Part I
The imperative of exploration

From the perspective of determinism and constrained contingency that pervades the history of life . . . life and mind emerge not as the result of freakish accidents, but as natural manifestations of matter, written into the fabric of the Universe.

Christian de Duve (1995)

1 Exploration as metaphor

The urge to explore has been ingrained in human nature since the emergence of our species. The story of the vast movements of peoples across oceans and continents is woven into the history of humankind. For millennia this drive has been at the core of European culture and history. The Greeks and Romans of antiquity explored distant regions of Asia and Africa far from their established empires. Vikings from Scandinavia and, quite probably, Irish monks reached the shores of North America centuries before Christopher Columbus set out on his voyage of discovery across the 'Ocean Sea'. In the fourteenth century Marco Polo penetrated the Chinese empire. In the centuries that followed, Henry the Navigator sponsored the vast Portuguese exploration of the coast of Africa, Cartier explored Canada and Magellan made the first perilous circumnavigation of the globe. The eighteenth and nineteenth centuries saw the great voyages of discovery of Captain Cook in the Pacific and the exploration of large swathes of Central and South America by Humboldt, who described the regions' plants and climate and studied the Earth's magnetic field. Charles Darwin's famous voyage around the world aboard the *Beagle* provided the evidence which would lead him to the theory of evolution. Nearer our own times, polar explorers have numbered such European pioneers as Nansen, Shackleton, Amundsen and Scott.

In the twentieth century, the mantle of pioneering exploration fell to the United States and the Soviet Union in their superpower rivalry, opening the way to outer space when the tiny Sputnik 1 forged its way across the world's skies in October 1957. Four years later, Yuri Gagarin became the first human in space with his single-orbit flight around the Earth, demonstrating that where robots would first go humans would soon follow. Unmanned and, later, manned missions

to our Moon followed, and by the end of the century Pioneer 10 had photographed and flown past all of the great and outer planets and left the Solar System for the emptiness and darkness of deep interplanetary space. We seem now to stand at the threshold of a great leap forward in the story of human exploration and new questions crowd forward:

- What does our present knowledge about the nature and origins of life tell us about the existence and pervasiveness of life in the Solar System?
- What are the limits to human survivability in interplanetary space and on planetary surfaces?
- Can we identify and prepare the development of key technologies to enable such human Solar System exploration?
- Can we expect to find other non-terrestrial life forms in the Solar System and, if so, how should we look for them and would they pose a threat to human exploration?
- Can we devise an ethical planetary exploration approach within existing international accords that reflects civilised values?
- What exactly is the unique role of humans in the exploration of the Solar System in pursuit of the search for life?

Some of the great voyages of discovery might be able to give us clues about how to approach these questions.

Magellan

In the early part of the sixteenth century, the intense competition between Spain and Portugal to discover and exploit the lands to the west and south of Christopher Columbus's 'Ocean Sea' came forcefully to the attention of Pope Alexander the Sixth. The Pope drew a line on the map of the Atlantic and ceded the eastern portion to Portugal and the western part to Spain. Ferdinand Magellan, a Portuguese mariner who could not get the support of the Portuguese king, ended up sailing under the flag of the King of Spain after convincing the royal court at Seville that a Spanish expedition sailing west could find a way through the islands into the ocean beyond.

