STATUS UPDATED: 1 March 2003

PIONEER MISSIONS

Pioneer 10 distance from Sun : 82.39 AU Speed relative to the Sun: 12.222 km/sec (27,340 mph) Distance from Earth: 12.31 billion kilometers (7.65 billion miles) (Round-trip Light Time = 22 hours 49 minutes)

After over 30 years, it appears that Pioneer 10 has sent its last signal to Earth. The power source on Pioneer 10 finally degraded to the point where the signal to Earth dropped below the threshold for detection in its latest contact attempt on 7 February 2003. No more attempts at contact are planned at this time. The previous three contacts had very faint signals with no telemetry received. Pioneer's last, very weak signal was received on 23 January 2003. The last time a Pioneer 10 contact returned telemetry data was on 27 April 2002.

Project Manager: Larry Lasher

30 YEARS FROM LAUNCH AT CAPE CANAVERAL ON MARCH 2, 1972, PIONEER 10 DATA WAS RECEIVED AT MADRID

GOLDSTONE

On 1 March 2002, DSS 14 transmitted an uplink, and two no-op commands at 200 kw to the spacecraft.

MADRID

22 hours later, from 79.4 AU, DSS 63 acquired the downlink on time at -183 dbm. After peaking the signal to -178.5 dbm, they locked the telemetry at 16 bps with SNR of -0.5 db.

