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Last Updated: 01/06/2026

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release January 28, 1986

REMARKS OF THE PRESIDENT
ON SPACE SHUTTLE EXPLOSION

The Roosevelt Room

1:00 P.M. EST

THE PRESIDENT: Please, sit down. Well, I'm sure we all realize there's a little change in the procedures. I'd looked forward to coming in here and having a little session with you and some briefing, all very carefully sequestered until 9:00 tonight on the State of the Union, but in view of the tragedy that has befallen us, I don't think we'll do that.

I know that you're interested in keeping up with this, as I am also, to find out the extent of it and what has taken place, so I just wanted to say hello and I appreciate your coming here and maybe we can do the other thing another time.

Q Mr. President, can you give us your comments on the tragedy so that we can tell the American people your words, your thoughts?

THE PRESIDENT: Well, what can you say. It's a horrible thing that -- and all of us have witnessed it and actually seen it take place and I just can't rid myself of the thought of the sacrifice and the families that have been watching this also -- the families of those people onboard and what they must be going through at this point and I'm sure all of America is more than saddened but feels the great weight of this and wishes, as I do, that there was something we could do to make it easier for those who've suffered such a loss.

Q Mr. President, what is the latest word you've gotten? Have you gotten any definitive word on the condition --

THE PRESIDENT: Actually, no. We have no more information than you yourselves have and -- that are going down there. It's a case of having to wait.

Q Mr. President, do you want to see all systems halted until we find out explicitly what happened in this tragedy?

THE PRESIDENT: Well, I'm not a scientist. I do have confidence in the people that have been running this program and this is the first -- n, what is it, 56 some flights that something of this kind has happened. I certainly want everything done that can be done to find out how this could have happened and to ensure against its happening again. But there again, I have to say that I'm sure that the people that have to do with this program are determined to do that right now. And I'm quite sure also, when you look at the safety measures that sometimes those of us looking on have gotten a little impatient with when flights have been aborted and it hasn't seemed as if the situation -- well, it seems as if they were taking things too seriously. Now we know they weren't. And so I'm confident that there will be no flight until they are absolutely as certain as a human being can be that it is safe.

Q Mr. President, do you think it raises questions about having citizens aboard the Space Shuttle?

THE PRESIDENTS: Well, they're all citizens and I don't think anyone's ever been on there that isn't a volunteer. I know

reasons why they, or someone like them should be included in flights of this kind. So, no -- that is the last frontier and the most important frontier we have to say that the space program has been most successful, most effective and -- I guess, we've been so confident of it that it comes as such a tremendous shock when something of this kind happens.

Q Will you still go ahead, sir, with your message tonight?

THE PRESIDENT: What?

Q Will you go ahead with your message tonight?

THE PRESIDENT: Yes, I feel that we -- things like that have to go on.

Q Mr. President, are you afraid there'll be any public backlash against the space program because of this tragedy?

THE PRESIDENT: I shouldn't think so and I would certainly do everything I could to express an opinion the other way. You know, we don't -- we have accidents in every line of transportation and we don't do away with those things. They've probably got a better safety record than we have out on the highways.

Q Mr. President, will you tell us --

Q Do you think it was a mistake to put the teacher onboard?

THE PRESIDENT: What?

Q Do you think it was a mistake to put the teacher onboard?

THE PRESIDENT: No. Again, as I say, this is a thing -- and this is what the whole space program is leading towards -- is actual use.

Q Mr. President, will you tell us exactly who brought you the news and exactly what you thought and said at that point?

THE PRESIDENT: We were all sitting in there, and I was preparing myself for your questions on the State of the Union Address when the Vice President and John Poindexter came into the room. And all they could say at the time was that they had received a flash that the space shuttle had exploded. And we immediately went into the adjoining room where I have a TV set to get on this, because there was no direct word and -- except that word that had -- being made public also. And there we saw the replaying and saw the thing actually happen. And it just was -- I say -- a very traumatic experience.

Q But how does that effect your State of the Union speech tonight? I mean, we were told you were going to give an upbeat -- "the State of the Union is good," you know, optimistic speech. This has got to cast a pall on it, doesn't it?

THE PRESIDENT: Yes, it sure does. And, certainly, there could be no speech without mentioning this. But you can't stop governing the nation because of a tragedy of this kind. So, yes, one will continue.

Q Mr. President --

Q -- philosophically, do you take some solace in the fact that over the years the American space program has been remarkably safe, that we've not lost as many people as we've been led to believe have been lost in the Soviet Union?

THE PRESIDENT: Well, I think we've all had a great pride in that. And it is a kind of -- well, it'd be something to cling to right now, although it doesn't lessen our grief at what has just taken place.

Q Mr. President, sending civilians in space is based on the assumption that it was routine to go into space, that it was now safe, even a teacher we could send up. Do you think that notion has now -- is now gone?

THE PRESIDENT: Well, what would you -- what could you say, other than that here was a program that had a 100-percent safety record? The only other fatality did not take place in a space shuttle. It took place in an old-type of capsule --

Q Mr. President --

MR. BUCHANAN: One question. One more question.

Q -- so many children have -- you know -- been a part of this particular space shuttle because of the teacher. And they're doing classrooms. Can you do something to help help them -- say something that would help them to understand --

THE PRESIDENT: I think people closer to them have got to be doing that. As I say, the world is a hazardous place, always has been, in pioneering. And we've always known that there are pioneers that give their lives out there on the frontier. And now this has happened. It probably is more of a shock to -- to all of us because of the fact that we see it happen now and -- thanks to the media -- not just hearing about it as if something that happened miles away. But I think -- I think those that have to do with them and -- must, at the same time, make it plain to them that life does go on and -- and you don't back up and quit some worthwhile endeavor because of tragedy.

Q Do you have any --

MR. BUCHANAN: -- got some folks in the Oval Office that are waiting --

THE PRESIDENT: Oh.

Q Sir, do you have any special thoughts about Christa McAuliffe, who, I think it was in this room, was named as the first teacher? What are your thoughts about her today?

THE PRESIDENT: I can't get out of my mind her husband and her children. But then that's true of the families of the others. Theirs probably more so because the families of the others had been a part of this whole program and knew that they were in a hazardous occupation. But knowing that they were there and watching, this just is -- well, your heart goes out to them.

THE PRESS: Thank you.

END 1:07 P.M. EST

NASA 5 MANIFEST
51-L Launch
January 25-26, 1986

	DCA to KSC	KSC to DCA
Dr. William R. Graham Acting Administrator National Aeronautics and Space Administration	X	X
Mrs. Nina Graham	X	X
The Honorable John H. Sununu Governor of New Hampshire		X
Christopher Sununu		X
Senator Jake Garn (R-UT) Chairman Senate Subcommittee on HUD- Independent Agencies Committee on Appropriations		X
Mr. Jeff Bingham Administrative Assistant, Senator Jake Garn	X	X
Dr. Lawrence F. Davenport Assistant Secretary for Elementary and Secondary Education Department of Education	X	X
Mrs. Margo Carlisle Executive Director Council for National Policy	X	X
Mrs. Andrea Meade Lawrence Chair, Mono County, California Board of Supervisors Two-time Gold Medalist, 1952 Winter Olympic Games	X	X

NASA 5 MANIFEST
51-L Launch
January 25-26, 1986

Ms. Polly Gault Staff Director Senate Education, Arts & Humanities Subc., Labor and Human Resources Committee, (Sen. Robert Stafford (R-VT), Chairman)	X	X
Ms. Susan McGuire Staff Director House Education & Labor Committee (Rep Augustus Hawkins (D-CA), Chairman)	X	X
Dr. Beth Buehlmann Minority Staff Director House Education & Labor Committee, (Rep. James Jeffords (R-VT), Ranking Minority Member)	X	X
Mrs. Suzanne Bingham Chief Clerk, Senate Banking Committee	X	X
Ms. Martha Pellegrini Legislative Assistant (Rep. Robert C. Smith (R-NH))	X	X
Mr. Patrick Windham Staff Senate Commerce, Science & Transportation Committee (Sen. Ernest Hollings, (D-SC) Ranking Minority Member)	X	X
Mr. John F. Murphy Assistant Administrator for Legislative Affairs National Aeronautics and Space Administration	X	X
Ms. Carolyn Washington National Aeronautics and Space Administration Honoree	X	X (NASA 1)
Mrs. Mary Weatherspoon Senior Protocol Officer National Aeronautics and Space Administration	X	X (NASA 1)

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from Jerry May - DSC 5022

KW

Since the beginning of the U.S. Space Program and the successful first launch of a U.S. spacecraft in 1958 the program and American science have grown by leaps and bounds. This has not been achieved without endless hours of sacrifice and dedication by scientists, engineers, astronauts, American industry, and thousands of private citizens. Today's tragedy reminds us of how difficult it is to achieve success and the costs that must be paid in exploring new frontiers. The U.S. Space Program has been remarkably successful and compared to other national efforts relatively accident free. With the tragic loss of Gus Grissom, Ed White and Frank Chaffe in the Apollo fire of 1967 and today's accident, we cannot allow our sorrow to dim our vision; that would be a disservice to those astronauts we have lost, and indeed, all those who have not yet flown. The astronauts who we lost today gave their lives for science, for the American dream and in pursuit of the quest for knowledge that is so important to the vision of all Americans. They were heroes and heroines in every sense of the word. They represented America's commitment to excellence and they have not died in vain. This setback will not diminish our commitment to the exploration and use of space in fulfilling America's goals for maintaining leadership in space. The Shuttle "Challenger" and her crew left earth today filled with optimism and enthusiasm for the mission and the country for the future. We should not disappoint them.

Names Shuttle Crew
Went by:

Mike Smith
Dick Scobee (SKOW-bee)
Judy Resnik (RES-nick)
Ron McNair
El Onizuka (owe-ni-ZOO-kuh)
Greg Jarvis
Christa McAuliffe

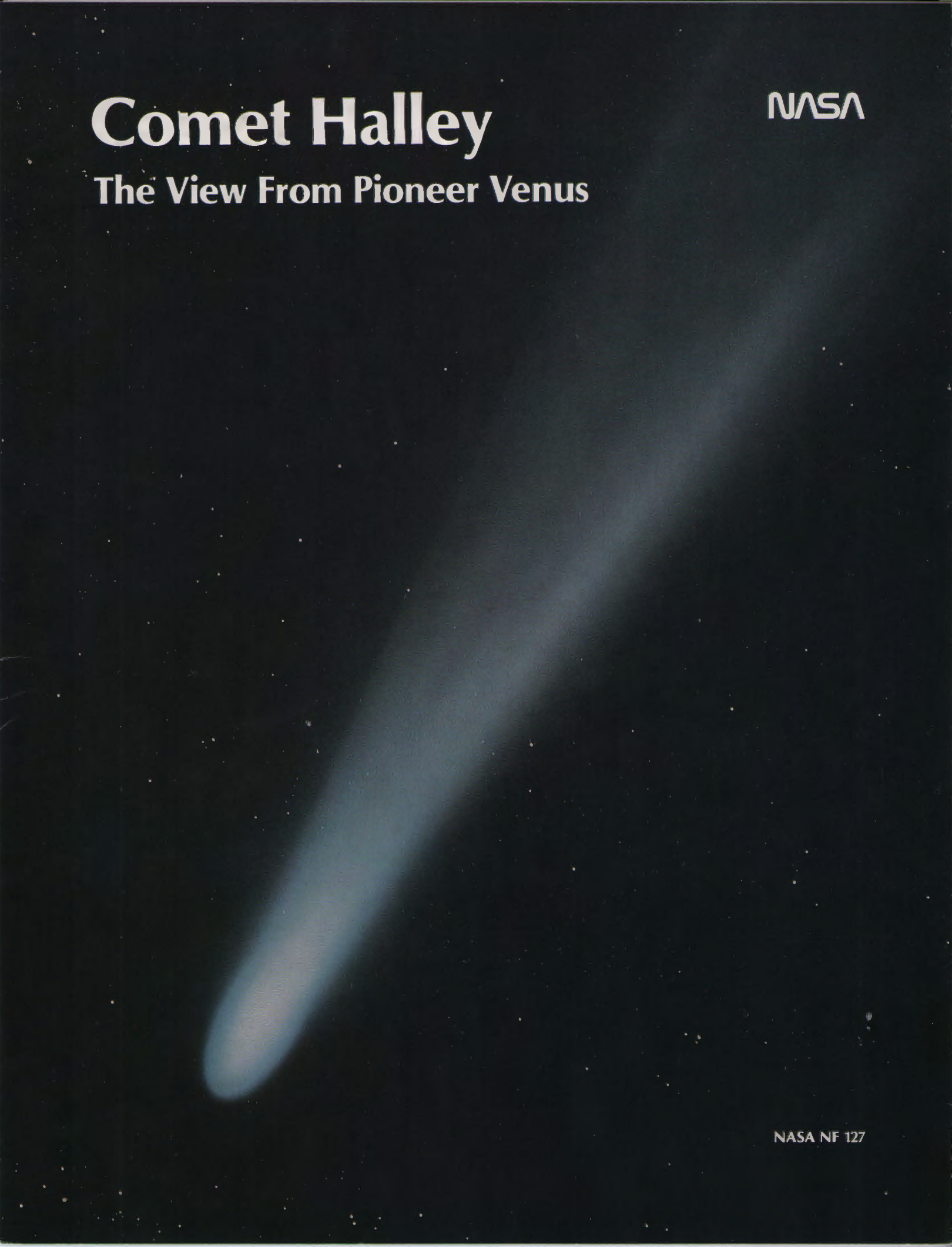
Evelyn Times
NASA
453-8364

Michael Smith
Francis R. Scobee
Judith Resnik
Ronald McNair
Ellison Onizuka
Gregory Jarvis

Comet Halley

The View From Pioneer Venus

NASA



NASA NF 127

Of Space, Not of Earth

Edmond Halley, scientist friend of Sir Isaac Newton, placed comets in their rightful place as celestial rather than terrestrial objects. Using observations of the bright comets of 1531, 1607, and 1682, he applied Newton's method of computing orbits of celestial bodies to calculate the paths of these comets. From the similarity of their elliptical orbits he concluded that these comets were one and the same comet which visits the inner Solar System every 75-76 years. Earlier beliefs that comets were atmospheric phenomena akin to meteors and aurora were finally totally dispelled when the comet again returned in 1758 and made a close approach to Earth as Halley had predicted.

Later, other astronomers searched ancient records and traced observations of the same comet back into the Middle Ages and ultimately to comets recorded in China and Babylon as long ago as 240 B.C. Sometimes its passage through the inner Solar System coincides with a favorable position of Earth from an observational point of view. At such times the comet becomes a splendid object in the sky. At other apparitions, such as the current one in 1986, the comet not only fails to pass near to Earth but also passes through perihelion, its closest approach to the Sun, on the far side of the Sun from Earth. The most active and spectacular period of the comet's passage, generated by solar radiation, is then hidden from Earth by the intervening brilliance of the Sun itself.

Comets are important to study because they are thought to preserve a record of the primordial nebula out of which the Solar System and its planets formed. Because comets spend most of their time in the cold outer reaches of the Solar System they are believed to preserve the record better than the planets do, since planets are subject to other modifying processes. Information on cometary ingredients can provide important clues about the early chemical and physical history of the Solar System.

Several spacecraft are headed for Halley's Comet on its current return, but they have all been targeted to intercept the comet when it is close to the plane of Earth's orbit, many weeks after perihelion.

Only one spacecraft is situated to observe Halley at its perihelion when it will be most active; Pioneer Venus orbiting the planet Venus. This spacecraft will be on the far side of the Sun at the time of Comet Halley's passage.

Another First for Pioneer

The Pioneer program has achieved many pioneering feats in the Solar System. The Pioneer 10 spacecraft was first to show that a spacecraft could pass safely through the asteroid belt. It became the first spacecraft to explore the giant planet Jupiter and its planet-sized moons. Pioneer 11 was first to explore the ringed planet Saturn. Pioneer 10 also became the first spacecraft to escape from the Solar System into the interstellar void carrying a message to possible extraterrestrials. Venus Pioneer probes penetrated the enormously dense atmosphere. The Pioneer Venus Orbiter charted the complex surface features, and observed for many years the particles and fields around the planet and their interaction with the solar wind.

The spacecraft that will observe Comet Halley is *Pioneer Venus Orbiter.* This highly reliable spacecraft is still gathering data about Venus and its interaction with the Sun to a high order of accuracy. It has already observed two other comets using an instrument that collects ultraviolet radiation from them: Comet Encke in April 1984 and Comet Giacobini-Zinner in September 1985. Giacobini-Zinner was observed just after the comet passed perihelion and when the comet was about 100 million miles (161 million km) from the spacecraft and just beyond Earth's orbit. Measurements were made simultaneously with the passage of the ICE spacecraft through the comet's tail.

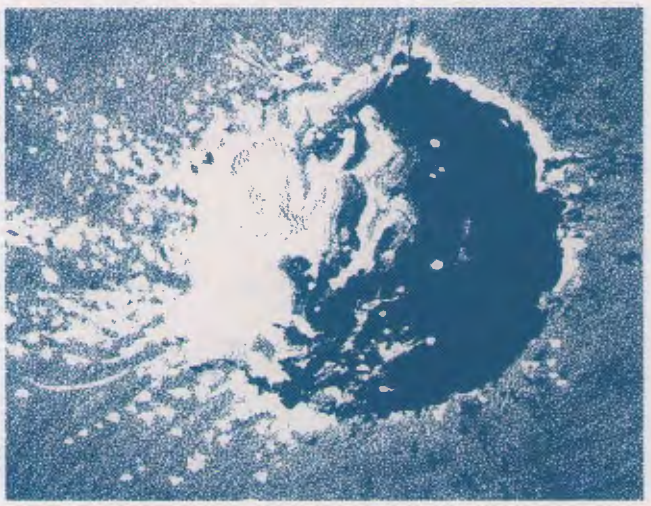
The Pioneer Venus Orbiter discovered that Encke was losing water at a faster rate than expected. The observation suggests that water ice and dust are distributed unevenly in cometary nuclei. Also the observations showed that Giacobini-Zinner is much more active than Encke, but less active than is expected of Halley.

Pioneer Venus observations also detected Lyman alpha ultraviolet emissions from the hydrogen coma as far as three million miles (5 million km) on either side of the nucleus of Giacobini-Zinner.

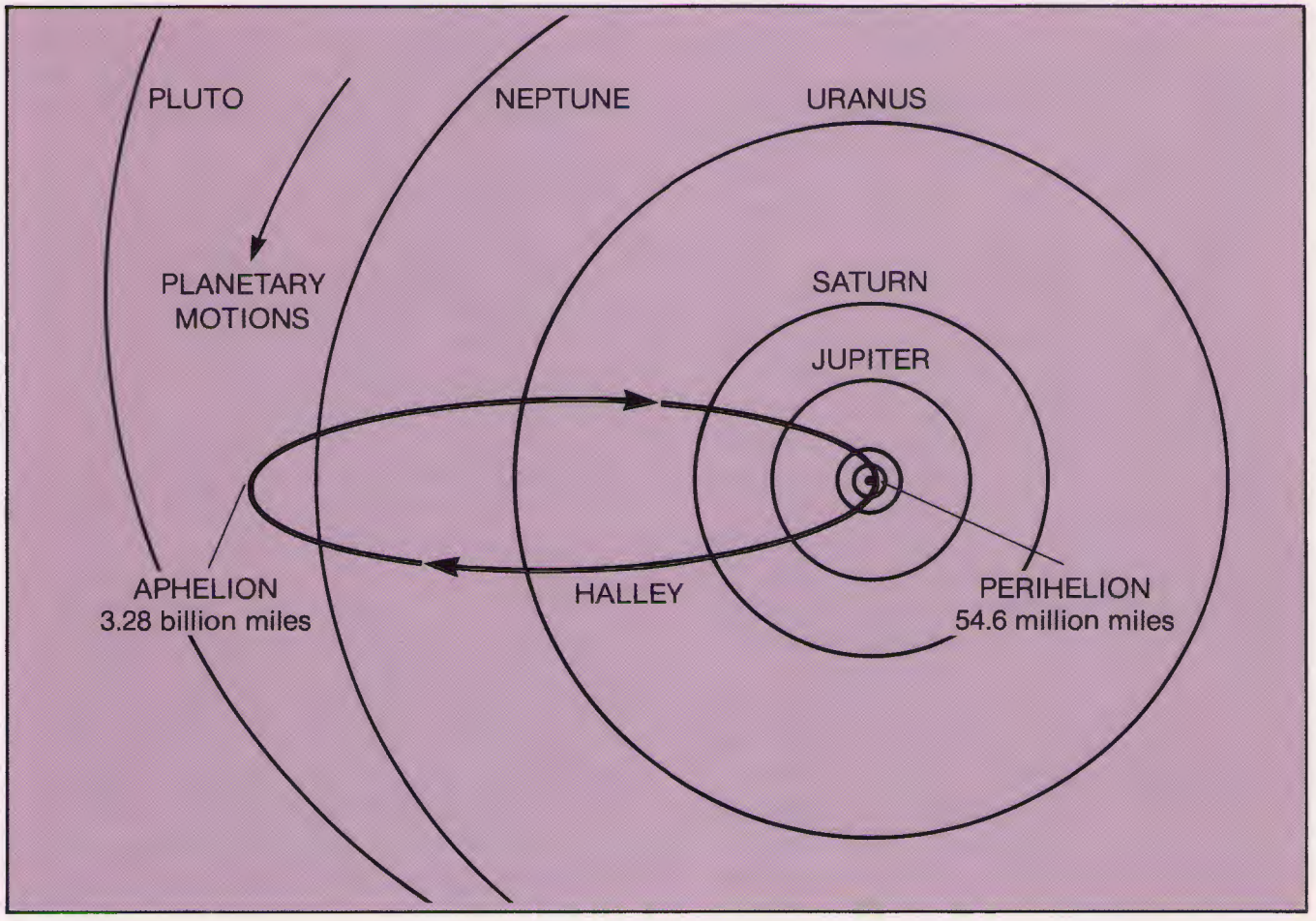
Perihelion Passage

Comet Halley moves around the Sun opposite to the Earth's motion and on an elongated elliptical orbit which is inclined 18 degrees to that of the Earth. The comet's greatest distance from the Sun (aphelion) in 1948 was 3.28 billion miles (5.28 billion km), which is beyond the orbit of Neptune. The comet's closest approach to the Sun (perihelion) on February 9, 1986, will be 54.6 million miles (87.9 million km), which is inside the orbit of Venus.

The comet consists of a nucleus which is believed to be an irregularly shaped, roughly spherical body with a diameter of about five miles (eight km). From observations of the sunlight reflected from the nucleus, astronomers conclude that the nucleus of Comet Halley is rotating about once in 2 to 3 days. This nucleus is thought to consist of ices — predominantly water ice — mixed with rocky dust particles, a mixture that has been likened to a dirty snowball. This description was confirmed by the observations of Giacobini-Zinner.



A cloud of gas and dust is released from the comet's nucleus as it approaches the sun.

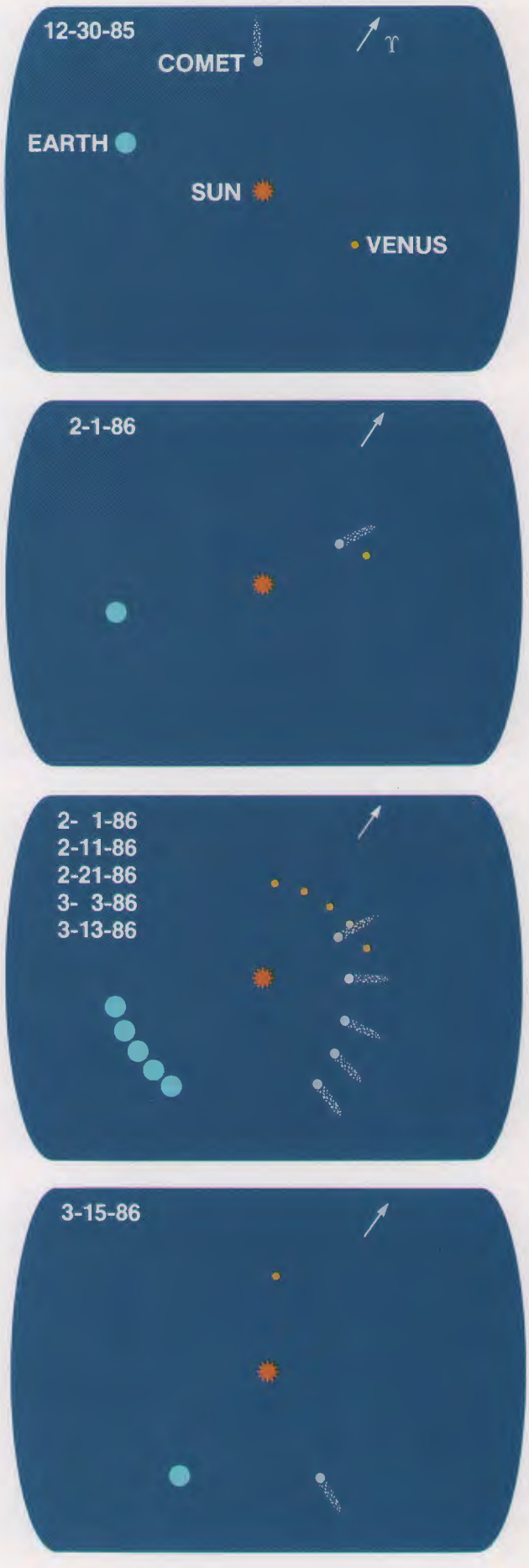


As the comet approaches the Sun, solar radiation heats the surface of the nucleus and changes the ices into gas, thereby releasing a cloud of gas and dust which spreads outward around the nucleus. This cloud is referred to as the coma. Sunlight reflected from the gas and dust of the coma produces the visible comet seen from Earth in the night sky. The nucleus is too small to be seen, but the coma can extend around the small nucleus for tens of thousands of miles. The coma reaches its greatest size when a comet is about twice Earth's distance from the Sun. The visible gas cloud is thought to consist mainly of carbon-bearing molecules with traces of other gases. The water vapor is not visible because of its transparency, but is inferred from ultraviolet observations.

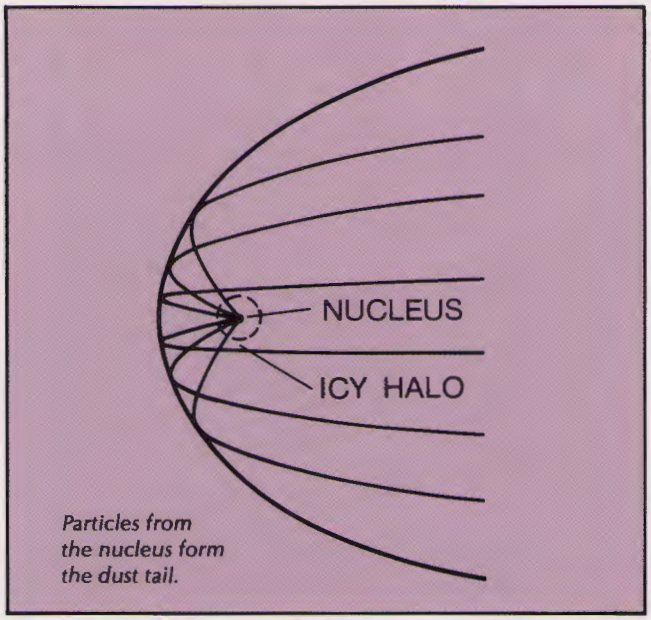
Material that forms the coma emerges from the nucleus irregularly, and as the material is pushed from the nucleus into the coma it acts as an array of weak rocket jets to affect the rotation rate and orbital motion of the comet. Jets from Comet Halley, confirmed in detail by new image-processing techniques applied to 1910 photographs, reveal dust particles spiraling outward into the coma. Jets from the nucleus, in addition to gravitational effects of the planets, change the comet's orbit. In the 30 recorded appearances of Halley's Comet it has sometimes taken just over 74 years to return to perihelion, while at others it has taken nearly 80 years.

Surrounding the visible coma, and traveling with it, is an invisible hydrogen cloud extending for millions of miles around the nucleus of the comet. The presence of hydrogen, oxygen, and carbon atoms was speculated from theory, but direct observation required ultraviolet-sensitive instruments. The halo was confirmed by spacecraft observing ultraviolet light from comets.

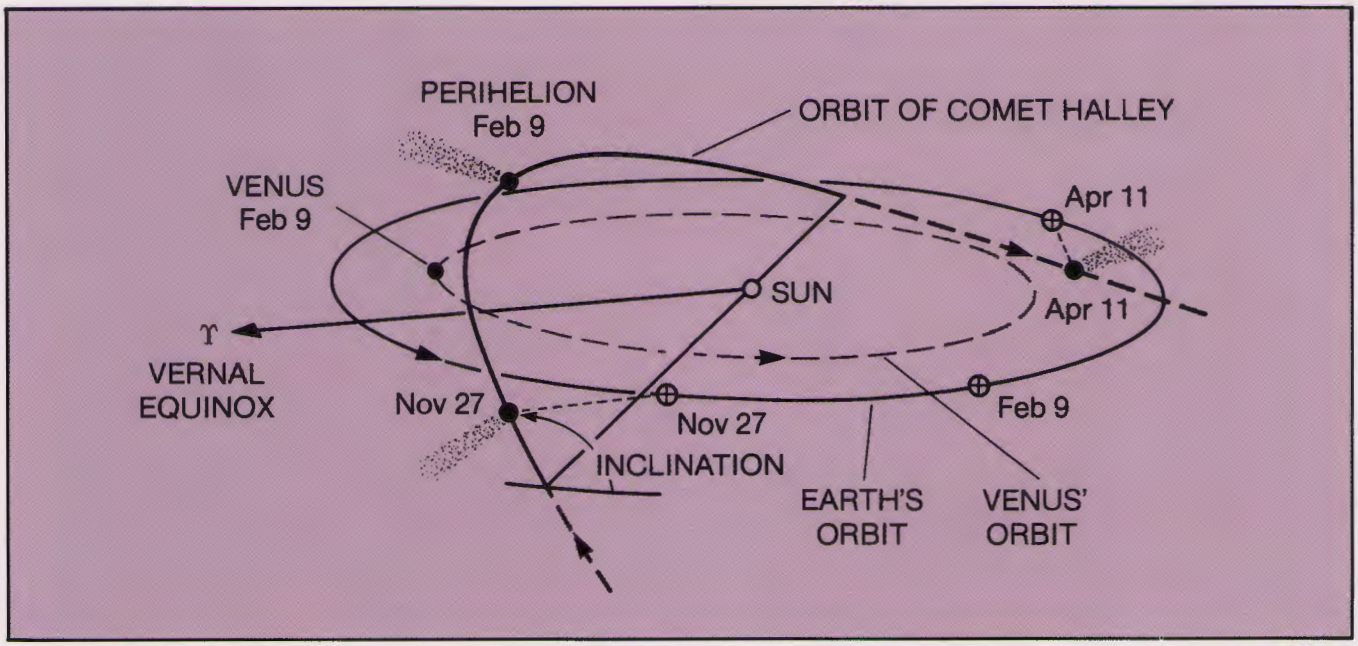
Action of solar radiation on the coma produces two tails, a dust tail and a plasma or ion tail, both of which grow as the comet approaches the Sun. These tails point away from the Sun. Plasma tails are wispy in appearance; dust tails are smooth. The dust particles in the tail are accelerated by solar radiation pressure and move relatively slowly away from the comet. As a result the dust tail tends to curve away from the comet because the comet's speed changes along its elliptical



path. The dust tail can appear as a fan-shaped nebulosity when it is viewed broadside because dust particles of differing masses are accelerated to different velocities. The ion tail moves very much faster and is relatively straight. It results from solar radiation ionizing neutral molecules, and the resulting electrically charged ions being accelerated by the magnetic field of the solar wind at its enormous velocity of hundreds of miles per second. The ion tail stretches millions of miles from the comet in a direction away from the Sun. The dust tail is much shorter. Tails usually begin to develop when a comet is about one and a half times Earth's distance from the Sun (1.5 astronomical units or 140 million miles, 225 million km). Before its tail forms, a comet is a fairly inconspicuous, nebulous blob of light.



Particles from the nucleus form the dust tail.



The View from Pioneer Venus

On February 9, 1986, Comet Halley will hurtle at over one hundred thousand miles per hour within 54.6 million miles (87.9 million km) of the Sun before starting its outward journey again. At the perihelion passage solar radiation will have maximum impact upon the nucleus. The blizzard of charged particles and associated magnetic fields of the solar wind will tear at the hydrogen halo and the coma. At this time the comet will have passed by Venus; its closest approach to Venus being February 4, 1986, five days before perihelion. At the time of closest approach to Venus, the comet will be above the plane of Venus' orbit and some 25 million miles (40 million km) from the planet, between the planet and the Sun.

Preparing for the unique opportunity to observe Comet Halley at close range during its perihelion passage, the Pioneer Missions Operations Team will send commands to the spacecraft to change the tilt of its spin axis. Pioneer Venus Orbiter spins on this axis five times a minute as it travels around Venus. Thrusters on the spacecraft will fire at a predetermined time in each spin so as to tilt the spacecraft to the desired



Lick Observatory photograph

position for its ultraviolet instrument to scan the comet instead of Venus. A similar maneuver was successfully made in 1984 to inspect Comet Encke and in 1985 to inspect Comet Giacobini-Zinner. The thrusters will fire about 100 half-second pulses to move the spin axis.

