to carry men forward into the universe, to gain a new foothold on the Moon, and to prepare for new journeys to worlds beyond our own.'

The schedule presented calls for a new Crew Exploration Vehicle (CEV) to be developed and tested by 2008, for robotic rovers to begin exploring the lunar surface, and for the International Space Station (ISS) to be completed, and the Space Transportation System (Space Shuttle) to be retired by 2010. The CEV is to begin human space flight by 2014, and return to the Moon and establish a lunar base between the years 2015 and 2020. Missions to Mars would commence beyond 2020.

To assist NASA, the President named Edward 'Pete' Aldridge, former Secretary of the Air Force, to be Chairman of the new Space Exploration Commission. The Chairman and his Commission had 120 days to make recommendations to President Bush. Aldridge has stated that priorities will certainly touch on affordability, the talent base at NASA, and contributions by other countries and commercial enterprises. It was no small task for the Commission to tackle the existing bureaucracy and to change the culture of NASA, which had languished in near-Earth orbit for 30 years.

As to affordability, Bruce Murray, former Director of NASA's Jet Propulsion Laboratory, has been quoted as saying: 'It's not a financial issue. NASA's budget doesn't have to increase dramatically for this to take place.' This is probably fortunate, as we are looking at an 'unfunded mandate' with the current state of the federal budget. In addition, until 2010, when the ISS is completed and the Shuttle is retired, 39%, or $6.1 billion, of NASA's current budget is devoted to these activities. In 1961, when President Kennedy mandated that the United States would create a lunar programme called Apollo, funding was not available. However, against much opposition, the President opened the federal coffers and gave NASA carte blanche.



Astronaut Dick Gordon during EVA training for Apollo 15.

Dick Gordon and Jack Schmitt training for Apollo 15. Gordon would have been the thirteenth man to walk on the Moon as Commander of Apollo 18, had it not been cancelled.

Because of this, and the dedication of some 400,000 people, the programme was accomplished.

As with Apollo, the Mars Manned Missions will be preceded by unmanned missions that will provide necessary knowledge. I recall how important it was for Apollo to gain the knowledge provided by the unmanned flights of the Rangers and the Surveyors to the Moon. In fact, Surveyor 3 was a target for my flight on Apollo 12. The equivalent for Mars manned exploration are the flights of Viking, Pathfinder, Beagle 2 (European Space Agency), Mars Global Surveyor, and Russian Mars flights. The surface operations of Sojourner, Spirit and Opportunity have and will provide needed intelligence for future exploration. There will certainly be additional unmanned missions before manned missions to Mars are accomplished. In some regards these relationships somewhat mitigate the heated argument of 'manned vs. unmanned', since we need both to be a vibrant society and nation.

Speaking of debate, I remember one that was crucial to the success of Apollo. In the early 1960s, argument raged about how we would go to the Moon – by direct ascent, *à la Jules Verne*; by Earth orbit rendezvous with spacecraft launched on separate boosters and assembled in Earth orbit before heading out to the lunar surface; or by lunar orbit rendezvous in which the separated vehicles (the Command Service Module and the Lunar Module) would be launched on a single booster and the LM ascent stage would rendezvous in lunar orbit with the CSM after the landing, before the journey home. The direct ascent method was rejected as not being practical. This left Earth orbit rendezvous, which Wernher von Braun favoured, and lunar orbit rendezvous, which the Manned Spacecraft Center, led by Bob Gilruth, favoured. The choice was not made until a high-level management meeting, when someone in attendance reminded those assembled that the mission was to be accomplished 'before the decade of the 1960s was over.' That ended the debate, and lunar orbit rendezvous became the way to accomplish Apollo.

