78)
Lunar Orbiter 3
Nation: U.S. (33)
Objective(s): lunar orbit
Spacecraft: LO-C
Spacecraft Mass: 385.6 kg
Mission Design and Management: NASA LaRC
Launch Vehicle: Atlas-Agena D (no. 20 / Atlas D no. 5803 / Agena D no. AD128 / 6632)
Launch Date and Time: 5 February 1967 / 01:17:01 UT
Launch Site: ETR / launch complex 13
Scientific Instruments:

1) imaging system
2) micrometeoroid detectors
3) radiation dosimeters

Results: Lunar Orbiter 3 was the final Lunar Orbiter mission to study potential Apollo landing sites; further missions would be dedicated to scientific and global surveys. The spacecraft arrived in lunar orbit on 7 February 1967. Initial orbital parameters were 200 x 1,850 kilometers at 21° inclination. During its eight-month mission, the spacecraft took 211 frames of pictures, although only 182 were actually returned to Earth because of a problem on 24 February with the motor that rewound the film. Despite the minor glitch, Lunar Orbiter fulfilled its original mission objectives, returning images of 15.5 million square kilometers of the near side and 650,000 square kilometers of the far side. On 30 August 1967, ground controllers commanded the vehicle to circularize its orbit to 160 kilometers in order to simulate an Apollo trajectory. Later, on 9 October 1967, the probe was intentionally crashed onto the lunar surface at 14°36' north latitude and 91°42' west longitude. The photographs from the first three Lunar Orbiters allowed NASA scientists to pick eight preliminary landing sites for Apollo by early April 1967, including site 2 in the Sea of Tranquillity, where Apollo 11 would land, and site 5 in the Ocean of Storms, where Apollo 12 (and also Surveyor 3) would disembark.

79)
Surveyor 3
Nation: U.S. (34)
Objective(s): lunar soft-landing
Spacecraft: Surveyor-C
Spacecraft Mass: 997.9 kg
Mission Design and Management: NASA JPL
Launch Vehicle: Atlas-Centaur (AC-12 / Atlas D no. 292 / Centaur D)
Launch Date and Time: 17 April 1967 / 07:05:01 UT
Launch Site: ETR / launch complex 36B
Scientific Instruments:

1) imaging system
2) surface sampler

Results: Surveyor 3 was the third engineering flight of the series; for the first time, it car-

Charles Conrad, Jr., Apollo 12 Commander, examines the unpiloted Surveyor 3 spacecraft during the second extravehicular activity (EVA-2). The Lunar Module (LM) *Intrepid* is in the right background. This picture was taken by astronaut Alan L. Bean, Lunar Module pilot. The *Intrepid* landed on the Moon's Ocean of Storms only 600 feet from Surveyor 3. The television camera and several other components were taken from Surveyor 3 and brought back to Earth for scientific analysis. Surveyor 3 soft-landed on the Moon on 19 April 1967.

ried a soil-sampling instrument that could reach up to 1.5 meters from the lander and dig up to 0.5 meters deep. Unlike the previous Surveyors, Surveyor 3 began its mission from parking orbit around Earth with a burn from the Centaur upper stage, now capable of multiple firings. Although the landing radar cut out prematurely, basic inertial control ensured that Surveyor 3 landed on the lunar surface with minimal vertical velocity at 00:04:17 UT on 20 April 1967 in the southeastern region of Oceanus Procellarum, at 2°56' north latitude and 23°20' west longitude. A fairly strong sideways motion made the lander hop twice before coming to a standstill. Less than an hour after landing, the spacecraft began transmitting the first of 6,315 TV pictures of the surrounding areas. The most exciting experiment of the mission was the deployment of the remote scooper arm, which, via commands from Earth, dug four trenches and performed four bearing tests and thirteen impact tests. Based on these experiments, scientists concluded that lunar soil had a consistency similar to wet sand, with a bearing strength of 0.7 kilograms per square centimeter—solid enough for an Apollo Lunar Module. Last contact was made on 4 May 1967, two days after the lunar night began. More than three years later, Apollo 12 astronauts Charles Conrad, Jr., and Alan L. Bean landed the Intrepid LM near the inactive Surveyor 3 lander on 18 November 1969. The astronauts recovered parts from Surveyor 3, including the soil scoop and camera system, to allow scientists to evaluate the effects of nearly two and one-half years of exposure on the Moon's surface.