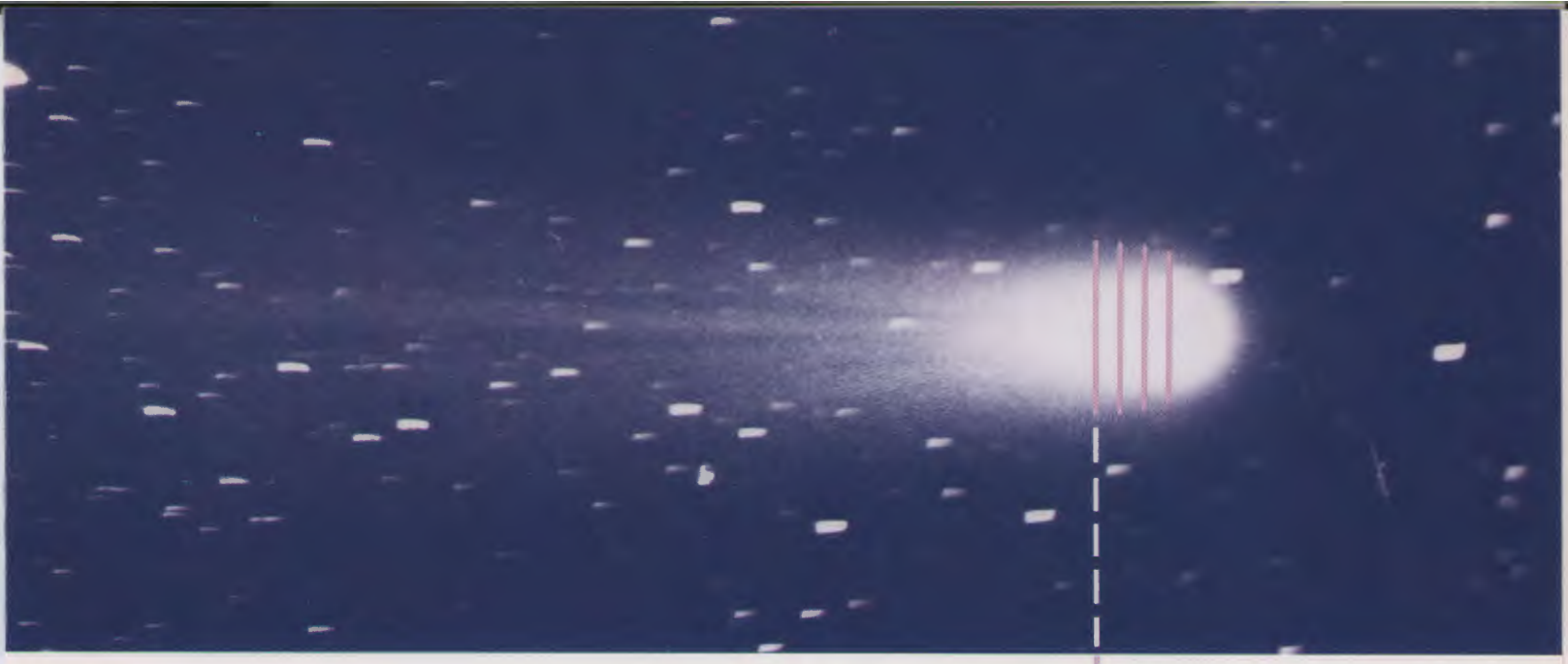
Because the ultraviolet spectrometer carried by Pioneer was designed with a small field of view to map variations in Venus' atmosphere, a general picture of the comet can be gathered as a series of strips, one each spin, with the comet moving slightly between each spin to expose a sequence of strips along its length. The ability to scan at high resolution across the comet's coma, tail, and hydrogen halo, allows the distribution of particles and gases to be determined. The ultraviolet data recorded by this instrument will be studied by scientists at the University of Colorado, Boulder. There, a team of researchers, headed by Dr. A. Ian F. Stewart, the principal investigator for the ultraviolet spectrometer instrument on the Pioneer Venus Orbiter, will use the new data to learn more about the makeup, evolution, and activities of the comet.

This spectrometer, one of many scientific instruments carried by the Venus Orbiter, detects light in the ultraviolet region of the spectrum. Most atoms emit ultraviolet light when exposed to sunlight. By measuring the wavelength and intensity of the emitted ultraviolet light, researchers can determine which elements are in the comet and in what relative quantities. Thus, data from this experiment will inform us of the comet's gas composition, its water vaporization rate, and the ratio of gas to dust in the coma and in the nucleus.

Comets are thought to be frozen remnants of the material that formed the Sun and the planets, so information on cometary ingredients can provide important clues about the early chemical and physical history of the Solar System.

Objectives of the ultraviolet experiment are to determine the composition of the gaseous coma and to measure the total gas production rate of the comet continuously during its passage through perihelion and, in particular, the rate at which water sublimates from the nucleus. This can be established by measuring the ultraviolet emission from hydrogen, oxygen, and the hydroxyl radical in the coma and thereby determine the relative amounts of these gases. Nitrogen, carbon, sulfur, carbon monoxide, and carbon dioxide will also be searched for.

Such observations through the perihelion passage are very important to ascertaining the effects of solar radiation and the solar wind upon the comet. Rapid and large changes of the angle at the comet between the Sun and the spacecraft during about two months of observations will allow scientists to investigate the way light is scattered by the dust at different phase angles to help estimate the density and distribution of sizes of dust particles.



Pioneer Orbiter will observe Comet Halley in detail for about five weeks in February and March 1986. During that time the comet will travel at high speed away from Venus. It will be about 25 million miles (40.2 million km) from the spacecraft at the time of perihelion passage on February 9, and some 125 million miles (200 million km) away when the observations end about March 6. The Orbiter will also make long-range, less-detailed observations of the comet in December 1985. Through the month of January 1986, comet observations will be curtailed by solar interference with communications as Venus passes on the far side of the Sun from Earth.

In addition, the spacecraft will continue monitoring the solar wind with particle and fields sensors to provide important data on the state of the wind affecting the comet for correlation with observations by other spacecraft and ground-based observers. Pioneer Orbiter has a special relationship to the study of comets' interactions with the solar radiation and plasma wind, because it has been used since late 1978 to study *in situ* just such interactions of the wind with the planet Venus. Like comets, Venus is unprotected from the solar plasma by an intrinsic planetary magnetic field.

Expected Results

Ultraviolet spectra at much closer range than possible from Earth will be obtained during the perihelion passage and the post-perihelion period. These will be correlated with observations by Earth-orbiting astronomical observatories where possible. Materials present in the coma and tail will be identified, and the rate these materials are evaporated from the nucleus and within the coma will be established. Changes in evaporation rate and gaseous components will help us understand the uneven composition of the nucleus. Substances not previously identified in comets may be discovered, thereby providing a more detailed description of the composition of the nucleus, and hence of primordial material of the Solar System. From these data, scientists expect to obtain a better understanding of the chemical processes taking place in the inner coma and how the coma reacts with the solar wind.

Coupled with ground-based observations and observations from other spacecraft on inbound and outbound legs of the comet's path, Pioneer Venus Orbiter will help provide another important piece of the jigsaw puzzle of how solar systems are formed and how planets develop to the point at which they can support biological systems with the ability to question their own origin and purpose.



Halley's Comet

Orbital inclination	162 degrees 18 degrees retrograde
Orbital period	75 years
Longitude of ascending node	58 degrees
Argument of perihelion	112 degrees
Semi-major axis	17.9185 A.U.
Perihelion passage distance	9 February 1986 0.5871 A.U. 54.6 million miles 87.9 million km
Aphelion passage distance	1948 35.25 A.U. 3.28 billion miles 5.28 billion km
Earth close approaches	27 November 1985 0.62 A.U. 57.6 million miles 92.7 million km
	11 April 1986 0.42 A.U. 39.0 million miles 62.8 million km
Venus close approach	4 February 1986 0.27 A.U. 25.1 million miles 40.4 million km

(Note: one A.U. is 92,900,000 miles (149,500,000 km), the mean distance of Earth from the Sun.)

Pioneer Venus Orbiter

Launched	20 May, 1978
Arrived at Venus	4 December, 1978
Weight	824 lb 374 kg

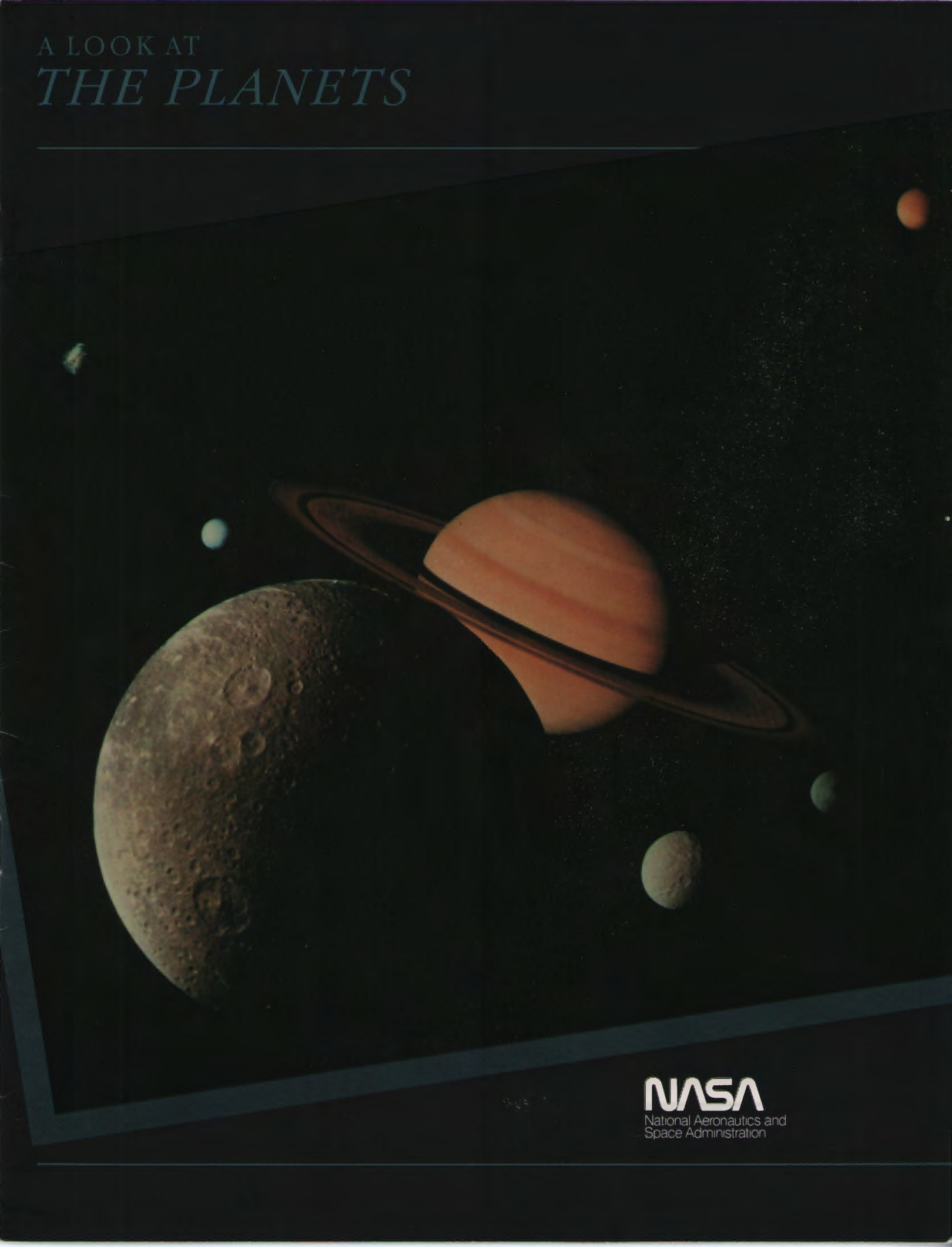
The Pioneer Orbiter is controlled and managed from NASA Ames Research Center, Moffett Field, California.
Project Manager, Richard O. Fimmel
Science Chief, Roger A. Craig
Space Operations Office Chief, John W. Dyer
Flight Director, Robert W. Jackson
Assistant Flight Director, David W. Lozier
Trajectory Analyst, James A. Phillips
Power Systems and Hardware, Martha A. Smith
Ground Data System Manager, Manfred N. Wirth

Ultraviolet Spectrometer

Principal Investigator	A. Ian F. Stewart
Optics type aperture f/number	Cassegrain telescope 5 cm 5
Monochromator type focal length f/number diffraction grating	Ebert-Fastie 12.5 cm 5 3600 grooves/mm
Spectral resolution	13 A
Grating steps	4.4 A
Wavelength ranges	1100-1900 A 1800-3400 A

A LOOK AT

THE PLANETS



NASA

National Aeronautics and
Space Administration

Front cover: A clockwise montage of the Moons—Dione (in front of Saturn), Enceladus, Rhea, Titan, Mimas and Tethys.

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A LOOK AT

THE PLANETS

American manned expeditions have explored the Moon, our robot craft have landed on and reported from the surface of Mars, our spacecraft have orbited and provided much information about Mars and Venus, and made close-range observations while flying past Mercury, Jupiter and Saturn.

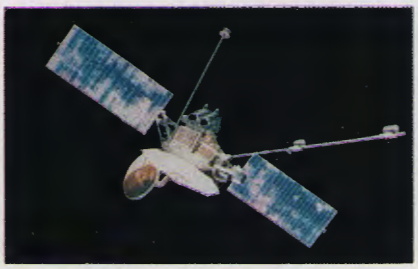
These voyagers brought a quantum leap in our knowledge and understanding of the solar system. Through the electronic sight and other "senses" of our automatic probes, color and complexion have been given to worlds that existed for centuries as fuzzy disks or indistinct points of light.

Future historians will likely view these pioneering flights to the planets as one of the most remarkable human achievements of the 20th Century.

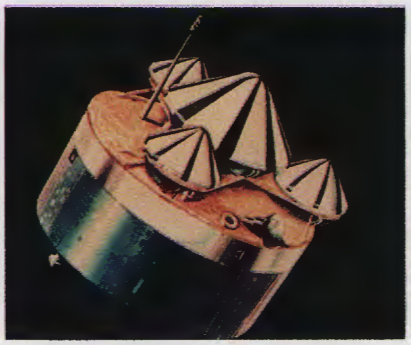


Volcanic explosion on Io.

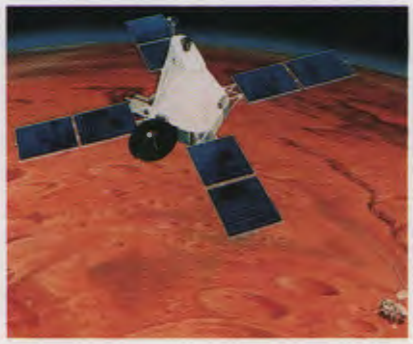
Spacecraft	Mission	Launch Date	Arrival Date	Status
Mariner 2	Venus flyby	8/14/62	12/14/62	Mission complete, craft in solar orbit.
Mariner 4	Mars flyby	11/28/64	7/14/65	Mission complete, craft in solar orbit.
Mariner 5	Venus flyby	6/14/67	10/19/67	Mission complete, craft in solar orbit.
Mariner 6	Mars flyby	2/24/69	7/31/69	Mission complete, craft in solar orbit.
Mariner 7	Mars flyby	3/27/69	8/5/69	Mission complete, craft in solar orbit.
Mariner 9	Study Mars from orbit	5/30/71	11/18/71	Mission complete, inoperable craft remains in Martian orbit.
Pioneer 10	Jupiter flyby	3/2/72	12/3/73	Primary mission complete, craft continues to return heliospheric information enroute toward interstellar space. First manmade craft to pass all the planets. Surging for tenth planet.
Pioneer 11	Jupiter/Saturn flybys	4/5/73	12/2/74 (Jupiter) 9/1/79 (Saturn)	Primary mission complete, continues to return heliospheric information enroute toward interstellar space.
Mariner 10	Venus/Mercury flybys	11/3/73	2/5/74 (Venus) 3/29/74 (Mercury) 9/21/74 (Mercury) 3/16/75 (Mercury)	Mission complete, craft in solar orbit
Viking 1	Unmanned landing on Mars	8/20/75	7/19/76 (in orbit) 7/20/76 (lander touchdown)	Mission complete, craft remains on surface and in orbit. Lander continues to send monthly weather reports/photos.
Viking 2	Unmanned landing on Mars	9/9/75	8/7/76 (in orbit) 9/3/76 (lander touchdown)	Mission complete, craft remains on surface and in orbit. Both lander and orbiter have ceased operation.
Voyager 1	Tour of Jupiter	9/5/77	3/7/79 (Jupiter) 11/12/80 (Saturn)	Primary mission complete, craft continues to return heliospheric information enroute toward interstellar space.
Voyager 2	Tour of the outer planets	8/20/77	7/9/79 (Jupiter) 8/25/81 (Saturn) 1986 (Uranus) 1989 (Neptune)	Mission continues, craft has surveyed two of four planetary targets. On way to Uranus.
Pioneer Venus 1	Orbital studies of Venus	5/20/78	12/4/78	Orbiter continues to return images and data.
Pioneer Venus 2		8/8/78	12/9/78	Mission complete, probes impacted on surface.



Mariner 10



Pioneer Venus 1 and 2



Viking 1

MERCURY



Mariner 10 space probe passed within 805 kilometers (500 miles) of the solar system's innermost planet.

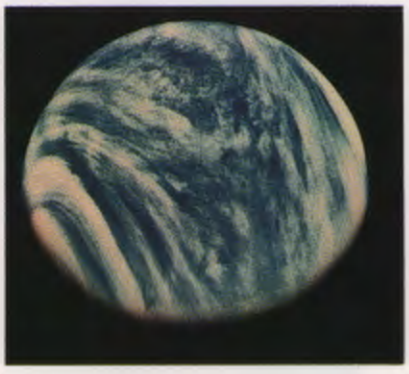
The photographs revealed an ancient, heavily cratered surface on Mercury, closely resembling our own Moon and huge cliffs crisscrossing the planet. These apparently were created when Mercury's interior cooled and shrank, compressing the planet's crust. The cliffs are as high as two km (1 mi.) and as long as 1,500 km (932 mi.).

The spacecraft reported temperatures ranging from 510 degrees Celsius (950 degrees Fahrenheit) on Mercury's sunlit side, to −210 C (−346 F) on the dark side. Mercury literally bakes in daylight and freezes at night.

The days and nights are long on Mercury. It takes 59 Earth days for Mercury to make a single rotation. It spins at a rate of about 10 km (about 6 mi.) per hour.

Mercury, like Earth, appears to have a crust of light silicate rock.

VENUS



The Mariner 2 space probe passed within 34,762 km (21,600 mi.) of Venus and became the first spacecraft to scan another planet. Mariner 5, flew much closer to the planet, passing within 4,023 km (2,500 mi.) of Venus on the second U.S. flyby.

Venus more nearly resembles Earth in size, physical composition and density than any other known planet.

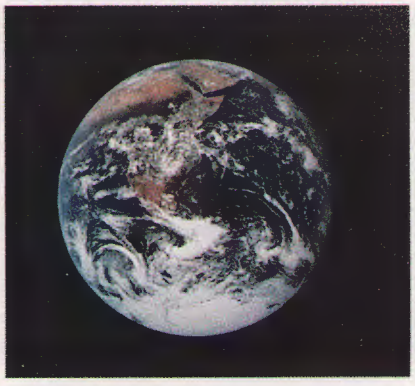
Surface temperatures are 482 C (900 F), hot enough to melt lead.

Among the features determined are two continent-like highland areas. One, about half the size of Africa, is located in the equatorial region. The other, about the size of Australia, is to the north.

There is evidence of two major active volcanic areas, one larger than Earth's Hawaii-Midway volcanic chain (Earth's largest) with a mountain higher than Everest (Earth's highest mountain).

Venus' predominant weather pattern is a high speed circulation of Venus' clouds, which are made up of sulphuric acid. These speeds reach as high as 362 km (225 mi.) per hour. The circulation is in the same direction—east to west—as Venus' slow retrograde rotation.

EARTH



The American satellite, Explorer 1, discovered an intense radiation zone, now called the Van Allen Radiation Belt, surrounding Earth.

We now know that our wispy upper atmosphere, once believed calm and quiescent, seethes with activity, swelling by day and contracting by night. It is affected by the changes in solar activity and contributes to weather and climate on Earth.

As viewed from space, Earth's distinguishing characteristics are its blue waters and white clouds. Enveloped by an ocean of air consisting of 78 percent nitrogen and 21 percent oxygen, the planet is the only one in our solar system known to harbor life. Circling the Sun at an average distance of 149 million km (93 million mi.), Earth is the third planet from the Sun and the fifth largest in the solar system.

Its rapid spin and molten nickel-iron core give rise to an extensive magnetic field, which, coupled with the atmosphere, shields us from nearly all of the harmful radiation coming from the Sun and other stars. Most meteors burn up in Earth's atmosphere before they can strike the surface. The planet's active geological processes have left no evidence of the ancient pelting it almost certainly received soon after it formed. The Earth has a single natural satellite—the Moon.

MOON



The first human footsteps upon an alien world were made by American astronauts on the dusty surface of our airless, lifeless companion.

Six two-man crews landed on and explored the lunar surface and returned a collection of rocks and soil weighing 382 kilograms (842 pounds) and consisting of more than 2,000 separate samples.

Rocks collected from the lunar highlands date about 4.0 to 4.3 billion years old. It's believed that the solar system formed about 4.6 billion years ago. The first few million years of the Moon's existence were so violent that little trace of this period remains. As a molten outer layer gradually cooled and solidified into different kinds of rock, the Moon was bombarded by huge asteroids and smaller objects. Some of the asteroids were the size of small states, like Rhode Island or Delaware, and their collisions with the Moon created huge basins hundreds of kilometers across.

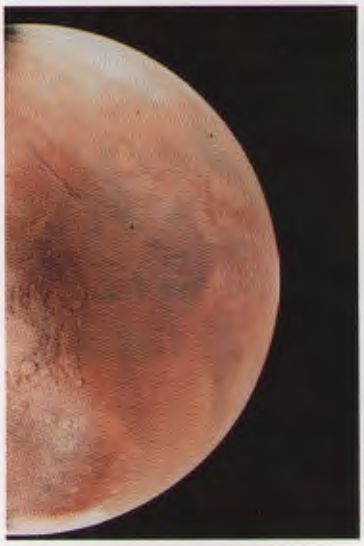
The catastrophic bombardment died away about four billion years ago, leaving the lunar highlands covered with huge overlapping craters and a deep layer of shattered and broken rock. Heat produced by the decay of radioactive elements began to melt the inside of the Moon at depths of about 200 km (124 mi.) below its surface. Then, from about 3.8 to 3.1 billion years ago, great floods of lava rose from inside the Moon and poured out over its surface, filling in the large impact basins to form the dark parts of the Moon called maria or seas. Explorations show that there has been no significant volcanic activity on the Moon for more than three billion years and, since then, the lunar

surface has been altered only by the rare impacts of large meteorites and by the atomic particles from the Sun and stars.

If our astronauts had landed on the Moon one billion years ago, it would have looked very much as it does today, and thousands of years from now, the footsteps left by the Apollo crews will remain sharp and clear.

One question about the Moon that remains unsolved is where did it come from? Three theories attempt to explain its existence: that it formed near the Earth as a separate body, that it separated from the Earth, or that it was formed somewhere else and then captured by the Earth. The notion that the Moon may have once been part of the Earth now appears less likely than the other suggestions because of the difference between the two bodies in chemical composition, such as the absence of water, either free or chemically combined in rocks. The other two theories are about evenly matched in strengths and weaknesses. The origin of the Moon remains a mystery.

MARS



Of all the planets, Mars has long been considered the solar system's prime candidate for harboring extraterrestrial life.

One reason for scientists to expect life on Mars arose from apparent seasonal color changes on the planet's surface. That led to speculation that conditions might support a bloom of Martian vegetation during the warmer months and cause plant life to become dormant during colder periods.

Two Viking spacecrafts were launched on a mission designed to answer several questions, such as: Is there life on Mars?

We still don't know whether life exists on Mars. Small samples of the red Martian soil were specially treated in three different experiments designed to detect biological processes. While some of the tests indicated biological activities were possibly occurring, the same results could be explained by the planet's soil chemistry. There was a notable absence of evidence that organic molecules exist on Mars.

Photos from the Plain of Chryse show a bleak, rusty red landscape, a gently rolling plain, littered with rocks and graced by rippled sand dunes.

Both Viking landers became weather stations, recording wind velocity and direction, temperatures and atmospheric pressure.

The Martian weather changed little. The highest atmospheric temperature recorded by either lander was −21 C (−6 F) at the Viking 1 site in midsummer. The lowest temperature, −124 C (−191 F), during winter.

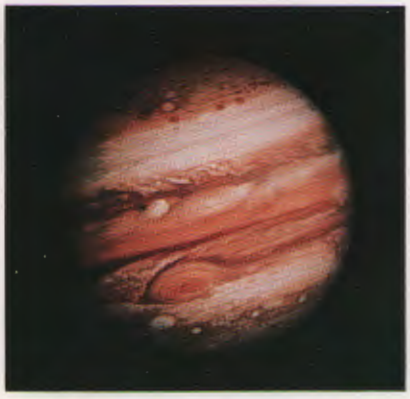
The Martian atmosphere, like that of Venus, is primarily carbon dioxide. Present in small percentages are nitrogen, oxygen and argon, with trace amounts of krypton and xenon. Martian air contains only about 1/1000 as much water as Earth's but even this small amount can condense out and form clouds which ride high in the atmosphere or swirl around the slopes of towering Martian

volcanoes. Local patches of early morning fog can form in valleys.

There is evidence that in the past, a denser Martian atmosphere may have allowed water to flow on the planet. Physical features closely resembling shorelines, gorges, riverbeds and islands suggest that great rivers once existed on the planet.

Mars has two small, irregularly shaped moons, Phobos and Deimos, each with ancient cratered surfaces.

JUPITER

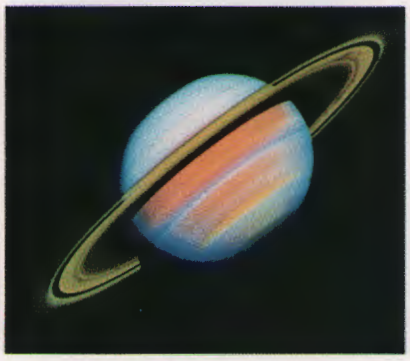


Exploring spacecraft found Jupiter to be a whirling ball of liquid hydrogen, topped with a uniquely colorful atmosphere which is mostly hydrogen and helium. It contains small amounts of methane, ammonia, ethane, acetylene, phosphene, germanium tetrahydride and possibly hydrogen cyanide.

The Great Red Spot is a tremendous atmospheric storm, rotating counter-clockwise, similar to an Earth hurricane.

Largest of the solar system's planets, Jupiter rotates at a dizzying pace—once every 9 hours 55 minutes. It takes the massive planet almost 12 Earth years to complete a journey around the Sun.

SATURN



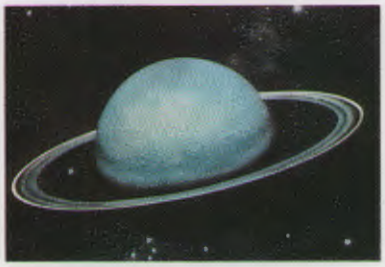
Saturn is composed mostly of hydrogen, has a more subtle, butterscotch hue and its markings are often muted by high altitude haze.

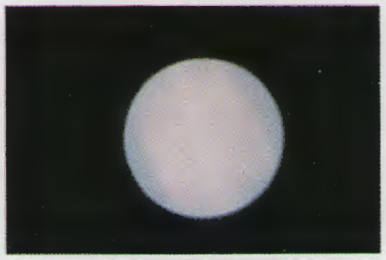
The Pioneer spacecraft discovered that there are actually thousands of ringlets encircling Saturn. Saturn's rings are composed of countless low-density particles orbiting individually around the equator at progressive distances from the planet's cloud tops.

Analysis of radio waves passing through the rings showed that the particles vary widely in size, ranging from dust to boulders. Most of the material is ice and frosted rock.

Unable either to form into a moon or to drift away from each other, individual ring particles appear to be held in place by the gravitational pulls of Saturn and its satellites.

URANUS And NEPTUNE





The first spacecraft to reach these bluish green giants will be Voyager 2, scheduled for a 1986 encounter with Uranus and a 1989 survey of Neptune. The two planets are roughly the same in mass and diameter. They are colder and significantly denser than Saturn. The atmospheres of both Uranus and Neptune are known to contain methane, which gives the planets their unusual greenish color. Both planets are believed to possess deep atmospheres which are principally composed of hydrogen and helium. Scientists theorize the planets have cores of rock and metal surrounded by layers of ice, liquid hydrogen and gaseous hydrogen. Uranus has a system of faint rings discovered in 1977. Uranus has five known moons.

PLUTO



Pluto is an oddity of the solar system. It has nothing in common with the gas giants. It travels farther from the Sun than any of the rest, yet the eccentricity of its orbit periodically carries it inside of Neptune's orbit. Pluto's orbit is also highly inclined; that is, it is well above and below the plane of the other planets' orbits.

Observations calculate its diameter to be between 3,000 and 3,500 km (1,864 and 2,175 mi.), which is about the same size or somewhat smaller than our Moon. Earth-based observations indicate Pluto's surface is covered with methane ice.

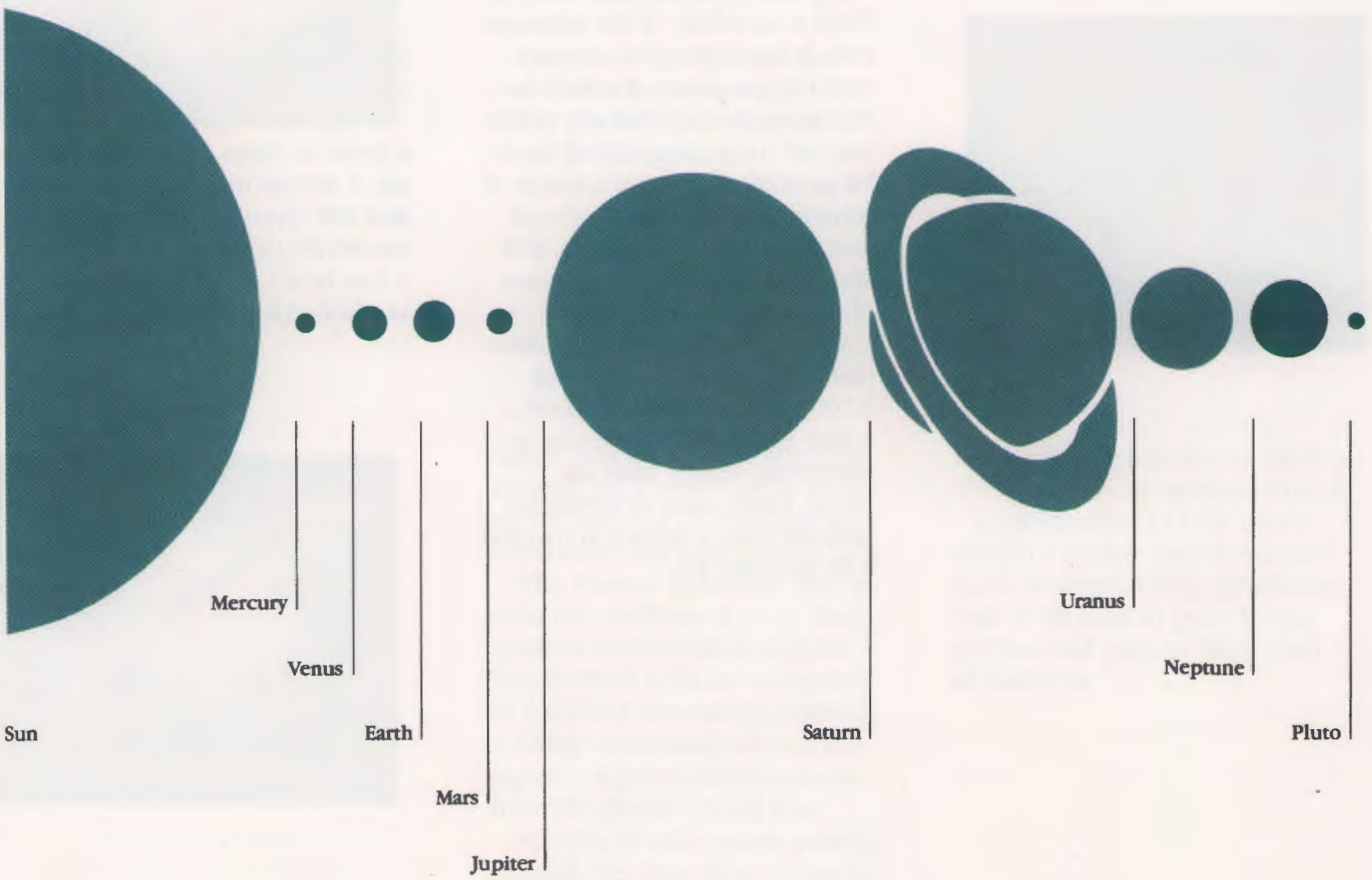
Small as it is, Pluto has a satellite. The moon was discovered in 1978 and named Charon.

There are no plans for sending a probe to Pluto. Of the nine planets, it will be the only one not visited this century by automated spacecraft, providing the Voyager 2 flies near Uranus and Neptune as planned for 1986 and 1989.