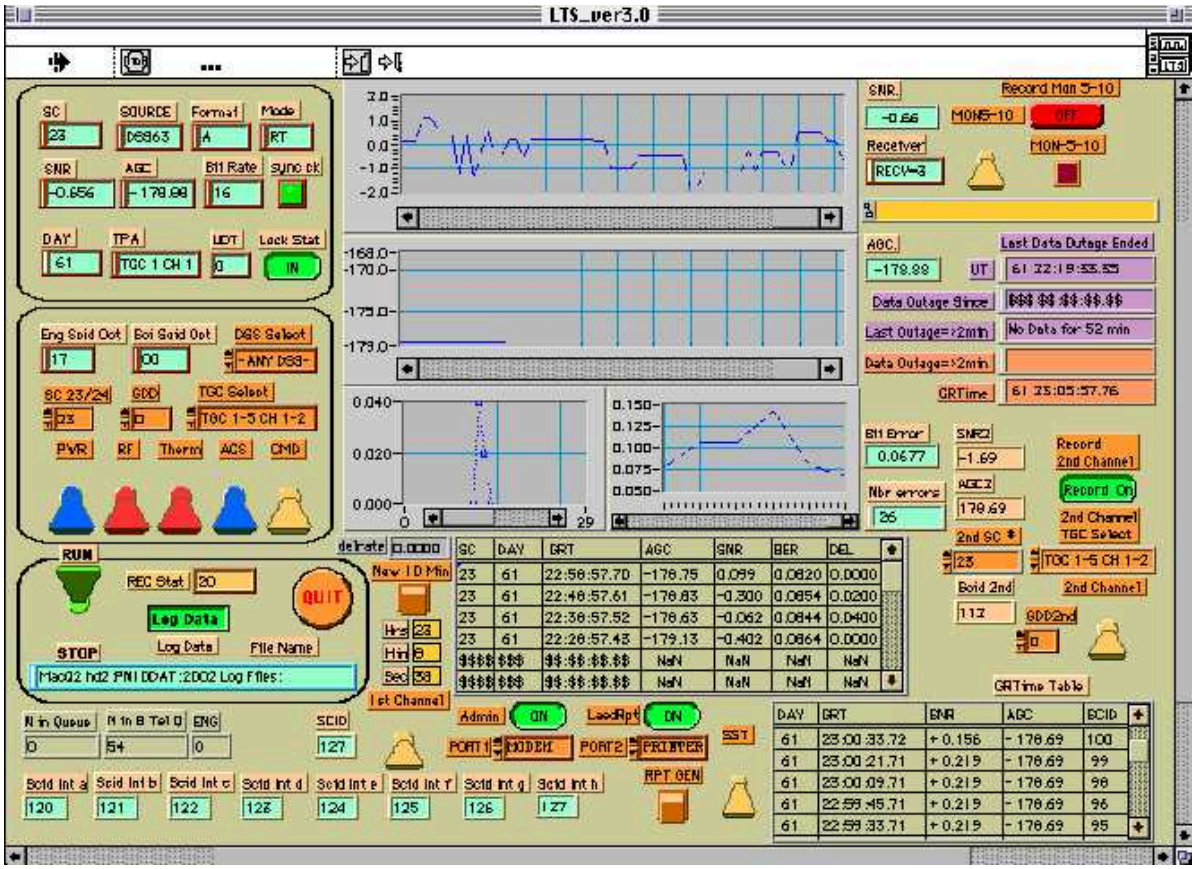
ARICEBO

SETI Institute also acquired the same signal at Puerto Rico. SETI has been using Pioneer 10 as a reference signal.

PIONEER SPACECRAFT CONDITIONS

Very cold with most temperature readings at the bottom of their scale. Bus voltage about 26 volts (nominal is 28). Uplink received from DSS 14 at -131.7 dbm. Two commands received, both confirmed as executed. Geiger Tube Telescope Instrument on, and data received.

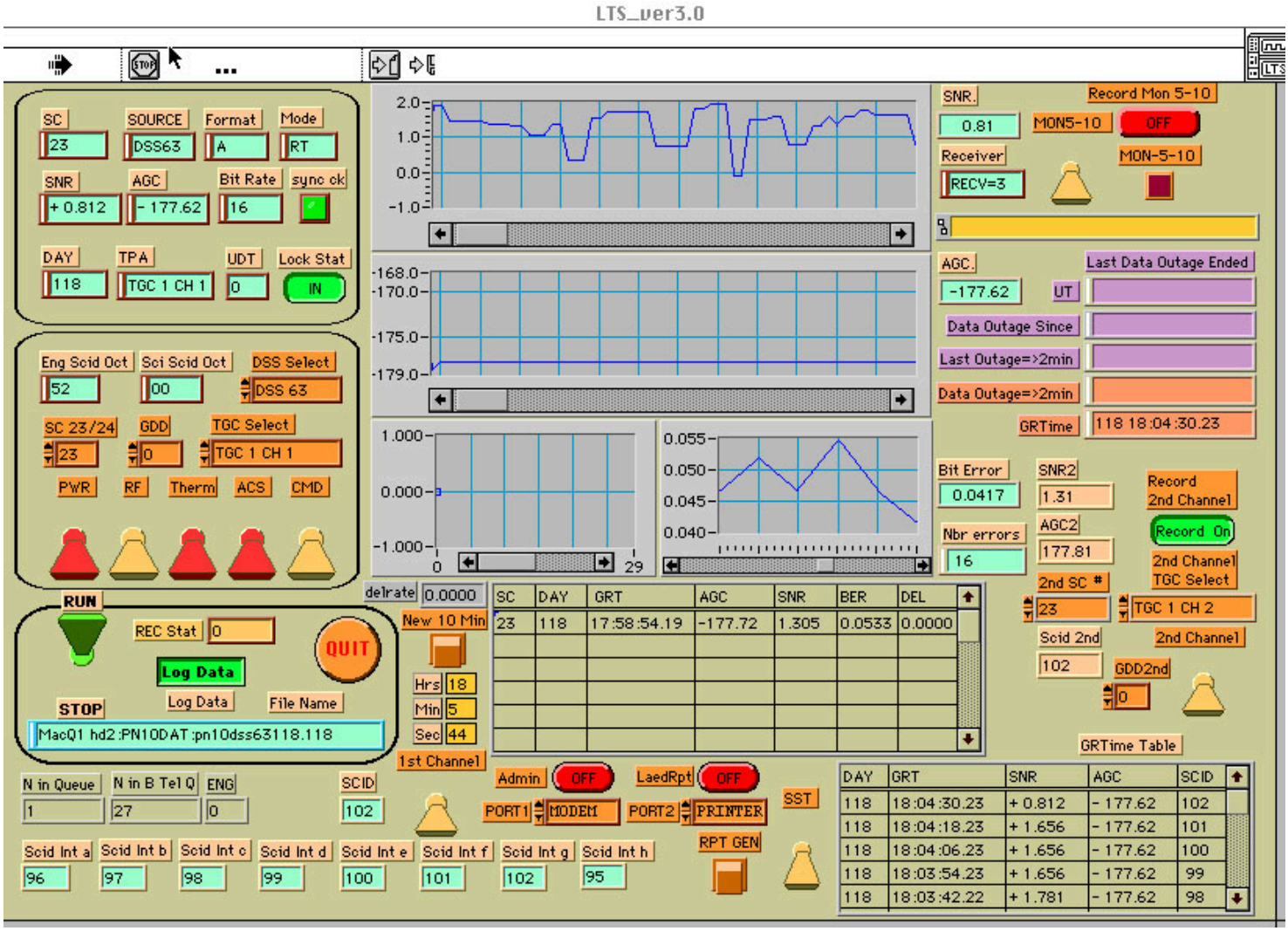
Above from report given to JPL by Bob Ryan