80)
Lunar Orbiter 4
Nation: U.S. (35)
Objective(s): lunar orbit
Spacecraft: LO-D
Spacecraft Mass: 385.6 kg
Mission Design and Management: NASA LaRC
Launch Vehicle: Atlas-Agena D (no. 22 / Atlas D no. 5804 / Agena D no. AD131 / 6633)
Launch Date and Time: 4 May 1967 / 22:25:00 UT
Launch Site: ETR / launch complex 13
Scientific Instruments:
1) imaging system
2) micrometeoroid detectors
3) radiation dosimeters

Results: Lunar Orbiter 4 was the first in the series dedicated to scientific surveys of the Moon. After a burn at 21:54 UT on 8 May 1967, the spacecraft entered a 2,705 x 6,034-kilometer orbit inclined at 85.48 degrees, becoming the first vehicle to enter polar orbit around the Moon. Controllers successfully overcame a problem with the Thermal Camera Door, and subsequently, during its two-month mission, the orbiter took pictures of 99 percent of the near side and 75 percent of the far side of the Moon in a total of 193 frames. The images had a resolution of up to 60 meters. In early June, controllers lowered the spacecraft's orbit to match that of Lunar Orbiter 5 so that scientists could collect gravitational data in support of the latter mission. Before losing contact on 17 July, Lunar Orbiter 4 took the first photos of the lunar south pole and discovered a 240-kilometer-long crustal fault on the far side. Since contact was lost before controlled impact, the spacecraft naturally crashed onto the Moon on 6 October 1967 due to gravitational anomalies.

81)
Kosmos 159 / [Luna]
Nation: USSR (46)
Objective(s): highly elliptical orbit around Earth
Spacecraft: Ye-6LS (no. 111)
Spacecraft Mass: unknown
Mission Design and Management: GSMZ Lavochkin
Launch Vehicle: 8K78M (no. Ya716-56)
Launch Date and Time: 16 May 1967 / 21:43:57 UT
Launch Site: NIIP-5 / launch site 1
Scientific Instruments: unknown
Results: This spacecraft was a one-off high-apogee Earth satellite developed to acquire data on trajectory measurement techniques on future lunar orbital missions. By perfecting such techniques, engineers could accurately measure trajectories of future lunar orbiters affected by anomalies in the Moon's gravitational field. Mission designers had planned to send the probe into a highly elliptical orbit with an apogee of 250,000 kilometers, but the

Blok L upper stage evidently cut off too early. Instead, the spacecraft, named Kosmos 159, entered a lower orbit of 260 x 60,710 kilometers at 51.7° inclination. Despite the incorrect orbit, controllers no doubt used the spacecraft for its original mission. No data is available on when the ground lost contact with the spacecraft. Kosmos 159 reentered Earth's atmosphere on 11 November 1967.

82)

Venera 4

Nation: USSR (47)
Objective(s): Venus impact
Spacecraft: 1V (no. 310)
Spacecraft Mass: 1,106 kg
Mission Design and Management: GSMZ Lavochkin
Launch Vehicle: 8K78M
Launch Date and Time: 12 June 1967 / 02:39:45 UT
Launch Site: NIIP-5 / launch site 1
Scientific Instruments:

Lander:

1) radio altimeter
2) aneroid barometer
3) eleven gas-analyzer cartridges
4) two resistance thermometers
5) ionization densitometer

Bus:

1) magnetometer
2) cosmic-ray counters
3) charged-particle traps
4) ultraviolet photometer

Results: Venera 4 was the first Venus probe built by the Lavochkin design bureau, although Lavochkin engineers retained the basic design layout of the earlier Korolev probes. The spacecraft consisted of a main bus about 3.5 meters high and a 383-kilogram lander probe designed to transmit data as it descended through the Venusian atmosphere. This capsule was designed to endure loads as high as 350 g and land on both land and liquid. For atmospheric entry, it was equipped with a thick ablative heatshield. After a midcourse correction on 29 July 1967, Venera 4 approached Venus on 18 October and released the lander at 04:34 UT, immediately prior to entry of the bus. Parachuting into the planet's atmosphere, the lander turned on its scientific instruments 5 minutes later when the rate of descent lowered to 10 meters per second (at 55 kilometers altitude). The probe continued to transmit for 93 minutes as it slowly fell through the atmosphere. Initially, Soviet scientists believed that the probe transmitted until contact with the surface. In reality, transmissions ceased at an altitude of 27 kilometers when the high atmospheric pressure and temperatures crushed the probe. The data implied that surface temperatures and pressure were 500°C and 75 atmospheres respectively. Venera 4's gas analyzers also found that the planet's atmosphere was composed of 90 to 95 percent carbon dioxide with no nitrogen. The spacecraft bus measured the planet's weak magnetic field and found no ring of radiation belts. It detected a very weak atmosphere of atomic hydrogen about 9,900 kilometers above the planet. Venera 4 was the first spacecraft to transmit data from a planet's atmosphere.