A Portrait of the Planets

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Distance From Sun (Millions of Kilometers)	57.9	108.2	149.6	227.9	778.3	1,427	2,870	4,497	5,900
Period of Revolution	88 days	224.7 days	365 days	687 days	11.86 years	29.46 years	84 years	165 years	248 years
Rotation Period	59 days	243 days Retrograde	23 hours 56 minutes	24 hours 37 minutes	9 hours 55 minutes	10 hours 40 minutes	13-24 hours(?) Retrograde	18 hours 30 min.(?)	6 days 9 hours 18 minutes Retrograde
Inclination of Axis	Near 0°	3°	23°27′	25°12′	3°5′	26°44′	97°55′	28°48′	?
Inclination of Orbit to Ecliptic	7°	3.4°	0°	1.9°	1.3°	2.5°	0.8°	1.8°	17.2°
Eccentricity of Orbit	.206	.007	.017	.093	.048	.056	.047	.009	.254
Equatorial Diameter (Kilometers)	4,880	12,100	12,756	6,794	143,200	120,000	51,800 (?)	49,500 (?)	3,000 (?)
Atmosphere (Main Components)	Virtually None	Carbon Dioxide	Nitrogen Oxygen	Carbon Dioxide	Hydrogen Helium	Hydrogen Helium	Helium Hydrogen Methane	Hydrogen Helium Methane	None Detected
Satellites	0	0	1	2	14 (?)	12(?)	5	2	1
Rings	0	0	0	0	1	1,000 (?)	9	?	?

Relative Sizes





Saturn's rings are seen to the south (lower left) of their shadow on the cloudtops.



National Aeronautics and
Space Administration

PAM 107
July 1985

(Noonan)
January 28, 1986
1:00 p.m.

PRESIDENTIAL REMARKS: DEATH OF SPACE SHUTTLE CHALLENGER CREW
TUESDAY, JANUARY 28, 1986

Ladies and gentlemen, we have a brief statement. Nancy and I are pained by this tragedy -- as you are, as all of the people of our country are. This is a national loss.

We forget what courage it takes to go into space and explore the heavens, we forget what it takes. In more than a quarter of a century of the United States space program we have never lost an astronaut in flight -- ~~we have never had a tragedy like this.~~ And so we have forgotten the courage it takes, and the courage it took for the crew of the shuttle. But they -- the Magnificent Seven -- were, by necessity, always aaware of the dangers, and they overcame whatever fears they had to do their jobs brilliantly.

Here are seven heroes -- Michael Smith, Francis Scobee, Judith Resnick, Ronald McNair, Ellison Onizuka, Gregory Jarvis, and Christa McAuliffe. We mourn them, we mourn them as a Nation, together.

To the families of the Seven: We cannot bear, as you do, the full impact of this tragedy -- but we feel the loss, and we are thinking about you so very much. Your daughters and sons, your husbands, wives and parents -- they were daring and brave and they had that special grace, that special spirit that said: give me a challenge and I'll meet it with joy. They had a hunger to explore the universe and discover its truths. They wished to serve and they did, and brilliantly.

They honored us by the manner in which they lived their lives. We will never forget them nor the last time we saw them -- this morning, as they prepared for their journey, and waved goodbye, and "slipped the surly bonds of earth" to "touch the face of God".

USA Today Friday Jan 24-26 1986

L.A. dealer is driven in fight to save Jeep

John Walker considers the Jeep CJ to be the Coca Cola of automobiles, and he wants plans to drop the car stopped in their tracks.

The Los Angeles Jeep dealer has mounted a "Keep the Jeep" drive to persuade American Motors Co. to continue making the rugged, no-frills vehicle whose basic design hasn't changed since 1941.

Saturday he'll lead a CJ parade to L.A.'s main post office to mail a petition with 4,500 signatures supporting the car.

"It's a nostalgic thing," says Walker, 50. "It just hurts to see it go away."

There's "absolutely no possibility" the company will reverse gears — as Coca Cola did in reviving Classic Coke — AMC's Lloyd Northard says.

The company says complaints that the CJ is unsafe didn't figure in the decision to end production Tuesday.

A crew with class



AP

THE CHALLENGER TEAM: Crew for the shuttle, scheduled to blast off at 9:36 a.m. EST Sunday, will be: from left, front; copilot Michael Smith, commander Francis 'Dick' Scobee and Ronald McNair. From left, rear; Ellison Onizuka, Christa McAuliffe, Gregory Jarvis and Judith Resnik. McAuliffe is the 'teacher in space' and Jarvis is a payload specialist with the Hughes Aircraft Corp. Highlights of the flight: McAuliffe's broadcast of two lessons to USA classrooms, observations of Halley's Comet, launch of a communications satellite. (McAuliffe's family, 1A)

Artificial heart pioneers praised

Developers of artificial hearts got a pat on the back Thursday from Una Loy Clark, widow of Barney Clark, the first human to receive a permanent mechanical heart implant.

"I thank God for men of vision and the pioneering spirit who possess the courage to face possible failure," Clark told artificial organs experts meeting in Salt Lake City.

Said Penn State surgeon Dr. William Pierce: "It's very clear that the total artificial heart has gained a very powerful supporter and spokesman."

At 64, Clark, who has three children and five grandchildren, expects to spend more time at her Seattle home after two years of speaking across the USA on behalf of the American Heart Association.

Her husband of 39 years died March 24, 1983, after 112 days with a Jarvik-7 heart.

Clark said she's disturbed by criticism of the artificial heart and by calls for a moratorium on implants.



By Larry Rubenstein, UPI

CLARK: It was painful to watch husband suffer

Young OK'd

Detroit Mayor Coleman Young has been approved as the first black member of the exclusive Detroit Golf Club, shattering an 80-year-old racial barrier. The club's board voted him in Wednesday night.

Death

Willard Van Dyke, a documentary film pioneer and former colleague of photographer Ansel Adams, died Thursday. Van Dyke, 79, suffered a heart attack in Jackson, Tenn., during a trip from Santa Fe, N.M., to Harvard University, where he was to be artist-in-residence.

Bush, Kemp treat Cuomo like front-runner

New York Gov. Mario Cuomo hasn't said he's running for president, but two Republican contenders gave him front-runner treatment Thursday.

At the New York Conservative Party's annual dinner:

■ Vice President George Bush criticized Cuomo's grant-

Gary McGivern.

"I can tell you one thing about the difference between a liberal politician and a conservative one," Bush said. "Gov. Ronald Reagan kept cop-killers in jail."

■ Rep. Jack Kemp of New York attacked Cuomo, saying

reduce "New York's absurdly high tax rates by at least 40 percent — and not raising state spending by 40 percent as Mario Cuomo has."

Cuomo has said he has no plans to seek the Democratic presidential nomination, but might do so to prove those who

CORRECTION: A story on federal revenue sharing in Thursday's USA TODAY mistakenly said Cleveland raised taxes six times in the last seven years. There have been six tax-increase proposals; two were adopted.

Reported by Eric Small, P

...porate mergers, takeovers. Learn about investor risks, benefits, and price workers pay; trends in 1986.

Compiled by Theresa Berry

Inside USA TODAY 6 SECTIONS

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Life

REACH FOR THE ROYAL

Classified	8-11D
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Bonus REACH FOR THE BONUS
Super Bowl XX Section E

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analysis by San Diego passer Dan Fouts

Teachernaut schooled for Sunday blast

By Julie Morris
and Chet Lunner
USA TODAY

CAPE CANAVERAL, Fla. — High school social studies teacher Christa McAuliffe begins the ultimate field trip Sunday when she rides the space shuttle Challenger into orbit.

The launch — set for 9:36 a.m. EST unless expected thunderstorms force a delay — will make McAuliffe, 37, the first ordinary USA citizen in space.

The Concord, N.H., teacher will conduct two live lectures in orbit Wednesday. Public Broadcasting Service will televise the classes.

She will be questioned by students at Concord High and McCall-Donnelly Elementary in McCall, Idaho, where backup Barbara Morgan teaches.

McAuliffe said, "I don't think any teacher has been more ready to have two lessons."

And astronaut Jillison Onizuka said, "I think this is a big step to getting word to youngsters that one day space flight will be as routine as the 747."

McAuliffe has 300 family members and friends here. Husband Steven with Scott, 9, and Caroline, 6, will watch from Kennedy Space Center.

COVER ST

Bowl 'It's b than

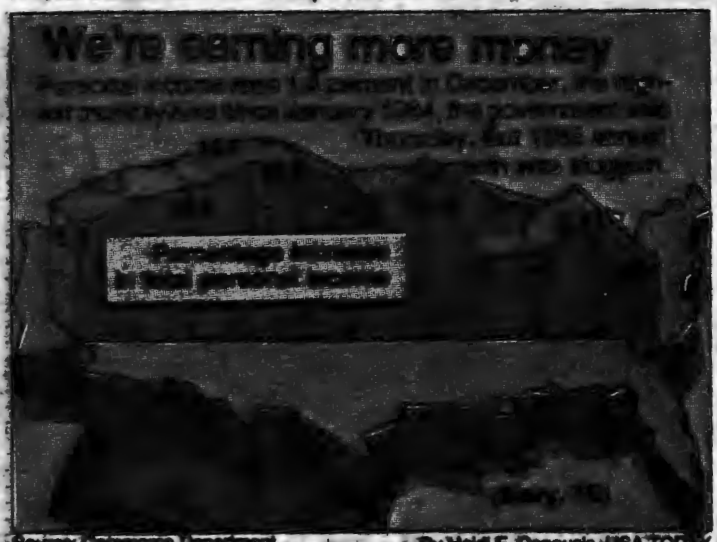
NBC, NFL selling game as a holiday; USA juggles its schedules for big event

brass on a seagoing ship. T
Sunday's game for delayed
Cuba, or the Gulf of Suez —
catch the live satellite feed
Chicagoans Barbara Ad
squeezing their wedding w
The cruise ship Festival
passengers won't miss the,
"It's become bigger than
Turner, associate director
tion. "Actually, it's somew
What began as a nation
cades ago has become an
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are packaging Super Bowl
That's how former Olym
"I really like the excitemen
have a good time. We even

Please

USA SNAPSHOTS

A look at statistics that shape the nation

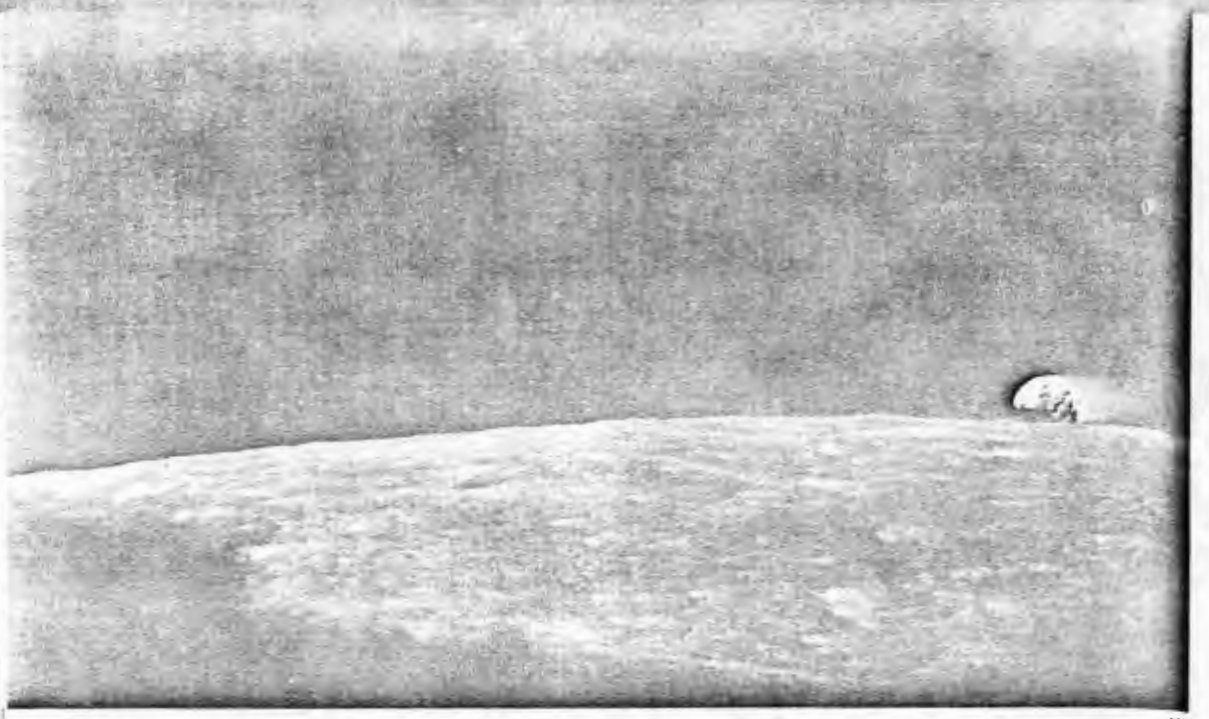


Source: Commerce Department

By Heidi E. Dapcusia, USA TODAY

MONDAY IN USA TODAY: SPECIAL SUPER BOWL SECTION

LEGEND
Below



The earth as seen by the Apollo 8 astronauts when they swung around the rim of the moon.

SPACE EXPLORATION, the direct investigation of space and the objects it contains, whether by unmanned satellites and space probes or by man himself. For centuries man has observed and recorded the movements of the sun, moon, stars, and planets. With the invention of the telescope in the early 16th century and of a great variety of scientific instruments since that time, scientists began to develop man's modern concept of the universe. However, not until the middle of the 20th century did it become possible to send man's tools and man himself outside the limits of his planetary home, the earth, to investigate the space environment, the earth's moon, and eventually other members of the solar system such as the planets Mars and Venus.

Space exploration is presently confined to the solar system—the sun, its planets and their satellites, and objects such as meteors and comets. Man may someday send probes to other stars and solar systems. The British Interplanetary Society, for example, has studied design concepts for a spaceship able to reach Barnard's star, 5.9 light-years away. This star is believed to have a planetary system.

The first section of this article discusses how vehicles are propelled into space, the energy they use, the trajectories they follow, and the design requirements of different kinds of missions. The second section outlines the very special human problems encountered by the space traveler. The third section relates the fascinating history of space flight, from ideas expressed in early writings to the first actual flights. Recent unmanned space flights are described in the fourth section, and manned space flights in the fifth section; a special feature beginning on page 357 tells the story of the June 1969 voyage of Apollo 11, in which men set foot on the moon for the first time. The sixth and final section deals with future plans and ideas for exploration of the entire solar system and the possibilities for manned and unmanned exploration of the stars.

For further information on the techniques and achievements of space exploration, see the following articles: ASTRONAUTICS; JUPITER; MARS; MERCURY; MOON; NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ROCKET; SATELLITE, ARTIFICIAL; SATURN; SPACE SHUTTLE; VENUS.

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1. Principles of Space Flight

To accomplish the launching of even the simplest satellite into orbit around the earth, scientists must deal with several complex factors. These include the earth's gravitational attraction, the control of the satellite after launch, and the nature of the space environment in which the satellite must function.

GETTING INTO SPACE

Rockets provide the power needed to launch a spacecraft and carry out its mission. The reactive force of a rocket is called its *thrust*. If its thrust is twice the weight of the launch vehicle at lift-off, the spacecraft assembly will rise at an initial acceleration of one gravity (g), or 32.2 feet (9.8 meters) per second per second. In order to enter orbit, the spacecraft must attain a horizontal velocity of about 18,000 miles (28,800 km) an hour.

Staging. Rocket pioneers grasped a way to increase the final velocity achieved by a spacecraft by separating its rocket propulsion system into separate stages. They found that by arranging stages on top of one another and discarding the empty propellant tanks of each stage, the loss in deadweight resulted in a great increase in the velocity attainable. Staging is extremely important in space flight because the weight of a spa-

craft, or *payload*, is usually only a small fraction of 1% of the total weight of the multistage launch vehicle at takeoff.

As a multistage rocket vehicle moves upward, propellants in the first stage are consumed, decreasing the vehicle weight. Acceleration increases until staging occurs, at which time the first stage (consisting of the propellant tanks, rocket motor, and supporting structure) separates and falls away. The second stage motor then ignites, and the spacecraft, traveling at several hundred or several thousand miles per hour, begins to accelerate again. The procedure continues until the last stage has achieved the desired flight velocity and is discarded.

Speed of Ascent. Within certain limits, the longer it takes to leave the earth and its atmosphere on a space mission, the less economical the procedure becomes. At low accelerations the spacecraft wastes great amounts of rocket propellant, because each second it loses in effect a velocity of 32 feet (9.8 meters) per second as a result of gravity. Thus the quicker the craft attains orbital or escape velocity, the less propellant it need waste in counteracting gravity.

The resisting effect of earth's gravity on the outward motion of a spacecraft subsides slowly as the distance between the earth and the spacecraft increases. At an altitude of 100 miles (160 km) the gravitational attraction of the earth and the spacecraft is 1% less than at the earth's surface, at 1,700 miles (2,700 km) it is ½ that at the earth's surface, and at 60,000 miles (96,000 km) it is 1/20. The gravitational attraction of the earth, for practical purposes, would be negligible for spacecraft at distances of a few million miles out in space.

There usually are limits to which a spacecraft can be accelerated without risk of structural damage. Also, in manned space flight, a properly positioned and secured space traveler cannot comfortably experience more than 5g or 6g during takeoff. High-g launchings also encounter aerodynamic drag loss due to high-speed flight in the dense lower atmosphere. Thus in determining optimal launching speeds and rate of achieving orbital velocity, certain lower and upper limits of acceleration are considered.

FLIGHT PATHS

The sounding rockets used for upper atmospheric research that appeared shortly after World War II were fired vertically to altitudes of over 100 miles (160 km). These single or multistaged rockets reached maximum speeds of the order of 3,000 to 5,000 miles (4,800–8,000 km) per hour at the moment of completion of burning of the propellants (burnout). Burnout occurred at altitudes from about 15 to 20 miles (24–32 km), and from this point on the rockets coasted upward, gravity slowly reducing their speed to zero at peak altitude. The rockets then descended, picking up speed until they finally crashed into a desert or ocean. The maximum altitudes and speeds attained by these rockets were not great enough to achieve an orbital path, or closed path around the earth. Since the type of flight they followed had a definite beginning and end and was not repetitive, it is often called *trajectory*.

Earth Orbital Flight. A rocket (final stage and spacecraft) that achieves a burnout velocity of at least 18,000 miles (28,800 km) per hour at an altitude of over 125 miles (200 km), and that is directed on a path essentially parallel to the earth's surface, will establish an orbital flight path around the earth. At this altitude, molecules of air are so widely dispersed that aerodynamic drag is almost negligible. Thus the orbiting spacecraft, or artificial earth satellite, would remain aloft for years, circling the earth in the same manner as the moon, the earth's natural satellite. At this velocity, the satellite develops a centrifugal force that exactly balances the pull of earth's gravity. Less orbital velocity is required in orbits that are a greater distance from the earth, because the force of earth's gravity decreases with increasing distance.

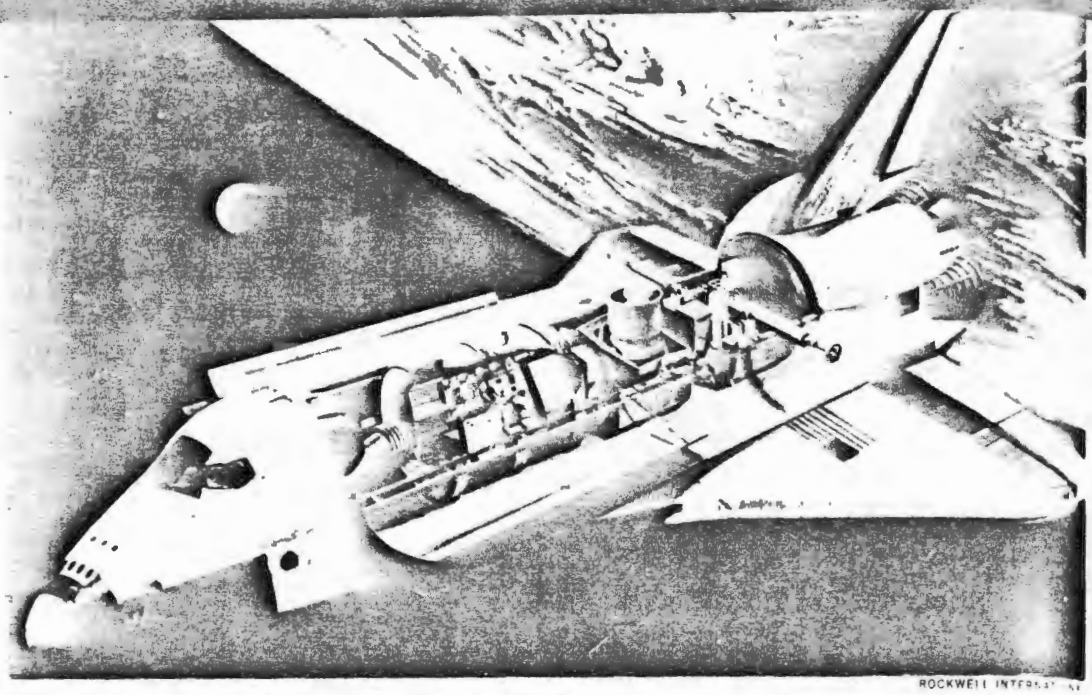
In the usual launch of a satellite, the space vehicle takes off vertically and then slowly tilts toward the east, achieving a 90° turn at burnout with at least sufficient velocity to orbit at the desired altitude. Satellite launchings are usually made toward the east, since the earth rotates in that direction 1,040 feet (317 meters) per second at the equator. (The speed decreases with increasing latitude, becoming zero at the poles.) It is possible to launch a satellite in a westerly direction, but about 2,000 feet (610 meters) per second of additional launch velocity is required. Satellites are also launched longitudinally into polar orbits.

As the orbital altitude increases, the orbital period—the time required to circle the earth—also increases, and the orbital velocity decreases. At an altitude of 1,075 miles (1,718 km) the period is 2 hours, and at 26,000 miles (41,600 km) the period is 24 hours. Since the latter is the same length of time that it takes for the earth to rotate once, the satellite (if in equatorial orbit) is said to be *geostationary*. This means that the satellite will always be above the same point on the earth's surface. Satellite orbital velocity at this altitude is about 7,000 miles (11,200 km) per hour. The moon, which has an orbital altitude of 240,000 miles (384,000 km), has a period of about a month and an orbital velocity of 2,300 miles (3,100 km) per hour.

Earth satellites usually travel in elliptical paths. However, they can be put into circular orbits. Circular orbits are more difficult to achieve because they require more precise control of speed and direction during launching. If the velocity at burnout is greater than required for a circular orbit, the point of burnout will be at *perigee*, the point closest to the earth in the spacecraft's elliptical orbit. If the burnout velocity is less than required for a circular orbit, the point of burnout will be at *apogee*, the point farthest from the earth in the spacecraft's orbit.

Planetary Flight. To escape the earth's gravitational attraction, a spacecraft must achieve a minimum velocity of 25,000 miles (40,000 km) per hour. This is also the minimum velocity required to reach Mars or Venus, whereas a flight to distant Jupiter would require a velocity of at least 32,000 miles (51,000 km) per hour. A flight to Pluto or the nearest star would require a minimum velocity of 37,000 miles (59,200 km) per hour.

A flight to the moon or another planet requires precise timing as well as precise aiming and control of speed, because of the motions of members of the solar system. Ideally, a spacecraft is kept on a flight path, or trajectory, that requires a minimum expenditure of energy. Minimum energy trajectories are elliptical paths called *transfer orbits*. In the transfer orbit to Mars,



ROCKWELL INTERNATIONAL

The U.S. Space Shuttle, first successfully flown in 1981, has a large cargo bay for carrying payloads into orbit

speed must be reduced in climbing out of the earth's and sun's gravitational attraction, because the orbital velocity of Mars is less than that of the earth. Venus has an orbital velocity greater than earth's, and therefore the transfer orbit to Venus requires an increase in velocity. Midcourse application of rocket power is usually necessary to effect the changes in velocity. If a fly-by rather than a landing is planned, an exact match of the planet's orbital velocity is not necessary. Launch timing is particularly important because of the changing relative orbital positions of the planets. For example, the relative orbital position of Mars and Venus gives favorable opportunities for minimum-energy transfer orbits only about every two years.

NAVIGATION

Space flight requires navigation in three dimensions rather than essentially two, as in the case of travel on the earth's surface or in its atmospheric envelope. Furthermore, the rotation of the earth, the orbital speeds of the planets and other bodies, the varying gravitational influences and the immense distances and varying relative positions of members of the solar system necessitate precise navigation. A combination of information radioed from earth to a spacecraft and measurements from it of bright stars in known positions allow very accurate guidance in our solar system.

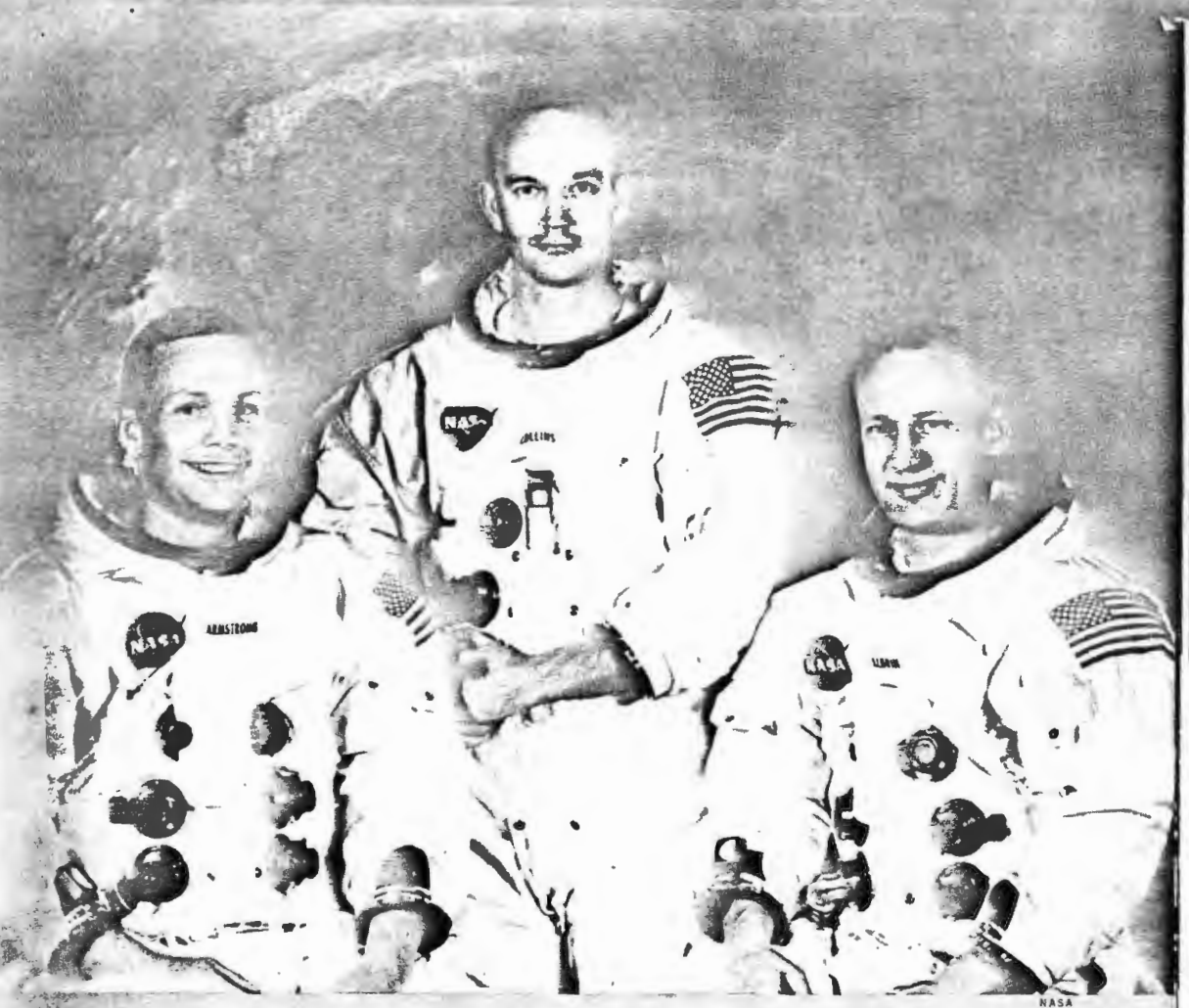
Inertial Guidance. The requirements of guidance and control of a spacecraft vary widely, depending upon the type of spacecraft and its mission. Basic to most guidance systems is a positional memory system known as *inertial guidance*. By the use of spinning gyroscopes, precise measurements are made of any deviation or change in the planned velocity of a spacecraft.

Any significant deviation from the flight plan must be corrected to achieve the desired flight path. During the launch phase, the corrections may be made at once by changing the angles of the vernier thrust rocket motors, jet vanes in the rocket motor exhaust, or rocket motor which is hung on a gimbal-ring mount. In the case of a lunar mission, the data on deviation and corrective thrust requirements may be stored in a computer memory system on the spacecraft, at the same time being transmitted to tracking stations. A mid-course and late mid-course correction maneuver can then be made by firing a rocket motor in a precisely determined direction for a precisely determined length of time. This application of thrust places the spacecraft on a corrected trajectory to accomplish its mission. During a power maneuver, acceleration measurements continue to be made. Any differences in the corrected flight path from the original course are taken into account in further power maneuvers.

Tracking and Communications. In orbital flight and in lunar and planetary space missions, the rotation of the earth makes many tracking stations necessary in order to keep continuous radio and radar contact with the space vehicle. For this reason a worldwide network of large-antenna tracking stations has been established. (NASA's Tracking and Data Relay Satellite System, used for Shuttle launches, will shift much tracking equipment into orbit, away from stations on the ground in foreign countries that might become politically unstable.) Through telemetry—the production and transmission of radio signals representing temperature, pressure, acceleration, and such data—the flight path and various conditions are monitored at tracking stations. Instructions or queries also may be transmitted to the spacecraft. Thus a dialogue is maintained, although the spacecraft is thousands or millions of miles away. Proper performance of on-board transmitters and receivers requires precise orientation of antennas and solar-cell power systems. A deep-space probe will be programmed to "lock on" to a very bright star or group of stars as a reference point during flight. In earth orbital space flights, both sun seekers and earth-horizon scanners may be used.

Since large amounts of data are desired at tracking stations, and the transmission power requirements of the spacecraft transmitters and receivers are limited, techniques of compressing data and achieving high-speed transmission are used. On board memory-storage systems for

(Continued on page



The crew of Apollo 11 (*left to right*): Neil Armstrong, Michael Collins, and Edwin Aldrin.

The First Men on the Moon

believe that this nation should commit itself ...eving the goal, before this decade is out, of ... a man on the moon and returning him safely ... On May 25, 1961, President John F. ... addressed these words of commitment to ... Congress and the American people. When ... the Soviet Union had already sent a man ... around the earth, and the United States ...unched a manned suborbital flight. The time ... to have arrived for translating into reality ... old dream of mankind—to have men leave ... planetary cradle and stride on alien worlds.

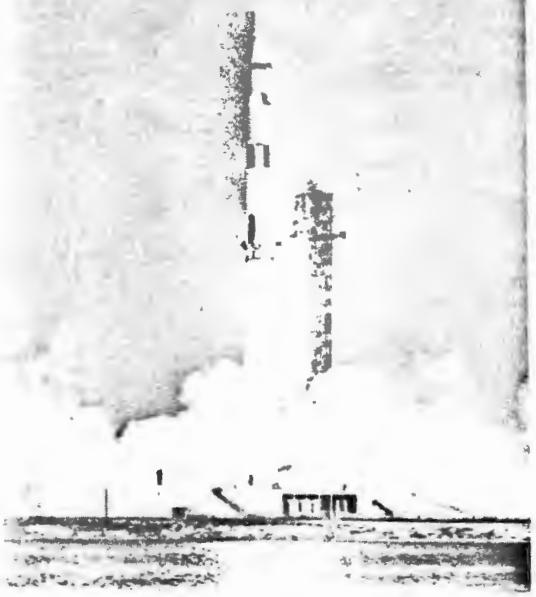
... July 20, 1969, the flight of Apollo 11 achieved ... dream. Two astronauts took the first steps on ... world. Men had walked on the moon.

... mission of Apollo 11 was a triumph for ... science and technology. Beyond that, it ... triumph for a centuries-long chain of scien... inventors, whose work and dreams had ... flight possible. The roster of their names ... back from rocket engineers of the recent ... as Konstantin Tsiolkovsky and Robert H. ... to ancient astronomers, such as Aris..., who first began to discover the true nature ... universe. The following feature pages de... Apollo 11's historic flight.

... be the task of future historians to assess ... on man's history of the first lunar landing. Even from this short range of time, however, it can be asserted with good reason that man has reached another crossroads in his quest for knowledge, and that his thinking about himself and his world can never again be quite the same. What man can achieve some day among the stars may indeed be limited only by his own self-knowledge, or lack of it, and by the energy with which he pursues new goals in the exploration of space. As Robert H. Goddard wrote in 1932: "There can be no thought of finishing, for aiming at the stars, both literally and figuratively, is the work of generations, but no matter how much progress one makes there is always the thrill of just beginning."

THE CREW OF APOLLO 11

The three astronauts who made up the crew of Apollo 11 were Neil A. Armstrong, a civilian, and Edwin E. Aldrin, Jr., and Michael Collins, both Air Force officers. Each of the men had made one previous flight into space and was a veteran pilot with several years of training. Aldrin was also a graduate of the Massachusetts Institute of Technology with the degree of doctor of science in astronautics. On the Apollo 11 flight Armstrong was the mission commander, Aldrin served as the commander of the lunar module (code-named *Eagle* for the flight), and Collins was the pilot of the space-



NASA

Saturn 5 lifts Apollo 11 into space on July 16, 1969.

craft's command module (code-named *Columbia*). Armstrong and Aldrin were the men who would descend to the surface of the moon. See also ASTRONAUTS.

