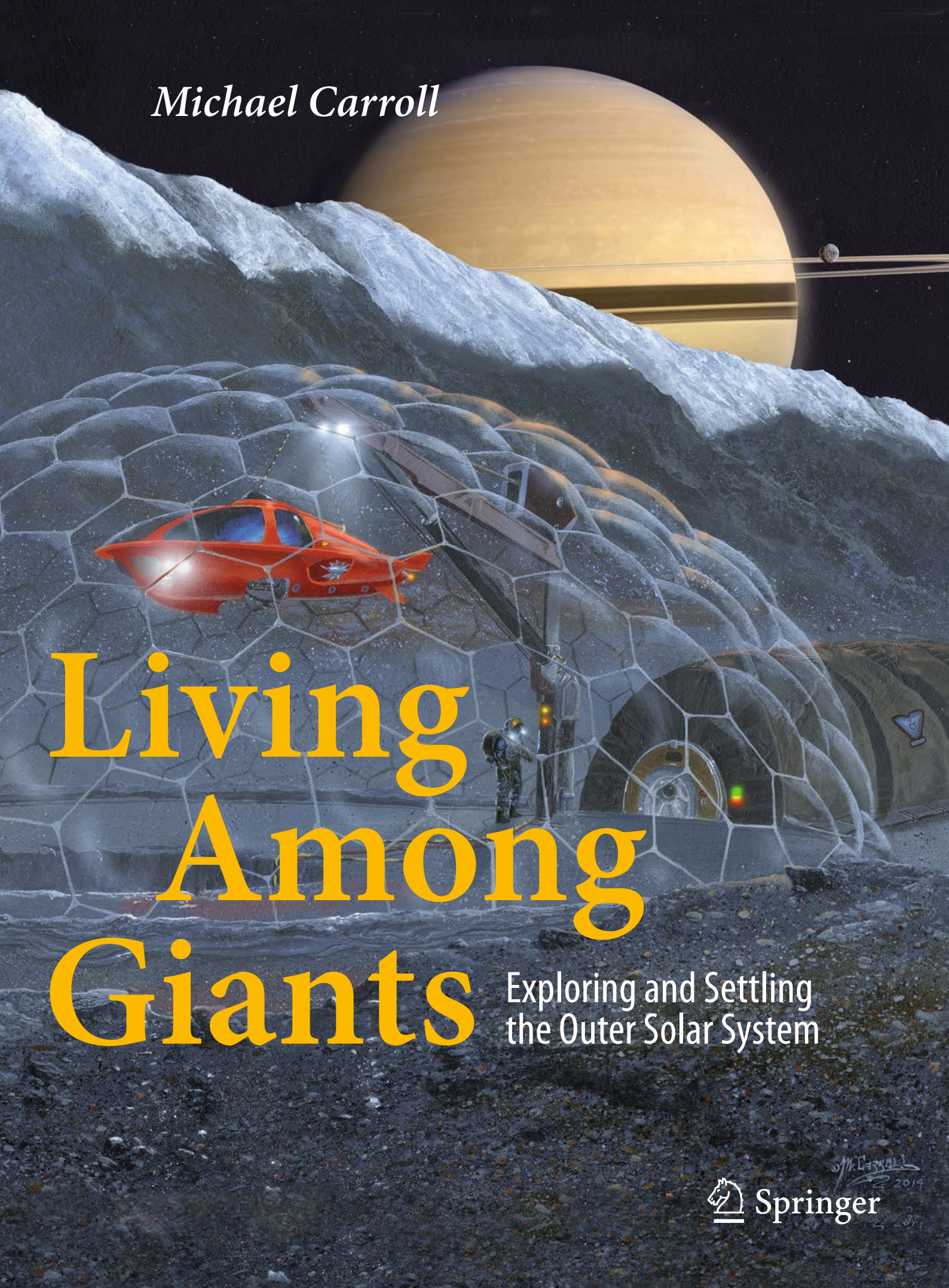

Michael Carroll

Living Among Giants

Exploring and Settling the Outer Solar System

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Written and illustrated by Michael Carroll

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Michael Carroll
Littleton, CO, USA

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This book is dedicated to the memory
of Lucien Rudaux, who first showed us what
things might be like out there,
and to Chesley Bonestell, who inhabited
those places with real people like you
and me.

