Chapter 4

The Space Age Begins

Sputnik: Soviet Challenge

In the last weekend of September 1957, Bill Pickering made yet another trip to Washington, DC. Fall was a pleasant time to visit the capital. The oppressive heat of summer had given way to the milder temperatures of fall, and the frantic rush of tourists and vacationing school children had diminished to a quieter and more tolerable level of noise. The autumn tones of trees and gardens and the lengthening shadows of the waning sun gave the city a gentle patina of tranquility that would be a precursor to the harsh reality of the winter months to follow.

Pickering was a delegate to an international conference hosted by the National Academy of Sciences as part of its commitment to the U.S. participation in science programs for the International Geophysical Year (IGY). The IGY had begun on 1 July 1957 and was scheduled to run through December 1958. This conference, sponsored by the Comité Spéciale de l'Année Géophysique Internationale (CSAGI), would focus on planning the rockets and satellite part of the IGY program.

It was not the first time that the CSAGI had addressed this issue. Three years earlier at a 1954 conference in Rome, CSAGI had challenged IGY participants to give consideration " . . . to launching small satellite vehicles, to their scientific instrumentation and to new problems associated with satellite experiments, such as power supply, telemetering, and orientation of the vehicle." At that time, the Soviet Union had not joined the IGY program and only the U.S. responded.

By the time the CSAGI assembled in Barcelona two years later (1956), the Soviet Union had joined the IGY program and there its representative announced that the USSR would also use Earth-orbiting satellites to make measurements of temperature, pressure, cosmic ray intensity, micro-meteorites, and solar radiation during the IGY. He gave no further details or advance information. For its part, the U.S. undertook to fully describe the details of its sounding and satellite plans to assist those who wished to make correlated measurements by other means.[1]

Thus, by the time of the Washington conference, sufficient time had elapsed for both countries to implement their projects and throughout the week the meetings were pervaded by a general sense of expectation that an imminent launch date for an Earth satellite would be announced by either the U.S. or the Soviet Union. But the delegates were disappointed—there was no such announcement.

What happened next is best described in Pickering's own words:

> I was at that IGY meeting and on the Monday they had various nations get up and say what they were doing. The Russian delegate, Anatoly Blagonravov made the Soviets' report. He spoke in Russian and the translator followed him in English. Among other things, he said that they were getting pretty close to launching a satellite. The guy sitting next to me understood Russian and he said to me, 'He didn't say that—in Russian, he said the launching was *imminent'*.
>
> Now this was on Monday, and nothing happened until Friday when the meetings wound up and the Russians held a cocktail party to celebrate the end of the proceedings. So we all trooped over to the Russian Embassy for the cocktail party and there was the usual drinking and that sort of thing. Nothing was said about a satellite. Then during the evening, Walter Sullivan from the New York Times came in and asked me, 'What have they said about the satellite? Radio Moscow says that they have got a satellite in orbit.' So I talked to Lloyd Berkner who was the senior scientist present, and he and Walter Sullivan got Blagonravov aside and then Walter proposed a toast to the success of the Soviet satellite. Then the Russian vodka flowed like mad.[2]

Next morning a large gathering of scientists and reporters packed the auditorium of the National Academy of Sciences to hear Blagonravov give a lengthy public statement on the important new Russian achievement. While praising Sputnik as an example of Russian accomplishments in science and technology, he criticized the U.S. claims for its, as yet undemonstrated, satellite program. Nevertheless, the audience understood Blagonravov's pride in his country's achievement and applauded his assertion that this would "serve as an inspiration to scientists throughout the world to accelerate their efforts to explore and solve the mysteries and phenomena of nature remaining to be explored."[3]

The Russian criticism stung Pickering deeply. He knew, as few others did, that given the "go-ahead" a U.S. satellite could have been launched months earlier. Pickering recalled his frustration:

> The reaction in this country was amazing. People were startled to realize that this darn thing was going overhead about ten times per day and there was not a thing they could do about it—and realizing that what was thought to be a nation of peasants could do something like this—with this amount of technical complexity.[4]

Speaking of the public reaction in this country Homer Newell wrote:

> How brightly the red star shone before all the world in October 1957! Streaking across the skies, steadily beeping its mysterious radio message to those on the ground, Sputnik was a source of amazement and wonder to people around the globe, most of whom had no inkling of what was about to happen. In the U.S. many were taken aback by the intensity of the reaction. Hysteria was the term used by some writers, although that was doubtless too strong a word. Concern and apprehension were better descriptions. Especially in the matter of possible military applications there was concern, and many judged it unthinkable that the U.S. should allow any other power to get into a position to deny America the benefits and protection that a space capability might afford. A strong and quick response was deemed essential.[5]

Pickering returned to Pasadena to confront a sense of subdued frustration at JPL. The staff was, for the most part, well aware that the addition of a single live-stage motor to their existing upper-stage rocket motors could put a satellite in orbit. Furthermore, they knew how to do it and they had all the hardware they needed to do it. All they lacked was the approval to "go ahead." "We thought," said Pickering, "if the Army would only tell us to go ahead we could do this. We've got this reentry test vehicle—all we have to do is to put another stage on it and it will go into orbit." But the word to "go ahead" did not come.

Pickering was swamped by calls from the media wanting his reaction, opinion, and future predictions about the Sputnik affair but constrained by his orders from General John B. Medaris, he could only remain silent about his innermost thoughts for the future.

Despite its frustration over the rejection of the Project Orbiter proposal, and quietly encouraged by Pickering, JPL engineers began to formulate a quick response to the challenge posed by Sputnik. It would have to be something that the Army would support and for which it could get approval to carry out, and it would have to be something they could build quickly using material and parts that they already had. There would be no time for lengthy development and testing. The question was: what sort of response?

Pickering reasoned that, since the Soviets had more lifting capacity than the U.S., putting up a little satellite would not make much of an impression compared to Sputnik. Rather than just putting up another Earth-orbiting satellite, Pickering suggested they aim to shoot something to the Moon. "That would be dramatic, and a step in the right direction," he said. Calculations soon showed that if they put some larger upper stages on the Army's Jupiter,[6] employing much the same philosophy as they had used for Project Orbiter but on a larger scale, then they could indeed put a significant payload on the Moon.

That was it—they gave it a name, "Red Socks," and Pickering took it over to DuBridge at Caltech for his approval. "This is something where we can react to what the Soviets have done by doing something more dramatic," he said. DuBridge agreed and together they went to Washington to sell the idea to the Army. Although General Gavin, Head of Research and Development (R&D) for the Army, liked the idea, the Under-Secretary for R&D in the Department of Defense (DOD) deferred his opinion until an alternative proposal could be developed by the Air Force. So, in an atmosphere of interservice rivalry, the Red Socks proposal foundered.[7] As far as the Pentagon was concerned the country had made a choice for its Earth-satellite program, and that was to be Project Vanguard.

Explorer: America's Response

About one month later a second Russian satellite, bigger than Sputnik 1 and carrying a live dog, appeared over the skies of the U.S. This second, spectacular Russian coup finally prompted the DOD to give the Army and JPL its long deferred authorization to prepare Project Orbiter as a back-up for the Navy's ailing Project Vanguard. It was the moment that the Army Ballistic Missile Agency (ABMA) and JPL had been waiting for since 1954.

Medaris called Pickering to an urgent meeting at Huntsville to inform him of the plan for implementing Project Orbiter. Pickering took two of his senior managers with him to meet with Medaris and the von Braun team. Pickering recalled the subsequent events:

> Medaris' office was right next to the Conference Room and I went in before the meeting and . . . basically I told him, 'You give us the Redstone and we will do all the rest.' He listened but didn't say anything—but when we went into the meeting Medaris said, 'Now this is the way it is going to be. . . .' And that was the way it was.[8]

ABMA would build the Redstone launching rocket to do the heavy lifting off the launch pad, and JPL would build the two upper stages and the satellite itself plus the instrumentation to go in it. JPL would also provide the radio telemetry and ground tracking system plus whatever guidance was needed to orient the spinning upper stage once it separated from the Redstone.

For some time, Pickering had been concerned about the future direction of the Laboratory mainstream effort. Although it was currently engaged with the Sergeant and final stages of Corporal as well as the reentry test vehicle (RTV) programs for the Army, he did not see a future role in military programs for the Laboratory. He was convinced that the path to the future began with a satellite program, and he was determined to lead the Laboratory in that direction. Here was the opportunity he needed to take the first step, and he intended to take it without hesitation. It turned out to be a seminal decision.

Work on the new project began immediately. Pickering assigned Jack Froelich to lead the project. Under Froelich's urgent direction, engineers began to assemble the scaled-down Sergeant motors that would provide the upper stages for the Redstone and to fabricate the satellite and the 4th stage motor that would finally inject it into Earth orbit. In a parallel stream of activity, Pickering's telecommunication expert, Eberhardt Rechtin, began to set up the radio receiving stations that would track the satellite and record its telemetry down-link, as it passed overhead. Suddenly the Lab was seething with energy and the spirit of incentive that had begun to dwindle under the dull pressure of the Sergeant program began to rekindle.

Pickering himself undertook the task of finding a suitable scientific package for the satellite. As a member of the IGY satellite-planning group, he was well aware of the science payloads that had been selected for the Vanguard satellite flights. One of them, Pickering suggested, Van Allen's Geiger-counter package, would be a logical choice of instrument for the cylindrical spinning body of Project Orbiter. The IGY committee concurred and directed Pickering to contact Van Allen and work out the details. Delighted with an opportunity to extend his cosmic ray research into regions beyond Earth's atmosphere, Van Allen agreed and arranged to provide the cosmic ray instrument and a scientist to help integrate it into the new Orbiter satellite.

A few weeks later, time ran out for Project Vanguard. The launch had been set for 6 December 1957 at Cape Canaveral, Florida, with full media coverage including national television. Public interest was very high, not only because of the partisan feelings aroused by the Sputnik affair two months earlier, but also because this was to be the first public viewing of a live rocket launch. Now the time had arrived. The countdown proceeded smoothly toward its spectacular climax. At T-zero, the gleaming slender launch rocket roared to life, spewed forth a giant plume of flame and smoke, then rose a few feet from the pad and exploded in a huge conflagration of orange and red flames. It was an apocalyptic moment of total failure before the incredulous gaze of a national audience. Unsympathetic press reports dubbed it the United States' "Flopnik."

For those new to the field of rocket development it was a moment of utter despair. For others, like Pickering and von Braun whose long experience in the field had made them aware of the difficulties that were associated with such complex systems, it was not altogether unexpected. They knew only too well that it took a long period of developmental experience, often painful, to achieve the exacting levels of reliability that such ventures required. That took time and experience, the one thing that Vanguard had not enjoyed.

For William Pickering and Wernher von Braun, however, there was another message in that dismal event—they were up next. The launch, of what was to be known for security purposes as Redstone Missile Number 29, was scheduled for 29 January 1958, a date that had allowed just 80 days from the order to proceed to launch. If the launch failed it could be attributed to a test failure of Army Missile 29; if it succeeded it would be hailed as America's answer to the Soviet challenge for space supremacy. Until then the payload for Missile 29 remained unnamed. The stakes were high for all involved.

Froelich's engineers had made good progress in preparing and testing their hardware for the January launch. In its final form, the satellite consisted of a steel cylinder, 80 inches long and 6 inches in diameter that contained the final 4th-stage rocket motor and the scientific instrumentation package consisting, principally, of Van Allen's Geiger counters. Two battery-powered transmitters would radio the science measurements to the ground and at the same time provide a signal for the ground receivers to track the position of the satellite as it moved across their field of view.[9]

Ever since he had demonstrated the efficacy of radio-based position finding techniques as compared to optical-based methods in the early Corporal guidance tests at White Sands, Pickering had maintained a strong interest in ground-based radio tracking techniques based on the Doppler principle. He believed that a velocity vector, represented by the Doppler component of a radio signal received from a moving missile or satellite, offered a more fundamental, accurate and practical data type than the angle data generated by optical devices for the determination of trajectories and orbits respectively. Pickering had charged Eberhardt Rechtin, another of his brilliant former Caltech students, with responsibility for developing a sensitive ground-based radio tracking system that could not only detect very weak signals from a tiny in-flight transmitter but could also extract the telemetry data that they carried. In addition, and perhaps most astonishing of all, it would use a small but significant part of the residual signal to measure the Doppler effect, or change in radio frequency, as the missile or satellite moved along its path relative to the receiving station. They called the system "Microlock," after the basic "microwave phase-lock" principle that enabled the sensitive ground receivers to track the phase of the satellite's incoming radio signals with extraordinary precision.

Microlock receivers at Cape Canaveral had been used for the early reentry test flights but now, faced with the need to cover an Earth-orbital flight, Pickering ordered his communications experts to set up three additional stations spaced roughly equally around the globe: one in California (near San Diego), one in Malaysia, and a third in West Africa. With the suitcase-size receiving equipment and a couple of technicians to set them up and operate them, Pickering had, in effect, a primitive international network of tracking stations for his satellite. These simpler stations would capture telemetry from the passing satellite, while the more complex stations in Florida and California would generate the Doppler data needed to determine the satellite orbit, in addition to capturing the telemetry data.

As the launch date drew closer, Medaris instructed Pickering to treat Missile 29 and its payload with the utmost security to keep its real identity hidden from public knowledge until after the launch. Decoys were to be arranged to cover the identity of all personnel that were associated with the satellite work, particularly Jack Froelich and Pickering himself.

As part of this subterfuge, Pickering planned to be in New York on 29 January, the opening day of the launch window, to present a paper at a meeting of the Institute of Aerospace Science. After the meeting, he planned to return unobtrusively to Washington to await the outcome of events at Cape Canaveral.

William Pickering did indeed spend that evening in Washington far from the unfolding drama at Cape Canaveral; not in the comfort of a quiet hotel but huddled over a single telephone in a small, nondescript conference room deep in the Pentagon, in Washington, DC. Earlier, the Secretary of the Army had "invited" Pickering, von Braun, Van Allen, and Berkner to follow the launch activities from there, probably to ensure that they were well hidden from public view. The office-size conference room contained a table and a few chairs, one standard telephone and, in the corner, a teletype machine that from time to time chattered with messages from the launch site control center, nothing more. To find out what was happening they would call the Cape, or vice versa.

Enormous sighs of relief and applause followed each successive announcement that the launch was "good," that the upper stages had separated, and the high-speed cluster had fired. Finally, von Braun remarked, "the rest is up to JPL."[10] Pickering took over the phone to talk to Al Hibbs, his orbit determination expert at the Cape who was busy figuring out with pencil and paper just when the new satellite should appear over the horizon in California. It was then that the group was informed that, by an edict of the White House, the name of the new satellite was to be Explorer 1, and that there would be no public announcement until its signal had been picked up, and confirmed, in California.

Time seemed to stand still while they waited. The contact time predicted by Hibbs passed with no report of contact. Pickering recalled:

> So I am sitting there with the telephone stuck in my ear, and there is no signal, and the Secretary and all the others are glaring at me thinking, 'Where the hell is it?' I am really in the hot seat. So I tried to make chit-chat to Frank Goddard at JPL when suddenly he got a 'signal received' report from the nearby San Gabriel Valley Amateur Radio Club followed almost immediately

> by a report from the San Diego Microlock. It was eight minutes late[11] according to Hibbs' estimate which, considering the real time nature of all this, was a pretty damn good estimate.[12]

A few moments later, a man from the Naval Research Laboratory (NRL) came in to confirm that a Navy station in San Diego had also received and confirmed the signal. There was much back-slapping, hand-shaking, and congratulating all around, but no champagne in the Pentagon office that night. Explorer 1 was in orbit, Pickering and von Braun were jubilant, and the nation was about to "go wild."

A short time later, Pickering, Van Allen, and von Braun were bundled into a car and driven a few blocks to the Academy of Sciences building over on the National Mall. The weather had turned rainy and cold and the streets were deserted. Here and there an occasional taxi, waiting impatiently at a traffic light, was the only sign of life in the sleeping city. Apparently the news that Explorer 1 was in orbit had preceded their arrival. A packed news conference, hosted by Richard Porter, Chairman of the IGY panel on Earth satellites, was in already in progress and news reporters and other interested observers of history in the making waited expectantly for further details. The crowd greeted their arrival, via a back entrance because they could not get in the front entrance for the crush of people, with great enthusiasm, and bombarded the three heroes with questions until well into the early hours of Saturday morning. An Explorer model happened to be on hand and pictures of Pickering, von Braun, and Van Allen holding the new satellite aloft were taken and subsequently published around the world.

It was no coincidence that an Explorer was available in Washington that night. Pickering observed:

> The plan always visualized success and that we were going to have a press conference and tie it into the National Academy of Science to emphasize that this was a scientific program, not just a stunt or a military program. Also, the committee that approved Van Allen's payload was essentially an IGY committee so in that sense it was tied to the IGY. But as far as the general public was concerned, the whole thing was perceived as just a reaction to Sputnik.[13]

The next morning the news press, many with extra editions, announced the achievement with blazing headlines: "U.S. SATELLITE RINGS EARTH: Army Launches Moon into Space," (*Los Angeles Times*); "U.S. SATELLITE CIRCLING EARTH: Caltech Moon Launched," (*Los Angeles Examiner*); "ARMY LAUNCHES U.S. SATELLITE INTO ORBIT: President Promises World Will Get Data," (*New York Times*). Pictures of Pickering, von Braun, Van Allen, and members of the JPL team and details of the Redstone and Explorer filled the back pages. Radio and television broadcasts scrambled to get the news on their early morning news programs.

Pickering, Van Allen, and von Braun show Explorer 1 to the world (NASA Image P8485).

Articles on JPL, and profiles of Pickering, von Braun, and Van Allen appeared in many of the prestigious newspapers and magazines around the world. Overnight, it seemed, Bill Pickering had been thrust into the harsh spotlight of public attention and his image, together with that of von Braun's, came to represent an icon for America's venture into an awesome new frontier beyond the familiar boundaries of Earth—the frontier of space.

When Pickering returned to Pasadena the next day, he stepped into a different world from the one he had left a few days earlier. Newsmen seeking interviews and comments, calls of congratulation and organizations requesting appearances poured into his home and JPL office from all sides. He had, in a word, become a "personality." As he recollected, "it took a bit of getting used to, because so many people were wanting to say a few words or take a picture. You were on the spot all the time."[14]

His children too, became objects of attention when their teachers explained the significance of the event and its association with their local school. At last, Muriel understood what her husband had been doing for the past several years. She began to share some of the glory and for her too, life was never the same. Now she was expected to appear with her husband at public functions to recognize his achievement and to fulfill her role as a part of his newfound public image.

The four remaining launches in the Explorer project played out over the next few months with mixed success. Two were highly successful, and together with Explorer 1, returned important new science data that led to the detection and exploration of the great belts of radiation around Earth appropriately named the "Van Allen Belts," for their discoverer, James Van Allen.[15] The second and fifth launches failed.

In reflecting on the fortuitous outcome of the first Explorer, Pickering viewed it as the beginning of "a slow climb up the learning curve," where failure was not acceptable under any circumstances, and the only path to success lay through costly experience, thorough understanding of the total problem, and exacting attention to the minutest of technical detail. This early insight of the problems inherent in the new technology of space flight, would serve him well in the stressful years that lay ahead.

A Very Public Figure

Pickering's speech to the Institute of Aerospace Science in New York in late January 1958 marked the last of his public appearances as a "private" figure. Forty-eight hours later that changed dramatically with the success of Explorer 1 and he became a very prominent "public" figure in every sense of the word, nationally and internationally. His public utterances on "space," and everything remotely related to it, appeared in the news media, radio, and television across the country and around the world; requests for personal appearances throughout the country poured into the JPL director's office. Undaunted by the extra workload and traveling it entailed, Pickering did his best to accede to most of the requests. He came to regard his public speeches as "part of my job," and used them to advocate his opinions on a variety of less technical subjects related generally to the U.S. space program and the Soviet threat to U.S. technological superiority. His public speeches, which were about to become a dominant part of his professional life, reflected his changing outlook, the breadth of his interests beyond the purely technical, the depth of his insight, and the public spirit of the times.

Borne on the tremendous wave of public interest in the new technology of "space," that followed the Explorer and Vanguard launches, Pickering addressed the Los Angeles Chamber of Commerce in March 1958. His topic was "The Engineer in the Space Age."[16]

He said:

> This meeting [today] is another evidence of the tremendous interest which the public displays toward this newest technical break-through-the dawn of the Space Age . . .The progress of civilization is today measured to a large extent by its technological achievements. . . .

Acknowledging that America's technological leadership had been challenged by the Soviet launching of Sputnik and recognizing that within five years the Soviets could challenge the U.S. in all fields of science, Pickering proposed a policy for the future that would reverse that imbalance and strengthen the United States' response to the Soviet challenge. He believed that "the answer lay with our scientists and engineers and with the support which we, as a nation must give them." He called for "a better understanding on the part of our political and industrial leaders of the importance of science to the national welfare." More support for basic research, more scientists and engineers, and more and better teachers to train them were the essentials of his message. He asserted:

> University and high school teaching must emphasize the real essentials of science and the scientific method. Mathematics and physics must become of prime importance. The ability to think clearly, to analyze a problem on the basis of essential data, to understand the fundamental principles involved these are the essential skills . . . and teaching is a critical factor, and Russia is doing a better job than we are.

The need for more scientists and engineers, higher standards for advanced education, better-trained teachers, and a national space program under civilian control: these were recurring themes in many of his speeches that followed.

While satellites, rather than manned space flight, were obviously of more immediate interest to Pickering, he had very clear ideas about the role that man should take in space. He gave voice to those ideas the following month in Denver, Colorado, at a symposium on "Man in Space" sponsored by the Air Force Office of Scientific Research.[17]

He began with the assumption that " . . . we have the capability to place a man in space in an Earth satellite or on some extraterrestrial mission," and then posed the question, "What do we gain by placing a man in the vehicle?" It depends, said Pickering, on the purpose of the mission. If the intent was to land a man on the Moon, or Mars, then a human passenger was obviously required. If however, the objective of the mission was to make scientific observations then, Pickering asserted, remotely-controlled instruments were a better alternative.

For scientific missions he saw the human passenger as " . . . an unnecessary complication."

However, when it came to the actual exploration of the Moon or planets, Pickering said the task of navigating across the vast distances of space and surveying the planet for viable landing sites would be done by robot vehicles, "but detailed exploration after a landing . . . must surely take man's intelligence."

In a prescient view of the distant future, Pickering summed up his thoughts on the role of man in space: "The capability for manned space flight becomes useful only when we consider the exploration of other planets. Before that time comes, unmanned vehicles can accomplish almost all of the missions assigned to space flight, in a cheaper more reliable fashion."

As Congress moved toward embracing a national space program, Pickering became concerned about potential conflict between military and scientific institutions for control of the nation's space enterprises. He voiced his concern in an address to the Association of the United States Army at San Pedro, California, in May 1958.[18]

Noting that the success of America's first Earth satellite was the result of a joint effort of the military and scientific communities, represented by ABMA and JPL, and that more joint programs were planned, Pickering said " . . . even as these preparations go ahead, unresolved questions cast their shadows before them . . . the essential ambivalence of the scientific-military mission in space will . . . become larger as the space program grows more ambitious."

He observed that while the scientist and the military man agreed on the necessity of exploring space and had worked closely together in the past to establish and demonstrate the basic principles, they were motivated by different objectives that could best be served by a separation of the programs in the near future. Pickering believed that these ideas were reflected in President Eisenhower's recent (2 April) recommendation to Congress " . . . to establish a new, independent federal agency that would be responsible for space technology, space science, and the civil exploration of space."

Congress was then considering this legislation; "I trust that a decision will be forthcoming before the end of the session," he said.

A week later, Pickering was speaking before the Louisiana State Department of Education in New Orleans. This time, the subject was "Education in the Space Age."[19] Pickering put his audience on alert when he opened with:

> There should be no doubt in the mind of any well-informed citizen that the U.S. and the USSR possess the power to annihilate each other, and this is a new situation which has never been faced before in the history of mankind. . . . Only seven months ago, on 4 October 1957, the U.S. lost an important battle in this conflict. The launching of the first Sputnik came as a shock to our people, but to people all over the world it was taken as proof that our much vaunted technological superiority was now second to the USSR . . . it was even interpreted to mean that the communist system had proved superior to the capitalist system. Fortunately, the launching of Explorer 1 on 31 January has done much to restore the balance. But it may be years before we have wiped out the memory of that October day.

"What do we, as citizens, do about it?" Pickering asked. "A few of us are in the front lines, so to speak, and we will fly satellites and lunar vehicles but we have no illusions about the strength of our opponent." Comparing the size and capabilities of the Soviet satellites with those of the U.S. led him to believe that the Russians were capable of "building, launching, and guiding rockets capable of being used as inter-continental ballistic missiles." "This is no time for complacency," he said, "We need to give all the support we can to our missile and satellite programs."

Pickering said that it was important to understand the true implications of the Cold War, the forces that controlled the political climate, the weapons being used, and the importance of science and technology. "We live in a time of tensions that are unlikely to be resolved in the next few years, and we must see that the coming generation is prepared for its part in the [continuing] struggle. The education system of our country must accordingly be prepared to accept the responsibility of training the citizenry for its part in this world struggle," he said.

Here, Pickering reiterated the themes that he had discussed at his earlier speech in Los Angeles on the "Engineer in the Space Age;" more engineers and scientists, better qualified teachers, higher standards for advanced education, well-rounded academic programs, and emphasis on mathematics and physics.

"For our very survival it is essential that the nation support a public education program adequate for the space age," he concluded.

As the euphoria over Explorer subsided and the sometimes wild conjecture about the future direction of a space program engaged the public interest, the reason for, and ultimate benefit of, a national space program came into question. With this in mind and, always alert for a catchy title for his speeches, Pickering chose "The Four Reasons" for his address to the Pasadena Chamber of Commerce in June 1958.[20]

He said:

> We are standing tonight at what might be called the door to space . . . and we have paused momentarily on the threshold to collect ourselves and our equipment for the adventures that stretch before us. . . . There are two basic questions that can be asked at this stage—why do we want to go into space and how do we propose to get there?

Citing the President's Science Advisory Committee for an answer to the first question, Pickering said that each of the following four factors was reason enough to justify a national space program:

> Natural curiosity leads man to try to go where no one has gone before; being strong and bold in space enhances the prestige of the U.S.; A defense objective ensures that space is not used to endanger our security; and Space technology offers new opportunities for science experiments that will increase our knowledge and understanding of the Earth, solar system, and the universe.

"Taken together," he said, "they do indeed constitute a compelling reason to embark on such a program with all reasonable speed."

He explained how the development of large and powerful rockets for military purposes had in fact "opened the door to space," and in doing so had created a strong rivalry between our military and scientific institutions for control of the nation's space program. Although the present national space program was being directed by the Advanced Research Projects Agency (ARPA) of the DOD, Congress was considering a bill to establish a civilian agency, the National Aeronautics and Space Administration (NASA), with authority to direct "aeronautical and space research sponsored by the government."

How would these two agencies interact? Pickering believed

> The right answer must lie somewhere between the two extreme views. The costs of space vehicles are so large as to require a coordinated national effort. Therefore both military and scientific objectives must be considered . . . ARPA and NASA must cooperate so that all phases of our space program are put into proper perspective . . . we need a positive program, not hysterically reformulated every time Russia sends up another Sputnik, but logically and scientifically planned and funded with the objectives of reestablishing America's preeminence in this area of technology and insuring our military position in space, and opening a new era in human development.[21]

Although the U.S. program roughly paralleled that of the USSR, he believed that it lagged the Soviet program by about two or three years. He said:

> With the Soviets possessing this lead, it might seem that we will remain in a sorry state to contest their leadership. This, I refuse to believe. Admittedly we are a late starter in the race; most of our actions have been merely reactions to Soviet action that were motivated, to a large extent by fear, but surely this nation can cast off such a miserable, defensive psychological response. Here we stand at the door to one of the greatest adventures of the human spirit. We have an opportunity to show the world how we can lead mankind in hope and freedom, leaving behind fear and suspicion. We can do it—we must do it.

The Pasadenians rewarded his presentation with a long and enthusiastic standing ovation.

The first year of the Space Age made an arresting and appropriate subject for Pickering's address to the Aircraft Industries Association in November 1958. "Just a year earlier," he reminded his audience, "the country was still recovering from the shock of seeing the Russians place two satellites in orbit only about one month apart." Pickering said there had been a universal, almost hysterical demand that something be done quickly to off-set that perceived "Cold War victory." Now it was time to review what had been done to catch up with the Russians in the field of guided missiles and space development.

He carefully explained what was then known about Russian progress and what could be deduced from the performance of their satellites and ICBM test vehicles that had been launched successfully.

By comparing the size and weight of the Russian and American satellites launched so far, and the energy required to place them in orbit, Pickering observed that "the missile that launched Sputnik III must have been at least as large as America's most advanced heavy rocket, the Atlas. Yet the United States had not yet fired a complete Atlas, let alone developed it to the state where it could be used for a satellite launching vehicle." Obviously, Russia was "way ahead of the United States in the guided missile art."

In answer to the important question of "are we showing signs of catching-up?" Pickering could give only a qualified "Yes." He believed that a "psychology of failure" was developing in the nation, largely as a result of the public tendency to "gloss over" our failures in the missile and satellite test programs.

He cited recent media examples from the Vanguard, Explorer, and Pioneer missions that particularly annoyed him. "Better luck next time" or "Man against impossible odds," or "Man against Newton's laws." These were not examples of "glorious failures." None were acceptable. He asserted that these failures were due to "insufficient engineering analysis and test of a condition that was encountered in flight." He totally rejected a recent media comment that " . . . nothing succeeds like a failure." It was a carry over from the Vanguard experience and overlooked the point that a missile was a very complicated device that called for thorough engineering analysis and preflight testing.