83)

Mariner 5

Nation: U.S. (36)
Objective(s): Venus flyby
Spacecraft: Mariner-67E / Mariner-E
Spacecraft Mass: 244.9 kg
Mission Design and Management: NASA JPL
Launch Vehicle: Atlas-Agena D (no. 23 / Atlas D no. 5401 / Agena D no. AD157 / 6933)
Launch Date and Time: 14 June 1967 / 06:01:00 UT
Launch Site: ETR / launch complex 12
Scientific Instruments:

1) ultraviolet photometer
2) S-band occultation experiment
3) dual-frequency occultation experiment
4) solar plasma probe
5) magnetometer
6) trapped-radiation detector
7) celestial mechanics experiment

Results: In December 1965, NASA approved a project to modify the Mariner 4 backup spacecraft to conduct a closer flyby of Venus than the only other NASA probe to fly past Venus, Mariner 2. Unlike Mariner 4, however, Mariner 5 did not carry an imaging instrument. Initially, NASA had planned to send Mariner 5 on a flyby at a miss distance of 8,165 kilometers, but the Agency altered its plan in favor of a more modest 75,000-kilometer flyby in order to prevent the nonsterilized vehicle from crashing into the planet.

After a midcourse correction on 19 June, Mariner 5 began transmitting data about Venus on 19 October during its encounter. Closest approach was at 17:34:56 UT at a range of 4,094 kilometers. Mariner 5 found no radiation belts trapped by Venus' magnetic field. The ultraviolet photometer detected a hydrogen corona (as did the Soviet Venera 4), but no oxygen emission. Mariner 5's instruments indicated that the planet's surface temperature and pressure were 527°C and 75 to 100 atmospheres respectively—which countered the Soviet claim that its Venera 4 spacecraft had managed to transmit from the planet's surface. On 4 December 1967, NASA lost contact with the spacecraft, although controllers briefly regained contact on 14 October 1968. The spacecraft did not transmit any further telemetry, and NASA eventually stopped attempts to communicate with the vehicle, now in heliocentric orbit.

84)
Kosmos 167 / [Venera]
Nation: USSR (48)
Objective(s): Venus impact
Spacecraft: 1V (no. 311)
Spacecraft Mass: c. 1,100 kg
Mission Design and Management: GSMZ Lavochkin
Launch Vehicle: 8K78M
Launch Date and Time: 17 June 1967 / 02:36:38 UT
Launch Site: NIIP-5 / launch site 1
Scientific Instruments:

Lander:
1) radio altimeter
2) aneroid barometer
3) eleven gas-analyzer cartridges
4) two resistance thermometers
5) ionization densitometer

Bus:
1) magnetometer
2) cosmic-ray counters
3) charged-particle traps
4) ultraviolet photometer

Results: This identical twin craft to Venera 4 failed to leave Earth orbit when its Blok L transinterplanetary stage failed to fire, apparently because the engine's turbopump had not been cooled prior to ignition. The spacecraft remained stranded in Earth orbit and reentered Earth's atmosphere on 25 June 1967.

85)
Surveyor 4
Nation: U.S. (37)
Objective(s): lunar soft-landing
Spacecraft: Surveyor-D
Spacecraft Mass: 1,037.4 kg
Mission Design and Management: NASA JPL
Launch Vehicle: Atlas Centaur (AC-11 / Atlas D no. 291 / Centaur D)
Launch Date and Time: 14 July 1967 / 11:53:29 UT
Launch Site: ETR / launch complex 36A
Scientific Instruments:

