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This section was lightly adapted from an original posting by Larry Klaes (klaes@verga.enet.dec.com), mostly minor formatting changes. Matthew Wiener (weemba@libra.wistar.upenn.edu) contributed the section on Voyager, and the section on Sakigake was obtained from ISAS material posted by Yoshiro Yamada (yamada@yscvax.ysc.go.jp).

MARINER 1, the first U.S. attempt to send a spacecraft to Venus, failed minutes after launch in 1962. The guidance instructions from the ground stopped reaching the rocket due to a problem with its antenna, so the onboard computer took control. However, there turned out to be a bug in the guidance software, and the rocket promptly went off course, so the Range Safety Officer destroyed it. Although the bug is sometimes claimed to have been an incorrect FORTRAN DO statement, it was actually a transcription error in which the bar (indicating smoothing) was omitted from the expression "R-dot-bar sub n" (nth smoothed value of derivative of radius). This error led the software to treat normal minor variations of velocity as if they were serious, leading to incorrect compensation.

MARINER 2 became the first successful probe to flyby Venus in December of 1962, and it returned information which confirmed that Venus is a very hot (800 degrees Fahrenheit, now revised to 900 degrees F.) world with a cloud-covered atmosphere composed primarily of carbon dioxide (sulfuric acid was later confirmed in 1978).

MARINER 3, launched on November 5, 1964, was lost when its protective shroud failed to eject as the craft was placed into interplanetary space. Unable to collect the Sun's energy for power from its solar

panels, the probe soon died when its batteries ran out and is now in solar orbit. It was intended for a Mars flyby with MARINER 4.

MARINER 4, the sister probe to MARINER 3, did reach Mars in 1965 and took the first close-up images of the Martian surface (22 in all) as it flew by the planet. The probe found a cratered world with an atmosphere much thinner than previously thought. Many scientists concluded from this preliminary scan that Mars was a "dead" world in both the geological and biological sense.

MARINER 5 was sent to Venus in 1967. It reconfirmed the data on that planet collected five years earlier by MARINER 2, plus the information that Venus' atmospheric pressure at its surface is at least 90 times that of Earth's, or the equivalent of being 3,300 feet under the surface of an ocean.

MARINER 6 and 7 were sent to Mars in 1969 and expanded upon the work done by MARINER 4 four years earlier. However, they failed to take away the concept of Mars as a "dead" planet, first made from the basic measurements of MARINER 4.

MARINER 8 ended up in the Atlantic Ocean in 1971 when the rocket launcher autopilot failed.

MARINER 9, the sister probe to MARINER 8, became the first craft to orbit Mars in 1971. It returned information on the Red Planet that no other probe had done before, revealing huge volcanoes on the Martian surface, as well as giant canyon systems, and evidence that water once flowed across the planet. The probe also took the first detailed closeup images of Mars' two small moons, Phobos and Deimos.

MARINER 10 used Venus as a gravity assist to Mercury in 1974. The probe

did return the first close-up images of the Venusian atmosphere in ultraviolet, revealing previously unseen details in the cloud cover, plus the fact that the entire cloud system circles the planet in four Earth days. MARINER 10 eventually made three flybys of Mercury from 1974 to 1975 before running out of attitude control gas. The probe revealed Mercury as a heavily cratered world with a mass much greater than thought. This would seem to indicate that Mercury has an iron core which makes up 75 percent of the entire planet.

PIONEER (MOON, SUN, VENUS, JUPITER, and SATURN FLYBYS AND ORBITERS)

PIONEER 1 through 3 failed to meet their main objective - to photograph the Moon close-up - but they did reach far enough into space to provide new information on the area between Earth and the Moon, including new data on the Van Allen radiation belts circling Earth. All three craft had failures with their rocket launchers. PIONEER 1 was launched on October 11, 1958, PIONEER 2 on November 8, and PIONEER 3 on December 6. PIONEER 4 was a Moon probe which missed the Moon and became the first U.S. spacecraft to orbit the Sun in 1959. PIONEER 5 was originally designed to flyby Venus, but the mission was scaled down and it instead studied the interplanetary environment between Venus and Earth out to 36.2 million kilometers in 1960, a record until MARINER 2. PIONEER 6 through 9 were placed into solar orbit from 1965 to 1968: PIONEER 6, 7, and 8 are still transmitting information at this time. PIONEER E (would have been number 10) suffered a launch failure in 1969.

PIONEER 10 became the first spacecraft to flyby Jupiter in 1973. PIONEER 11 followed it in 1974, and then went on to become the first probe to study Saturn in 1979. Both vehicles should continue to function through

1995 and are heading off into interstellar space, the first craft ever to do so.

