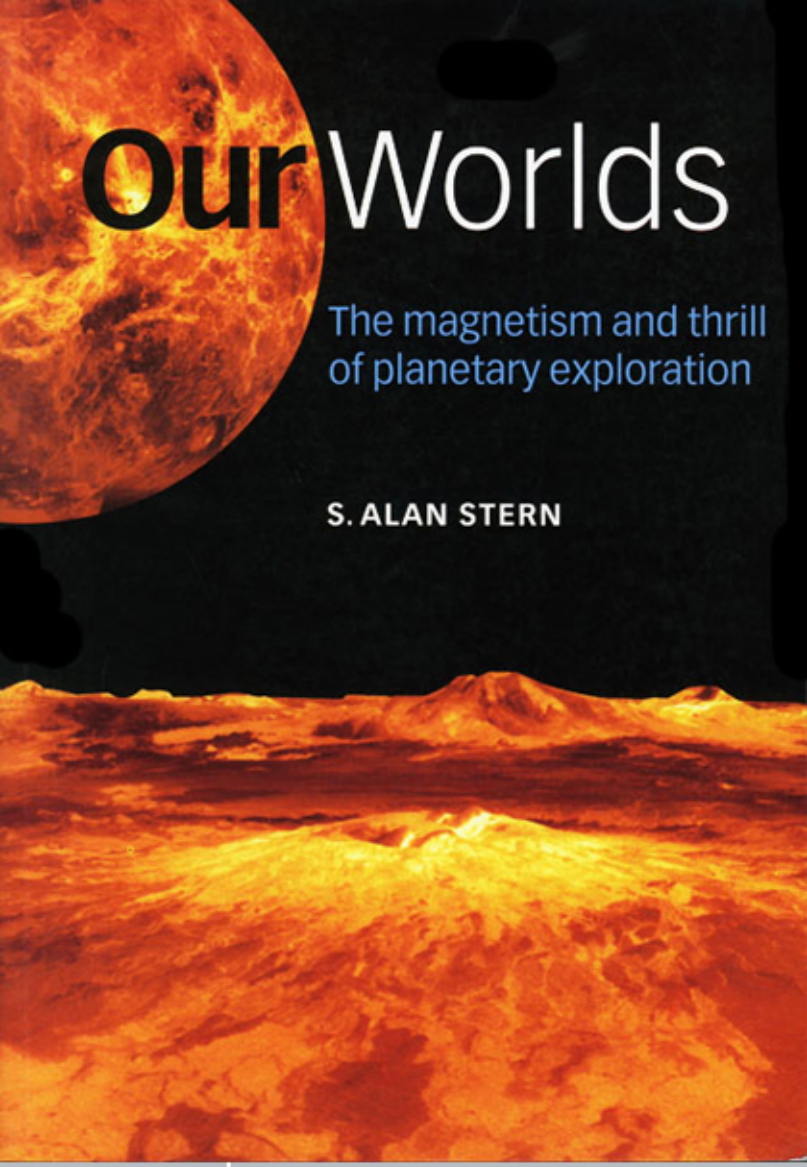
Our Worlds

The magnetism and thrill of planetary exploration

S. ALAN STERN



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As described by leading planetary scientists

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For Jordan,
and his world

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Preface

Modern human civilization now stretches back almost 300 generations, to the earliest organized cities. For most of that time, each clutch of humans identified their settlement and its surrounds as their home. Less than 100 generations ago, information transmission and transportation technologies were capable enough that people could form nation-states consisting of many cities and villages and consider them as a new kind of ''home.'' In the last two generations—with the advent of space travel—many people have come to see their ''home'' as the whole Earth. This idea would have been essentially unthinkable to the ancients—for the world was too large for their technology to integrate the world, or even a nation-state, into an accessible and cohesive community.

So too, it is hard for us, now, to think of our ''home'' as being something even larger than our planet. After all, we are still trapped, both physically and to a very great degree intellectually, on our wonderful home planet. A century ago, Konstantine Tsiolkovsky described the Earth as the cradle of mankind, and that it *still* is. Yet, a logical extension of human history, and our present push outward to explore the worlds beyond Earth with robot craft, is that our descendants will very likely consider the wider realm of the solar system as much a home as we, the descendants of ancient, regional civilizations, consider the whole of planet Earth as our home today.

For a few tens of dozens of humans, those who are planetary scien-

tists, this vision is already becoming a familiar and natural concept. And it is this concept, in part, that gave birth to the idea to bring together a few of the very best planetary scientists in the world to write about their favorite worlds, and in doing so to give a little perspective on what makes both them, and their favorite places, tick. We wanted to tell some stories of planetary exploration through the eyes of the scientists who culminate their explorations by interpreting, with human warmth, the cold 1's and 0's flashed back to Earth from sensors on spacecraft scattered across the solar system.

Of course, with nine planets and over 70 known satellites, not to mention the myriad asteroids and comets, there were many choices of locale to describe, and many fine scientists to choose from to provide personal descriptions. How to choose?