HEADING TOWARD THE MOON

The mission of Apollo 11 got under way at 9:32 A. M. Eastern Daylight Time (EDT) on July 16, 1969. Approximately one million spectators in the Cape Kennedy, Fla., area and hundreds of millions of television viewers around the world watched the Saturn 5 rocket rise slowly from Launch Complex 39 with its manned Apollo payload.

The astronauts entered a temporary "parking" orbit about 115 miles (185 km) above the earth, where the guidance system of the instrumentation unit computed the exact moment for the S-4B stage of the rocket to reignite in order to insert the spacecraft into its translunar path. This path was calculated so that, should the engine of the service module fail to place the Apollo 11 in lunar orbit, the spacecraft would swing around the moon and return to earth along a "free return" trajectory—the same flight path used on Apollos 8 and 10.

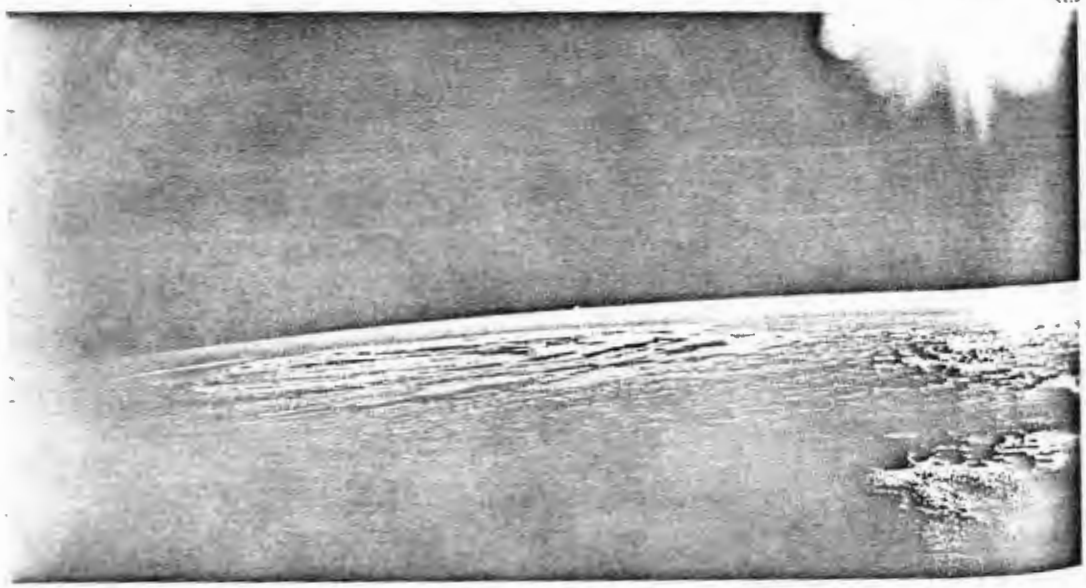
The firing of the S-4B stage took place on schedule, speeding the spacecraft to an initial velocity of nearly 24,300 miles (39,100 km) per hour. So accurate was the firing that three of four planned midcourse corrections were subsequently canceled. The long journey to the moon had begun.

Early in the translunar coasting period, several necessary maneuvers were carried out to reorient the spacecraft. The linked command and service modules were turned about so as to dock with the lunar module, after which *Eagle*'s four connections to its adapter and the S-4B stage were severed with spring thrusters and explosive bolts. Later, about 34 hours into the flight, the astronauts relayed their first scheduled color television broadcast to the world. They reported being deeply impressed by the image of the receding earth, with Aldrin adding the perhaps unnecessary comment that "The view is out of this world."

The Soviet Union placed an unmanned probe, Luna 15, into orbit around the moon while Apollo 11 was still en route, and the astronauts were kept informed of its progress. The purpose of the probe was never made clear by the Soviet Union, but one common theory was that it had been meant to follow the progress of the Apollo mission. Another theory held that Luna 15 was an unsuccessful attempt to collect a sample of lunar soil and return it to earth—as Luna 16 managed to do in 1970—before the Apollo mission was concluded. The probe eventually crashed into the moon.

As Apollo 11 neared the lunar surface, the time came to fire the service module's propulsion system. The engine burn reduced the spacecraft's velocity from approximately 6,500 to 3,700 miles (10,460 to 5,960 km) per hour and placed the astronauts in an elliptical orbit around the moon. Apollo 11 had traveled 244,930 miles (394,337 km). The time was 1:22 P. M. (EDT), July 19.

Circling the earth, the astronauts look down over sea and clouds as they prepare to head out toward the moon

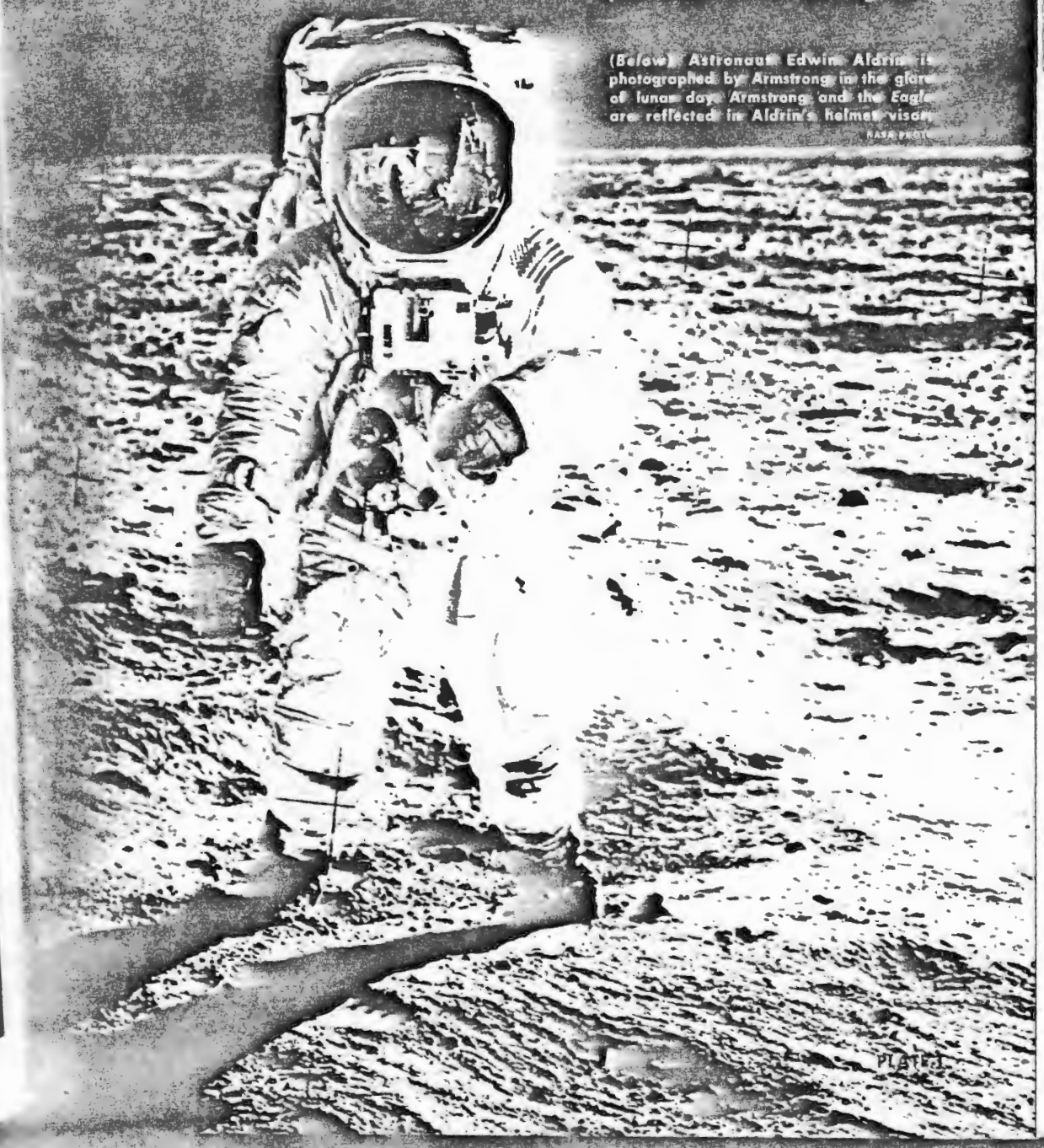


FIRST MEN ON THE MOON

"That's one small step for a man, one giant leap for mankind." With these words Neil Armstrong stepped down from the ladder of *Eagle*, the lunar module of Apollo 11, and set foot upon the surface of the moon. Thus July 20, 1969, entered history as the day when man, for the first time, walked on a world other than his native earth. Apollo 11 marked the climax of years of effort by the U.S. National Aeronautics and Space Administration to place a man on the moon by 1970.

(*Below*) Astronaut Edwin Aldrin is photographed by Armstrong in the glare of lunar day. Armstrong and the *Eagle* are reflected in Aldrin's helmet visor.

NASA PHOTO



HEADING TOWARD THE MOON

On July 16, 1969, as millions of spectators viewed the event over television, the Apollo 11 astronauts began their historic eight-day journey. Below, an automatic camera high on the tower of Launch Complex 39 at Kennedy Space Center, Florida, records the early moments of liftoff. The mighty, 364-foot Saturn 5/Apollo 11 space vehicle slowly rises past the camera on a column of flame, its initial 7.5 million pounds of thrust generated by the burning of kerosine and liquid oxygen.

NASA Photo

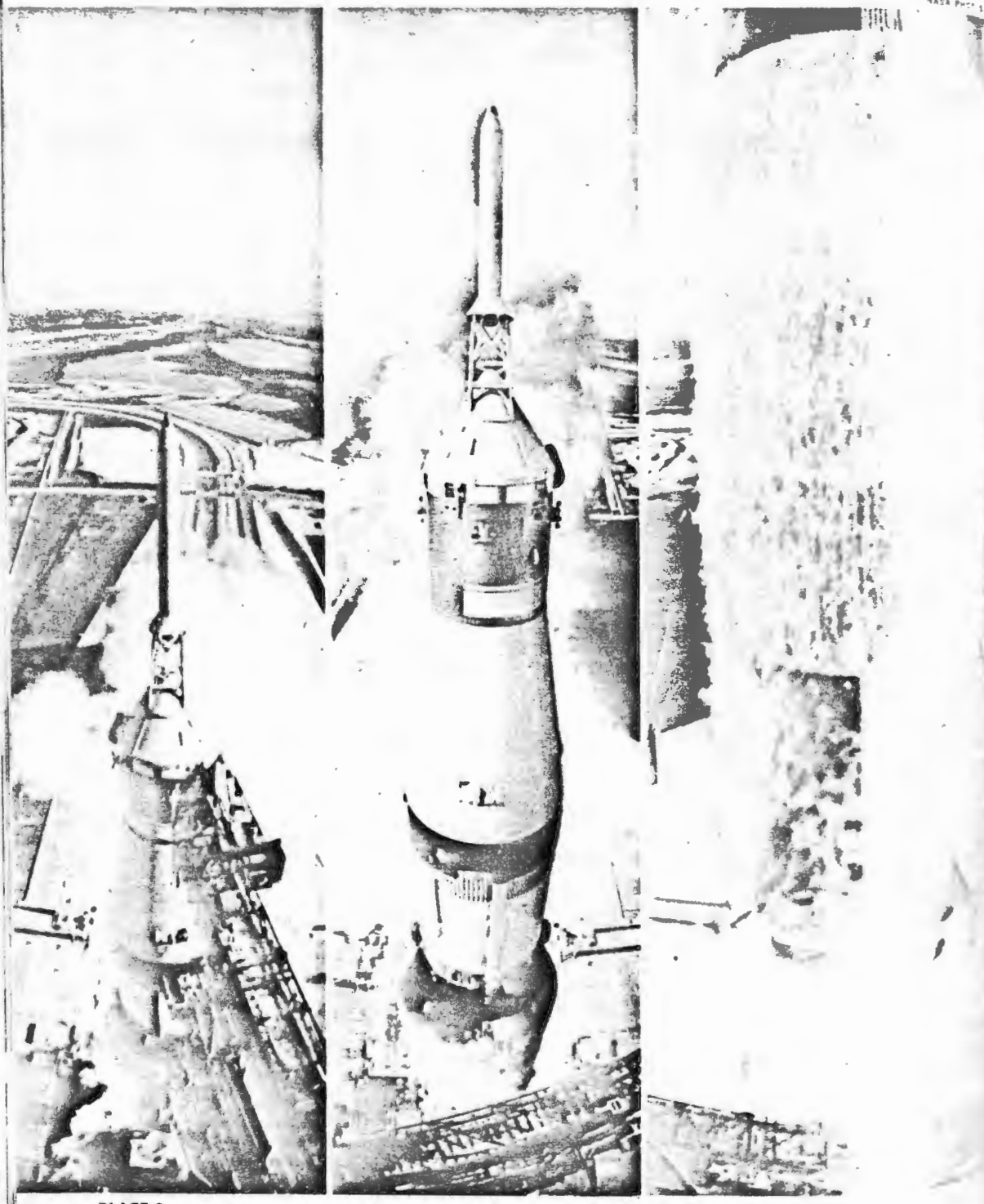


PLATE 2



Once in lunar trajectory, the astronauts use their cameras to photograph the earth they are leaving. North Africa and the Arabian peninsula are clearly visible in the midst of swirling patterns of clouds.

PLATE 3

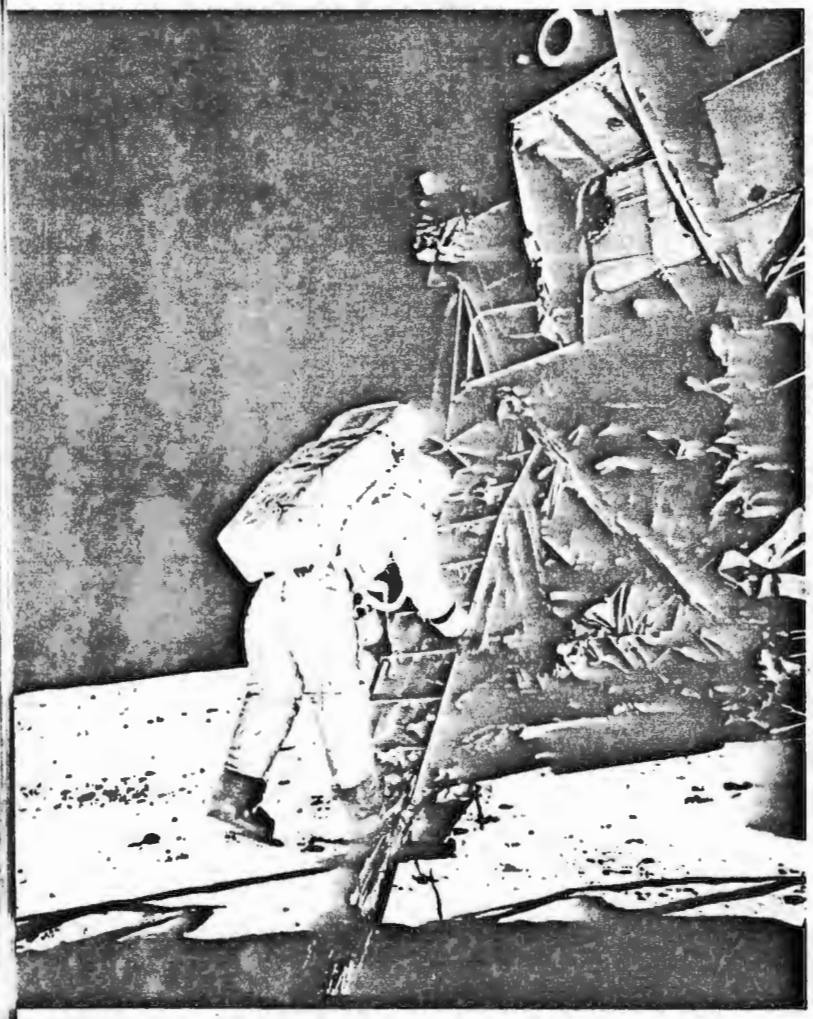


Apollo 11 Emblem

ON THE LUNAR SURFACE

Four days after Apollo 11's launch, astronauts Neil Armstrong and Edwin Aldrin entered *Eagle*, the lunar module, and descended to the surface of the moon, while Michael Collins remained in lunar orbit in the command module *Columbia*. Armstrong's first words as the LM touched down in the Sea of Tranquility were: "Houston, Tranquility Base here. The Eagle has landed." (Above, the emblem worn by the crew of Apollo 11 symbolized the landing.) The two men spent 21½ hours working and resting on the moon before rising in *Eagle*'s ascent stage to rejoin Collins in lunar orbit and return to earth.

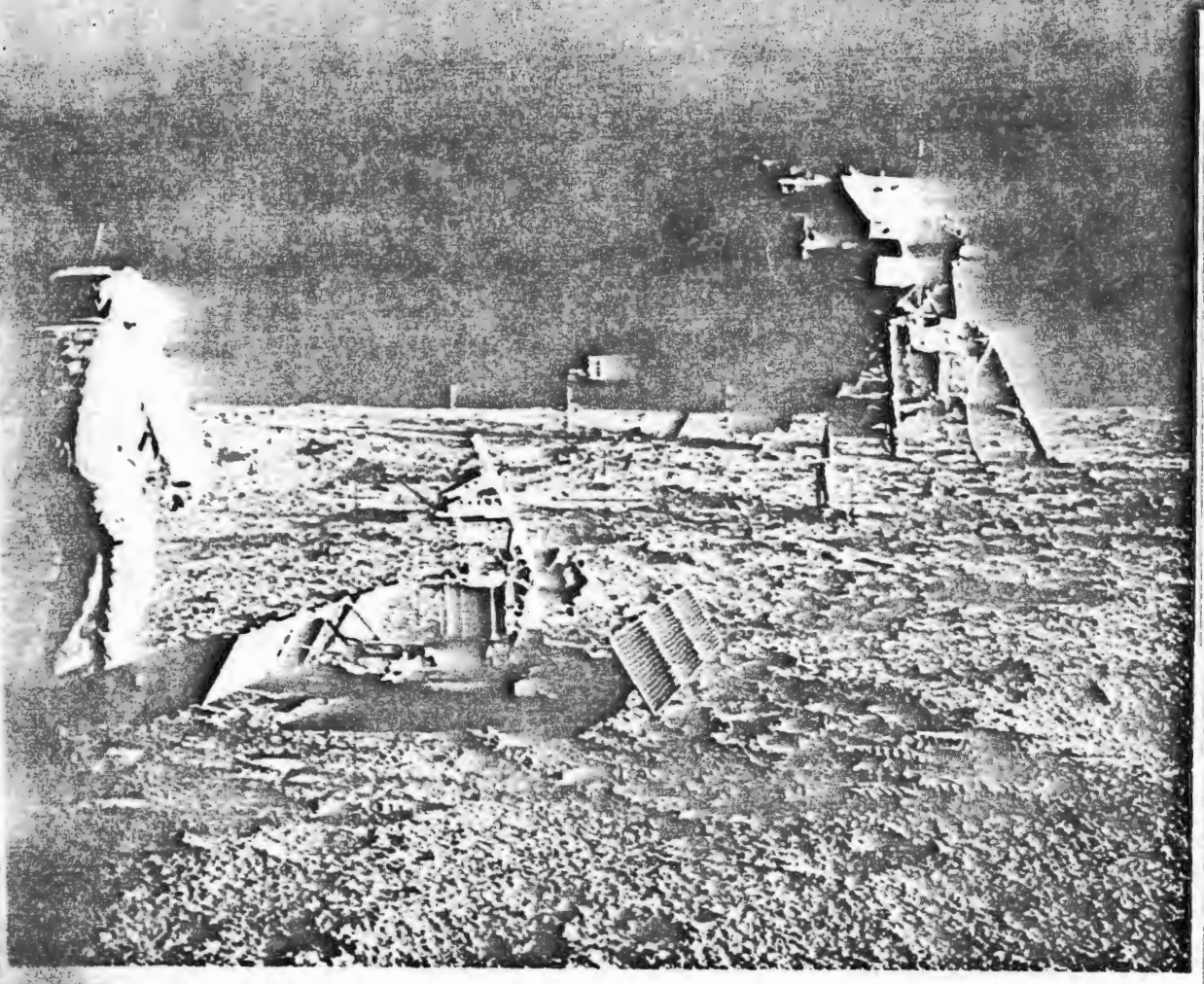
NASA PHOTOS



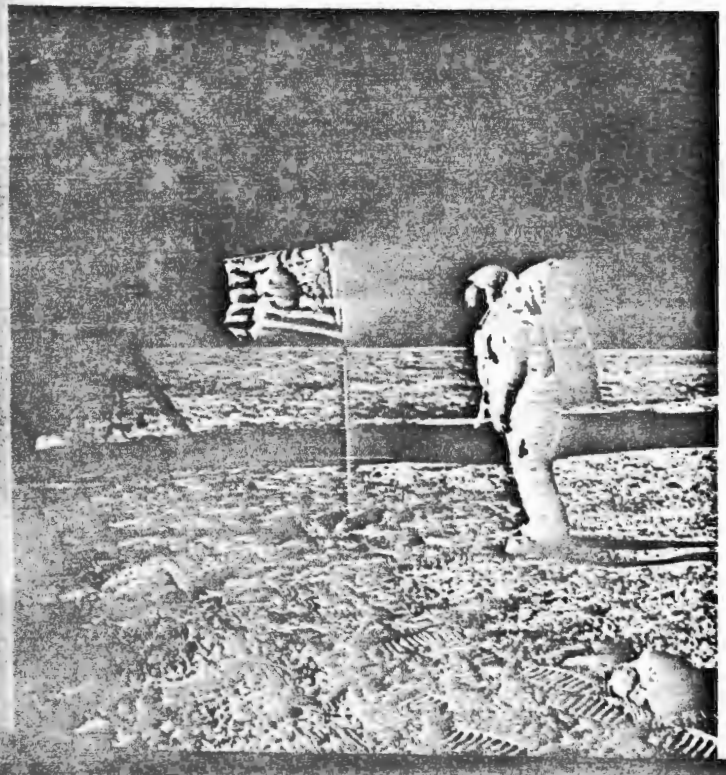
(Above) Aldrin cautiously descends the ladder of *Eagle* as he is photographed by Armstrong, who had stepped out on the moon a few minutes earlier.



***(Right)* Walking around the rim of a small crater, Aldrin carries two of the instruments that were set up and left behind on the lunar surface to send back scientific information.**



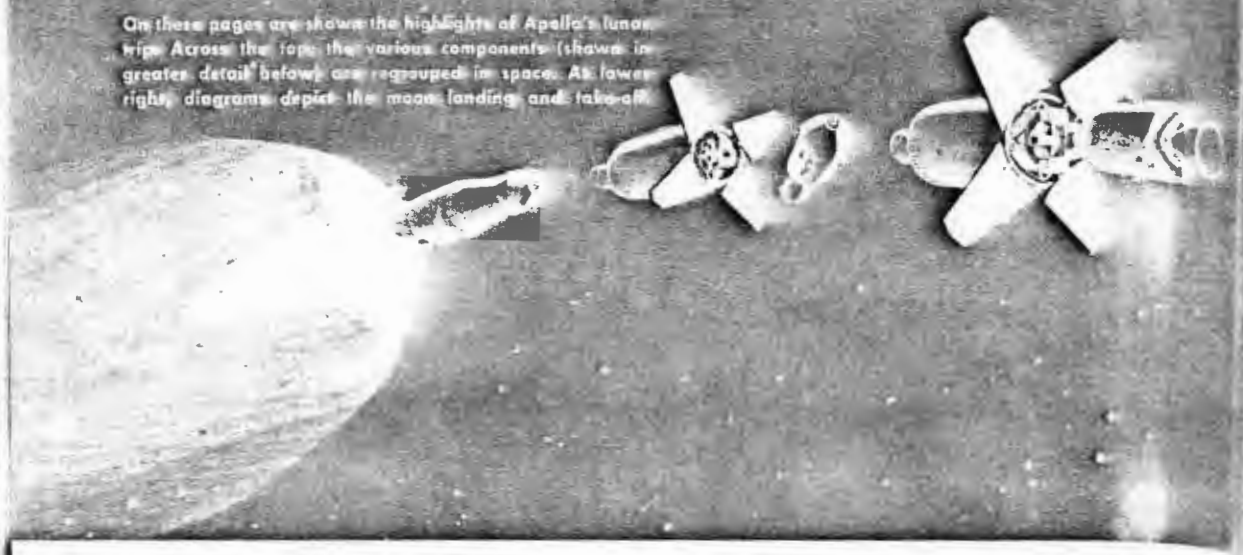
Against a backdrop of "magnificent desolation," as he described the lunar landscape, Aldrin sets up a seismic detector to measure tremors on the moon's surface. The LM stands in the background, and beside it the U.S. flag.



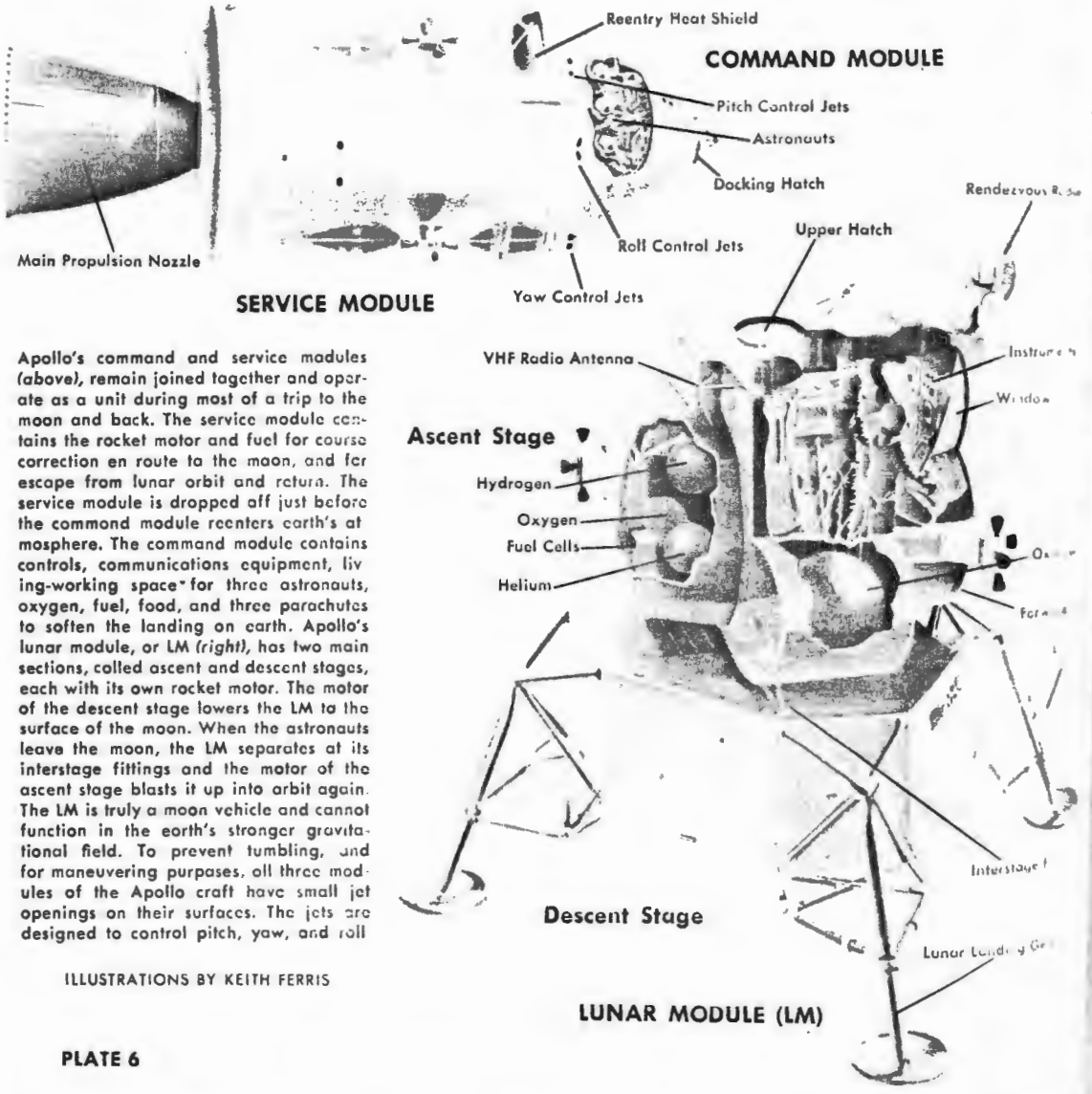
Aldrin poses for a photograph beside the metal U.S. flag. The prints made by the boots of the two astronauts in the fine, powdery surface material are clearly visible in the foreground—marks that may remain undisturbed indefinitely.

PROJECT APOLLO—TRIP TO THE MOON

On these pages are shown the highlights of Apollo's lunar trips. Across the top, the various components (shown in greater detail below) are regrouped in space. At lower right, diagrams depict the moon landing and take-off.

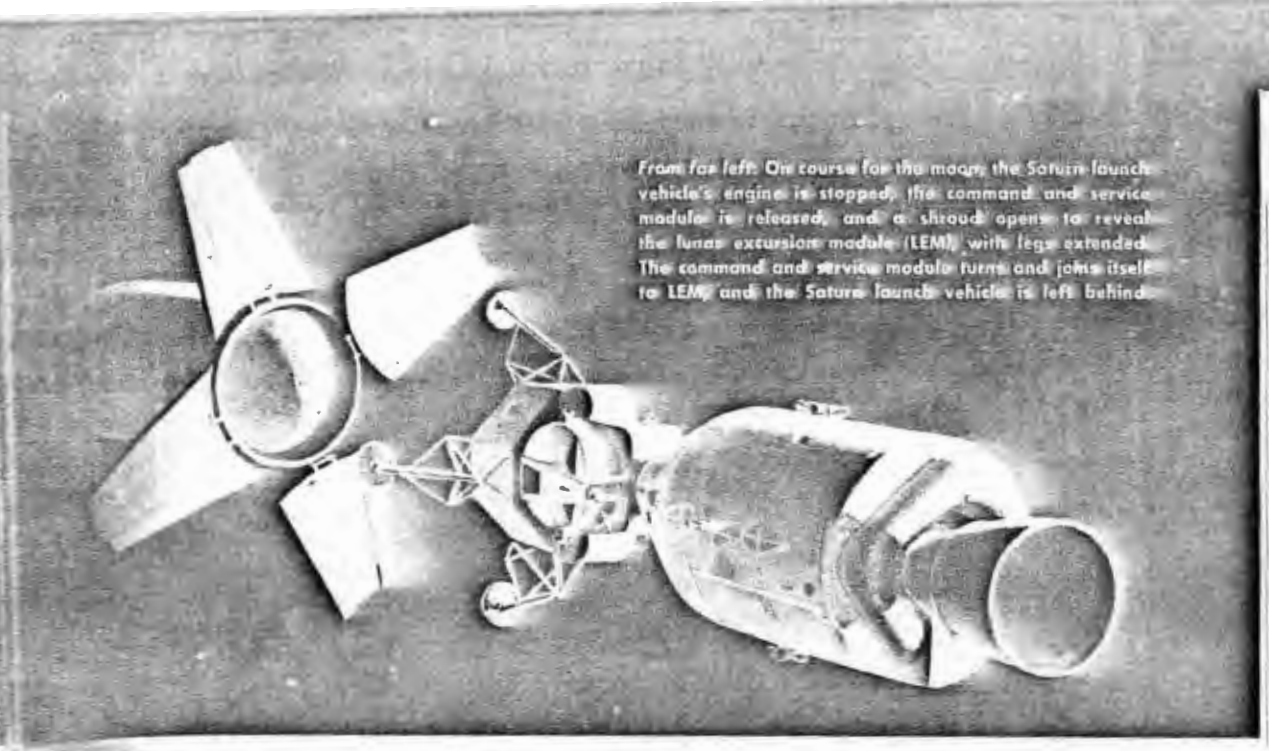


COMMAND, SERVICE, AND LUNAR MODULES



Apollo's command and service modules *(above)*, remain joined together and operate as a unit during most of a trip to the moon and back. The service module contains the rocket motor and fuel for course correction en route to the moon, and for escape from lunar orbit and return. The service module is dropped off just before the command module reenters earth's atmosphere. The command module contains controls, communications equipment, living-working space for three astronauts, oxygen, fuel, food, and three parachutes to soften the landing on earth. Apollo's lunar module, or LM *(right)*, has two main sections, called ascent and descent stages, each with its own rocket motor. The motor of the descent stage lowers the LM to the surface of the moon. When the astronauts leave the moon, the LM separates at its interstage fittings and the motor of the ascent stage blasts it up into orbit again. The LM is truly a moon vehicle and cannot function in the earth's stronger gravitational field. To prevent tumbling, and for maneuvering purposes, all three modules of the Apollo craft have small jet openings on their surfaces. The jets are designed to control pitch, yaw, and roll

ILLUSTRATIONS BY KEITH FERRIS



From far left: On course for the moon, the Saturn launch vehicle's engines is stopped, the command and service modules is released, and a shroud opens to reveal the lunar excursion module (LEM) with legs extended. The command and service module turns and joins itself to LEM, and the Saturn launch vehicle is left behind.