He said:

> We have tried to run before we can walk. . . . The key to obtaining real improvement [in the missile program] is a recognition by both the government and industry of the fact that missile design is an engineering problem, and that failure can mean one of two things, either a failure to understand the problem or poor engineering design. In either case, the lesson to be learned from failure is to review the problem in an analytical manner, then apply the results of analysis.

He blamed the publicity associated with the satellite programs for much of the problem. It was essential, he said, that our space programs not ignore the possibility of failures, but be conducted "in such a way that success is expected" and is not perceived "as a lucky fluke."

"We must set success as our goal and be content with nothing less. Only then will we catch, and surpass, the USSR in this vital area," he concluded.

As the space program moved forward, now under the direction of NASA, Pickering would have cause to reiterate the ideas expressed in this speech time and again, when a succession of temporary failures obscured the larger picture and threatened to divert attention from the intermediate steps that, in his opinion, were essential to the achievement of ultimate success.

The age of space had arrived.

Endnotes

1 Newell, Homer E., *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP-4211, 1980).

2 Mudgway, Douglas J., Oral history interview with William H. Pickering. Pasadena, California, May, 2003.

3 Newell, Homer E., *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP-4211, 1980).

4 Mudgway, Douglas J., Oral history interview with William H. Pickering. Pasadena, California, May, 2003.

5 Newell, Homer E., *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP-4211, 1980).

6 At that time, the Jupiter was being developed as a 2000-mile range, intermediate range ballistic missile by the United States Army.

7 Pickering believed that this decision was representative of the rivalry that existed between the Army and the Air Force.

8 Mudgway, Douglas J., Oral history interview with William H. Pickering. Pasadena, California, May, 2003.

9 Pickering, William H., with James H. Wilson, "Countdown to Space Exploration: A Memoir of the Jet Propulsion Laboratory, 1944-1958." In: Hall, ed. *History of Rocketry and Astronautics* (Springfield, Virginia: American Astronautical Society History Series, Vol. 7 Part II, October 1972).

10 Ibid.

11 Its late arrival over California was attributed to the extra velocity it picked up as it passed through the jet stream, which resulted in a slightly larger orbit than Hibbs had predicted.

12 Mudgway, Douglas J., Oral history interview with William H. Pickering. Pasadena, California, May, 2003.

13 Ibid.

14 Ibid.

15 Van Allen, James A., "Radiation Belts Around the Earth." *Scientific American*, 200, March 1959.

16 See Folder 12 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

17 Ibid. See Folder 14.

18 Ibid. See Folder 15.

19 Ibid. See Folder 16.

20 Ibid. See Folder 18.

21 Ibid. See Folder 22.

Chapter 5

The Learning Curve

Toward the Moon

As the Explorer program moved toward its conclusion in the fall of 1958, Pickering's dreams of sending a spacecraft to the Moon began to take form and substance in a project called Pioneer.

Directed by Advanced Research Projects Agency (ARPA), the program was shared between the Air Force and the Army with two probe launches assigned to each of the services. The probes would carry temperature sensors and the now-famous Van Allen Geiger counters to extend radiation belt studies deeper into space, hopefully to the region of the Moon. When the first two Air Force-managed Pioneers failed, the Jet Propulsion Laboratory/Army Ballistic Missile Agency (JPL/ABMA) team was quick to set early December 1958 for its Pioneer launch attempt.

Essentially, simplified versions of the earlier Red Socks proposal, the JPL/ABMA lunar probes were the third and fourth launches in the Pioneer lunar probe series. ABMA supplied a much more powerful launch vehicle called Jupiter to lift JPL's upper stages for injection on to a trajectory that would reach the vicinity of the Moon, and perhaps beyond. JPL supplied the conical satellite with its scientific instrumentation and a new, more refined radio tracking and telemetry system that operated at 960 MHz, a much higher frequency than that used for the Explorers.

Pickering knew that to maintain continuous radio contact as Earth rotated under a probe traveling on a trajectory in deep space would require a three-station network of receiving stations. This meant that the upgraded radio system now carried by Pioneer 3 would require a completely new, and much more complex, ground tracking system than the simple arrangement used for Explorer. To bring this into being on short notice he depended on his former student, and trusted communications chief, Eberhardt Rechtin. For the immediate purpose of tracking Pioneer, Rechtin needed a large, steerable, 26 meter-diameter, parabolic, antenna—a facility that, at the time, existed only in the minds of radio astronomers. Six months later, after a prodigious design, procurement, and construction effort, the huge antenna, the first of its kind, stood ready for operation at a remote site near Goldstone Dry Lake in the heart of California's Mojave Desert. As Pickering so well understood, this effort and what sprang from it, was quite as significant to the U.S. space program as the launch itself.[1]

When Pioneer 3 was launched three days later on 6 December 1958, the new Goldstone antenna had no problems in tracking the probe out to 63,500 miles, the limit of its flight, but regrettably far short of the desired lunar distance.

A few weeks later, as if to mock the U.S. effort, the Soviets announced the success of their Luna 1 space probe. It had passed within 4,000 miles of the Moon on 2 January, and continued into orbit around the Sun claiming the distinction of the first spacecraft to escape the clutches of Earth's gravitational field. The race was truly on, and no one felt it more keenly than Pickering.

Although Pioneer 3 did not succeed in reaching the vicinity of the Moon, the next attempt with Pioneer 4 in March 1959 was completely successful, and did much to assuage the disappointment of the earlier launch. However, it did little to assuage Pickering's aspiration to be "first in deep space." He sought a more ambitious space program that could clearly demonstrate the superiority of U.S. technology and management and secure a reputation for JPL that none could challenge.

In April of that year, Pickering gave an address to the alumni association of California Institute of Technology[2] that epitomized his innate desire to be first in deep space. Obsessed with the perceived relegation of U.S. to second

Pioneer 4 became the first U.S. space probe to explore deep space on 3 March 1959 when it passed the Moon at a distance of 37,300 miles and continued to gather space science data until its batteries became depleted at a distance of 407,000 miles from Earth. The fiberglass cone that enclosed the electronic package is 50 cm long and 25 cm in base diameter. The gold coating makes it electrically conductive and the white stripes serve to control its temperature in space to about 40 degrees centigrade. An 8 cm long probe at the apex is electrically insulated from the cone to create a dipole antenna for radio transmissions to Earth on a frequency of 960 MHz (Photo: NASA/JPL-Caltech Archives, Photo number 291-3730).

position in the space race, he burned with ambition to bring the U.S. program into the dominant position. In "The Exploration of Space" he made a plea for public support of the emerging U.S. space program: " . . . the public generally has not been made aware of the urgent significance of supporting a basic research program that will pay off some X years later with a visible launching of a rocket headed perhaps to the Moon or to the planets." He thought the public was justified in asking what had been achieved since the U.S. started with a rush to compete with Russia in space. In fact we have done a great deal, but most of it is below the surface, he said "we have added greatly to the knowledge about the Earth, its atmosphere and conditions in space, and paved the way with a Vanguard meteorological satellite for what someday we may be able to use as a weather satellite for long-range weather forecasts." On the other hand, to the scientists, the discovery of the Van Allen radiation belts was of major scientific interest. But we could not expect the scientific and non-scientific communities to be stimulated by the same things. The facts show " . . . that there are far more people interested in spectator sports in this country than are interested in the more esoteric aspects of science," he said, and " . . . this lack of interest in the motivation and meaning of science will become increasingly important as the budget demands for space experiments go higher and higher."

At present, public support for our space programs was being sustained by wounded national pride in the obvious success of the Russian rocket technology but, he asked, "What of the time when, and if, it occurs, when we achieve equality with the Russians. Will the American public lose its interest in space and demand reductions in the space budget?" Pickering thought that the future held much of great practical interest to the public. He cited weather satellites as an example, but believed that the most public interest would be aroused by the possibility of developing "communications satellites by which it would be possible to beam television programs from Europe to the U.S."

But first, he cautioned, to even think about catching up to the Russians, we must have bigger and better launch vehicles, or booster rockets, to lift the heavy payloads into space. The existing launch vehicles, based on military designs for ICBMs were simply not powerful enough. He noted a succession of heavy lift boosters that were currently under development for non-military purposes; the largest two were the Saturn and Nova. The Saturn would be capable of placing heavy payloads, including manned capsules, into Earth orbit, while the Nova would be " . . . capable of transporting a man to the surface of the Moon and returning him to a safe landing on Earth."

He said that these programs would be costly, and the public would be justified in asking for a reason why it is important to do these things and what it would expect to get out of it. "We do these things," he said, "because of the unquenchable curiosity of man. The scientist is continually asking questions and setting out to find the answers. In the course of getting these answers, he has provided practical benefits to man that have sometimes surprised even the scientist." He cited Roentgen's discovery of x-rays and Van Allen's discovery of the radiation belts as examples. "Who can tell what we will find when we get to the planets . . . or predict what potential benefits to man exist in this enterprise. It seems to me that we are obliged to do these things, as human beings," he concluded.

It was a bold statement, issued from the heart of a man who passionately believed in the issue he advocated, and who possessed the personal courage and technological acumen to back it up.

As evidenced by his public utterances in 1958 following the Explorer success, Pickering had given considerable thought to the form in which the U.S. should expand its interest in the new field of space, and he had formed very definite ideas about the role that he saw for JPL in such an enterprise. He believed that military interests and civilian interests in the development of space were sufficiently divergent to justify the establishment of entirely separate and independent programs to serve the needs of each. The civilian program would be the frontline challenge to the Soviet thrust into space, and should leapfrog ahead of the Soviets with bold attempts to reach Venus and Mars rather than diverting effort to reach the Moon. In Pickering's view, JPL's demonstrated expertise and experience clearly placed it in an indisputable position to lead such a program.

Meanwhile, down the corridors of power in Washington, DC, alternative plans to create a new government agency to handle the nation's space program were rapidly gathering form and substance.[3]

By the time President Eisenhower signed the bill that created the National Aeronautics and Space Administration (NASA) in July 1958, Pickering was resigned to the fact that he would have to find a place for JPL in the NASA organization if he was ever to realize his ideas for a national space program. Not all of his executive staff agreed with him. Some held little regard for the bureaucratic constituency of NASA and its aerospace-driven background. They feared that the talents of JPL would be squandered if it became merely a research "service" for the aerospace industry. Nevertheless, Pickering held to his own opinion, knowing that the JPL-Caltech hierarchy also believed that "the Laboratory had a mission to set the new space agency on the proper course."[4]

When NASA sought the views of the scientific community and specialists in relevant fields, as a basis for developing its space science program, Pickering lost no time in offering his point of view. Pickering's conceptual ideas for a space science program, and how they might be carried out, were reflected in a five-year plan of solar system exploration developed for the new Agency by a JPL team led by Albert Hibbs.[5]

In the firm belief that JPL should play a leading role in NASA, Pickering wrote to J. R. Killian, President Eisenhower's science advisor, setting out his view on the role that JPL should play in the new administration. He warned Killian that unless the new Agency accepted the concept of JPL as the national space laboratory, there would be a danger that the military would seize the initiative and leave NASA to provide only supporting research with an occasional scientific payload. However, as the national space laboratory, JPL with all of its unique experience would become a key NASA resource that, given a clearly defined responsibility, could draw up a viable long-term space program for the nation.[6]

Late in 1958, when NASA approached Caltech with the idea of transferring JPL from Army to NASA jurisdiction, both Pickering and Caltech President Lee DuBridge responded with enthusiasm. Under the final arrangement, Pickering agreed to complete the Sergeant weapon development program for the Army and to do some further limited research for the Army. On 3 December 1958, Eisenhower signed an executive order that authorized the transfer and Pickering, his entire staff, and JPL's future research programs came under the direction of NASA.

Thus, it came about that Pioneer 3, launched on 6 December 1958 and the new 26-m antenna at Goldstone that tracked it, combined to carry out NASA's first mission into deep space.

Early that morning, NASA convened its first post-launch press conference at its temporary headquarters in Washington, DC, with Dr. Abe Silverstein, Director of Space Flight Development representing NASA and Kellogg, von Braun, and Pickering representing the IGY Satellite Panel, ABMA, and JPL, respectively. Unlike the Explorer event, this press conference was very formalized and far less spontaneous and exuberant. It marked the first of many media events that exposed Pickering to public scrutiny. Some would be excruciatingly depressive, others wildly exuberant. Silverstein said the Pioneer 3 launching had been "functionally successful" and called the accomplishment " . . . a supreme achievement in the engineering sciences and the arts." He paid tribute to the cooperation of ABMA and JPL that had brought about this contribution to the IGY and noted that the Pioneer 3 program was managed by NASA under the direction of Dr. Keith Glennan. NASA was making sure that the public recognized the new order of authority in the nation's space program. Most of the questions from the audience were related to an explanation of how the rocket and upper stages worked; Pickering, von Braun, and Kellogg answered cautiously.[7] In conclusion, Silverstein extended NASA's thanks to "the Army Team, the team at our new Jet Propulsion Laboratory at Pasadena and to the scientists who provided the instrumentation that went into the Bill Pickering payload." Silverstein was bent on driving home the message that NASA was in control.[8]

Pickering, however, chaffed under the tightening constraint that he perceived NASA was imposing upon his personal ambitions for the exploration of space. The Explorers and Pioneers represented, like the first Corporals that went before them, an improvised solution to an existing problem that that made use of old ideas and, at best, current technology. Pickering envisioned much more ambitious and challenging goals for the embryonic space program of the U.S. But NASA regarded such ambitions with reservation and came to perceive Pickering and JPL as a significant, but irritating, member of its family of Field Centers.

At the end of September, as the Sputnik affair neared its second anniversary, Pickering spoke before the 1959 Annual Meeting of the American Institute of Chemical Engineers in St. Paul, Minnesota, on the subject of "Space—the new scientific frontier."[9] The nascent organization of NASA had begun to formulate its plans for a national space program and, although the role of JPL in the new Agency had not yet been fully established, Pickering had become reconciled to the fact that if it was to survive, JPL would have to accept authority and direction from Washington. Nevertheless, Pickering had very clear ideas about the direction the space program should take and plenty of advice for NASA as to how to go about it, as this speech clearly shows.

Pickering began by expressing his concern that the current wave of public support for the U.S. space program that had been energized by the Russian show of technological superiority would soon subside as the reality of the enormous costs associated with a viable space program became apparent.

Pickering used a comparison of successful space shots, eleven for U.S. versus three for USSR, to show that while the U.S. could point to more satellites and more, and better, science results, the Soviets had put much heavier payloads into space, including one that hit the Moon. Obviously this achievement implied the use of more powerful rockets with superior guidance systems. "Whether we like it or not," said Pickering, "this capability can, and presumably is being used to build missiles which place all of the U.S. cities within range of launch sites in Russia."

Pickering did not see any evidence that we were catching up with the Russians and believed that the nation " . . . must understand the nature of the task ahead of us and the way in which we must organize to accomplish the task." In a world where technological achievement is regarded as the mark of success of a civilization or a political system, satellites and Moon shots represent achievements of the highest order, as the Russians obviously realized. For much of mankind, exploration of the heavens represented an entirely new thought, and as much a landmark in the history of human development as Darwin's theory of evolution. Thus, Pickering reasoned " . . . space achievements become one of the most important weapons in the Cold War."

Pickering expressed the view that we needed a realistic evaluation of our future national space program that would allow us to

> . . . advance as rapidly as possible to a position where we have begun to explore the Moon and the nearby planets. . . . Then,

> we can consolidate our scientific knowledge with detailed experiments, and then we can establish possible military applications. We should not now divert our efforts into costly military ventures of doubtful value. . . . Which was more important to the real interests of the United States, a military photographic satellite, or an interplanetary vehicle which could give an answer to the question of life on Mars?

Either one, he thought, could be accomplished in the next few years, but not both. "I happen to believe that the mission to Mars should be given priority," he said.

Pickering delivered a rousing finish to his address. The exploration of space, he asserted, presented us with much more than a fascinating new scientific frontier; it represented a new dimension in human thought and gave us a powerful weapon in the Cold War. He asked:

> Where will we stand ten years from now? Will we still find the Russians scoring firsts in space? Will the Russian Prime Minister send our President a desk ornament made from lunar materials? Will the new map of the Moon carry Russian place names? If so, Khrushchev will have been right; Communism will 'bury Capitalism.'

"But this does not have to be true," he explained. "We have the resources to respond to this challenge. Give us your support. Try to understand our program. Separate the realities from science fiction–then stand back. Watch us go!"[10]

The JPL Director's plan for future exploration of space caused considerable comment when it arrived at NASA in April 1959. Known as the Hibbs report, the plan called for launching four spacecraft to Venus, three spacecraft to Mars, and five spacecraft to the Moon, over the period August 1960 through March 1964. The details of the report bore the unmistakable imprint of the ambitious Pickering ideas.

But NASA demurred. Pickering's vision of a planetary program focusing on the planets under his direction was finally dashed, when in mid-December 1959 he received a letter from Richard Horner, NASA's Associate Administrator, directing him to concentrate on lunar rather than planetary exploration. However, much of his private opinion differed from that of NASA; there was no option other than to move forward as directed. The free-wheeling Army days were long gone.

Sensing Pickering's displeasure at these instructions, Dr. Silverstein, Director of Space Flight Development at NASA, sent several of his top scientists to JPL to discuss the details of the NASA program with Pickering and his staff. In the less than cordial discussions that followed, Pickering, Hibbs, and several other top JPL scientists made their objections and concerns known to the NASA officials. When asked whether NASA had considered the question of competition with Russia, scientific objectives, and the matter of organization in its planning, Newell pointed out that the overall objectives of the NASA program in space flight were: the extension of the domain over which man may move and be active, and the extension of human knowledge about Earth, its environment and space, and the objects of space. NASA regarded both of these as very important and had designed programs to support them strongly. Referring to the matter of competition with Russia, Newell said:

> In the matter of Russian competition, it is clearly understood that whether it be stated openly or not, the United States is in competition with Russia and the stakes are very high indeed. It is further understood that the loss of the space race would be of great seriousness to the United States, economically, culturally and politically.

Pickering could have had no dissent from that point of view coming from NASA's top spokesman. Newell continued:

> But it is felt that our competition with Russia must be based on a sound program of science and technological development and not on the performance of what may be called 'stunt-type' missions. If the latter approach were taken, we would be in danger of being scooped or bettered by the Russians and made to look even worse than we are, and in the long run we would lose out by not properly developing our ability to compete.[11]

How those words must have resonated with Pickering as he heard his own opinions from a dozen speeches over the past year, echoed back to him from the voice of NASA.

Perhaps they softened his attitude toward his new masters for at the end of the negotiations, it was resolved that:

> . . . NASA Headquarters would remain responsible for overall program planning, while JPL would lead the engineering and execution of lunar and planetary missions—a position that it has maintained for the most part through the present time. NASA officials assured JPL that while lunar exploration remained the Agency's main area of solar system interest, planetary work would get underway soon, with launches to Mars and Venus whenever they were in optimum position for a planetary mission . . . and finally, NASA pledged to create a single working committee for lunar and planetary exploration in the NASA management structure."[12]

With the scope of JPL's responsibilities clarified, the parties hammered out a compromise that blended NASA's immediate interest in lunar flights with Pickering's longer term interest in planetary missions.

The first two lunar flights would be essentially engineering test flights to evaluate requirements for attitude control and communications. The final three flights would gather scientific data about the lunar surface in the "period immediately preceding impact." In one of the few documented cases where JPL and NASA reached a simple mutual agreement the overall project was named Ranger. The Ranger missions would demonstrate the ability to perform a scientific program in space and clarify the requirements for attitude stabilization and planetary communications—all of it technology necessary for its subsequent planetary missions to Venus and Mars. These later missions were to be named Mariners.

In his history of project Ranger, Cargill Hall wrote, "The Ranger program would also meet another need, publicly expressed by JPL Director William Pickering, to demonstrate the superiority of the 'American Way' to uncommitted states in the international community."[13] It was a very pertinent comment, as Pickering's public statements clearly showed throughout 1959.

In addition to his involvement in the formative discussions with NASA, then in progress between Washington and Pasadena, Pickering found time to deliver several public addresses in the last quarter of 1959.

His address to the Seventh International Meeting of Communications (Engineers) in Genoa, Italy, was a prime example of Pickering at his best, a lecture-style delivery with equations, anecdotes, illustrations, and technical wisdom and foresight and, for its time, a most compelling subject: "Communications with a Lunar Rocket."[14] He began by comparing the new challenge in radio communications technology—communicating over distances that had increased by four orders of magnitude—with that of the change in technology "brought about by the atomic bomb which increased the power of explosives by some such amount." Rockets will soon be available that can send spacecraft into orbits that extend far beyond Earth's orbit around the Sun, he said. It would be up to the communications engineers to make these vehicles useful by returning their data to Earth.

Pickering explained how the basic "radar equation" related the operating frequency, antenna size, transmitter power, and receiving capability of a radio system to the distance over which it could send and receive data, and illustrated his argument using examples from the recent Pioneer space mission and the new Goldstone antenna. He covered all the fine technical nuances that affect the performance of a communications channel to predict that "communications engineers will indeed be able to provide communications for space vehicles traveling far throughout the solar system." Finally, he pointed out that space vehicles that might take 8 to 10 years to reach their destinations afforded communications engineers an opportunity to improve their Earth-based techniques as the mission progressed, so that when the vehicle eventually arrived at its target, they would have the necessary capability to communicate with it.

"Do We Have a Space Program?" delivered to the American Rocket Society (ARS) in Washington in November was essentially a replay of the themes that he had espoused to the Institute of Chemical Engineers in September: the importance of a successful space program as a powerful weapon in the Cold War, U.S. versus USSR, seen as a clash in cultures, openness versus secrecy, do we have the right space program?[15]

Pickering repeated his strong belief that "our national stature and prestige in the world" was at stake in our race with the Russians. He reiterated his opinion that "in the 2 years since Sputnik, we have not succeeded in matching the Russian achievements."

The remedies that Pickering proposed were similar to those we saw earlier: make the public understand the importance of a space program, clearly define a national objective, establish management and funds to properly support it, and clarify the relative priorities of our civilian and military programs. And then he called for action: " . . . as professional engineers and scientists . . . our task is to educate the public and Congress to the realities and needs of a national space program," he said.

The prestigious space journal *Astronautics* reprinted the full text of Pickering's speech in its January 1960 issue.[16]

Pickering closed out 1959 with an address on "The Scientific Uses of Artificial Satellites and Space Craft" to the Association for the Advancement of Science in Chicago on 26 December.[17] Somewhat like his address in Italy on space communications, this speech was completely technical and addressed the scientific implications of the science program. He pointed out that there were four types of experiments that could be made with Earth satellites: radiation measurements, magnetic field measurements, observation of the appearance of the earth from space, and observations of residual atmosphere. In addition, information about the gravitational field and the shape of Earth could be obtained from precise observations of satellite orbits. Many of the experiments had already been carried out and had given startling results, most notably the discovery of the Van Allen belts of radiation that surround Earth.

Pickering saw a bright future for science in space. He concluded:

> Space vehicles that come close to the Moon or planets and eventually land softly on the Moon or planets open up a whole new era of scientific exploration that covers all of the natural sciences. . . . The discovery of life on some planet will be a most important factor in answering the question of the origin of life, and be as important a factor in human thought as the theory of evolution.

Pickering appended an interesting table to this speech. It compared U.S. launchings and successes with those of the Soviets. The numbers spoke for themselves. It had taken the U.S. 27 attempts to get 13 satellites into Earth orbit successfully. In the same period, the Soviets had succeeded six times with an unknown number of attempts. Pickering believed it unlikely that they had achieved a better success rate than the U.S. He asserted that these numbers were an encouraging indication that the U.S. was rapidly catching up, despite the public's perception to the contrary.

William Pickering turned 49 years old in December 1959 just as these momentous ideas were becoming a reality. Still a young man by any measure, ambitious, gifted, and assured of his place in the technological world of his choice, he brought his talents and a sense of hubris to NASA as later events would clearly show. But for now, he had come to terms with the inevitability of the new direction imposed by NASA upon the Laboratory, and whatever private reservations he may have had about the scientific wisdom of NASA's lunar program he held no illusions about its importance to the international prestige of the U.S. NASA's promise of later missions to Venus and Mars provided additional incentive for his commitment to the Ranger and Mariner programs. Between them, the Ranger and Mariner programs would dominate the rest of his professional life at JPL and determine the fortune of the thousands of young men and women, scientists, engineers, and support personnel upon whose unique skills and dedication the success of both programs depended.

The Learning Curve

At the beginning of 1960, the course for JPL's foreseeable future in space had been essentially determined. Under NASA's direction, JPL would carry NASA's lunar program forward with Project Ranger, while the parallel Mariner program would represent NASA's interest in planetary exploration, beginning with Venus and Mars. Pickering regarded Mariner as the more important program in terms of enhancing the "national prestige" ethos to which he so strongly adhered. He viewed the Ranger program, essentially, as a means to gain access to the "learning curve" of experience in designing and building planetary spacecraft and operating them in deep space.

Pickering organized the technical staff of the Laboratory in the form of a matrix: technical divisions vertically and flight projects horizontally. Each flight project office drew on the technical talent available in each of the divisions, as required to support its individual project. At the completion of each project, the assigned engineers resumed duty with their line divisions. In this way the best talents in each discipline were available to the flight projects for as long as needed to complete each task.

For Pickering, the "matrix" was yet another source of contention with NASA. NASA believed that a hierarchical organization, rather than a matrix arrangement, was much easier and cleaner to manage for carrying out project-type enterprises. "But I wanted to hang on to the matrix form," he said, "because the projects have a relatively short life and there are a multiplicity of them. So you should be able to pick people out of the matrix and have them work for two bosses, one in the Project, the other in the Division. Furthermore, you can use other [experts] in the matrix to help solve problems [that arise] in the projects."[19] Obviously, to make that idea work, the project manager must have commensurate authority. Pickering recognized that fact and chose very strong personalities for his project managers and gave them a direct line of authority to himself.

Pickering depended largely upon weekly meetings with his senior staff, a group of about 30 of the Laboratory's executives and top level managers from the technical and administrative divisions, to keep track of progress on the flight projects, discuss problems and their resolution, and to discuss and disseminate policies and practices within the Laboratory.[20] The weekly Director's meeting became the forum for interaction between Pickering and his top-echelon executives:

> I did not try to enter into the day-to-day decision making for example. That was one of the strong points about the organization, we allowed people throughout the organization to talk to one another and do things as they saw fit without having to come all the way to the top. I was not involved in day-to-day thinking. When they had problems, the project manager dealt with it. My interaction was to isolate the in-house Ranger project from NASA, and eventually from Congress, of course.

He explained ruefully that, although NASA was the primary contact with Congress, the fact of the matter was that "Congressional committees wanted to come out here and visit the place and talk to various people like myself, so that I ended up getting more and more involved in appearing before Congressional committees to talk about these things."[20] Congressional and other high-level visitors were soon to demand a significant portion of Pickering's on-lab time. Always the most courteous of hosts, Pickering found few of the visits of significant value to his program except in the most general way. But he said that was part of his job.[21]

While Pickering accepted the inevitability of NASA's direction of JPL, that fact in no way reflected his perception of the big picture. The government's delineation of the rationale for a national space program and its designation of responsibility for carrying it out, remained issues of great contention to Pickering in early 1960, and he took advantage of every opportunity to make his views known to the public as evidenced by this speech to a Los Angeles organization of construction engineers.

In a dinner meeting address in January 1960 that he titled "The Space Snafu," he once again reviewed the space shots that had made public headlines since the Sputnik event and compared the Russian achievements with those of the U.S.[22] Based on these numbers, he concluded that the Soviets had demonstrated a significant lead over the U.S. in the ability to throw heavy loads into space and to deliver them to a predetermined point in space with remarkable accuracy. This fact implied that the Soviets could deliver ICBMs to any point in the U.S. with equal efficiency. It was a cause for great concern, but not for despair. "The United States had been a late starter in the past, but had always shown a remarkable aptitude for catching up, and seizing the lead," he said.

Pickering believed that space would be no exception and there were already signs of progress in that direction, but he sensed that there was confusion in the mind of the general public about the direction that the nation's space program should take.

The public had a right to ask, "Why do we need to spend a billion dollars on a space program?" he said. The principal reason for spending a billion dollars on space, Pickering suggested, arose from the political reality of our engagement in a Cold War with the USSR. "If we are interested in having the U.S. considered a first class power in this world, then it is essential for the U.S. to have a first class space program," he said.

Now, the world faced a new situation, " . . . the arms race has become a space race . . . and the strength of the country is measured by its achievements in space and not by its armaments."

To succeed in this race, Pickering called for better public recognition of the importance of space to force the government to create a unified national space program that avoided conflict between civilian and military interests for limited resources. "Finally," he said, "the public must learn to distinguish the reality of space exploration from the fantasies of science-fiction."

