EXPLORING THE SOLAR SYSTEM

The History and Science of Planetary Exploration

EDITED BY
ROGER D. LAUNIUS

PALGRAVE STUDIES IN THE HISTORY OF SCIENCE AND TECHNOLOGY

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James Rodger Fleming (Colby College) and Roger D. Launius (National Air and Space Museum), Series Editors

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Introduction

Roger D. Launius

Without question, the solar system exploration program has become the stuff of legends and myths in some measure because of its rich harvest of knowledge about Earth's neighboring planets, a transformation of our understanding of the solar system's origin and evolution, and a demonstration of what might be accomplished using limited resources when focusing on scientific goals rather than large human spaceflight programs aimed at buttressing American prestige.[1] That is the purpose of this collection of essays about episodes in the history of solar system exploration. It seeks to illuminate a broad set of perspectives on this unique topic, and to pose questions about the trajectory of planetary exploration from the beginning of the space age to the present.

Most assuredly, success in opening a window to the solar system effort did not take place by magic. It required considerable effort. The foundation for this was laid in the 1950s, when space science first became a major field of study. During the decade of the 1960s both the United States and the Soviet Union began an impressive effort to gather information on the planets of the solar system using ground-, air-, and space-based equipment.[2] Especially important was the creation of two types of spacecraft, one a probe that could be sent toward a heavenly body and the second an Earth-orbiting observatory that could gain the clearest resolution available in telescopes because it did not have to contend with the atmosphere. The studies emanating from this new data revolutionized humanity's understanding of Earth's immediate planetary neighbors. These studies of the planets, perhaps as much even as Project Apollo, captured the imagination of people from all backgrounds and perspectives. Photographs of the planets and theories about the origins of the solar system appealed to a very broad cross-section of the public. As a result, NASA had little difficulty in capturing and holding a broad interest in this aspect of its efforts.

This story has been told largely as a set of flight projects from the 1950s to the present. During the decade of the 1960s, as a direct outgrowth of the Apollo mandate to land Americans on the Moon by the end of the decade, NASA space science focused much of its efforts on lunar missions with projects Ranger, Surveyor, and Lunar Orbiter.[3] Even so, a centerpiece of NASA's planetary exploration effort in this era was the Mariner program, originated by NASA in the early part of the decade to investigate the nearby planets. Built by Jet Propulsion Laboratory scientists and technicians, satellites of this program proved enormously productive throughout the 1960s in visiting both Mars and Venus. Mariner made a huge impact in the early 1960s as part of a race between the United States and the Soviet Union to see who would be the first to reach Venus. It was also the closest planet to Earth, and a near twin to this planet in terms of size, mass, and gravitation. Later missions would later expand on the knowledge of the planet.[4]

At the same time Mars attracted significant attention, an attraction it has yet to relinquish for most planetary scientists, prompting missions there as well. In July 1965 Mariner 4 flew by Mars, taking 21 close-up pictures. Mariners 6 and 7, launched in February and March 1969, each passed Mars in August 1969, studying its atmosphere and surface to lay the groundwork for an eventual landing on the planet. Their pictures verified the Moon-like appearance of Mars and gave no hint that Mars had ever been able to support life. Among other discoveries from these probes, they found that much of Mars was cratered almost like the Moon, that volcanoes had once been active on the planet, that the frost observed seasonally on the poles was made of carbon dioxide, and that huge plates indicated considerable tectonic activity. Mariner 9, scheduled to enter Martian orbit in November 1971, detected a chilling dust storm spreading across Mars; by mid-October dust obscured almost all of Mars. Mariner 9's first pictures showed a featureless disk, marred only by a group of black spots in a region known as Nix Olympia (Snows of Olympus). As the dust storm subsided, the four spots emerged out of the dust cloud to become the remains of giant extinct volcanoes dwarfing anything on the Earth. Mons Olympus, the largest of the four, was 300 miles across at the base with a crater in the top 45 miles wide. Rising 20 miles from the surrounding plane, Mons Olympus was three times the height of Mt. Everest. Later pictures showed a canyon, Valles Marineris, 2,500 miles long and 3.5 miles deep. As the dust settled, meandering "rivers" appeared indicating that, at some time in the past, fluid had flowed on Mars. Suddenly, Mars fascinated scientists, reporters, and the public.[5]

While successes in planetary science have been very real all was not rosy with the politics of planetary exploration. In many respects the 1960s proved a training ground for how to envision, develop, and gain approval for planetary science missions. These political realities were played out thereafter. The labyrinth of modern science policy ensures that those engaged in government-funded science must play a savvy game of bureaucratic politics that is at once both insightful and extreme. A variety of strategies arose to succeed at this game. These included keeping individual projects small so as to avoid serious scrutiny, bringing aboard the project as many scientific disciplines as possible to ensure that everyone has a stake in the effort, developing large partnerships with multifaceted research and educational institutions in numerous congressional districts, and creating international coalitions, to name only a few.

