“Pioneering Space” Part II

By Gideon Marcus

An Unnumbered Pioneer

Just six months after Louis Dunn gave the order to start production, through dint of hard effort and ingenuity, the first Thor-Able three-stage booster towered 88 feet above Launch Complex 17 pad A on Merritt Island, Florida. The serial number, 127, was printed on the Thor IRBM first stage, and USAF was proudly emblazoned along the Vanguard second stage. Atop the third stage rested the world’s first lunar probe. Roy Johnson, head of ARPA, and U.S. Air Force Major General Bernard Schriever, who directed the first U.S. ICBM programs, were among those in attendance.

The general was apprehensive about this flight and with good reason. In October 1957, Thor 108 inexplicably exploded in mid-flight. Six months later, the first ARTV Thor-Able blew up 146 seconds into its flight. This time, the malfunction was linked to the Thor’s turbopump gearbox. Further research determined that 108 had experienced the same problem. This discovery did not come as a complete surprise. Dolph Thiel, propulsions expert at Space Technology Laboratories and Peenemünde veteran, had noted early that year that Thor’s turbopump design was thoroughly marginal and recommended that the problem be fixed in the next run of the Thor missile. The problem was that several of the potentially faulty Thors had already been built and were committed for a variety of missions: several test flights, two more ARTV flights—and the Able-1 lunar probes.

Carl McIlwain Image courtesy of Gideon Marcus

Should the Thor flights continue or be suspended? That was the critical decision facing General Schriever. Fourteen Thors had been launched thus far. Two had failed in flight. Statistically, each Thor had a one-in-seven chance of exploding. Grounding the Thor would cause several months of delay in a number of projects. On the other hand, even in the event of the loss of one or two missiles, valuable guidance data could be gathered. The only hard decision involved the three Able-1 missions. General Schriever decided the odds were good enough, and ordered no delays, balancing the risk of a public relations disaster against the benefits of accelerated development.[1]

Seconds ticked by as the launch time grew ever closer. The countdown was a “T-minus” system with built in holds before the launch time as opposed to the older variety, which pushed the launch forward with every delay. This type of countdown is commonplace now, but at the time this was a new innovation developed to accommodate missions with inflexible launch windows, lunar shots being among them. Hitting the vicinity of the Moon from the rapidly spinning surface of Earth is a complicated billiard shot. The opportunity to reach lunar orbit comes only four days out of every month, and there is only a 35-minute window on even the best of those days. If they missed the window, the launch crew must wait 28 days for Earth and Moon to be in similar respective positions again. The launch windows were so narrow that mission planners had long since decided to not provide trajectory compensation for launch holds. Instead, each Thor was preprogrammed with a particular roll program, which varied depending on the launch day. The Air Force took for granted that the rocket would be ready to fire at the proper time.[2]

Able-1’s first countdown went by almost without a hitch. The Thor-Able booster was fully fueled by the afternoon of 16 August. Engine and electrical checks were begun at 1930 and completed ahead of schedule. On launch day, at T-35 minutes, interstation communications were checked. All stations reported that they were ready for operations, though the link to Singapore was somewhat noisy.

At around the same time, telemetry modulation of the Able-1’s low-frequency transmitter mysteriously ceased, the antenna instead locking on to a local, low-level transmission. At T-15 minutes, a short hold was called to turn off local telemetry receivers in the hopes that they were attracting the probe’s transmitter, but the problem persisted. The payload’s Doppler receiver did lock just fine when the local ground transmitter was turned on. It was ultimately concluded that there was some low level interfering signal unrelated to the transmitters and receivers at the blockhouse. Mission controllers ultimately decided that the problem was not a large one and that it would likely correct itself after takeoff anyway. No further problems were encountered during the countdown and Thor 127’s motors ignited at 0718 on August 17, four minutes behind schedule.[3]

As America’s first lunar mission began its stately ascent from Pad 17-A, the mood became jubilant. At 73.6 seconds later, elation turned to horror. The main bearing on the first stage’s turbopump, driven by the intense revolutions of the pump shaft, walked its way out of its housing and tore Thor 127 pieces—the same disaster that had befallen Thors 108 and 116. The mission was over. General Schriever had lost his gamble. Dolph Thiel placed his head in his hands and sobbed.[4]

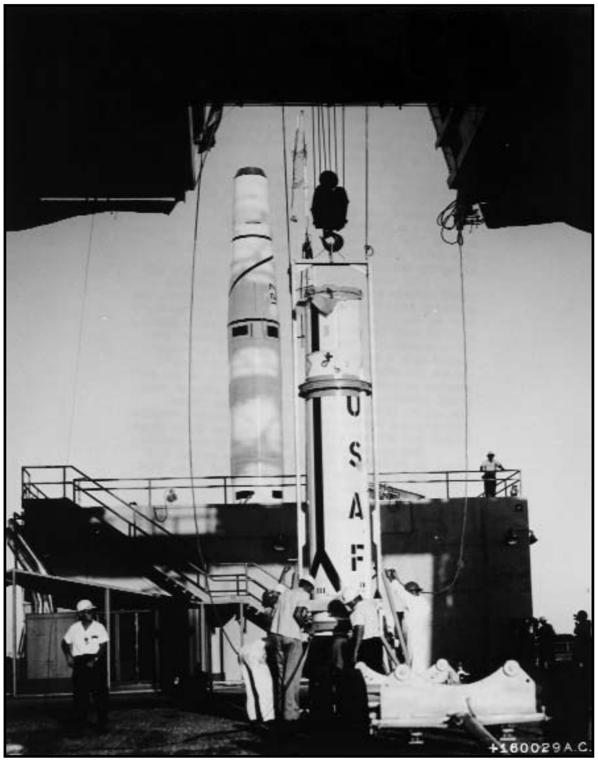
The next flight was optimistically planned for mid-September. This date was pushed to mid-October, which among other things gave Van Allen's team time to complete its ion counter experiment.