Evidently, Pickering was catching the attention of officials in high places. About one month after making this speech, Pickering (along with Howard Seifert of Space Technology Laboratories and president of the ARS; George Arthur, president of the American Astronautical Society; and Guyford Stever, professor of aeronautical engineering at Massachusetts Institute of Technology) was called to testify before the Congressional House Committee on Science and Astronautics. Pickering's testimony, which essentially replicated the "Space Snafu" speech, was reported by the *New York Times*:

> . . . the space program was being hampered by confusion, indecision and increasing military domination . . . Dr. Pickering urged that, 'a truly unified national space program' embracing both military and civilian research be established under the control of [NASA]. At present, he complained, the space program lacks a clear objective and effective coordination between the civilian and military space efforts.[23]

Writing for *Aviation Week*, Ford Eastman said, "Lack of motivation, funds, or clearly defined policies were described last week as the major weaknesses impeding the U.S. space program by top space technology experts appearing before the House Committee on Science and Astronautics."[24]

In the laboratories and machine shops around JPL, work on the hardware and electronic systems for the first Rangers and Mariners made good progress in 1960. In that fact, Pickering found cause for great satisfaction, but his relations with NASA were a different matter altogether. Reflecting on this period of his career at JPL, Pickering said:

> At the beginning, I don't think that I appreciated the difference between the viewpoints of the civil service side of NASA and ourselves. As far as I was concerned, our first allegiance was to Caltech and not to the U.S. government. We were part of the Caltech community and we wanted to maintain the academic type of approach with the freedom of choice that is implicit in that [Caltech president] DuBridge supported that concept. He thought it was a proper function for a university because it was research, it was civilian, and because it was scientifically oriented.[25]

Preserving the campus-like environment that his staff found so attractive was one thing but, Pickering soon found, convincing his senior staff that the Laboratory had to now conform to the dictates of the NASA organization regardless of their personal opinions about the merits of the directions that were being passed down to them was quite another. Pickering told the senior staff:

> We have to realize that we are part of the national program . . . and the science experiments for the program should be selected on the national level and that means NASA should properly select them. . . . They accepted that, although with the egotistic [outlook] we had at the time—that we were the only experts, we got into a lot of fights with the selected scientists over their experiments.[26]

At NASA, no one was closer to the source of the problems than Homer Newell. Describing this period in *Beyond the Atmosphere* he wrote:

> As work progressed, trouble continued to brew. NASA managers came to feel that the JPL's traditional matrix organization, which might have been fine for general research and smaller projects, was totally inadequate for large-scale projects with pressing deadlines. NASA also found the Laboratory's record keeping, contract administration and supervision and reporting, inadequate. As a result, NASA began a campaign to get Pickering to tighten up the organization and to improve the administrative side of the house.[27]

NASA also took exception to the large amount of time that Pickering devoted to non-JPL matters—the American Institute of Aeronautics and Astronautics (AIAA), the International Astronautical Federation (IAF), and the International Academy of Astronautics (IAA), for example.[28]

For a time Pickering ignored NASA's strongly worded suggestion that he appoint a deputy-director to give continuous attention to the internal running of the Laboratory. Finally, however, he was forced to accede to NASA demands. Newell wrote:

> This last suggestion was especially disturbing to Pickering, who, despite NASA management's doubts about the quality of his leadership, felt keenly his role as defender of his people. The question of a deputy for the laboratory remained a bone of contention for a long time and even when one was appointed, NASA felt that Pickering did not make proper use of the position.

But NASA itself was not without blame as Newell recognized only too well:

> While the laboratory continued to insist on its independence, NASA insisted that JPL was a member of the NASA team with the same responsibilities to headquarters that other NASA centers had. Headquarters meddled too much in JPL affairs and took on too much project, as opposed to program, responsibility. Headquarters' program managers often by-passed the JPL project office and sought information or gave instructions directly to project engineering staff, or interacted directly with JPL contractors.[29]

NASA's displeasure with Pickering's heavy involvement with the IAF and other professional societies was especially painful to Pickering at this time because he believed that "it was part of his job" to represent JPL and the U.S. space program to the informed public at large. He believed that task was most effectively accomplished at the highest levels within the scientific and technical communities.

In August 1960, he had attended the 11th Congress of the International Astronautical Federation in Stockholm, Sweden. At that time, the IAF president was Academician Leonid I. Sedov of the USSR. Twenty-nine countries, including USSR, China, Germany, Japan, India, United Kingdom, France, Norway, Sweden, Denmark, Poland, and Italy sent representatives from the upper echelons of their scientific and technical establishments. The U.S. contingent included von Braun, Seifert, and Pickering who represented the ARS. An international science convention was an opportune time for a space coup as the Soviets had already demonstrated with the Sputnik affair. What would it be this time? No one knew, but a persistent air of expectancy pervaded the formal gatherings of the world's scientific and technological elite. Pickering clearly recollected with great relish what took place:

> . . . it was just after the U.S. launched the first Echo balloon.[30] The Swedes had put on a musical concert for us out at Grottingen, the Versailles of Sweden. At intermission, the people drifted outside and to their astonishment, the Echo balloon [satellite] drifted

> across the sky. It was a time when satellites were few and it caused great excitement. The whole crowd came outside to look at it—except the Russians.

Immediately, Pickering was asked to brief the assembly on the purpose and technical details of the Echo satellite. There is no reason to doubt that he was fully prepared and responded to all questions with confidence. The leading French newspaper, *Le Soir*, reported the event including Pickering's details, in major headlines, "Un satellite-ballon américain a été placé sur orbite." In Pickering's view, it was another small step in the "right direction."

Casting a shadow over this whole situation was the undeniable fact that Pickering's ideas about the urgency and direction of the space program differed from those of the Eisenhower administration and those of NASA. Eisenhower doubted the value of sending a man into space, and wanted desperately to avoid a space race with the Soviets.

Within six months however, all such conflicting opinion had become moot by a succession of major political events that began with the outcome of the Presidential election in November 1960 when John F. Kennedy succeeded General Eisenhower as the nation's Chief Executive. While the nation's attention was focused on Kennedy's response to the communist threats from Cuba, yet another Russian spectacular swept unannounced and unexpected across the skies of America. It was a huge Russian space capsule called *Vostok 1* and, as if to further deride the U.S. effort in space, it carried a human payload. On 12 April 1961 the Russian Cosmonaut, Yuri Gagarin, claimed the distinction of first man to fly in space. Understandably, this event lent new urgency to Pickering's argument over the significance of "national prestige." One week later, the country's sense of pride was further tarnished by the disastrous outcome of the invasion of Cuba that resulted in the Bay of Pigs debacle.

Sensing a change in attitude at NASA, Pickering asked his senior staff to put all available effort into working up a new space plan for JPL. "The new study should take into account the primary importance of propaganda . . . etc," he directed. The new study did just that. "The primary objective," it stated boldly, "is to be first." It called for landing a man on the lunar surface in 1967, establishing a lunar base by 1969, and placing a man on Mars in 1973. While that was surely spectacular enough for propaganda, opinions among the JPL staff were varied, although generally in favor, and Pickering endorsed the proposal and passed it on to NASA.[31]

Meanwhile, the White House had set in motion the search for a national space initiative that culminated in President Kennedy's call on 25 May for the nation to commit itself to putting a man on the Moon by the end of the decade. Kennedy believed that it was essential for the U.S. to take a leading role in space: " . . . if we are to win the battle that is going on around the world between freedom and tyranny." Hearing these words from the President must have touched Pickering's pride and assurance in the value of his own beliefs. But how would NASA react? He did not have to wait long to find out. Within days, NASA issued a new space flight plan that gave national priority to a manned lunar landing, declaring that the objectives of JPL's Ranger project were now considered to be in "direct support" of Apollo. Almost overnight, the rationale for the national space program had changed. Gone was the peaceful, measured scientific approach of the past. Now it was considerations of national security surmounted by the objectives of "national prestige" that would drive the NASA programs, and Pickering felt himself vindicated.

In 1961, the American Rocket Society (ARS) claimed members of Congress, government officials, high-ranking military officers, leaders of industry, engineers, scientists, and students among its 20,000-person membership. It was the largest and most prestigious organization of its kind in the country, if not the world, and encompassed the entire missile and space business of the U.S. When the ARS spoke, people listened. In October 1960, the ARS elected William Pickering to the office of president of the society for the following year. This action obliged him to deliver the opening address at the society's annual convention in New York. The theme on this occasion was "Space Flight Report to the Nation," and Pickering planned to speak on "Space, Professional Societies, and the National Interest," themes he had delivered to other professional societies in the past.

Pickering began:

> At this moment in history, the future of our nation, indeed of the whole civilized world, depends to a large extent on the skill and ingenuity of you, the members of the ARS. Missiles for hot war, Space for cold war; these two elements of our strength are critical in determining our national posture, our standing among nations, our ability to lead the free world.

Because of its unique membership, the role of the ARS in supporting the national interest was quite clear, but Pickering questioned whether the proliferation of professional societies in recent years was "truly in the best interests of the profession [of engineering] and of the nation." Pressure to produce papers and speeches for a multiplication of professional society conferences, and the time and resources expended in attending them, could endanger the quality of the material presented. If this happened, "the whole system of technical societies will no longer be of value to the engineer and scientist and had best be abandoned," said Pickering.

Pickering commended the ARS for its efforts to achieve the highest quality in its papers and standards for membership but, he said, " . . . the quality of ARS membership may be said to be of direct interest to the national welfare. If the ARS can improve this quality, by so much will the society contribute to the national interest. There are very few societies in this position."

In 1957, the ARS had recognized its obligation to help the government by offering a recommendation for a national space flight program to President Eisenhower.[32]

Now, Pickering addressed a message directly to President Kennedy. Speaking on behalf of the ARS and its members, he said, "Mr. President, we in the American Rocket Society welcome your program for the conquest of space. We believe in it. We know it can be done. We pledge our help in every way possible."[33]

As originally conceived by NASA, and negotiated with JPL in December 1959, the Ranger program was to comprise five spacecraft arranged in two groups. Rangers 1 and 2 in the first group were intended principally to gain flight experience with the new technology required for missions to the Moon and later, to the planets. They would carry a minimal amount of sky science.[34] They would not be aimed for the Moon but boosted into a large elliptical orbit that reached part way to the Moon to prolong their flight and observing time. The second group comprising Rangers 3, 4, and 5 would be targeted to impact the Moon. They would embody more advanced technology, including a central computer brain and would carry sky science and a large array of lunar science.

These plans were in consonance with the principles that Pickering had espoused in many of his public statements: a measured approach to new technology, understand each problem before moving to the next, thoroughly understand and test new ideas before implementing them, and allow the technology to drive the schedule not vice versa.

Although they were regarded as test machines to gain flight experience, these spacecraft were in fact extremely complicated arrangements of interdependent electronic and mechanical systems. For these spacecraft to work correctly every component had to perform flawlessly—there was no room for failure. But Pickering's men were confident of their designs and were not used to being proved wrong. "We were experts, we knew how to do it," Pickering believed.[35] They resented any criticism of the efficacy of their designs and processes from the people at NASA. Last minute attempts by NASA to add more science experiments were strongly resented. In JPL's view it was "technology first" on these flights, with science as second priority. In this regard, Pickering staunchly supported his project manager in resisting NASA's demands for more science.

All five were launched between July 1961 and April 1962. In JPL's first major setback, the first four spacecraft completely failed to achieve their stated mission objectives. The reasons for the four successive failures varied, and were not all attributable to JPL, although much of the blame eventually devolved upon Pickering as Director, and provided much substance for criticism by his detractors at NASA. Of the first four Rangers, only Ranger 4 provided some cause for subdued satisfaction when its mid-course guidance system successfully directed the spacecraft into the predicted lunar impact target zone.

It was an irony of personal fate for Pickering that, in the midst of this depressing situation, the prestigious National Academy of Sciences, should announce his election to membership of that august body.

In late April 1962, the news headlines told the bizarre story:

Monday, 23: "Ranger 4 Moon Shot Racing for Target; Made in Pasadena Package Aloft." *Star-News*, Pasadena, California.

Tuesday, 24 April: "Rocket's Brain fails; Moon Shot Written Off." *Miami Herald*, Miami, Florida.

Wednesday, April 25: "Academy Cites JPL Director. Dr. William H. Pickering has been elected a member of the National Academy of Sciences it was announced yesterday in Washington . . . Dr. Pickering returned to Pasadena last night from Cape Canaveral where he had participated in the launching of Ranger 4." *Star-News*, Pasadena, California.

Thursday, April 26: "JPL Scientists Hail Feat of Hitting the Moon; Ranger 4 Strikes on the Dark Side." *Star-News*, Pasadena, California.

Although JPL could find some satisfaction in having reached the Moon with Ranger 4, the first for an American spacecraft, there could be no denying that the Soviets had already done that, and the outcome of Ranger 4 had done nothing to advance the Apollo program. A chastened Pickering could only find solace in the messages of congratulation on his election to the National Academy of Sciences that poured in from JPL, Caltech, and colleagues across the nation.

The failure of the first four Rangers provided a severe practical demonstration of the hazards of space flight, and the extraordinary precautions that were required to overcome them. Although Pickering saw this experience as making way up "the learning curve," he made sure that his senior staff also recognized this fact, and that they took strong and immediate action to incorporate the "lessons learned" into their design and test procedures for Ranger 5.

While part of the Laboratory workforce struggled with the vicissitudes of the Ranger program, a new mission which held great "space appeal" for the brilliant minds at JPL had made its appearance on the JPL task list. It was the first of the planetary initiatives that Pickering had advocated for so long, and it was called Mariner.

NASA had approved the Mariner program in mid-1961, and JPL began work on the design for its first planetary project, a mission to Venus, in the fall.[36]

The initiation of the Mariner program presented Pickering with further new problems of a type in which he had limited experience and which held little personal interest for him. Not personal but personnel—and not enough of the latter to handle the new work on Mariner in addition to the on-going Ranger project. It was hardly surprising that much of the JPL engineering staff lacked the requisite experience to adequately handle the esoteric tasks entrusted to them. The new space technologies in daily use at JPL were being invented as the work proceeded. In the infancy of the space program there was no pool of "space-experienced" engineers in industry or academia to draw upon. The Laboratory's budget had increased substantially over the years too, and its proper management, as much the responsibility of the Director as oversight of the technical issues, created a further distraction for Pickering and his senior staff.

Nevertheless, under the strong leadership of Mariner Project Manager, Jack James, work on the new project proceeded in parallel with, although somewhat behind, the Ranger project. Benefiting from the Ranger experience, James obtained approval from Pickering to set up a much more powerful project office for Mariner, with greatly enhanced authority to draw upon the best technical support available at the Laboratory to support his new project. His authority was enhanced to a large degree by the "space appeal" of the planetary mission and by the technical challenges—irresistible to JPL engineers and scientists—that went with it.

Less than a year after JPL began serious work on them, the first (of two) Mariners stood atop an Atlas-Agena booster rocket combination at Cape Canaveral ready to make NASA's first attempt to visit Earth's neighbor—Venus. It was a mighty effort but it did not succeed. Again, Pickering's hopes, dreams, and reputation were dashed by a problem not of his own making. Within the first 5 minutes of flight, the Atlas launch vehicle lost its guidance control signals and had to be destroyed when it threatened range safety boundaries. The problem was traced to a minor programming error in the computers that executed the Atlas guidance functions, and a work-around was soon developed. A month later, on 27 August 1962 the second Mariner departed for Venus—and everlasting space glory.

Finally separated from its launch vehicle and moving serenely along a trajectory that would intercept Venus in December, Mariner 2 performed flawlessly and began sending back a steady stream of new and exciting science data on the interplanetary medium. At both JPL and at NASA, the excitement and relief that followed the launch success of Mariner 2 went some way toward dissipating the sense of despondency that had arisen out of the recent string of Ranger failures. It was due to reach Venus just 108 days later.

Meanwhile, Pickering's high hopes for a fifth attempt to reach the Moon with yet another Ranger spacecraft dissipated miserably a few hours after launch. Killed by a massive, on-board power failure, the Ranger 5 became simply a piece of space junk floating interminably in orbit around the Sun. For NASA and JPL it was the "last straw."

The Ranger project, the United States' much vaunted effort to leapfrog the Soviet's demonstrated pre-eminence in space was in chaos and, to make matters worse, the chaos was highly public. All eyes turned to William Pickering, for that was—as President Harry Truman would have said—"where the buck stopped."

Both JPL and NASA were on the steep part of the learning curve now, where a great deal of learning was required to produce measurable progress, and the consequences of failure to make progress were swift and severe. Within a month, independent failure review boards convened by both JPL and NASA had delivered damming assessments of JPL's handling of the Ranger program to Pickering's desk.

Another Ranger launch should not be attempted, said the JPL Board, until the Laboratory had cleaned up its engineering design, review, testing, and management processes. Also a stronger project manager was needed: " . . . someone with a reputation for dogmatic pursuit of excellence."[37]

If Pickering was shocked by what his own people were telling him, he was devastated by the report from NASA that followed a few days later. Known as the "Kelley Report," it delivered a stinging rebuke and criticism of his management of the Laboratory.[38] At the end of it all, the report made a number of strong recommendations for change and, as a final anathema to Pickering, it proposed that NASA should exercise closer monitoring of Ranger project activity at JPL.

Pickering was embarrassed to say the least, but he had little cause for rebuttal. The study that he had endorsed in 1961 called for an even faster paced program of launches. Pickering's senior staff resented some of the allegations saying that Ranger was a high-risk project and NASA had accepted that fact right from the start. Nevertheless, Pickering had no option but to accept the criticisms and comply with the Kelley recommendations despite his personal feelings of outrage.

In subsequent negotiations it was agreed that there would be one simple objective for future Rangers: obtain a few TV images of the Moon with better resolution than pictures taken from Earth. There would be no additional scientific instruments on future Rangers and no heat sterilization. The launching of Rangers 6-9 would be postponed for as long as it took to convince NASA and JPL that there was a high chance of success for both the launch vehicle and the spacecraft. It would take them another year to learn that "a high chance" was a necessary, but not sufficient, condition of success.

Toward Venus

While the new course for Ranger was being negotiated with NASA Headquarters, Pickering endured another emotional roller coaster at JPL. For the previous 108 days Mariner 2 had been moving flawlessly along the trajectory that would intercept the orbit of Venus on 14 December. During that time it carried out an astonishing number of "firsts in deep space." It had responded to Earth commands to extend its solar panels, line up with the Sun and Earth, and stabilize its orientation in space. In mid-journey it had adjusted its trajectory to eventually pass very close to Venus. Furthermore, it had used its high-gain antenna to maintain two-way communication with Earth via JPL's new Deep Space Instrumentation Facility, which had by then expanded from the single antenna at Goldstone to include two huge 26-meter-diameter antennas, one in Woomera, Australia, and the other in Johannesburg, South Africa.[39]

During its flight to the planet it had sent back new data on interplanetary fields and particles and capped it off with a 42-minute, close-up scan of the surface during which it measured the surface temperature and determined the height and density of the cloud cover that surrounded the planet.[40] It had achieved all of its mission objectives and generated many "firsts" in space as well. It had made space history and the world was amazed. The media turned Pickering into an instant hero.

Writing for the *New York Times* under the front page headline, "Mariner Inspects Venus at Close Range; Radios Data 36,000,000 Miles to Earth," John W. Finney reported, "The United States achieved a significant 'first' in the exploration of space today by sending a Mariner spacecraft near the planet Venus to take man's first close-up observations of a planet."[41]

At a news conference in Washington, DC, James Webb, the new head of NASA, called it "a historic scientific event and outstanding first in space for our country and the free world. . . ."

But there was more than science behind NASA's obvious satisfaction with the success of the mission. Before the eyes of the world the U.S. had demonstrated, for the first time, the return of scientific data directly from the vicinity of another planet. " . . . United States had at least [last] beaten the Soviet Union in scoring a spectacular and impressive first in the space race" said the *New York Times*.

For Pickering those words suggested that his ambition "to be first in deep space" was at last becoming a reality.

Quite apart from the issues of national prestige and technological preeminence, it was also regarded as " . . . the most significant, as well as the most spectacular of the nation's scientific efforts in space thus far. . . ."[42]

Pickering must have been more than happy with the press reports that day. Mariner 2 had indeed survived the space environment and carried out a successful guidance maneuver, it had navigated 182 million miles in 109 days to a distant planet, demonstrated telemetry from deep space, and returned a substantial amount of significant science data, all matters of the deepest interest to him. Moreover, it had beaten the Soviets to it. With time of course, such engineering accomplishments would be refined and would become a standard part of JPL's remarkable repertoire of expertise in deep space technology. But then, in December 1962, such things had not been done before and Pickering and his team were the first to demonstrate their practical application where it mattered most, in deep space.

Among the first to recognize the Mariner 2 achievement at the highest level was President Kennedy. Pickering received an invitation to visit the President early in the new year to brief him on the momentous event. Pickering determined to take Jack James and Robert Parks along with him to the White House to share the honors.

A few months later, *Time* magazine featured "Physicist William Pickering" on its front cover, and a full length article titled "Voyage to the Morning Star" that praised Pickering and his JPL team for its effort and gave a very cogent account of the mission and the science results.[43]

The clear success of the first Mariner mission to Venus and the worldwide acclaim that accompanied it, together with the obvious implication that it had wrested the lead in space from the Soviets, provided a much needed lift for the flagging spirits of Pickering's hard-pressed team at JPL. But for all the hoopla, the success was a hollow one for Pickering. Coming in the midst of the Ranger debacle, the Mariner 2 success had certainly eased the palpable mood of depression that hung over JPL, but there was persistent uncertainty as to whether the new measures instigated by NASA would work out, despite NASA's added "help." Only the future would tell. The outlook from the Director's office, obscured not only by concern for the eventual outcome of Ranger, but also by apprehension over the forthcoming contract renewal negotiations with NASA in the new year, was far from clear. There, NASA would have the high ground and could use its dominant position to force Pickering to conform to its own ideas of how the Laboratory should be managed. Pickering could take small consolation in knowing that a large part of the problem was of his own making.

Pickering's angst could only have been heightened by the knowledge that NASA's demands for restructuring the Ranger organization would entail the

President Kennedy discusses the Mariner 2 mission to Venus with William Pickering and NASA officials at the White House, 17 January 1963. Left to right: Pickering, James, Webb, Parks, President Kennedy, Newell, and Cortright. James and Parks hold a model of Mariner 2 to be presented to the President (Photo: By Robert L. Knudsen, The White House).

replacement of its two principals. Both Cummings and Burke were highly popular characters at JPL and he regarded both engineers as personal friends. It was a dark day indeed, more so for its proximity to the much heralded Mariner Venus success, when he made the announcement. The bad news shocked the entire establishment. Henceforth, Robert Parks would direct both the lunar and the planetary Programs, and the new Ranger project manager would be Harris M. "Bud" Schurmeier.[44] It was the week before Christmas in 1962.

That year, Christmas Day came on a Tuesday. As was the custom, Pickering closed the Laboratory on the preceding Monday to give his people a long weekend break from the daily pressures of work. Personally, he too welcomed some respite, brief though it might be, from the "hot-seat" at JPL, and a chance to pause and "reflect on events," as he was fond of saying. This year there was much to reflect upon in both his professional and private lives.

Despite the string of failures that had dogged the Ranger program, the success of the Mariner Venus mission had brought him enormous public acclaim, mainly because it had, at least, evened the score with the Soviets, and the public desperately needed a public hero at that time. The strain of his worsening relationships with NASA Headquarters was, in a large measure, offset by the overwhelming public acceptance of his ideas and observations on the space program and his prognostications for winning the Cold War. He had been quoted in practically every reputable technical journal in the country and featured in the second volume of a book titled *Men of Space*.[45] News media across the country hung on his every word—dissent from his voiced opinions and ideas was minimal.

Requests for his appearance at scientific, engineering, and educational functions across the country were legion in 1960 to 1962. They came from professional organizations to PTA meetings, from congressional hearings to high school graduation ceremonies. He gave 20 speeches in 1960, 19 in 1961, and 11 in 1962, at locations from one side of the continent to the other.[46]

By Christmas 1962 his daughter Beth was into her second year at Cornell University in Ithaca, New York. She had demonstrated an outstanding aptitude for science and mathematics, two topics of great interest to both father and daughter. She had returned to Altadena for the Christmas period and Pickering would enjoy her lively company immensely.[47]

Now a young adult, Pickering's son Balfour was starting a career of his own in the electronics field and Pickering looked forward to spending some time with him also during the Christmas break.

In keeping with long established tradition, Altadenans were expected to decorate and illuminate the front yards of their homes during the festive season, and neighborly competition generally produced very elaborate displays of lights and animated Christmas scenes. It was a natural enterprise for the

Director of one of the nation's leading centers of technology. Having a demonstrated aptitude for all things electrical, homeowner Bill Pickering found no difficulty in changing focus from sending a Mariner spacecraft to Venus, to stringing Christmas lights across his front yard in Altadena.

That year the level of excitement in the Pickering household was well above normal. To recognize the success of the Mariner mission to Venus, the well-known Pasadena institution Tournament of Roses had elected William Pickering to the honor of Grand Marshal for the famous Rose Parade on New Year's Day in Pasadena. A spectacular annual event, watched by a national television audience of many millions and witnessed by hundreds of thousands of spectators lining the city streets, the Rose Parade was a Pasadena social milestone of the highest order that, in the closing days of 1962, involved the whole Pickering family in a frenzy of preparation and eager anticipation.

Endnotes

1 The 26-meter antenna at Goldstone, hurriedly built to support the Pioneer 3 launch in December 1958 was the first of several that eventually developed into NASA/JPL's mighty, worldwide Deep Space Network (see Mudgway, Douglas J., *Uplink-Downlink: A History of the Deep Space Network* (Washington, DC: NASA SP-4227, 2001).

2 Folder 24 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

3 Logsdon, John M., ed., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program* (Washington, DC: NASA SP-4407, 2001), p. 268.

4 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982).

5 Hibbs, Albert R., ed., "Exploration of the Moon, Planets, and Interplanetary Space." Pasadena, California: JPL Technical Report 30-1, April 1959.

6 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 98.

7 Both the launch vehicle provided by ABMA and the upper stages provided by JPL were military items and therefore still classified, although the Pioneer probe itself was not.

8 See Folder 23 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

9 Folder 26 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

10 For a press report of this speech, see *Aviation Week and Space Technology*, 23 November 1959, p. 26.

11 Ibid, p. 338.

12 Soon after, Homer Newell, one of the scientists who visited JPL on that occasion made good on the NASA pledge by establishing the Lunar and Planetary Programs Office. Headed by NASA, but staffed by outside scientists, this office took various forms in the years to come and served NASA and the space program well in recommending projects that the agency should undertake (see Logsdon, John M., ed., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program* (Washington, DC: NASA SP-4407, 2001).

13 Hall, R. Cargill, *Lunar Impact: A History of Project Ranger* (Washington, DC: NASA SP-4210, 1977), p. 23.

14 Folder 27 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

15 Folder 28 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

16 *Astronautics*, January 1960, pp. 83, 84.

17 Folder 30 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

18 Mudgway, Douglas J., Oral history interview with William H. Pickering. Pasadena, California, July 2003.

19 The role and composition of both the senior staff and the executive council, the two principal groups through which Pickering interacted with the laboratory as a whole, are sent an interoffice memo No.195, on 14 February 1963, to senior staff from W. H. Pickering. Folder 1, JPL 150, Archives and Records Center, Jet Propulsion Laboratory, Pasadena, California, 2003.

20 Mudgway, Douglas J., Oral history interview with William H. Pickering. Pasadena, California, July 2003.

21 Pickering's geniality made JPL an attractive venue for high-level visitors during his tenure as Director, as the archival records clearly show. See Folders 1-95, JPL-186, Archives and Records Center, Jet Propulsion Laboratory, Pasadena, California, 2003.

22 Folder 31 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

23 Finney, John W., "Scientist Says Indecision Curbs the U.S. effort." *New York Times*, 25 February 1960.

24 Eastman, Ford, "Space Lag Blamed on conservative Effort." *Aviation Week and Space Technology*, 29 February 1960.

25 Mudgway, Douglas J., Oral history interview with William H. Pickering. Pasadena, California, July 2003.

26 Ibid.

27 Newell, Homer E., *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP-4211, 1980), pp. 265, 266.

28 Pickering did not accept that criticism and felt justified in using government time and resources to carry on his interests in the IAF, IAA, AIAA, AAS, IEEE, and several other professional institutions, as the archival records show. He considered those activities as "part of the Director's job in enhancing the image of NASA in general and JPL in particular." See JPL-187 and JPL-3, JPL Archives and Records, and Mudgway oral history.

29 Newell, Homer E., *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP-4211, 1980), pp. 265, 266.

30 Echo was a large metal-coated balloon satellite intended for experiments in atmospheric drag, geodetics, and passive coast-to-coast communications.

31 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 116.

32 Recommendation for a "National Space Flight Program." Astronautics, January 1958.

33 Folder 66 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2003.

34 Sky science, as distinct from planetary science, implied investigations of the interplanetary medium, energetic particles, magnetic fields, and the like.

35 Mudgway, Douglas J., Oral history interview with William H. Pickering. Pasadena, California, July 2003.

36 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 127.

37 Ibid, p. 131.

38 Hall, R. Cargill, *Lunar Impact: A History of Project Ranger* (Washington, DC: NASA SP-4210, 1977), p. 173.

39 Mudgway, Douglas J., *Uplink-Downlink: A History of the Deep Space Network* (Washington, DC: NASA SP-4227, 2001).

40 Three weeks later when Mariner 2 fell silent at a distance of 87.4 million kilometers from Earth it had established a new (communications) record for a deep space probe (Siddiqi, p. 35).

41 John W. Finney in the *New York Times*, Saturday, 15 December 1962, p. 1.

42 "The Voice from Venus," *New York Times*. Monday, 17 December 1962.

43 "Voyage to the Morning Star," *Time*. 8 March 1963.

44 Hall, R. Cargill, *Lunar Impact: A History of Project Ranger* (Washington, DC: NASA History Series, NASA SP-4210, 1977), p. 177.

45 Thomas, Shirley, *Men in Space, Vol.2* (Philadelphia: Chilton Company, 1962)..

46 Although he undoubtedly had help with the preparation of the less technical speeches, the effort entailed in presenting so much material across the nation, quite apart from the amount of transcontinental traveling that it involved, was quite amazing. Even more so, when one considers that, at the same time, he was running a major research institution. It is not difficult to understand why NASA officials expressed some concern for the well-being of the laboratory entrusted to Pickering's care. The laboratory's record of success to that time did nothing to diminish the strength of their views. Despite the criticism however, Pickering seems to have thrived on the public recognition that attended these appearances, and reveled in the opportunities they provided to indulge his natural predilection for "teaching."