AT THE MOON — LANDING AND TAKE-OFF

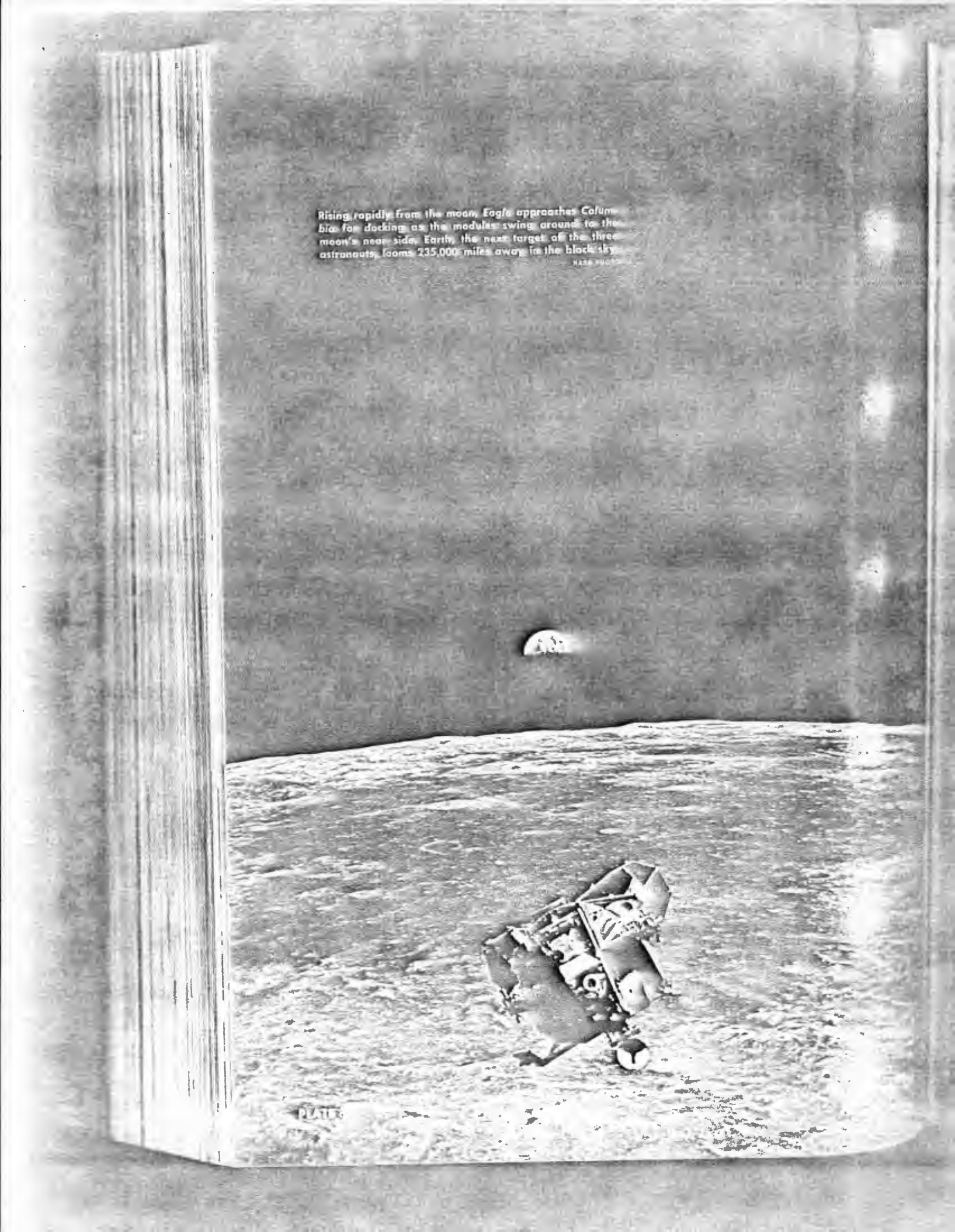




[illegible] the command, service, and lunar modules [illegible] unpowered orbit around the moon, there is a checkout of the crew and all equipment. Then [illegible] astronauts transfer from the command module [illegible] the LM and the two modules seporate, with [illegible] third astronaut remaining in lunar orbit as [illegible] LM descends toward the surface. Once the [illegible] has landed, the two astronauts go outside [illegible] craft to explore the surface, perform ex[illegible], and gather samples. At the proper [illegible] for rendezvous with the command and service [illegible], they blast off in the LM's upper stage, [illegible] the lower stage on the moon. With their [illegible] motor and attitude control jets they get [illegible] orbit, maneuver into position, and dock with [illegible] command module. The LM's upper stage then [illegible] jettisoned, and remains in lunar orbit. The [illegible] fire the rocket of the service module [illegible] a trajectory back toward earth. The [illegible] is also used to make midcourse corrections [illegible] this way, if necessary. As the spacecraft [illegible] the earth the service module is jettisoned [illegible] command module turned around so that re[illegible] into the atmosphere takes place with its [illegible] shield forward. The module then descends [illegible] ocean surface with the aid of parachutes.



PLATE 7



Rising rapidly from the moon, *Eagle* approaches *Columbia* for docking as the modules swing around to the moon's near side. Earth, the next target of the three astronauts, looms 235,000 miles away in the black sky.

NASA PHOTO

IN LUNAR ORBIT

After completing two circuits of the moon, the astronauts reignited the propulsion system to bring their craft into a roughly circular orbit, between 62 and 75 miles (100 and 121 km) above the lunar surface. Gazing down at the cratered land below, Armstrong described the first view of the area where he and Aldrin planned to touch down a few hours later. "It looks very much like the pictures but like the difference between watching a real football game and one on TV. There's no substitute for actually being here."

The orbital flight continued as on-board systems were checked out thoroughly. This completed, flight commander Armstrong and the controllers in Houston agreed that it was time for the descent maneuver to begin. The first step was to undock *Eagle* from *Columbia*. This took place while Apollo 11 was passing above the far side of the moon. Armstrong and Aldrin pressurized the tunnel between the two modules and opened the connective hatches to crawl into *Eagle*, where they made extensive readouts of all systems and subsystems before undocking. Collins remained aboard *Columbia*.

As the modules returned to the near side of the moon, Armstrong reported to Houston, "The *Eagle* has wings." The lunar module was ready, and the men were about to descend to the moon's surface.

DESCENDING TO THE MOON

Tension now rose aboard *Eagle* and *Columbia*, at mission control in Houston, and in front of television receivers in homes and public places all around the world. (It is estimated that about 500 million persons listened in as the landing took place.) *Eagle*'s descent-stage engine was fired, first at 10% throttle and then at 40%. The lunar module's orbital path became highly elliptical, with a perilune of about 50,000 feet (17,250 meters) above the surface. This was the maneuver to insert the craft into descent orbit.

When the landing approach "corridor" had been established, the engine was again fired, near the perilune point, to permit the craft to sink downward to the moon. Everything proceeded under the automatic control of the on-board computer until *Eagle* was about 7,600 feet (2,320 meters) above the surface and 26,000 feet (7,930 meters) uprange from the planned touchdown site in the Sea of Tranquility, northwest of Crater Moltke. The craft was further braked at this point, and dropped to about 500 feet (150 meters) as the crew received visual cues from the landscape and assessed the terrain below for the best place to land.

At an altitude of about 450 feet (137 meters), Armstrong and Aldrin took over the controls, having decided against an automatic landing sequence in favor of a semiautomatic procedure. Because of a program alarm that indicated the on-board computer was being overworked, the astronauts and Houston brought *Eagle* down through a verbal exchange of instrument data and visual observations. The last few moments were extremely tense ones for everyone involved, for in addition to the program alert, the lunar module's guidance and navigation system was heading the astronauts toward a very rocky crater. Armstrong had to burn the engines for another 70 seconds in order to reach a smoother landing site about 4 miles (6.4 km) away.

The final moments came as Aldrin reported, "Forward, forward, good. Forty feet. Picking up some dust.... Drifting to the right.... Contact light. OK. Engine stop!" The engine was to be stopped almost immediately after devices dangling below *Eagle*'s footpads contacted the surface and caused a light to shine on the instrument panel. Armstrong delayed for one second; then, looking down onto a sheet of lunar soil blown radially away in all directions by the rocket exhaust, he shut off the engine. "Tranquility Base here. The *Eagle* has landed," said Armstrong. The time was 4:17:41 P. M. (EDT), July 20. Men were on the moon.

ON THE LUNAR SURFACE

Up until this moment of the flight, the millions of television viewers could only listen to words being passed between Apollo 11 and ground control. Soon they would be able to watch events on the moon as well. Ironically, one man who could not

In lunar orbit, the Apollo 11 astronauts see the earth over the lunar horizon.

NASA





NASA

THE COMMAND MODULE, as seen by astronauts Armstrong and Aldrin before their descent to the surface.

see what was happening on the lunar surface until after the mission was completed was Michael Collins, who had to be content with listening to the voices of his crewmates as he circled the moon.

Originally the mission plan had scheduled about eight hours for checking out systems, eating, and resting, before the astronauts would actually leave their lunar module. However, after assuring themselves that *Eagle* was in good shape, Armstrong and Aldrin requested permission to cancel or at least postpone a 4-hour rest period. They wanted to go out on the lunar surface as soon as they could get ready. Houston agreed; it seemed unlikely that the two men would do much sleeping at this stage of their momentous journey.

Nevertheless, more than three hours were needed to get suited up for the extravehicular activities. The donning of portable life-support-system backpacks proved particularly time-consuming in the cramped quarters of *Eagle*. In their suits at last, the astronauts depressurized their cabin—which proved to be another tedious process—and opened the hatch. It was six and a half hours since the lunar module had landed.

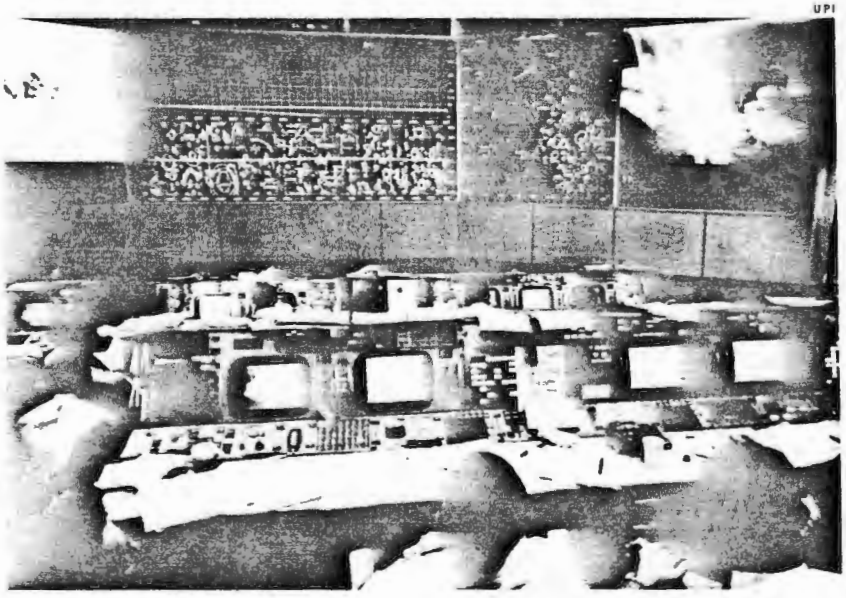
Armstrong slowly descended the 9-rung ladder leading down from the "porch" of the lunar module to the moon's surface. At the second rung he released a fold-down equipment compartment on the side of the module, releasing a television camera that would then record the first steps taken by a man on the moon. Soon the silhouetted figure of Armstrong could be seen, as he continued his descent of the ladder. When he took his first cautious step onto the lunar soil, at 10:56:20 P. M. (EDT), he paused to say the now-familiar words: "That's one small step for a man, one giant leap for mankind."

Soon Armstrong began to give verbal descriptions of the material on which he walked. "The surface appears to be very, very fine grain, like a powder. . . . I can kick it loosely with my toes. Like powdered charcoal. I can see footprints of my boots in the small, fine particles. . . . No trouble to walk around." Meanwhile Aldrin remained in the lunar module, monitoring the television camera and observing his companion's movements outside. Finally he asked, "Is it OK for me to come out?" A few minutes later he stood on the moon.

Like tourists visiting a spectacular vacation area, the astronauts took dozens of photographs exclaiming "Beautiful view!" and "Magnificent desolation!" They showed television viewers the plaque on *Eagle*'s descent stage, which read:

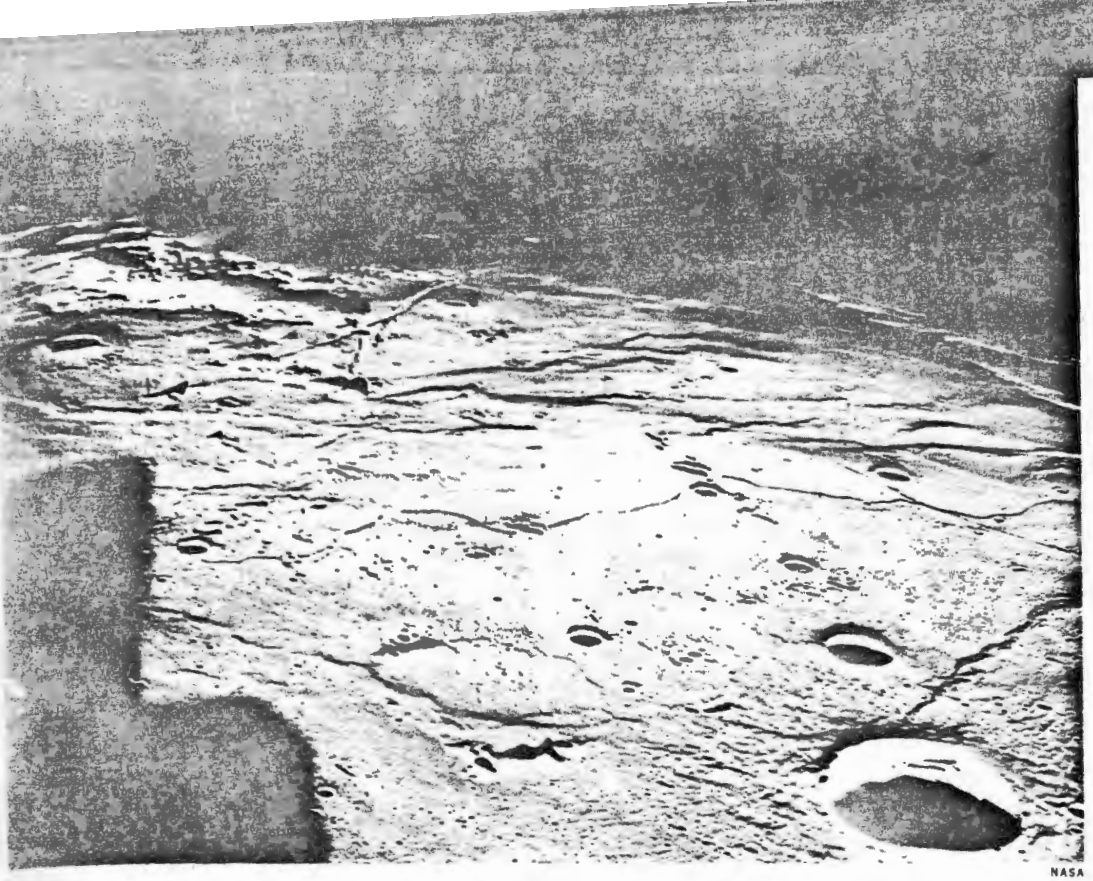
HERE MEN FROM THE PLANET EARTH
FIRST SET FOOT UPON THE MOON
JULY 1969, A. D.
WE CAME IN PEACE FOR ALL MANKIND

The plaque was signed by the astronauts and President Richard M. Nixon, who later made a telephone call from the White House, through Houston facilities. Nixon observed, "Because of what you have done, the heavens have become a part of man's



UPI

MISSION CONTROL personnel in Houston, Texas, monitor Apollo 11 as the astronauts carry out their tasks. In the tense moments of the actual landing on the moon, close cooperation between Houston workers and the crew of *Eagle* managed to avert an abort of the landing.



NASA

landing site is near the edge of dark area at top center. Part of the landing craft is silhouetted at left.

In the early minutes of their extravehicular activities Armstrong and Aldrin also erected a metallic U. S. flag near the landing craft, before returning to their busy schedule.

WORKING ON THE MOON

The surface activities involved three principal tasks. First, the astronauts checked and photographed *Eagle* from all angles, to determine if any blast or landing damage had occurred. They also studied the depressions—only 1 to 2 inches (about 2.5 to 5 cm) deep—made by *Eagle*'s footpads, to gain information on the moon's surface properties. Second, the astronauts had to familarize themselves with the environment by walking and running; their evaluations of clothing and equipment would be invaluable in making plans for later landing missions. Third, they collected as much operational and scientific information as possible during their short period of extravehicular activity.

Armstrong gathered about 45 pounds (20 kg) of rock and soil samples; the samples were placed in sealed bags that were then inserted in two aluminum boxes. The astronauts also set up three instrument systems for obtaining scientific data: a solar wind composition detector, a seismic detector, and a laser reflector from which scientists back on earth later "bounced" laser beams for a more accurate determination of the landing site and of the distance of the earth and the moon and the distance between them.

The solar wind device consisted simply of a sheet of aluminum foil deployed so that the foil would be exposed directly to the sun's rays. In effect it was a trap for the inert gas constituents of the stream of particles constantly flowing outward from the sun. (The lunar soil itself was later found to be rich in solar wind particles.) Near the end of the stay on the moon, the solar wind device was folded and placed in one of the sample containers.

The seismic detector was deployed to monitor possible "moonquakes," meteoroid impacts, free oscillations of the moon, and general signs of internal activity. The instrument was powered by a radioisotopic heater developed by the Atomic Energy Commission. Almost immediately after its deployment, the station went into operation; it has since provided scientists back on earth with much valuable data about events on the moon.

Armstrong also attempted to take two core samples of subsurface materials. He described the difficulty he encountered in this task. "I could get [the first coring device] down about the first two inches without much of a problem and then I would pound it in about as hard as I could do it. The second one took two hands on the hammer, and I was putting pretty good dents in the top of the extension rod. And it just wouldn't go much more than—I think the total depth might have been about 8 or 9 inches. But even there, it . . . didn't seem to want to stand up straight, and it would dig some sort of a hole but it wouldn't just penetrate in a way that would support it . . . If that makes any sense at all. It didn't really to me."

The astronauts also provided interesting verbal descriptions of their lunar environment. Aldrin reported "literally thousands" of craters about 1 to 2 feet (0.3 to 0.6 meter) in diameter in the area. There were also boulders of all shapes, up to 2 feet across, and some even larger. Many of them were above the ground, while others were partially or almost completely buried. The footprints left by the astronauts were about an eighth of an inch (0.3 cm) deep.

Armstrong and Aldrin found mobility was no problem, although both men described the ground as "slippery" (possibly as a result of the many tiny glass spherules later found in the samples of lunar soil). They quickly became accustomed to the low gravity, but found it best to anticipate their motions three or four steps in advance as they worked (in



NASA



ON THE MOON, Aldrin (*left*) poses beside one of *Eagle's* footpads. He and Armstrong (above) erect a metal U. S. flag to mark the Tranquility Base site

order to compensate for the reduced length of time that the foot remains on the ground during a stride on the moon).

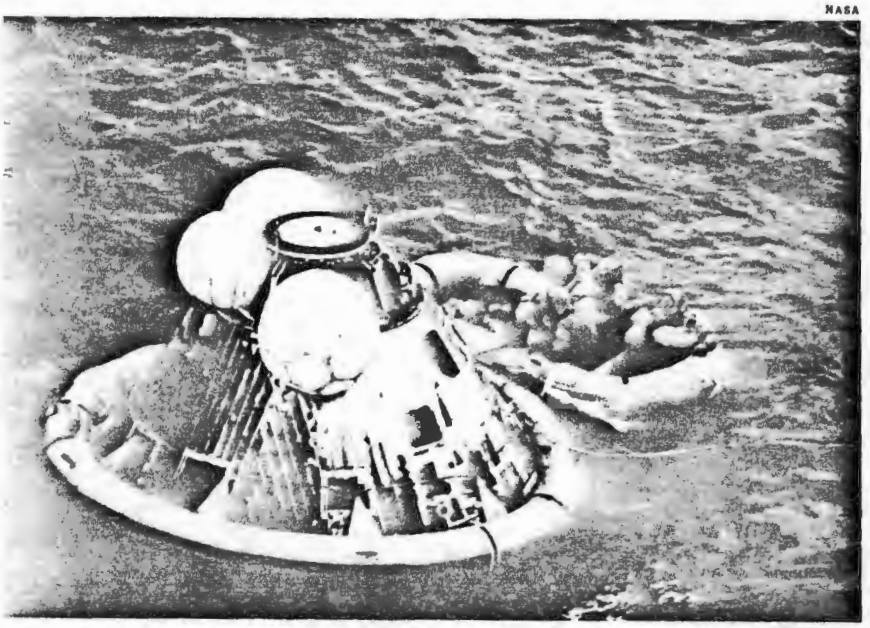
The period of extravehicular activity came to an end when the astronauts had to begin their return to the landing craft, after about two and a half hours of work on the surface. They stowed the solar wind experiment, dusted off their extravehicular mobility units, kicked their boots clean against the footpad of the lunar module, ascended the platform, swung open the hatch, disconnected the equipment conveyor, and jettisoned equipment and items no longer needed. Among the litter that *Eagle* jettisoned were cameras, the television unit, hand-tools, core bits, the environmental control system cannister and bracket, some used urine bags, and the two portable life support systems. Armstrong and Aldrin took a well-earned rest before their return the next day to *Columbia*.

In a news conference held after the astronauts had returned from their Apollo mission, Armstrong and Aldrin were asked about the time spent outside the landing craft: "Was there ever a moment on the moon when either one of you were just a little bit spellbound by what was going on?" Armstrong replied, "About two and a half hours."

RETURNING TO EARTH

Lift-off from the lunar surface took place at 1:55 P. M. (EDT) on July 21. Despite their strenuous hours of activity on the moon, the two *Eagle* crewmen actually slept very little before the time of launch. When the ascent engine was fired, the stage soared rapidly upward in what Armstrong described as a very smooth and quiet ride. Left behind were the descent stage of *Eagle*, along with the instruments and debris of man's first stay on the moon.

NASA



BACK ON EARTH the astronauts await recovery by helicopter as their life raft bobs in the Pacific Ocean. The men, dressed in isolation garments donned before they left the craft, as a precaution against possible contamination of the earth by harmful materials from the

The ascent engine had to burn for more than seven minutes in order to produce a final velocity of 4,128 miles (6,646 km) per hour. The first phase of the ascent involved a vertical rise, so that the craft might clear any possible lunar terrain features. The craft was then tipped over by 52° for insertion into lunar orbit. Thereafter, maneuvers brought the two ships within rendezvous distance of each other, and *Eagle* and *Columbia* began to dock. The ships suddenly gyrated, to the surprise of the astronauts, but docking was accomplished thereafter without mishap and only three minutes behind schedule. Aldrin and Armstrong crawled back into *Columbia* to rejoin Collins, the hatches were closed, and *Eagle* was jettisoned. *Columbia* was Apollo 11 once again, minus its lunar module.

The journey homeward was essentially a repetition of the events in the missions of Apollo 8 and Apollo 10. The three astronauts functioned much as they had on the moonward journey, making navigational checks, rolling the spacecraft, and so forth. The return trip took about 60 hours, during which the astronauts again transmitted a television program to earth. During this program each of them, in turn, reflected on the meaning of their flight. Aldrin said, "This has been far more than three men on a voyage to the moon; more, even, than the efforts of one nation. We feel that this stands as a symbol of the insatiable curiosity of all mankind to explore the unknown."

Some three and a half hours before the Apollo began to reenter the atmosphere, the astronauts turned the command module away from the sun to permit it to cool to the maximum possible extent. The service module was then separated from the command module.

At about 400,000 feet (125,000 meters) above the earth, the command module began to heat up. As the module penetrated deeper into the atmosphere, the temperature of the heat shield rose to approximately 5,000° F (2,760° C), and the astronauts experienced a deceleration force of more than six g's (six earth gravities). At an altitude of about 24,000 feet (73,000 meters) the heat shield was jettisoned, and the drogue parachutes were deployed.

Five minutes later, with the drogue parachutes severed and the main parachutes of Apollo 11 spread out above their spacecraft, the astronauts splashed down in the Pacific Ocean southwest of Hawaii, within sight of the recovery ship USS *Hornet*. The time was 12:40 P. M. (EDT), July 24. The historic mission was at an end.

The astronauts landed about 2 miles (3.2 km) away from their intended target and 13 miles (20 km) from the waiting recovery ship, the USS *Hornet*. The three men and their capsule were quickly retrieved by Navy frogmen and helicopters. Before they left their capsule, Armstrong, Aldrin, and Collins were handed three biological isolation garments with plastic-visored face masks. This was the first of several steps taken back on earth to reduce to an absolute minimum any danger of contamination from lunar materials. During their return flight, the astronauts also had followed precautionary procedures, such as vacuuming their equipment and filtering the cabin atmosphere to remove stray particles of lunar dust.

As soon as they emerged in their germ-proof garments and entered the waiting life rafts, the astronauts were thoroughly washed with a decontaminant, after which they in turn washed the frogman who performed this chore, in case he should have become contaminated in the process. The hatch of the Apollo spacecraft was also scrubbed. These safety measures had been developed by an interagency committee prior to the flight, although most scientists felt that the possibility was remote that any microorganisms of any sort existed on the moon, whether dangerous or benign.

Upon being delivered to the *Hornet*, where President Nixon waited to greet them, the astronauts were immediately transferred to a quarantine van called the Mobile Quarantine Facility. The president spoke to the three men through a window of this facility, congratulating them on their epic flight. The astronauts, still inside their quarantine van, were then taken to Hawaii and flown back to the Manned Spacecraft Center at Houston. There they and their precious cargo of lunar rocks and soil were transferred to a Lunar Receiving Laboratory, where they remained under observation for 18 more days. Having shown no sign of ill effects from having come in contact with the moon, Armstrong, Aldrin, and Collins were permitted to emerge from isolation on August 11. Now truly returned to the world of men, the astronauts had to prepare for another arduous mission: the days and weeks of strenuous parades, interviews, and acclamation that were to follow. For a while, the first men on the moon became the first citizens of earth.

WERNHER VON BRAUN, *Former Deputy Associate Administrator for Planning, NASA*
FREDERICK I. ORDWAY, III
Research Institute
University of Alabama in Huntsville

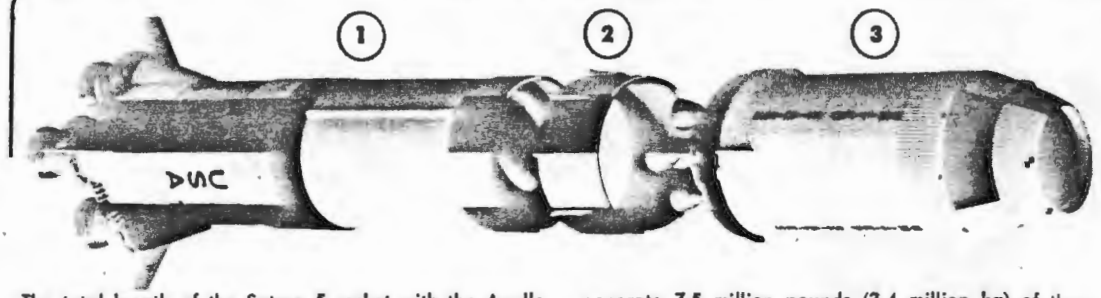
NASA



ISOLATION CHAMBER because of possible contact with harmful organisms on the moon, Apollo 11 crew is greeted by President Nixon after a successful return to the earth on July 24, 1969.

...tope vehicles...rces with-...ation. For ...developed for ...craft is specially

Many ...come se... neously, in ...gency of the ...



The total length of the Saturn 5 rocket with the Apollo spacecraft and escape system is 364 feet (111 meters). The first stage (1) is 138 feet (42 meters) long. Its weight of 4.7 million pounds (2.1 million kg), with kerosene/liquid oxygen propellant aboard, accounts for ¾ of the launch weight. The five F-1 engines together generate 7.5 million pounds (3.4 million kg) of thrust. An interstage (2) connects the first and second stage (3), which boosts the Apollo to a height of 117 miles (188 km) and a speed of 15,300 miles (24,630 km) per hour. The second stage has five J-2 engines that generate over a million pounds (450,000 kg) of thrust.

(*Continued from page 356*)
and photographs facilitate the transmission of information when it is asked for by coded signal from the earth.

Manned Flight Control. With man on board a spacecraft, the availability of his judgment and selection facilitates some of the guidance and communications activities on the craft. However, man's presence also introduces the need for additional monitoring equipment.

Generally, instructions for maneuvers of manned spacecrafts are transmitted from earth to the vehicle, and the space traveler executes the orders at the determined time. Override control may be provided, in case the space traveler is unable to perform the maneuvers because of his physical condition or because of nonoperative on-board controls. In an earth-orbit rendezvous, the data for transfer of orbit is provided from the earth and is based on tracking data of both orbiting vehicles. Once the rendezvousing spacecraft establishes radar contact with the other spacecraft, the space traveler can close on the target and eventually use direct visual observation for the final docking, or contact, maneuver.

SPACECRAFT DESIGN

The elements of design of a spacecraft are governed by its mission and operational requirements. Thus the wide panorama of different flight projects undertaken by the United States and the Soviet Union has resulted in widely varying spacecraft designs. The spacecraft's destination, the tasks that are to be performed, the duration of the space flight, the physical conditions to which the spacecraft will be exposed, and whether or not it will be manned are all basic considerations in spacecraft design.

Axiomatic in the design of a spacecraft is the continual compromise between the most desirable and the feasible, within budgetary and time-for-completion requirements. In the early years of space flight, limitations of propulsion necessitated great stress on low weight for payloads. Today, recoverable launch vehicles such as the Space Shuttle have given engineers more freedom in balancing weight against factors such as cost and reliability (long operating life). Weight remains important but is not the controlling factor it once was. In the next generation of launch vehicles, weight for most space systems will become secondary to cost and reliability.

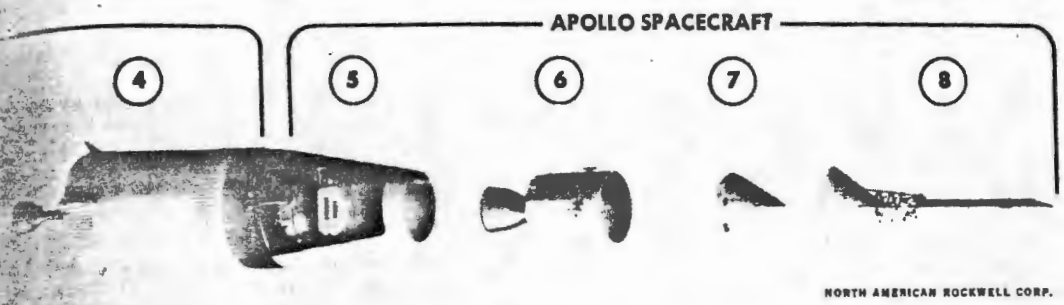
Many factors must be considered simultaneously in designing a spacecraft. The stringency of the requirements calls for a team of technical specialists, systems engineers, and administrators that work closely together. These teams, with their unique industrial, academic, and governmental backgrounds, utilize the experience of past space programs in design concepts.

Unmanned Satellites and Space Probes. Some of the earliest uses of earth satellites were to relay communications signals, monitor the weather, map the earth's natural resources, and detect nuclear explosions. Satellites now serve so many purposes it is impossible to describe the extent of their use in a short space. Each kind of satellite mission has its own requirements for onboard sensors, altitude control, attitude control, propulsion, electrical power, transmitters and receivers, guidance, and, increasingly so, provisions for landing or recovery.

Most satellites and space probes are not designed for return to earth and recovery. Therefore, they do not have to withstand the high-g loads of reentry, nor do they require heat-shielding. In orbit, in the weightless condition, the spacecraft may appear flimsy by terrestrial standards. Extensible antennas may stretch out hundreds of feet. Large panels of solar cells may unfold to absorb sunlight, converting the radiation to electric power. Storage batteries provide a ready power supply for short-term, heavy power requirements and for periods when the spacecraft may be in the earth's shadow. Nuclear power supplies can serve the same purpose.

Manned Spacecraft. In the case of a manned spacecraft, provisions must be made for the space traveler's protection and needs. These include radiation shielding and an environmental control system to provide oxygen, remove carbon dioxide from the cabin atmosphere, and regulate temperature and pressure. Food and water must also be supplied, as well as a means for collecting physical wastes. The space traveler must be provided with instrument displays, controls, warning signals, and a means of visual observation and communication. Finally, an even higher reliability called *man-rating* is called for in the design and test of manned craft.

Reentry Equipment. Recovery of earth satellites requires the use of retrorockets, or braking rockets, which apply thrust in the direction opposite to the flight path. The resultant loss in velocity of several thousand feet per second causes the spacecraft to drop toward the earth. As the vehicle enters the outer fringes of the atmosphere aerodynamic drag begins to occur, and the spacecraft arcs increasingly sharply toward the earth



NORTH AMERICAN ROCKWELL CORP.