"*Without adventure, civilization is in full decay.*"

– Alfred North Whitehead

Preface

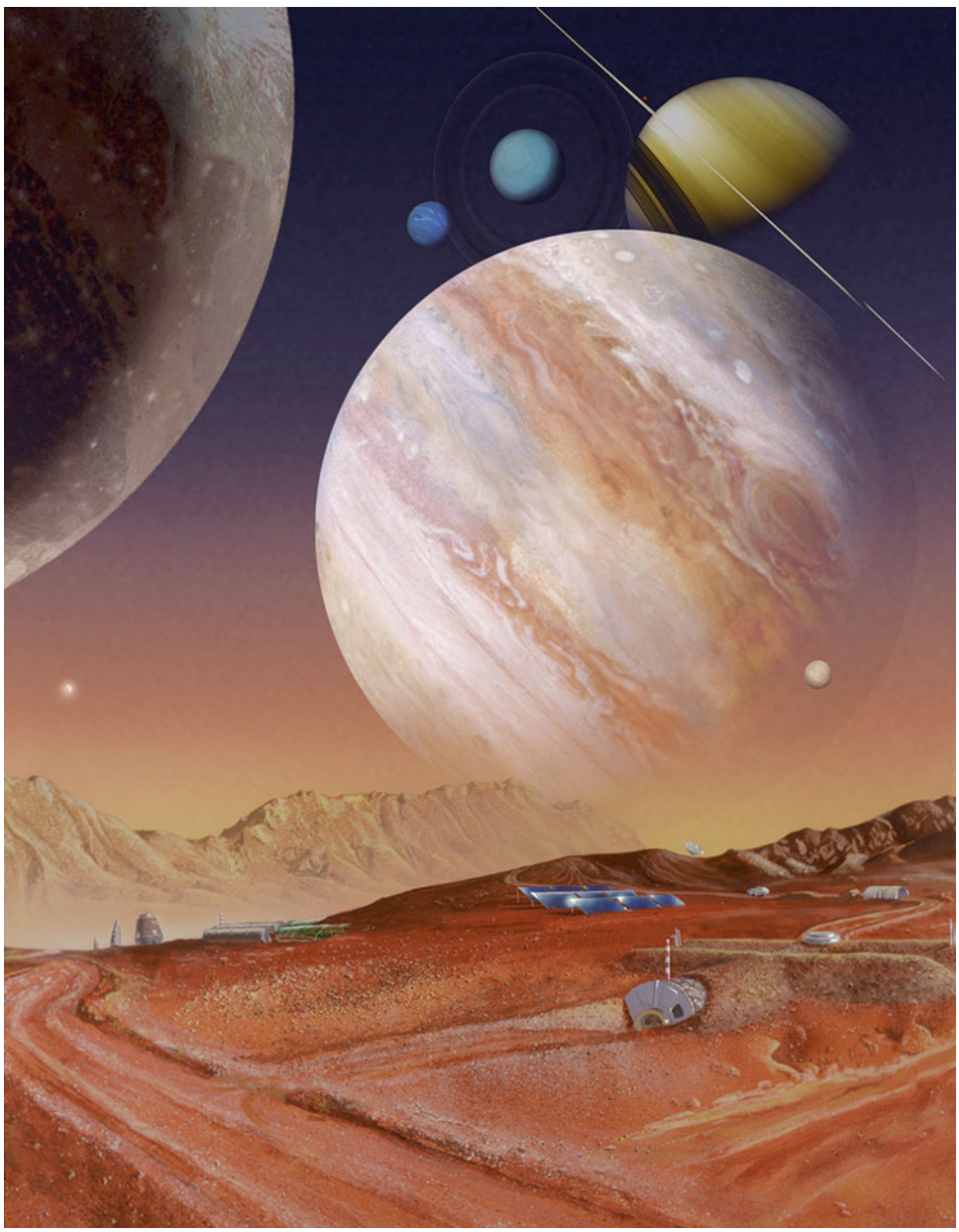

Fig. P.1 Mars is the next logical site for human habitation. But what other sites offer promise? (Paintings ©Michael Carroll)

