O, Pioneers! (Part 1): The motes in God's eye

February 27 2012, By Richard Corfield

Artist’s concept of Pioneer 10 on its journey in space. Credit: NASA

March 2012 marks the fortieth anniversary of the launch of one of the most extraordinary spacecraft ever constructed - Pioneer 10 - the first true deep space probe. The story of the Voyager spacecraft is well known but that of the Pioneer probes much less so.

The Pioneer probes were the brainchild of the Ames Research Center at Moffat field in northern California. Incorporated into NASA with the rest of the NACA facilities in 1958, it was run by an individual, Smith DeFrance, whose credentials firmly predated jet aircraft. A former NACA pilot, his flying career had ended after he lost an eye during a flight test and promised his wife that he would never climb aboard an airplane again.

Smith DeFrance was a conservative administrator but he knew a good thing when he saw one. As early as 1962 he even made the four-day round trip to Washington by train to persuade his bosses at NASA that Ames could build one of the first generation of unmanned interplanetary probes - the Pioneers. The brash young man Smith DeFrance had put in charge of the program was Charlie Hall.

All of the Pioneer probes were of relatively simple construction, reflecting Hall's belief that simplicity is preferable to complexity when designing machinery for deep space. This philosophy explains why it was Ames that launched the first two true deep space probes to Jupiter and beyond - Pioneers 10 and 11.

A good example of the emphasis on simplicity was the imaging equipment that Pioneers 10 and 11 carried to acquire the first ever close-up photographs of Jupiter. Designed by University of Arizona space scientist Tom Gehrels, they were not cameras as such - and indeed were included as part of the onboard science package not to take pictures in the conventional sense at all but to acquire data about color and color intensity. The telescopes were equipped with blue and red scan sensors that could acquire strips of images as the spacecraft rotated. These data were digitized and returned send back to Earth where the strips were built up into full color images at mission control.

The reason for using the IPP (as it was called) rather than a more conventional camera was to keep the weight down (the entire spacecraft weighed only 570 pounds). It is fair to say that the IPP’s ability to produce ‘pictures’ was in fact secondary to its scientific functions, but it is the pictures – the first such ever returned from such remote vastness of deep space - that exerted a powerful hold on the public imagination at the time. Neil Gehrels, Tom Gehrels’s son and a noted space scientist in his own right, told me, "The Pioneer instrument… gave unique information on the aerosols and molecules … in [the] atmospheres of Jupiter and Saturn. [However], it is best known for providing the first in-situ pictures of the giant planets."

Pioneer 10 carried another ten experiments as well, to examine phenomena ranging from the intensity of Jupiter's radiation belts and magnetic field to meteoroid detectors (to measure the density of objects in the Asteroid Belt) to an infrared radiometer to measure the temperature of Jupiter's cloud tops.

John Zarnecki, Professor of Space Science at the Open University in Milton Keynes told me, "Before Pioneer 10, we didn't know if space exploration of the outer Solar System was possible – some said that the radiation, the distance, the need to traverse the asteroid belt and other hazards would make it impossible to do. Pioneer 10 showed the naysayers to be very wrong!"

To power all of this equipment meant making innovations to the design of the spacecraft itself – what is known as 'the Bus'. Because it would be heading away from the Sun it could not use solar panels but would have to have some other power source. Also, it's orientation would have to be stable enough to accurately transmit the data its instruments gathered from Jupiter and interplanetary space accurately back to Earth. The former problem was solved by providing the spacecraft with two SNAP-2 Plutonium-238 power sources that were mounted on booms to prevent their radioactivity from interfering with the instruments.

The craft also carried two radio transmitters that could accurately fire data back to Earth because the attitude of the craft was passively maintained by spinning on its line-of-flight axis. But the spin of the probe imposed a limitation on the Image Photopolarimeter - it could only assemble an image strip by strip. This motion world have made a conventional camera useless.

In mid-February of 1972 Pioneer 10 was moved to the gantry at launch complex 36-A at Cape Kennedy Air Force Station. Just prior to launch the craft's twin Radioisotope Thermoelectric Generators (RTGs) were bolted to twin booms that would unfurl when the craft was safely in deep space. The RTGs were as terrifying as they were imperative for the success of the mission.

Designed to keep the spacecraft fully powered for at least fifty years, they could safely be viewed only through thickly leaded windows in their isolation facility, and even with their thick casings the Plutonium-238 fuel pellets inside made them too hot to touch. At least one engineer on the Pioneer 10 team declined to be present at the RTGs' installation on the grounds that he still wanted to have a family.

It was another of the many ironies that surrounded the later Pioneer spacecraft that despite the highly radioactive power sources NASA was about to blast into the skies, most Americans were far more concerned about the line drawings each spacecraft would carry. On both Pioneer 10 and 11 Cosmologist and science popularizer Carl Sagan had arranged that a gold-plated aluminum tablet be added as an interstellar greeting card in case either craft should ever encounter an alien civilization.