The third stage (4) has a single J-2 engine that sends the spacecraft into final orbit. The Apollo lunar module (5) housed in an adapter for the launch and early stages of flight. It is equipped with engines for the descent to and ascent from the moon's surface. The service module (6) which carries power and other support systems for the command module (7), has an engine that provides 22,000 pounds (9,900 kg) of thrust and that can be restarted as many as 50 times. The command module is "home" for the three moon-journeying astronauts. The launch escape system and the boost cover (8) are normally jettisoned about 3 minutes 8 seconds after launch.

(The Space Shuttle has control surfaces that enable it to take a shallower, smoother path.) Heating due to friction produced by air passing over the spacecraft becomes so intense that the spacecraft reaches incandescence if it is not properly shielded. Several kinds of materials can be used for shielding.

In lunar landings, the absence of atmosphere eliminates the possibility of aerodynamic drag recovery. Accordingly, retrorockets are used in the final descent phase. Radar sensors ignite the braking rockets at the precise moment, bringing the spacecraft to a hovering condition a few feet above the lunar surface. The rocket motors then shut down, and the spacecraft drops the final few feet to the surface. Since lunar gravity is about ⅙ that of earth's gravity, the problem of impact is lessened significantly.

Automated research packages have thus far been landed on the planets Venus and Mars by means of drag devices, since both planets sustain atmospheres. The atmosphere of Venus is thick and the hidden surface of the planet is very hot, so the design problem is to develop a package that can endure the high temperatures it must encounter. The atmosphere of Mars, on the other hand, is very thin in comparison to the earth's atmosphere, while surface temperatures are not a problem; the difficulty is to obtain sufficient aerodynamic drag.

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Man in Space

Man's conquest of space has required coping not only with a hostile environment but also with the effects of space travel itself. In leaving the earth the space traveler leaves a dense, life-sustaining atmosphere and ascends through increasingly rarified air before entering the vacuum of space. During lift-off and reentry into the earth's atmosphere, his body is subjected to vibration and great forces of acceleration and deceleration. While traveling in space, his body is weightless. Also, the space traveler leaves the familiar social and physical environment of the earth and works in constant hazard, alone or in a small group, and is therefore subject to psychological stresses not encountered on earth. These and other factors must be taken into account to ensure his well-being.

Life Support System. Man is accustomed to an atmosphere that is 21% oxygen, 78% nitrogen, and 1% other gases, at a total pressure of 760 mm (29.9 inches) mercury. The earth's atmosphere is simulated for the space traveler by a support system that provides him with the necessary oxygen, and often an inert gas, at a suitable pressure. Oxygen is supplied at a pressure great enough to saturate the red blood cells in the lungs' air sacs. The red blood cells carry oxygen and distribute it throughout the body. The partial pressure of oxygen entering the lungs' air sacs varies somewhat because of the exchange of oxygen for carbon dioxide, but it is generally about 150 mm (5.9 inches) mercury. The life support system pressure will ideally be that of earth's with mixed gases, but the total pressure may be reduced to 200 mm (7.9 inches) mercury inside the cabin as the percentage of oxygen is increased.

Oxygen at partial pressures above 150 mm mercury may be toxic to the human body, and it is certainly so at partial pressures over 760 mm mercury. Increasing the oxygen pressure also increases flammability, and in pure oxygen even human skin will burn. The body's need for an inert gas such as nitrogen, which makes up 78% of the earth's atmosphere, has not been proved definitely. However, it is clear that the presence of nitrogen reduces the burning rate of materials inside the cabin.

In addition to providing oxygen at a suitable pressure, the support system must also remove water and carbon dioxide, which are products of respiration; remove contaminants; and maintain the cabin temperature against the extremes of the space environment.

Acceleration. Launching a space vehicle requires sufficient acceleration to escape earth's gravity. For orbital flight, accelerations as high as 6g, or 6 times the force of gravity experienced at the earth's surface, are required. During reentry to the earth, peaks of 10g to 13g may be reached. Man cannot withstand these forces either standing or sitting, but he can withstand them in the supine or prone position. For this reason the astronaut couch was developed for takeoff or landing, and the spacecraft is specially oriented during reentry.

The body's tolerance to acceleration depends on the magnitude of the force and its duration. The primary effect of increased g is on the circulatory system. At 5g the blood has the weight of iron, and as g increases, blood fills the lower portions of the lungs, displacing air. The exchange of oxygen for carbon dioxide is impaired by an insufficiency of ventilated lung sacs.

Vibration. The rocket motors that launch spacecraft also introduce marked vibrations. Intense vibrations between 1 and 20 hertz (cycles per second) are the most detrimental to the body. Minimal tolerance of the body is at vibrations of from 4 to 6 hertz, which is the natural frequency of the major body cavities. Tolerance times of these vibrations are short at low g levels. Prolonged subjection to such vibrations may cause tissues to be torn.

Weightlessness. Man has evolved in an environment where his body weight depends on the gravitational attraction between the mass of his body and that of the earth. On the moon, where the gravitational force is ⅙ that of the earth, a man's weight is only ⅙ of his weight on earth. On Jupiter, where the gravitational force is over 2.5 times that of the earth, a man would weigh over 2.5 times as much as he did on earth. On Mars a man would weigh just a little more than ⅓ of his weight on earth. An orbiting body experiences no gravitational force at all and is therefore weightless.

Many of the body's systems are adapted to earth's gravity. The musculoskeletal system is adapted to gravity for posture and for the power to move about and to move other objects. The circulatory system is adapted to move blood from the heart to the periphery of the system and back to the heart while the body is in an upright, supine, or prone position. Man's sense of balance and sense of movement or position are also oriented to earth's gravity. These systems may adapt over a long period of time to a new environment of weightlessness. If they do, a new "space adapted" state will exist that will put the space traveler at a considerable disadvantage when he returns to his native planet after a long stay in space.

Radiation. The space traveler has to be protected against the high-speed atomic particles of cosmic rays and solar flares, and the charged particles geomagnetically trapped in the doughnut-shaped Van Allen belt that surrounds the earth. These ionized particles are damaging to living tissues. Depending on the dose and the dose rate, there may be immediate effects ranging from nausea to death, which requires a very high dose. Doses above 100 rads cause changes in the digestive system and in the formation of blood, which may cause death. Death from these causes would occur within one month. If the dose is small or protracted, the effect will be a significant life shortening.

Low-inclination orbits—orbits at a small inclination to the equator—at 230 miles (370 km) are subject to the least radiation, while polar and synchronous orbits and planetary expeditions occasion more risk. In a low-inclination orbit the cosmic ray dose would be about 0.01 rad per day with 1.0 gram/cm^2 (0.2 ounce/inch^2) shielding. In the Van Allen belt, the dose might be 1 rad to 10 rads per hour. In a solar flare period of three to four days, the dose rate might be 100 rads for the duration.

Isolation. The problems of performing for a long time alone or in small groups are complex. Information gained by simulation of the space environment is indefinite. As one astronaut has put it, "In simulation the friendly environment is outside the simulator—in the real flight it is the hostile environment that is outside." Psychological effects of the space environment will have to be determined and procedures to select psychologically stable astronauts determined before man can undertake a journey to Mars, which may take a year.

Flight Experience. Early manned flights such as Apollo and, more importantly, long-lasting flights such as the 84-day Skylab mission completed in 1974, established a benchmark in understanding man's capacity for long flights in orbit or in deep space. The data on inflight and postflight physiological performance give strong assurance of man's ability to endure in space. No firm evidence of long-lasting physiological impairment or deterioration has been reported. The records of heart rate and blood pressure during the flights show no significant deviation from expected results or from simulation data. However, some questions concerning certain aspects of heart action and blood circulation have been raised in reports of Russian flights. These reports have also expressed concern about the possible effects of dizziness and loss of equilibrium experienced while the body is weightless. These physiological effects of space travel have not been confirmed by American flights.

During flight and especially during extravehicular activity there is evidence of physiological changes such as marked weight loss, fast heartbeat, lowered blood pressure when changing from a reclining to an erect position, and changes in the blood. The effects on the circulatory system are reversible, and the return to normal occurs within five days. There is also an apparent loss of calcium, fluid, and muscle mass. These physiological changes have been termed *deconditioning phenomena*, but more appropriately they might be termed aspects of a *space adaptive state*.

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3. History of Space Flight

The history of space flight is the story of man's age-old dreams of flight, his gradual awareness of the environment of the earth, the solar system and space, and the development of the technology required to implement travel away from the earth. For hundreds of years, individual speculators and scientists contributed to the growth of man's understanding of the universe, but the story of man's actual achievements in space does not really begin until the middle of the 20th century. Then the desire for space flight was matched at last by an understanding of the space environment, and the technology was finally at hand to build the rocket-powered launch vehicles and spacecraft that could survive that environment.

Growing Knowledge of the Universe. The ancient Babylonians, Greeks, and Egyptians studied the stars and planets and mapped their

ments in the sky. However, it was Galileo's use of the telescope on the skies in the early 17th century that added immensely to man's knowledge. Within a few weeks, Galileo had studied the mountains and valleys on the moon, concluding that it was a solid world. He also spotted four tiny specks of light revolving about Jupiter. He deduced correctly that the apparent small size of these moons differed from the earth's moon because of the great distance to Jupiter. Thus in 1610 a scale of distance of the proper order of magnitude for the solar system was established for the first time. Observations made with the telescope also confirmed the heliocentric theory of the solar system developed by Copernicus 100 years earlier. Johannes Kepler in the early 17th century brilliantly established the exact motions of the planets in elliptical orbits. Later in the same century Isaac Newton formulated his "laws of motion," placing astronomy and physics on a solid foundation. Flight in free balloons, commencing in 1783, added to man's knowledge of the atmosphere.

Early Speculations on Space Flight. Persian, Greek, Hindu, and Chinese legends include accounts of men flying to heaven on wings, emulating birds. Lucian of Samos, a Greek, wrote in 160 A. D. of flying to the moon on artificial wings. Many centuries passed, however, before it was learned that the earth's atmosphere, which is necessary for winged flight, does not extend more than one ten-thousandth of the distance to the moon.

The 17th century fictional accounts of flight to the moon by Kepler (*Somnium*) and Francis Godwin of England (*Man in the Moone*) took into account the increasing understanding of the moon. For the next two centuries, books on space flight continued to appear, although many were fantasy rather than an attempt to extrapolate man's knowledge of nature. Cyrano de Bergerac, in his mid-17th century tales of voyages to the moon and the sun, was the first to suggest rocket propulsion.

In 1865, Jules Verne's *From the Earth to the Moon* appeared and had immense popularity. Edward Everett Hale a few years later wrote *The Brick Moon*, probably the first treatment of the artificial satellite. At the turn of the century H. G. Wells' *First Man in the Moon* also had wide appeal. The balloon ascents and the relatively great engineering achievements of the Victorians led many to believe that flight to the moon might be possible. In the first decade of the 20th century man did achieve atmospheric flight in airships and heavier-than-air craft.

ROCKET PIONEERS

Three brilliant men, Tsiolkovski, Goddard, and Oberth, are recognized as space flight pioneers. All were teachers, mathematicians and physicists, and modest men. All were passionately interested in the possibility of manned flight to the moon and the planets.

Tsiolkovski. In the USSR, Konstantin Eduardovitch Tsiolkovski wrote technical treatises and science fiction to publicize his concepts. In 1898 he completed his first article on liquid propellant rocket propulsion for space flight. He understood the advantages of liquid oxygen and liquid hydrogen as ideal propellants and conceived of artificial satellites as orbiting refueling stations for interplanetary flight. He also described life-support systems for manned spacecraft, problems of effects on astronauts of high accelerations at takeoff, and the need for retrorockets for return to the braking atmosphere of the earth. Tsiolkovski received little support and recognition for several decades. Although he was increasingly recognized in the USSR by the 1930's, he was little known outside that country.

Goddard. In the United States, Robert H. Goddard experimented with solid propellants for rocket motors in college and graduate school. Early in the century he noted the potential for ion propulsion for interplanetary flight. In 1916–1917, while a professor at Clark College, he performed laboratory experiments in which he generated metallic ions in a vacuum and accelerated them by an electrostatic field.

Goddard devoted his entire life to developing rockets for upper atmospheric research, and dreamed of exploring interplanetary space. He was aided by modest grants from the Smithsonian Institution from 1916 to 1929. In 1921, Goddard switched from solid propellants to liquid oxygen and gasoline propellants. Five years later, at Auburn, Mass., he flew the world's first liquid propellant rocket a modest, but historic, 184 feet (56 meters). In 1929 he moved to Roswell, N. Mex. Supported by Daniel and Florence Guggenheim Foundation funds, and aided by a small team of machinists and technicians, he built and flew larger rockets with gyro stabilization, turbopumps, jet-exhaust and aerodynamic control vanes, and achieved supersonic flight.

Although he published only two papers (1919, 1936), he kept meticulous scientific notebooks and sent numerous reports to the Smithsonian Institution for file and record purposes. Some of these documents, which he asked to be held in archive, are concerned with exploration of the moon, lunar base site selection, and manned and unmanned exploration of Mars and Venus.

Goddard continued to improve the stability and reliability of his sounding rockets, and when World War II broke out he offered his services to the U. S. Navy. He was developing a liquid propellant (turbopump supply) jet-assist-takeoff (JATO) unit for aircraft at Annapolis, Md., when he died in 1945.

Oberth. The third great pioneer was Hermann Oberth who was born in Transylvania (now in Rumania). In 1923 he published *The Rocket Into Interplanetary Space.* It was largely a mathematical proof of the potential of rocket propulsion in multistage space launch vehicles, and attracted little attention. Oberth's work was ignored by most scientists, as were Tsiolkovski's and Goddard's. Although they did not refute the assertions nor find fault with the mathematical proofs, they considered the practicality "obviously absurd." In 1929, Oberth published *The Road to Space Travel,* a remarkable work with detailed drawings of large launch vehicles for manned spacecraft and retrorockets and parachutes for recovery. Also discussed was the utility of earth satellites for reconnaissance of the surface and signaling with mirrors since in 1929 long-distance radio transmission was still in its infancy.

Oberth was primarily a theoretician; he left to others the engineering development of rocket vehicles. Nevertheless, his writings were enormously influential in attracting interest and experimenters to rocketry. He is the only great pioneer who survived to see artificial satellites launched in 1957.

(Continued on page 371)

SPACE ACHIEVEMENTS

PROLOGUE

2d Century Ptolemy of Alexandria formed concept of motions of sun and planets about earth; Lucian of Samosata wrote of flight to the moon.

13th Century Reports of rockets used by Chinese at Kai-fung-fu (1232) and by Tatars in Europe (1241).

16th Century Nicholas Copernicus described motions of planets about sun; Tycho Brahe described elliptical orbit of Mars and comet about sun.

17th Century Sir Isaac Newton formulated laws of motion; Johannes Kepler described elliptical orbits of planets and wrote *Somnium*; Francis Godwin wrote *Man in the Moone*.

19th Century Jules Verne wrote *From the Earth to the Moon*; K. E. Tsiolkovski derived fundamental principles of space flight; Edward Everett Hale wrote *The Brick Moon*.

1900 H. G. Wells published *The First Man in the Moon*.

1903 Wright brothers made the first airplane flight.

1919 Robert H. Goddard published *A Method of Reaching Extreme Altitudes*.

1923 Hermann Oberth published *The Rocket Into Planetary Space*.

1926 Robert H. Goddard fired first liquid propellant rocket.

1927 German space flight society Verein für Raumschiffahrt was formed.

1929 Hermann Oberth published *Roads to Space Travel*.

1930 American Interplanetary Society was formed. Later named American Rocket Society, it became the American Institute of Aeronautics and Astronautics on a merger with the Institute of Aerospace Sciences.

1931 German racket society developed a 100-pound thrust liquid propellant rocket.

1932 Tsander and others (USSR) developed a 110-pound thrust rocket.

1934 Wernher von Braun tested a 660-pound thrust A-3 racket (Germany).

1935 Robert H. Goddard's gyrostabilized rocket reached an altitude of 7,500 feet.

1942 First A-4 (V-2) rocket successfully test-fired to 53 miles (Germany).

1945 WAC Corporal rocket (U. S. Army, JPL/CIT) fired to 43.5 miles.

1946 U. S. Air Force "World-Circling to Spaceship" study began.

1947 First of captured German V-2's fired as sounding rockets in New Mexico.

1949 First launching of U. S. Navy Viking saunding rocket; Bumper-WAC two-staged rocket reached 244 miles altitude.

1950 First Congress of International Astronautical Federation met (Paris).

1954 Project Orbiter was organized (U. S. Army and Office of Naval Research).

1955 U. S. announced Vanguard satellite program for International Geophysical Year (IGY).

SPACE AGE

1957

Oct. 4 USSR launched first earth satellite, Sputnik 1; air density, temperature, cosmic radiation, meteoroid data; 184 pounds.

Nov. 3 Sputnik 2, USSR satellite, carried dog Laika; biomedical, cosmic radiation, solar X-ray, ultraviolet data; 1,121 pounds.

1958

Jan. 31 First U. S. satellite, Explorer I; cosmic radiation, meteoroid data; discovered Van Allen belt; 18 pounds. Burned up in atmosphere March 31, 1970.

Mar. 17 Vanguard 1, U. S. satellite, solar powered transmitters, highly elliptical orbit; 8 pounds.

May 15 Sputnik 3, USSR satellite, orbiting geophysical laboratory; 2,926 pounds.

Dec. 6 Pioneer 3, U. S. moon probe; failed to reach moon; discovered outer region of Van Allen belt; 13 pounds.

Dec. 18 Score, U. S. satellite; transmitted voice communication; 8,750 pounds.

1959

Aug. 7 Explorer 6, U. S. satellite; radiation, magnetic field, micrometeorite data; took first TV photo of earth cloud cover; 143 pounds.

Sept. 12 Luna 2, USSR moon probe, first probe to impact moon; magnetic field, cosmic and solar radiation, micrometeoroid, gas composition data; 860 pounds.

Oct. 4 Luna 3, USSR moon probe; took first photographs of far side of moon; 960 pounds.

1960

Mar. 11 Pioneer 5, U. S. solar satellite, telemetered and transmitted information from 22.5 million miles, mopped interplanetary magnetic field and interaction of earth's magnetic field with solar wind, 95 pounds.

April 1 TIROS 1, U. S. satellite, first of series of highly successful meteorological satellites; transmitted 22,952 photographs of earth cloud cover over 2½ months; 263 pounds.

Aug. 10 Discoverer 13, U. S. satellite; ejected 300-pound reentry capsule recovered from Pacific Ocean; first object recovered from space; 1,700 pounds.

Aug. 12 Echo 1, U. S. satellite; inflation of 100-foot diameter balloon in orbit, producing first passive communication satellite; reflected communications between U. S. and U. K.; 166 pounds.

1961

April 12 Vostok 1, USSR manned satellite; Yuri A. Gagarin, first man in orbit; 1 orbit in altitudes ranging from 112 to 203 miles; flight time 1 hour, 48 minutes; spacecraft weight at liftoff, 10,417 pounds.

May 5 Mercury Freedom 7, U. S. suborbital flight of Alan B. Shepard, Jr.; flight time 15 minutes; spacecraft weight at liftoff, 4,040 pounds.

June 29 Transit 4A, Injun 1, Solrad 3, U. S. satellites; first triple launch and nuclear power supply in space

July 21 Mercury Liberty Bell 7, U. S. manned suborbital flight by Virgil Grissom; flight time 16 minutes.

Aug. 6 Vostok 2, USSR manned satellite; Gherman Titov 17 orbits; flight time 25 hours, 11 minutes.

1962

Feb. 20 Mercury Friendship 7, U. S. satellite; John H. Glenn, Jr.; first U. S. manned orbital flight; 3 orbits flight time 4 hours, 56 minutes.

Mar. 7 OSO 1, U. S. solar satellite; carried 13 experiments, observed salar flares; 458 pounds.

May 24 Mercury Aurara 7; U. S. manned satellite flight by M. Scott Carpenter; 3 orbits; flight time 4 hours 56 minutes.

July 10 Telstar 1, U. S. satellite; first commercially financed comsat; TV, voice, photograph transmissions between U. S., U. K., France; 170 pounds.

Aug. 11 Vostak 3, USSR manned satellite; Andrian Nikolayev; 64 orbits; flight time 94 hours, 22 minutes

Aug. 12 Vostok 4, USSR manned satellite; Pavel Popovich, 48 orbits; flight time 70 hours, 57 minutes.

Aug. 26 Mariner 2, U. S. Venus probe launched; 447 pounds; see Dec. 14.

Sept. 28 Alouette 1, Canadian satellite; U. S. booster ionospheric measurements; 320 pounds.

Oct. 3 Mercury Sigma 7, U. S. manned satellite; Walter Schirra; 6 orbits; flight time 9 hours, 13 minutes

Dec. 14 Mariner 2, U. S. Venus probe, passed within 22,000 miles of Venus; surface temperature measurements, communications to 54 million miles

1963

May 15 Mercury Faith 7, U. S. manned satellite; L. Gordon Cooper; 22 orbits; flight time 34 hrs., 20 min

June 14 Vostok 5, USSR manned satellite; Valeri Bykovsky; 81 orbits; flight time 119 hours, 6 minutes

June 16 Vostok 6, USSR satellite; Valentina V. Tereshkova, first woman in space; 48 orbits; flight time 70 hours, 50 minutes.

July 26 Syncom 2, U. S. satellite; first synchronous communications satellite; 22,300 miles; 86 pounds

Oct. 16 Vela 1, Vela 2, U. S. satellites; nuclear explosion detection; 297 pounds.

1964

Jan. 30 Electron 1, Electron 2, USSR satellites; first USSR dual launch, earth radiation belt measurements

July 28 Ranger 7, U. S. moon probe; photographed surface of moon before impact; 806 pounds.

Sept. 4 OGO 1, U. S. satellite; orbiting geophysical observatory; 1,073 pounds.

Oct. 12 Voskhod 1, USSR satellite; first three-man spacecraft; Konstantin Feoktistov, Vladimir Komarov, and Boris Yegorov; 16 orbits; flight time 24 hours minutes; spacecraft weight at liftoff, 11,731 pounds

1965

Feb. 16 Pegasus 1, U. S. satellite; two 14 x 48 foot panels meteoroid detection; 23,000 pounds.

A Selected Chronology of Milestones in Space Exploration

Mar. 23 Gemini 3, U. S. manned satellite; Virgil Grissom; 3 orbits; flight time 4 hours, 53 minutes; spacecraft weight at liftoff, 7,100 pounds.

April 6 Early Bird, U. S. satellite; first commercial communications satellite in synchronous orbit; 85 pounds.

April 23 Molniya 1A, USSR satellite; first USSR communications satellite.

June 3 Gemini 4, U. S. satellite; James McDivitt and Edward White; first U. S. walk in space by White; 66 orbits; flight time 17 hours, 59 minutes.

July 14 Mariner 4, U. S. Mars probe, launched Nov. 28, 1964; passed within 6,200 miles of Mars; transmitted 20 photographs of surface; 575 pounds.

Aug. 21 Gemini 5, U. S. manned satellite; L. Gordon Cooper and Charles Conrad, Jr.; 128 orbits; flight time 190 hours, 56 minutes.

Dec. 4 Gemini 7, U. S. manned satellite; Frank Borman and James Lovell; 220 orbits; flight time 330 hours, 35 minutes; spacecraft weight at liftoff, 8,069 pounds.

Dec. 15 Gemini 6, U. S. manned satellite; Walter Schirra and Thomas Stafford; first rendezvous in space, moved within a foot of Gemini 7; 17 orbits; flight time 25 hours, 51 minutes.

1966

Jan. 31 Luna 9, USSR lunar probe; first soft landing on moon; transmitted photographs of surface; 220 pounds.

Mar. 16 Gemini 8, U. S. manned satellite; Neil Armstrong and David Scott; first docking in space with previously launched target vehicle; 6.5 orbits; flight time 10 hours, 18 minutes.

Mar. 31 Luna 10, USSR lunar probe; first probe to achieve lunar orbit; 540 pounds.

May 30 Surveyor 1, U. S. lunar probe; first U. S. probe to soft-land; transmitted 11,150 photographs of surface; 596 pounds.

June 3 Gemini 9, U. S. manned satellite; Thomas Stafford and Eugene Cernan; 47 orbits; flight time 72 hours, 21 minutes.

July 18 Gemini 10, U. S. manned satellite; John Young and Michael Collins; rendezvous with target vehicle; first retrieval of space object (test package on target vehicle) by Collins during EVA; 46 orbits in altitudes ranging from 100 to 475 miles; flight time 70 hours, 47 minutes.

Aug. 10 Lunar Orbiter 1, U. S. lunar satellite; first U. S. lunar orbiting probe; photographs of surface for Apollo landing site; 853 pounds.

Sept. 12 Gemini 11, U. S. manned satellite; Charles Conrad, Jr., and Richard Gordon; 47 orbits in altitudes ranging from 100 to 850 miles; flight time 71 hours, 17 minutes; spacecraft weight at liftoff, 8,374 pounds.

Nov. 11 Gemini 12, U. S. manned satellite; James Lovell and Edwin Aldrin; 63 orbits; flight time 94 hours, 33 minutes.

1967

April 23 Soyuz 1, USSR satellite; Vladimir Komarov; Komarov killed on April 24 in recovery phase; 18 orbits; flight time 26 hours, 35 minutes; spacecraft weight at liftoff, about 15,000 pounds.

Sept. 7 Biosatellite 2, U. S. satellite; biological experiments; recovered after 30 orbits; 1,120 pounds.

Oct. 18 Venera 4, USSR Venus probe, launched June 12; ejected 884-pound capsule that returned data on the planet's atmosphere.

Oct. 19 Mariner 5, U. S. Venus probe, launched June 14; passed within 25,000 miles of Venus; 540 pounds.

Oct. 30 Cosmos 186, Cosmos 188, USSR satellites; first automatic rendezvous and docking.

Nov. 7 Surveyor 6, U. S. moon probe; first lateral movement on surface; 617 pounds.

1968

Jan. 7 Surveyor 7, U. S. moon probe; claw sampling and analysis of soil; 21,000 photographs; 2,293 pounds.

April 22 Space rescue treaty signed by 43 nations, including U. S., U. K., and USSR.

May 17 ESRO 2B, international satellite; U. S. booster; 11-nation joint program; 164 pounds.

Sept. 4 Explorer 38, U. S. satellite; first of series of radio astronomy satellites; 610 pounds.

Sept. 15 Zond 5, USSR moon probe; first unmanned round-trip flight to moon; recovered Sept. 22.

Oct. 11 Apollo 7, U. S. manned lunar spacecraft; Walter Schirra, Donn Eisele, and Walter Cunningham; orbital test at altitudes ranging from 141 to 176 miles; 163 orbits; flight time 260 hours, 8 minutes; spacecraft weight at liftoff, 45,989 pounds.

Oct. 26 Soyuz 3, USSR manned satellite; Georgi Beregovoy; 64 orbits; flight time 94 hours, 51 minutes.

Dec. 21 Apalla 8, U. S. manned lunar mission; Frank Borman, James A. Lovell, Jr., and William A. Anders; first manned lunar orbitol flight; 10 orbits of moon; flight time 147 hours.

1969

Jan. 14 Soyuz 4, USSR manned satellite; Vladimir Shatalov; docked with Soyuz 5; 48 orbits; flight time 71 hours, 14 minutes.

Jan. 15 Soyuz 5, USSR manned satellite; Boris Volynov, Aleksei Yeliseyev, and Yevgeny Khrunov; transfer of two men to Soyuz 4; 49 orbits; flight time 72 hours, 46 minutes.

Mar. 3 Apollo 9, U. S. manned satellite; James McDivitt, David Scott, and Russell Schweickart; lunar module test; 151 orbits in altitudes ranging from 118 to 327 miles; flight time 241 hours, 1 minute.

May 16 Venera 5, USSR Venus probe, launched Jan. 5; returned 53 minutes of data as it parachuted through planet's atmosphere; 2,491 pounds.

May 17 Venera 6, USSR Venus probe, launched Jan. 10; same mission and size as Venera 5, but did not accomplish mission.

May 18 Apollo 10, U. S. manned lunar mission; Thomas Stafford, Eugene Cernan, and John Young; test of lunar excursion module in lunar orbit; 31 revalutions of moon; flight time 192 hours, 3 minutes.

July 16 Apollo 11, U. S. lunar landing mission; Neil A. Armstrong, Edwin E. Aldrin, Jr., and Michael Collins; Armstrong and Aldrin first men to walk on surface of moon, July 20; men collected 55 pounds of rock samples; flight time 195 hours, 18 minutes; spacecraft weight at liftoff, 95,000 pounds.

July 31 Mariner 6, U. S. Mars probe; launched Feb. 24; passed Mars at 2,200 miles; together with Mariner 7, transmitted about 200 pictures; 910 pounds.

Aug. 5 Mariner 7, U. S. Mars probe, launched Mar. 27; passed above Mars south pole; 910 pounds.

Oct. 11 Soyuz 6, USSR manned satellite; Georgi Shonin and Volery Kubasov; 79 orbits; flight time 118 hours, 42 minutes.

Oct. 12 Soyuz 7, USSR monned satellite; Anatoly Filipchenko, Vladislov Volkov, and Victor Garbatko; 79 orbits; flight time 118 hours, 41 minutes.

Oct. 13 Soyuz 8, USSR manned satellite; Vladimir Shatalov and Aleksei Yeliseyev; Soyuz 6, 7, and 8 not linked together in flight; 79 orbits; flight time 118 hours, 41 minutes.

Nov. 14 Apollo 12, U. S. lunar landing mission; Charles Conrad, Jr., Alan L. Bean, and Richard F. Gordon, Jr.; Conrad and Bean landed on moon Nov. 19 and visited Surveyor 3 probe; they become third and fourth men to walk on surface of moon; flight time 244 hours, 36 minutes.

1970

Feb. 11 Rising Sun 1, first Japanese satellite launched by Japanese rocket; 50 pounds.

April 11 Apollo 13, U. S. lunar landing mission; James Lovell, Jr., Fred Haise, Jr., and John Swigert, Jr.; mission aborted when oxygen tank exploded; safe return on April 17; flight time 142 hours, 55 minutes; recovery site, 600 miles south of Pago Pogo.

April 24 Communist China launched first satellite; transmitted music, telemetric signals; 381 pounds.

June 1 Soyuz 9, USSR manned satellite; Andrian Nikolayev and Vitali Sevastianov; 287 orbits; flight time 424 hours, 59 minutes.

Sept. 12 Luna 16, USSR lunar probe; landed on moon on Sept. 20, in Sea of Fertility; drilled 14 inches into surface and collected rock samples; capsule returned samples to earth on Sept. 24.

Nov. 10 Luna 17, USSR lunar probe; landed Nov. 17 in Sea of Rains; released Lunokhod 1, first robot vehicle on moon; powered by solar cells.

Dec. 15 Venera 7, USSR Venus probe, launched Aug. 17; ejected capsule landed on surface, transmitted data for first time from another planet; 2,570 pounds.

1971

Jan. 31 Apollo 14, U. S. lunar landing mission; Alan Shepard, Edgar Mitchell, and Stuart Roosa; Shepard and Mitchell landed on moon Feb. 5; flight time 216 hours, 2 minutes.

Apr. 19 Solyut 1, USSR orbiting laboratory; launched for use by Soyuz flights; about 36,000 pounds.

April 23 Soyuz 10, USSR manned satellite; Vladimir Shatalov, Aleksei Yeliseyev, and Nikolai Rukavishnikov; briefly linked to Salyut; 33 orbits; flight time 47 hours, 46 minutes.

SPACE ACHIEVEMENTS (cont.)

June 6 Soyuz 11 launched with Georgi Dobrovolski, Vladislav Volkav, and Viktar Patsayev; cosmonauts spent 23 days in Salyut; all three killed following cabin decompression during reentry.

July 26 Apollo 15 lunar landing mission launched with David Scott, James Irwin, and Alfred Worden; Scott and Irwin land on moon July 30 and make three exploratory trips; return to earth on August 7.

Nov. 13 Mariner 9, U. S. Mars probe (launched May 30), orbits Mars, photographing the planet.

Nov. 27 Mars 2, USSR Mars probe (launched May 19), orbits Mars; lands insignia capsule on planet.

1972

Feb. 14 Luna 20, USSR lunar probe, launched; lands on moon Feb. 21 in Sea of Fertility; returns rock samples to earth on Feb. 25.

March 2 Pioneer 10 spacecraft launched; passes within 81,000 miles of Jupiter on Dec. 3, 1973; continues out of solar system with plaque bearing symbolic message for other civilizations (first man-made object to leave our solar system).

March 27 Venera 8, USSR spacecraft, launched; reaches Venus on July 22 and lands instruments on planet.

April 16 Apollo 16 lunar landing mission launched with John Young, Charles Duke, and Thomas Mattingly; Young and Duke land on moon April 20 and make three lunar excursions; return to earth on April 27.

Dec. 7 Apollo 17 lunar landing mission launched with Eugene Cernan, Ronald Evans, and Harrison Schmitt; Cernan and Schmitt land on moon on Dec. 11 and make three lunar excursions; return on Dec. 19.

1973

Jan. 8 Luna 21, USSR lunar probe, launched; lands on moon on Jan. 16 and unloads Lunakhod 2 vehicle, which travels 23 miles in next four months.

April 5 Pioneer 11 spacecraft launched; flies within 26,600 miles of Jupiter on Dec. 2, 1974.

May 14 Skylab 1, first U. S. space station, placed in earth orbit at altitude of 271 miles.

May 25 Apollo spacecraft launched with Charles Conrad, Jr., Joseph Kerwin, and Paul Weitz; docks with Skylab space station; crew live 28 days in Skylab, return to earth on June 22.