The authors of *Marswalk One* concentrate on what humans will do on the martian surface. Left untreated are the interesting propulsion methods of journeying from the Earth to Mars. Currently available chemical fuels require coasting flight after leaving Earth orbit, and a 7–9-month flight to the vicinity of Mars. This is not very appealing, and other methods and propulsion systems should be available to reduce the transit time to an acceptable level. These propulsion systems include nuclear thermal engines, and ion propulsion that utilises a portable nuclear reactor to heat charged gas. Both of these systems provide acceleration to reduce the transit time and reduce the crew's exposure to zero-gravity flight, which may or may not cause concern. Of great promise is a plasma-propulsion rocket being developed in NASA's laboratories by former astronaut Franklin Chang-Diaz. Although a few years from realisation, by this method the transit time would be reduced to 40 days. This, of course, would be attractive to anyone on a mission to Mars.

Marswalk One deals with some of the above, but primarily turns to the science that will be carried out on the martian surface supported by orbital operations – as did the Apollo Command Module (or mother-ship). Hardware to be developed, and the required technology (existing or new), will be explored, as they apply to surface exploration. This book treats subjects such as manned versus unmanned exploration, communications, training, required scientific disciplines, landing sites, martian space suits designed following Apollo and Shuttle EMU experiences, on-site science laboratories, traverses and the duration of such, habitats, lessons learned to be applied to future missions, the return home, the consideration of quarantine after having been gone from Earth for up to two-and-a-half years, and from Mars for the duration of the flight home. Left to the imagination of the reader is the juxtaposition of the human/Mars experience.

I have always said that spaceflight provides one with a different perspective of our planet. While Earth-bound, we all have a certain point of view of our planet either at home, in our cars, on a ship, or during aircraft in flight at 40,000 feet. Flight in Earth orbit provides another perspective, as does flight at lunar distances – which very few humans have experienced. I believe the final perspective will be from Mars, when the Earth, as she is visible, will be that blue dot in the vast void of space.

As in the past, there will be many arguments, discussions and debates regarding President Bush's initiative of a new Crew Exploration Vehicle, the establishment of a lunar base, and eventual missions to Mars after 2020. As an example, it is not intuitively obvious that the CEV can be designed to fly in Earth orbit, travel to the Moon, and handle the task of taking crews to Mars and returning them to Earth. There are those who see 'the Moon as a lunar base' as an objective, and not a stepping stone for martian exploration. Two very prominent individuals share this feeling. One is Louis Friedman, the Executive Director of the Planetary Society, who has been quoted, in referring to the Moon: 'I don't see how it's getting humans ready for another trip to Mars.' Even more outspoken is Robert Zubrin, President of the Mars Society and author of 'The Case for Mars'. Zubrin sees the Moon as a long-term detour, and says that it is 'the same swindle we fell for on the space station ... The schedule is the first red flag. We could go to Mars in six years if we really wanted to.'

To the Moon, or a mission to Mars? There are proponents and detractors for each, or both. NASA's chief long-range planner, Gary Martin, has his work cut out, and he will be a very busy man. I find this very exciting for the future of space exploration. The authors of *Marswalk One* propose much for discussion. Let the debates begin!

Richard F. Gordon
NASA Astronaut, 1963–72
Pilot, Gemini 11
Command Module Pilot, Apollo 12

Authors' preface

Over the past fifty years, many volumes have been written about the prospects for human exploration of Mars, but there has been very little written about what can be expected from the first crew to achieve the historic landing on the Red Planet. That is the purpose of this volume. The problem with detailing the first landing of humans on Mars is that we have no idea when the landing will take place, how it will be achieved, or how long the crew will remain on the surface – let alone the identity of the crew-members and what they will do when they are there.

Therefore, while other authors have concentrated on how to get to Mars, how to perform extended surface operations over many years, on establishing martian bases, or the theory of terraforming, creating many discussions on the prospect and scope of human exploitation of the fourth planet, we aim to focus on what might take place on the very first landing, and the activities of the first humans to place their boot-prints in the dust of Mars. In many ways the challenge of landing this first crew on Mars will set the stage for the events that follow.