Project Phoenix has been observing Pioneer 10 at Arecibo in Puerto Rico through the auspices of the SETI Institute. The signal from Pioneer 10 was also picked up at Arecibo on 2 March 2002.

From the 2 March 2002 contact, Dr. Van Allen reports that the University of Iowa cosmic ray instrument on Pioneer 10 provided 44 minutes of data that met rigorous validation criteria. These data show that the cosmic ray intensity at 80 AU is substantially less than its earlier maximum value in 1998-99. Hence, Pioneer 10 is still under the delayed influence of solar activity and has not yet reached the cosmic ray modulation boundary of the heliosphere.

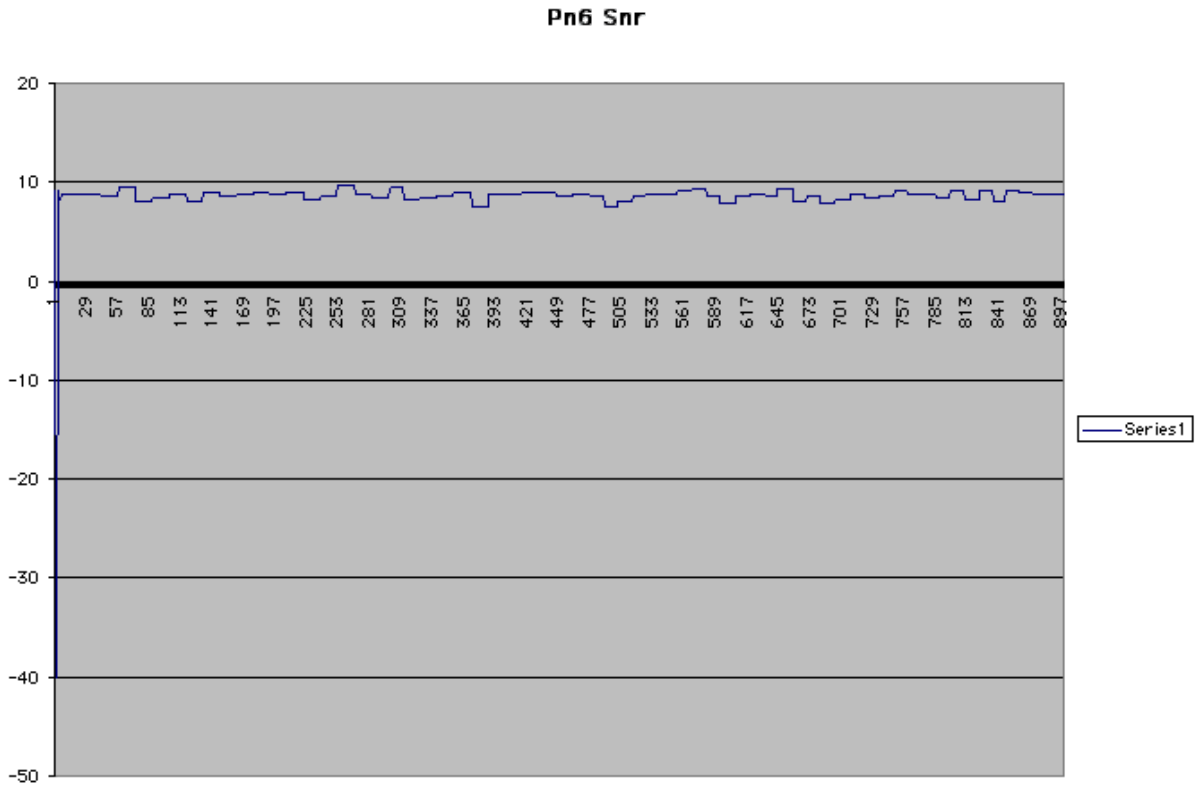
At GMT 17:27:30, Saturday, 4/28/01, the signal from Pioneer 10 was received at station 63 in Madrid, the first time since August 5/6 of 2000. So it appears that Pioneer 10 has life, albeit in another mode - i.e., only in a two-way coherent mode. We have been listening for the Pioneer 10 signal in a one-way downlink non-coherent transmission mode since last summer with no success. We therefore conclude that in order [for Pioneer 10] to talk to us, we need to talk to it. This means from now on, we need two-way round-trip light time (RTLT) passes to allow the Deep Space Network (DSN) to send up a strong stable signal to lock up with a coherent downlink signal.