Pioneer 1 Flies

Two months after the failed flight of Able-1, Thor 130 stood ready on the pad. Though President Dwight Eisenhower had created the National Air and Space Administration on 29 July 29, and on 1 October 1958 the new agency officially took control of all civilian space missions, the Thor-Able booster still bore the letters "USAF" on the second stage. Its payload, however, did receive a new name. The Army's series of satellites was called "Explorer" and their public information officer proudly proclaimed them the "Pioneers in Space." Stephen A. Saliga, chief designer of Air Force exhibits at the Air Force Orientation Group, Wright-Patterson AFB, suggested the Air Force show who the real Pioneers in space were by naming the new lunar orbiter, "Pioneer."[5] His proposal was accepted, and under this new naming scheme, the Able-1 flying in October would be known to the world as "Pioneer 1." In the interests of consistency, the failed August flight was designated "Pioneer 0."

As with *Pioneer 0*, all concerned felt great trepidation about the launch—more so now that they'd already lost one of their three spacecraft. Unlike the August mission, Pioneer 1's flight was a matter of public scrutiny. If all went well, the spacecraft would be the world's eighth space mission, America's fifth, and the first to approach the Moon, much less orbit it. All eyes on both sides of the Iron Curtain waited to see if America's first civilian lunar shot would be a success or not. Professor Van Allen, developer of Pioneer's ion counter, hedged his bet. "The success of the experiment does not depend on whether the rocket hits, or even comes near the moon. We will consider the flight a success if the rocket reaches out 40,000 miles, let alone 220,000 miles!" he declared.[6]

Before its flight, Pioneer 1 was painstakingly sterilized with both a chemical bath and a torrent of ultraviolet. While no evidence existed that the Moon bore any kind of life, the remote possibility that terrestrial molecules might adversely affect life or prelife processes on the Moon was justification enough for the precaution.[7]



Pioneer 0 launch assembly

Image courtesy of Gideon Marcus

At the Cape, Dr. George Mueller, director of the Able-1 project at STL, and U.S. Air Force Lieutenant Donald Latham directed launch operations, their 40-person crew completing readiness checks with all STL ground stations the day before launch. In addition to the primary tracking stations at Canaveral, Hawaii, Singapore, Manchester, and Millstone (NH), ten Vanguard Minitrack stations in Peru, Antigua, Chile, Ecuador, the Bahamas, South Africa, Texas, Havana, and Australia stood by to relay tracking data through the Cape.[8] Preparations continued right up to launch time. At one point, the Ramo-Wooldridge man in charge of the Hawaii station reported that the antenna there was frozen. Mueller laconically replied that the man had 12 hours to fix it, or they would launch anyway. The antenna was repaired in time for the launch.[9]

The countdown proceeded largely without incident. Ten seconds before deadline, there was a momentary hold: a supervisor had not responded to one of many thumbs-up signals in the blockhouse. The countdown resumed a few seconds later with no further problems. At 4:42 a.m. eastern daylight time, Saturday, 11 October 1958, NASA's first space probe departed its launch pad only 13 seconds behind schedule.[10]

Just 16 minutes later, all three stages on the Thor Able had fired successfully. At the shutdown of the first stage, the velocity vector was some 2.5 degrees too high and the speed some 800 ft/sec above projections. At second stage shutdown, Pioneer was hurtling somewhere between 23,125 and 23,150 feet per second, which was actually around 200 ft/sec *below* what it should have been. Pioneer was slightly off course, now suffering from three degrees of "loft" or vertical displacement. Pioneer's integrated accelerometer thus cut off the engine prematurely, despite there being some 10 seconds of fuel left in the second stage.[11] At the time, no one knew what caused the first stage loft. Wind was suggested as the culprit,[12] but the Air Force later concluded that the problem was caused by the first-stage autopilot.[13] By third-stage burnout, something was seriously amiss, though it took some time for the mission controllers to ascertain this. The velocity vector was off some 5 degrees now. Somehow the third stage had been cocked from center some 15 degrees after separation from the second stage. This deviation from the planned flight path presaged failure for the spacecraft's primary mission.

As of third-stage burnout, Pioneer was traveling at some 500 ft/sec less than the desired 35,206 ft/sec, which would allow it to escape Earth's gravity. All eight vernier rockets, designed to keep the probe on course, were fired to make up deficit. Although they added some 160 feet per second to Pioneer 1's speed, this was still far short of the goal.[14] At 10:15 a.m. EDT, the Pentagon released that tracking data was being received from Inglewood, Millstone, and Manchester, in addition to several Minitrack stations. However, they announced, it would not be clear whether or not Pioneer 1 was on course (albeit under speed) until it could be seen by the Hawaii tracking station. At 11:45 a.m. EDT, the Pentagon reported that it appeared that

Pioneer 1 was departing from the intended trajectory.[15]

"Additional data and still further analysis are required to determine the exact trajectory of Pioneer," they said.