The outer Solar System may seem an unlikely destination for future human travels, let alone settlements. The cold and distant worlds of gas, rock, and ice seem to repel rather than to beckon. Humans have been to the Moon, and we have our sights firmly upon Mars and the asteroids, but could there be a role to play by the outer Solar System in the drama of humanity's future?

If humankind is to explore and eventually settle the outermost reaches of our Solar System, we cannot do it by bringing everything with us. The distances are far too great. We must, in a sense, live off the land. There is another destination, much closer, that offers us resources to do just that – the Red Planet, Mars.

A lot has been made of Mars. Although the Red Planet is not as close to Earth as Venus is, its atmosphere is clear enough to view the surface through telescopes. Mars intrigued at the outset, with its Earthlike seasonal tilt and day, its polar caps, and its mysterious, undulating dark regions. Flagstaff astronomer Percival Lowell brought the popularity of Martian canals to a frenzy, crafting detailed maps of Martian "canal" networks and "oases" and writing popular speculative books about life on Mars. Writers such as Wells, Burroughs, and Bradbury took their cue from the work of early astronomers such as Lowell,[1] continuing the nineteenth- and twentieth-century culture's love affair with the Red Planet.

We are left with the legacy of these writers and scientists. Most of the Mars they described has crumbled before the scrutiny of space probes, but our desire to find Martian life – even in microbial form – continues to inform, some would say contaminate, our priorities for space exploration. During a recent meeting of the American Astronomical Society's Division for Planetary Sciences, one researcher quipped, "If you compare what we know about Mars to what we know about Ganymede, it's shameful."

Still, if humans are to venture beyond the Moon for any length of time, the best place to go is one where we can live off the land. Mars has the resources to do so. It possesses large amounts of water, and its rarified atmosphere is 95 % carbon dioxide (CO_2), a molecular combination of carbon and oxygen. Water can be electrolyzed to produce hydrogen and oxygen. The hydrogen can be reacted with carbon dioxide from Martian air, to make methane, an efficient rocket fuel, and more water, which can be electrolyzed again. So the final products are methane and oxygen. Oxygen is something that most explorers prefer to breathe and is a major part of rocket propellant. Martian water is also useful for drinking and for tending plants, which themselves manufacture oxygen using the Martian CO_2.

Groups ranging from major aerospace corporations to private industry have carried out engineering studies in many forms, fleshing out scenarios for human Mars missions and settlements. They foresee the manufacture of Martian concrete and bricks to construct everything from rover garages to underground housing. Their crystal balls glimmer with visions of greenhouses full of bamboo, which grows fast and makes strong

1. Lowell also helped to discover the dwarf planet Pluto. Using observations of Uranus and Neptune, he predicted where a new planet should be and searched in vain for it. However, it was later discovered that Lowell Observatory captured the planet in photos in 1915, a year before Lowell's death. Pluto was discovered by Clyde Tombaugh in 1930. In recognition of Lowell's contributions to its search, the planet's symbol incorporates the initials of Percival Lowell, PL.

building material. Some even envisage genetically engineered goats, tilapia, strawberries, and poi to feed the masses of incoming Earth settlers.

Mars seems the next logical step. But Mars is taking the lion's share of planetary probe pie, and many believe it is time to shift a few more of our resources farther out. "What about Venus?" some ask. After all, the hellish world is Earth's twin in size, closest to us in distance, and complex both geologically and atmospherically. But Venus will be no home for humans in the foreseeable future using reasonable technology. All of our landers have succumbed to its 900 °F surface temperatures in just over an hour, and even the most current advances in engineering could not extend that stay much beyond a day or two. Brutal pressures claw at electronics, and acids eat away at insulation, while the heat demands cooling energy that might be used otherwise. It is not a nice place to visit.