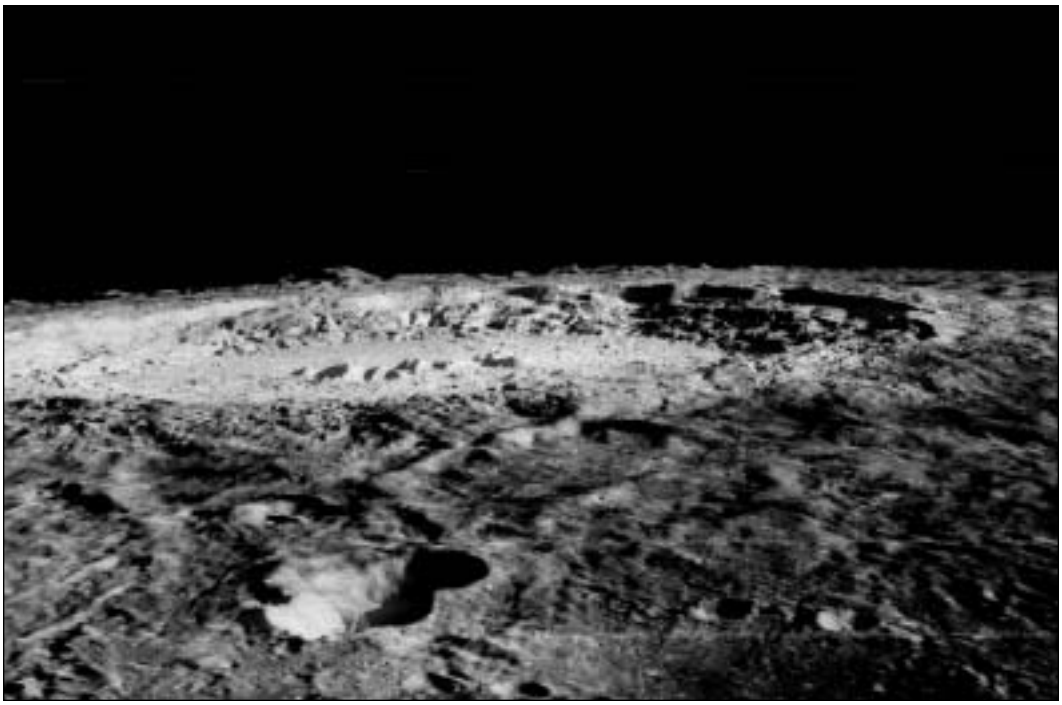
1) imaging system
2) surface sampler
3) soil magnet

Results: Like Surveyor 3, Surveyor 4 was equipped with a surface claw (with a magnet in the claw) to detect and measure ferrous elements in the lunar surface. The mission was completely successful until all communications were abruptly lost 2 seconds prior to retrorocket cutoff at 02:03 UT on 17 July 1967, with only 2.5 minutes left to landing on the Moon. The landing target was Sinus Medii (Central Bay) at 0.4° north latitude and 1.33° west longitude. NASA concluded that the lander might have exploded when contact was lost.

86)
Explorer 35 / International Monitoring Platform 6
Nation: U.S. (38)
Objective(s): lunar orbit
Spacecraft: IMP-E
Spacecraft Mass: 104.3 kg
Mission Design and Management: NASA GSFC
Launch Vehicle: Thor-Delta E-1 (no. 50 / Thor no. 488 / DSV-3E)
Launch Date and Time: 19 July 1967 / 14:19:02 UT
Launch Site: ETR / launch complex 17B
Scientific Instruments:

1) magnetometers
2) thermal ion detector
3) ion chambers and Geiger tubes
4) Geiger tubes and p-on-n junction
5) micrometeoroid detector
6) Faraday cup

Results: Explorer 35 was designed to study interplanetary space phenomena—particularly the solar wind, the interplanetary magnetic field, dust distribution near the Moon, the lunar gravitational field, the weak lunar



This image from Lunar Orbiter 5 shows crater Copernicus, 93 kilometers wide and located within the Mare Imbrium Basin at the northern near side of the Moon (10° north latitude and 20° west longitude). The picture shows the crater floor, floor mounds, rim, and rayed ejecta. Rays from the ejecta are superposed on all other surrounding terrains, which places the crater in its namesake age group: the Copernican system, established as the youngest assemblage of rocks on the Moon.

ionosphere, and the radiation environment. The spacecraft left Earth on a direct ascent trajectory and entered lunar orbit on 21 July 1967. Initial orbital parameters were 800 x 7,692 kilometers at 147° inclination. The spacecraft, similar to Explorer 33, also in lunar orbit, found that the Moon has no magnetosphere, that solar wind particles impact directly against the surface, and that the Moon creates a "cavity" in the solar wind stream. After six years of successful operation, the satellite was turned off on 24 June 1973. Explorer 35 was launched by the fiftieth Thor-Delta booster, of which only three had failed, giving the booster a success rating of 94 percent.