As a guiding concept, we selected scientists rather than worlds. What kind of researchers did we select? We chose individuals who had shown a deep, career-long emphasis and passion for some specific place they had been attracted to. All are known for being particularly good speakers, or writers, or both. And all were members of the second generation of planetary scientists, trained or inspired by first-generation mentors who had seen the birth of our field at the dawn of the space age. These are the intellectual 'sons and daughters,' so to speak, of legendary pioneers like Kuiper, Urey, Sagan, and Shoemaker.

We asked each of the researchers writing for this book to tell a personal story involving their own career and motivations, and to describe some part of a favorite world in which they had invested long years exploring, and to tell their story from the heart. The eight wonderful and diverse essays in this book range across the breadth of planetary science, from the inner to the outer worlds, from telescopic to robotic exploration, and from computerized armchairs to dives below the Antarctic ice. The stories encompass soaring tales of personal exploration and the dark, inner fears of a scientist living at the edge of funding difficulties. You will learn about the mountains of the Moon, the craters of Venus, the volcanos of Io, the possibility of seas on Titan, and more. Within this book you will find both a good deal of planetary science, and a perspective from several insiders about how planetary science is done. You will also see a good deal about what drives and interests

planetary scientists. And, on occasion, you will see their inner hopes and aspirations revealed.

So, come and visit a few worlds across the larger home that humankind is coming to know. Come and see a little bit of the heart within our science, and the hearts of planetary scientists. Come and visit *Our Worlds*.

Alan Stern
November, 1997

Welcome home

ALAN STERN

At night, when the last rays of the Sun vanish over the western horizon, and the brilliant blue is gone from the sky, a little something wonderful happens. We planetary landlubbers can suddenly see across the deep cosmic ocean to other shores.

And what a view it is! Across the cold but crystal clear expanse of vacuum so simply named ''space,'' shines the light of the hundred billion stars within our home galaxy. A few thousand are close enough, and bright enough, to see with unaided eyes as individual lighthouses, beaconing against the deep. The rest merely add to the faint mist of light we call the Milky Way. So too, the dark night sky reveals a few galaxies, the nearest other star islands in God's Cosmic Pacifica. But it is not the galaxies that we seek, nor even the much closer stars of the Milky Way. What calls most strongly to many of the mariners of Earth are the worlds that share the space around the Sun.

The ancients discovered the planets because these beacons moved across the night sky, changing their positions noticeably as the weeks and months slid by. And when the long eyes of the first telescopes were pointed heavenward, only four short centuries ago, they revealed that the five long-familiar wanderers of the night sky, ''the planets,'' were wholly unlike the stars—for they appeared as rounded worlds, replete with clouds and fuzzy spots that one could imagine were mountains and valleys!

During the first ten of the twelve generations that have walked the green hills of Earth since telescopes revealed the planets as worlds, progress in understanding these places was slow. What the telescope could do well, when combined with a diligent astronomer, was chart the solar system and catalog its population. Using telescopes, planetary astronomers learned that most worlds (Mercury and Venus being the exceptions) carried with them about the Sun smaller worlds, moons, some of which were merely mountain sized, but others were large enough to be worlds unto themselves. With their telescopes, astronomers also discovered that the solar system was sprinkled with pockets of debris from the days of its origin, the asteroid belt between Jupiter's orbit and Mars, the Kuiper disk lying beyond Neptune, and the far away Oort cloud.

But the telescope and the human eye, alone, were too feeble a tool to reveal much about the worlds it could see. Looking at worlds through a telescope is something like the astronomical equivalent of trying to perform a complete medical diagnosis with a stethoscope. That didn't prevent the practitioners of astronomy from trying to picture the worlds that join Earth in orbit about the Sun, of course, but the work was hard and the results meager. So, over the first two and a half centuries of telescopic exploration of the solar system, astronomers barely learned more than how to measure a few basic attributes of each world, such as its size, mass, and the length of its day.

Of course, these first facts no more revealed the richness and wonder of the planets than would the Mona Lisa be described by saying, ''image of a young woman, 120 by 70 centimeters in scale, oils on canvas.'' The telescope alone revealed too little.

One thing that was missing was the ability to build accurate and sensitive cameras, spectrometers, and similar devices to make a useful harvest of the light that the telescopes gathered. And so, slowly at first, but then at an exponentially increasing rate, astronomers and engineers invented tools to dissect and record the light that shone down from each world, and to thus learn something about its composition, its temperature, and its atmospheric makeup. But even with exquisite and increasingly sophisticated devices at the business end of their telescopes, even with observatories perched on mountain tops high above the worst of

weather and atmospheric turbulence, the planets were still too far away to see in much detail.

What was also missing was the ability to set off from Earth and travel to the other worlds. To see these places up close. To map them carefully. To land on their surfaces, and probe their atmospheres. To touch and feel them. To make them real. To leave astronomy behind for a new kind of science, a mix somewhere between astrophysics and geophysics, called planetary science. To come to know worlds by going to them. To be there.