Sagan had been inspired to propose this to NASA by Eric Burgess, a writer for the Christian Science Monitor. Burgess was worried that with all the focus on the scientific aspects of the Pioneer 10 and 11 missions, people might lose touch with the essential wonder of sending a spacecraft out beyond the asteroid belt for the first time. It was a excellent point, and it paved the way for the famous golden records carried aboard the later Voyager spacecraft.

Pioneer 10 in the final stages of construction. Credit: NASA Ames Research Center

Each of the Pioneer plaques contained a visual reference to the Earth's position in space – relative to fourteen local pulsars - plus a depiction of the timing of the hyperfine transition of the hydrogen atom to introduce aliens to the way we measure time. Both images would feature prominently on the Voyager golden records as well. But far more problematic to the delicate sensibilities of early 1970s America were the images of two naked humans, male and female. They had been drawn by Sagan's wife at the time, Linda Salzman Sagan, and approved by NASA mogul John Naugle.

Large swathes of middle America were outraged. When images of the plaques were portrayed in the press the usual approach was to airbrush out the couple's genitals or cover them with duct-tape. Andrew Khinoy of the Philadelphia Inquirer put it succinctly "What they're ready to accept in outer space, they're not ready to accept in Philadelphia, at least, not on the front pages of their newspapers."

Ironically, in fiction at least, Pioneer 10 does meet an alien civilization. In Star Trek V The Final Frontier it is used as target practice by a Klingon Bird of Prey commander Captain Klaa to while away the monotony of a boring deep space patrol.

Not perhaps, what Carl Sagan had in mind!

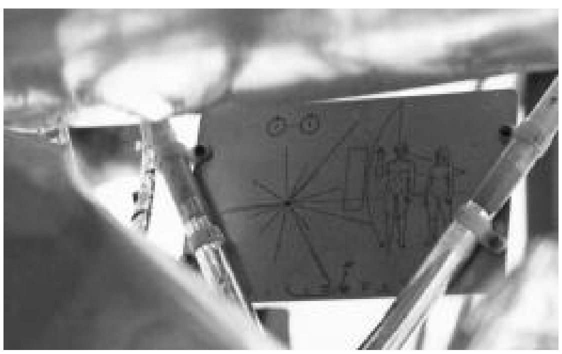
A Pioneering Journey

At 8:49 PM Eastern Standard Time on Thursday, March 2nd, 1972, the mighty engines of Pioneer 10's Atlas first stage lit up the night sky as they flung the tiny spacecraft towards Jupiter.

Less than eighteen minutes later, Pioneer 10 was moving faster than any man-made object before, traveling at a staggering 32,000 mph. Only eleven minutes later, Pioneer 10 had crossed the orbit of the Moon and was speeding toward the asteroid belt -- the first of the many big unknowns the spacecraft would encounter. Nobody knew whether the density of rubble in the region would smash the craft or damage its onboard instruments. On February 15th, 1973, they had their answer: Ames officially declared that Pioneer 10 had navigated the belt with no mishaps. It was now on its way for an encounter with the hostile environment of Jupiter.

Here the problem would be radiation, something that at least one scientist on the Pioneer team knew Jupiter supplied by the bucket-load. James Van Allen had discovered the radiation belt around Earth that today bears his name -- a direct result of the flight of America's very first satellite, Explorer 1, launched during the International Geophysical Year of 1958. Van Allen was also responsible for the discovery that the agitated radio signals emitted from Jupiter, known since the invention of radio telescopes, gave evidence that the region around Jupiter roasted in radiation doses that would fry a human in seconds. With Pioneer 10 approaching at speeds beyond imagination, and with a communication delay time of several minutes, the mission planners could only cross their fingers and hope the instruments survived.

Periapsis - Pioneer 10's closest approach to Jupiter - was predicted for Monday, December 3rd, 1972 at 6.24 Pacific time. By then Jupiter's massive gravity had accelerated Pioneer 10 to 82,000 mph and the radiation levels had risen to levels ten times greater than predicted. Everyone knew what this meant; the imaging photopolarimeter would fail first, and then the other instruments would gradually shut down. By the time of Pioneer 10's closest approach to Jupiter the spacecraft would be effectively dead.



The plaque depicting a naked man and woman mounted on the Pioneer spacecraft. Credit: NASA

But just minutes before the predicted shutdown, radiation levels started to tail off. Van Allen discovered why. Unlike Earth’s magnetic field, which extends somewhat evenly from pole to pole, Jupiter's is a toroidal ring that wobbles around the planet like a spinning plate on a stick. Once the ring moves out of your way you are back in low radiation space. For Pioneer 10 this happened just in time to stave off disaster. Yet Pioneer

10 did not escape unscathed. Some of the preliminary images of the moon Io were lost because of radiation-induced glitches. But, at 6:30 PM on December 3rd, Pioneer 10 was flying just 81,000 miles above the swirling cloud tops of Jupiter's atmosphere – and it was still taking pictures. Gehrels’s photopolarimeter kept rolling and humanity’s first encounter with the largest planet in our solar system was safely transmitted home. One of the most haunting images in the lexicon of space exploration is the view that Pioneer 10 sent back as she passed Jupiter and headed into the deepest unknown.