47 Beth Pickering Mezitt, Personal recollections of my father, William H. Pickering. Private correspondence with the author, May, 2003.

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Chapter 6

The Steep Part of the Curve

For as long as most people could remember, the morning of New Year's day in Pasadena had always dawned fine and clear. To millions of viewers across the nation who watched the annual Rose Parade on their new color television sets that morning, the endless procession of gorgeous, flower-covered floats, spectacular marching bands and baton twirlers, traditionally-costumed equestrians and their beautiful horses, television and film stars, dignitaries, breathtakingly beautiful Princesses and the stunning Rose Queen, Pasadena's Tournament of Roses appeared almost unreal. Set against the backdrop of the towering San Gabriel Mountains, the brilliant morning sunshine and intense blue sky, it was always and altogether a made-for-television spectacular. So it was again on 1 January 1963. That year the theme for the event was "Memorable Moments."

Two weeks earlier, JPL's Mariner 2 spacecraft had reached Venus and successfully transmitted a package of scientific data back to Earth. It was a first for mankind; it was conceived and built in Pasadena, and it was indeed a "Memorable Moment." Pasadena was understandably proud of the man who made it happen, its own Pasadenan—William Pickering. As the Grand Marshal for that year, William H. Pickering would lead the Rose Parade along its three-mile route through the crowd-lined streets of the city of Pasadena.

"I didn't see much of the Parade," he recalled. "My family and I were in the lead car, but it was a great experience."

His daughter Beth remembered the excitement of choosing the new clothes, practicing the "royal wave" with her mother, early morning breakfast before the Parade began at the Tournament of Roses headquarters at the Wrigley Mansion on Orange Grove, meeting the Rose Queen and her court of Princesses, and riding with her brother Balfour in the front seat of the Grand Marshal's car. "It was a once in a lifetime experience," she recalled wistfully.

Grand Marshal William Pickering and wife Muriel wave to the crowds from the leading car of the Rose Parade, Pasadena, California, 1 January 1963 (Photo: NASA/JPL-Caltech Archives, Photo number P2298Ac).

A couple of days prior to the big event, Pickering had given an address to the directors of the Tournament of Roses at a preparade banquet.[1] It was a lengthy and insightful discussion of the impact of science on modern society and government and, unlike much of his earlier public discourse, alluded only briefly to themes of the Cold War and military versus civil control of the nation's space program. Rather than speak of the "impact" of space he suggested that we should regard space as a force that accelerates changes that are already under way like "the need to bring trained minds and informed intelligence to the solution of problems which are not only scientific but political, social, economic, and cultural as well."

Because science was heavily involved in so many of our most important social and political problems "individual citizens should have an improved understanding of what science is, how it operates and the circumstances which make it prosper," he said. Furthermore, the financial support of big science had now passed largely to state and national governmental agencies that were ultimately responsible to the whole body of citizens for their control. To exercise this power wisely, these citizens must be able to better understand the issues, costs, and consequences of the problems. "In the world of the future," he said, "many more politicians will have to learn about science and many scientists will have to learn more about the realities of the political arena."

Pickering saw encouraging signs ahead:

> Trends and changes were taking place in a more confident climate than had marked our first space venture. . . . This new emphasis will reflect less how we react to the Soviets in the field of space, but will reflect the exciting promise which space exploration offers to the whole fabric of our national life, our industry, our agriculture, our education, and to ourselves as thinking beings.

And, although the world could not yet see it, Pickering's "new emphasis" did indeed come to pass, as we shall see.

The Pickering family spent the afternoon of that day as principal guests of the Tournament of Roses at the famed Pasadena Rose Bowl college football game, where championship teams from the Pacific and Western conferences met each New Year's Day to compete for Rose Bowl honors. Pickering recalled enjoying the game much more than he had enjoyed the parade.

That night Pickering grabbed a selection of the Mariner 2 images of Venus from the science teams at JPL and took the red-eye flight to Washington, DC. Along with a select group of NASA officials, he was due at the White House the following day to brief President John Kennedy on the initial findings of the world's first close-up view of another planet. Pickering no doubt assured the President that the blurry images of the darkly shrouded planet marked a significant forward step in closing the gap on the Soviet lead in space, a topic of great concern to the President at that time.

Back at JPL a few days later, Pickering turned to the pressing tasks at hand for 1963. Under the highly focused direction of Bud Schurmeier, a work force that reached as high as 900 engineers, technicians, and scientists reworked the original Ranger designs to meet the new guidelines for success of Ranger 6. The mission objective was very clear—a few television pictures of the Moon at better resolution than images taken from Earth—and everything was to be directed toward that end. Confident that Schurmeier brought the necessary motivation, knowledge, and experience to the task, Pickering regarded it as his responsibility to see that Schurmeier was provided with the necessary resources to carry it out and was shielded, as far as possible, from distracting demands for attention from NASA program management.

While this important work continued at JPL, Pickering rode the wave of public acclaim that followed closely upon the Mariner Venus success. What would eventually become an ever-increasing stream of civil honors began when the Association of Engineering Societies elected William H. Pickering as the "Engineer of the Year for 1962." The Association presented its George Washington Medal for Engineering Achievement at a sumptuous banquet at the Beverly Hilton Hotel in Los Angeles in February. In accepting the award, Pickering spoke eloquently of the need for unity of interest between engineering and science and the avoidance of debilitating competition for private and public funds. "There were lessons to be learned from George Washington's admonishment to 'form friendships with all, but entangling alliances with none'," he concluded.[2] Over the past several years, Pickering had been the recipient of numerous awards from the U.S. Army and Air Force for his work on military programs, but the George Washington Medal represented the first, of many, awards from the civil sector.[3]

In April he gave a lecture on "Mariner 2—First Spacecraft to Venus" at Columbia University in New York, and a week later a lecture on "Man at the Threshold of Space" at UCLA in Los Angeles. Two speeches in May, one at a conference on "The Peaceful Uses of Space," at the University of Illinois, the other on "Business Publications" at a business management conference in Del Monte, were followed by "Some Thoughts for a Graduating Class" at the Polytechnic school in Pasadena in June and "Some Thoughts on Guidance Systems" to the American Institute of Aeronautics and Astronautics in Boston in August and "Frontiers in Space Instrumentation" to the Instrument Society of America in Chicago in September. All illustrated the wide diversity of his interests and the rising demand and popularity of his public appearances, which showed no sign of diminishing.[4]

In November 1963, the newly-formed American Institute of Aeronautics and Astronautics (AIAA) held its inaugural meeting in Pittsburgh, Pennsylvania. Formed by the merging of the American Rocket Society (ARS) and the Institute of Aerospace Science (IAS), two great aerospace societies of the day, the AIAA owed much to the energies of William H. Pickering. As Pickering recalled many years later, in his inimitable way:

> I was president of the ARS and Gene Root of Lockheed was president of the IAF. We got together with a few other people and decided that the two engineering organizations really ought to join forces, because the aeronautics people were getting interested in rocketry and the rocket people were getting interested in flying things. The next problem was who should run it, and they decided I should. So I became the first president of the AIAA.[5]

The official merger went into effect in February of 1963.

Nearing the end of the year, in November Pickering delivered the first presidential address to the AIAA with the title "Exploration of Deep Space."[6] Pickering observed that the role of science and technology in the civilization of the future would continue to grow, making it essential that the young people of the day be properly prepared to take responsible parts in the new era. Nevertheless, it was important to keep a proper balance and not try to make everybody into a scientist while recognizing that "a knowledge of science is going to be the mark of the well educated man of the future." He then delivered a lengthy but masterful lecture, illustrated with slides, that covered the whole gamut of the technology of space exploration as it was known at that time. The motions and relative distances of the Sun and planets, spacecraft, launch vehicles, navigation, guidance systems, communications systems, scientific instruments, rationale for space exploration, status of Soviet space programs, and, finally, examples from his recent personal experience of the successes and failures of the U.S. space program were all included. Only Pickering could have given a presentation of that scope and depth and enhanced it with the credibility of personal experience.

It was a dazzling performance that must have held his audience spellbound, for everything that he told them was utterly beyond the experience of the vast majority of the engineering professions of the time.

He ended on a note of high anticipation for the success of Ranger 6, which, he implied, embodied all that had been learned so painfully from the experiences of past launches.[7]

Despite outward appearances to the contrary, a dark cloud of dissension had gradually gathered about JPL during the past couple of years. The problem concerned management relationships between JPL, Caltech, and NASA.

Pickering had enjoyed a large measure of independence from NASA-imposed controls through 1961. It was, after all, hard to argue with success and the NASA bureaucracy was forced to accept JPL as a brilliant, but arrogant, outsider to the NASA family of civil service Field Centers. Pickering did whatever was necessary to achieve JPL's objectives as he perceived them, and he ran its organization, management, and financial accounting practices in a loose arrangement more akin to a university administration than that of a civil service institution. Pickering believed this type of working environment attracted the best people and that they were the key to JPL's early successes. Alluding to NASA's control over JPL programs, Pickering once remarked wistfully, "Why don't they just give us the money and go away?"[8]

All of that changed in 1962 as the string of Ranger failures began to mount. "The academic, relaxed atmosphere that pervades the JPL Campus . . . did not encourage quick responses and strong team efforts on project-oriented tasks," complained one NASA official.[9] Pickering's indirect management style came under criticism too, as did the excessive time he spent away from the Laboratory on public appearances and in non-NASA matters, particularly the AIAA.[10] NASA also found deficiencies in JPL's business procedures, property accountability, contracting administration, and security arrangements.

What was needed, said NASA in January 1963, was a strong general manager to "oversee day-to day operations." Sensing that both his authority and his ability to run the Laboratory were being challenged by an entity for which he held little respect, Pickering refused to accede to NASA's request. As Pickering perceived it, the business management of JPL was not the problem—NASA's interference and oversight of JPL's internal affairs was the problem.

Pickering also faced internal problems with his highly motivated technical staff. It was difficult to persuade his senior staff to accept the NASA approach to the various technical issues about which they held such divergent opinions. But with a long string of Ranger failures on the record they were in no position to argue. Recalled Pickering:

> If Ranger had been a success right from the start, I would have had a much more difficult time keeping those guys in line. But we were forced to admit that we were having troubles. Even though we were the best in the world, there were people from outside who could tell us what we were doing wrong—that was hard to accept.[11]

These issues came to a head during the negotiations for renewal of the NASA-Caltech contract in the latter part of 1963. NASA officials, particularly Administrator James Webb, had long been dissatisfied with the so-called "management" fee—the fee that Caltech charged NASA for its oversight of JPL. Together with the lack of responsiveness and poor performance of JPL, compounded by Caltech's disappointing involvement in research support for JPL's scientific programs, the issue of management fee gave NASA good cause to press Caltech for changes to the existing arrangements. The demands included the appointment of a general manager for JPL. Some in NASA felt so strongly about the issue that they talked of canceling the contract entirely, or even replacing Pickering as Director.[12]

Caltech, on the other hand, wished to increase the fee, arguing that an increase was justified by the increase in JPL's budget. At the same time, DuBridge was acutely aware that Caltech could not afford to lose the lucrative NASA contract that had, by then, become a substantial part of the institution's financial resources.

Meanwhile Pickering, apprehensive about any further NASA encroachment on his domain at JPL, continued to resolutely resist any change, particularly in the matter of appointing a business manager.

In the outcome of the acrimonious negotiations that followed, it quickly became apparent that neither side could afford to lose the other. Eventually the two sides hammered out a compromise by which Caltech agreed to forego its demands for a fee increase in exchange for a restructuring of the basis on which NASA estimated the fee. Pickering also agreed to an annual evaluation of JPL's management, technical, and schedule performance.[13]

Satisfied with the outcome of the contract negotiations, and pacified with the promise of a new business manager for JPL, NASA deferred signing the agreement until it could evaluate Pickering's response to its provisions.

For Pickering, the aftermath of the 1963 contract negotiations was less acceptable. For all intents and purposes, the Laboratory had now become a government-furnished facility subject to the authority of NASA. Still worse, it would be subject to an annual performance review by NASA program managers, an embarrassment not imposed upon other NASA Centers.

Pickering responded with a token gesture. In December he appointed his former student Brian Sparks to the position of Assistant Director for Technical Divisions for the Laboratory. It was a transparent foil that fell far short of satisfying NASA's demand for a fully empowered deputy that would manage the Laboratory's business operations.[14]

Pickering seemed oblivious to the adverse reaction that this move caused at NASA. At the end of 1963, his attention was more likely focused on the events taking place in the clean rooms of JPL's spacecraft assembly area where sterile-clothed engineers were in the final phases of the preflight qualification tests of the lunar spacecraft Ranger 6. Success was on everyone's mind. Nothing would help JPL's tarnished image at NASA so much as a successful Ranger flight to the Moon culminated by a handful of close-up images of the lunar surface.

The exigencies of the contract negotiations and the strained relations with NASA had little effect on the general feeling of optimism that pervaded the offices, conference rooms, laboratories, and machine shops around the Laboratory in January 1964. They were, as Pickering intended "shielded from all that distraction." Focused on the job in hand, engineers reworked Ranger 6 to embody all of the changes and additions that could conceivably contribute to ensuring a successful mission. Taking advantage of the additional weightlifting capacity of the Atlas launch vehicle, spacecraft designers added redundant units for critical spacecraft elements such as the attitude-control system, the radio transponder, and the solar-powered battery charging system. It was a tradeoff of spacecraft weight versus improved reliability.

Most, but not all, of the Laboratory's personnel were preoccupied with Ranger 6 that January. A small number were involved in making final arrangements for the Coronation Ball, a very popular annual social function which, that year, was planned for late January at the Moulin Rouge ballroom in Hollywood. Known as "The Queen of Outer Space Ball," tradition demanded that the Director and his lady dignify the function with their presence, and that the Director perform the culminating function of crowning the chosen "Queen of Outer Space." It was an obligation that Pickering willingly accepted and had performed enthusiastically throughout his tenure as Director. However, as the Ranger 6 launch schedule slipped into late January it raised the possibility that someone other than the Director might have to crown the "Queen" that year.

By the end of January, Ranger 6 had been trucked to the Florida launch site, mated with the awesome Atlas-Agena launch vehicle, and successfully passed the rigors of its final prelaunch tests. Encapsulated in its protective shroud at the very tip of the two gleaming rockets that would hurl it to the moon, Ranger 6 waited as the final seconds of the countdown elapsed. Then, with a mighty shove from its Atlas launch vehicle and a powerful kick from its second-stage Agena, Ranger 6 finally shrugged off Earth's gravity and headed out toward the Moon. The date was 30 January 1964. The spacecraft was due to arrive on the lunar surface 68 hours later.

Except for an unexpected glitch shortly after liftoff, when the television system suddenly came on and just as suddenly switched off, the launch was perfect. Puzzled by the unexpected television incident and unable to come up with an explanation for its occurrence, or to see anything wrong on their telemetry monitoring channels, the spacecraft engineers elected to let the mission continue. It was the logical thing to do—or so it seemed at the time. Right on time, Ranger 6 executed a perfect mid-course maneuver that adjusted its trajectory to target the chosen point of impact on the lunar surface.

All seemed well, and to the engineers and officials anxiously waiting at JPL and NASA Headquarters, success seemed within reach. The spacecraft could not do other than continue on to impact the lunar surface, assuredly transmitting the long-awaited pictures as it did so.

During the long wait from launch, a crowd of newsmen and television crews had assembled in JPL's new Von Kármán auditorium, where an official commentator, television monitors, and frequent press conferences kept them informed of the progress of the mission. As hopes for success mounted around the Laboratory, Pickering told the newsmen, "I am cautiously optimistic."[15] His caution turned out to be well-founded.

Shortly after midnight on 2 February, in full view of a packed auditorium, the Ranger 6 mission drew to a swift and terrible conclusion. Eighteen minutes before impact, the TV cameras began the warm-up sequence as scheduled. The tension in the Von Kármán auditorium became palpable as the audience agonized through the final 5 minutes before the first television pictures should appear. But none came. JPL announcer Walt Downhower counted down the dreadful minutes to impact as Ranger 6 barreled in toward the lunar surface at over 4,500 miles per hour, blind and beyond help. He reported impact at 1:24 a.m. Pacific Time.

It was over. Ranger 6 too, had failed. After a perfect flight, the unthinkable had happened—the television cameras had failed to turn on. Why? Nobody knew nor, at the time, could they even conjecture.

Up in the visitor's gallery of the new Space Flight Operations Facility, Pickering had gathered with Homer Newell and several other important guests to listen to the voice commentary from Goldstone tracking station. At the fateful announcement, "still no video—impact," both men were momentarily struck speechless. In any case, words were unnecessary. Each knew what the other was thinking and what this result could portend for JPL and for Pickering in particular. Pickering recalled the dramatic moment:

> Then we had to go over to the Von Kármán, and the place was full of the press, and tell them it had been a failure. It was made all the worse because everyone was so optimistic, the flight had gone so smoothly, right on target up to that point. In fact, Bud

> Schurmeier had laid in a good supply of champagne to celebrate, but instead we had to go through this disaster. I never want to go through something like that again—ever. It was probably the lowest point in the Lab history. I was very concerned about how the Laboratory personnel would regard it after all the other failures. . . .[16]

He was about to find out. As it turned out, William Pickering and Muriel did make it to the Queen of Outer Space Ball, which took place a few days later. He entered the packed ballroom with a heavy heart, uncertain as to how the crowd would react. But, to his utter amazement, he was greeted with standing applause and wild cheers of encouragement. "That show of confidence made me feel very good," he said, "the people realized we had a problem but they were going to solve it and not give up."[17] And later in the evening he crowned the Queen, just as he had done many times before. But the sparkle and excitement of the evening gave no hint of what lay ahead for the Laboratory.

The immediate fallout from the Ranger 6 disaster produced two committees of inquiry: one convened by JPL and the other by NASA. Both review boards determined that high-voltage circuits that powered the television camera and transmitter had been destroyed by electrical arcing as the launch vehicle passed through Earth's upper atmosphere. That was the probable cause of the TV "glitch" observed shortly after lift-off. There, the agreement ceased. The JPL review board believed the basic design was sound and it suggested ways in which the problem could be fixed.[18] The NASA review board thought differently—very differently.

Headed by Earl Hilburn, a harsh critic of Pickering's administration from the earlier contract negotiations, the NASA review board brought an aggressive attitude to the investigation. It challenged Pickering's long-held concepts for standards of excellence in design and testing and pointed to what it perceived as major deficiencies in JPL's prelaunch test procedures. The suggestions of incompetence that were implied in the report's harsh criticism included the television system contractor, JPL, and even the NASA Office of Space Science and Applications.[19]

Inevitably, a Congressional investigation would follow with William Pickering as its prime witness.

The Congressional hearings began on 17 April in Washington, DC, under the chairmanship of Representative Joseph Karth. Prior to the hearings, Karth made several visits to JPL to familiarize himself with the space program and JPL's role in it. On each occasion the Karth party was hosted by Victoria Melikan, Pickering's newly arrived manager for public affairs.[20] As a consequence of these visits, JPL officials came to respect Karth's show of interest in the subject of his investigation, and to regard his judgment as an important indicator of public wisdom and one which they could not afford to dismiss lightly.

Director William Pickering presents roses to JPL's Queen of Outer Space at the Coronation Ball, Moulin Rouge, Hollywood: February 1964 (Photo: NASA/JPL-Caltech Archives, Photo number P32568B).

Melikan's handling of the Karth Committee visits to JPL helped immeasurably to enhance JPL's image in the hearings that followed, and set a precedent on which Pickering came to depend for his public relations for the rest of his career at JPL.

During the Congressional hearings, Pickering remained unapologetic. While conceding that there had been management problems at the Laboratory and valid criticism of its business practices, he asserted that ultimately, JPL had always responded to NASA's technical direction, and he argued that the freedom associated with the university type of atmosphere he had created at JPL was conducive to the unique type of work carried out by the Laboratory.[21]

In his typical understated style Pickering recalled, "It was the first time I had been called up before a committee in just that way, and also of course put in a defensive position. It was quite an experience listening to the [arguments] back and forth across the committee."[22]

In the end, the subcommittee found shortcomings in NASA's oversight of JPL and recommended that NASA should exercise closer control over Laboratory activities, particularly its Ranger program. It drew attention to Pickering's reluctance to accept direction from NASA, calling it "embarrassing unwillingness," and recommended that NASA install a general manager as a deputy to the Director.[23]

Undeterred by the controversy and criticism that swirled about them in the aftermath of the Ranger 6 debacle, Schurmeier and his team, strongly supported by a strengthened team from Radio Corporation of America (RCA), set about readying yet another Ranger for yet another attempt to reach the lunar surface with all systems "go for impact." Ranger 7 would embody all that had been learned, deduced, analyzed, and surmised from the Ranger 6 debacle. As Cargill Hall wrote, "All of Ranger's participants very clearly understood that personnel changes were likely in Pasadena and in Washington should Ranger 7 also fail and the Hilburn Board's contentions be proved accurate. The tension was correspondingly magnified and the pressure to succeed now was unbelievable."[24] By mid-June, the NASA "Buy-Off" committee had reviewed all of the test records and reports and determined that Ranger 7 and its modified television subsystem met, or even exceeded, the established test criteria. With NASA approval in hand, the JPL team moved Ranger 7 to Cape Kennedy for mating and a final round of testing with its Atlas-Agena launch vehicle.

On 28 July, the scene was once again set for the unfolding of another Ranger space drama, but this time the stakes were higher than they had ever been, and for no one were they higher than for William Pickering. His professional career and his reputation now rested on the outcome of the Ranger 7 mission. As the mission played out over the next 68 hours, everything fell into place: launch, separation, solar panel extension, high-gain antenna deployment radio signal strength, midcourse-maneuver, camera warm-up, and a myriad of telemetry measurements all sequenced perfectly.

Newsmen from around the world had begun gathering at the Von Kármán auditorium days earlier and, together with several hundred sleepless and tensed JPL employees, listened to Ranger 7's final moments of glory as the JPL announcer relayed events from Goldstone. Cargill Hall recorded the countdown:

> Five minutes from impact . . . video signals still continue excellent . . . everything is GO as it has been since launch. . . . Three minutes . . . no interruption, no trouble. . . . Two minutes all systems operating . . . pictures being received at Goldstone. . . . One minute to impact . . . excellent . . . signals to the end . . . IMPACT!

Abruptly, the hum from Ranger's distant radio telemetry signal ceased, only the low hiss of electronic noise remained on the loudspeakers. Cheers, and many tears, erupted throughout the packed auditorium. To most of those present, including this author, the event seemed too surreal, too Hollywood movie-like to be real. The unlikely, gleaming machine that most of us had worked on, or seen many times in the spacecraft assembly area at JPL, was actually on the Moon, and we had pictures to prove it. It hardly seemed possible.

Within the hour, President Johnson called to congratulate Newell and Pickering, NASA and JPL, and its industrial contractors. He invited Newell and Pickering to the White House to brief him on the Ranger 7 findings the following day. Joined now by Project Manager Bud Schurmeier, Pickering and Newell made their way over to the Von Kármán auditorium to be greeted with a standing ovation. "How different from last time," mused Pickering. "This is JPL's day and truly an historic occasion," observed Homer Newell. "We have had our troubles," Pickering reflected ruefully, "but this is an exciting day." When a newsman asked how he viewed the Laboratory's future after the success of Ranger 7 Pickering promptly replied, "I think it has just improved." When the laughter and applause subsided, he gave credit for Ranger's success to Bud Schurmeier and the Ranger teams at JPL, NASA, and in industry. It was all very appropriate.

The following morning, Saturday, Pickering and Newell flew to Washington with a selection of the Ranger 7 pictures to brief the President.

Evincing more interest in the geopolitical implications of Ranger's success than in its scientific import, the President commented: "We know this morning that the United States has achieved fully the leadership we have sought for free men. This is a battle for real existence in the world isn't it—for survival?" That remark would have resonated with William Pickering—it echoed the main thrust of much of his public advocacy over the past several years.

The Ranger images, over 4,000 of them, astounded scientists and public alike with their extraordinary clarity, revealing thousands of craters of varying size from meters to hundreds of meters in diameter, far more than anyone expected. Scientists exulted in the new data and what its subsequent analysis might tell them about the formation of the Moon, and the nature of its surface. Apollo mission designers were pleased to discover that the lunar surface was smoother, and therefore less threatening for a lunar landing, than they had expected.[25]

The reaction to the Ranger success was no less jubilant in Washington than in Pasadena. NASA officials, reporters, and a large Congressional delegation that had listened to the proceedings in the auditorium at NASA Headquarters were overjoyed at the outcome and congratulations flowed freely. Of particular note, House Space Committee Chairman George Miller was prompted to declare that Ranger 7 " . . . puts us well ahead of the Soviets in the exploration of space." Referring to the recent Karth Committee investigation, he added, "I want to make it crystal clear that the Jet Propulsion Laboratory is doing a splendid job."[26]

Cargill Hall wrote, "On newsstands at the airports and across the land, papers acclaimed the Ranger 7 and its lunar pictures in superlatives—on the front page and in editorials. From the Seattle *Post Intelligencer* to the *Miami Herald*, or the Boston globe to the San Diego *Union*, the praise was unanimous. Overseas the foreign press responded in similar vein, seeming to agree, that the U.S. had at last forged ahead of the Soviet Union in space exploration. Even the Soviet press accorded the flight modest plaudits, though pointing out that the USSR had photographed the moon five years before. The glowing accounts frequently heralded Ranger 7 as the greatest advance in space research since Galileo had trained his telescope on the heavens—it was heady stuff."[27]

The *New York Times* recognized the Ranger 7 achievement with blazing front-page headlines that hinted at its implications for the Apollo manned missions to follow, rather than its effect on the U.S. position in the space race with the Soviets.

New York Times writer Richard Witkin reported that the " . . . details of the lunar region were seen as one thousand times clearer than before," and hailed the feat as " . . . a leap in knowledge." As an indication of the national significance of the event, the *New York Times* reported the full text of the post-flight news conference at JPL, devoting altogether at least four full pages in its Saturday edition to Ranger 7. Taking advantage of an opportunity to extol the virtues of its television technology, RCA took out a magnificent full page advertisement in that same edition emphasizing its association with the successful Ranger 7 mission.

First image of the Moon taken by a United States spacecraft: Ranger 7 took this image on 31 July 1964 at 13:09 UT about 17 minutes before impacting the lunar surface. The area photographed covers about 360 km from top to bottom. The large crater at center right is the 108 km diameter Alphonsus. The Ranger 7 impact site is off the frame to the left of the upper left corner (Photo: NSSDC image ra7 B0001; also available online at *http://nssdc.gsfc.nasa.gov/planetary/lunar/ranger)*.

The following day, Sunday, 2 August, the *New York Times* again devoted its leading front page articles to Ranger 7, including close-up pictures of the lunar surface, and a picture of William Pickering briefing the President on the Ranger 7 photographs. Reporting on this visit, *Times* writer Tom Wicker said that scientists had told the President that the Ranger 7 pictures " . . . had demonstrated that selected lunar areas were suitable for manned landings." He also reported that the President had " . . . turned the occasion into a resounding endorsement of the moon-landing project and a justification of the American space effort."

As he returned to Pasadena, Pickering would have had good reason to feel vindicated over his leadership of JPL's space program and perhaps excused for his impatience with those at NASA who thought otherwise. It was easy to be critical with failure but hard to argue with success.

The Congressional Subcommittee's recommendation that "JPL should appoint a strong general manager as deputy for the Director" was timely, but somewhat superfluous for, by then, Caltech had already initiated action to find a suitable man for the job, despite the objections of William Pickering.

The successful candidate was Alvin R. Luedecke, a former Major General in the U.S. Air Force, and retiring general manager of the Atomic Energy Commission. To all appearances, Luedecke was the perfect man for the job. NASA was delighted and Caltech was greatly relieved to have, as it thought, cleared up the matter. But Pickering was dismayed. With wide-ranging responsibility for day-to-day management of Laboratory resources and authority for the direction of its financial, technical, and administrative activities, Luedecke represented that very situation that Pickering had resisted for so long: a palpable NASA presence in his Laboratory and a powerful dissenting voice in its operation. Luedecke took up office in August 1964 right after the Ranger 7 euphoria had subsided, and the struggle between Pickering and Luedecke began.

Pickering would recall his concerns at the time:

> In view of all the criticism that had gone on about me I was in no position to resist their choice [for Deputy Director]. I agreed in principle to changing the flavor of the Laboratory with a deputy, but I wanted to do it on my terms rather than on his terms. Right from the beginning it was clear that we had different philosophies about things. He wanted to bypass me when he could, and go directly to NASA. [Obviously] we could not work together.[28]

For Pickering, the arrival of a general manager on the Laboratory staff was a bitter letdown after the sense of elation that followed Ranger 7. However, hard though it was for him to accept it personally, the reality was that the character of the Laboratory had changed with its increasing status as a government-sponsored institution. Now accountable for an annual expenditure of hundreds of millions of government dollars, JPL could no longer expect to enjoy its former freedom, no matter how desirable that may have been. But that was not the end of the matter, as subsequent events would soon show.

Pickering in Public (1963–1964)

If William Pickering's productivity was slowed down, or in any other way adversely affected by the dissension that swirled about him in 1964, it was certainly not apparent in the quality, or quantity, of his public discourse. From thirteen in 1963, the number of his public speeches increased to twenty-one in 1964. Together with the publication of five technical papers, this effort made 1964 one of his most productive years. When reminded of this fact in later years, and questioned about the time away from the Laboratory that the transcontinental and international speech-making tours entailed, he was somewhat taken aback. "I never realized it was that many," he said, allowing that he had received much help in preparing his speeches from Harold Wheelock, a JPL writer who had " . . . a good turn of phrase."[29] The two speeches that follow are illustrative of Pickering's genius for choosing a topic to match the dominant interest of his audiences, the economics of space for the bankers and spacecraft guidance for the engineers, and for conveying an equal sense of credibility, depth of knowledge, and enthusiasm for both.