The compilation of this book was all the more difficult because it discusses a programme yet to be defined. Many plans for a Mars mission have been proposed, but no-one has ever put forward a detailed plan of what the first crew will do when they get there, simply because we do not know when or how we will achieve that goal. As there are, at present, no firm plans to mount a human expedition to Mars (although there are plenty of proposals, studies, ideas and dreams), we expect this book to open a discussion focusing on what to include and what to expect on the pioneering landing. Although others may follow after a short interval, what will be the requirements for the initial step onto the planet? Where could they land? What will be the exploration plan? What role will robotic vehicles play in the mission? How far will they travel? How many EVAs could they mount? Will samples be studied *in situ* or on the way home? What types of research will be focused upon by experiments? These are the questions posed for the first landing. Other tasks include deciding upon the type of landing vehicle to support the crew. Will it be self-contained, or will it rely on previously landed robotic vehicles to provide the supplies for the return trip? Will it be rudimentary for short duration, or have facilities for a prolonged surface stay? What will happen in the event injury, death, or a rescue situation? It is clear that, like Apollo aiming for the Moon, until a programme is assigned to reach Mars there will be far more questions than answers. When, at last, we have a firm and sustained commitment to Mars, we can begin to cement the plans for the first landing. Until then, we can only suggest and discuss possibilities.

As this is a book about the future, it is clear that the story will be debated and will evolve until the point where a firm decision is reached, hardware and procedures are defined, and a flight plan is written. This book originated in a discussion between the authors, of the many ideas that have been proposed on how to get to Mars, and when this happens, the sequence of events for setting up a base, and colonising or terraforming the planet. But these are large-scale and long-term goals, and while the very first mission will clearly depend on its timing, the capabilities of the hardware and the final location of the landing site, there still has to be a starting point for surface exploration and a programme for the first crew on Mars. Apollo 11 was the first cautious exploration of the lunar surface, and Apollo 17 ended our first phase of human lunar exploration; but it is expected that the first landing on Mars will be a combination of both caution and exploration, simply because of the distance the crew will have to travel.

The authors consulted many sources to provide a contemporary and informative review of the current (2004) ideas of what the first Mars exploration team will probably be tasked to do. It will inevitability generate further debate and discussion and reveal new information; and this is encouraged, to help generate public awareness of the case for sending humans to Mars, supported by robotic technology and merging the world's space programmes for a common goal.

The authors express a desire to update this work at a suitable point when a programme for surface exploration is more clearly defined. Until then, communication is encouraged though our Marswalk page on the website, http://www.astroinfoservice.co.uk. We hope that a future edition of this book will include a report of the first excursions across the Red Planet, detailing the equipment, procedures, activities and findings of the first humans to explore Mars – when we can clearly identify the date that the first steps on the Red Planet can be identified as Marswalk One.

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December 2004

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In addition, the following astronauts and cosmonauts have each offered a personal insight into working in pressure garments, either from the Shuttle on EVA repair, on space stations on long missions, or on the Moon: Joe Allen, Jerry Carr, Gene Cernan, Bill Fisher, Michael Foale, Ed Gibson, Georgi Grechko, Bernard Harris, Jim Irwin, Jack Lousma, Bruce McCandless, Story Musgrave, Bill Pogue, Yuri Romanenko, Jerry Ross, Yuri Usachev, Paul Weitz, and John Young. Additional thanks are also extended to Jerry Carr, for access to his personal library. All illustrations are courtesy NASA, unless otherwise stated.

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We also look forward to discussing the topics in this book with those who will turn the dream into reality, and hopefully with those who will turn the reality into history – the first Marswalkers. But that is another story, and another book ...

List of illustrations

Evolution of a Marswalk

Wardrobe for Mars

Surface exploration

Science on the surface

Living the dream

The return

Prologue

'By the year 2000 we will undoubtedly have a sizeable operation on the Moon, we will have achieved a manned Mars landing, and it's entirely possible we will have flown with men to the outer planets.' – Wernher von Braun (*c.* 1970).

Following the first Apollo lunar landing in 1969 it was widely expected that authorisation for a programme to explore Mars would soon follow, leading to the first crew landing on Mars by 1980. However, only a year after the Apollo 11 mission, NASA was forced to cut its planned lunar landing programme from ten to just six, having also aborted the Apollo 13 landing due to an in-flight explosion. A variety of domestic and foreign issues had had an impact on the future direction of the US human space programme for the 1970s and beyond. Apollo 17 – the final Apollo mission to the Moon in December 1972 – came home just four years after Apollo 8 had completed the first human voyage to another world. A total of twenty-four American astronauts had ventured to the Moon, and only twelve of these had explored the surface, for three days at most.