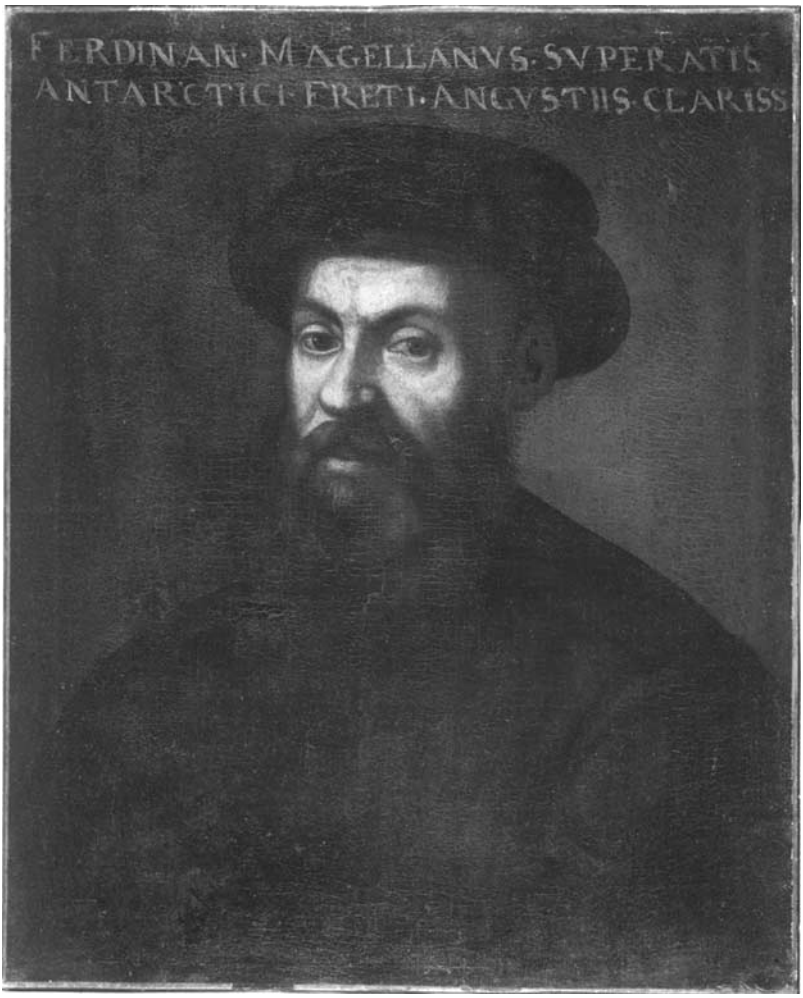

FIGURE 1.1 Ferdinand Magellan. (Courtesy of Mariners Museum, *Newport News*.)

He set sail from Seville on 10 August 1519. Of the five ships that left Seville that day only one ship, the *Vittoria*, returned to Seville after the first circumnavigation of the globe, on 6 September 1522. Magellan himself had been killed in the Philippines trying to convert the natives to Christianity and had discovered and named the Pacific Ocean. Within a span of just over three years, Magellan's voyage had

FIGURE 1.2 Magellan discovers the Straits of Magellan. (Courtesy of the Mary Evans Picture Library.)

determined the size and overall composition of our planet in terms of its two major oceans and the manner by which our globe can be circumnavigated. No man before or after, with the possible exception of Cook, has had a comparable effect on the exploration of the Earth, and settled forever the questions of its size and overall geography.

Captain Cook

On Friday 12 July 1776, Captain James Cook set sail from Plymouth in search of the North West Passage. He had renamed the three-masted collier under his command, *Resolution*, a fitting tribute to his state of mind in setting out on such a long and potentially perilous journey. It would involve stops in Tenerife, Table Bay and Queen Charlottes Sound in New Zealand before even the first mile of exploration could be embarked upon. The other ship in his command was also renamed by Cook. It took the name *Discovery*, and would join *Resolution* later on. No clearer names could have been chosen to portray Cook's determination to discover the hypothetical northern passage between the Pacific and the Atlantic Oceans. Cook had been engaged in voyages of exploration since 1772. Two- and three-year voyages of discovery were not unusual for explorers of the eighteenth

century. Similar journey times there and back should not be daunting for human explorers of Mars in the twenty-first century.

The exploration of foreign places requires human qualities which transcend the values generally held in esteem at the conclusion of the twentieth century, a century which valued cleverness over fortitude, insight over intuition, calculated over hunch-based risk-taking, corporate over individual enterprise. The explorers of the twenty-first century will need to rediscover some of the values which drove men to take the personal and corporate risks which they did in the seventeenth and eighteenth centuries. Whereas Captain Cook's voyages appeared on the face of them to be neutral voyages of discovery, there was always the British Admiralty behind their financing. They were never simple voyages of discovery, but rather voyages of discovery in the furtherance of the interests of English trade and enterprise. So there is a lesson to be learned here.