However, if we look the other direction, beyond Mars, we find surprisingly rich resources and promise. True, the outer Solar System is dark and bitterly cold. Distances make communication and travel difficult. But the outer worlds, giants of gas and ice, possess entourages of icy and rocky moons replete with water, minerals, and hydrocarbons, and it is there where we may find a new future.

Arthur C. Clarke believed that the realm of the outer planets was a natural destination for humankind. He said, "We are exiles here on dry land, in transit between the ocean of water in which we were born and the ocean of space where most of history will run its course."

Mars settlement advocate Robert Zubrin takes it a step further, asserting that we *must* go. "The Hawaiian islands popped out of the ocean. The birds flew overhead and dropped seeds, and brought life to those places. There is oxygen in the air because life put it there. There is soil on the ground because life put it there. This is what we do. It would be unnatural if humans, being the kind of bird that the biosphere has developed to spread life across space, didn't drop the seeds of life on the desert islands out there in the cosmos."

If people like Clarke and Zubrin are right, Mars will be a stepping-stone along the way to farther shores. The worlds awaiting us beyond, in the frigid darkness, harbor abundant natural resources and deep mysteries that will likely lead to our foundational understanding of our planetary system. Carolyn Porco, Principal Investigator for the Cassini Saturn Orbiter imaging team, puts it this way: "No matter how you measure it, whether you count the number of bodies, whether you add up the amount of mass, or whether you calculate the volume taken up by the orbits of those bodies, the vast majority of our Solar System lies out beyond the orbit of the asteroids. Inside are just a bit of flotsam. It's all in the outer Solar System."

Moreover, future travelers to the realm of the gas and ice giants will be confronted by glorious, spectacular views beyond anything experienced thus far. Aside from practical scientific and technological gain, travel to the icy cliffs, thundering geysers, incandescent volcanoes, and swirling storms will bring inspiration. As artist/explorer Frederick Church once said,

"Exploration is good for the soul." Henry David Thoreau advised that: "We need the tonic of wildness … At the same time that we are earnest to explore and learn all things, we require that all things be mysterious and unexplorable, that land and sea be indefinitely wild, unsurveyed and unfathomed by us.…" Although we've plastered our Earth maps to their corners with information from satellite and ground surveys, our maps of the worlds beyond still have vast territories labeled *Thar be dragons*. The cosmos compels us to fill them in. We have gone there with our robots, but the history of space exploration shows us that where our robots go, the footprints of humans will follow.

Littleton, CO, USA Michael Carroll

About the Author

Springer author/artist Michael Carroll received the AAS Division of Planetary Science's Jonathan Eberhart Award for the best planetary science feature article of 2012, an article based on his Springer book *Drifting on Alien Winds*. He lectures extensively in concert with his various books and has done invited talks at science museums, aerospace facilities, and NASA centers. His two decades as a science journalist have left him well connected in the planetary science community. He is a Fellow of the International Association for the Astronomical Arts and has written articles and books on topics ranging from space to archaeology. His articles have appeared in *Popular Science*, *Astronomy*, *Sky & Telescope*, *Astronomy Now* (UK), and a host of children's magazines. His 20-some titles also include *Alien Volcanoes* (Johns Hopkins University Press), *Space Art* (Watson Guptill), *The Seventh Landing* (Springer 2009), and *Drifting on Alien Winds* (Springer 2011). His latest coauthored book is Springer's *Alien Seas: Oceans in Space* (2013).

Carroll has done commissioned artwork for NASA, the Jet Propulsion Laboratory, and several hundred magazines throughout the world, including *National Geographic*, *Time*, *Smithsonian*, *Astronomy*, and others. One of his paintings is on the surface of Mars – in digital form – aboard the Phoenix lander. Carroll is the 2006 recipient of the Lucien Rudaux Award for lifetime achievement in the astronomical arts.