Hear Pioneer Speaks contact

Pioneer 6 was featured on the Star Date radio broadcast by the University of Texas McDonald Observatory on 16 December 2000 - the 35th anniversary of its launch. Pioneer 6 is the oldest NASA spacecraft extant.

There was a successful contact of Pioneer 6 for about two hours on 8 December 2000 to commemorate its 35th anniversary. The control room at NASA Ames Research Center in Mountain View, CA, was manned by Project Manager: Larry Lasher, Flight Director: Dave Lozier, Chief Flight Controller: Ric Campo, and Flight System Engineer; Larry Kellogg, with Network Operations Project Engineer: Ida Millner at JPL. Some 35 years from the launch date of 12/16/65, Pioneer 6 telemetry data were received expeditiously as spacecraft lockup occurred on the first attempt on Day 344 UT 0000:45 (local time 4:00:45 PM PST) at DSS-14 at Goldstone. Pioneer 6 was 83 million miles distant from Earth. The track lasted approximately 2.5 hours. The Signal-to-Noise Ratio (SNR)=9 dB and signal strength (AGC)=-164 remain at approximately the same levels as the last previous contact in October 6, 1997 demonstrating the stability and durability of NASA's oldest extant spacecraft. Viva la Pioneer.



PIONEER 10 HONORED BY STAMP! On November 18, 1999 the US Postal Service issued a stamp commemorating the Pioneer 10 spacecraft . It was selected as one of the 15 icons for the decade of the 1970s as part of its Celebrate the Century postage stamp series. The US Postal Service consulted with the Pioneer Project Manger to ensure its accuracy. The following inscription was chosen for the stamp: Launched March 1972, "Pioneer 10" was the first spacecraft to travel to an outer planet, providing data and images of Jupiter. Eleven years later, it became the first man-made object to leave the solar system.