The huge tracking station at Jodrell Bank in England was the first to report that Pioneer 1's velocity was insufficient for a lunar orbit, but it was still unclear whether or not Pioneer 1 might be saved in an eccentric Earth orbit.

As of 10:47, Pioneer 1 had reached 36,600 nautical miles above Earth, far higher than any artificial device had traveled before. The Hawaii tracking station, not scheduled to begin tracking Pioneer 1 until 1:00 p.m., came online shortly after noon.

At 12:47 p.m. EDT, the craft was some 45,300 nautical miles above Earth. At 1:45 p.m. EDT, another statement was released. Hawaii had confirmed that Pioneer 1 was still departing from its planned trajectory.[17] Ominously, Pioneer 1 also reported that the internal temperature had settled at around 40 degrees Fahrenheit, far below what it was supposed to be. For the first time in the history of the space race, data was reduced, analyzed, and released to the public within hours. The world was kept apprised of Pioneer 1's situation and findings every step of the way via radio and newspaper.

As Pioneer 1 ascended toward its apogee, the spacecraft was ordered in the midafternoon to jettison the previously fired vernier rockets so that the probe's trajectory could be more easily altered by its onboard retrorocket. At 5:45 p.m. EDT, the Air Force announced that it would try to fire the fourth-stage engine to give Pioneer the "most scientifically useful path."[18] There was still hope that the TV camera might take high-altitude pictures of Earth.[19] As of 4:47 p.m. EDT, Pioneer had reached 56,500 nautical miles in altitude. By 8:00 p.m. EDT, Pioneer was at 58,725 nautical miles, its speed down to a few thousand feet per second. Shortly after, at 8:09 p.m., the station at Singapore began tracking Pioneer. With this, every station built or employed for the purpose of communicating with the spacecraft had been engaged. Hawaii was also still tracking at this point.

By 10:47 p.m. EDT, Pioneer had crept to 67,550 nautical miles.[20] Arrangements were made for the Hawaii station to order Pioneer's retrorockets to fire at midnight.[21] This task would fall onto Richard G. Stephenson of Rolling Hills, head of STL's space computing and tracking section, hailed by the press as "the man with the golden thumb." The original mission plan had called for Stephenson to perform this duty some 2.61 days after launch as the spacecraft reached the vicinity of the Moon (though, in fact, an auto-detonator was also installed to fire the rockets automatically should his radio command have fail) Instead, per the USAF order, Stephenson sent the fire order less than one day after liftoff. There was no response from Pioneer. Its course remained unchanged.[22]

For two hours, the STL team attempted to ignite Pioneer's retrorockets to no avail. The spacecraft simply would not acknowledge the order. It was later determined that the spacecraft's low internal temperature was to blame. Because of the dramatic third-stage course deviation, the Sun's rays fell primarily on Pioneer's unpainted sections rather than on the spacecraft's ingenious thermally regulating paint scheme. The frigid 36-degree internal temperatures meant that the probe's internal batteries simply could not generate enough current to receive instructions from Earth.[21]

Pioneer continued to send telemetry for the remainder of the flight, however, returning valuable engineering and experimental data on the downward leg of is suborbital flight path, before plunging into the atmosphere above the southern Pacific Ocean at 12:46 a.m. EST, Monday, 13 October 1958.[24]

No Lunar Orbit, But a Triumph for Sky Science

Out of Pioneer's four primary experiments, only the Naval Ordinance Test Station imaging system, whose activation was contingent on the firing of the probe's retrorocket, failed to return any data. While Pioneer 1 did not reach its intended goal, the vicinity of the Moon, it still flew an order of magnitude higher than any probe before it. Its instruments took extensive measurements from deep into cislunar space giving the first glimpse of a truly exospheric environment.[25]

Micrometeoroid Detector

Pioneer's micrometeoroid detector data put to rest any fears that menacing clouds of dust posed a hazard to human spaceflight. The probe's acoustic diaphragm reported surprisingly few hits—just 11 low momentum impacts were recorded in the first nine hours of flight. When a mean velocity of 10,000 meters per second was assumed for these particles, this came out to a measured density of just one micrometeoroid per cubic kilometer. While the data did suggest that micrometeoroid flux decreased with distance from Earth, the impact count was so low that any meaningful statistical significance from their distribution was impossible to determine.

During the flight, Pioneer 1 was exposed to the Epsilon Arietid meteor shower radiant. STL scientists had hoped that a higher flux from this direction might serve as a kind of calibration and allow analysts to see any directional variations in micrometeoroid flux density. As it turned out, Pioneer recorded just one high momentum impact through the entire flight. It was impossible to deduce anything from that save for the tentative conclusion that there were not many high momentum micrometeoroids in cislunar space.[26]