One issue constantly debated, and never fully resolved, was the tradeoff resulting from the balance of cost, scale, and schedule for space probes. A perennial source of debate in planetary exploration, those engaged in deciding on planetary missions ask whether or not NASA should build a large number and variety of small, inexpensive probes or consolidate many kinds of experiments onto a few large, expensive spacecraft? Both sides have valid rationales. Small, inexpensive satellites could not accomplish a great deal at any one time and had limited scientific value but their smallness made them less conspicuous in the political process and perhaps many could be built and flown and thereby overcome the limitations of any one probe. Also, if one or more of them failed, the entire planetary program would not suffer as much. Large, costly satellites, on the other hand, were a scientist's (but not an accountant's) dream provided they worked properly, but if any component failed the returns could be greatly diminished. They also attracted more scrutiny in Washington, and had to be astutely managed to ensure funding. Finally, they took much longer to shepherd to completion. It was not uncommon for huge projects to take more than a decade for research, development, and launch.

Between the 1960s and the present various NASA leaders have swayed back and forth on this question, much of the time advocating, but not always able to deliver, a mixture of large and small spacecraft to avoid the long hiatus that came if a mission failed. Such an approach, while also having drawbacks, was designed to minimize the potential difficulties envisioned in a spacecraft's failure.

One overwhelmingly significant incident in this story is the long shadow cast by the cancellation of a Mars lander in 1967. No event was more significant in the first quarter century of planetary exploration than the political debacle of losing that mission. It was an enormously important object lesson, and its legacy is everywhere apparent.

In the summer of 1967, even as the technical abilities required to conduct an adventurous space science program were being demonstrated, the planetary science community suffered a devastating defeat in Congress and lost funding for a satellite lander to Mars. No other NASA effort but Project Apollo was more exciting than the Mars program in the middle part of the 1960s, yet this enormous setback took place. The planet had long held a special attraction for Americans, so much like Earth and possibly even sustaining life, and the lander would have allowed for extended robotic exploration of the red planet. A projected $2 billion program, the lander was to use the Saturn V launch vehicle being developed for Apollo.

The problem revolved around the lack of consensus among scientists on the validity of this Mars exploration initiative. Some were excited and supported the mission; most opposed it as too risky and too expensive. Without that consensus in 1967 and with other national priorities for spending for "Great Society" social programs, combating urban unrest, and for the military in Vietnam, the Mars lander was an easy target in Congress. It was the first space science project ever killed on Capitol Hill. The NASA administrator, James E. Webb, frustrated by congressional action and infuriated by internal dissension among scientists, stopped all work on new planetary missions until the scientists could agree on a planetary program. As 1968 began, the entire US planetary exploration program consisted of two Mars flybys scheduled for 1969.[6]

The scientific community learned a hard lesson about the pragmatic, and sometimes brutal, politics associated with the execution of "Big Science" under the suzerainty of the Federal government. Most important, scientists realized that strife within the scientific community had to be kept within the community in order to put forward a united front against the priorities of other interest groups and other government leaders. They learned that they had to resolve internal differences inside their community, not in complaints to the media or in testimony before Congress. While imposing support from the scientific community could not guarantee congressional support for a mission, without it virtually any initiative would not be funded. They also learned that while a $750 million program found little opposition at any level, a $2 billion project crossed an ill-defined but very real threshold triggering intense competition for those dollars.[7] Having learned these lessons, as well as some more subtle ones, the space science community regrouped and went forward in the latter part of the decade with a trimmed-down Mars lander program called Viking, which was funded and eventually provided important scientific data in the mid-1970s.