A Note About the Paintings

Living Among the Giants has a dozen or so original paintings done specifically for the project. Almost all are traditionally done on canvas. We live in a digital world, and this book is about technologically advanced things, so I decided that traditional paintings would bring a visual softness to the subject. Some are "tradigital," such as the painting of the astronaut on Titan. In this case, I began with a traditional painting on board and then added digital touches in Photoshop and Terragen. I hope my readers will enjoy the results!

Acknowledgments

My artistic thanks goes to Carolyn Porco of the Space Science Institute and Joe Spitale of the Planetary Science Institute for their patience and wisdom on Saturn's ring "spikes." A special shoutout goes to Rob Callison for ideas on submarine psychology. For translations of Lucien Rudaux's work, I am indebted to Jenna Khazoyan and Caroline Carroll. Bill Higgins was of tremendous help in providing material and insights into the history of science fiction. Thanks to Wes Patterson and Chris Paranicas at Johns Hopkins Applied Physics Laboratory for use of their Europa sputtering diagram (if you don't know what that is, you'll find out in Chap. 5). Ted Stryk generously lent his digital magic to images of various planets and moons. Thanks to Keith Cooper and the team at *Astronomy Now*, and to Dave Eicher and the gang at *Astronomy*, for letting me borrow from articles written for them. Cynthia Rodriguez and Princess Cruise Lines generously gave permission for me to use their logo and beautiful ships as reference for our own cosmic cruise ship in Chap. 10. Aldo Spadoni brought life to the Iapetus Ridge Resort, aka "New Santorini," and Edie Carroll (my very own Mom), Marilyn Flynn (special commendation for last-minute frenzy), and Bill Gerrish made my words look intelligent, more or less (there's only so much one can do). My talented daughter Alexandra helped transcribe interviews, a critical part of any book like this. Thanks to Alice Salvage, Chris White, and Matt Levin at Magnolia Pictures and Wayfare Entertainment for the cool scene from *Europa Report*.

And many thanks to Maury Solomon – fearless editor at Springer – for her years of support.

Contents

Part I
The Backdrop

Fig. 1.1 The Flemish painter Garrit Dou (1613–1675) crafted this masterpiece of an astronomer working by candlelight. The scholar's tools include a liquid-filled beaker, an hourglass, a huge book, and a celestial globe showing the constellations of the night sky. Although telescopes were invented at the opening of the seventeenth century, most early astronomers did not have access to them; the objects in the painting were the tools of their trade. At the end of the day, the ancient student of the sky could only dream of what travelers might discover out there (Painting by Garrit Dou, ca. 1658)

Chapter 1
Early Ideas

In the first century A.D., Greek Hellenistic thought and culture continued a centuries-long spread throughout the western world. While the Mayan kingdom debuted its long count, China's Han dynasty officially adopted Confucianism, and a Jewish rabbi was stirring things up in the Middle East, Lucian of Samosata was quietly writing a story about travel to the Moon. As with much fiction, his was more a commentary and satire of contemporary literature than a narrative of imagined events. Lucian didn't have much hard science to go on in the first century.

Lucian's *True History* detailed a nautical voyage of discovery interrupted by a violent waterspout. After a harrowing, windy week, the narrator and his intrepid crew found themselves deposited on the Moon. Lucian described his voyage:

> [O]n the eighth day we saw a great country in it, resembling an island, bright and round and shining with a great light. Running in there and anchoring, we went ashore, and on investigating found that the land was inhabited and cultivated. By day nothing was in sight from the place, but as night came on we began to see many other islands hard by, some larger, some smaller, and they were like fire in color. We also saw another country below, with cities in it and rivers and seas and forests and mountains. This we inferred to be our own world.[1]

Lucian's story, written some nineteen centuries ago, includes elements of space travel, encounters with aliens, artificial atmosphere, and even the scientific desire to explore and discover. The Moon continued to be the central object of cosmic speculation for centuries to come.