Ion Counter

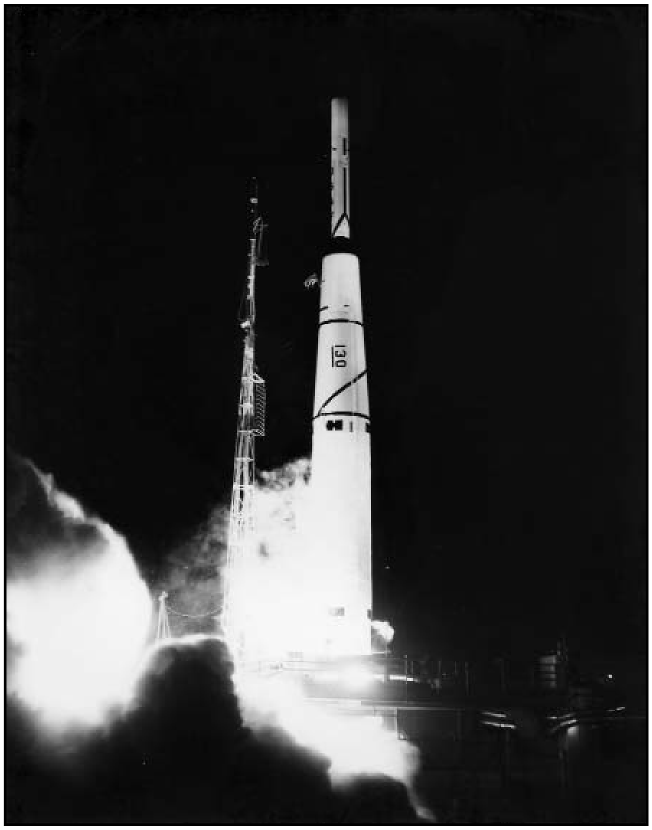
Pioneer 1 also dispelled concern about the deadly belts of radiation discovered previously by Dr. Van Allen's experiments on the Explorer satellites. The ion counter, constructed by Van Allen's team at the University of Iowa, returned data from 3,500 km to 36,000 km above Earth and covered a latitude range of 35º N to 5º N. No data was sent below 3,500 km as the transmitter was tied up for the first 17 minutes providing vehicle performance information.[27] Although initial findings were released almost immediately, the full analysis took a number of weeks and was a kind of side-work for University of Iowa's Carl McIlwain, whose primary focus was the study of aurora.[28] Data was first presented in January 1959. *The Journal of Geophysical Studies* received the finished article in late March, and it was published in May.

This article detailed an astonishing discovery. Pioneer 1 had reported that the level of ionizing radiation rose to a peak of 10 roentgens/hour at 10,000 km and held at about 8 roentgens/hour up to 17,000 km. Above that altitude, however, the radiation level dropped steadily, eventually becoming immeasurable above 29,000 km. This confirmed the trapped radiation surrounded Earth in a finite band rather than extending infinitely into space. These Van Allen Belts, as they came to be called, were no longer considered an obstacle to crewed lunar missions.

Because Pioneer 1's ion counter was suspected of having a leaky tube (see "Pioneering Space, Part 1," *Quest: The History of Space Flight Quarterly* 14:2, 2007:52–59), there was some concern that its measurements were inaccurate. Four similar chambers were evaluated using the cobalt source at the UCLA Medical Center where scientists had calibrated the tube used on Pioneer. Two of the tested tubes retained their pressurization while the other two, known to have leaks, eventually stabilized at an internal pressure close to atmospheric. Most important, it did not seem that outside air was getting *in*, which would compromise the experiment. As the sensitivity of the experiment was directly proportional to the argon pressure in the tube, it was a simple matter to apply a constant correction to Pioneer's data based on its internal pressure, projected to be 1.58 atmospheres at launch. Of course, if the tube had reached equilibrium before launch, that is, the tube had just one atmosphere of pressure, then the sensitivity of the instrument would have been correspondingly reduced by almost 50 percent. Therefore, there was the possibility that the strength of the field was significantly underreported.[29] Even if this were the case, the boundaries of the Van Allen Belt had been clearly delineated and even a first order model of the distribution of ionized particles above Earth was tremendously useful. Dr. Van Allen could confidently declare the mission a success.

Above: *Pioneer 1* assembly Image courtesy of Gideon Marcus

Below: *Pioneer 1* lift-off Image courtesy of Gideon Marcus



Magnetometer

Of all Pioneer's experiments, it was the magnetometer that returned the most enigmatic results. Pioneer's magnetometer was designed to measure the strength of the surrounding magnetic field. As the spacecraft rotated, the instrument returned a signal that varied in a sinusoid fashion. The amplitude of the magnetometer signal indicated the strength of the magnetic field. By comparing the relative phase of the magnetometer's sinusoid with that of the spacecraft's radio signal, which would not be affected by external factors, analysts were able to indirectly measure transient magnetic effects. Using this clever trick, Pioneer was able to detect rotations of the magnetic intensity vector and oscillations in its amplitude.

Not only did the experiment corroborate the findings of ground-based observatories, it also discovered new magnetic phenomena, particularly in the two hours the spacecraft spent at an altitude of about 10 Earth radii. Up to that point, the magnetic fields Pioneer traversed had not deviated far from the theoretical model derived from terrestrial measurements. Above 80,000 km, the measured fields were distinctly stronger than had been expected for that height. There were two sources of potential error that might have accounted for these results. The large dynamic range of the magnetometer tended to increase absolute error. Also the fluctuations in the data complicated determination of a statistical mean. Still even when these factors were taken into consideration, the difference between the measured and expected field strengths was outside the margin of error. One exciting interpretation of these measurements was that Pioneer had flown through the boundary where Earth's magnetic field interacted with the coronal wind emanating from the Sun, a sort of geopause corresponding to the heliopause where the solar wind interacts with galactic radiation.[30]

The question raised by Pioneer's findings was whether or not the probe had discovered a global phenomenon or a local anomaly. In support of the former, it was suggested that the deviation from the predicted field strength might have been due to an error in the assignment of the position of the geomagnetic pole at high altitudes. But it was also possible that circulating currents produced an uneven distribution, and Pioneer had encountered a more dense section of the field. Finally it was possible that centrifugal forces acting on an ionized medium within the magnetic field caused local increases in the magnetic field density. Pioneer 1's data was insufficient to resolve the issue.[31]

In the end, Pioneer 1 raised more questions than it answered. Further missions were required to sort out these mysteries.