Cradle vista

Whoever it was that said that travel is broadening certainly had it right. The single most humbling lesson we have learned in planetary exploration is just how incorrect (and usually naive) our first astronomically based perceptions of the planets were.

Why was this the case? For one thing, telescopic observations generally produce too low a resolution to really see the details of the worlds we study. Telescopic observations are also fundamentally limited in their ability to reveal the compositional and physical details that *in situ* measurements on a planet, such as wind speed, mass spectroscopy, gravitational harmonics, and seismic studies, can.

In essence, our ability to understand the planets from Earth was about equivalent to trying to fully understand the geology, climate, and cultures of, say, Asia, by flying over in a space Shuttle with a pair of binoculars. As a result, most of our conceptions about the planets, before the age of space exploration, were, . . . well, *mis*conceptions.

Remember? We thought Mercury had an atmosphere, with clouds, and Venus might be an inhabited swampland. Mars seemed to be green with vegetation each spring. And the asteroids were thought to be the remnants of an exploded planet. The giant planets were uninteresting, except for that funny red spot on Jupiter, and only Saturn had rings. The moons of the giant planets were boring, and pretty much all the same.

Today we know that *none* of these ideas, all based on the best available evidence at the dawn of the space age, just 40 years ago, was correct.

To learn what the planets were truly like we had to go there, but it wasn't easy. The first impediment was distance. Even with our best rockets, crossing the great, vacuous gulf between the planets takes months within the compact inner solar system, and years in the outback beyond Mars and the main asteroid belt. The second impediment was money, for the tools of technology are expensive. Even in the 1990s age of smaller, cheaper missions, individual spacecraft often cost more than small fleets of jet transports, and their launch vehicles usually about double that expense. As Tom Wolfe wrote ''No bucks, no Buck Rogers.'' The third impediment was (and to a large extent still is) the heavy engineering required to make spacecraft and their launch vehicles work reliably. Space pioneer Werner von Braun once said that, ''We can beat gravity, but the paperwork is enormous.''

Nevertheless, the political necessities of the cold war forged a pathway to the planets in the form of a very public competition between the United States and the Soviet Union. What were the two superpowers trying to prove? That each had a society that could lead the world. And lead they did, for the historic explorations they financed and executed will stand, as long as humans record their history, as positive testaments to the United States and the Soviet Union, and to the curiosity, prowess, and ingenuity of twentieth-century civilization.

Free bird

And so, owing to politics (as opposed to manifest density, or greed, or even very much to scientific curiosity), beginning in 1959, we went exploring.

Our first steps were simply aimed at the Moon, less than one hundredth the distance to the nearest planet, for it was a time for learning the basics of how to launch and fly spacecraft. Launch vehicles exploded. Rockets went off course. Spacecraft spun out of control, lost radio contact, or failed for one of a dozen other reasons. Soviet records are sketchy, but US records show that, of the first four Pioneer and six Ranger missions to the Moon in the late 1950s and early 1960s, *none* fully succeeded, and only three of these ten missions could be called a partial scientific success.

The first coup in planetary exploration came early, in 1959, when the Soviets launched Luna III on a week-long mission to obtain the first images of the heretofore-hidden far side of the Moon. Luna III's main scientific result was in discovering that the lunar far side has a vastly different appearance from the front side. This, like many early discoveries that were to come, was a lesson primarily about how little we had known, or could know, from studying far away worlds solely from Earth.

By the early 1960s, both the United States and the USSR had undertaken vigorous programs to make flybys of the two nearest planets, Venus and Mars. Only about half of the attempts succeeded; but when they did, they spoke volumes. Later in the 1960s, while the robots made further forays to Earth's two nearest planetary neighbors, Apollo spacecraft delivered nine human crews to the vicinity of the Moon. Six of these crews were sent to the surface to deploy instruments, collect samples, and explore the geology of lunar mountains, valleys, and plains. It's a shame, but human exploration paused there, never to be restarted in the twentieth century.

The 1970s saw Venus and Mars exploration move into a more sophisticated phase, with entry probes, landers, and globe-circling orbiters designed to make far more in-depth studies than simple flyby visits ever could. And, later in the 1970s, the United States branched further afield, launching a triple flyby mission to Mercury and four different flyby spacecraft to Jupiter.

Few US missions were launched in the 1980s. However, the Russians continued their spectacular string of successes with Venus exploration, and the three of the US probes that reached Jupiter in the 1970s went on to reconnoiter Saturn. One of these probes, Voyager 2, was even sent on to make the historic first explorations of the Uranus and Neptune system. Meanwhile, a flotilla of European, Russian, and Japanese flyby missions was launched at Halley's Comet, and a US spacecraft was redirected to fly by another comet, called Giacobini-Zinner. By the time the 1980s ended, all of the planets save Pluto had been visited, and the Galileo mission was *en route* to make the first close reconnaissance of an asteroid, and then on to orbit Jupiter.

And what of recent times? The 1990s have witnessed a reflowering of