This is not the first time the US Postal Service has commemorated Pioneer 10. A stamp was also issued in 1974. (Thanks to Larry Klaes)

PIONEER 10 DEFLECTED BY A KUIPER BELT OBJECT? Preliminary results indicate that Pioneer 10 has had an encounter with a Trans-Neptunian object at 56 AU. Using coherent radio Doppler data generated by the Deep Space Network (DSN) at S band frequencies (wavelength ~ 13 cm), PN 10 experienced a gravitational deflection in December 1992. The new body, found by a team at Queen Mary and Westfield College in London, UK, and the Jet Propulsion Laboratory in California, is probably a so-called Kuiper Belt object. If the observations are confirmed by other astronomers, it will be only the second time in history that a Solar System object has been discovered by its gravitational effect alone. The first was the planet Neptune which was discovered in 1846. Its position was predicted because of its gravitational tug on the planet Uranus, which appeared to be behaving oddly following its discovery 59 years earlier.

This story was reported by BBC News Online Science Editor Dr David Whitehouse on 28 September 1999

ANOMALOUS GRAVITATIONAL FORCE? A discussion of this phenomenon appears in the 4 October 1999 issue of Newsweek magazine (See also the December 1998 issue of Scientific American.) The mystery of the tiny unexplained acceleration towards the sun in the motion of the Pioneer 10, Pioneer 11 and Ulysses spacecraft remains unexplained. A team of planetary scientists and physicists led by John Anderson (Pioneer 10 Principal Investigator for Celestial Mechanics) has identified a tiny unexplained acceleration towards the sun in the motion of the Pioneer 10, Pioneer 11, and Ulysses spacecraft. The anomalous acceleration - about 10 billion times smaller than the acceleration we feel from Earth's gravitational pull - was identified after detailed analyses of radio data from the spacecraft. A variety of possible causes were considered including: perturbations from the gravitational attraction of planets and smaller bodies in the solar system; radiation pressure, the tiny transfer of momentum when photons impact the spacecraft; general relativity; interactions between the solar wind and the spacecraft; possible corruption to the radio Doppler data; wobbles and other changes in Earth's rotation; outgassing or thermal radiation from the spacecraft; and the possible influence of non-ordinary or dark matter. After exhausting the list of explanations deemed most plausible, the researchers examined possible modification to the force of gravity as explained by Newton's law with the sun being the dominant gravitational force. "Clearly, more analysis, observation, and theoretical work are called for," the researchers concluded. The scientists expect the explanation when found will involve conventional physics.

Pioneer 10 will continue into interstellar space, heading generally for the red star Aldebaran, which forms the eye of Taurus (The Bull). Aldebaran is about 68 light years away and it will take Pioneer over 2 million years to reach it.

Pioneer 11

(Launched 5 April 1973)

The Mission of Pioneer 11 has ended.

The last communication from Pioneer 11 was received in November 1995, shortly before the Earth's motion carried it out of view of the spacecraft antenna.

The spacecraft is headed toward the constellation of Aquila (The Eagle), Northwest of the constellation of Sagittarius. Pioneer 11 will pass near one of the stars in the constellation in about 4 million years.

Frequently-asked Questions (FAQ's):

Question:
Who were the Pioneer Project managers?
Answer:
Charles Hall, the original Project Manager from 1962 to 1980, is the manager most responsible for the immense success of Pioneer. He was Project Manager from conception through successful implementation of the primary missions of Pioneer 6 through 13. Charlie retired after the encounter of Pioneer 11 with Saturn in 1979. The space community was saddened to learn of the death of Charles Hall on 26 August 1999. Over a period of 13 years, 8 Pioneer spacecraft were successfully launched by the Pioneer Project Office under Mr. Hall's management and direction. NASA Administrator Daniel Goldin has this to say of Charlie Hall: "The entire NASA family mourns the loss of Charlie Hall. His intelligence, persistence and leadership throughout his career at NASA, and particularly as the original program manager for the Pioneer Project, continue to inspire us to reach the stars and beyond. Charlie Hall's Pioneer 10 craft may be over 6.8 billion miles from Earth, but his spirit will always be with us at NASA." Richard Fimmel successfully managed Pioneer 6 through 12 through their extended missions. Fred Wirth was the third Project Manager and is responsible for the design of this Web document. Larry Lasher , the present Project Manager, organized the 25th anniversary celebration of Pioneer 10 and presided over the retirement of the Pioneer Mission program. He instituted the training program and then arranged for support of an advanced technology program investigating chaos theory on the Pioneer 10 signal that allows us to continue following Pioneer 10. Dr. Lasher is the primary point of contact for information about the Pioneer Missions.