Pioneer—The First Communications Satellite

Pioneer 1 was the first spacecraft to fly high enough to test satellite communications relay technology. Telemetry was relayed through Pioneer from Cape Canaveral to Manchester, England, and later from Hawaii to the Cape, and finally across the world from Hawaii to Manchester. This experiment presaged the development of geosynchronous communications satellites. Project Director George Mueller is credited with the development of this experiment.[32]

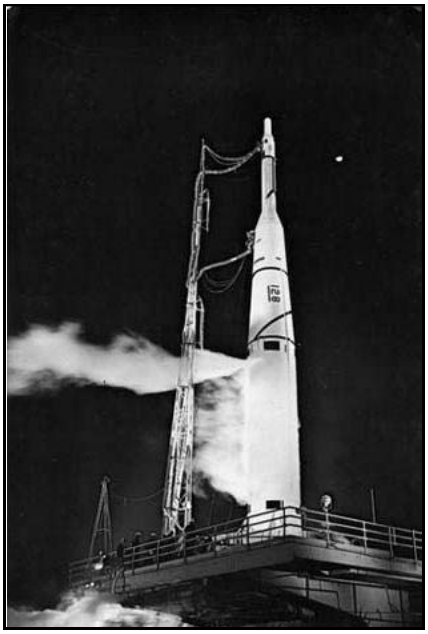
Improving on Success

Pioneer 2 was scheduled for launch at the next opportunity, just four weeks after the flight of Pioneer 1. Chuck Sonett and his experiment team scrambled to put together a package that could confirm and enhance data collected on the last mission. At the same time, Mueller directed efforts to eliminate the issues that had marred the momentous flight of Pioneer 1.

What had caused the third stage to deflect so far off course? STL's president, Louis Dunn, at a press conference on 12 October, blamed the first-stage autopilot. Some believed that the vernier rockets had contributed to the deviation.[33] Others felt that if the second stage had kept burning until it was out of fuel rather than cutting off at third-stage separation with ten seconds of fuel remaining, the craft would have reached orbital velocity.[34]

As it turned out, the cause of deviation was fundamental to the design of the second stage. A support beam at the front of the stage had been mounted asymmetrically for perfectly sound engineering reasons. When the third stage fired against the second, this asymmetry deflected the thrust and sent the booster careening off course. Even though the third stage on Pioneer 1 went on to perform within 5 percent of its predicted performance, the damage had already been done.[35] Ten more seconds of second stage thrust probably would not have made a difference.

The man with the unenviable job of reporting this information to NASA was Budd Cohen. Cohen had come to Ramo-Wooldridge as a clerk. By October 1958, he was manager of the Astrovehicles department at STL. As such, he was officially responsible for the faulty design of the second/third stage interface though he had not personally been involved in its development. Before coming to STL, Cohen had worked for the National Advisory Committee on Aeronautics under Abe Silverstein. On the eve of Cohen's departure from the public service, Silverstein treated him to a diatribe against the evils of the private sector. "They're all crooks!" he declared, doing his best to dissuade Cohen from leaving. He left anyway. Several years later, as luck would have it, the man Cohen had to report his findings to was the brand new director of NASA's Office of Space Flight Programs, Abe Silverstein. This unpleasant reunion seemed to confirm the unfavorable view Dr. Silverstein had of commercial enterprise in general, and his department's disdainful view of STL, specifically.[36]



Pioneer 2 lift-off   Image courtesy of Gideon Marcus

Several changes were made to Pioneer 2 and the Thor-Able launch vehicle based on the Pioneer 1 flight. There was no time to redesign the second- to third-stage interface. Instead, to ensure that Pioneer 2 did not suffer the same fatal course deviations as Pioneer 1, engine cutoff was governed by a manual Doppler command trigger rather than the automatic accelerometer. A one-second delay between second-stage cutoff and third-stage ignition was introduced. Theoretically, these modifications would ensure that the third stage was well away from the second before firing and also guarantee that the second stage was empty before separation.[37] The number of spin motors/verniers was increased from 8 to 12 not only to make sure Pioneer 2 was spun to the proper rate of 2 revolutions per second, but also to better correct for any deviations of the booster during flight. A second transmitter, operating at 100 milliwatts on 108.09 Mhz (as opposed to primary transmitter's frequency of 108.06 Mhz), was added so that telemetry could still be sent at the same time the spacecraft received Doppler command signals. Finally, a more robust battery was installed so that the spacecraft would respond even if the temperature plunged below anticipated levels once again.[38]

An Updated Experiment Package

Proportional Counter

The most significant addition to the Pioneer 2 experimental package was the proportional counter telescope. Through balloon and sounding-rocket flights, it had become apparent that there was an indirect connection between solar activity and the overall level of cosmic rays. According to theory, the solar wind affected the magnetic fields around and beyond Earth, which in turn created variations in the degree to which entering cosmic rays were diffused. John A. Simpson, an astrophysicist at the University of Chicago, was working on this problem when the Pioneer mission was announced.