PIONEER Venus 1 (1978) (also known as PIONEER Venus Orbiter, or PIONEER 12) burned up in the Venusian atmosphere on October 8, 1992. PVO made the first radar studies of the planet's surface via probe. PIONEER Venus 2 (also known as PIONEER 13) sent four small probes into the atmosphere in December of 1978. The main spacecraft bus burned up high in the atmosphere, while the four probes descended by parachute towards the surface. Though none were expected to survive to the surface, the Day probe did make it and transmitted for 67.5 minutes on the ground before its batteries failed.

RANGER 1 and 2 were test probes for the RANGER lunar impact series. They were meant for high Earth orbit testing in 1961, but rocket problems left them in useless low orbits which quickly decayed.

RANGER 3, launched on January 26, 1962, was intended to land an instrument capsule on the surface of the Moon, but problems during the launch caused the probe to miss the Moon and head into solar orbit.

RANGER 3 did try to take some images of the Moon as it flew by, but the camera was unfortunately aimed at deep space during the attempt.

RANGER 4, launched April 23, 1962, had the same purpose as RANGER 3, but suffered technical problems enroute and crashed on the lunar farside, the first U.S. probe to reach the Moon, albeit without returning data.

RANGER 5, launched October 18, 1962 and similar to RANGER 3 and 4, lost all solar panel and battery power enroute and eventually missed the Moon and drifted off into solar orbit.

RANGER 6 through 9 had more modified lunar missions: They were to send

back live images of the lunar surface as they headed towards an impact with the Moon. RANGER 6 failed this objective in 1964 when its cameras did not operate. RANGER 7 through 9 performed well, becoming the first U.S. lunar probes to return thousands of lunar images through 1965.

LUNAR ORBITER 1 through 5 were designed to orbit the Moon and image various sites being studied as landing areas for the manned APOLLO missions of 1969-1972. The probes also contributed greatly to our understanding of lunar surface features, particularly the lunar farside.

All five probes of the series, launched from 1966 to 1967, were essentially successful in their missions. They were the first U.S. probes to orbit the Moon. All LOs were eventually crashed into the lunar surface to avoid interference with the manned APOLLO missions.

The SURVEYOR series were designed primarily to see if an APOLLO lunar module could land on the surface of the Moon without sinking into the soil (before this time, it was feared by some that the Moon was covered in great layers of dust, which would not support a heavy landing vehicle). SURVEYOR was successful in proving that the lunar surface was strong enough to hold up a spacecraft from 1966 to 1968.

Only SURVEYOR 2 and 4 were unsuccessful missions. The rest became the first U.S. probes to soft land on the Moon, taking thousands of images and scooping the soil for analysis. APOLLO 12 landed 600 feet from SURVEYOR 3 in 1969 and returned parts of the craft to Earth. SURVEYOR 7, the last of the series, was a purely scientific mission which explored the Tycho crater region in 1968.

VIKING 1 was launched from Cape Canaveral, Florida on August 20, 1975 on a TITAN 3E-CENTAUR D1 rocket. The probe went into Martian orbit on June

19, 1976, and the lander set down on the western slopes of Chryse Planitia on July 20, 1976. It soon began its programmed search for Martian micro-organisms (there is still debate as to whether the probes found life there or not), and sent back incredible color panoramas of its surroundings. One thing scientists learned was that Mars' sky was pinkish in color, not dark blue as they originally thought (the sky is pink due to sunlight reflecting off the reddish dust particles in the thin atmosphere). The lander set down among a field of red sand and boulders stretching out as far as its cameras could image.

The VIKING 1 orbiter kept functioning until August 7, 1980, when it ran out of attitude-control propellant. The lander was switched into a weather-reporting mode, where it had been hoped it would keep functioning through 1994; but after November 13, 1982, an errant command had been sent to the lander accidentally telling it to shut down until further orders. Communication was never regained again, despite the engineers' efforts through May of 1983.

An interesting side note: VIKING 1's lander has been designated the Thomas A. Mutch Memorial Station in honor of the late leader of the lander imaging team. The National Air and Space Museum in Washington, D.C. is entrusted with the safekeeping of the Mutch Station Plaque until it can be attached to the lander by a manned expedition.

VIKING 2 was launched on September 9, 1975, and arrived in Martian orbit on August 7, 1976. The lander touched down on September 3, 1976 in Utopia Planitia. It accomplished essentially the same tasks as its sister lander, with the exception that its seismometer worked, recording one marsquake. The orbiter had a series of attitude-control gas leaks in

1978, which prompted it being shut down that July. The lander was shut down on April 12, 1980.