Question:
How far will Pioneer travel and on what path?
Answer:
Pioneer 10 will be in galactic orbit for billions of years. It is moving in a straight line away from the Sun at a constant velocity of about 12 km/sec. Until Pioneer 10 reaches a distance of about 1.5 parsec (309,000 AUs) - about 126,000 years from now - it will be dominated by the gravitational field of the Sun. After that Pioneer 10 will be on an orbital path in the Milky Way galaxy influenced by the field of the stars that it passes.

Question:
Where are the the Kuiper Belt and the Oort Cloud relative to Pioneer 10?
Answer:
Pioneer 10 is now at a distance of ~ 80 AU from the Sun and so still confined to the Kuiper Belt. The Kuiper Belt is a flat disk-shaped region of asteroids and short-period comets extending roughly from 30 up to 100 astronomical units (AU). Pioneer 10 travels at the rate of speed of 2.58 AU/year. The Oort Cloud of icy bodies is believed to extend out from 20,000 to about 100,000 AU from the Sun. It is a hollow spherical cloud in which as many as 2 trillion icy snowballs may orbit. The effects of the motions of nearby stars could throw these icy bodies into the inner solar system, where they would become long-period comets.

Question:
Why does the RTG power decrease?
Answer:
Power for the Pioneer 10 is generated by the Radioisotope Thermoelectric Generators (RTG's). Heat from the decay of the plutonium 238 isotope is converted by thermoelectric couples into electrical current. The electrical output depends on the hot junction temperature, the thermal path to the radiator fins, and the cold junction temperature. It is the degradation of the thermoelectric junction that has the major effect in decreasing the power output of the RTG. In the 30-year time scale

operation of Pioneer 10, the 92 year half-life of the isotope does not appreciably affect the RTG operation. The nuclear decay heat will keep the hot junction temperature hot for many years but unfortunately will not be able to be converted into enough electricity to power the transmitter for much longer.

Question:
How much has Pioneer been eroded?
Answer:
All the wear, pitting, and erosion that Pioneer 10 has sustained are probably over now. The asteroid belt and the severe conditions of Jupiter have already been experienced. Now, Pioneer is in the vacuum of space where the average spatial density of molecules is one trillionth the density of the best vacuum we can draw on Earth. We expect Pioneer to last an indeterminate period of time, probably outlasting its home planet, the Earth. In 5 billion years, the Sun will become a red giant, expand, envelop the orbit of the Earth, and consume it. Pioneer will still be out there in interstellar space. Erosional processes in the interstellar environment are largely unknown, but are very likely less efficient than erosion within the solar system, where a characteristic erosion rate, due largely to micrometeoritic pitting, is of the order of 1 Angstrom/yr. Thus a plate etched to a depth ~ 0.01 cm should survive recognizable at least to as distance ~ 10 parsecs, and most probably to 100 parsecs. Accordingly, Pioneer 10 and any etched metal message aboard it are likely to survive for much longer periods than any of the works of Man on Earth.

Question:
What about Pioneer 1 to 5?
Answer:
Pioneers 1 through 5 were launched from 1958 through 1960 and made the first thrusts into space toward the Moon and into interplanetary orbit. Pioneer 1 provided data on the extent of the Earth's radiation belts. Pioneer 2 suffered a launch vehicle failure. Pioneer 3 discovered a second radiation belt around Earth. Pioneer 4 was the first American spacecraft to escape Earth's gravitational pull as it passed within 58,983 km (36,650 miles) of the moon. The spacecraft did return data on the Moon radiation environment, although the desire to be the first man-made vehicle to fly past the moon was lost when the Soviet Union's Luna 1 passed by the Moon several weeks before Pioneer 4. Pioneer 5 was designed to provide the first map of the interplanetary magnetic field. The vehicle functioned for a record 106 days and communicated with Earth from a record distance of 36.2 million km (22.5 million miles). The early Pioneers were exploratory missions that led to intriguing new questions that required more advanced types of spacecraft capable of exploring space to considerable distances within and beyond Earth's orbit. This led to the Pioneer 6 through 9 series that made the first detailed comprehensive measurements of the solar wind, solar magnetic field, and cosmic rays.