Since Apollo 17, all human spaceflight missions from all nations have operated in Earth orbit only. There were many studies and arguments in favour of a return to the Moon and for venturing out to Mars, but nothing ever came of them. In January 2004 – four years after von Braun's latest date for a lunar base and a manned landing on Mars – we finally turned our gaze back to the Moon and out towards Mars.

Therefore, at some yet to be determined day in our near future, we shall once again witness commentary from another world, as we did when we listened to Neil Armstrong on 20 July 1969: 'The hatch is coming open ... Okay, Houston, I'm on the porch.' On the TV screen, a ghostly black-and-white image reveals Neil Armstrong slowly descending the ladder towards the surface. At the bottom of the ladder he drops gently to the landing pad, and then springs back up to the lower rung to test the ascent to the crew compartment. 'OK, I just checked ... Getting back up to that step ... It's not even collapsed too far, but it's adequate to get back up ... It takes a pretty good jump.' Then, as the world holds its breath, history is marked with a paragraph of explanation and a statement of fact: 'I'm at the foot of the ladder ... The LM footpads are only depressed in the surface about one or two inches ... The surface appears to be very, very fine grained, as you get close to it. It is almost like powder ... Now and then very fine. I'm going to step off the lander now'. Armstrong lifts his left foot and, holding on to a lower rung of the ladder, gently but firmly places his boot on the Moon-dust, stating: 'That's one small step for [a] man, one giant leap for mankind.'

Seconds later, Armstrong moved his right boot onto the surface and began to move around in the immediate vicinity of the landing pad, slowly accustomising himself to moving around in the suit in the $\frac{1}{6}$ Earth-gravity. Armstrong had stepped off the LM 109 hrs 24 min 15 sec after leaving the launch pad on Earth. Looking around, he commented on the vista before him, and his first impressions from the surface: 'The surface is fine and powdery ... I can pick it up loosely with my toe [of the boot]. It does adhere in fine layers like powdered charcoal to the sole and sides of my boot. I only go in ... maybe an eighth of an inch, but I can see the footprints of my boot and the tread. There seems to be no difficulty in moving around as we suspected. It's perhaps easier than in the simulations at one-sixth gravity that we performed on the ground. The descent engine did not leave a crater of any size. There is about 1-foot clearance on the ground. We are essentially on a very level place here. It's quite dark here in the shadow, and a little hard for me to see if I have a good footing. I'll work my way over into the sunlight here without looking directly into the Sun. Looking up at the LM, I'm standing directly in the shadow now looking up at the windows, and I can see everything quite clearly.'

One of the first tasks was the collection of a small sample of soil so that, in the event of early termination of the mission, at least a small sample of lunar material would be returned to Earth. Due to the restrictions of the pressure garment, Armstrong was guided by Aldrin from inside the LM and, using a telescopic handle with a scoop attached, gathered the first sample from the Moon and placed it in the leg pocket of his pressure garment: 'This is very interesting. It's a very soft surface, but here and there where I plug with the contingency sample collector, I run into a very hard surface. But it appears to be very cohesive material, of the same sort. I'll get a rock in here ... It has a stark beauty all of its own. It's like much of the high desert of the United States. It's different but it's very pretty out here. Be advised that a lot of rock samples out here, the hard rock samples, have what appear to be vesicles in the surface. I'm sure I could push it [the sample collector] in further, but it's hard for me to bend down further than that.' As Aldrin joins Armstrong on the surface, the two men are struck by the stark contrast and the moonscape before them. Armstrong notes: 'Isn't that something? Magnificent sight down here.' Aldrin sums up a whole panorama of Tranquillity Base in just two words: 'Magnificent desolation.' For a couple of hours on 20/21 July 1969, most of the civilised world was spellbound by the activities of two men a quarter of a million miles away.