87)
Lunar Orbiter 5
Nation: U.S. (39)
Objective(s): lunar orbit
Spacecraft: LO-E
Spacecraft Mass: 385.6 kg
Mission Design and Management: NASA LaRC
Launch Vehicle: Atlas-Agena D (no. 24 / Atlas D no. 5805 / Agena D no. AD159 / 6634)
Launch Date and Time: 1 August 1967 / 22:33:00 UT
Launch Site: ETR / launch complex 13
Scientific Instruments:

1) imaging system
2) micrometeoroid detectors
3) radiation dosimeters

Results: Lunar Orbiter 5 was the last in a series of highly successful missions to map the Moon for potential landing sites and conduct general observational surveys. Two days after a midcourse correction on 3 August, it entered lunar orbit at 16:48 UT. Initial orbital parameters were 196 x 6,040 kilometers at 85.0° inclination. The spacecraft photographed thirty-six different areas on the near side and mapped most of the far side via a set of 212 frames during its first month in orbit. These included five potential Apollo landing sites, as well as possible targets for Surveyor missions. Controllers also extensively used the spacecraft to map the Moon's gravitational field in order to predict orbital perturbations

on future lunar orbital missions. The probe also obtained spectacular high-quality photos of Earth showing Africa and the Middle East. Lunar Orbiter 5 was commanded to land on the lunar surface and did so at 0° north latitude and 70° west longitude on 31 January 1968. In total, the five Lunar Orbiters photographed 99 percent of the lunar surface.

88)
Surveyor 5
Nation: U.S. (40)
Objective(s): lunar soft-landing
Spacecraft: Surveyor-E
Spacecraft Mass: 1,006 kg
Mission Design and Management: NASA JPL
Launch Vehicle: Atlas-Centaur (AC-13 / Atlas 3C no. 5901C / Centaur D-1A)
Launch Date and Time: 8 September 1967 / 07:57:01 UT
Launch Site: ETR, launch complex 36B
Scientific Instruments:

1) imaging system
2) alpha-scattering instrument
3) surface sampler
4) footpad magnet

Results: Brilliantly overcoming a near-fatal helium leak in a pressure regulator, engineers from JPL and Hughes Aircraft Company (the prime contractor for the spacecraft) managed to safely deposit Surveyor 5 on the surface of the Moon in the south-eastern region of Mare Tranquillitatis at 1°25' north latitude and 23°11' east longitude at 00:46:42 UT on 11 September 1967. The malfunction put the lander about 29 kilometers away from its target in an angular incline within the slope of the rimless crater. Surveyor 5 was, however, the most successful of the series. The lander returned 18,006 photos before lunar night descended on 24 September. Controllers successfully commanded the vehicle to take further photographs during the second lunar day between 15 and 24 October 1967 and the fourth lunar day in December. In total, 20,018 pictures were transmitted. In another experiment, on 13 September, controllers fired the main engine for 0.55 seconds to examine the effects of disturbing the lunar surface. NASA announced that no new craters were created, nor was there any significant dust cloud. The alpha-scattering instrument had earlier been released onto the surface and found the soil to be composed of more than half oxygen with amounts of silicon and aluminum. Contact was lost with the lander on 16 December 1967.

89)
no name / [Zond]
Nation: USSR (49)
Objective(s): circumlunar flight
Spacecraft: 7K-L1 (no. 4L)
Spacecraft Mass: c. 5,375 kg
Mission Design and Management: TsKBEM
Launch Vehicle: 8K82K + Blok D (Proton-K no. 229-01 / Blok D no. 12L)
Launch Date and Time: 27 September 1967 / 22:11:54 UT
Launch Site: NIIP-5 / launch site 81L
Scientific Instruments: unknown
Results: This spacecraft, a 7K-L1 type, was the first of a series of spacecraft that the Soviets tried to send on circumlunar missions as part of a larger project to send cosmonauts around the Moon. The program, which was officially approved in October 1965, was set off by two technological flights in Earth orbit in March and April 1967. The 7K-L1 spacecraft was a stripped-down version of the larger 7K-OK Soyuz spacecraft intended for Earth-orbital operations. During this launch, one of the six first-stage engines failed to fire because of blockage of a propellant line, and the launch vehicle was destroyed at T+97.4 seconds.