In May 1958, Simpson met with Hugh Odishaw, executive director of the U.S. National Committee for the International Geophysical Year, in Washington, DC. As it turned out, an academy meeting was being held the next day, Odishaw informed Simpson, and that some ARPA people would be in attendance. Simpson rushed off to at the Cosmos Club, an elite social club on Massachusetts Avenue, to prepare a draft proposal—using the back sides of club correspondence paper! He presented it the next day, and official approval came on 27 May. This was Simpson's first space experiment, tentatively scheduled for launch on Pioneer 1.[39]

Simpson submitted a budget proposal to the office of Homer Newell, chair of the IGY satellite panel. Confirmation of funding came on 16 June 1958. The construction team consisted of Simpson as principal investigator, Peter Meyer, a fellow physicist at Chicago, and Charles Yun Fan.[40]

Dr. Fan had worked with Aden Meinel on auroral physics for five years before deciding to accept a teaching position at the University of Arkansas, which was where he was when Simpson asked Fan to come to Chicago and assume responsibility for the construction of a set of proportional counters for the Pioneer 2 project. Dr. Fan only expected to be away for the three months it would take to construct and implement the experiment. After arriving in Chicago, he found a way to significantly improve the original design but it meant delaying the experiment until Pioneer 2.[41]

The actual device was composed of seven tubes, two inches in length, six of them arranged concentrically around the seventh and shielded in lead. The experiment would tally cosmic rays entering the central tube in addition to events affecting the central tube and two diametrically opposite outer tubes. Fan's triple coincidence design, superior to the original double coin-

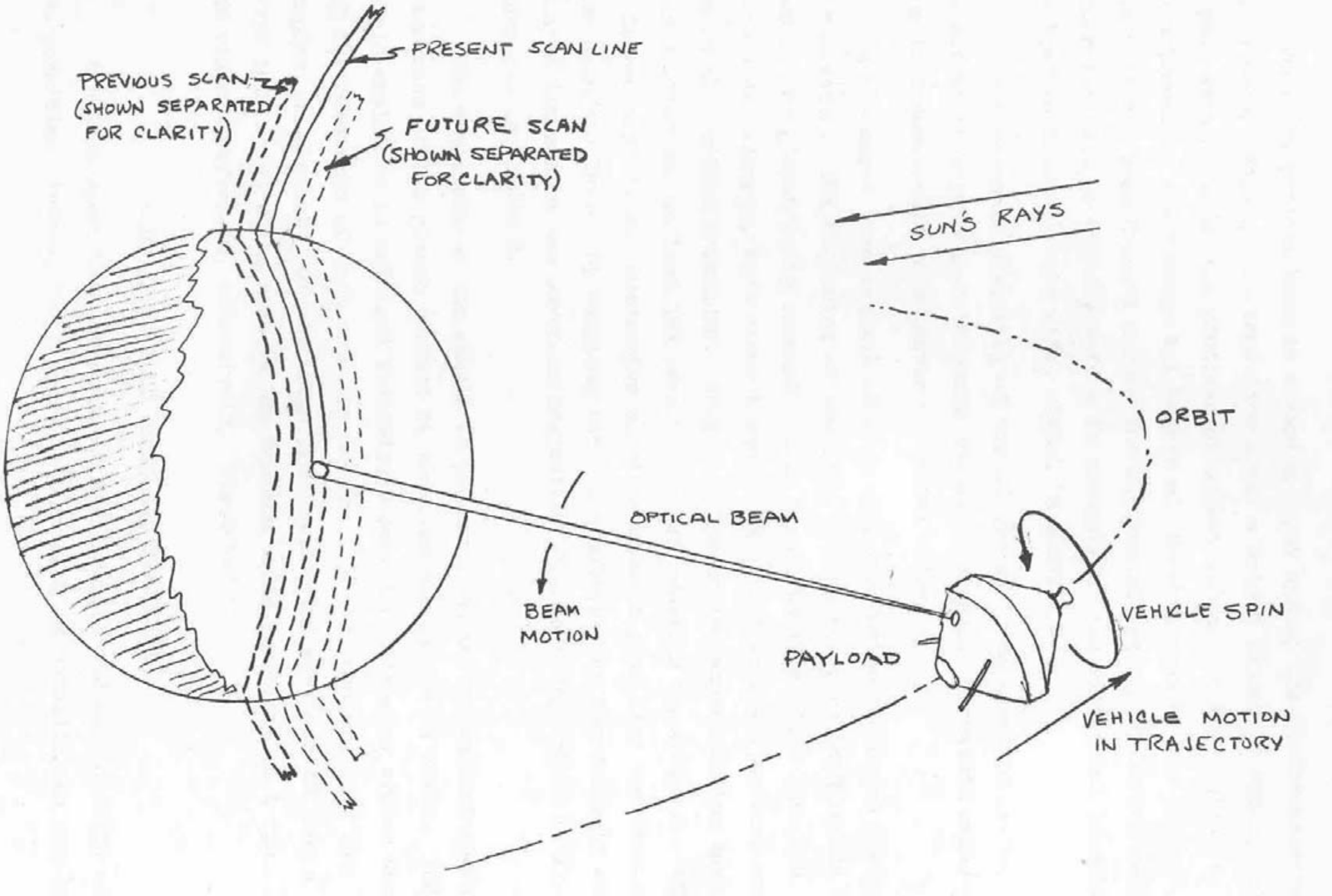


Figure 1. Illustration of TV System Operation.