The orbits of both VIKING orbiters should decay around 2025.

VOYAGER 1 was launched September 5, 1977, and flew past Jupiter on March 5, 1979 and by Saturn on November 13, 1980. VOYAGER 2 was launched August 20, 1977 (before VOYAGER 1), and flew by Jupiter on August 7, 1979, by Saturn on August 26, 1981, by Uranus on January 24, 1986, and by Neptune on August 8, 1989. VOYAGER 2 took advantage of a rare once-every-189-years alignment to slingshot its way from outer planet to outer planet. VOYAGER 1 could, in principle, have headed towards Pluto, but JPL opted for the sure thing of a Titan close up.

Between the two probes, our knowledge of the 4 giant planets, their satellites, and their rings has become immense. VOYAGER 1&2 discovered that Jupiter has complicated atmospheric dynamics, lightning and aurorae. Three new satellites were discovered. Two of the major surprises were that Jupiter has rings and that Io has active sulfurous volcanoes, with major effects on the Jovian magnetosphere.

When the two probes reached Saturn, they discovered over 1000 ringlets and 7 satellites, including the predicted shepherd satellites that keep the rings stable. The weather was tame compared with Jupiter: massive jet streams with minimal variance (a 33-year great white spot/band cycle is known). Titan's atmosphere was smoggy. Mimas' appearance was startling: one massive impact crater gave it the Death Star appearance.

The big surprise here was the stranger aspects of the rings. Braids, kinks, and spokes were both unexpected and difficult to explain.

VOYAGER 2, thanks to heroic engineering and programming efforts,

continued the mission to Uranus and Neptune. Uranus itself was highly monochromatic in appearance. One oddity was that its magnetic axis was found to be highly skewed from the already completely skewed rotational axis, giving Uranus a peculiar magnetosphere. Icy channels were found on Ariel, and Miranda was a bizarre patchwork of different terrains. 10 satellites and one more ring were discovered.

In contrast to Uranus, Neptune was found to have rather active weather, including numerous cloud features. The ring arcs turned out to be bright patches on one ring. Two other rings, and 6 other satellites, were discovered. Neptune's magnetic axis was also skewed. Triton had a canteloupe appearance and geysers. (What's liquid at 38K?)

The two VOYAGERS are expected to last for about two more decades. Their on-target journeying gives negative evidence about possible planets beyond Pluto. Their next major scientific discovery should be the location of the heliopause.

Since there have been so many Soviet probes to the Moon, Venus, and Mars, I will highlight only the primary missions:

LUNA 1 - Lunar impact attempt in 1959, missed Moon and became first craft in solar orbit.

LUNA 2 - First craft to impact on lunar surface in 1959.

LUNA 3 - Took first images of lunar farside in 1959.

ZOND 3 - Took first images of lunar farside in 1965 since LUNA 3. Was also a test for future Mars missions.

LUNA 9 - First probe to soft land on the Moon in 1966, returned images from surface.

LUNA 10 - First probe to orbit the Moon in 1966.

LUNA 13 - Second successful Soviet lunar soft landing mission in 1966.

ZOND 5 - First successful circumlunar craft. ZOND 6 through 8

accomplished similar missions through 1970. The probes were

unmanned tests of a manned orbiting SOYUZ-type lunar vehicle.

LUNA 16 - First probe to land on Moon and return samples of lunar soil

to Earth in 1970. LUNA 20 accomplished similar mission in

LUNA 17 - Delivered the first unmanned lunar rover to the Moon's

surface, LUNOKHOD 1, in 1970. A similar feat was accomplished

with LUNA 21/LUNOKHOD 2 in 1973.

LUNA 24 - Last Soviet lunar mission to date. Returned soil samples in

VENERA 1 - First acknowledged attempt at Venus mission. Transmissions

lost enroute in 1961.

VENERA 2 - Attempt to image Venus during flyby mission in tandem with

VENERA 3. Probe ceased transmitting just before encounter in

February of 1966. No images were returned.

VENERA 3 - Attempt to place a lander capsule on Venusian surface.

Transmissions ceased just before encounter and entire probe

became the first craft to impact on another planet in 1966.

VENERA 4 - First probe to successfully return data while descending

through Venusian atmosphere. Crushed by air pressure before

reaching surface in 1967. VENERA 5 and 6 mission profiles

similar in 1969.

VENERA 7 - First probe to return data from the surface of another planet

in 1970. VENERA 8 accomplished a more detailed mission in

VENERA 9 - Sent first image of Venusian surface in 1975. Was also the

first probe to orbit Venus. VENERA 10 accomplished similar

mission.