It had been eight years and two months since President John F. Kennedy had initiated the quest for the Moon, and less than twelve years since Sputnik was launched to start the space age. But by 20 July 2019, if all goes according to plan, we should see the thirteenth person step on the Moon in time to celebrate the fiftieth anniversary of the famous first Moonwalk by Armstrong and Aldrin. But will we see the first step on Mars by 2029? Will the sixtieth anniversary of the first Moonwalk also coincide with the first EVA on Mars and introduce a new term into spaceflight history: Marswalk One? Whatever the answer to this question, it is clear that the first step on Mars will be nothing like the first step on the Moon.

The Apollo 11 astronauts' descriptions of the lunar terrain were typical of the planned landing area – a relatively flat Mare region chosen in consideration of safety requirements rather than for scientific interest. At Mars, the landing sites of the two Viking landers and the three rovers (Sojourner, Spirit and Opportunity) were quite different, but although each had their specific characteristics, they all had a distinctly 'martian' appearance.

Armstrong's method of exit was to crawl out backwards on his hands and knees to a small porch and down a nine-rung ladder to step off a footpad and onto the lunar surface. The method of stepping onto Mars will very much depend on the final design of the landing vehicle and chosen mode of vehicle exit. The time between leaving Earth and stepping onto the Moon was just over four days, but the difference between leaving Earth and stepping onto Mars will be several months. It is unlikely that the crew will exit only a few hours after landing, and a period of acclimatisation will be required, with surface operations not taking place until several days after landing.

Armstrong noted that the LM descent engine did not produce a crater, because of the low gravity and the absence of an atmosphere, and also because the engine shut off when the contact probe on a landing leg touched the surface. For Viking (1976), the lander engines had a specially designed system of fine multiple-exhaust nozzles, so that there would be very little disturbance of the martian surface as the lander approached. The effect of the first crew-landing will depend on the chosen site and the design of the vehicle braking system. Much of Mars is covered with dust, ranging from large granules of material to particles finer than talcum powder. With the $\frac{1}{3}$ Earth-gravity and the presence of a thin atmosphere, the final approach and landing will be very different from a lunar touch-down. Dust will be disturbed, and will billow around and be blown away from the landing area, leaving a small crater and perhaps a dust cloud that would settle around the landing area. Dust kicked up by the landing engine(s) will cause problems if it settles on any of the solar panels feeding the power systems. Before beginning sampling operations, the crew will have to walk or use a rover to travel to an area of ground undisturbed by their landing and activities.

One of the observations on Apollo was the dramatic contrasts in light and shadow. On Mars, the thin, dusty atmosphere will even out any shadow, so there will not be the crisp shade and sunlit features seen on the Moon. The communications delay between the Apollo crews and Earth was only a couple of seconds, allowing real-time 'live' TV and radio transmissions from the Moon. For a crew on the surfce of Mars, direct communication with the orbital crew would be the most 'local' while in orbit overhead, or via relay satellites deployed in orbit. The orbital craft would not be a 'mission control' as such, but rather an extra set of eyes to oversee the landing area during the risky descent and ascent, and a relay between the surface and Earth (up to twenty minutes away from immediate communications). EVA choreography and mission planning would be another option from orbit, but command and control would be more surface-based, with support from orbit and the final decision resting with mission control on Earth.

The first landing would probably be along the lines of Apollo 12/Surveyor 3, featuring a pin-point landing near an earlier robotic lander. This could be a logistics or habitation module already checked out before the crew departed from Earth, or the return fuel and hardware, depending on the final method of journeying to and from the planet. The crews would also number far more than three (two on the surface and one in orbit) for a week or so in space, and there would more probably be between six and twelve crew-members on a mission of two to three years. Robots would be awaiting them at or very near the landing site, ready for teleoperation by the crew from the lander both before and after the first EVA.