In September of 1610, German astronomer and mathematician Johannes Kepler wrote a short paper confirming Galileo's discovery of Jupiter's four large moons. It was called, simply, *Observation-Report on Jupiter's Four Wandering Satellites.* The pamphlet marked the first time that anyone had referred to moons of other planets as "satellites." Kepler may have had in mind Jupiter's royal standing as king of the planets. In Kepler's day, heads of state and other important figures surrounded themselves with a cadre of fans doubling as bodyguards. These early paparazzi were known by the Latin word *satellitem*. (Kepler had used the term in a letter to Galileo as well.)

Kepler didn't limit his writing to scientific journals. Over a period of 20 years, he transformed his 1608 student dissertation into what many consider to be the first work of modern science fiction. Called *Somnium*, the story was actually published after Kepler's death in 1630. Kepler's narrative opened as he was reading a book by a magician. He fell asleep (the magician's writing must not have been very engaging) and dreamed of an Icelandic boy taken to the Moon by daemons, kindly spirit-guides. Inhabitants of the Moon called it Levania.

Kepler's story anticipated many scientific issues, such as atmosphere (his travelers must have moist sponges over their nostrils to breathe), the cold of space (travelers wrap themselves in blankets), and great distances

1. Internet Sacred Text Archive translation, public domain. http://www.sacred-texts.com

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between Earth and the Moon. Like any good science fiction, Kepler's writing echoed scientific thinking of the time. It described the appearance of eclipses from the Moon; it portrayed the size of planets as changed because of the Moon's distance from Earth; it even gave a guess as to the size of the Moon and described the effects of lunar tidal lock (the phenomenon of the same side of the Moon always facing Earth). Sadly, Kepler awakened before we could learn about such subtleties as good landing sites and lunar mascons.

It would be many decades before writers tackled the nature of the outer Solar System, let alone the idea of exploring those distant worlds. Dutch mathematician Christian Huygens was undaunted by distances and rudimentary instruments. Huygens studied the cosmos at the end of his 50-power telescope, where he made such discoveries as Saturn's moon Titan, the length of a Martian day, and details of the Orion and other nebulae. In his 1698 book *The Celestial Worlds Discover'd: Or, Conjectures Concerning the Inhabitants, Plans and Productions of the Worlds in the Planets*, Huygens examined the nature of outer planets, especially as they related to clouds and water:

> [A]bout Jupiter are observ'd some spots of a darker hue than the rest of his Body, which by their continual change show themselves to be Clouds … Since 'tis certain that Earth and Jupiter have their Water and Clouds, there is no reason why the other Planets should be without them.… this Water of ours, in Jupiter or Saturn, would be frozen up instantly by reason of the vast distance of the Sun. Every Planet therefore must have its Waters of such a temper, as to be proportion'd to its heat.

Significantly, Huygens went on to speculate about the moons of the outer planets.

> [A]ll the Attendants of Jupiter and Saturn are of the same nature with our Moon, as going round them, and being carry'd with them round the Sun just as the Moon is with the Earth. Their Likeness reaches to other things, too … whatsoever we can with reason affirm or fancy of our Moon (and we may say little of it) must be suppos'd with very little alteration to belong to the Guards of Jupiter and Saturn, as having no reason to be at all inferior to that.

The idea that the moons of Jupiter and Saturn are similar to our own Moon carried well into the decade of the 1960s. In intervening years, literary characters visited our own Moon,[2] saw dinosaurs on Jupiter,[3] lived in colonies on Ganymede,[4] passed Saturn on a comet,[5] and witnessed the first human expedition to Neptune in Hugh Walter's 1968 novel *Nearly Neptune*.

Mars continued to be the driver of interplanetary travel tales, with Percival Lowell unwittingly at the helm. In his wildly popular and supposedly non-fiction book *Mars as the Abode of Life*, Lowell declared:

> Thus, not only do the observations we have scanned lead us to the conclusion that Mars at this moment is inhabited, but they land us at the further one that these denizens are of an order whose acquaintance was worth the making.[6]

2. For example, *From the Earth to the Moon* (1865) by Jules Verne.

3. *A Journey in Other Worlds* (1894) by John Jacob Astor IV.