90)
Surveyor 6
Nation: U.S. (41)
Objective(s): lunar soft-landing
Spacecraft: Surveyor-F
Spacecraft Mass: 1,008.3 kg
Mission Design and Management: NASA JPL
Launch Vehicle: Atlas-Centaur (AC-14 / Atlas 3C no. 5902C / Centaur D-1A)
Launch Date and Time: 7 November 1967 / 07:39:01 UT
Launch Site: ETR / launch complex 36B
Scientific Instruments:

1) imaging system
2) alpha-scattering instrument
3) surface sampler
4) footcomplex magnet

Results: Surveyor 6 landed safely on the Moon at 01:01:04 UT on 10 November 1967 in the Sinus Medii (Central Bay) at 2.45° south latitude and 43.21° west longitude. The spacecraft

returned 29,952 images of the lunar surface during less than two weeks of operation before the onset of lunar night on 24 November. Although controllers regained contact briefly on 14 December 1967, primary landing operations had ceased by this time. On 17 November 1967, before termination of operations, Surveyor 6 was commanded to fire its three main liquid-propellant thrusters for 2.5 seconds. As a result, the lander became the first spacecraft to be launched from the lunar surface. Surveyor 6 lifted up to about 3 meters before landing 2.5 meters west of its original landing point. Cameras then studied the original landing footprints in order to determine the soil's mechanical properties and, now that the source point had been displaced, also accomplish some stereo imaging.

91)
no name / [Zond]
Nation: USSR (50)
Objective(s): circumlunar flight
Spacecraft: 7K-L1 (no. 5L)
Spacecraft Mass: c. 5,375 kg
Mission Design and Management: TsKBEM
Launch Vehicle: 8K82K + Blok D (Proton-K no. 230-01 / Blok D no. 13L)
Launch Date and Time: 22 November 1967 / 19:07:59 UT
Launch Site: NIIP-5 / launch site 81P
Scientific Instruments: unknown
Results: This was the second Soviet attempt at a robotic circumlunar mission. On this launch, one of the four second-stage engines of the Proton rocket failed to ignite at T+125.5 seconds due to a break in the engine nozzle. The wayward booster was then destroyed on command from the ground at T+129.9 seconds.

92)
Pioneer 8
Nation: U.S. (42)
Objective(s): heliocentric orbit
Spacecraft: Pioneer-C
Spacecraft Mass: 65.36 kg
Mission Design and Management: NASA ARC
Launch Vehicle: Thor-Delta E-1 (no. 55 / Thor no. 489 / DSV-3E)
Launch Date and Time: 13 December 1967 / 14:08 UT
Launch Site: ETR / launch complex 17B
Scientific Instruments:
1) single-axis fluxgate magnetometer
2) plasma analyzer
3) cosmic-ray telescope
4) radio-wave propagation experiment
5) cosmic-ray gradient detector
6) electric field detector
7) cosmic dust detector
8) celestial mechanics experiment

Results: Pioneer 8, like its two predecessors, was sent to heliocentric orbit to study interplanetary space, particularly to carry collected information on magnetic fields, plasma, and cosmic rays. Although the spacecraft carried a different complement of scientific instruments from those of Pioneers 6 and 7, its findings were correlated with those of the other two probes. The spacecraft was launched into a path ahead of Earth to provide the vehicle with added velocity in solar orbit in order to move out beyond Earth's orbit at 1.0 x 1.1. AU. It arrived at Earth's magnetospheric bounds at 19:00 UT on 15 December 1967. Later, on 18 January 1968, Pioneer 8, the Sun, and Earth were perfectly aligned to allow investigation of Earth's magnetic tail in detail, first performed by Pioneer 7 in 1968. Controllers have intermittently maintained contact with the spacecraft for nearly thirty years, although only one instrument, the electric field detector, remained operational past 1982. During tracking on 23 July 1995, NASA was unable to switch on Pioneer 8's transmitter, probably because the spacecraft was too far away from the Sun to charge the solar panels. On 22 August 1996, contact was reacquired via a backup transmitter. The electric field detector remains functional as of June 2001, nearly thirty-six years after launch.