There was jubilation at Ames. Charlie Hall could not resist pointing out that humanity had gone from Galileo’s first glimpse of the moons of Jupiter through a telescope to actually visiting the planet in only twelve generations. It was a sobering reflection on mankind’s extraordinary technical progress in the last half millennium.

By today’s standards the images returned by Pioneer 10 were not much to look at. They were grainy and composed of only two colors - red and blue. The additional colors they later possessed in press releases were added in manually by deciphering the digitized color data. But the pictures represented a pivotal moment in uncrewed space exploration. In future missions, as the public’s enormous appetite for space images became apparent to NASA, cameras would become overwhelmingly important. Space exploration, from Pioneer 10 on, would have to strike the delicate balance between achieving cutting edge science and the public’s desire for spectacular photographs of exotic places. NASA and the other space agencies would quickly become adept at it.

So successful was the Jupiter flyby that the normally conservative aviators of Ames found themselves thinking far outside the box. If Pioneer 10 had fared so well, why not take a chance with Pioneer 11? They calculated that a minor tweak of Pioneer 11’s orbital trajectory would not only take it past Jupiter but place it on an intercept course for the next gravitational gas-station down the road: Saturn.

There were sound scientific reasons for going to Saturn. Pioneer 10 had almost succumbed to the deadly radiation in Jupiter's giant magnetic field, and Ames wanted Pioneer 11 to get closer still to Jupiter. Rather than risk exposing the fragile craft to levels of radiation that would almost certainly fry its circuits, they decided to modify the flyby so that it went almost vertically from pole to pole. This meant that the passage through Jupiter's radiation field would be briefer – though more violent -- and also made the Saturn trajectory possible. It was ambitious, but the opportunity was too enticing to miss.

Pioneer 11 slipped into Jovian space in early November 1973. Unlike her predecessor, she would be flying past Jupiter in a retrograde orbit – against the planet's rotation – which would allow more detailed imaging with the IPP as well as better measurements of Jupiter's magnetic field with a revamped instrument, designed by James Van Allen with his characteristic ingenuity. The different orbit would also allow Pioneer 11 to examine Jupiter's polar regions, where the mission scientists hoped the atmosphere might be more transparent than near the equator.

Instrumentation and approach were not the only things the Ames team did differently. Knowing from their Pioneer 10 experience that radiation would interfere with the operation of the instruments they started uploading a continuous stream of compensating commands via the giant antennae of JPL's Deep Space Tracking network. The tactic worked like a charm, and Pioneer 11 did not hemorrhage data in the way Pioneer 10 had.

At 9pm Pacific Time on December 2nd 1973, Pioneer 11 arrived at its point of closest approach with Jupiter, only about 26,000 miles above the cloud tops. For the team at Ames it was an anxious couple of hours, because this time periapsis would occur above Jupiter's far side, and radio communication with the craft would temporarily cease. The Canberra station was the first to reacquire the signal This time the period of instrument malfunction had been mercifully brief. The second fly-by of Jupiter had been a success too. NASA official Robert Kramer told the assembled press corps "Pioneer 11 flew into the fiery jaws of the dragon and got scorched a little, but it is a tough little bird and is now headed for Saturn."

Before the flights of Pioneer 10 and 11 Jupiter had been a largely closed book. Little more was known than that it had moons and a very active radiation environment. If the Pioneer probes sent home any single message, it was that Jupiter was much more complicated than anyone had previously imagined. For example, the planet is practically all liquid. Its chemistry is dominated by compressed hydrogen and helium, and as far as anyone can see, the planet has no solid core. If there is a core, it is likely to consist of something unusual – some have even suggested metallic hydrogen, a substance not found on Earth because of the colossal pressures required for its synthesis.

The Pioneer probes found that Jupiter's atmosphere is a witch's cocktail of ammonia, methane, and water vapor stirred into a continuous maelstrom that screams eternally across the face of the planet. One of the few features of the planet that had been observable from Earth -- the giant red spot that glares malevolently from its equatorial region -- turned out to be a purely atmospheric phenomenon, a hydrogen and ammonia hurricane bigger in diameter than the Earth that has been raging for centuries.

Pioneer discovered that Jupiter is a net emitter of heat. This internal heat, together with the abundance of hydrogen and other elements on Jupiter, may be responsible for the planet's metallic core, which in turn creates the immense toroidal magnetic field that traps radiation in the planet's vicinity. The Pioneer missions also showed that the Jovian moons play a part in maintaining the complexity of the magnetic and radiation environment around the planet. The larger moons in particular absorb a great deal of radiation and leave trails of reduced radiation in their orbital wakes.

The Ames gamble had paid off. Pioneer 11 had not only survived its Jupiter encounter but was now headed across the gulf of space to Saturn. The journey would take fully six years, most of it spent above the plane of the ecliptic. The price for the first close look at Saturn was a slow path and a long wait.

More information: O, Pioneers! (part 2): The derelicts of space

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