July 28 Apollo spacecraft launched with Alan Bean, Jack Lousma, and Owen Harriott; docks with Skylab space station; crew remain in space 59.5 days, return to earth on Sept. 25.

Nov. 3 Mariner 10, U. S. Venus and Mercury probe, launched; flies past Venus on Feb. 5, 1974, at distance of about 3,600 miles; continues flight to Mercury, coming within 460 miles of that planet and sending back close-up pictures, March 29; makes second flyby of Mercury, Sept. 21.

Nov. 16 Apollo spacecraft launched with Gerald Carr, Edward Gibson, and William Pogue; in orbit 84 days in Skylab space station; return to earth Feb. 8, 1974.

1975

May 25 USSR spacecraft Soyuz 18 launched with Pyotr Klimuk and Vitaly Sevastianav; docks with Salyut 4 space station; crew spend 63 days aboard Salyut, return to earth on July 26.

July 15 Joint Apollo-Soyuz earth orbital mission (first cooperative international space flight) begins as Thomas Stafford, Vance Brand, and Donald Slayton are launched in Apollo from Cape Canaveral, Fla., and Aleksei Leonov and Valery Kubasov are launched in Soyuz 19 from Kazakhstan, USSR; two spacecraft dock on July 17; Soyuz returns to earth on July 21, and Apollo on July 24.

Oct. 22 and 25 Soviet spacecraft Venera 9 and 10 land instruments on Venus and return first photographs of the planet's surface, along with scientific data.

1976

July 6 USSR spacecraft Soyuz 21 launched with Boris Volynov and Vitaly Zholobov; docks with Salyut 5 space station; returns Aug. 24, after 50 days in orbit.

July 20 and Sept. 3 U.S. spacecraft Viking 1 and 2 softland on Mars. They send back first photographs from the planet's surface and much scientific data.

Aug. 22 USSR spacecraft Luna 24 returns from moon with sample of lunar soil; lands in USSR.

1977

Feb. 18 U. S. space shuttle makes first test flight atop Boeing 747 jet at Edwards, Calif.

Dec. 10 Cosmonauts Yuri Romanenko and Georgi Grechko launched in Soyuz 26; in orbit 96 days in space station Salyut 6; return on March 16, 1978.

1978

June 15 Cosmonauts Vladimir Kovalenok and Aleksandr Ivanchenkov launched in Soyuz 29; in orbit 139 days in space station Salyut 6; return on Nov. 2.

Dec. 4 and 9 U. S. Pioneer Venus 1 and 2 spacecraft go into orbit around planet Venus, returning data.

Dec. 21 and 25 USSR Venera 11 and 12 spacecraft land probes on surface of planet Venus.

1979

Feb. 25 Cosmonauts Vladimir Lyakhov and Valeri Ryumin launched in Sayuz 32; in orbit 175 days in Salyut 6; return on Aug. 19.

March 5 U. S. spacecraft Voyager 1 makes closest approach to Jupiter, photographing planet and its moons.

June 27 U. S. weather and earth-resources satellite NOAA 6 orbited for National Oceanic and Atmospheric Administration. It and TIROS-N (orbited Oct. 13, 1978) provide round-the-clock scanning of land, sea, and atmosphere and monitor solar radiation levels above the atmosphere.

July 9 U. S. spacecraft Voyager 2 passes planet Jupiter, returning photographs and scientific data.

July 11 U. S. space station Skylab 1 falls in Australia.

Sept. 1 U. S. space probe Pioneer II makes closest approach to Saturn, returning photos and data.

Dec. 24 Successful first launch of European Space Agency's rocket Ariane, designed to compete with NASA's Space Shuttle for putting payloads into earth orbit.

1980

Aug. 7 Viking 1 orbiter circling Mars is shut off by radio command after collecting data for four years.

Oct. 11 Cosmonauts Leonid Popov and Valeri Ryumin return to earth from space station Salyut 6, setting new space endurance record of 185 days.

Nov. 12 U. S. spacecraft Voyager 1 makes closest approach to Saturn, returning photographs and scientific data. Among discoveries are new rings, irregular ring structures, and new moons.

Dec. 10 Cosmonauts Leonid Kizim, Oleg Makarov, and Gennadi Strekalov return to earth on Soyuz T-3, after two-week mission to repair and refurbish Salyut-6 space station.

1981

April 12–14 U.S. Space Shuttle *Columbia* makes first orbital test flight with astronauts John Young and Robert Crippen.

June 19 European Space Agency's Ariane rocket places into orbit ESA weather satellite Meteostat 2 and Apple, a geosynchronous communications satellite for India.

July 25 U. S. spacecraft Pioneer 10 passes a point 25 astronomical units (AU) from sun. (One AU is distance of earth from sun, about 92.6 million miles or 150 million km.) Found that at that distance the solar wind does not slow down and that the interplanetary magnetic field is twisted into knots.

Aug. 25 Voyager 2 flies by Saturn; transmits back highly detailed pictures of Saturn's rings and satellites; continued on toward Uranus (1986) and Neptune (1989).

1982

March 1 and 5 Soviet Venera 13 and 14 spacecraft land on Venus; they return photographs and analyses of soil.

July 2 Soviet-French team of cosmonauts Vladimir Dzhanibekov and Aleksandr Ivanchenkov and French Col. Jean-Loup Chrétien land after a week in Salyut space station.

Nov. 16 U.S. Space Shuttle *Columbia* completes its 5th flight, landing at Edwards AFB, Calif., after 5 days in orbit.

Dec. 10 Cosmonauts Anatali Berezovoi and Valentin Lebedev return to earth after record 211 days in space.

1983

April 4–9 U.S. Space Shuttle *Challenger* makes first flight of 5 days in orbit with astronauts Paul Weitz, Karol Bobko, Story Musgrave, and Donald Peterson.

June 13 Pioneer 10 spacecraft crosses the orbit of Neptune, the most distant planet, becoming the first man-made object to go beyond the solar system.

(Continued from page 367)

Kibaltchich and Ganswindt. Nikolai I. Kibaltchich, a Russian revolutionary and explosives expert, was arrested in the assassination of Czar Alexander II in 1881. While in prison awaiting execution, he sketched and wrote of the concept of a flying manned platform propelled by a series of successive explosions with controllable thrust. Kibaltchich's writings remained unseen in prison files until after the Bolshevik revolution in 1917. Hermann Ganswindt, a German inventor, conceived about 1890 of a spaceship propelled similarly to Kibaltchich's by a series of downward-firing cartridges. Ganswindt published little but gave lectures and wrote to newspapers while he battled lawsuits. His space concepts were little publicized for several decades. One of Goddard's earliest patents (1914), as well as his early rocket motor experimentation, was based upon the firing of successive explosive charges. This was not unrelated to Kibaltchich's and Ganswindt's concepts, but there is no doubt that Goddard's ideas were independently conceived.

ROCKET DEVELOPMENT

There was minimal use of rocket propulsion during World War I. Dreams of space flight, however, were awakened in the late 1920's by amateur rocket societies in many countries. Rocket enthusiasts with more or less technical skill formed these societies in the USSR, Germany, Austria, United States, Britain, and, sporadically, elsewhere.

In Germany, the success and promise of rocket motor development led to take-over of research by the German Army in 1933. In the USSR the work of Friedrich A. Tsander and M. K. Tikhomravov culminated in successful launchings of liquid rockets. In Britain, the British Interplanetary Society was prohibited from testing rockets, but the group produced fundamental papers on spacecraft and launch vehicle design, studied space flight problems and even designed some instrumentation. The American Interplanetary Society (later the American Rocket Society) commenced their experimental program based upon that of the German society. In 1938 the first well-designed regeneratively cooled motor was tested successfully. This rocket engine motor laid the foundation of the first U. S. rocket engine industrial enterprise a few years later.

Peenemünde Team. World War II closed down the activities of rocket societies in all nations, with the exception of Germany, and instead major efforts were placed on conventional, if improved, armament. In Germany, Wernher von Braun, an enthusiastic young member of the German Spaceflight Society, was installed as technical leader of a small rocket activity of the German Army, headed by Capt. Walter Dornberger. Dornberger, a talented officer, was convinced of the future of rocket power. During the next decade this team grew into a major installation at Peenemünde on the north German coast, employing tens of thousands of people. The group produced the A-4 (more popularly known as V-2), which was an immense step forward in rocket technology. At the war's end the German engineering achievement was recognized by von Braun as a stepping-stone to reaching the velocities necessary to achieve space flight.

After the war, von Braun and about 100 members of his Peenemünde team went to the United States and became citizens. Working first at White Sands Proving Grounds in New Mexico, they launched V-2's carrying scientific instruments to altitudes of over 100 miles (160 km). The high-altitude sounding rockets Viking and Aerobee, which were developed in the United States, continued to be tested at White Sands while von Braun and his team moved to the Army's Redstone Arsenal at Huntsville, Ala. There they developed the Redstone ballistic missile, an updated version of the V-2. A version of the Redstone was used to launch the first U. S. satellite, Explorer I. Later under the aegis of NASA at its newly established Marshall Space Flight Center in Huntsville, the von Braun team designed and developed the Saturn series of launch vehicles for the Apollo moon program.

Other German rocket scientists and engineers, along with rockets and the V-2 manufacturing and testing equipment, were captured by the Russians. By 1952 the American rocket engineer George P. Sutton, working from unclassified information, could deduce rapid Soviet progress in development of "high-thrust large rockets for long-range missiles or satellite vehicles."

Later Rocket Societies. By 1954 the earlier rocket and space flight societies had been reorganized in most countries, augmented by guided missile engineers. The International Astronautical Federation had been formed by these societies in 1950, and annual congresses were being held in Europe. The American Rocket Society (ARS) had established its Space Flight Committee to consider ways of achieving space flight.

It is interesting to note that whereas prewar society members were interested in the dream of space flight, postwar membership, comprising young scientists and rocket engineers, was singularly lacking in interest in achieving space flight. Abetting the desire to remain "respectable," a major industrial member of the ARS even threatened to withdraw support if certain of the enthusiasts did not reduce public emphasis on the subject. Many rocket engineers, struggling with day-to-day problems, agreed. Nevertheless, von Braun and others authored a series in a major popular magazine, laying out a program for achieving space flight—first with an instrumented satellite, then manned flight in orbit, followed by moon and Mars missions. The technology of space flight was at hand, and the problems and unknowns were outlined or postulated. Those imbued with the excitement of realizing space flight in their time schemed and considered how an initial program could be justified.

SPACE FLIGHT ACHIEVEMENTS

The opportunity for achievements presented itself in the International Geophysical Year. The IGY was a program for international cooperation among meteorologists, geophysicists, and other scientists in obtaining scientific data on a world-wide basis from July 1957 through December 1958. The concept of an instrumented, artificial earth satellite was accepted as a desirable part of the IGY program by the international convening group of scientists.

Russia's Space First. In July 1955 the United States established an earth satellite program, selecting Vanguard rather than the Army's Jupiter C rocket. Vanguard was an all-new, 3-stage launch vehicle design capable of placing a 21.5-pound (9.7-kg) instrumented satellite in orbit. Thus commenced the chain of seriocomic events

culminating in the Russian launch of the first artificial satellite, Sputnik, on Oct. 4, 1957. This demonstration of Soviet space power caught the world by surprise as Sputnik's "beep-beep" signal was tracked around the world. Many high-level U. S. officials and scientists first tried to downgrade the event, but the public nevertheless responded in shock and concern.

The USSR next launched the dog Laika into orbit in Sputnik 2 on Nov. 3, 1957, to obtain biomedical data. Sputnik 1 weighed 184 pounds (83 kg), and Sputnik 2 weighed 1,121 pounds (504 kg). When the first attempt to orbit the 8-pound (3.6-kg) Vanguard satellite failed disastrously on December 6, worldwide press reaction was instantaneous: the fact that the USSR led the West in space was equated to mean Russian scientific and technical superiority.

The real explanation was that the USSR had made use of their large, military rocket development. The Soviets had developed a much larger intercontinental ballistic missile (ICBM) capable of carrying a nuclear fission warhead. The United States, having successfully developed the smaller, more powerful fusion warhead, could achieve ICBM capability with a much smaller launch vehicle. Thus the United States had a more efficient ICBM arsenal, but the USSR had a much greater space launch capability.

Early Efforts. It should be added that immediately after World War II some considerations had been given to the feasibility of launching an earth satellite, but that the U. S. Department of Defense rejected the idea as having neither scientific nor military value. By mid-1954, however, von Braun and his team had a plan for launching a minimum weight satellite. It was based on a special test vehicle required for the Army's Jupiter, an intermediate range ballistic missile (IRBM) under development. That is, the 1,500-mile (2,400-km) range of Jupiter required a high-performance launch vehicle for reentry tests. The special booster was an elongated Redstone rocket with three upper stages of clustered solid rockets. Essentially the same launch vehicle, designated Jupiter C, could meet the Jupiter reentry test needs and also have satellite launch capability. Thus a satellite launch vehicle was available as a by-product of the Army's ballistic missile development program. By the fall of 1954 a quasi-approved program, Project Orbiter, was under way, supported by the Army and the Office of Naval Research.

Project Orbiter was not regarded as being as important as the Navy's 3-stage vehicle, Vanguard, which had the advantage—so it seemed to the deliberating scientists—of having no military "taint." The Vanguard program was underfunded and plagued with administrative and technical problems. Yet when the Naval Research Laboratory stated that by July 1958 perhaps only one success out of six launchings might result, no one worried about the propaganda effect of a successful Soviet launching. And no one conceived that the USSR would launch such a *large* satellite. Not until March 17, 1958, was a Vanguard satellite—not the first U. S. satellite— successfully launched. It performed perfectly in its orbit for some years.

A year of frenzied U. S. effort commenced in 1958, with Congressional investigations in Washington attempting to find scapegoats for the U. S. space lag and to counter the Soviet achievements in space. It was brought out that if Department of Defense approval had been given, Jupiter C could have launched a satellite a year before Sputnik. Five days after Sputnik 2 was launched, the Army was given the go-ahead to use a Jupiter C as a launch vehicle as a backup program for Vanguard. On Jan. 31, 1958, the first U. S. satellite, Explorer I, was boosted into orbit by Jupiter C. Instrumentation was developed by California Institute of Technology's Jet Propulsion Laboratory and James Van Allen of the University of Iowa. An unusually high radiation count recorded and transmitted by Explorer I was noted. In March 1958, by the use of a tape recorder, Explorer III provided data that mapped the inner area of a doughnut-shaped zone of radiation surrounding the earth. In December 1958 Pioneer III discovered the outer area of the radiation; at the time it was thought to be a separate region, but this was later found not to be true. The radiation belt, now called Van Allen belt, was considered the most significant major scientific discovery resulting from the IGY.

The earlier Pioneer I and Pioneer II had been lunar probe attempts using a launch vehicle based upon the Thor IRBM. Pioneer III was launched by a Juno booster. None of these Pioneer probes succeeded in reaching the moon. However, important new data were obtained from the attempts. Meanwhile, the Thor IRBM and Atlas ICBM were tested.

In the midst of these U. S. deliberations about the Soviet lead, the USSR orbited Sputnik 3 on May 15, 1958. It weighed more than a ton. As an orbiting geophysical laboratory containing many experiments, it operated successfully for two years before orbital decay caused it to reenter the earth's atmosphere and burn up.

NASA. Clearly the United States needed a national space program and an organization to manage it. The technical centers of the National Advisory Committee for Aeronautics (NACA) began to pour out plans for manned space flights from earth orbit to the moon. The Eisenhower administration and the Congress felt a clear need to create a legislative base for a U. S. space program. On July 29, 1958, the National Aeronautics and Space Act (amended in 1978) was signed into law, creating a civilian agency to explore and exploit space—the National Aeronautics and Space Administration (NASA), based on the NACA. NASA had overall responsibility for space programs for other than military needs. Dedicated to the exploration of space by unmanned and manned spacecraft and dissemination of the knowledge gained, NASA was given a broad charter that included encouragement of international cooperation. The remainder of the Vanguard program and its personnel were transferred from the Navy to NASA. The von Braun team at Huntsville became part of NASA, and the Jet Propulsion Laboratory went under exclusive contract to NASA.

The year 1958 was drawing to a close when an Atlas ICBM was placed in orbit, carrying a tape recording of a Christmas message of President Eisenhower. It was transmitted on signal, becoming the first voice telemetered from space. At the year's end a rapidly escalating space race was under way both by NASA and in such military programs as reconnaissance and nuclear explosion detection satellites, using Air Force IRBM's and ICBM's and a Navy submarine-launched Polaris IRBM. Nevertheless, the space advantage clearly was with the USSR

would be three or four years before equal capability of the two nations could be argued successfully. Space programs from 1959 are discussed in the following section.

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4. Unmanned Space Flights

Space programs range from those that aim at acquiring information in the space relatively close to the earth to those with exploration of the planets and interplanetary space as a goal. Several types of space probes, or unmanned space vehicles, have been designed, and others are being planned for these missions.

TERRESTRIAL SPACE PROBES

Terrestrial probes, or earth satellites, are designed to fly at heights of hundreds of thousands of miles above the earth. They may carry a variety of instruments to explore the terrestrial region of space, which extends to roughly 150,000 miles (240,000 km). The instruments measure the interaction of the earth, its atmosphere, and its magnetic and gravitational fields with interplanetary space, solar and cosmic radiations, and the interplanetary magnetic field. Some probes carry biological material to study the effect of space conditions on its processes. Experimental packages range from tens to hundreds of pounds. Some probes are recoverable and others are not, but most contain radio telemetering equipment enabling data gathered in space to be transmitted to earth during flight. Typically, terrestrial space probes are launched by small carrier vehicles. See also SATELLITES, ARTIFICIAL.

MOON EXPLORATION

A variety of probes has been developed to explore the moon, ranging from fly-by spacecraft to impact vehicles, circumlunar vehicles, orbiters, and soft landers. The first successful lunar probe was the USSR's Luna 1, or Mechta, launched on a fly-by trajectory in January 1959. Weighing nearly 800 pounds (360 kg), it consisted of two joined hemispheres.

Between the summer of 1958 and December 1958, the United States made four attempts to approach the moon with Pioneer-type spacecraft, two of which traveled less than a third of the required distance. Three attempts to place orbiters around the moon also failed. The United States followed Luna 1 in March 1959 with its Pioneer 4 fly-by, and in September the Russians responded by becoming the first to place an object on the moon when they struck the lunar surface with their Luna 2. A month later the Russians launched the first circumlunar probe, Luna 3, which took the first photographs of the far side of the moon. From 1962 through 1965 the Americans launched a series of Ranger spacecrafts to the moon in vain attempts to take close-up photographs of the lunar surface. Finally, between March 1964 and July 1965, Rangers 7, 8, and 9 took thousands of photographs.

First Soft Landings. In the early 1960's the Russians proceeded with a program to soft-land a spacecraft on the moon. However, their Lunas 5, 6, 7, and 8 either missed the moon entirely or were destroyed by impact on its surface. Finally, on Feb. 3, 1966, they successfully soft-landed Luna 9. The spacecraft televised and transmitted photographs of the surface across 250,000 miles (400,000 km) of space, giving man a close-up look at the surface's structures. Objects only a few inches in size showed up. The experiment demonstrated that the bearing strength of the lunar ground was sufficient to hold a large spacecraft and that the craft was not destined to sink into layers of dust, as some astronomers had predicted.

The United States succeeded next in making a soft landing on the moon. After 63 hours and 36 minutes of flight following its launch by an Atlas-Centaur carrier, Surveyor 1 set down on June 2, 1966, just 9 miles (14 km) off target in the Oceanus Procellarum. During three lunar day-night cycles, or about six earth weeks, over 11,000 high-resolution, close-up photographs of the moon were taken and transmitted back to earth. Particles as small as 1/50th of an inch (.05 cm) in diameter could be detected. Thousands of commands to the spacecraft were sent from earth over the deep space communication network during the course of Surveyor's active lifetime.

The craft was not expected to survive its second two-week-long night on the moon, but it did show brief signs of life in October and again in November, and finally, on January 6, 1967. Signal strength was low during these brief "awakenings," and no additional pictures could be taken.

Moon-Orbit Missions. On April 3, 1966, the Soviets' Luna 10 became the first probe to successfully orbit the moon. The first successful U. S. Lunar Orbiter entered into orbit around the moon on Aug. 14, 1966. It had been launched on August 10 by an Atlas Agena D carrier, which put the spacecraft first into a half-hour orbit around the earth and then into the translunar trajectory. When the spacecraft neared the moon, the control engine was fired for some 10 minutes to lower velocity and put the craft into orbit. Apolune (the point in its orbit furthest from the moon) was nearly 1,150 miles (1,850 km), and perilune (the point in its orbit nearest the moon) was slightly less than 120 miles (190 km). On its 26th orbit of the moon, the first pictures were taken, developed, and stored. Electronic scanning and transmission to earth commenced on August 18. Later, Lunar Orbiter 1's perilune was lowered to 36 miles (58 km) to enable close-up photos to be taken. The last photo was made on August 29, and two months later the spacecraft was deliberately impacted onto the moon to prevent the possibility of its radio signals disturbing communications between earth and Lunar Orbiter 2, whose launching was imminent.

The Lunar Orbiter program was designed to photograph possible sites for the Apollo landing missions and to enlarge man's knowledge of the far and near sides of the moon. Moreover, earth-based analysis of the motions of the spacecraft helped determine the precise shape of the moon and any gravitational anomalies it might contain. It was confirmed that the moon is slightly pear-shaped, bulging about ¼ of a mile (.4 km) at its north pole.

While Lunar Orbiter 1 was sending photographs of the moon back to earth, the Soviets launched Luna 11 on Aug. 24, 1966. The probe reached its target on the 28th. It traveled within 100 miles (160 km) of the moon at perilune—about twice as close as Luna 10—and reached out to nearly 750 miles (1,200 km) at apolune. Luna 12 followed on October 22, achieving lunar orbit. With a perilune of slightly over 60 miles (97 km) and an apolune of 1,081 miles (1,739 km) it sent back a series of photographs of the surface below, presumably including prime target landing areas for later manned space vehicles.

On Nov. 6, 1966, 850-pound (386-kg) Lunar Orbiter 2 headed for the moon, and on the 10th was successfully put into a 122 to 1,163 mile (195 to 1,860 km) lunar orbit. On November 15, perilune was lowered to about 30 miles (50 km), and photography commenced on the 18th. Excellent pictures were returned of the surface of the moon, particularly of potential Apollo landing sites.

Lunar Orbiter 3, boosted by its Atlas Agena D carrier from Cape Kennedy on Feb. 5, 1967, entered moon orbit as planned and soon began sending photographs. The spacecraft entered into a temporary orbit of approximately 135 miles (217 km) perilune and 1,115 miles (1,794 km) apolune and then transferred to 34 and 1,145 miles (55 and 1,842 km) respectively. The primary mission of the 850-pound (386-kg) probe was to photograph possible landing sites for Apollo astronauts, particularly the prime site in eastern Mare Tranquillitatis. It drew great attention by photographing the Surveyor 1 spacecraft that landed on the moon in early June 1966, some 35 miles (58 km) from the crater Flamsteed in Oceanus Procellarum.

Lunar Orbiter 4, unlike its predecessors, went into a near polar orbit and sent back its first picture of the south polar region on May 11, 1967. The spacecraft was launched by an Atlas Agena D a week earlier. Problems with the optical system—moisture condensation on the lens protection windows and sunlight leakage—were solved by remote command.

The final vehicle in the series, Lunar Orbiter 5, was launched on Aug. 1, 1967, and after nearly 90 hours and 255,000 miles (410,000 km) of flight, it entered into orbit. Its missions were to continue detailed photography of more than 40 preselected sites on the near side of the moon and to cover the heretofore unphotographed regions along the western equator on the far side. The spacecraft took its photographs from various orbits around the moon. As a by-product of its lunar mission, it took a picture of the nearly full earth showing much of Africa, Europe, and Asia.

One spacecraft not so closely tied to the Apollo program was Explorer 35, launched on July 10, 1967, and sent 12 days later into a highly elliptical orbit around the moon. The instrumentation aboard indicated that the moon has been volcanically active in geologically recent times, that there are extensive lava fields only slightly disturbed by meteoritic impacts, and that the lunar magnetic field—if it exists at all—is no stronger than the weak interplanetary magnetic field. No evidence at all was found of trapped radiation belts similar to the Van Allen belt surrounding the earth. The craft was also known as a lunar-anchored interplanetary monitoring platform, or IMP.

In April 1968, the Soviets placed their Luna 14 into moon orbit with an apolune-perilune of 540 and 100 miles (870 and 160 km). It was instrumented to study the relationship between the masses of the earth and the moon, the lunar gravitational field, the interaction of the solar wind and the moon, and the characteristics of the motion of the moon in its orbit around the earth. In October 1971 another probe in this Soviet series, Luna 19, entered an orbit 79 to 84 miles (127–135 km) above the moon in order to photograph and map the surface.

Examining the Moon's Surface. The USSR launched its Luna 13 on Dec. 21, 1966. Luna 13 followed a familiar translunar trajectory and reached the moon on Christmas Eve. The spacecraft landed near the crater Seleucus in Oceanus Procellarum. It soon began transmitting photographs of the lunar surface, which were shown in Moscow on Christmas Day. In addition to camera equipment, the spacecraft carried a gamma radiation measuring device and a rod that was poked into the ground to determine the soil's bearing strength. Russian scientists reported that the mechanical properties of the moon's surface under the spacecraft were similar to those common for ground on earth, though the lunar surface density was much lower. Other instruments measured dispersed radiation from a gamma source and recorded cosmic corpuscular radiation reaching the lunar surface.

Although Surveyor 2 failed to make a soft lunar landing on Sept. 20, 1966, the program continued optimistically during 1967 with firings that alternated with Orbiter launchings. The first of several Surveyor lunar probes launched during the year, Surveyor 3 touched down in Oceanus Procellarum on April 20 following takeoff from Cape Kennedy three days earlier aboard an Atlas Centaur. It was a few miles off target and about 380 miles (610 km) east of Surveyor 1. Surveyor 3 sent back its lunar surface photographs according to plan. In addition it sent invaluable data obtained by a digging and scraping mechanism that was used to determine the mechanical properties of the lunar soil. The sampler confirmed that the moon could bear the weight of an Apollo manned spaceship. Initial analysis showed that the soil resembled a hard-packed wet sand and that the strength increased with depth. In a related experiment, sampler claws lifted a piece of lunar soil a couple of feet above the surface and then dropped it. It crumbled like dirt. By the time Surveyor 3 completed its first lunar day, it had taken over 3,000 photographs and made ready for the two-week lunar night when temperatures drop to about −260° F (−160° C).

A few minutes before Surveyor 4, launched on July 14, was to touch down on the moon in Sinus Medii, all communications were lost. However Surveyor 5, launched on September 8, began sending close-up photographs of the lunar surface on the 11th. It also carried an experimental package that made chemical tests by alpha ray bombardment. Preliminary analyses revealed that the lunar surface material is much like terrestrial rock. The experiment specifically indicated the existence of basalt, which is a dark, dense, fine-grained igneous rock. Silicon was especially noted as a constituent of the soil beneath the spacecraft. Surveyor 5 survived a lunar night and commenced operations again on October 13.

Surveyor 6 had a more difficult mission because it had to land in rough terrain in Sinus Medii, a plain just south of the equator. In addi-

tion to taking thousands of photographs, the 650-pound (295-kg) lander made measurements with an on-board soil analyzer. On November 17 it was commanded to make a "hop" on the moon's surface. Its 6½-second flight took it about 10 feet (3 meters) high to a landing 8 feet (2.4 meters) away. The maneuver provided new data on the lunar surface bearing strength. Plans for a longer flight were cancelled because the propellant supply was insufficient.

With the successful conclusion of the Surveyor 6 operation, scientists were fully satisfied that the surface in the mare regions of the lunar equatorial zone was suitable for the forthcoming manned Apollo landings. The Surveyor program had thus completed its investigations for Apollo, with the result that the remaining spacecraft in the series could be used for purely scientific research.

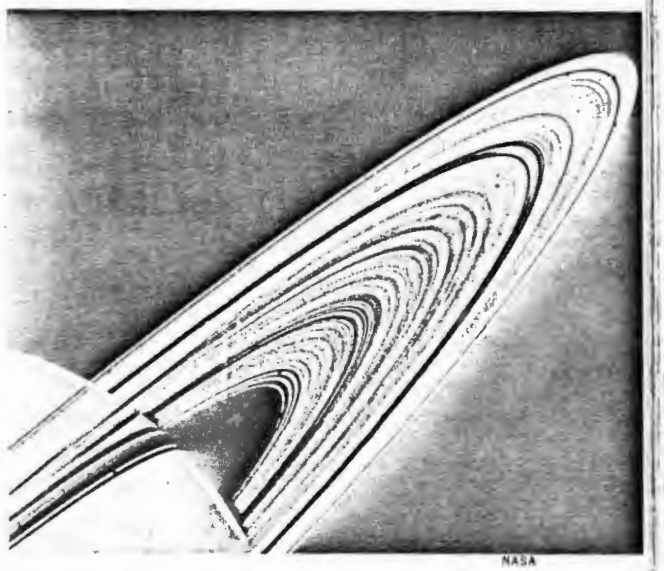
The site selected for Surveyor 7 was the highland area around the crater Tycho, nearly 41° south latitude and between 11° and 12° west longitude. Launched by an Atlas Centaur on Jan. 7, 1968, Surveyor 7 reached the Tycho landing site on the evening of January 9. Devices were aboard the probe to dig into the lunar surface and analyze the scooped-out materials. Mirrors made of beryllium were attached to the frame to provide expanded television coverage of the ground beneath, and magnets were attached to the landing pads to determine whether magnetic particles were present in the soil. Surveyor 7 also carried temperature sensors, strain gauges, and accelerometers to furnish data on spacecraft performance and response to commands. In addition, the probe transmitted thousands of surface photographs to ground stations on earth. With the successful conclusion of Surveyor 7's work, the U. S. unmanned lunar exploration program came to at least a temporary end.

On Nov. 10, 1970, the Soviet Union launched the 17th in its Luna series of probes. Luna 17 landed on the Sea of Rains on November 17 and unfolded a ramp down which an automated vehicle called Lunokhod 1 ("Moon Rover 1") soon came rolling. Carrying television cameras, an X-ray spectrometer, a probe, and other instruments, it ran on eight solar-powered wheels and sent back data until Oct. 4, 1971.

Other Luna spacecraft followed, some of them failures. On Jan. 16, 1973, Luna 21 landed on the edge of the Sea of Serenity and released a self-propelled vehicle, Lunokhod 2, equipped with various scientific instruments, including a soil tester, a laser reflector for measuring earth-to-moon distances, and television cameras. During its four-month lifetime, the surface rover transmitted 80,000 pictures of the lunar surface, and traveled some 23 miles (37 km).

Round Trips to the Moon. On Sept. 15, 1968, the Soviet Union launched Zond 5 on a trajectory that sent the probe arching behind the moon and back to earth, where it parachuted to a landing in the Indian Ocean on September 21. It was recovered the following day. The probe became the first spacecraft to make the round trip. Zonds 6, 7, and 8 made similar journeys on Nov. 10–17, 1968, Aug. 8–14, 1969, and Oct. 20–27, 1970, respectively.

The Soviet Union's Luna 16, launched on Sept. 12, 1970, became the first unmanned spacecraft to land on the moon and then return safely to earth. The probe set down in the Sea of Fertility just south of the moon's equator on September 20, after orbiting the moon for several days. Luna 16 transmitted pictures of its landing site, and its robot electric drill dug 14 inches (35 cm) into the surface, retrieving rock samples. A capsule that had formed part of the original spacecraft returned these samples to earth on September 24, where they were recovered for study by Russian scientists.



NASA

The beautiful rings of Saturn, in computer-assembled composite photograph taken by Voyager 1 on Nov. 6, 1980.

Luna 20 landed in an upland area bordering the Sea of Fertility on Feb. 21, 1972. It drilled out rock samples and returned them in a capsule that landed in Kazakhstan on February 25.

Luna 24 reached the moon on Aug. 18, 1976, scooped up some lunar soil from the Sea of Crises, and landed in western Siberia on August 22.

PLANETARY FLIGHTS

Although the race to land men on the moon dominated space exploration in the 1960's, U.S. unmanned Mariner spacecraft swept by Venus and Mars in 1962 and 1964, respectively, and made extensive reconnaissance of Mars in 1969 and 1971. Throughout the 1970's, U. S. unmanned planetary vehicles dominated space exploration, also making sweeps by Venus, Mercury, Jupiter, and Saturn. Two U. S. Viking spacecraft landed on Mars in 1976 and systematically analyzed the materials and surroundings of the landing sites. The Voyager 1 spacecraft, launched on Sept. 5, 1977, gave a history-making close-up view of Jupiter on March 5, 1979, and then delivered a stunning portrait of Saturn and its satellites in December 1980.

The Soviet Union launched many rockets toward Mars and Venus over the two decades, with some success in exploring Venus, but all the truly successful explorations of the planets were performed by U. S. spacecraft.

Venus. The inner planet Venus was the target of the world's first planetary probe, Venera 1. Launched by the USSR on Feb. 12, 1961, it bypassed its objective by 62,000 miles (100,000 km). The first American attempt at Venus failed in July 1962, but Mariner 2, fired on August 27,

went right on course and reached the vicinity of the inner planet in mid-December. Flying by the shrouded world at a distance of less than 22,000 miles (35,000 km), it conducted many measurements. Among other findings, it was revealed that Venus is very hot, with a surface temperature of over 700° F (370° C).