Question:
Why and how is Pioneer 10 being maneuvered?
Answer:
The Pioneer spacecraft is spin-stabilized, spinning at approximately 4.28 rpm (Revolutions Per Minute), with the spin axis running through the center of the dish antenna. If a person were to sit in the spacecraft, looking through a hole in center of the dish antenna with a telescope, he would see the Sun traveling very slowly to the left. The Earth's path would describe a very narrow ellipse (the orbit is seen nearly edge-on) around the Sun. In July the Earth is near the right hand edge of the ellipse, and 6 months later will be near the left hand edge of the ellipse. The angle to the spacecraft between the left edge of the ellipse and the right edge is less than 2 degrees. In order to communicate with the spacecraft, the Earth has to be within 0.8 degrees of the boresight of the spacecraft antenna. Since the Earth moves by almost 2 degrees, the spacecraft has to be re-aimed at the Earth about twice a year. This is done by a "CONSCAN (conical scan) precession maneuver" executed by the spacecraft.

The radio signal transmitted from an antenna on Earth is focused and reflected by the spacecraft dish antenna toward a small feed horn located on a tripod which is centered in front of the spacecraft dish antenna, and then conducted to a receiver in the spacecraft. During a CONSCAN maneuver, the feed horn is physically moved by 8 inches to one side. A ground command turns on a heater in a bellows filled with liquid Freon. The Freon boils, the bellows expands, and moves a mechanical piston and cam attached to the feed horn mounting plate against a mechanical stop. A micro switch cycles the heater power on and off to keep the feed in the offset position.

With the feed in the offset position, the radio signal from the tracking station is seen by the spacecraft receiver as varying sinusoidally in amplitude (amplitude modulated). This error signal contains amplitude and phase information on the pointing angle between the spacecraft spin axis and the Earth and the direction to the Earth during the spin cycle. The minimum amplitude occurs during the spin cycle when the antenna points to the Earth, whereas the maximum occurs when the antenna dish points away from the Earth. The frequency of the modulation is equal to the spacecraft spin rate (4.28 rpm). The error signal is processed on board the spacecraft to calculate the timing requirements for firing the jets at the appropriate instant in the spin cycle to precess the spin axis towards the Earth.

The CONSCAN processor averages the modulation over two revolutions of the spacecraft. On the third revolution, it orders two hydrazine thrusters (mounted 180 degrees apart on the rim of the dish antenna) to fire a short pulse of 0.0312 seconds duration. This moves the spacecraft spin axis a tiny amount toward the minimum amplitude value, i.e., the Earth, reducing the amplitude of the modulation by a small amount. This process is repeated each three revolutions, each time reducing the pointing angle error and the modulation amplitude. When the pointing angle is within 0.3 degrees of boresight, the processor terminates the maneuver automatically. Typically, about 20 to 28 pulses are fired. A ground command then executes to turn off the power to the feed offset heater, the gaseous Freon recondenses to pull the mechanism back to the normal centered position, and the maneuver is completed.

Question:
If the spacecraft are leaving the Solar System, why does the distance from Earth sometimes get shorter?
Answer:
It is a matter of a hyperbolic escape trajectory, geometry, and relative velocity vectors. The distance from the Sun is always increasing. However, since the Earth travels around the Sun faster than the spacecraft moves away from the Sun, the spacecraft-earth distance decreases for a few months, and then rapidly increases again.

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