STL graphic courtesy of Gideon Marcus

cidence plan, would serve to help map the radial distribution in the high flux above Earth and enable the telescope to better complement the Iowa ion counter experiment.[42]

Before sensitive experiments like the counter telescope could be cleared for flight, the equipment had to be subjected to violent physical stress to ensure the devices would withstand the flight into orbit. To this end, it was standard procedure to strap experiments to a special table and subject them to a "shake test." STL had a shake table; the University of Chicago did not. But Sonett's team was in bad esteem with NASA's Space Science Board for alleged shoddy construction and calibration of experiments in addition to their rough and ready management of the contributing scientists. Simpson was unwilling to use STL's facilities, and insisted on handling all aspects of package development. Rather than build or purchase their own shake table, his team hit on the idea of dropping their apparatus out of the third floor window of their laboratory and into a toy sandbox.

The test worked.[43]

STL Television

Space for experiments was always at a premium on Pioneer. In order to make room on the probe for the new telescope, the original Navy-provided imager had to be deleted without ever having returned a single pixel. A completely new system had to be developed for the Pioneer 2 flight. STL engineers Charles Sonett, Stewart Baker, and John Kelso developed their own design, one with limited capabilities but weighing only three pounds.

Like the Navy imager, the STL television used a mirror in an optical unit that reflected intercepted light onto a photosensor, which would produce a voltage proportionate with the amplitude of the received beam. Pioneer 2's TV, with its strict weight restrictions, lacked the heavy transmitter and power supply that enabled the NOTS camera to produce a continuous, though crude, image using a few kilohertz of bandwidth. Instead, Sonett's team designed a camera that utilized the two rps spin rate of the spacecraft along with a clever algorithm to dramatically reduce bandwidth needs. As the spacecraft spun, it would scan a 64-degree segment of its revolution, begun as the optical beam crossed the limb of its target. Each of these scan lines was divided into 128 elements about 0.5 degree square, corresponding to the 0.5 degree wide optical aperture. One of the elements would be sampled and then transmitted back to Earth every time the spacecraft rotated. Each time Pioneer 2 spun, the sampling began a touch later to target the next element in the scan line. With the probe's rate of revolution, one degree of the Moon or Earth would be imaged and returned. Thus, it would take 128 revolutions just to scan one 0.5 degree wide line! But the system would only use the ridiculously tiny bandwidth amount of 1 Hz.[44] According to computer predictions, Pioneer had barely a 50 percent chance of making a lunar orbital insertion at all, much less in any specific orbit. Therefore, the STL TV was optimized based on a best-guess "average" orbit of around 6,700 km.

The Able second stage Image courtesy of Gideon Marcus

At that range, the 0.5 degree scan lines would just touch. Further away, there would be gaps between the scan lines. Any closer and there would be overlap.

At that distance, the lunar diameter would subtend an angle of about 30 degrees and the resolution of an individual element was about 25 miles. The beam angle of the camera was aimed some 135 degrees from the nozzle end of the spin axis. On television activation with the firing of Pioneer 2's retrorocket, the Moon would have presented itself half full. If Pioneer 2 made it into orbit, the probe would be able to scan the fully illuminated far side of the Moon and obtain a good view of the half-illuminated Earth. It was not expected that the Sun's rays would enter the acceptance cone of the optics unit at any time during the flight.[45]

Sonett's team used a GE photoflood light situated behind a Cupric Chloride filter to calibrate the package. Then a double-sided mirror, revolving at one rps to simulate the rotation of the spacecraft, was then placed between the camera and a 39-inch square test pattern. The camera was switched on and after two hours had returned a blocky but recognizable 128 by 128 facsimile.[46]

No one was really happy with the performance of the camera. At one point, an angry Frank Lehan, deputy head of guidance, collared Chuck Sonett in the STL parking lot. "Why can't you design a system that would work?" he demanded. Two days later, Sonett was summoned to the guidance office and compelled to explain to his superiors why his camera was so limited. In the end, little could be done. STL knew ahead of time that the camera would do little more than turn on and display black or white. But Sonett's camera was the only one which would fit on Pioneer, and that ended the discussion.[47]

Magnetometer

The addition of a second telemetry transmitter had immediate application in the magnetometer experiment, allowing monitoring of the Automatic Gain Control on the amplifier and the direct amplifier output. The experiment could now more easily detect the transient phase and amplitude changes first discovered by Pioneer 1.[48]

Flight of Pioneer 2

Just a few weeks after Pioneer 1's historic flight, Thor 129 stood ready on the launch pad. The Thor-Able's second stage, which had borne the letters "USAF", had been hastily painted over with white blankness.[49] On 6 November, preliminary readiness checks were completed. The operations center was fully staffed at T-4 hours.[50] The launch was scheduled for early on 7 November, but during the countdown, a valve in the pumping system between the tankage and combustion chamber of the first stage engine became stuck. The prudent decision was made to delay the launch one day, though as it turned out, the valve was repaired before the scheduled launch time.[51]

Pioneer 2 launched at 2:30 a.m. EST, just 31 seconds after its scheduled liftoff. As of first stage cutoff, the booster's velocity was some 200 ft/second higher than nominal, and the rocket was pointed 1.5 degrees lower, 2.3 degrees to the left of nominal. At second stage cutoff, Pioneer 2 had reached a speed of around 27,000 feet/second and its flight path. Performance had been so good that it was still not certain how many verniers would need to be fired after third-stage burnout. Sadly, it was a question that quickly became academic.