To avoid future imbroglios, NASA formed a Lunar and Planetary Mission Board and an Astronomy Mission Board to assist in planning future missions and to provide a forum to identify and resolve differences among the scientists. In 1967 and 1968, space scientists hammered out a mutually acceptable planetary program for the 1970s. Although this program continued to emphasize the exploration of Mars by recommending what became Project Viking, a scaled-back mission to attempt a soft landing on Mars, it also included two Mars orbiters and other initiatives.[8]

In addition, the planetary science community developed a set of "decadal surveys" beginning in 1968 that developed a set of questions concerning lunar and planetary exploration, as well as options for answering them and missions for conducting scientific research. A succession of seven reports extending from 1968 to the most recent in 2011 have charted a comprehensive science and mission strategy for planetary science based on extensive review and input from a broad swath of planetary scientists in the United States. They have served for some 45 years to identify the most important scientific questions to be tackled by the scientific community, broadly considering the planets, moons, small and icy bodies, comets, and asteroids. Collectively, the planetary science community has been able to rally around the decadal survey thereafter to win political support for many of its priorities in scientific investigation.

At sum, these surveys have, according to Wesley T. Huntress, a former head of space science at NASA, succeeded in achieving the following:

1. Creating a revolution in space science by building a consensus for change among all stakeholders.
2. Working with divergent people and institutions, many of whom viewed others as rivals or even threats, to undertake some of the most spectacular robotic space science missions in NASA's history.

3. Negotiating the shoals of difficulties within the science community, its various components, and its relationships with other communities.
4. Working with the Office of Space Science staff, the NASA administrator and his staff, the administration's OMB and OSTP, and the members and staff of the Congress to obtain the resources and authority to carry out this exploration program.
5. Facilitating the often problematic relations between the National Academy of Science, NASA, other federal agencies, and international partners in space science.
6. Pursuing the strategic planning, management, and road-mapping necessary to undertake this exploration program.[9]

The various planetary decadal surveys, therefore, have provided a national plan for developing a stepwise exploration agenda and fostering associated scientific discoveries.

Relations between NASA's human and space science entities have been strained from the very beginning of the space age, although an uneasy existence has persisted to the present. Space scientists resented the priorities and media attention enjoyed by the human spaceflight programs, especially Apollo. They complained about the lack of plans or funding in these programs for scientific research in general and about the manner in which planetary science went lagging with the budgetary priorities of the piloted spaceflight effort. So intense were rivalries that these organizations contended for control of the Apollo science program. An uneasy sharing of power emerged in which the NASA associate administrator for space science, Homer E. Newell, created a Manned Space Science Division and required that the head of the division report to him on scientific issues and to the head of the Apollo program on technical and funding issues. One could argue that these measures led to remarkable scientific returns from Apollo, clearly never envisioned as a science program, but not without a fair measure of controversy and in-fighting among representatives of these two unique facets of NASA's overall mission.[10]

Similar challenges of negotiating the priorities of space science with the human spaceflight effort occurred during the Space Shuttle program. For example, only slowly and reluctantly did the shuttle program management adjust to the use of the shuttle for planetary and other space science activities.[11] For their part, the scientists had to modify many projects—including its planetary probes to Jupiter, Saturn, and Venus—so that they could be launched aboard the shuttle. Accordingly, after the launch of the Voyagers in 1977, NASA canceled the Titan-Centaur launch vehicle program and made plans to phase out the Delta and Atlas class expendable launch vehicles. Since the performance of the shuttle and its then-planned upper stage were less than that of the Titan-Centaur, the cancellation decreased the size of the payload that NASA could send to the planets. Subsequently, to restore this capability, NASA decided to develop a shuttle-compatible version of the Centaur. Later, it also canceled these plans for Centaur, then reinstated them, and finally canceled them for good after the *Challenger* accident in 1986.[12]

As a result of these decisions the planetary science community often found itself whipsawed between launch vehicle priorities and shuttle prerequisites. As only one example of the effect these issues had on the planetary science program, the team responsible for Galileo, NASA's Jupiter probe, spent several frustrating years and many millions of dollars trying to adjust the spacecraft's configuration and trajectory to accommodate the capabilities of the shuttle. Originally scheduled for launch in 1982 as an extended follow-on to the Voyager probe, NASA finally launched Galileo in 1991. Over that period, the cost of Galileo increased by about $1.3 billion. The *Challenger* accident delayed this project, and perhaps the entire planetary science program, by five–ten years. The *Challenger* accident had one salutary effect; scientists no longer had to use the shuttle for all of its launches. It could then purchase expendable launch vehicles from commercial vendors and use the shuttle only when required by the mission.[13]