Successful voyages of discovery have a back-story of exploration and discovery which will, if successful, mightily benefit those who have invested in them. Cook, the British Admiralty and others believed that the discovery of the North West Passage would facilitate trade between England, China, the Indies and the Pacific Islands and that English trade and commerce with the rest of the world would be greatly enhanced.

So we arrive at an interesting question: are there general lessons to be learnt from the voyages of exploration of the seventeenth and eighteenth centuries which could be applied to the space voyages of exploration of the Solar System in the twenty-first century? We will focus on:

- What were/are the arguments both for and against the enterprise? In Parts IV and V we will examine some of the arguments put for and against expanding human exploration out into the Solar System.
- What would be the logistical and psychological similarities? Hammond Innes, the writer of a convincing fictional account of Cook's last voyage, imagined Cook writing of his stay at the isolated Kerguelen Islands as follows:

  'The activity of both ships was so great that day that I doubt whether any man really believed it to be Christmas Day. And the next day was

no better, the filling of the casks with water having to be completed and all to be rowed back and forth between beach and ship, also grass for the cattle to be conveyed in the same manner after being cut from small sheltered areas at the end of the inlet where it did grow. All this work, and the killing of the seals and birds, was much hampered by rain, which was so heavy that the bare rock of the hillside was a sheet of water and every gully a raging torrent.'

Can we imagine similar logistical and psychological stresses in human voyages of discovery in the Solar System? Cook was clearly expert at using as far as possible those resources he found along the way. In Part IV we will look at present thinking about so-called '*in-situ* resource utilisation' in planetary exploration. In Part III we will examine the physiological and psychological stresses on the human system in long-duration exploration missions.

- Concerning the nature of exploration itself, Innes imagines Cook writing: 'I have always referred to the ease of handling of these ships. There is none built anywhere that I have found so entirely suited to the purpose of surveying uncharted and dangerous coasts. This I have proved, never at any time wanting a better. Slowness of sailing is no disadvantage in this work. What is important is to be able to stop the ship dead and turn her in her own length, which they do very readily. I am told they look clumsy, but that is only to those that have not sailed in them or who do not understand what is required of the work on which I have been engaged these last 8 years.'

  Can we imagine similar statements from future astronauts about the qualities of their ships? What is the importance of technology in exploration. Does it play a decisive role, as clearly it did in Cook's case? In Parts IV and V we will deal with this.

An epitaph to Cook was made by his surgeon onboard the ship, Samwell, as follows:

'With clear judgement, strong masculine sense and most determined resolution – with a genius peculiarly turned for enterprise, he pursued his objective with unshaken perseverance; – vigilant and active

in eminent degree; – cool and intrepid among dangers; patient and firm under difficulties and stress; fertile in expedients; great and original in all his designs; active and resolved in carrying them into execution.'

We ask, can our future explorers of the Solar System have these qualities?

It is necessary in all this to reflect on what the past can tell us about the future. The voyages of Magellan and Cook were both marked by searches for passages to other realms, the Straits of Magellan in the former case and the North West Passage in the latter.

Voyages of discovery can never be completely planned. Magellan and Cook, although they knew in general terms what they wanted to explore and discover, were never completely sure what they would find and how that would change and inform their future activities and decisions. Future human space exploration will have to proceed in a way which allows the enterprise and initiative of private individuals and companies as much freedom as possible to invest in space exploration and reap the benefits of those investments. The days of the monopolistic domination of all aspects of space exploration by space agencies, the manipulation of space activities for national propaganda purposes, and the use of billions of dollars and euros of taxpayers' money to further the ambitions of politicians will have to give way to a time when space becomes a real resource for humanity in general.