On second-stage burnout, the spin rockets then fired and spun the rocket to a satisfactory spin rate of 2.2 revolutions per second. The third stage separated properly, but then it failed to ignite. Somehow it failed to receive the firing command due to a break in the wire to the igniter or a poor connection, a failure in the internal firing transmitter, or a failure in the igniter itself. Whatever the specific cause, somehow the second/third stage separation broke the link between the command receiver and the third-stage engine. Something went on in that crippled stage, however, as the spin rate dropped dramatically as the booster attempted to light itself. The vernier rockets were then given command to fire but no effect was observed.[52]

Pioneer 2 was tracked for about 15 minutes, reaching a maximum altitude of 1,550 km and flying some 12,500 km before burning up above Africa.[53]

Shortened Flight Still Yields Results

Despite the brevity of the Pioneer 2 flight, the probe managed to return useful data. This was still a relatively high altitude mission and only the ninth shot into deep space. Unfortunately, because the flight was so short and Earth was largely in darkness, the much maligned TV camera missed the opportunity to take the first photograph of Earth from outer space.[54] The magnetometer also failed to return useful data. Corroboration of Pioneer 1's exciting findings at the fringes of Earth's magnetic field would have to wait.

On the other hand, the micrometeorite diaphragm returned surprising results. The instrument reported 20 strikes between 1,200 and 1,430 km in altitude, and this was likely an incomplete record given that ground tracking was intermittent during the flight. This high flux during such a brief time contrasted sharply with the long, relatively event-free Pioneer 1 mission. Sonett's team ventured the possibility that some kind of gravitational or electromagnetic containment of this meteoric debris had caused the higher measured flux.[55]

The ion counter also returned useful data. While Pioneer 2 did not travel high enough to confirm Pioneer 1's findings, the probe instead served as a follow up to the Explorer 4 mission. Both Explorer 4 and Pioneer 2 used essentially the same experiment, so the two data sets were easily compared. Analysts could assume that any differences in ion flux could be attributed to external factors such as altitude and geographic position. At an altitude of 1,550 km, Pioneer 2's instruments ion count rate was about 1,200 counts per second. According to Van Allen's theory of trapped radiation, counting rates should be relatively independent of longitude but strongly dependent on geomagnetic latitude. STL engineers Al Rosen and Paul Coleman were fairly sure that the Explorer 4 data for the same altitude and latitude would be comparable to Pioneer 2's, despite any difference in longitude between the two satellites. A call to Carl McIlwain at Iowa State confirmed their suspicion—the earlier satellite had indeed recorded a similar count rate. Van Allen's model had been confirmed.[56]

While the ion chamber could return the average number of ionizing collisions, giving information on the general radiation level, the proportional counter telescope actually counted the number of fast particles hitting the instrument every second. Combining the data sets from both experiments allowed analysts to discern the nature of the high energy particles detected by Pioneer 2. It was determined that the high specific ionization, that is, average radiation per particle, could not have been generated by high energy electrons alone, but rather by a combination of electrons and protons.[57]

Aftermath

It was a disappointing end to one of the most ambitious projects of the early space age. From inception to final launch, less than one year had elapsed. The booster developed for Pioneer went on to be one of the nation's most used workhorses. Pioneer 1 itself smashed all previous altitude records and returned unprecedented scientific information about conditions in deep space. And yet, despite all the positive spin her builders and the Air Force put on the Pioneer flights, they failed in their primary goal—to reach the Moon before the Soviets. With the completion of the Air Force project, it was now up to the Army to carry the torch with its two scheduled flights.

Sadly for American prestige, the December shot of Pioneer 3 was a bust, too, though the little probe set the new altitude record of 107,400 km. Pioneer 4, the last ARPA-commissioned lunar flight, launched in March 1959, managed a distant flyby of the Moon, but the Americans had already been beaten. On 2 January 1959, Luna 1, a Soviet probe almost 20 times heavier than Pioneer 1, had cruised just 3,995 km above the surface of the Moon.

In the end, the Soviet victory in the second round of the space race only served to spur the American lunar program. STL quickly lobbied for and won the contract for a new lunar orbiter, one that dwarfed its original efforts and would show up the Russians in a big way. The new probe would also be called Pioneer, a name that would become virtually synonymous with STL (and its parent company, TRW) throughout the 1960s. A new booster was required to launch such a heavy spacecraft. Since the Thor-Able fusion had been such a success, the new rocket would be the mating of the proven Able with the more powerful Atlas ICBM.

About the Author

Gideon Marcus is a graduate of the University of California's San Diego history department and a member of the AAS History Committee. This article marks the end of his initial three-part series on STL's first space efforts. Ultimately, this series will detail the company's space activities through 1960. The author thanks Guy Garnett and Janice Marcus for the editing of these articles as well as Stu Baker and Art LeBrun for the use of their photographs.

The author's previous articles on Pioneer appeared in *Quest*, volumes 13:4 and 14:2.

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Top: Astronaut Joseph P. Allen, STS-5 mission specialist, lets a spot-m
free during a period devoted to out the window photographs
Earth from the orbiting Columbia. Allen is on the flight deck p
behind the pilot's station.

Bottom: Pioneer 0 Liftoff.