VENERA 13 - Returned first color images of Venusian surface in 1982.

VENERA 14 accomplished similar mission.

VENERA 15 - Accomplished radar mapping with VENERA 16 of sections of planet's surface in 1983 more detailed than PVO.

VEGA 1 - Accomplished with VEGA 2 first balloon probes of Venusian atmosphere in 1985, including two landers. Flyby buses went on to become first spacecraft to study Comet Halley close-up in March of 1986.

MARS 1 - First acknowledged Mars probe in 1962. Transmissions ceased enroute the following year.

ZOND 2 - First possible attempt to place a lander capsule on Martian surface. Probe signals ceased enroute in 1965.

MARS 2 - First Soviet Mars probe to land - albeit crash - on Martian surface. Orbiter section first Soviet probe to circle the Red Planet in 1971.

MARS 3 - First successful soft landing on Martian surface, but lander signals ceased after 90 seconds in 1971.

MARS 4 - Attempt at orbiting Mars in 1974, braking rockets failed to fire, probe went on into solar orbit.

MARS 5 - First fully successful Soviet Mars mission, orbiting Mars in 1974. Returned images of Martian surface comparable to U.S. probe MARINER 9.

MARS 6 - Landing attempt in 1974. Lander crashed into the surface.

MARS 7 - Lander missed Mars completely in 1974, went into a solar orbit with its flyby bus.

PHOBOS 1 - First attempt to land probes on surface of Mars' largest moon, Phobos. Probe failed enroute in 1988 due to human/computer error.

PHOBOS 2 - Attempt to land probes on Martian moon Phobos. The probe did enter Mars orbit in early 1989, but signals ceased one week before scheduled Phobos landing.

While there has been talk of Soviet Jupiter, Saturn, and even interstellar probes within the next thirty years, no major steps have yet been taken with these projects. More intensive studies of the Moon, Mars, Venus, and various comets have been planned for the 1990s, and a Mercury mission to orbit and land probes on the tiny world has been planned for 2003. How the many changes in the former Soviet Union (now the Commonwealth of Independent States) will affect the future of their space program remains to be seen.

SAKIGAKE (MS-T5) was launched from the Kagoshima Space Center by ISAS on January 8 1985, and approached Halley's Comet within about 7 million km on March 11, 1986. The spacecraft is carrying three instruments to measure interplanetary magnetic field/plasma waves/solar wind, all of which work normally now, so ISAS made an Earth swingby by Sakigake on January 8, 1992 into an orbit similar to the earth's. The closest approach was at 23h08m47s (JST=UTC+9h) on January 8, 1992. The geocentric distance was 88,997 km. This is the first planet-swingby for a Japanese spacecraft.

During the approach, Sakigake observed the geotail. Some geotail passages will be scheduled in some years hence. The second Earth-swingby will be on June 14, 1993 (at 40 Re (Earth's radius)), and the third

October 28, 1994 (at 86 Re).

HITEN, a small lunar probe, was launched into Earth orbit on January 24, 1990. The spacecraft was then known as MUSES-A, but was renamed to Hiten once in orbit. The 430 lb probe looped out from Earth and made its first lunar flyby on March 19, where it dropped off its 26 lb midget satellite, HAGOROMO. Japan at this point became the third nation to orbit a satellite around the Moon, joining the United States and USSR. The smaller spacecraft, Hagoromo, remained in orbit around the Moon. An apparently broken transistor radio caused the Japanese space scientists to lose track of it. Hagoromo's rocket motor fired on schedule on March 19, but the spacecraft's tracking transmitter failed immediately. The rocket firing of Hagoromo was optically confirmed using the Schmidt camera (105-cm, F3.1) at the Kiso Observatory in Japan.

Hiten made multiple lunar flybys at approximately monthly intervals and performed aerobraking experiments using the Earth's atmosphere. Hiten made a close approach to the moon at 22:33 JST (UTC+9h) on February 15, 1992 at the height of 423 km from the moon's surface (35.3N, 9.7E) and fired its propulsion system for about ten minutes to put the craft into lunar orbit. The following is the orbital calculation results after the approach:

Apoapsis Altitude: about 49,400 km

Periapsis Altitude: about 9,600 km

Inclination: 34.7 deg (to ecliptic plane)

Period: 4.7 days

I also recommend reading the following works, categorized in three groups: General overviews, specific books on particular space missions,

and periodical sources on space probes. This list is by no means complete; it is primarily designed to give you places to start your research through generally available works on the subject. If anyone can add pertinent works to the list, it would be greatly appreciated.