Charles Darwin

It was 27 December 1831. A cloudy and calm day broke over Plymouth. During the morning the wind freshened and at 2 p.m. Captain Robert FitzRoy came aboard his 30-metre vessel, HMS *Beagle*, together with the 22-year-old naturalist, Charles Darwin, ready to depart from Devonport for a voyage of survey. The voyage eventually took about five years and brought the *Beagle* and its crew around the globe; in the first year, from the British Isles across the Atlantic to South America, where they spent more than 3 years on excursions to various sites, then around Cape Horn and up the Pacific coast of South America to

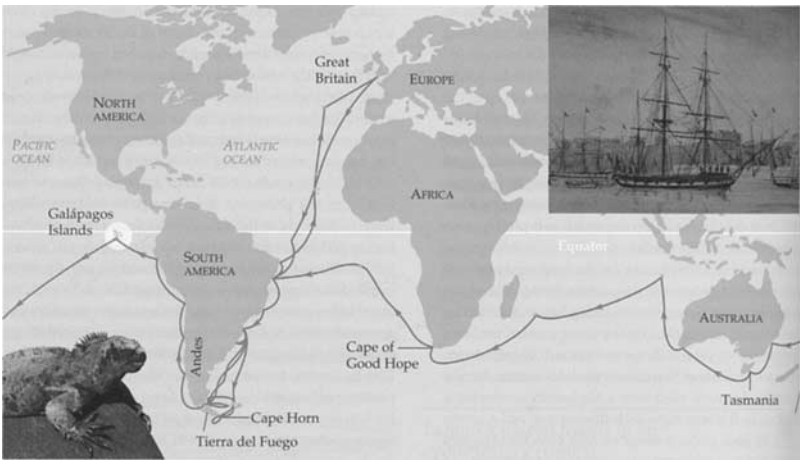

FIGURE 1.3 HMS *Beagle* in the Straits of Magellan and *Beagle* voyage (taken from *Darwin and the Beagle*, Penguin Books, 1969).

the Galapagos Islands. After crossing the Pacific to New Zealand, they visited Tasmania and Australia, crossed the Indian Ocean and passed into the Atlantic by way of the Cape of Good Hope, and returned to England at Falmouth, where they arrived on 2 October 1836. They made a wealth of new and exciting discoveries about the exotic plants and animals they found, with the most stunning at the Galapagos Islands. Yet nobody in 1836 realised that the voyage of the *Beagle* and the discoveries Darwin had made, especially on the Galapagos Islands, would lay the foundations for the formulation of the theory of evolution. Moorehead in his account of Darwin and the *Beagle* has written:

> *But now here on the Galapagos, faced with the existence of different forms of mocking birds, tortoises and finches on different islands, different forms of the same species, he was forced to question the most fundamental contemporary theories . . . Darwin's thesis was simply this: the world as we know it was not just 'created' in a single instant of time; it had evolved from something infinitely primitive and it was changing still.*

Charles Darwin's voyage on board the *Beagle*, and his discoveries during the voyage which finally led to the fundamental theory of evolution, is one of the most illuminating examples of how exploration serves as a pathfinder for shaping human cultural and scientific perspectives. In the endeavour to explore the Earth, humans have crossed the seas, climbed the highest mountains, visited the poles and studied the deepest parts of the oceans. Now, humans have conquered the furthest limits of habitability on our planet. If this urge to explore is ingrained in human nature and if it will impel future human generations to continue on this path, what will result as we set out on the first steps of human exploration of the Solar System?

Amundsen and Scott

We are in January 1912, just past midsummer again at the Antarctic. The Sun is off its maximum height as it slowly starts to head for the horizon and the descent into winter in late February. Five exhausted Britons struggle across the ice pulling their sledges behind them. They are expectant and slightly hurried, despite their exhaustion. Their leader urges them on – they are near their goal now. It is early afternoon. Up ahead they see an object – a man-made object. As they draw closer it is clear that it is a tent. The leader's heart begins to sink. Gradually things become clearer. The small tent has a pole emerging from its peak and attached limply to the pole is a flag. A flag with a red background and an offset blue and white cross. A Norwegian flag. Robert Falcon Scott and his British expedition to be the first to the South Pole have been beaten to that goal by Roald Amundsen and his Norwegian team, who had placed the Norwegian flag at the South Pole on 14 December 1911. In semi-secrecy, Amundsen had launched and carried out a highly successful and logistically efficient assault on one of the last bastions of the wilderness on Earth. Whereas Scott had disdained the use of dogs for his expedition, Amundsen started with 97 dogs and used them in a highly efficient and, according to some people, 'mechanistic' manner as a resource for both transportation and food. Basically, when the dogs became exhausted with pulling the