On Apollo 11, the first landing was planned as a single excursion of a couple of hours. Follow-up landings lasted for about 36 hours and included two surface excursions, with the final landing lasting three days with three surface excursions. Although longer surface activities were planned under the Apollo Applications Program, this never materialised. On Mars, the first excursion will probably be quite short, but would be followed by several days and weeks of activity by different crew-members. This will very much depend on the chosen mission profile, hardware design and programme goals. It will certainly be a precursor for even longer and more extensive expeditions in the second and subsequent phases.

Robotic precursor missions paved the way for Apollo, and monitoring from Earth was part of Apollo mission planning. A small programme of crewed missions under the Mercury and Gemini programmes helped refine the techniques and experience to mount Apollo missions of up to two weeks. Long-duration spaceflight operations of more than two weeks essentially came to the forefront after Apollo. For the first landing on Mars, years of research in long-duration spaceflight activities, return missions to the Moon, and intensive robotic activities, will be essential precursors – as will planning for other factors, including minimal solar activity during approach to the planet, avoidance of dust storms at or near to the touch-down areas and back-up sites, and good weather reports from the primary and back-up sites, without hindrance to final approach and landing abort parameters. In short, the landing would have to be chosen at a particular time of year, at the right time of day, in a landing site chosen with minimal dust storms, fog or clouds for a visual or instrument approach. These are just a few of the constraints on a mission that will last between two and three years.

Why? This is the fundamental question behind a human Mars mission! Certainly, science is not the sole rationale for exploring Mars, and other reasons are needed before we send people there. What is the lasting power of this motivation? Even without an answer to this question, humanity is currently searching for the reason to send humans. But, as roboticist Alex Ellery has said: 'Mars is only the first step to opening up the Solar System. It's not the end goal.'

In 1962 – the year after committing America to land on the Moon 'by the end of the decade' – President John F. Kennedy presented another of his famous 'space' speeches to an audience at Rice University, in Houston, Texas: 'We choose to go to the Moon! We choose to go to the Moon in this decade, and do the other things, not because they are easy but because they are hard.' If nothing else, then the same could be said of going to Mars – not because it is easy, but because it is hard ... extremely hard. But once we are there, on the surface, what will we do? How will humans cope with being away from Earth for up to three years, and with living and working in the hazardous environment of a far-off world. That is the subject of this book.

Destination Mars

As one of the brightest and most recognisable objects in the night sky during its closest approaches to Earth, Mars – the Red Planet – has long attracted human interest. For humans it was at first an object of religious significance, worshipped as a god of war, due to its remarkable rusty colour. Later, we pondered its apparent motion across the sky, puzzling over why it at times appeared to move 'backwards' across the heavens; and then we came to realise that the Earth is not the centre of the Universe and that Mars was simply moving in relation to ourselves around the Sun. After the invention of the telescope, Mars became an obvious target for observation because of its proximity, its colour, and the myth and mystery that surrounded it. Although there was almost nothing to be seen on Venus, we could, at least occasionally, observe Mars in some detail, although it was limited due to the poor definition of early telescopes.

These early observations also gave rise to numerous stories, speculations and theories about the possibility of life on Mars, the presence of seas, rivers and the famous 'canals', and whether or not the dark areas were martian vegetation. American astronomer Percival Lowell certainly fuelled the fire for such speculations in the 1890s when he theorised that the so-called 'canals' he had observed were created by intelligent beings to irrigate the dry equatorial regions of the planet by carrying water from the polar ice-caps. Evidence accumulated later refuted the presence of the 'canals', and proved that the martian environment was not suitable for life as we know it on Earth; but the debate has continued up to the present day, and the most recent missions to Mars have landed with the intention of trying to find evidence that there may have been life at an earlier time in Mars' history, when the environment of the planet was more hospitable than it is now.

It is not the purpose of this book to speculate about the possibility of life on Mars. At the time of writing, nothing definite has been found, but if the current crop of Mars missions finds such evidence, then further scientific investigation will be one of the priorities of any human expedition. Equally, it is not the purpose of this chapter to deal with the myths and misconceptions surrounding Mars. But if we are to send humans to the Red Planet we will need to know as much as possible to ensure that the journey and the stay is as safe as possible for the crew.