At a time when his future, and that of his Laboratory, balanced on the fate of Ranger 7 then in its final stages of prelaunch testing under the baleful eye of NASA monitors back in the Pasadena, it was somewhat ironic that Pickering was discussing the topic "Space—Boon or Boondoggle?"[30] with the California Investment Bankers Association in Santa Barbara. "The United States space venture, like any momentous objective, is always controversial," he said. "The argument was not about whether there should be a space program, but rather about how much of the nation's limited resources should be devoted to it. The present debate was . . . whether or not the present rate of development of the space program was warranted."

Pickering saw the Kennedy-inspired initiative to place a man on the Moon by 1970 as a goal, rather than a "fiat," that would never be achieved by leaders of the program who honestly doubted the feasibility of the goal itself. "In any such operation, with a time limit for its completion . . . the major element of success is largely found in the enthusiasm and drive of key personnel which expands like contagion and inspires the team to do the impossible," he said.

Pickering felt that another necessary prerequisite to achieving the goal by 1970 would be gathering the necessary physical data (on the lunar surface conditions) to ensure the success of a manned landing. This could be done with instrumented robot spacecraft, he said.

While many prominent leaders had questioned the diversion of engineering and scientific talent to the space program at the expense of other fields of research, Pickering quoted NASA data that showed "only six percent of the national manpower pool in science and engineering was devoted to NASA contracts with private industry, plus an additional one percent in government laboratories." This was not an "overwhelming drain" for a program of such substantial value to the nation.

Pickering observed that, while arguments in the economic, scientific, and military areas were far from conclusive, it was in the human and psychological area that "the real catalyst is to be found which precipitated the program."

Given that the space race is economically possible and scientifically feasible, "Is the space race a valid psychological weapon in the battle for world leadership between the USA and the USSR?" he asked. "Armed might, while an essential element of United States world prestige and leadership, is not sufficient to ensure preeminence in the world community," he argued. "In the modern complex society, nothing adds more prestige than technological preeminence."

Pointing to the world attitude after the "Sputnik affair" as an example, he continued, "Technological supremacy is a key tool in winning the admiration and the minds of men for our system against its communist and collectivist competitors." Unlike the space race, few other projects would be "immediately understood, by the poorest coolie in the rice paddies of China or the bush dwellers of darkest Africa," he said.

"The discovery and investigation of new horizons of knowledge has ever been an insatiable yearning of mankind," he observed. Whether or not the international prestige of the U.S. warranted the cost of the space program, there were "numerous other blessings which flowed into our economy, into our scientific technology, and into our human ego, which together or by themselves, made the program a boon and not a boondoggle."

Within a few weeks of General Luedecke's arrival at JPL as General Manager, Pickering took off on a lengthy international lecture tour that included Poland, South Africa, and Spain. It began at the annual congress of the International Astronautics Federation in Warsaw, Poland. There, in company with Bud Schurmeier, he generated enormous enthusiasm for the U.S. space program when he showed a movie of the Ranger 7 lunar mission.

In South Africa a week later, he embarked on a lecture tour of several well-established universities at the invitation of the South African Institute of Electrical Engineers. The lecture in Johannesburg was the centerpiece of his South African tour. "Guidance for Interplanetary Spacecraft" was a speech of the kind where William Pickering had few equals—an esoteric, technical subject in a field where his unique experience commanded profound respect and his technical achievements and aspirations for the future of space were unchallenged and admired.[31] It was delivered to a professional audience in a university lecture style with many slides to illustrate salient points.

Travel through space he said:

> . . . introduces some fundamental new concepts. By contradistinction with the airplane, the spacecraft does not require the application of a continuous forward thrust, nor is it subject to external disturbing forces. For most of its journey it travels freely, without drag, falling through the gravitational field . . . in free fall, the path is exactly determined by the shape of the gravitational field and the initial position and velocity of the spacecraft." A precise knowledge of the so-called 'initial conditions' allowed spacecraft navigators to determine the position of a spacecraft 'for all future time.'

Interplanetary spaceflight, Pickering explained, involved two major and quite distinct, phases. In the first phase the spacecraft plus booster rocket is controlled along a predetermined path to establish an initial position and velocity. In the following phase, the spacecraft is controlled in attitude, and minor adjustments are made to its velocity to correct for initial guidance errors that occurred during the powered flight period. He went on to describe how guidance and control was accomplished in each of these distinct periods and the methods used to establish reference directions for each: gyros or inertial platforms for rockets and celestial references of Earth, the Sun, and stars for spacecraft.

The problem of calculating the path of a spacecraft traveling to another planet was complicated by the fact that the path was determined by the influence of three successive gravitational fields: first that of Earth, then by that of the Sun, and finally by the gravitational field of the target planet. "The complete journey is therefore best described in three different coordinate systems which must be carefully matched to achieve the desired target accuracy. Without a modern high speed digital computer, this would be impossible to solve in any reasonable time," he said.

Using the recent Ranger flight to the Moon and the Mariner flight to Venus as examples, he showed how the separate orbital motions of Earth, Moon, and Venus and the arrival conditions required by the science experiments limited the opportunities for launch to very tightly constrained "windows of duration" in both time and calendar date.

After a spacecraft had been launched successfully and injected on to a path close to the nominal trajectory, it became necessary to make a precise determination of that trajectory in order to know if the targeting requirements would be met. For that purpose a high precision, ground-based radio tracking station such as the one near Johannesburg was required.[32]

Concluding, Dr. Pickering said that with the potential solution to the problem of guidance for interplanetary spacecraft demonstrated by Ranger and Mariner " . . . it is now possible to explore the solar system. Landings on the

Moon close to desired targets and flights passing near other planets can be made, and spacecraft can be sent into orbit around the moon or planets." It would not be long before William Pickering made good on his prescient observation.

In September 1964, the Italian city of Genoa, acting through the office of the Mayor and upon the recommendation of the International Institute for Communications, awarded the Medaglia Colombiana 1964 (1964 Columbus Medal) to William Hayward Pickering, with the following citation:

> For high executive skills, for the decisive contribution made to research and experiments on space probes for interplanetary exploration, and for the success achieved with the Ranger VII, not so much from the standpoint of ballistics of the future as because of the scientific value of the pictures taken (as many as 3900) in the last minutes of the mission, which constitute in the whole, a clear demonstration of the manner in which electronics and the information theory, smooth the way for the explorers of cosmic space.

The Mayor noted that "Professor Pickering was in Genoa in October 1959 as speaker before the 7th International Communications Conference, where he submitted a most interesting paper on 'Communications with Lunar Satellites' in which he anticipated the underlying causes for the success of Ranger 7."

Because his speaking schedule in South Africa prevented him from attending the Columbus Day celebration in Genoa to receive the medal, Pickering asked U.S. Ambassador Frederick Reinhardt to accept the award in his stead.

So it was done. In a brief acceptance speech Ambassador Reinhardt pointed out that Professor Pickering "was particularly anxious for his Italian colleagues to know that he wished to share the honors bestowed upon him by the city of Genoa with the other scientists and engineers who made possible the success of Ranger 7."

With obligations to his South African hosts completed in mid-October, Pickering returned to California. He was anxious to catch up with the progress of the Ranger 8 lunar spacecraft at JPL but more importantly, for the moment, to support Jack James and his Mariner team as it worked through the final prelaunch test sequences for Mariners 3 and 4 at Cape Kennedy.[33]

Toward Mars

The first mission to fly by Mars presented its designers with a number of significant technical challenges that took them well beyond those associated with lunar missions. Many of the problems were those very guidance and control issues that Pickering had discussed on his South African tour.

Mars was about three times further from Earth than Venus, which meant that the tracking stations would see only about one tenth of the signal power from Mariners 3 and 4 than they had seen from Mariner 2 at Venus. Because the spacecraft distance from the Sun would be greater too, the Mars spacecraft would require larger solar panels. Nor could these spacecraft use Earth as a reference point for their attitude stabilization system. To the Mars-bound spacecraft, Earth would appear only as a faint crescent-shaped object against a bright star background at those times when it was not obliterated by the light from the Sun. Canopus would be the celestial point of reference for Mariners 3 and 4, but how would they find that particular star amongst the thousands of other bright objects in the celestial sphere?

Spacecraft designers would have to balance the increased weight of the video cameras and their articulated mounting platform together with the other science instruments, against the payload weight limitation imposed by the launch vehicle's ability to throw the heavy spacecraft the extra distance to Mars.

And then too the new spacecraft would take almost nine months to reach Mars compared with a mere three months taken by Mariner 2 to reach Venus. That translated into much longer operating life and correspondingly higher reliability for all elements of the spacecraft, particularly for the electronics.

But Pickering's "team" thrived on such challenges. As Pickering had so often asserted in public, it was challenges such as these that attracted the best of the country's engineering talent. Even within the Laboratory, the intellectual and technological challenge of the Mariner project attracted more of the better engineers at the expense of the less glamorous Ranger project.

In 1963 and 1964 new designs, some based on what had worked successfully before, others based on new and innovative ideas and techniques, were translated into hardware and software as the new breed of Mars spacecraft gradually took shape in the labs and test facilities at Pasadena. Quality assurance of the highest order, formalized failure-reporting and closeout, life and vibration testing, verifiable performance margins, and end-to-end system testing became enduring features of engineering life on the project. Over it all, Jack James' pervasive management style kept the project moving steadily forward, without the need for Pickering's intervention.

Two weeks after Pickering returned from South Africa, Mariner 3 left the launch pad at Cape Kennedy bound, regrettably, not for Mars, but for ignominious extinction. Within minutes after lift-off, the tubular shroud designed to protect the spacecraft during its passage through Earth's atmosphere, failed to disengage from the spacecraft as programmed and, in so doing, initiated a sequence of events that ended hours later with a dead spacecraft and a total failure of the mission. Pickering was appalled to say the least, although it was by no means clear at the time what had caused the shroud failure. Within days, James and his engineers traced the failure to the unvented honeycomb sandwich structure of which the shroud was constructed. Apparently, it had not been adequately tested under the conditions of heat and vacuum that it experienced as the launch vehicle passed through the upper atmosphere.

With the "launch window" for Mars due to close in less than 30 days, James made a decision to substitute an all-metal shroud for the original fiberglass honeycomb version. Whether a new shroud could be built in the time remaining before the 1964 "launch window" closed, stood as an open question, but did not deter the team from trying. It did not remain an unresolved question for long.

Just 17 days after the first shroud failed, a replacement all-metal shroud arrived at Cape Canaveral for attachment to the Mariner 4 launch vehicle. While a second shroud went for accelerated testing, the countdown for Mariner 4 got under way at the Cape. The brilliant recovery from this crisis demonstrated the Laboratory's expertise at its best. The tests revealed no further flaws, and Mariner 4 eventually launched without problem on 28 November. All being well, Mariner 4 would arrive at Mars in mid-July the following year and return mankind's first close-up pictures of that most intriguing of planets. What would it see—Martians, canals, craters, or oceans? No one knew, but many were anxious to find out and theories abounded.

While JPL's latest dramatic production began to unfold in deep space, Pickering closed out the year with submission of a lengthy paper on "The Ranger Program" for publication by the AIAA, and an address on "The Surveyor Project" to the Management Club at the Hughes Aircraft Company in Los Angeles.

Although the public recognition that grew around William Pickering began, inevitably, to influence the lifestyle of both him and his wife, he never allowed it to dominate their private lives.

Muriel remained the warm, gentle, supportive personality that she had always been:

> . . . she took her public role very seriously. She certainly had parameters for herself as a Caltech wife . . . and later . . . as the wife of a famous person leading JPL. All the major events were a matter of careful planning, intense review, and analysis. Her approach was far more serious (than that of her husband). With Dad, the review of the events had always been from the point of view that the most amazing things happen and it's all incredible and often quite amusing. With Mom, it was conduct and correctness and protocol.

Perhaps it reflected a difference in their level of confidence to deal with the situations with which they became publicly engaged. His daughter agreed:

> Certainly, my Dad was confident in his knowledge and didn't need to operate with any pretensions. He loved what he did, and he was good at it, and because he knew that others contributed to

> all the successes he acted with humility. He was comfortable with who he was and what he was doing.[34]

The controversy and criticism that surrounded William Pickering in 1963 and 1964 did nothing to dampen his enthusiasm for the space program and its overall objective to demonstrate the United States' preeminence in space technology. Nor was he deterred by the string of mission failures that were attributed to his leadership of the Laboratory in those years. Disappointed, yes, but not deterred. It was all part of the unavoidable learning process; "the steep part of the curve—just a part of the big picture," he would have said with a throaty chuckle and a twinkle in his eye. Moreover, he was firmly convinced that substantial progress had been made. His public lectures, especially those of a technical nature, were testament to his belief. Although there had been some successes with Mariner 2 and Ranger 7, the best was yet to come, and even if his detractors at NASA could not yet see it, Pickering sensed that redemption was just around the corner.

Endnotes

1 Folder 83 in the William H. Pickering Speech Collection, Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2004.

2 Folder 84 in the William H. Pickering Speech Collection, Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2004.

3 Folders 212-247 in the William H. Pickering Office File Collection, Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-186, 2004.

4 Folders 85-96 in the William H. Pickering Speech Collection, Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2004.

5 Mudgway, Douglas J., Oral History Interview with William H. Pickering, Part 6B, Pasadena, California, July 2003.

6 Folder 95 in the William H. Pickering Speech Collection, Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2004.

7 The records note that the only copy of this speech is a transcript from an AIAA tape recording that ran out of tape before the speech concluded. It is assumed therefore, that this speech was delivered without a fully prepared text.

8 Mudgway, Douglas J., Oral History Interview with William H. Pickering, Part 6B, Pasadena, California, July 2003.

9 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 136.

10 Newell, Homer E., *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP-4211, 1980), p. 265.

11 Mudgway, Douglas J., Oral History Interview with William H. Pickering, Part 6A, Pasadena, California, July 2003.

12 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 148.

13 Ibid, p. 149.

14 Newell, Homer E., *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP-4211, 1980), p. 267.

15 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 151.

16 Mudgway, Douglas J., Oral History Interview with William H. Pickering, Part 6B, Pasadena, California, July 2003.

17 Ibid.

18 Hall, R. Cargill, Lunar Impact: A History of Project Ranger (Washington, DC: NASA SP-4210, 1977), pp. 223–252.

19 Ibid.

20 Kluger, Jeffrey, *Journey Beyond Selene; Remarkable Expeditions Past Our Moon and to the Ends of the Solar System* (New York: Simon and Schuster, 1999).

21 Hall, R. Cargill, *Lunar Impact: A History of Project Ranger* (Washington, DC: NASA SP-4210, 1977), pp. 223-252.

22 Mudgway, Douglas J.,Oral History Interview with William H. Pickering, Part 6B, Pasadena, California, July 2003.

23 Hall, R. Cargill, *Lunar Impact: A History of Project Ranger* (Washington, DC: NASA SP-4210, 1977), p. 252.

24 Ibid, p. 256.

25 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 163.

26 Hall, R. Cargill, *Lunar Impact: A History of Project Ranger* (Washington, DC: NASA SP-4210, 1977), p. 273.

27 Ibid, p. 278.

28 See Mudgway, Douglas J., Oral History Interview with William H. Pickering, Part 6D. Pasadena, California, July 2003.

29 On close inspection, it is apparent that the essentially "technical" speeches were written by Pickering himself; the more general, politically or philosophically oriented speeches were probably crafted by Wheelock, although there is no evidence to confirm that.

30 Folder 111 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2004.

31 Folder 114 in the William H. Pickering Speech Collection. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2004.

32 The tracking station near Johannesburg was one of three that comprise the Deep Space Network. The other two are in Woomera, Australia, and Goldstone, California.

33 Originally called Cape Canaveral to identify its physical location, the launch site was renamed Cape Kennedy in 1964 to honor the late President.

34 Beth Pickering Mezitt, Personal Recollections of my father, William H. Pickering. Private correspondence with the author, May 2003.

Chapter 7

Point of Inflection

Moon (1965–1968)

By the middle of the third quarter, William Pickering had lost interest in the game. The first half of the 1965 Rose Bowl college football championship match had been very one sided—the second half was turning into a rout. He recalled the events of a couple of years earlier when, as Grand Marshal for the 1963 Tournament of Roses, he and his family had been the guests of honor at the game. Now, he simply enjoyed privileged seating for himself and his family and was happy to be able to share this part of New Year's Day with them. As the game wound down to its inevitable conclusion, 34 to 7 in favor of Michigan, Pickering's thoughts drifted to other matters, foremost among them, the Ranger situation.

Of late there had been a steadily rising crescendo of criticism of the splendid images from Ranger 7. Questions had been raised about the real scientific value of the Ranger 7 images, and it had been implied that some of the claims of "importance for Apollo" went beyond what the actual imaging data showed. The Ranger imaging team had vigorously defended its interpretation, but after all the effort and expense, Ranger's worth to science, and to Apollo, remained unclear. As Cargill Hall noted, "To be sure, the solitary experiment remaining aboard the Ranger spacecraft, the visual imaging television system, had fulfilled the lunar mission objective specified by NASA. But the first close-up pictures had seemed to generate as much heat as they did light."[1]

And now, as Pickering slowly escorted his family through impatient crowds back to the Rose Bowl parking lot, Ranger 8 stood, in all its pristine beauty, not two miles away in the "clean room" at JPL, awaiting the decision of the "buy-off" committee to ship it to Cape Kennedy—the next step in another appointment with the Moon. Would it pass the intense scrutiny of the NASA-appointed committee and, if it did, would it actually make it to the lunar surface? Or was the Ranger 7 success merely a fluke, the result of a 1 in 7 chance of success? No one would know for sure until mid-February when, if all went well, Ranger 8 would transmit its final images to Earth in the last few minutes before it impacted the lunar surface.

Meanwhile, William Pickering faced a crowded schedule for the new year that began with his induction to the newly-founded National Academy of Engineering which had been established the previous year as a fourth element of the National Academies. As a founding member, he joined the company of the most prominent engineering professionals of the time: Terman, Ramo, Everitt, Millikan (Clark), Dryden, and Bode, to name a few. Together with his membership of the National Academy of Science he was becoming a significance presence in the prestigious world of American high science and engineering.

Right after a quick trip to Washington to consummate the formalities, Pickering embarked on a lengthy lecture tour of New Zealand. Sponsored by the University of Auckland, the 11th New Zealand Science Congress took place in February 1965, high summer for that part of the world. Distinguished scientists, principally from British affiliated countries took part. The Congress began with a public lecture in the Auckland Town Hall featuring "New Zealand's own space scientist," Dr. William Hayward Pickering speaking on "The Exploration of the Moon."[2] For the New Zealand public-at-large the topic was irresistible—it was a "standing room only" event.

Ever since the previous October when he had accepted the invitation to attend the conference, he had been deluged with invitations to address numerous local scientific and engineering organizations throughout New Zealand—all of which he, naturally, accepted.

The local media reported his every word with front-page headlines and pictures and comments. "N.Z. Born Scientist Has Big Role in U.S. Space Flights" exclaimed the *N.Z. Herald*; "Rocketing Posers His $200m Task," screamed the *Auckland Star*; "World Gets Benefit of Space Race," shouted the *Christchurch Star*; "Flying Saucers Reports Are Dismissed," reported the *Dunedin Evening Star*; and, in Wellington, the *Evening Post* announced loftily "U.S. Space Expert Visits Old School-Pupils thrilled to hear talk by famous Old Boy." Interviews with Muriel were immensely popular with the media and served to create a softer image of the world famous scientist who talked "their" language and really was "their hero." The Pickerings' visit gave rise to a remarkable outpouring of public interest and national pride in what were perceived as his personal achievements in a world beyond most people's furthest imagination. The Pickerings even found time for short family reunions with some of the Hayward family in Christchurch and members of the Pickering family in the Auckland area. The Institution of Professional Engineers N.Z. (IPENZ) took advantage of his visit to elect him to the rank of Honorary Fellow and the Governor-General invited Pickering and his wife to lunch.

Following his every move, the press suddenly reported that Dr. Pickering would be cutting his stay in New Zealand short. "My colleagues back in

Pasadena want me back earlier," he said. A few days later, in Christchurch, Pickering brought a gasp of amazement from his audience when he apologized, "I am sorry I am unable to stay longer in New Zealand, but I learned this morning that Ranger 8 is on its way to the Moon and I want to be back in the United States before it gets there." Who else in the world could say that? wondered those present. Pickering's words made them feel they were part of the drama unfolding on the other side of the world. To his adoring countrymen it was all part of Pickering's charisma—his enduring public appeal.

Just over 24 hours later, Ranger 8 unerringly executed its final sequences and, right on target, delivered thousands more dazzling close-up images of the lunar surface to its anxious controllers at the Goldstone tracking station during the final 24 minutes of its 248,000-mile journey. And by then of course, Pickering was back in Pasadena to preside over the momentous event.

Now it was the turn of the American press to laud the achievements of William Pickering. The *Pasadena Star-News* headlined "6000-Photo Finish Marks Ranger Trip-Jet Lab Jubilant on Shot." Speaking to a gathering of press, radio, and television reporters in the Von Kármán auditorium Pickering said, "It was a great satisfaction to see the project go so smoothly."[3] Scientific opinion based on quick reviews of the images suggested that the surface would be safe for an Apollo landing. While recognizing that a Russian spacecraft had already photographed the far side of the moon from a distance of 40,000 miles, Pickering believed that the Ranger images were far superior to those taken by the Russian spacecraft from a distance of 40,000 miles above the back surface of the Moon.[4]

The hint of justifiable pride in Pickering's remark was inescapable; Ranger 7 had not been a fluke, or just a matter of chance, after all. Perhaps, Pickering might have thought, the learning curve is flattening out—at last JPL is approaching the "point of inflection," as it were.

Whatever his innermost thoughts may have been, there was little time for pursuing them further for less than two weeks later he was due in Paris, France, to receive "Le Prix Galabert d'astronautique." Awarded annually by the Fédération Internationale d'Astronautique (IAF), an exclusive institution of which he was also president, the prize was also accompanied by a cash award of 7,000 Francs. Russian cosmonaut Valentina Terechkova received a similar award. French newspapers described him variously as " . . . père des engins spatiaux Mariner et Ranger,"[5] and "Le père des photos lunaires U.S."[6] and, naturally, reported the comments of Le Pr. Pickering in French, " . . . si la vie existe dans le système solaire c'est sur la planète Mars."[7] For his formal address to the IAF Bureau on 4 March he presented the "Exploration of the Moon" speech that he had given in Auckland a few weeks earlier.[8]

No doubt the French audience would have received his presentation with enthusiasm equaling that of its reception in New Zealand—it was a subject of universal interest at the time.

Early the following week, Pickering was in London, England, as the guest of the prestigious British Interplanetary Society. Founded in 1933, the Society was devoted to promoting the exploration of space and astronautics. In the course of a short visit, Pickering again presented "Exploration of the Moon" to an equally receptive audience of scientists and engineers. The following day he was back at JPL. He had been away from Pasadena for just six days.

Among the mail waiting his return he found an invitation from the National Space Club requesting the pleasure of his company at the Robert H. Goddard Memorial Dinner in Washington on 19 March. The featured speaker would be Vice President Hubert Humphrey. The occasion would celebrate the award of the annual Robert H. Goddard Memorial Trophy for 1965 to William H. Pickering " . . . for his leadership of the Ranger 7 Team in obtaining the first close-up pictures of the Moon." The trophy, a sculptured bust of Robert H. Goddard who was generally recognized as the father of modern rocketry, was presented by Hugh Dryden, Deputy Administrator of NASA.

Meanwhile, Ranger 9, which had completed its assembly and checkout tests at JPL, was now in the final stages of its prelaunch checkout at Cape Canaveral.

Morale and enthusiasm at the Laboratory had changed enormously in the past few weeks. Confidence in Ranger 9 and its design was at an all time high and expectations for yet another successful mission to the Moon were unbounded. Pickering later recalled:

> Ranger 7 and 8 had showed the extent of worldwide interest in what we were doing, particularly the photography, which was a 'natural' for the media. The fact that we told them for Ranger 9 we would give it [the television images] to them in real time was a demonstration of [our confidence] that it was going to work, and they were going to get something interesting. They were absolutely fascinated, no doubt about it.[9]

And he was right.

With the addition of appropriate scan converters to the existing data-processing equipment at JPL, it became possible to give the media a real-time television "feed" suitable for live broadcast on commercial television channels across North America. On 24 March, with Ray Heacock describing the lunar features as they appeared in rapid succession on the monitors in the Von Kármán auditorium, an awestruck audience of JPL personnel and media representatives and an unseen public television audience of many millions enjoyed the spectacle of "live television from the Moon" during the final minutes of the Ranger 9 mission to the Moon. It was a spectacular end to the first era of lunar exploration.

At the news conference that followed, Pickering observed:

> The project we reflect on today has been a long and difficult road since 1959. We had our problems in the early days . . . [but]

> the achievements of the last three flights have shown that Ranger could carry out these deep space missions under remote command, that Ranger has indeed demonstrated the soundness of the basic system design and the close-up photographs . . . have opened a new field of the exploration of the Moon.

Historian Cargill Hall noted that, "Most could agree with those observations including Earl Hilburn, whose congratulatory telegram was to be found among others fast arriving at the Laboratory."[10]

From New York to Los Angeles the press acclaimed the world's first demonstration of "live television from the Moon" as Ranger's most impressive achievement. " . . . a front row seat on science," "Astronomy for the masses," and "High and historic drama," were typical comments to be found in the newspapers across the land. President Johnson, too, had been impressed by the television spectacular of Ranger 9 and, inspired by the additional success of the manned *Gemini* spacecraft a few days earlier, issued a public statement in which he declared, "Ranger 9 showed the world further evidence of the dramatic accomplishments of the United States space team . . . ."[11] Along with *Gemini* astronauts Grissom and Young, Schurmeier was summoned to the White House a few days later to be honored for his contribution to the exploration of space with the award of NASA's Exceptional Scientific Achievement Medal.

Despite the unequivocal successes of Rangers 7, 8, and 9, funding for the six follow-on missions that were intended to carry the real science payloads, was diverted to Apollo. Pickering was somewhat philosophical about NASA's decision to discontinue the Ranger project. He remembered:

> That was not an unreasonable thing to do. . . . If I were running the NASA program . . . and, I could put science on Apollo . . . by canceling other programs, I would do it. Also I think from the point of view of public value we had just about milked Ranger for all it was worth with Rangers 7, 8, 9.[12]

With the cancellation of the remaining six Ranger missions, JPL's lunar program turned its attention to the Surveyor, lunar-lander project. In addition to a huge technological challenge, Surveyor brought a new management problem to the Laboratory. It was to be built under JPL contract supervision by a highly-regarded, aerospace contractor Hughes Aircraft Corporation. But the contract had not gone well, and by early-1965 when the spotlight moved away from Ranger and on to Surveyor, the Hughes contract had become a source of great concern to William Pickering.

Nevertheless, with the launch of the first Surveyor still one year away, and the work at Hughes gathering momentum, Pickering focused his attention on events in the more immediate future—events for which he held no ambivalent

JPL Director William Pickering indicates the impact of Ranger 7 on the lunar surface (Photo: NASA/JPL-Caltech Archives, Photo number P3412B).

feelings whatsoever—foremost among them, the progress of Mariner 4 arrival at the planet Mars, was then just three months away.

Important as it was, the first Mariner encounter of Mars was temporally preempted for Pickering's attention by the imminent marriage of his daughter Elizabeth Anne to Robert Wayne Mezitt of Massachusetts. The wedding itself was carried out "flawlessly" as Pickering would have said, as if describing a planetary encounter, and both he and Muriel were delighted with their daughter's choice of husband.

After the wedding William Pickering hastened back to California for another appointment with history. On 14 July, Mariner 4 arrived at Mars and completed its mission "flawlessly" by transmitting 21 television images of the Martian surface back to Earth as it passed by the planet at a distance of 10,000 miles above the surface. The images, covering about 1 percent of the planet's surface, were transmitted from Mars to the tracking stations of JPL's Deep Space Network at a rate of approximately eight bits per second, a major feat in deep space communications for its time.[13] As the numbers, representing light and dark areas of the Mars surface, arrived at JPL by teletype from the distant tracking stations, jubilant scientists pasted the tapes in strips on a large card and colored the like areas to produce the first digital image of Mars's surface features. Later, JPL's science

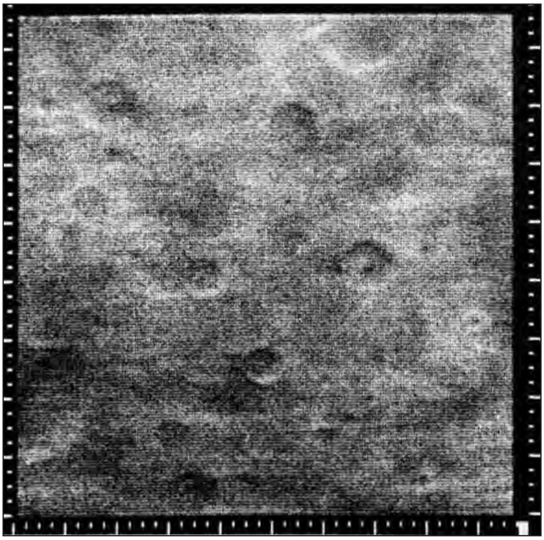
Pickering family group at the wedding of Elizabeth Anne Pickering to Robert Wayne Mezitt, Ithaca, New York, June 1965 (Photo: Courtesy of Pickering Family Trust).

team presented the crude image to the Director with great pride. Eventually the crude image became a much-valued artifact of a historical "first" in deep space and, incidentally, an icon of Pickering's long-held ambition to be "first in deep space." It took a while longer to produce the detailed images that the scientists required for their analysis of the Mars surface features.