4. *Victory Unintentional* (1942) by Isaac Asimov.

5. Off on a Comet (1877) by Jules Verne.

6. *Mars as the Abode of Life* by Percival Lowell (The MacMillan Company, 1909).

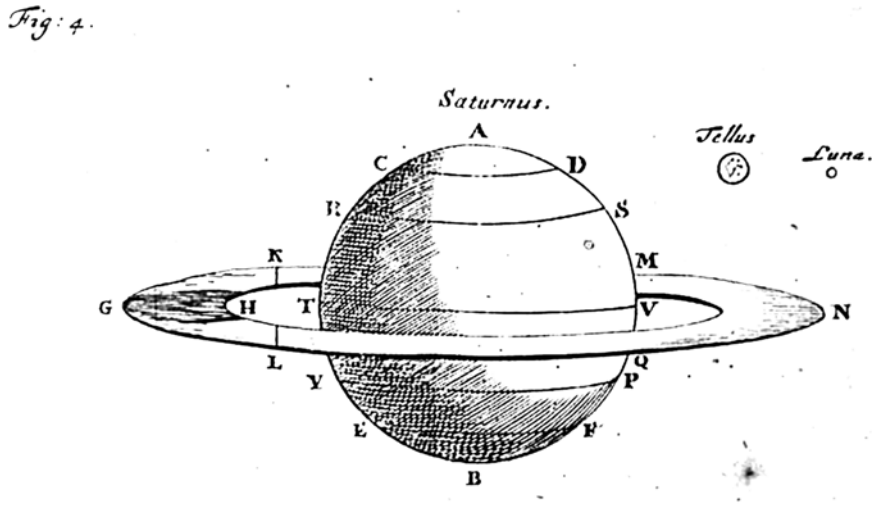

Fig. 1.2 Drawing of Saturn and its rings by Christiaan Huygens, ca. 1659. Note his comparison to Earth at right (Image from Systema Saturnium)

The novelist Edgar Rice Burroughs, famous for his Tarzan tales, fully embraced Lowell's thoughts on Mars, spinning a series of narratives populated by six-legged tiger-like Thoats, green four-armed Martian insect men, and of course, a beautiful princess, Dejah Thoris.[7]

Burroughs paints a picture of Dejah Thoris and her Martian civilization as attempting to preserve Mars' dying atmosphere, something Lowell's observations certainly inspired. Here, she berates the brutish green Martian race for their lack of understanding:

> The work we were doing was as much in your interests as in ours, for you know full well that were it not for our labors and the fruits of our scientific operations there would not be enough air or water on Mars to support a single human life. For ages we have maintained the air and water supply at practically the same point without an appreciable loss, and we have done this in the face of the brutal and ignorant interference of you green men. Why, oh, why will you not learn to live in amity with your fellows?

Burroughs wrote what some would call informed fantasy, but H. G. Wells was more interested in the science of his time. Where Burroughs' John Carter simply dreams his way to Mars, Wells' books outline the details of spacecraft and space travel. Martian anatomy is described in detail, tied to contemporary scientific assumptions about the Martian environment.

H. G. Wells' Martians "drew their plans against us," but 30 years later, as a real Cold War was ramping up on Earth, the Martians of Ray Bradbury became far more sedate, and certainly more mystical:

> They had a house of crystal pillars on the planet Mars by the edge of an empty sea … Mr. and Mrs. K had lived by the dead sea for twenty years, and their ancestors had lived in the same house, which turned and followed the sun, flower-like, for ten centuries. They had the fair, brownish skin of the true Martian, the yellow coin eyes, the soft musical voices.

Although the literature reflected scientific thinking of its time, the outer planets offered little fodder for hungry authors. The distant worlds had given up few secrets over the centuries. Still, writers dreamed of that

7. Originally published as a serial in the magazine *The All-Story*, beginning in February 1912.