Though naturally I recommend all the books listed below, I think it would be best if you started out with the general overview books, in order to give you a clear idea of the history of space exploration in this area. I also recommend that you pick up some good, up-to-date general works on astronomy and the Sol system, to give you some extra background. Most of these books and periodicals can be found in any good public and university library. Some of the more recently published works can also be purchased in and/or ordered through any good mass- market bookstore.

General Overviews (in alphabetical order by author):

J. Kelly Beatty et al, THE NEW SOLAR SYSTEM, 1990.

Merton E. Davies and Bruce C. Murray, THE VIEW FROM SPACE:

Kenneth Gatland, THE ILLUSTRATED ENCYCLOPEDIA OF SPACE

Kenneth Gatland, ROBOT EXPLORERS, 1972

R. Greeley, PLANETARY LANDSCAPES, 1987

Douglas Hart, THE ENCYCLOPEDIA OF SOVIET SPACECRAFT, 1987

Nicholas L. Johnson, HANDBOOK OF SOVIET LUNAR AND PLANETARY

Clayton R. Koppes, JPL AND THE AMERICAN SPACE PROGRAM: A

Richard S. Lewis, THE ILLUSTRATED ENCYCLOPEDIA OF THE

Mark Littman, PLANETS BEYOND: DISCOVERING THE OUTER SOLAR

Eugene F. Mallove and Gregory L. Matloff, THE STARFLIGHT

Frank Miles and Nicholas Booth, RACE TO MARS: THE MARS

Bruce Murray, JOURNEY INTO SPACE, 1989

Oran W. Nicks, FAR TRAVELERS, 1985 (NASA SP-480)

James E. Oberg, UNCOVERING SOVIET DISASTERS: EXPLORING THE

Carl Sagan, COMET, 1986

Carl Sagan, THE COSMIC CONNECTION, 1973

Carl Sagan, PLANETS, 1969 (LIFE Science Library)

Arthur Smith, PLANETARY EXPLORATION: THIRTY YEARS OF UNMANNED

Andrew Wilson, (JANE'S) SOLAR SYSTEM LOG, 1987

Specific Mission References:

Charles A. Cross and Patrick Moore, THE ATLAS OF MERCURY, 1977

(The MARINER 10 mission to Venus and Mercury, 1973-1975)

Joel Davis, FLYBY: THE INTERPLANETARY ODYSSEY OF VOYAGER 2, 1987

Irl Newlan, FIRST TO VENUS: THE STORY OF MARINER 2, 1963

Margaret Poynter and Arthur L. Lane, VOYAGER: THE STORY OF A

Carl Sagan, MURMURS OF EARTH, 1978 (Deals with the Earth

information records placed on VOYAGER 1 and 2 in case the

probes are found by intelligences in interstellar space,

as well as the probes and planetary mission objectives

themselves.)

Other works and periodicals:

NASA has published very detailed and technical books on every space

probe mission it has launched. Good university libraries will carry

these books, and they are easily found simply by knowing which mission

you wish to read about. I recommend these works after you first study

some of the books listed above.

Some periodicals I recommend for reading on space probes are NATIONAL

GEOGRAPHIC, which has written articles on the PIONEER probes to Earth's Moon Luna and the Jovian planets Jupiter and Saturn, the RANGER, SURVEYOR, LUNAR ORBITER, and APOLLO missions to Luna, the MARINER missions to Mercury, Venus, and Mars, the VIKING probes to Mars, and the VOYAGER missions to Jupiter, Saturn, Uranus, and Neptune.

More details on American, Soviet, European, and Japanese probe missions can be found in SKY AND TELESCOPE, ASTRONOMY, SCIENCE, NATURE, and SCIENTIFIC AMERICAN magazines. TIME, NEWSWEEK, and various major newspapers can supply not only general information on certain missions, but also show you what else was going on with Earth at the time events were unfolding, if that is of interest to you. Space missions are affected by numerous political, economic, and climatic factors, as you probably know.

Depending on just how far your interest in space probes will go, you might also wish to join The Planetary Society, one of the largest space groups in the world dedicated to planetary exploration. Their periodical, THE PLANETARY REPORT, details the latest space probe missions. Write to The Planetary Society, 65 North Catalina Avenue, Pasadena, California 91106 USA.

Good luck with your studies in this area of space exploration. I personally find planetary missions to be one of the more exciting areas in this field, and the benefits human society has and will receive from it are incredible, with many yet to be realized.

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NEXT: FAQ #11/15 - Upcoming planetary probes - missions and schedules