Again, the media hailed William Pickering as the man behind yet another, amazing achievement in space.

The *New York Times* carried a piece by Walter Sullivan on the front page titled "Mariner 4 Makes Flight Past Mars." While noting that the spacecraft had already determined the absence of a significant magnetic field on Mars, the article pointed out that it would take over 8 hours for the spacecraft to play back a single image of the planet surface features at just over eight bits per second.

At that rate, it would take about 10 days for all the images to trickle back to Earth across the vast emptiness of space. At the press conference Dr. Pickering had warned the media not to expect too much from the Mariner television system. However, he said these would be "the first ever obtained in the vicinity of another planet," and, " . . . should be better than any ever obtained from earth if the system operates properly." Among many other things, the pictures



Mariner 4 picture of Mars surface (Photo: Available online at *http://nssdc.gsfc.nasa.gov/imgcat/midres/m04_09d.gif)*.

should lay to rest the age-old controversy over the existence of Martian canals that underlay early beliefs of an advanced Martian civilization.[14]

In addition to Sullivan's leading article on the Mariner 4 encounter with Mars, The *New York Times* also carried a handsome personal tribute to Pickering titled "Expert on Spacecraft; William Hayward Pickering." The article described JPL and Pickering's early career, of course, but it also captured the quintessence of Pickering's advocacy for the national space program, and its importance to the nation's international stature. It suggested that his "greatest contribution" may have been his positive efforts to influence government and public attitudes toward support for the space program, and lauded his determination to rally public confidence in the nation's power to recover from the shock of Soviets' dominance in space engendered by the Sputnik affair and subsequent Moon shots. It commended Pickering's belief in "strong leadership and good engineering management," rather than spectacular space events of shallow scientific significance, and his unshakeable opinion "that the most important aspect of the space race was international prestige." The writer observed that Pickering called for an end to military competition for space projects, and urged a truly unified national space program " . . . with both military and civilian research coordinated under NASA."

Finally, the article recognized the impressive standing that Dr. Pickering bore as an honored member of many national and international scientific organizations, as evidenced by the great esteem with which he was regarded by his colleagues. But, said one, "None of these honors can add luster to the stature he has acquired in 'nearly accomplishing the impossible'."[15]

All of these opinions and comments reflected the impact that Pickering had generated with his plethora of public speaking, published articles, and widespread influence in professional societies of all kinds, as we have seen.

A week later, with the first several Mars pictures in hand, *Time* magazine recognized William Pickering for the second time with a front page cover titled "Mariner's William Pickering."

The *Time* article titled "Portrait of a Planet," told of first impressions of the images. Although the pictures were not all that great—"grainy and ill-defined" and it would require much more analysis to interpret their real import—they conveyed a most important message " . . . from 135 million miles in space . . . Mariner 4 had sent home the first close-up portrait man has ever made of far-off planet Mars." The other photos were similar and showed extensive desert-like areas, with a few indistinct surface features that suggested shallow Moon-like craters and elongated depressions. In addition to the images, the scientific return from Mariner included important data on the fields and particles of the deep space. All of this data had been returned to Earth over the longest deep space communications link ever achieved.[16]

The *Time* article, attributed the success of the Mariner 4 mission to Mars to " . . . one of the most skilful and resourceful teams ever gathered together in pursuit of scientific knowledge." Alluding to Pickering's difficult times with his NASA critics, *Time* said, "These men were part of the arrogant, egotistic, brilliant, experienced, and single-minded team on which William Pickering staked his career, and his reputation, when he defended his management style to those who would have it otherwise, but who were now the beneficiaries of its success." Acknowledging Bill Pickering's leadership, *Time* concluded "these men have fashioned the most ambitious and successful space venture yet." It was indeed another handsome tribute that did much to vindicate Pickering's faith in himself, his style of leadership and the capabilities of his "team" at JPL.

Although these pictures would add little to the question of life on Mars, Pickering was optimistic about the future, "I've always felt we'll find some form of life on Mars, and I look forward to the day when we are landing capsules there and searching for life," he said.[17]

Neither William Pickering, nor anyone else for that matter, could have known how prescient that observation really was. Just ten years later, NASA and the JPL team would be doing exactly that—searching for life on Mars with a huge spacecraft called Viking.

The Mariner 4 mission left a lasting impression with William Pickering. "The images showing that Mars is more like the Moon and not like the Earth was an important scientific achievement," he recalled, "because there were a lot of people who were inclined to believe . . . that there was some kind of civilization on Mars. But these [pictures] proved definitely that there was a difference between Mars and Earth."

Perhaps more than anything else, the Mariner 4 mission firmly established United States' lead in the race with the Soviets, a sentiment that would be echoed from the White House a short time later when the President again summoned Pickering, together with Oran Nicks, Director of NASA's Lunar and Planetary Programs Office, to receive NASA's Distinguished Service Medal.

For Pickering, Mariner 4 represented a transition from the developmental to the operational phase in the evolution of planetary spacecraft.[18] As Pickering put it, "We now knew how to do it." JPL had reached the "point of inflection" on Pickering's learning curve.

In the last four months of 1965, Pickering made a dozen major speeches and presentations. Muriel accompanied him on some of the longer trips. Together they visited Athens, Greece, to open the XVIth Congress of the International Astronautical Federation (AIF); Kauai, Hawaii, for the Governor's Conference on Oceanography; and the International Space Electronics Symposium in Miami, Florida. He delivered a paper on the "Mariner Flight to Mars" for the journal *Astronautics and Aeronautic*s in October, and another on "Some New Methods for Planetary Exploration" for the National Academy of Sciences fall meeting in Seattle, Washington.[19] In the latter speech he spoke of a new application for radio astronomy where the radio "beam" from a very powerful transmitter at the Goldstone tracking station had been pointed at distant planet Venus. Careful interpretation of the characteristics of the radio signals reflected from the planet had revealed much hitherto unknown scientific knowledge about the dynamics of the planet and its surface.

Turning to robotic spacecraft, Pickering said that within the past five years it had become possible to conduct scientific experiments and make scientific observations from the vicinity of the planets themselves by making use of robot spacecraft to carry the instruments to the desired locations. Scientists from both the U.S. and the Soviet Union had demonstrated these techniques with varying degrees of success, but both countries would undoubtedly continue these efforts. Pickering illustrated all of his salient points with examples from Mariner 4, and explained how the telemetry data was received

Wearing the NASA Distinguished Service Medal, William Pickering explains the pictures of Mars's surface taken by Mariner 4 to President Johnson: August 1965 (Photo: NASA/JPL-Caltech Archives, Photo number P5109A).

at the tracking stations in California, Australia, and South Africa, and passed to JPL for processing and scientific analysis. Mariner 4 was the most sophisticated planetary spacecraft yet launched by the U.S., but the next generation of planetary spacecraft would be much larger in both weight and capability. "Present plans call for orbiting and landing versions of Voyager, starting in 1971, for Mars exploration," he said.

The speech was a masterful summary of the state-of-the-art in planetary exploration, and presaged future developments in deep space exploration that, although threatened by the voracious fiscal appetite of the mighty Apollo program, nevertheless survived and eventually came to pass in ways that he could not then have imagined. William Pickering spoke from a position of increasing strength, obviously secure in the knowledge that the space program as he saw it was making good progress in the right direction.

At the end of that year he could regard with some pride, and not a little wonder for he was a modest man, the collection of prestigious medals and prizes, some accompanied by significant monetary awards, which had been bestowed upon him by prominent institutions in the field of aerospace related technology. From France came the Prix Galabert and from the U.S. Space Club came the prized Goddard Memorial. U.S. Army Ordnance presented the Crozier Gold Medal and the U.S. Army elected him as their Citizen of the Year for 1965. The American Society of Mechanical Engineers awarded him its "Spirit of St. Louis Medal" for 1965, while the Scientific Research Society of America gave him its Proctor Prize for that year. And it was in that remarkable year also, that President Johnson presented him with NASA's Distinguished Service Medal.[20] Almost all of these awards were based on his outstanding contribution in one way or another to the field of "space exploration." Although he had not actively sought recognition, he accepted it all graciously and, in most cases, responded with a personal appearance and an appropriate speech of acceptance.

Interpreted loosely in Spanish as "a shady glen," La Cañada, to use its original Spanish spelling, was one of several small communities that originated as orange orchards along the foothills of the western San Gabriel Valley at the turn of the 20th century. By the 1960s the orange groves had gone and La Cañada had become an equestrian-oriented community of larger, upper-class, country homes whose wealthy owners regarded the presence of the Jet Propulsion Laboratory in the nearby arroyo as an intrusion into their exclusive community.

By that time, several large, sparkling new buildings had appeared within JPL's campus. The successes of Ranger and Mariner enhanced the reputation of JPL as an attractive place to work, and the population of the Laboratory increased rapidly. Scientists, engineers, technicians, secretaries, administrators, and support staff quickly filled the vacancies at JPL as they became available.

Newcomers moved into the area and La Cañada became a highly desirable place to live and to raise a family.

On the broad flanks of the hillside overlooking JPL to the north, the fashionable community of Flintridge developed almost as a mirror image of the big homes that comprised the original La Cañada enclave across the valley. This was the location that William Pickering chose for his new home. With a breathtaking view on all three sides, a swimming pool, and a direct view down to the rapidly expanding JPL campus, it was a natural choice for the public figure that William Pickering had now become. Pickering's helicopter, exiting the JPL landing pad en route for the airport, passed his home at eye level, affording, on occasion, an opportunity for a quick wave to Muriel.

Both he and Muriel quickly settled in to the social life of the new community. Muriel established close associations with many of the civic groups in La Cañada. For his part, William took an active interest in the educational and local government groups that had begun to shape the character of the rapidly evolving city of La Cañada-Flintridge.

The Surveyor lunar landers were strange, three-legged machines that, rather than crashing violently as the Rangers had done, would descend gently to the surface. They would deliver video and science measurements in real-time from the Moon to engineers and scientists at JPL. Later versions were to be equipped with a miniature trenching tool that scientists would manipulate remotely from JPL to reveal the nature of the lunar material to a depth of a few inches below the surface, turn over rocks to reveal what lay beneath and generally test the mechanical properties of the lunar soil. Other instruments would test the chemical composition of the soil. All of these data, in addition to close-up photographs of the near and distant lunar landscapes, would stream continuously to Earth during the lunar daytime when solar power would be available. The findings of these complex spacecraft would surely provide the Apollo mission designers with the critical details of the strength of the lunar soil on which the safety of the manned landings depended. As a minimum, the Surveyor data would confirm their assumptions, and extend the predictions that had been based on the data from the three Rangers.

But there were problems—not so much with the Surveyor spacecraft, but with the Surveyor contract.

Somewhat paralleling the problems that beset JPL in its early Ranger days, the problems with the Hughes contract stemmed from inadequate planning, the nature of a cost-plus-fixed-fee contract, inadequacy of the company's management, and technical infrastructure to handle a project of this complexity, and lack of sufficient supervision by NASA and JPL.[21] The previous year Pickering had been forced by a fully empowered NASA review into designating Surveyor as the "top priority activity of JPL" and instituting a massive "rescue operation" that involved assigning as many as five hundred of the Laboratory's most experienced personnel to work full time on Surveyor; the author was one of them. Under these extreme measures, the technical and engineering status of the contract slowly improved, but contractual problems persisted.

Into this vexatious situation stepped General Luedecke, Pickering's Caltech-appointed deputy. Almost immediately, Luedecke invoked his authority, business acumen, and empathy with NASA Headquarters to discipline the Surveyor cost accounting processes.[22]

If Pickering felt ambivalent about Surveyor, he left no record of it, and there is no suggestion that he gave it less than his full support. To all outward appearances, JPL's problems were now behind it; having, at least, equalized the race for primacy in space, the Laboratory could look forward to even greater triumphs in space in the years ahead. Such was the image that Pickering's frequent and wide-ranging public appearances created in the minds of those who heard him and those who read the widely published reports of JPL's spectacular successes.

These perceptions were further enhanced when, in June 1966, the first Surveyor spacecraft landed gently on the surface of the Moon, activated its cameras and, without fuss or bother, began transmitting the first pictures of the lunar soil beneath its feet. It was accomplished so easily that it almost seemed a matter of routine, rather than being a technological feat of the first order. Surveyor had landed upright, its three landing pads penetrating the lunar soil to a depth of an inch or two with all of its systems in perfect working order.

For the next month Surveyor 1 responded faultlessly to over 100,000 commands from its Earth-bound controllers. It returned more than 11,000 images of the lunar landscape including rocks near and far and material around them, and, for the first time, enabled Apollo mission designers to see exactly what their manned landing craft and its occupants would face when they eventually touched down on the lunar surface. And once again it had become a media "feeding frenzy."

Pickering remembered the occasion well:

> There was a lot of media excitement about the first one. They had gotten used to real-time coverage on Ranger and they wanted to do the landing in real time, but I did not want them to do that because we were pretty unsure about the success of this thing. But they did an end run around me and we got orders from Washington to, 'Give it [real-time television of the landing] to the media.' So that is what we did . . . and they spread it all around the world. It was just as well it was a success.

When asked about the Apollo reaction to the Surveyor success he added somewhat ruefully: "I felt the Apollo people should have been more interested in this than they were, but they said 'Good landing,' that's all."[23] Astronaut-scientist Harrison Schmitt thought differently, "Ranger and Surveyor were of tremendous importance," he replied when asked how valuable they were to the manned Apollo missions adding, "There was a more political question, I think, than geological question about the nature of the surface."[24]

A few weeks later, a *Life* magazine article waxed eloquently over the Surveyor pictures and what they represented, "The color photographs constitute a crowning achievement in Surveyor's success . . . it carried out its task so efficiently that even its most optimistic designers were dumbfounded."[25] Although the Soviet spacecraft Luna 9 had preempted Surveyor by landing successfully on the Moon a few months earlier, it had survived only three days and returned only nine lunar images, a fact that did nothing to minimize the elation over the Surveyor's success.

Inevitably, some of the credit for the successful mission was attributed to General Luedecke's influence on the contract relations with Hughes and JPL, and NASA Headquarters viewed his efforts with great satisfaction.[26] But rather than build upon this perception to improve his relationship with Luedecke, Pickering, rather inexplicably, elected to curtail his deputy's influence by sharply limiting his authority. Pickering issued new job descriptions that reduced the authority of his deputy director, while simultaneously increasing the authority of his several assistant directors who were responsible for technical and administrative work of the divisions.

As a consequence of this action, the balance of executive power at JPL effectively reverted back to where it had been prior to the time that NASA had forced Caltech to appoint a deputy director for JPL. Not surprisingly, Luedecke viewed this as an affront to his authority and appealed to NASA for help to resolve, what was for him, an impossible situation.

For the next year, a stream of accusations, denials, protests, and complaints surged back and forth between the four parties, NASA, Caltech, Luedecke, and Pickering. Eventually, Pickering took the position that Caltech would have to choose between him and Luedecke, and that while Luedecke remained in office, he could no longer continue as Director. To back up his argument, Pickering reminded DuBridge of his allegiance to JPL and concerns that JPL could well become "merely a job-shop for NASA."[27] There could be little doubt that Pickering was voicing his most deeply felt concerns and putting his career on the line to prove it.

Ultimately, Caltech's Board of Trustees upheld Pickering's position and General Luedecke quietly resigned and moved away to a position as president of a large university in Texas. The position, however, had not gone away. Shortly afterwards Caltech hired Rear Admiral John F. Clark to fill the position of deputy director at JPL. It was a happy choice. Admiral Clark quietly settled in to the deputy director position at JPL and was readily accepted by both the Director and the senior staff of the Laboratory. When Clark retired a few years later, Caltech continued the military tradition with the appointment of Air Force General Charles Terhune as deputy to Pickering. Pickering and Terhune eventually became great friends and created a productive management partnership that acted for the remainder of Pickering tenure, to the mutual benefit of NASA, Caltech, and JPL.

Despite the furor surrounding his interpersonal relationships at JPL in 1966, Pickering still managed to find time for international visits and speeches—Paris, France, "Why Go to the Moon?;" Madrid, Spain, "AIF conference;" London, England "Speech on the BBC2"—in addition to delivering ten or more speeches from one side of the U.S. to the other. Two honorary doctorates, one from Occidental College in California, the other from Clark University in Massachusetts, the Magellanic Premium from the American Philosophical Society, and a further foreign distinction of the meritorious Order of Merit of the Republic of Italy were indicative of the great esteem with which William H. Pickering was regarded in this country and abroad.

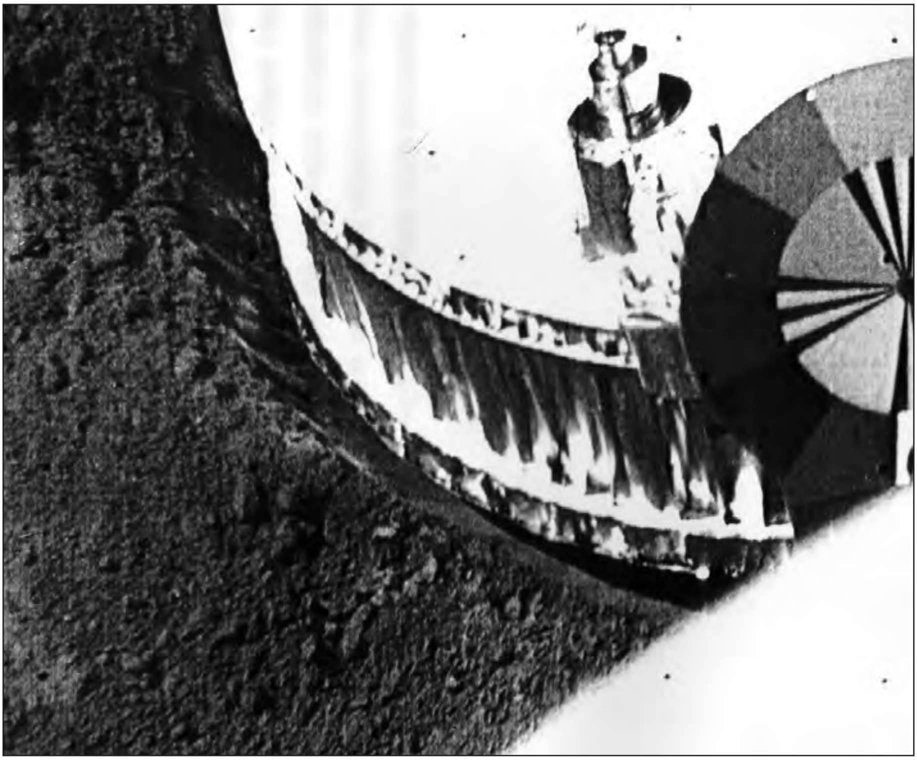
Excitement over the success of Surveyor 1 was short lived. Surveyor 2, launched about three months later, experienced a failure during its midcourse maneuver and crashed uselessly on the Moon a few hours later. It would be April the following year before the program resumed with the launch of Surveyor 3. In addition to their television cameras, Surveyors 3 and 7 were each equipped with a remotely controlled digging tool called a surface sampler. It could be used for soil mechanics experiments that involved trenching, scooping, and depositing lunar surface material in view of the camera. It could also be used to push around, or overturn, small rocks within range of its extendable arm. Magnets attached to the footpads of Surveyors 5, 6, and 7 tested the soil for its magnetic properties and an alpha-ray scattering experiment was used to make chemical analyses of the lunar soil.

Except for Surveyor 4, which disappeared without trace about two minutes before touchdown, all of the remaining Surveyors succeeded in reaching the surface of the Moon and carrying out their lunar experiments as planned. Close-up pictures of the lunar terrain, portions of the spacecraft, and crescent Earth viewed from the Moon became commonplace, as scientists struggled to interpret the avalanche of new data that flowed into their data banks.[28]

NASA's lunar lander program concluded in January 1968 with Surveyor 7, but by that time Pickering had set his sights on Mars and the planets that lay beyond. The Surveyor missions soon faded from public view and the world's attention became riveted on the unfolding drama of the Apollo manned lunar landings. Surveyor made a brief reappearance on the world stage in November 1969 when Apollo 12 astronaut Pete Conrad retrieved the camera from Surveyor 3 still standing peacefully where it landed gently in the Ocean of Storms more than two years earlier. Returned to Earth on Apollo 12, the camera from Surveyor 3 was closely examined, and to the amazement of its designers, determined to be in good condition. Eventually NASA presented it to William Pickering on his retirement, and it became a permanent exhibit at the Air and Space Museum in Washington, DC.

The appointment of a more compatible individual as deputy to William Pickering did much to ease the tensions in the Director's office at JPL, but did nothing to quench the NASA Administrator's drive to mold JPL and its recalcitrant Director to his vision of the ideal NASA/Caltech/JPL triad. No sooner had General Ludecke departed the Laboratory than Administrator Webb announced the formation of yet another NASA-sponsored committee to investigate JPL/Caltech management. The new committee was to be chaired by UCLA professor Chauncey Starr, a professional colleague who was well known to, and highly regarded by, Pickering. Rather as Pickering had anticipated, the Starr Committee's findings at the conclusion of its nine-month investigation of JPL and its interactions with NASA and Caltech were rather benign, and fell far short of the sweeping changes that Webb had looked for in initiating the investigation in the first place.[29]

The long shadow of Webb's influence swept over JPL for the last time a few months later during the 1968 contract negotiations. Once again NASA



Surveyor footpad and trench in lunar soil (Photo: National Space Science Data Center).

attempted to "diminish Pickering's authority and JPL's autonomy." As was to be expected, Caltech and JPL objected strongly and resisted most of NASA's demands. Before any of the new agreements could be put into effect, however, James Webb retired from NASA and was succeeded in October 1968 by the former Deputy Administrator Thomas Paine.[30]

Almost immediately the hitherto conflicted negotiations began to make progress. New guidelines designed to achieve "mutual objectives" were set, a fund to sponsor independent research at JPL was established, and Paine consented to a substantial increase in the Caltech "fee." And, what would later prove to be of great importance to Pickering, NASA permitted JPL to seek funding from "agencies other than NASA."[31] Both sides appeared satisfied with the ultimate and wide-ranging outcome of the negotiations.

Without the burdensome influences of Webb and Luedecke in his professional life, the future might well have looked rosy indeed to William Pickering —but that was not how it turned out.

Apollo 12 astronaut Pete Conrad retrieves camera from Surveyor 3 standing in the Moon's Ocean of Storms. Returned to Earth on Apollo 12 for analysis, the camera was eventually delivered to William Pickering (Photo: NASA/JPL-Caltech Archives, Photo number P10623B).

Planets (1967–1969)

As he soon discovered, the future held challenges that taxed Pickering's leadership abilities beyond anything he had encountered or could have expected. The technical and administrative challenges of the early 1960s were now superseded by an urgent need to diversify JPL's interests and attend to its very survival.[32] Changes were everywhere. The tremendous verve, excitement, motivation, and pride that drove the Laboratory staff to extraordinary accomplishments in the past began to dissipate as "deep space spectaculars" became commonplace and the exploits of the Apollo astronauts stole the public's interest. Other NASA centers, too, began to compete with JPL for NASA and public recognition, as their own deep space missions began to make headlines in the national media. The intrepid Pioneers from Ames Research Center, the highly successful Lunar Orbiters, and, later, the magnificent Vikings from Langley Research Center were prime examples.

Although he did not undertake so much international travel in 1967 and 1968 as he had done in earlier years, there was no let up in Pickering's frenetic drive to address institutions and organizations far and wide across the U.S. Fifteen public addresses in 1967, one of them in Belgrade, Yugoslavia, and thirty in 1968, including several in New Zealand and one in Genoa, Italy, surely represented a remarkable personal effort on the part of a man who, while directing a major technological institution engaged in the world's leading space initiative, was simultaneously engaged in career-threatening internal controversy with its principal sponsor. On top of all this, he continued to garner awards and honors from civic and professional organizations alike. The city of Pasadena, the Aeronautics and Astronautics Society, American Institute of Aeronautics and Astronautics, and Institution of Electrical and Electronics Engineers were among those that recognized his contribution to the new field of space exploration with their most prestigious awards.[33]

As they had done so often in the past, Pickering's speeches in 1967 and 1968 reflected his concerns for the present and future condition of the U.S. space program. In 1967 he frequently visited themes that reviewed the progress of the first decade since Sputnik: "Progress in Unmanned Space Exploration," "The Opening Decade of Space Exploration," and looked forward to the future with "The Next Steps in Space Exploration" and "The Next Ten Years in Space." By the following year, his evident concern for the shrinking space budget and the disproportionate allocation of available funds to the Apollo manned program at the expense of the unmanned exploration of the solar system became clearly apparent with "Why Explore the Solar System" and "Neo-Sputnik: The Age of Unreason in Space Exploration."

This latter speech, delivered to a group of businessmen at the Los Angeles Rotary Club in August 1968, revealed his concern for the present and his vision for the future of the space program. The broad sweep of the ideas he espoused in this speech stand in marked contrast to the petty aggravations that competed for his attention at JPL in those years.

"A decade earlier Sputnik shattered some long-held ideas among Americans, that the Soviets were inept scientifically and technologically . . . and the American public reacted with near panic," Pickering said. But after some hasty improvising and some early failures, the U.S. recovered to the point where, by mid-1968 it holds " . . . a comfortable lead in scientific innovation and technological productivity." He attributed much of the credit for this situation "to the expansion of government support of research and development." That had now changed. While the 1969 budget allocated $2 billion for Apollo, it only provided funding for, at best, " . . . a minimal planetary program."

"Can the nation maintain its world leadership in science and technology without vigorous support from the government and the public?" he asked. Citing recent polls that showed public interest in the space program to be at its lowest ebb since the beginning of the decade, he said that many respondents were willing to abandon planetary research to the Soviets. "Even landing astronauts on the Moon had lost much of its glamour." On the other hand, the Soviets, he claimed " . . . showed every sign of being eager to resume the lead in space exploration which . . . they consider a valuable weapon in the contest for men's minds," and could be expected to "launch to Mars and Venus at every opportunity."

"If we do not avoid . . . the type of irrationalism which ignores the hard lessons learned during the current turbulent decade," he warned, " . . . one day in the early 1970s a new Sputnik is likely to appear on our horizon."

"Must history repeat itself?" he concluded.[34]

Embedded within this compelling speech were clear references to powerful forces like the reduction in funding for the space program, dominance of the Apollo program for available funds, and diminishing public support for continued space exploration that would determine the character of the planetary program for the remaining years of Pickering's tenure with the Laboratory.

That it survived this hiatus in the nation's planetary space program is, in no small measure, due to Pickering's efforts to diversify the scope of the Laboratory's interests.

Toward the end of 1965, William Pickering had received an important message from NASA Headquarters. Although not unexpected, it was welcome nevertheless for it authorized him to initiate work on a new mission to Venus. This mission would take advantage of the 1967 Venus "inferior conjunction"[35] when Earth and Venus would be on the same side of the Sun and therefore the distance between Venus and Earth would be at a minimum. To save time and cost, the Mariner 5 spacecraft was to be constructed from surplus Mariner 4 flight-qualified components that had been carefully preserved at JPL. Only minimal changes to basic design of the spacecraft were permitted, and the science instruments were limited to a radiation detector and a magnetometer.

The most important science experiment, measurement of the density of the Venusian atmosphere, was to be determined by analysis of the changes to the spacecraft's own radio signals as the spacecraft moved behind the planet's disk as viewed by antennas on Earth, an astronomical condition known as occultation.

Despite the Laboratory's major emphasis on Surveyor, enough effort was found to build and launch the new planetary spacecraft on schedule. Mariner 5 reached Venus without incident, in October 1967, a little less than two years after Pickering received the "go ahead" from NASA. Although the encounter period of closest approach was only about one hour in duration, it was sufficient for the instruments to make their critical measurements; it was searching for the presence of a magnetic field and a belt of radiation, and measuring the height and temperature of the upper atmosphere. When the spacecraft disappeared briefly behind the planet as viewed from Earth, the radio "occultation" data, which held the key to the composition and density of the atmosphere, was recorded at the tracking stations for later analysis. It was a perfect mission in every sense.

The *New York Times* reported the event on an inner page with a comprehensive article by John Noble Wilford that quoted the Mariner project scientist in explaining the mission and the science results.[36] There was no mention of the JPL Director, as there had been on previous occasions. He was evidently standing back to give prominence to his project managers when the press was around. As his daughter commented, " . . . he was becoming self-conscious about getting all the praise when others did all the work."[37]

To some extent, the impact of Mariner 5's encounter with Venus was upstaged by that of a Soviet spacecraft, Venera 4, that had dropped a capsule on to the Venusian surface the previous day and, the Soviets claimed, had made measurements of atmospheric density and temperature from the actual surface for a short time before the capsule failed. This had made front page news in The *New York Times* the previous day but the Soviets' data had been called into question by the occultation data received from Mariner 5.[38]

This was the first demonstration of the powerful new technique of radio "occultation" that would become a key experiment on all planetary encounters in the future. Pickering was really impressed. Recalling the occasion with obvious pleasure. He said:

> We got into an argument with the Soviets over that [use of radio occultation data]. . . . Shortly after Mariner 5 went to Venus, there was an IAF meeting where the Soviets presented their claim that Venera 4 had landed but failed on impact. From this they calculated [a value for] the radius of the solid body of Venus—and Kliore [a prominent radioastronomy scientist at JPL] used his radio occultation data to show that they were wrong . . . the pressure of the atmosphere is what turned their

> machine off. They did not believe us until we showed them Kliore's data . . . then they accepted it and beefed up their modules to withstand the pressure.[39]

Although the Soviet spacecraft had arrived at Venus one day ahead of the American spacecraft, Pickering derived lasting personal satisfaction from having proved some of their data in error.