Throughout the space age robotic exploration of the planets took second stage to the human effort, but there were notable successes. One of them was the Viking mission to Mars. After a succession of missions that pulled back the curtain on the red planet, the first long-duration lander reached the Martian surface in 1976. Launched in 1975 from the Kennedy Space Center, Florida, *Viking 1* spent nearly a year cruising to Mars, placed an orbiter in operation around the planet, and landed on July 20, 1976, on the Chryse Planitia (Golden Plains), with *Viking 2* following in September 1976. These were the first sustained landings on another planet in the solar system. While one of the most important scientific activities of this project involved an attempt to determine whether there was life on Mars, the scientific data returned mitigated against the possibility. The two landers continuously monitored conditions at the landing sites and found both exciting cyclical variations and an exceptionally harsh climate that prohibited the possibility of life. The failure to find any evidence of life on Mars, past or present, devastated the optimism of scientists and led to a 20-year hiatus in the exploration of Mars.[14]

Likewise, the outer planets were opened to discovery by a set of daring missions in the 1970s. During the early 1960s, G. A. Flandro and Michael Minovitch, from the Jet Propulsion Laboratory, discovered that once every 176 years both the Earth and all the giant planets of the solar system gathered on one side of the Sun. This geometric line-up made possible close-up observation of all the planets in the outer solar system (with the exception of Pluto) in a single flight, the "Grand Tour." The flyby of each planet would bend the spacecraft's flight path and increase its velocity enough to deliver it to the next destination. This would occur through a complicated process known as "gravity assist," something like a slingshot effect, whereby the flight time to Neptune could be reduced from 30 to 12 years. Such a configuration was due to occur in the late 1970s, and it led to one of the most significant space probes undertaken by the United States.

To prepare the way for this outer planetary mission, NASA conceived Pioneer 10 and Pioneer 11 to visit Jupiter and Saturn. Both were small, nuclear-powered, spin-stabilized spacecraft that Atlas-Centaur sent beyond Earth. The first of these was launched on March 3, 1972, traveled outward to Jupiter, and in May 1991 was about 52 Astronautical Units (AU), roughly twice the distance from Jupiter to the Sun, and still transmitting data. In 1973, NASA launched Pioneer 11, providing scientists with their closest view of Jupiter, from 26,600 miles above the cloud tops in December 1974. The close approach and the spacecraft's speed of 107,373 mph, by far the fastest ever reached by a an object from Earth, hurled Pioneer 11 1.5 billion miles across the solar system toward Saturn. It was expected that as Pioneer 11 passed beyond Saturn it would continue to return data to Earth through the year 2000, in the process extending its original 30-month design life to 28 years.[15]

Meantime, NASA technicians prepared to launch what was called Project Voyager. While the four-planet mission was known to be possible, it was quickly deemed too expensive to build a spacecraft that could go the distance, carry the instruments needed, and last long enough to accomplish such an extended mission. Thus, the two Voyager spacecraft were funded to conduct intensive flyby studies only of Jupiter and Saturn, in effect repeating on a more elaborate scale the flights of the two Pioneers. Even so, the spacecraft builders designed as much longevity into the two Voyagers as possible with the $865 million budget available. NASA launched these from Cape Canaveral, Florida: Voyager 2 lifting off on August 20, 1977, and Voyager 1 entering space on a faster, shorter trajectory on September 5, 1977. Both spacecraft were delivered to space aboard Titan-Centaur expendable rockets.

As the mission progressed, with the successful achievement of all its objectives at Jupiter and Saturn in December 1980, additional flybys of the two outermost giant planets, Uranus and Neptune, proved possible—and irresistible—to mission scientists and engineers at the Jet Propulsion Laboratory in Pasadena, California. Accordingly, as the spacecraft flew across the solar system, remote-control reprogramming was used to reprogram the Voyagers for the greater mission. Eventually, between them, Voyager 1 and Voyager 2 explored all the giant outer planets, 48 of their moons, and the unique systems of rings and magnetic fields those planets possess.

The two spacecraft returned to Earth information that has revolutionized the science of planetary astronomy, helping to resolve some key questions while raising intriguing new ones about the origin and evolution of the planets in this solar system. The two Voyagers took well over one hundred thousand images of the outer planets, rings, and satellites, as well as millions of magnetic, chemical spectra, and radiation measurements. They discovered rings around Jupiter, volcanoes on Io, shepherding satellites in Saturn's rings, new moons around Uranus and Neptune, and geysers on Triton. The last imaging sequence was Voyager 1's portrait of most of the solar system, showing Earth and six other planets as sparks in a dark sky lit by a single bright star, the Sun. The Voyagers are expected to return scientific data until about the next decade since communications will be maintained until