"Spacecraft occultation," the powerful new type of radio science data that had been demonstrated so convincingly on the Mariner 5 Venus encounter, had been made possible by the recent addition of a gigantic new radio tracking antenna to JPL's Deep Space Network.[40] The new, 210-foot diameter antenna at Goldstone was the largest precision spacecraft-tracking antenna in the world, and embodied much new technology that would eventually enable future planetary spacecraft to reach the very edge of the solar system. There was only one for now, but two more would soon be built, one in Australia near Canberra and the other in Spain near Madrid.[41]

Except for the "occultation" experiment, Mariner 5 had not made full use of the additional capabilities afforded by the great new 210-foot diameter antenna at Goldstone, since its earlier spacecraft were designed to match the existing 85-foot diameter antennas of the Deep Space Network. But all of that was about to change as NASA again set its sights on Mars and ordered Pickering to begin work on the design and construction of two new spacecraft to unlock Mars's closely guarded secrets during the Mars 1969 opposition. These second-generation Mariner spacecraft would be designed to make full use of the giant new antenna to speed up the return of imaging science and engineering data from Mars to Earth and enable future spacecraft to penetrate even further, into the mysteries of deep space.

Compared to earlier versions, the second-generation Mariners were bigger, heavier, and carried a suite of greatly improved science instruments mounted on a scan platform. They also carried an improved television system, a central computer that could be reprogrammed in flight, an upgraded data storage system, a multiple channel telemetry system, and a capability to return data from Mars at 16,200 bits per second using the new Goldstone antenna. Mariner 6 and 7 would be the first of a new family of planetary spacecraft designed expressly for deep space exploration.

Both spacecraft experienced a number of problems, but eventually reached Mars within a few days of each other, toward the end of July 1969. In the media, the Mariner 6 and 7 encounters of Mars competed for public attention with the high level of residual interest from the Apollo 11 manned landing on the Moon that had taken place a week earlier. There could be little doubt that the United States' space program was in full swing.

In reporting the two events, The *New York Times* again quoted the project scientists rather than the Laboratory Director, and focused its attention on the

NASA/JPL's new 210-ft diameter antenna at Goldstone, California: April 1966 (Photo: NASA/JPL-Caltech Archives, Photo number 332-9278Bc).

technical and scientific aspects of the two missions. There was little or no reference to the space race or the U.S. preeminence that had characterized JPL's major space events a few years earlier.[42] The scientists found the presence of light and dark areas, the absence of "canals," the presence of polar snow caps, and gigantic surface features like Nix Olympia of particular interest, and characterized the surface as more Earth-like than Moon-like. The science team generally expressed uncertainty over possible existence of life. One writer noted the contribution of the Goldstone 210-foot (64-meter) diameter antenna, observing that it had made it possible to receive the Mariner data from Mars at 16,200 bits per second. Without it, the 85-foot diameter antennas would reduce the data rate to a mere 8 bits per second, meaning that each picture would take up to 6 hours rather than 5 minutes to reach Earth.[43] Pickering's telemetry system had come a long way from its earliest days and he fully appreciated the advanced deep space communications technology, mostly developed at JPL, that had made it possible.

If the Mariner 6 and 7 images of Mars raised more questions than they answered about the origin of the planet and the possibility of its harboring some sort of primitive life form, they also served to stimulate interest in a follow-on mission to Mars, this time using an orbiting rather than a fly-by spacecraft. And the next opportunity for a mission to Mars would come as soon as 1971.

Earth (1969–1976)

The absence of William Pickering as a prominent personality in the media depiction of the Mariner 5, 6, and 7 encounters of Venus and Mars was symptomatic of the changes then engulfing the Laboratory. The NASA budget, on which those events and the Laboratory's very future in space depended, had begun to diminish. By 1969, JPL's budget had fallen to little more than half of what it had been in the peak year of 1967, and NASA was calling for further substantial cutbacks in programs and staff. Ironically, just as the Laboratory appeared to be ascending the learning curve it was rapidly descending the funding curve. Both these facts were of profound concern to William Pickering. What was to be done?

Pickering's dilemma was, of course, but a reflection of NASA's overarching problem with diminishing Congressional support for space projects. NASA's approach took the form of building public awareness for "technology transfer," or "spin-off," from space technology to the public sector. Pickering, however, took a slightly different route to preserve his beloved organization. Invoking the earlier agreement in the NASA contract that allowed JPL to seek funding from non-NASA sources, Pickering established a "civil systems" organization within JPL and set about looking for suitable projects and sponsors to support it. If JPL's expertise in the technologies of space was not fully extended in supporting the nation's space program then Pickering believed it could, or should, be brought to focus on solving some of Earth's most pressing social problems.

This topic had apparently been on his mind for some time. In December 1968 he had delivered a lengthy speech in Los Angeles titled "Science and the Urban Crisis-A Fragmented Dilemma."[44] Pickering attributed the failure of Washington, local governments, scientific, industrial, and financial communities to alleviate the urgent social problems now facing America's cities to "fragmentation of authority at the local level."

In the closing years of the 1960s, the nation was disturbed by unrest throughout every phase of its social structure—from rioting in the ghettos to divisiveness over the Vietnam war; from crises in education to concern over the economy. The prospects for the future, said Pickering, " . . . were bleak indeed, unless we get major social and cultural innovations during the next three decades." To do that we must marshal our very considerable resources in industry, finance education, and, most importantly, apply science and technology to our social problems. A technique that had proven most effective in developing our postwar missile and aerospace problems was known as "systems engineering." And, he believed, these techniques held promise for application in the field of social engineering also.

Pickering quoted Vice President Humphrey in saying that "Systems analysis can contribute importantly to community planning, police and firefighting services, educational systems, urban modernization, control of crime and delinquency transportation . . . effective use of natural resources and the elimination of water, air and soil pollution." But to be effective, these techniques must be initiated at the federal level. Otherwise, "fragmentation of authority at the local level" would eventually bring about their failure. "Since our urban crisis constitutes a challenge of overwhelming national urgency, science and technology must address themselves to this critical area if we are to make real progress in this century," he said.[45]

And so William Pickering set the stage for a new perspective on the proper function of his Laboratory, one that invoked a broader vision than in the past—a vision that looked inward toward Earth and its humanitarian problems as well as outward toward the planets and their intellectual challenges.

Increasingly aware of fading public support for the space program, and faced with the grim reality of a rapidly dwindling budget and what that implied for the future of JPL, William Pickering began to consider an alternative to space research for that portion of his unique technological resources not otherwise dedicated to supporting NASA's dwindling planetary exploration program. Perhaps the organization could support a research and development program in the civil sector as a contiguous, but entirely separate level of effort, from the traditional NASA programs that had characterized it in the past. But, as was to be expected, not everyone in the Caltech-JPL family agreed with Pickering's decision.

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Chapter 8

New Initiatives

The institutional turbulence that clouded JPL relations with Caltech through the 1960s took a new turn in 1969 when Lee DuBridge, Caltech's long time president, mentor, and staunch supporter of William Pickering and his management of JPL, moved away from the Institute to become science advisor to President Nixon. DuBridge had always maintained a strong belief in the mutual benefits of the JPL-Caltech partnership, despite NASA criticism of JPL's management practices and his own faculty's growing doubt of the continued value of Caltech's association with JPL.

With DuBridge gone, Pickering would have to start over to build a viable working relationship with the new Caltech president who, like Pickering himself, was a physicist turned top-level administrator.[1] Former Secretary of the U.S. Air Force Harold Brown brought a background in the management of complex relationships between big science and national security to his new position. Early in his tenure, Brown initiated yet another committee to look into JPL-Caltech relations. Chaired by Professor Norman Brooks of Caltech, the committee decided that despite strong arguments to the contrary from the Caltech campus, the JPL-Caltech partnership should continue. However, it was critical of Pickering's civil systems projects, perceiving them as "unfocused and taking the Laboratory into areas in which it had little expertise." It saw the need for more "social science" in JPL's field of experience and more campus involvement in such nonspace programs. Some administrative changes were made, but in the end the Brooks report did little to change the status quo at the Laboratory and Pickering continued to run his civil systems programs much as he had done before.[2]

When asked why he embarked on a civil systems program in the face of the receding NASA budget rather than cutting back on staff levels, Pickering replied:

> My answer was that I had a bunch of good guys working there and . . . where would I start cutting back and why? Also, if I had suggested much cutting back I would have had to argue with NASA. Another thing is that an organization of that size gets a lot of momentum behind it and it becomes an entity. You either keep it going or it disappears.

As for Caltech participation in JPL planning for non-classified and civil system programs, Pickering thought:

> There should have been a lot more [JPL] contact with the faculty than there was. The reason [that] there was not, was due to the difference in cultures. The faculty had the individual entrepreneur type of culture while JPL had the team engineering, schedule, and cost type of culture, and those don't work well together.[3]

In October 1969, about a year after his "Science and the Urban Crisis" speech, William Pickering addressed the Los Angeles Philanthropic Association on the topic of "Space and the Humanitarian."[4]

Since earliest times, humans had learned with great success to exploit the resources of Earth. But they had not learned how to "equitably distribute those resources so as to minimize human deprivation and poverty . . . Our social progress has not kept pace with our spectacular material accomplishments. This lag in social progress is the concern of the philanthropist," Pickering said.

How then, Pickering asked "Do we relate space technology to the problems of the ghetto and the minority groups who are seeking greater social participation?" Pickering believed that our social problems "may have remained unresolved because of serious and deep disagreement about the goals and priorities of our national and local welfare and educational programs." Pickering suggested that the space program might be able to help find solutions to these types of social problems by "contributing experience gathered in the planning and management of some of the most massive technical programs in history." Systems analysis techniques, for example, could be used to improve understanding of the interactions between component parts of an overall social system. Adjustments could then be made in such a way as to attain the desired level of performance.

Such a process would require the merging of the broad disciplinary talents of scientists, engineers, and managers. "If sociologists, economists, politicians, and others of the behavioral and physical sciences are integrated into the system team, a structured approach can be made on wide social front," he said. Pickering cited successful examples of the application of these techniques in municipal fire and police departments, school expansion and vandalism problems, transportation, and air-pollution control.

While cautioning against too-rapid technical development that could give rise to secondary problems, Pickering called for a strong systems-based effort to devise a more equitable distribution of our resources that would extend our growing affluence to all segments of our society.

The following month Pickering traveled to London, England, where he delivered addresses to the Royal Astronomical Society and the British Interplanetary Society on the recent Mariner 6 and 7 missions to Mars. Large audiences of avid space enthusiasts supported his lectures on both occasions. Afterwards, the Interplanetary Society presented him with a special memento of the occasion as a mark of respect and admiration. It was a quick trip and was followed a few days later by another visit to New Zealand to address the Auckland Institute and Museum, an institution representing the local branch of the Royal Society of New Zealand. There he spoke in general terms of the Society's place in the Space Age.

What had been a busy year for William Pickering ended on a slightly ironic note when the Los Angeles Philanthropic Association elected William Pickering as its choice for "Outstanding American for 1969" and marked the occasion with the presentation of a splendid gold cup. That William Pickering, still an avid New Zealander after 40 years in this country, should be regarded as an "outstanding American" is a measure of the wide respect and esteem with which his public figure was held at the time.

In retrospect, 1969 seemed to mark a watershed in Pickering's total involvement in the space program. At this point, the Laboratory had survived and was running well under his direction. It had effectively seized the lead in the race to space, a goal that had engaged most of his attention in the early years, and had accumulated significant demonstrable evidence of its success in the field of planetary exploration. As evidenced by his public discourses, his attention now broadened to include "inner space"—the transfer of new technologies and system engineering principles (hitherto devoted to space initiatives) to the problems of social intercourse, communication, and human well-being. These new initiatives did not of course act to the detriment of on-going space projects, but allowed him to maintain the Laboratory workforce in the face of diminishing NASA budgets while at the same time demonstrating useful and practical examples of the transfer of space technology to the public sector.

One might also speculate that Pickering looked to the future, five or six years hence, when he would of necessity retire from JPL at age 65 and be in need of projects to which he could devote his talents for the remainder of his productive life. Perhaps the field of "civil systems" would provide a rewarding and challenging domain for such an enterprise.

Pickering was under no illusion as to the problems associated with successfully transferring the esoteric technologies that had grown out of the space program to the more mundane but no less important problems of urban management, as evidenced by a paper on "Practical Considerations of Technology Transfer," that he presented to the American Astronautical Society in March 1972.[5]

Pickering perceived that the public had begun to wonder when the "feats of high technological adventure" that they had witnessed and paid for in the past would produce some obvious practical benefits in the scenarios of everyday life such as "the seething ghetto, the ailing economy, the troubled social environment." Despite the enormous body of new technology and management "know-how" that the government had accumulated over the past several decades, there had been no progress in the social scene, education, or economics that could match the advances made in knowledge of our space environment. Noting that NASA had gone to great lengths to make its activities and scientific data generally available he said, "the dissemination of technical information is not identical with technology transfer. . . . The broad dispersal throughout society of space-generated knowledge is not the same as marketing a technology to fit, or match, a well-defined need in the civil sector."

The technology had not been transferred from the government sector to the civil sector, Pickering asserted, because industry had not been enthusiastic about accepting "government-generated information" and because the technologists had not adapted to a "marketing posture." He believed that the three groups involved (government, industry, and the civic sector) must learn to understand each other's environments and approaches to pressing problems. Pickering said it would be necessary to employ the concept of systems management to disperse the new technologies on a broad basis across many interactive user groups. He gave examples of how JPL was applying these principles to several civil programs in which it was engaged—one in city government, the other in the field of urban transportation.

But to achieve permanent success in technology transfer Pickering believed that "we must somehow deeply involve the social scientist in the application of technology. We must learn to satisfy the human condition with technological means while coping with the hard-nosed realities of modern life."

The new perspectives that Pickering had advocated in the late 1960s began to materialize at JPL in the early 1970s. A civil systems program office had been established under the management of Dan Schneiderman and, by 1972, it was actively pursuing a variety of nonspace-related projects directed to finding working solutions to current problems in the civil sector.

The *Los Angeles Times* reflected this new face of JPL in a 1972 article titled "JPL: Building a Better Mouse Trap is its Goal."[6] It was a far cry from its earlier headlines depicting the awesome achievements of JPL's exotic space-voyaging machines. This was really down-to-earth material, but it was realistic and reflected Pickering's broadened view of JPL's mission. The projects in work at the time covered a wide range of disciplines and applications such as transportation, the environment, law enforcement, education, and biomedical engineering.

The largest and perhaps the most complex of the JPL civil projects was the People Mover—an experimental computer-controlled transportation system then being constructed on the campus at the University of West Virginia at Morgantown. The Personal Rapid Transit (PRT) project, as it was officially called, represented most of the issues that Pickering had addressed in his public statements. Funded by the Urban Mass Transportation Administration, a government agency; designed with Space Age technology and systems management by JPL; built by Boeing, a leader in the aerospace industry; and sponsored by the University of West Virginia—the PRT project appeared to be assured of a successful outcome. By linking all three of the university's campuses with a computer-controlled fleet of up to 100 small passenger-vehicles moving over a network of elevated guideways, the system was intended to ease the students' problem of inter-campus commuting. Scheduled for completion in 1973, the PRT was viewed as the prototype for the development of similar systems in other areas of the country.

It should have been a success, but Pickering's hopes for a successful project were dashed when the project ran years over schedule and costs to complete the project far exceeded original estimates. Frustrated by precisely those factors that he had warned about, Pickering pulled the Laboratory out of the PRT once the initial development, for which JPL was obligated, was underway. Announcing the decision in his second "State of the Laboratory" message, Pickering told his staff "the Morgantown Project is being scrapped. I think that we can be very thankful that we got kicked out of that program. We got kicked out of it for the right reasons, because they weren't going to do the program correctly . . . and so we came to a parting of the ways."[7]

Eventually the PRT project was completed successfully without JPL's participation.[8]

In other projects, Schneiderman's scientists and engineers adapted the Laboratory's wide range of expertise to civil sector problems in the fields of air pollution abatement, law enforcement, education, and biomedical technology.

In all of these projects, Pickering insisted that the Laboratory's role was to work with sponsors to conceive and develop applications and to then make them available on a nonselective basis for manufacture by industry.

Pickering's civil systems program included another major project known as the Four Cities Program.[9] Begun in 1971, it was intended to explore and demonstrate new ways of linking federally-sponsored new technology with local government. It was implemented by assigning a science and technology advisor to the staff of the city manager for each of the four major California cities in the program. The advisors were drawn from major aerospace contractors in the region. JPL coordinated the program, evaluated the results, and provided technical guidance and support where necessary. Each science and technology advisor was given a mandate to study the technology transfer process, familiarize the city government with new technologies relevant to its problem areas, and look for market opportunities for their company. Feedback from these experiences in local government would, it was thought, benefit the aerospace companies by affording them greater awareness of social issues within their fields of interest.

At the end of the two-year period the evaluation report was optimistic, but fell far short of demonstrating the viability of the technology transfer process that Pickering was advocating.

Disappointing though the outcome of the Morgantown and Four Cities programs may have been, Pickering believed he understood the reasons for the adverse results and continued to advocate his ideas for applying the unique resources of his Laboratory to other problems of modern society.

Pickering's speeches in 1973 addressed those issues rather than more direct space-related topics that had characterized his discourses over the past decade. On two occasions he addressed branches of the IEEE; one in Boston, Massachusetts, the other in the San Gabriel Valley, California. Under the title "Reflections of the 1960s" he told the Boston Massachusetts branch of the IEEE that "in the future, the technologist may be dealing more with social problems—those of urban sprawl transportation, the environment, troubles of the people. He will be confronting the quality of life more than the reliability of an electronic circuit. Society will be his customer more than government." He went on to characterize the response of society as more Darwinian (that is, more evolutionary) than the Newtonian (or deterministic) environment that they were used to. The engineer and scientist of the future will have to deal with the "formless patterns of politics, economics, sociology, and psychology," he said. Warning that it would nevertheless be difficult to adapt to these changing motifs, he said that it would become more and more necessary in the decades to follow.[10] Similar themes ran through his address on "Technology in the Waning Century" to the San Gabriel Valley Branch of the IEEE.

Pickering's ideas, opinions, and experiences with technology transfer received an airing at the highest level when he testified before the Senate Commerce Committee's Subcommittee on Science, Technology, and Commerce in September 1973.[11] There, Pickering traced the growth of JPL's interest in transferring its intrinsic skills in aerospace technology to the civil sector and described instances where JPL had found productive areas for the application of those specific technologies that we saw earlier: medical engineering, the Four Cities program, transportation, etc.

Based on his experience in dealing with problems in the public sector, Pickering offered the following observations. First, technology transfer is a slow process—it takes a long time to understand the social, legal, and economic aspects of a technological solution to a civil sector problem and existing funding was not commensurate with that fact—and in the definition process there is a diffusion of responsibility and decision-making authority (for introducing new technology into existing systems). Also, there is distrust between public officials and technologists (regarding the advantages of introducing new technology into existing systems) and no mechanism exists to make civil sector technology that had been developed in federally-funded laboratories available to industry and commerce.

He offered similar comments with regard to federal programs of technology utilization and transfer with an additional, rather scathing criticism. "Most federal sponsors outside of NASA, DOD, and AEC either do not understand the research nature of a technical problem or they do not appreciate the problems of application. However, NASA and DOD also do not understand the social content of many national problems," he said.

Typical of Pickering, it was an intense, credible, hard-hitting elucidation of the subject based on his unique, up-to-date experience with real-life situations. Among those present, there was simply no one to challenge either his facts or the conclusions he drew from them. He obviously caught their interest for he was called upon by one of the Senators to elucidate further on his testimony relative to establishing a network of Regional Technology Applications Centers.[12]

By 1974, biomedical projects had become the largest part of the JPL civil systems program. In his annual "State of the Laboratory"[13] address in 1974 William Pickering talked of "the possibility of forming a medical sciences laboratory at JPL . . . with participation of the campus and some of the research hospitals in the area." The purpose, as Pickering explained, was to "exploit the science capability at campus, the engineering capability at the Laboratory and the medical research at some of the hospitals." Funding would be partly private and partly government and when it reached maturity the new medical laboratory would be "spun off." Feasibility studies were underway he said and both he and the president of Caltech believed "it is a good thing to do and we are hoping it will come about."[14]

Early in 1971, the Caltech sponsored a lecture series on "Systems Concepts: Contemporary Approaches to Systems." At this series, William Pickering presented a paper titled "System Engineering at the Jet Propulsion Laboratory" in which he traced the evolution of JPL to a systems engineering organization from its earliest times with the U.S. Army contracts to the present time. He explained how the Sergeant program represented a classical systems engineering task and how the experience gained therein migrated to JPL's lunar and planetary projects after it transferred to NASA in 1958.

Systems engineering required the optimization of the overall end-to-end system rather than the suboptimization of the individual elements of the system. Such a process was accomplished in a sequence of discrete steps beginning with a clear definition of the ultimate objectives and ending with an implementation plan. For lunar and planetary projects—which involve a spacecraft system, a tracking and data system, and a mission operations system—these steps became of critical importance and were followed meticulously in each case. He gave details of how each system was broken down into its functional elements to eventually reach a level of complexity commensurate with a single element. The functional boundaries of individual elements were established and controlled by defined interfaces.

Designing for success, testing for performance, mission planning, and project management were the key factors in carrying out a successful space mission and Pickering explained each of them in considerable detail.

Pickering viewed the practice of engineering as more concerned with management, information, and good judgment rather than with mathematical analysis. Wherever possible mathematical techniques were used to solve optimization problems, but many decisions had to be made with little or no quantitative information and for these cases good judgment and experience were required.

The Laboratory was now exploring the viability of a systems approach to solving problems in the civil sector and he gave examples in the areas of mass transportation and urban health systems.[15]

Important and newsworthy though it was at the time, the civil systems program generated little or no impact on the Laboratory's ongoing space programs and that was how Pickering intended it to be. He hoped to build up sponsorship for some of the civil systems programs to the point where they would be essentially self-supporting.

Meanwhile the planetary programs office, funded by NASA and directed by Pickering's former student Robert Parks, pressed on with the two planetary projects of immediate concern: a mission to Mars planned for the 1971 opportunity and another to Venus and Mercury planned for launch in 1973.

Space

The 1971 Mariner mission to Mars was NASA-JPL's most ambitious planetary project yet and the data it returned from Mars compelled scientists to reconsider long-held opinions of the origin and subsequent history of that intriguing planet.

The primary objectives of the 1971 Mars mission were to search for evidence of life and to gather data that would aid the design of a later Mars lander mission that would extend and intensify the search from selected locations on the Martian surface. To this end, each of the two spacecraft carried a comprehensive suite of scientific instruments that included a high-resolution television imaging system designed to photograph up to 70 percent of the entire Martian surface. Two of the country's most prominent planetary scientists, Carl Sagan of Cornell and Bruce Murray of Caltech, headed the Mariner Mars Imaging Team. The sophistication of the new spacecraft was matched by a complementary enhancement of the data collection and data processing capabilities of the worldwide deep space network (DSN) and the Space Flight Operations Facility at JPL.[16]

Now well experienced in the designing, fabricating, and testing of planetary spacecraft, Mariner teams prepared two identical spacecraft for launch during the Mars opportunity in May 1971. The first spacecraft, identified as Mariner 8, was lost when the Centaur second stage launch vehicle failed a few minutes after launch.

Acutely aware that the Soviets were also launching to Mars in this window of opportunity, Pickering agonized over loss of Mariner 8. He would have known that the Soviets had hastily prepared a Mars orbiter spacecraft which they called Kosmos 419, specifically to preempt NASA-JPL's Mariner attempt to be first into orbit around another planet.[17] He probably did not know that the Kosmos 419 had been launched from the Russian launch site at Baykonur the day following the Mariner 8 launch and that it too had experienced a failure during the launch sequence. A week or so later, when the Soviets launched two more Mars-bound spacecraft both heavy Mars landers and both injected successfully onto a Mars intercept trajectory, he would have been most apprehensive about the outcome of the Mariner 9 mission.

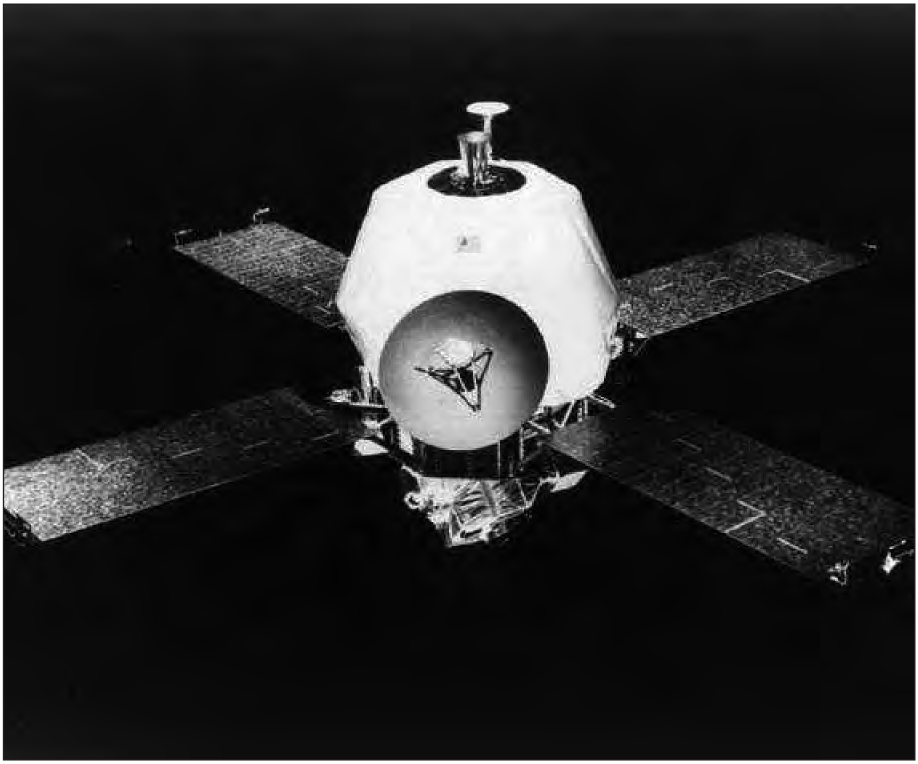
Pickering would have observed its successful launch and injection onto a near perfect trajectory to Mars on 30 May 1971, with a high degree of relief. As far as he could have known, based on meager progress reports coming from Russian sources, the Soviet Union then had three spacecraft en route for Mars—the U.S. had one. Mariner 9 thus represented Pickering's only opportunity to maintain the preeminent position that he had struggled so hard and for so long to achieve for the U.S. For Pickering the "space race" was still very much alive and he perceived the Soviet challenge as a threat that he was personally obliged to resist.[18]

By the time the spacecraft arrived at Mars in early November, an immense dust storm completely covered the planet, obscuring the vital Martian surface features that were a prime objective of the mission. According to observations from Earth-based telescopes it was the most severe dust storm ever recorded in terms of density, area, and persistence.

The first news reports were not hopeful. "Dust Storm Smears Mariner Photos of Mars," headlined the *Los Angeles Times*. The 5-mile high cloud of dense reddish-yellow dust appeared to be moving at about 20 to 30 miles per hour across the Martian surface and completely eliminated any possibility of photographing the surface features beneath. "While the storm may hinder mapping and photography of the surface features for a time, it will offer an excellent chance to study one of the great dynamic features of the planet," Pickering said.[19] The next day Mariner 9 again executed a flawless maneuver to slow down and enter a precisely-controlled orbit around Mars and in doing so became the first spacecraft to orbit a planet other than Earth.

By this time mission controllers and science teams working together had come up with a new strategy. Making use of the innovative reprogrammable computers carried by the spacecraft, they would defer the original mission plan that called for systematic mapping of the Martian surface to allow time for the dust storm to clear. Meanwhile the imaging and remote sensing instruments would be reprogrammed to allow scientists to conduct observations of the storm-related phenomena as the opportunities arose. Pickering quickly endorsed the plan and the necessary commands for in-flight reprogramming of the spacecraft computers were transmitted from the DSN to the distant spacecraft.

Meanwhile, the two Soviet spacecraft steadily approached their appointment with destiny at Mars. Back at the Soviet mission control center, Russian scientists and controllers must have watched with horror as JPL reports of the huge dust storm appeared regularly in the media around the world. They surely realized that the two Soviet spacecraft with their fully automated landing and science data gathering sequences would be extremely vulnerable to the deadly effects of the dust storm then pervading the Mars atmosphere and that there was nothing they could do about it. Their premonition proved to be justified. In what must have been a heart-wrenching event for the Soviets, Mars 2 suffered



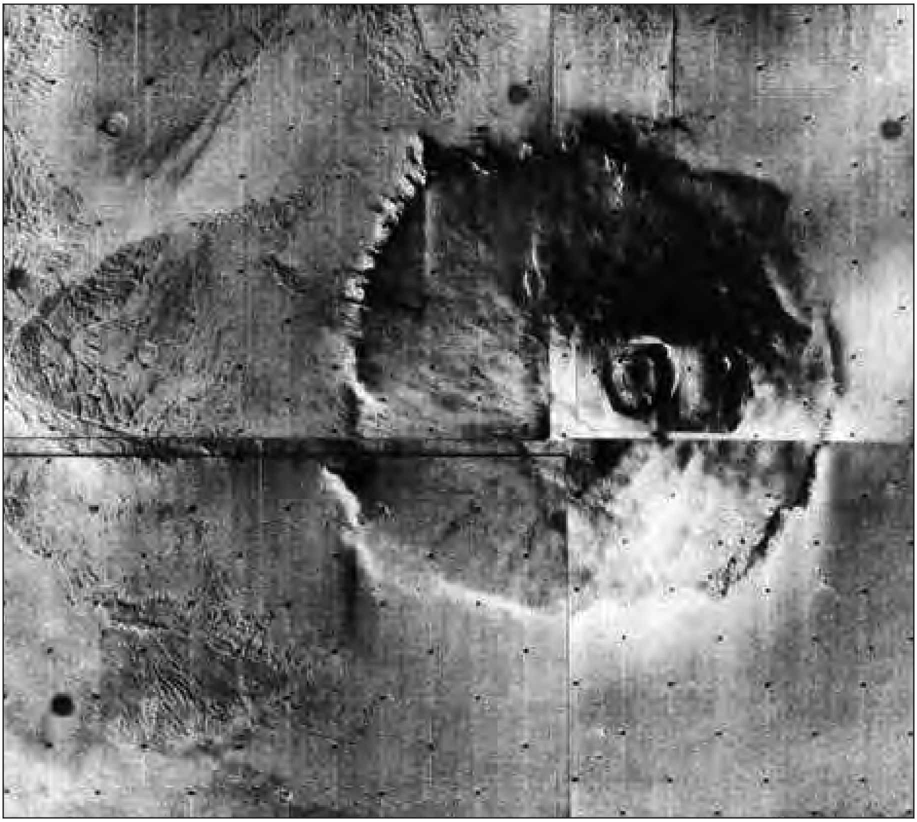
Mariner 9 spacecraft (Photo: NASM Archive, Image 71-h-717).

a malfunction as it entered the Mars atmosphere for the final landing sequence on 27 November 1971 to become "the first human-made object to make contact with Mars."[20] Although "make contact with Mars" sounds rather like a prosaic way of saying "crashed on Mars," it nevertheless represented a very significant achievement at the time, even if it was not the successful outcome that its designers intended. However, the second spacecraft, Mars 3 did perform its preprogrammed landing sequence successfully. It touched down on the Martian surface on 2 December 1972 to become "the first human-made object to perform a survivable landing on Mars." Soviet hopes for further success were dashed however when the first TV transmission from the spacecraft, showing only a "gray background with no detail, abruptly ceased after 20 seconds."[21]

How Pickering would have empathized with those Soviet scientists, recalling his desperate days with the first Ranger missions when a failed electronics device doomed the entire mission to failure, despite its considerable achievements in reaching that point in the mission. It should be recorded, however, that "despite the failure of the Lander imaging system, the two Russian orbiters carried out a full cycle of scientific experiments until contact with both was lost in July 1972."[22]

In mid-January 1972, the Mars atmosphere began to clear and spacecraft controllers initiated the surface mapping sequences, periodically synchronizing the spacecraft orbit to coincide with the view periods of the giant new 64-meter diameter antenna at Goldstone. An avalanche of science and imaging data began to flow regularly from Mars to Goldstone and to the scientists at Pasadena. The astounding images and other science data afforded scientists an entirely new appreciation for the genesis and development of the planet. A giant volcano, Olympus Mons, that dwarfed anything seen on Earth; an enormous canyon almost as long as the U.S. is wide and over six kilometers deep in places; braided channels that looked as though they were formed by flowing water and resembled terrestrial river valleys; images of the two moons of Mars, Phobos and Deimos; and radio science studies of the composition of the Mars atmosphere were just part of the cornucopia of new science that Mariner 9 delivered to Earth in the ensuing months.

The spacecraft continued in full operation until late October 1972 when, with its gas supply depleted and its attitude stabilization system disabled, the spacecraft began a slow uncontrolled descent to eventual destruction in the Mars atmosphere. The Mariner 9 mission was over. It had fully met and even exceeded its mission objectives and survived more than a year beyond its original design life. To Pickering, those facts indicated that his Laboratory had finally ascended the learning curve. As he always knew it would, it had learned how to build planetary spacecraft. As far as Mars exploration was concerned, he was satisfied that the U.S. had reasserted its premier position. For him personally that perception was very satisfying indeed.[23]



Nix Olympica (Photo: NASM Archive, Image 72-h-141).

Earlier that year he had prepared an article for a local newspaper titled "Odyssey to the Rim of the Solar System," in which he discussed Mariner 9 and its objectives and talked of future missions to Venus, Mercury, and Mars with landings on the Martian surface to search for evidence of primitive life. He also envisioned long duration missions that would use a new technique called gravity-assist to leapfrog from one planet to the next and thereby enable a spacecraft to eventually reach the very edge of the solar system and even beyond. Such a mission, already under study at JPL, was called the Grand Tour.

He predicted:

> Missions to the planets, and particularly to Jupiter, will tell us a great deal about the origin and evolution of our solar system and the inception and development of the life forms we know on Earth. During the remainder of this century, the thrust of man's probing intelligence will reach out to the very edges of the solar system.[24]

By April 1972 when he delivered "Thirty Trillion Bits" to a combined meeting of the AIAA/IEEE/SAMPE[25] in Salt Lake City he had a wealth of impressive data on the Mariner mission to share with his audience. Mariner 9 traveled approximately 247 million miles in 168 days to arrive at Mars on 13 November within 38 miles of its aiming point and within 2 minutes of the estimated arrival time. After the dust cleared from the Mars atmosphere eyes, Mariner 9 mapped 90 percent of the Mars surface and transmitted at least 5,700 pictures at approximately 5,250,000 bits each. In thousands of photographs Mars was revealed as a dynamic evolving world with structural features never seen before from Earth—features that included indications of recent volcanic activity, erosion processes apparently related to once flowing water, and vast stretches of sinuous canyons. Data returned from the other scientific instruments would enable significant revision of the scientific model of the planet and ranging and motion studies would aid in refining the geometry of Mars celestial mechanics environment.

"The Mariner 9 mission," he said, "is expected to return 12 to 15 times as much scientific data as all previous planetary missions combined."

Looking to the future, Pickering said that "although Mariner data is adding intriguing new dimensions to our knowledge of Mars, it is extremely unlikely that the existence of life forms on the planet can be determined from orbit. That demonstration must wait such missions as the 1975–1976 Viking project to orbit and land two spacecraft on the surface of the planet."[26]

In March of 1973, Pickering initiated what was to become a regular event—the Director's annual "State of the Laboratory" address to the entire Laboratory staff. In this, the first of its type, he reflected the austerity of the times and the impact on the Laboratory's activities caused by the hiatus in NASA's planetary program. He spoke of receding budgets, diminishing staff levels, relations with NASA and Caltech and industry, and the vulnerability of JPL to criticism and even serious cutbacks. While he saw a prospect for the nation to "continue a civilian space program of considerable size," but he warned that "the era of technological laissez-faire was at an end."

Concerned that in some areas JPL had acquired a less than desirable reputation as an expensive organization with which to do business he said, "we must make a strong effort to correct the gold-plating image that JPL has unfortunately acquired," and cited the current, fixed-price Mariner Venus-Mercury project as a significant step in that direction. He saw good prospects for the future of non-NASA projects: biomedical engineering, energy, environment and transportation, and public safety were promising fields. He concluded by emphasizing the need to consider costs at every level in the Laboratory's activities. "The future is not exactly ready and waiting as it was in 1958 . . . The problems are there but the money is harder to find. This time we must work to get it."[27]

In terms of NASA funding, the 1973 Mariner mission to Mercury and Venus epitomized the austerity of the 1970s and Pickering's concern with cutting costs. If the Laboratory was to survive in this environment, it was imperative that the costs to NASA of new planetary missions be reduced to an absolute minimum. That Mariner 10 was so unequivocally successful, both financially and scientifically, was a testament to the ingenuity, skill, motivation, and experience of the NASA-JPL teams that brought it to fruition and the science teams, most notably the imaging team led by eminent planetary scientist Bruce Murray of the Caltech, that gathered the science data and interpreted it.[28] It was at once a product of the call to "do better with less" that Pickering had issued in his first "State of the Laboratory" address and a demonstration of how the Laboratory could respond to NASA's straightened circumstances to keep the planetary exploration initiative alive and productive.

Launched at the end of 1973, Mariner 10 reached Mercury in March 1974 after a close flyby of Venus during which it made important science observations including imaging of that planet and made use of Venusian gravity to assist its flight to Mercury. It made three flybys of Mercury collecting, among other scientific data, some 2,300 detailed images that showed the surface of Mercury to be more Moon-like than Earth-like. The science data from Mariner 10 exceeded the scientists' greatest expectations.

But Mariner 10 could boast more than its scientific accomplishments—it also represented a number of major advances in deep space technology. It demonstrated, for the first time, the exquisitely complex technique of gravity assist: using the gravitational field of one planet to modify the trajectory of a spacecraft to enable it to reach another. Making use of all three giant 64-meter diameters of the DSN it returned data from Mercury at the unprecedented data rate of 118 kilobits per second and, using dual frequency radio transmissions from the spacecraft to Earth, it enabled radio science observations and demonstrated the improved efficiency of higher frequency radio communications from deep space. Finally, it was the first spacecraft to perform multiple encounters with a target planet.[29]

Long and careful planning enabled the project to meet its cost and performance goals and the cost-plus-fixed-fee contract with the Boeing Company that built the spacecraft showed that the Laboratory could now successfully manage a large, schedule-intensive contract with industry. In an overall sense, Mariner 10 represented the culmination of more than a decade of the Laboratory's evolving expertise in all aspects of the technology required to execute a successful planetary mission in deep space. But it was also the last of the Mariners—and the last of an era.[30] Planetary missions of the future would be bigger, more costly, more complex, and their management and direction would no longer be carried out by the close-knit group of brilliant, egocentric experts that William Pickering had assembled, inspired, nurtured, and defended throughout his years at JPL.

Pickering remained intensely interested in future planetary missions, but now he increasingly left the public presentations and recognition of the Laboratory's space program to others and devoted more and more of his personal attention to the issues of technology transfer and the problems of Earth rather than those of space.[31]

Society

The depth of William Pickering's evident concern for the well-being of society as a whole—perhaps more correctly, civilization as a whole, since most of what captured his interest pertained to the most advanced societal groups—is exemplified by a list of his public addresses in the last two years of his tenure at JPL. Among list of titles:

January 1974: New Challenges for the Engineer: "The urgent need is to improve the efficiency of existing energy-consuming processes and to develop new techniques that will make the nation essentially independent of international politics and able to pursue uninterrupted programs of orderly social development."[32]

January 1974: Improving the Environment: "It is mandatory that we recognize the urgent need to commit all of the high technical skills developed for aerospace applications into improvement of the environment."[33]

May 1974: Understanding the Universe: "Modern civilized man's only hope may be to learn to understand his universe [and to] create a society flexible enough to cope with an environment that changes overnight."[34]

May 1974: Digitizing the Social Conscience: "We must look to science and engineering to nurture a renaissance for our society if we are to enter the new century with clear prospects for survival."[35]

May 1974: Toward a New Society: "Science and technology will be needed even more than in this century or else the quality of life and our society will sharply decline."[36]

June 1974: Inheriting the Future: "Cybernetics alone cannot ensure survival . . . Your ultimate challenge will be to control, even eliminate the threat of growing scarcity of raw materials and the increasing rate of consumption by a burgeoning population."[37]

November 1974: The Next One Hundred Years: "The grim irony is that the gap between the rich and the poor nations is continually widening, despite our growing technological and communications capabilities . . . The evidence is increasingly clear that, in the next one hundred years, we must progress from selfish independence to cooperative interdependence, a condition where we substitute the regional blindness of nations for the overwhelming good of the race."[38]

In June 1974, Pickering prepared a proposal for submission to the Committee for Space Research (COSPAR), a prestigious international body dedicated to promote, on an international level, scientific research in space with emphasis on the exchange of results, information, and opinions. The proposal called for the establishment of "An International Solar System Decade" that would run from July 1976 through June 1986.

Just as the First Polar Year of 1882, the second Polar Year of 1932, and the International Geophysical Year of 1954 had reflected the scientific interests and observational capabilities of their times so, said Pickering, the International Solar System Decade (ISSD) could make use of presently available rockets, spacecraft, and advanced data acquisition techniques to support an international effort "directed at a better understanding of our whole solar system." In December 1974, in letters to Roald Z. Sagdeev of the Soviet Academy of Sciences and to G. Contopoulos, General Secretary of the International Astronomical Union, Pickering sought their support for COSPAR sponsorship of his proposal but to no avail.[40] "That [idea] never went very far—it was an example of my naiveté about political motives." But the idea was not dead and he did get another opportunity to pursue the topic of international cooperation in space.[41]

As 1975, Pickering's final year of tenure at JPL, wound down, many of the non-NASA organizations with which he had been associated during his long career recognized his contribution to their various areas of interest with nominations for their highest honors, or awards. The Collier Trophy, L. M. Ericsson Award, Marconi National Fellowship, George C. Marshall Medal, Delmer S. Fahrney Medal from the Franklin Institute, the WEMA Medal of Achievement, and Advancement of Engineering Award from University of Southern California were examples in the fields of aeronautics, astronautics, or aerospace technology. On each occasion, his acceptance speeches focused on themes of society and technology—topics that dominated his thinking at this period.

His contribution to science and regard for his greatly admired public figure in New Zealand had not gone unnoticed either. On 26 November 1975 he was immensely gratified with the notification that Her Majesty Queen Elizabeth II of England had graciously invested him as Honorary Knight Commander of the Most Excellent Order of the British Empire. The prestigious distinction recognized his "Contributions to Science" and carried the abbreviated nominals K.B.E. The "Honorary" prefix signified his formal, non-British citizenship. By tradition, the title would be conferred on the Queen's birthday in June the following year by her representative in New Zealand.[42]

Toward the Future

Two major new NASA initiatives, Viking and Voyager, dominated the closing years of Pickering's tenure at the Laboratory. Both had a long period of gestation within the NASA organization, but by 1975 both had been defined, approved, funded, and assigned to NASA centers for implementation. Viking, a major project designed primarily to search for biological evidence of life on the surface of Mars would be managed by the Langley Research Center in Hampton, Virginia. Voyager, a derivative of an earlier concept known as the Grand Tour, was an ambitious attempt to explore several of the outer planets in sequence, beginning with Jupiter, and would be managed by JPL.

The Viking launches, there would be two of them, were planned for the August-September Mars opportunity in 1975, while the two Voyagers were scheduled for the August—September opportunities in 1977. Both missions would depend upon JPL's DSN for their tracking and data acquisition support.

While his Flight Project Managers began to implement the daunting tasks of bringing these awesome new missions to reality at JPL, Pickering began to introduce related issues to his public audiences. Startling titles such as "Homo Sapiens; One of a Kind?," "Is there Life on Mars?," and "Extra-terrestrial Life: The Search Begins" were typical of his speeches in this period. In these talks, which attracted considerable public attention, Pickering used slides from recent Mariner missions and his redoubtable knowledge of physics, chemistry, and astronomy to make a case for justifying a search for elementary life forms on Mars. "If you accept the evidence that more favorable conditions might have existed on Mars in the past, it is altogether possible that life forms might have flourished at that time, and later learned to adapt to the present austere environment. . . . Considering the amazing variety and durability of life forms found on Earth, it seems improbable that we will detect none on Mars. It may be elusive and exist in extremely subtle variations but, if it is there, we should be able to find it." He followed these intriguing ideas with a description of the Viking Mars mission and told of the ways in which it would, hopefully, help to resolve questions that they engendered.

Looking beyond our solar system, he said, "The search for extraterrestrial life and advanced civilizations has largely been centered on radio astronomy techniques because of the enormous distances involved." He gave credence to the continuation of current programs to pursue the search, by citing new discoveries in the field of cosmological physics and chemistry.

Recent studies of intergalactic processes, he suggested, showed that "it is not unreasonable to presume that, given similar circumstances, the same kind of events that led to the origin of life on Earth are also occurring elsewhere in the universe. Astronomers are showing us that molecules identified in interstellar space are the progenitors of the protein and nucleic acids that are the basis to Earth life."

Turning to the philosophical implications of his visions he observed that "if one day we find traces of life on Mars, Titan, or in the atmosphere of Jupiter, the implications to human civilization will be enormous. Philosophy, religion, science, technology—all of the human arts—will have to be recast in a new image. The old ways will be suspect more than ever before. Man must then confront his dilemma; he must acknowledge the unacknowledgeable—we are not alone in the universe. Somewhere out there, the inevitability of other advanced, perhaps far superior, civilizations would become manifest. "Perhaps," he surmised, "nature did not throw away the pattern when she conceived us where nothing had existed before."[43]

In this pervasive environment, the huge Viking and Voyager projects moved steadily forward, dominating the work structure and straining the Laboratory, while the four civil systems programs—energy and environment, biomedical engineering, transportation, and public safety—continued to claim a small but vital part of Pickering's interest and attention.

At the end of 1975, just before his 65th birthday, Pickering called his supervisory staff together in the large new auditorium of the La Canada Intermediate School to hear what would be his final "State of Laboratory" message. By then it was generally known that he would be retiring within the next month or two and, in fact, plans were already being made to mark the occasion with appropriate farewell functions.

If Pickering harbored any feelings of nostalgia or regret on this occasion, they were not apparent in his very upbeat address. It was all "business as usual" for now. "Today I am not going to talk about retirement; that's several months off and I'll worry about it later," he began. He spoke of recent NASA action that confirmed JPL's primary role in planetary and lunar unpiloted missions and how that fact assured the future of the Laboratory. Current NASA programs that included Viking and Voyager were making good progress. He touched on JPL involvement in some automated Earth orbital missions and JPL's future interest in an active energy program for the Energy Research and Development Agency (ERDA). The work in civil systems had expanded to include a waste-water treatment plant and the Department of the Interior was looking to JPL for help with new technology applications to coal mining. This non-NASA activity continued to cushion the effect of inevitable reductions in NASA programs, he said.

He concluded on a high note:

> The Laboratory is in good shape with NASA . . . it has an opportunity to grow its activities with ERDA and other government agencies. If we continue to maintain an excellent staff, our opportunities for the future are just as good as they have been in the past. They are oriented in a somewhat different fashion than they were 10 years ago. But they are there and it is up to us to take advantage of them.

These were to be his last words as Director to the people with whom he had come so far, and whose standards of performance, dedication, and work ethic he valued so much and had defended so strongly. The essential elements required to carry the Laboratory toward the future were all there—it would be up to others to nurture and sustain them.

William Pickering turned 65 on 24 December 1975 and, in doing so, became subject to the Caltech institutional limitations on the maximum age for top-level administrators. Since the Caltech effort to find a successor had not yet run its course, Pickering agreed to remain in office a further three months, until 31 March the following year, to allow that to be completed.

Pickering regarded the situation with some equanimity. He recalled:

> So I had to retire . . . but having been around the lab for more than 20 years or so, I was beginning to feel myself, that it was time [for me] to go, and [for Caltech] to bring in new blood. Once the general concept had been established that I was going to leave shortly, the question of who would succeed me came in. . . . There was never any serious consideration of picking someone from the lab to succeed me, but rather getting someone from outside, particularly someone with a technical administration, governmental-type of background . . . that was the concept.[44]

JPL planned to bid him farewell with two formal social events in March 1976. These events were to be followed a few days later by a farewell reception at NASA Headquarters in Washington, DC. The AIAA also planned to hold a special "Thank You Bill Pickering" function, a few weeks later still in Los Angeles on 23 April.[45] The next few months it appeared would be a busy time for both Muriel and William.

As the prospect of his retirement from JPL and the NASA space program moved ever closer to reality, Pickering considered what he might do with the rest of his life. At 65 he was at the peak of his powers, physically fit, and mentally vigorous. His outstanding technological acumen and his unique achievements in space exploration had brought him worldwide recognition. His distinctions, awards, and honors were legion. His enviable record offered an open door to many options in industry, government, and academia. But, considering his roots, he inevitably felt drawn back to academia and the long-standing agreement he had made 20 years earlier with Lee DuBridge, former President of Caltech. DuBridge was long gone from Caltech by then, but Pickering held no doubts that the incumbent president, Harold Brown, would honor the agreement and allow him to return to Caltech as a full professor of electrical engineering if he so desired.

Pickering recalled the circumstances:

> When I had been active in the department in the 1940s . . . electrical engineering meant big motors, transformers, and generators.

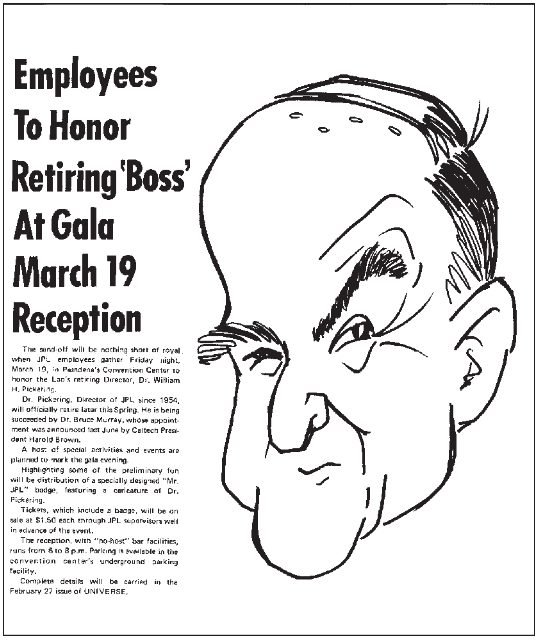
> So I go back 20 years later, and what do I find? There is no power engineering of any sort—everything is electronics or computers . . . So I thought about it a bit and thought that maybe I could work up a course that is a little bit on the fringes . . . and just about that time this guy from Saudi Arabia showed up!"[46]

Caught up in a whirl of social events related to the impending retirement, Muriel and William found little time to contemplate the impact to their well-ordered lifestyle that severance of William's connection to JPL would bring about. In Pickering's view, however, it was to be "retirement from JPL" and not in any sense retirement from an active and productive life, as future events would soon show.

The time passed quickly and soon enough the long-planned series of official retirement events began. On Friday, 19 March, several thousand employees, spouses, and guests gathered at Pasadena's spacious Convention Center to bid farewell to Dr. and Mrs. Pickering. The popularity of "Mr. JPL" buttons, worn with obvious delight by many of the attendees, served to heighten the political convention-like effect. Highlights of the evening included the unveiling of a magnificent near life-size portrait of William Pickering, a work by well-known artist Art Beeman who was also a long-time JPL employee.

NASA paid tribute to William Pickering the following week in a formal reception at NASA Headquarters in Washington, DC. The formalities included speeches and gifts (of which there were a considerable number) from the NASA executives and from the Center Directors. Among the gifts he received that evening were two of unique historical significance. One was the spare transmitter from the Explorer 1 Earth satellite from 1958 donated by the Kennedy Space Center; the other was the camera from the Surveyor 3 spacecraft that had soft-landed on the Moon in April 1967. Retrieved from the lunar surface and returned to Earth by Apollo 12 astronauts in November 1969, the camera had been the subject of an intense evaluation and found to be in excellent condition. Pickering was most impressed.[48]

Dr. and Mrs. Pickering with the near life-size portrait executed by Art Beeman of JPL, 19 March 1976 (Photo: JPL Photo number P16519B).



Employees To Honor Retiring 'Boss' At Gala March 19 Reception

The send-off will be nothing short of royal when JPL employees gather Friday night, March 19, in Pasadena's Convention Center to honor the Lab's retiring Director, Dr. William H. Pickering.

Dr. Pickering, Director of JPL since 1954, will officially retire later this Spring. He is being succeeded by Dr. Bruce Murray, whose appointment was announced last June by Caltech President Harold Brown.

A host of special activities and events are planned to mark the gala evening.

Highlighting some of the preliminary fun will be distribution of a specially designed "Mr. JPL" badge, featuring a caricature of Dr. Pickering.

Tickets, which include a badge, will be on sale at $1.50 each through JPL supervisors well in advance of the event.

The reception, with "no-host" bar facilities, runs from 6 to 8 p.m. Parking is available in the convention center's underground parking facility.

Complete details will be carried in the February 27 issue of UNIVERSE.

"Mr. JPL" button created by JPL caricaturist Bill Stephenson for the Pickering farewell event, March 1976 (Photo: JPL Archives, Universe, vol. 16, no. 14, 13 February 1976).

The event was a fitting tribute from the administration to one who, since long before most of its current members were in office, had played a major part in bringing NASA to its present preeminent position in humankind's efforts to explore the solar system.

Pickering's last formal appearance at JPL took place on 31 March 1976 at a ceremony before a full gathering of JPL employees on the beautiful central plaza now resplendent with a fountain, colorful flowering planters, mature trees, and many varieties of carefully tended shrubs. President Harold Brown of Caltech formally introduced Dr. Bruce Murray, well known to JPL scientists for his leading role on JPL's planetary imaging teams and former professor of planetary sciences at Caltech, as the new Director of Jet Propulsion Laboratory.[49]

It was over. After more than 20 years of leading the organization that he cherished almost as his own—which to some extent it was since he had, against all odds and opposition, made it in his own image—he had finally handed it over to someone else. Where would it go and how would it fare—well, only the future would tell but of this he was certain: he would not be a part of it.

That day, the *Los Angeles Times* paid an eloquent tribute to William Pickering. Writing that he "led the team whose talents and accomplishments brought the Moon, the planets, and the stars within man's reach." The *Times* continued, "Under Pickering's leadership, JPL was responsible for a record of formidable and almost incredible achievements in the unmanned exploration of space."

Recognizing that such magnificent accomplishments were always the result of team efforts, the *Times* writer noted the outstanding record of JPL in the era of space exploration and wrote "inseparably involved in that record is William Pickering, whose cool and quiet leadership has accounted for so much. His adopted country is grateful to this native of New Zealand for all that he has done. His career has been one of achievements that do honor to himself, his profession and his nation."[50]

Harold Brown, President of Caltech; William Pickering, retiring Director JPL; and Bruce Murray, incoming Director JPL, 31 March 1976 (Photo: JPL Photo number P16433A).

In the years after he left JPL as Director, Pickering was always made to feel welcome whenever he chose to visit the Laboratory. Security guards waved him through the main gate, he retained an assigned parking place, and he was made to feel like an honored guest by the entire staff. He frequently took visitors on tours of the Laboratory and was always on the invitation list for events of significance to its programs. These were the courtesies that meant most to him now.

If the fact that he no longer determined the course of action at JPL concerned him at all, it was not apparent either at the time, or in later years. "I just walked out," he said, and "never looked back."[51] Would he have gone back if he had been asked? "My answer to that is simply that I was never invited back. If I had been approached by someone at JPL [to return] for some reason, I'm sure I would have gone back," he answered.

Perhaps—but then at the time, he had other things on his mind.

Endnotes

1 See "Caltech's New President" in *The DuBridge Years*, Engineering and Science, California Institute of Technology, December 1968.

2 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 239.

3 Pickering, W. H., Interview with the author. Pasadena, California, July 2003.

4 See Folder 217 in the William H. Pickering Speech Collection, Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL-181, 2004.

5 Pickering, W. H., *Some Practical Considerations in Technology Transfer* (Springfield, Virginia: American Astronautical Society Publication 72-033, March 1972).

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14 Although JPL continued to make important progress in biomedical applications, the idea of a medical laboratory went no further during the Pickering years at JPL.

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31 In later years, the gravity-assist technique played a key part in several major deep space missions. Ulysses used the gravity fields of Jupiter to orbit the poles of the Sun; Voyager used the gravity of Jupiter, Saturn, Uranus, and Neptune to eventually reach the "rim of the solar system"; and the huge Galileo spacecraft depended on two gravity assists from Earth and one from Venus to reach Jupiter in 1995. Pickering observed all of this amazing technology with great interest and satisfaction, but he was not part of it.

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33 Pickering, William H., "Improving the Environment." Jet Propulsion Laboratory, Wheelock Collection 1061-25, January 1974.

34 Pickering, William H., "American-Armenian International College." Jet Propulsion Laboratory, Wheelock Collection 1061-92, May 1974.

35 Pickering, William H., "Digitizing the Social Conscience." Jet Propulsion Laboratory, Wheelock Collection 1061-80, May 1974.

36 Pickering, William H., "Toward a New Society." Jet Propulsion Laboratory, Wheelock Collection 1061-1, May 1974.

37 Pickering, William H., "Inheriting the Future." Jet Propulsion Laboratory, Wheelock Collection 1061-82, June 1974.

38 Pickering, William H., "The Next One Hundred Years." Jet Propulsion Laboratory, Wheelock Collection 1061-57/58, November 1974.

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41 In retrospect, Pickering did see most of the essential elements of his ISSD proposal implemented when NASA's space program regained momentum in later years and expanded to include many international cooperative space programs to study the Sun, most notably Helios and Ulysses.

42 Box 12, William H. Pickering Office File Collection 1955-1976, JPL 186, Archives and Records Center, Jet Propulsion Laboratory, Pasadena, California.

43 Pickering, William H., "Homo Sapiens: One of a Kind?" Jet Propulsion Laboratory, Wheelock Collection 1061-56, June 1975.

44 Pickering, W. H., Interview with the author. Pasadena, California, July 2003.

45 Folders 671, 672, Office of the Director Collection, 1959-1982. Pasadena, California: Archives and Records Center, Jet Propulsion Laboratory, JPL 142, 2004.

46 Ibid.

47 See "Lab-Oratory 1976-4," R. C. House Ed., for a report of the Pickering farewell events at both locations, Jet Propulsion Laboratory, 1976.

48 The Surveyor 3 camera, a very rare artifact indeed, eventually found its way to the Air and Space Museum in Washington, DC, where it remains on display in the section on "Exploring the Planets." See online at *www.nasm.si.edu/collections/space/space.html*, accessed 7 July 2007.

49 Koppes, Clayton R., *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982), p. 241.

50 "Pickering: So Much, So Well." Part B, p. 6, *Los Angeles Times*, 1 April 1976.

51 Pickering, W. H., Interview with the author, Part 7A. Pasadena, California, August 2003.