This successful probe was, for nearly five years, the only American attempt to unravel at close range the many mysteries surrounding Venus. The USSR launched Veneras 2 and 3, on Nov. 12 and 16, 1965. The first bypassed the planet on Feb. 27, 1966, at a distance of only 15,000 miles (25,000 km). The second, Venera 3, was followed by instruments until it entered the atmosphere of Venus on March 1—becoming the first man-made object actually to reach another planet. Both spacecraft conducted valuable experiments during their long interplanetary flights. However, breakdowns in communications prevented transmission of information from the planet.

The United States and the Soviet Union took advantage of the June 1967 launch opportunity. The Soviet Venera 4, launched on June 12, was followed in two days by the U. S. Mariner 5. Both were successfully placed in sun-centered orbits that took them into Venusian space in mid-October 1967. The Soviet probe weighed nearly 2,500 pounds (1,100 kg), the American only 540 pounds (240 kg). Both were instrumented to conduct interplanetary measurements en route to Venus and to investigate the planetary atmosphere on arrival.

Venera 4 separated into two spacecraft as it approached Venus. One penetrated the Venusian atmosphere. The other acted as a relay station, while continuing to orbit the sun. The lander portion of Venera 4, 844 pounds (380 kg) and 40 inches (1 meter) in diameter, parachuted slowly through the atmosphere on Oct. 18, 1967, relaying data back to the earth for 1 hour and 38 minutes after entry. The entire communications sequence was monitored by the Royal Radio Astronomy Laboratory at Jodrell Bank, England. The event was hailed as the first soft landing on another planet, but in 1969 it was conceded that the capsule probably had been crushed by extreme atmospheric pressures long before reaching the surface of Venus.

Preliminary analysis of data from the experiment indicated that the atmosphere of Venus is 15 to 22 times denser than that of earth, that the planet has no significant magnetic field, that carbon dioxide is by far the major atmospheric constituent, that water vapor may only amount to 0.1% and that temperatures rise to more than 540° F (280° C). Pressure at the surface was estimated to be 20 atmospheres, or 20 times earth's atmospheric pressure at sea level, but later probes raised both pressure and temperature estimates significantly.

Mariner 5 passed by Venus on Oct. 19, 1967. It detected a slight magnetic field. Measurements suggested that the atmosphere contains 69% to 87% carbon dioxide, and Venus appeared to be surrounded by a corona of magnetic hydrogen.

In 1969 the Soviet Union's Venera 5 and 6 spacecraft reached Venus on May 16 and 17, respectively. Both returned data for about an hour before presumably being crushed in the Venusian atmosphere.

On Dec. 15, 1970, the Soviet Union's Venera 7 probe reached the vicinity of Venus and ejected a capsule that descended to the planet's surface. It continued to transmit data for 23 minutes after making contact, marking the first time that information was received from the surface of another major planet of the solar system. The capsule reported an atmospheric pressure 90 times that at sea level on earth, and recorded a temperature of 887° F (475° C).

In 1972, Venera 8 reached the vicinity of Venus on July 22 and released a descent package that landed on the surface and transmitted data for about 50 minutes. A photometer indicated that sunlight penetrated the dense cloud cover, while other instruments found that the soil contained 4% potassium and trace amounts of uranium and thorium.

Soviet spacecraft Venera 9 and 10 reached Venus in October 1975. Venera 9 landed an instrument package on the planet on October 22, and Venera 10 also landed one on October 25. The two Soviet Venera spacecraft returned photographs of the terrain around the base of the capsules (the first ever taken of the planet's surface) showing sharp-edged rocks scattered over the landscape. Instruments reported the light to be about like that at midday under overcast skies on earth. Very low wind velocities were recorded, and the chemical content and density of the soil resembled that of basalt. See also VENUS.

In December 1978, two U. S. probes (Pioneer Venus 1 and 2) and two Soviet probes (Venera 11 and 12) reached Venus. Pioneer Venus 1 (subsequently called Pioneer Venus Orbiter) began orbiting the planet, returning radar mapping and other data on December 4. Pioneer Venus 2 entered the atmosphere of Venus on December 9 and sent out four scientific probes. The two Venera craft landed on December 21 and 25.

Soviet spacecraft Venera 13 and 14 landed on Venus in March 1982 and returned photographs and soil analyses. Venera 15 and 16, with surface-mapping radar, orbited Venus in October 1983.

Mars. On Nov. 1, 1962, the USSR launched Mars 1 into an earth-Mars transfer trajectory. Radio communications with the probe remained good at about 7 million miles (11 million km), but later its orientation system malfunctioned.

On November 5, during the November 1964 opportunity, America's Mariner 3 was launched, but the failure of the solar cell panels to deploy caused loss of communications. On November 28, however, Mariner 4 started on its long journey, and became the first of a series of successful Mars probes. It took the probe 7½ months to travel a path of 325 million miles (523 million km) before reaching the planet on July 14, 1965, when it flew past at a distance of 6,118 miles (9,844 km). Cameras on the Mariner 4 took over 20 photographs, revealing for the first time that Mars has a cratered surface not unlike that of the earth's moon.

Mariners 6 and 7 were launched on Feb. 24 and March 27, 1969, respectively. Mariner 6 flew nearly 242 million miles (390 million km), passing Mars on July 31 at a distance of 2,200 miles (3,540 km). Mariner 7, traveling nearly 138 million miles (228 million km) passed over the Martian south pole on August 5 at a similar height. The probes weighed 910 pounds (413 kg) and carried television cameras to take pictures with a resolution as great as 1,000 feet (300 meters). They also conducted thermal mapping of the atmosphere and surface and carried out ultraviolet analyses of the upper atmosphere.

In 1971 both the Soviet Union and the United States launched probes toward Mars. Mariner 8, the first U. S. probe, failed after launch, but Mariner 9 entered Martian orbit on November 13. Photographs of the Martian surface showed inactive volcanoes, deep canyons, dune-filled craters, and stepped terraces. Mariner 9 also photographed the Martian moons Deimos and Phobos.

Soviet space probes Mars 2 and 3 later reached the planet on photographic missions. Mars 2 ejected a capsule that carried a Soviet emblem to the surface, and Mars 3 released an instrumented package that relayed back radio data briefly. Mars 4, 5, 6, and 7 reached the vicinity of the planet in February-March 1974. Mars 4 shot past the planet, while Mars 5 orbited and photographed the surface and Mars 6 and 7 failed to soft-land capsules on the surface.

The U. S. space probes Viking 1 and 2 were launched in 1975. Viking 1 landed on Mars on July 20, 1976, and began returning pictures of the rock-strewn surface. Viking 2 landed on the planet on Sept. 3, 1976. Viking Orbiter 1 and Viking 2 ceased functioning in 1980, but Viking Lander 1 continued returning data until November 1982. See also MARS.

Jupiter. The first U. S. Jupiter probe, Pioneer 10, was launched on March 2, 1972. The 570-pound (256-kg) craft carried 11 instruments for measuring the radiation belt of Jupiter and analyzing its thick atmosphere as it swung past the planet less than 81,000 miles (130,350 km) away on Dec. 3, 1973, and then headed toward the outer fringes of the solar system, leaving it on June 13, 1983. Pioneer 10 carried a metal plate bearing a message in symbols that would convey the existence of the human race to any intelligent life forms that might intercept it.

Pioneer 11, launched on April 5, 1973, flew within 26,600 miles (42,800 km) of Jupiter on Dec. 2, 1974, photographing the polar regions. Two Voyager spacecraft flew past Jupiter in 1979, sending back much scientific data and excellent pictures of the planet and its moons. Voyager 1 made its closest approach to the planet on March 1, and Voyager 2 on July 9, before continuing on toward Saturn. See also JUPITER.

Mercury. Mariner 10, launched on Nov. 3, 1973, flew past Venus on Feb. 5, 1974, en route to Mercury, which it passed within 460 miles (740 km) on March 29, 1974. It swung past Mercury again on Sept. 21, 1974, and radioed back scientific data and pictures. See also MERCURY.

Saturn. Man's first close-up views of Saturn were radioed to earth by the Pioneer 11 spacecraft when it came within 13,000 miles (21,400 km) of the planet on Sept. 1, 1979. Aside from returning excellent pictures of Saturn, Pioneer 11 discovered an eleventh satellite and a seventh ring. The Voyager 1 and 2 spacecraft, after flying past Jupiter, passed Saturn in November 1980 and August 1981, respectively.

INTERPLANETARY PROBES

Interplanetary probes are instrumented solely or primarily to study the environmental conditions in space. The first, and very successful, American craft of this type was Pioneer 5, which was fired toward the orbit of Venus in March 1960. It was spherical in shape and made of aluminum alloy. It had four extended paddles containing 4,800 silicon solar cells and had instruments for studying the interplanetary magnetic field, micrometeorites, and radiation. It was followed by the successful Pioneer 6 in December 1965 and Pioneer 7 in August 1966. The latter's missions were to study the solar magnetic field, the solar wind and its influence on the earth's magnetic field, and cosmic radiations.

Pioneer 8 was fired into solar orbit on Dec. 13, 1967. Its prime missions were to define clearly the so-called "tail" of the earth's magnetosphere and to monitor events on the sun during the latter part of its 11-year cycle. Pioneer 9 went into solar orbit on Nov. 8, 1968, to provide data on solar radiation. Pioneer 10 flew past Jupiter on Dec. 3, 1973, and proceeded out of the solar system on June 13, 1983. Pioneer 11 also flew past Jupiter, on Dec. 2, 1974, and past Saturn on Sept. 1, 1979.

Voyager 1 passed Jupiter in March 1979 and Saturn in November 1980, while Voyager 2 passed Jupiter in July 1979 and Saturn in August 1981. Both returned excellent photographs.

Within the Zond series, the Soviet Union included several interplanetary probes. Zond 1, directed toward Venus in November 1962, and Zond 2, launched toward Mars in November 1964, were plagued with communications problems. Zond 3, fired in mid-July 1965, first took photographs of the far side of the moon. Zond 4, launched on March 2, 1968, was designed to study the far reaches of near-earth space.

Many spacecraft since the 1960's have flown between the planets, from Mercury to Saturn, exploring the interplanetary medium and the interaction of the planets with it. For example, in early 1981 the Saturn-bound Voyager 2 spacecraft swept through the long extension of Jupiter's magnetotail, showing that it extended almost to the orbit of Saturn. (This tail is formed by the solar wind drawing out Jupiter's magnetosphere on the downwind side.) Present emphasis is on exploring the outer reaches of the solar system and on detailed studies of the sun.

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5. Manned Space Flights

The major phases of U. S. and Soviet manned space programs are described below except for programs involving manned earth-orbiting space stations, which are discussed in the article on SATELLITE, ARTIFICIAL. Further data on individual missions and the men who flew them are provided in the article on ASTRONAUTS.

SOVIET MISSIONS

Whereas virtually all important aspects of the United States' intentions and timetable for the manned exploration of space in the 1960 decade were well publicized, very little reliable information was available on Russian plans. Many political figures in the Soviet Union claimed no im-

mediate plans for manned lunar exploration. Many foreign observers agree, however, that the Russians intended a manned circumlunar flight in a Zond spacecraft but canceled the mission, both because of problems with their rockets and because of the string of successes in the Apollo program. Concentrating instead on operations in earth orbit, the Russians began a long buildup of operations there with Salyut space stations and Soyuz (manned) and Progress (unmanned) supply vehicles.

Vostok. The first six Soviet manned space flights were made in 1961–1963 in one-man vehicles called Vostoks, each weighing more than 10,000 pounds (4,500 kg). The first man to leave the earth's atmosphere and enter space was Yuri A. Gagarin, who made a one-orbit flight of 108 minutes on April 12, 1961. The second Vostok to be launched achieved more than 17 orbits of the earth, and the third and fourth entries in the Vostok series attempted the first rendezvous of two vehicles in space. They also set new endurance records. Another rendezvous attempt was made by Vostoks 5 and 6. The latter vehicle was piloted by Valentina Tereshkova, the first and thus far the only woman to make a space flight. The two Vostoks passed within 3 miles (4.8 km) of each other during the attempt.

Voskhod. The next two Russian flights took place in October 1964 and March 1965. They were made in somewhat heavier spacecraft that were capable of accommodating three cosmonauts—another space first for the Russians. The second Voskhod flight also marked the first time that a man, Aleksei Leonov, went outside his vehicle while in orbit, protected only by his spacesuit from the harsh space environment.

Soyuz. After the mission of Voskhod 2, there was a long pause in the Soviet manned space program. It was not until April 23, 1967, that a new effort became known to the world at large, with the launching of Soyuz 1. The flight ended in tragedy. Cosmonaut Vladimir M. Komarov, who had previously flown in Voskhod 1, apparently had some difficulty with his craft while in orbit and may have terminated the flight earlier than planned. As the spacecraft reentered the atmosphere, the parachute recovery system aboard failed and Komarov plunged to his death.

The accident caused a delay in the Soyuz program of another 18 months. An improved Soyuz 3 was successfully launched and recovered in 1968. In January 1969 the Soviet Union orbited two more Soyuzes and accomplished a transfer of two cosmonauts from one vehicle to another. On successive days beginning on Oct. 11, 1969, three more Soyuzes were launched, and on June 1, 1970, the two-man crew of Soyuz 9 made a flight of nearly 18 days.

On April 19, 1971, the Russians sent an 18-ton orbital laboratory called Salyut into space. The workshop was soon joined in orbit by a crew of three cosmonauts launched in Soyuz 10. Soyuz 11 cosmonauts Georgi Dobrovolski, Vladislav Volkov, and Viktor Patsayev were killed on their return to earth after spending nearly 24 days in Salyut. Subsequent test flights of Soyuz resulted in corrections and improvements. Other Salyut space laboratories followed, with their crews supplied by Soyuz spacecraft launched at frequent intervals and with longer and longer endurance records being established.

In July 1975, Soyuz 19, with cosmonauts Aleksei Leonov and Valeri Kubasov, docked in space with an Apollo craft bearing U. S. astronauts Thomas Stafford, Vance Brand, and Donald Slayton, in the first international space flight.

On Aug. 19, 1979, Vladimir Lyakhov and Valeri Ryumin set an endurance record of 175 days 36 minutes in Salyut 6. This record was broken on Oct. 1, 1980, by Ryumin and Leonid Popov, who were launched on April 9 and returned on October 11 after 185 days in space.

In 1974 and 1976 the USSR launched military versions of Salyut (Salyut 3 and 5). In 1977 it launched Salyut 6. By 1980 this space station and its supply vehicles, including the new Soyuz T, introduced in November 1980, had broken new experimental ground in radio astronomy, in holography as an aid to spaceship operations, and in raising plants and animals in zero gravity.

On June 19, 1981, the USSR docked Salyut 6 with Cosmos 1267 (launched April 25), a large unmanned satellite designed to test systems and elements for future spacecraft. Salyut 6 reentered the atmosphere on July 29, 1982, after nearly five years in orbit, and was destroyed over the Pacific Ocean.

The new modular space station Salyut 7 was launched on April 19, 1982, to an altitude of 186 miles (300 km). Cosmonauts Anatoly Berezovnoy and Valentin Lebedev linked up with Salyut 7 on May 13 and remained in the space station 211 days, returning to earth on December 10 after having been visited by two other teams of cosmonauts. Salyut 7 subsequently was enlarged when the Cosmos 1443 technical satellite was joined to it, and on June 28, 1983, Cosmonauts Vladimir Lyakhov and Aleksandr Aleksandrov docked with the space station.

MERCURY AND GEMINI PROGRAMS

The Mercury and Gemini programs were the first two phases of the U. S. Apollo program, first announced in 1960. They extended over a period of 5½ years and included 16 flights.

Mercury. The initial manned space program of NASA was Project Mercury, and the first mission was Alan Shepard's suborbital flight above the Atlantic Ocean in *Freedom 7*, on May 5, 1961. A second suborbital flight was made that year by Virgil I. Grissom, one of the seven original astronauts, and a victim of the 1967 Apollo fire described below.

The first U. S. pilot actually to orbit the earth was astronaut John Glenn, who made three circuits of the planet on Feb. 20, 1962. Three Mercury flights followed in 1962 and 1963.

Gemini. Project Gemini, the second phase of the Apollo program, began with the manned flight of Gemini 3 in 1965. The Gemini vehicles, designed to carry two astronauts instead of one, were larger and more complex than the Mercury craft. The purpose of the Gemini flights was to provide training in orbital rendezvous and docking techniques and to carry out various biomedical experiments. These included studies of astronaut reactions to long-term weightlessness, compatibility of crew members in closely confined quarters, and physiological response during docking with other spacecraft and during ventures outside the vehicles.

There were 10 manned Gemini flights, the last one taking place in November 1966. The Gemini 4 mission marked the first venture outside a spacecraft by an American astronaut, Edward H. White II, another victim of the Apollo fire.

The first successful docking of two space vehicles occurred on March 16, 1966, when astronauts Neil Armstrong and David Scott brought their Gemini 8 in contact with an Agena target vehicle. Thereafter many rendezvous and docking experiments were carried out in other Gemini flights.

APOLLO PROGRAM

In 1962, President John F. Kennedy made the Apollo lunar landing a national goal, to be accomplished before the end of the 1960's. During the years that followed, the three basic Apollo modules were designed and built: the command module, to carry all three astronauts to and from the moon; the service module, to house the various propulsion, power, and environmental systems needed for the flight; and the lunar module that would actually land two of the astronauts on the moon.

Apollo Fire. Until 1967 the Apollo program moved forward without major problems. Then, on January 27, astronauts Virgil I. Grissom, Edward H. White II, and Roger B. Chaffee died in a flash fire that destroyed their Apollo AS-204 spacecraft as it underwent routine tests at Cape Kennedy. The three men were to have been the first astronauts in the Apollo program.

NASA delayed the program while it took measures to reduce the danger of fire, which in the case of the AS-204 was thought to have been caused by an electric arc. Among these measures was the employment of noncombustible materials wherever possible. Wiring within the spacecraft was changed, and metal troughs were placed over all exposed areas to prevent damage once the wiring was installed. The egress hatch was changed so that it could be opened from inside in about five seconds and the crew could escape within half a minute. These changes added about 1,400 pounds (630 kg) to the weight of the Apollo command module.

Early Apollo Flights. The first entries in the series of Apollo flights were unmanned tests of the spacecraft with the Saturn 1B and later the Saturn 5 booster that was used for lunar landing missions. Three unmanned missions took place: Apollo 4, on Nov. 9, 1967, to test the Saturn 5 and command module engines; Apollo 5, on Jan. 22, 1968, to test the lunar module's descent and ascent propulsion systems in space; and Apollo 6, on April 4, 1968, to test the overall capabilities of the entire vehicle. Minor difficulties were met during the Apollo 6 test, but they were not sufficiently serious to delay the first manned Apollo spacecraft mission, designated Apollo 7.

The flight began on Oct. 11, 1968, with veteran astronaut Walter M. Schirra, Jr., and rookies Donn F. Eisele and Walter Cunningham as the crew. The flight objectives included testing the performance and reliability of the various spacecraft systems in preparation for a moon journey. A number of maneuvers were performed, including rendezvous with the jettisoned second-stage booster rocket. The astronauts also practiced navigation, focusing their telescope on bright stars and using their sextant.

During the flight of 260 hours and 163 orbits, several live telecasts were made from the spacecraft—a first for the American space program. On October 22, after an 11-day tour, the Apollo craft began its descent to the Atlantic Ocean under the automatic control of a computerized guidance system. The splashdown was only 0.3 mile (0.5 km) from its intended target, and although the spacecraft landed upside down it was soon righted by inflated bags. Within an hour the men were aboard the waiting carrier *Essex*.

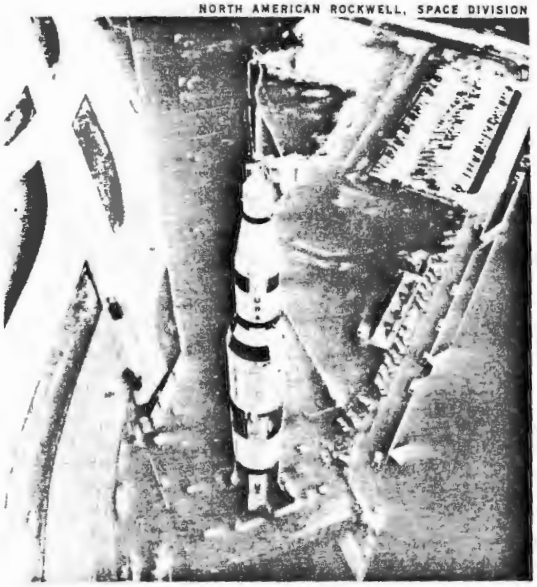
Circumlunar Flights. The capabilities of spacecraft and booster having been proved, men now prepared to leave earth orbit and travel to another object in the solar system for the first time. But before a landing would be attempted on the moon, NASA wished to conduct a series of preliminary circumlunar flights.

Apollo 8, the first manned spacecraft to circle the moon, took off from Cape Kennedy atop a giant Saturn 5 booster on Dec. 21, 1968. Frank Borman, James A. Lovell, Jr., and William A. Anders fired their vehicle into a lunar trajectory as they neared the end of their second earth orbit and headed toward rendezvous with the moon at an initial velocity of more than 24,000 miles (38,000 km) per hour. On December 24 the spacecraft was inserted into lunar orbit, and the astronauts described the moon's surface as they observed it from an altitude of 70 miles (110 km). The explorers began their return voyage on Christmas morning after 10 orbits of the moon, and they splashed down on target in the Pacific Ocean, near the carrier *Yorktown*, two days later.

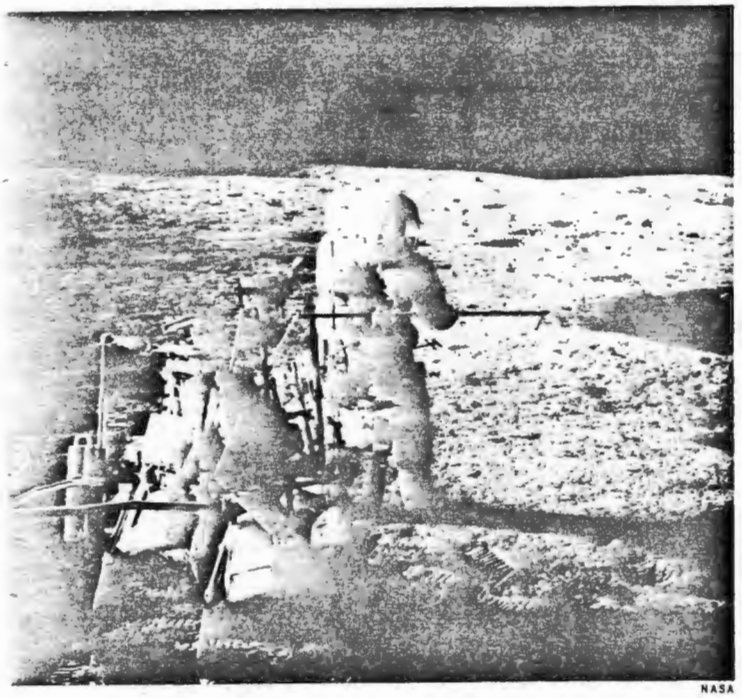
After a preliminary test of the lunar module in earth orbit by the men of Apollo 9—James A. McDivitt, David R. Scott, and Russell L. Schweickart—on March 3–13, 1969, another circumlunar voyage was undertaken. In broad terms, Apollo 10 combined Apollo 8's mission with the lunar module maneuvers of Apollo 9. The Apollo 10 was launched on May 18, 1969, with three veteran astronauts aboard—Thomas P. Stafford, John W. Young, and Eugene A. Cernan. On reaching the moon, the astronauts sent their craft into an elliptical and then a nearly circular orbit about 60 miles (100 km) above the surface. Stafford and Cernan transferred from the command module to the lunar module—code-named *Charlie Brown* and *Snoopy*, respectively, for the flight—and took the lunar landing craft to

SATURN 5 BOOSTER and Apollo 4 spacecraft move into place on the launch pad at Cape Kennedy.

NORTH AMERICAN ROCKWELL, SPACE DIVISION



Jan 27, 1967



NASA

APOLLO 14 COMMANDER Alan Shepard assembles a hand tool as he stands beside the small cart that he and Edgar Mitchell used to carry the devices of ALSEP—the Apollo Lunar Surface Experiments Package—to their place of deployment on the surface. In all, the package contained a dozen instruments.

within 50,000 feet (15,200 meters) of the moon's surface. During the low traverse the astronauts inspected the landing site planned for Apollo 11. Reascent to the command module was carried out so as to simulate the flight path of a lunar module leaving the moon. On May 26 the astronauts splashed down safely near the waiting recovery ship, and the stage was set for the climactic Apollo 11 lunar mission.

Lunar Landing Flights—*Apollo 11*. The journey of Apollo 11 is described in a special article beginning on page 357. The other lunar landing missions are described below.

Apollo 12. The second lunar landing mission, Apollo 12, took place four months after the Apollo 11 flight. The crew included veteran astronauts Charles Conrad, Jr., and Richard F. Gordon, Jr., and rookie astronaut Alan L. Bean. Conrad and Bean were to land on the moon in their lunar module *Intrepid*, while Gordon would remain in lunar orbit in the command module, code-named *Yankee Clipper*.

The launch took place on Nov. 14, 1969, while a storm hovered over Cape Kennedy. At the start a bolt of lightning briefly knocked out the spacecraft's power system, but the power was soon restored. The astronauts headed toward the moon on a trajectory differing from those of previous missions. That is, it was not a "free-return" but a "hybrid" trajectory, which did not provide an automatic safe return to earth should the lunar landing prove impossible.

Lunar touchdown occurred at 1:54 A. M. (EST) on November 19. When Conrad descended the module's ladder to the moon's surface, he jokingly referred to Neil Armstrong's well-known words on the same occasion in the previous flight. Said Conrad, "That may have been a small step for Neil, but that's a long one for me!" Viewers on earth were disappointed by the failure of the television camera soon after it was deployed by Conrad, but all of the main purposes of the mission were fully achieved. The two cheerful astronauts set up the Apollo Lunar Surface Experiments Package (ALSEP), whose instruments measured the strength of the solar wind, the solar magnetic field, and the earth's magnetic effect on the moon, besides studying the physics of the lunar surface and interior.

Other experiments included a lunar ionosphere detector, a lunar atmosphere detector, and a solar wind spectrometer. The men also performed field geological surveys and collected rock and soil samples. On their second stay outside *Intrepid*, they visited the nearby Surveyor 3 unmanned probe that had been sitting on the moon since April 20, 1967. After spending a total of more than 31 hours outside their LM, Conrad and Bean reentered the craft and rejoined Gordon in *Yankee Clipper* for a safe return to earth. Splash-down occurred on November 24.

Apollo 13. The next Apollo flight, intended to explore a region of hilly lunar terrain, with an added drilling experiment, nearly became a tragedy in space.

The crew of Apollo 13 consisted of James A. Lovell, Jr., and two rookie astronauts, Fred W. Haise, Jr., and John L. Swigert, Jr. The crew entered space on April 11, 1970, with only minor difficulties, and the flight went well for the first 56 hours. Then, shortly after 10 P. M. (EST) on April 13, the crew heard a sharp "bang" as they were testing spacecraft systems—and then began to happen very rapidly. The command module's electrical and life-supply systems failed, and the astronauts soon found that they would have to use the lunar module as a lifeboat for the rest of the journey.

It was later determined that a faulty insulation had caused one of the service module's oxygen tanks to explode. There was no longer any possibility of a lunar landing, and the sole mission of the astronauts was simply to get back to earth alive. For the rest of the perilous journey the astronauts resorted to an ingenious series of makeshift techniques in order to maintain their power and life supplies. After several suspenseful days, the adventure finally ended happily as the three astronauts made a safe splashdown in the Pacific Ocean on April 17.

Apollo 14. On Jan. 31, 1971, 10 months after the aborted flight of Apollo 13, a safety-modified Apollo 14 left Cape Kennedy with veteran astronaut Alan B. Shepard, Jr., and rookie astronauts Edgar D. Mitchell and Stuart A. Roosa aboard. The mission marked a return to active duty of the first U. S. astronaut, Alan Shepard.

A number of difficulties arose during the journey outward, including an inability to complete the initial docking maneuver of the command module *Kitty Hawk* with the lunar module *Antares* until the sixth attempt. Then one of the ascent-stage batteries of the *Antares* threatened for a time to fail. Even more seriously, before the lunar module began its descent maneuver on February 5, a false abort signal came from the LM. A makeshift program was worked out for the onboard guidance computer that told it to ignore the signal, just in time for the descent to start. The landing radar also refused to work properly until late in the maneuver. Despite these difficulties, *Antares* touched down safely on the moon at 4:18 A. M., February 5, only 65 feet (20 meters) from its designated target.

The landing site was a small valley in the Fra Mauro highlands at the eastern edge of the Ocean of Storms. On the first day the astronauts worked more than 4½ hours outside their craft, primarily setting up ALSEP, the Apollo Lunar Scientific Experiments Package. ALSEP contained an ion detector, a device for measuring the density of the atmosphere, a device for measuring energies of solar protons and electrons striking the moon, a laser reflector, and a passive and an active seismic detector. The astronauts carried the heavy equipment to the deployment site by means of a wheeled cart. They also set out geophones, which recorded the explosion of charges by an instrument called a "thumper."

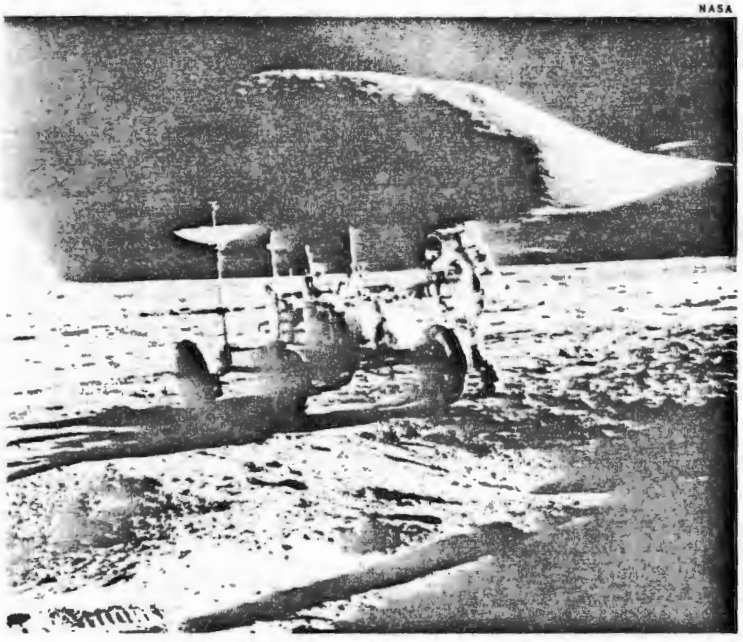
On Febraury 6 the astronauts again spent 4½ hours outside *Antares*, this time attempting to climb to the rim of Cone Crater, some 400 feet (120 meters) higher and 3,300 feet (1,000 meters) away. Confused by the rolling terrain and many boulder fields, and tired by the walk, the astronauts never quite achieved their goal, but they successfully collected many more rock samples. Before reboarding *Antares*, Shepard took some swings at a golf ball with a makeshift club. Rejoining *Kitty Hawk* after a stay on the moon of 33½ hours, the astronauts splashed down in the Pacific Ocean on February 9.

Apollo 15. A little more than six months after the return of Apollo 14, the fourth team of astronauts to achieve a lunar landing got under way. The crew consisted of a veteran space pilot, David R. Scott, and two rookies, James B. Irwin and Alfred M. Worden. Their spacecraft contained a new unit of equipment for use on the lunar surface, a four-wheel jeeplike vehicle called a lunar rover. With the range that it would provide, the men hoped to carry out a more thorough scientific exploration of the moon than had yet been attempted. Their landing site was to be a heavily cratered valley at the foot of the moon's tall Apennine Mountains.

The Apollo 15 crew was launched from Cape Kennedy on July 26. Four days later, at 6:16 P. M. (EDT), the lunar module *Falcon* touched down in the lunar highlands some 400 feet (120 meters) northeast of the target with Scott and Irwin aboard, while Worden remained in the *Endeavour*. Scott depressurized the module and opened its hatch for a brief survey, but real activity did not begin until morning, when the men spent about 6½ hours outside *Falcon*.

Many important scientific devices were again deployed, as on previous Apollo flights. However, for television viewers on earth the most interesting aspect of the work period was the moon tour made by their lunar rover, with the spectacularly fine images provided by a new television system. Scott and Irwin drove toward the Apennines and neighboring Hadley Rill, a canyon having an average depth of about 1,200 feet (360 meters). The rover performed very well except for some minor difficulty with a balky front-wheel steering apparatus, and when it came to a halt the camera was activated and then controlled by NASA personnel in Houston.

NASA



APOLLO 15's ROVER, a jeeplike vehicle that proved enormously useful in expanding the range of operations of astronauts on the moon, is loaded by James Irwin. A television transmission antenna, looking like an inverted umbrella, is mounted on the vehicle. Mount Hadley rises in the distance.

On August 1 the two men took a seven-hour ride that covered 8 miles (13 km) and brought them to the Apennine foothills, where they discovered crystalline rocks that they hoped might prove to be fragments of the original lunar crust. On August 2, they explored Hadley Rill again, returned to *Falcon*, and then rejoined Worden in lunar orbit. The crew circled the moon for another day. Splashdown took place on August 7 in the Pacific Ocean.

Apollo 16. The target of Apollo 16 was the Descartes region, a highland area in the south central region of the visible side of the moon, chosen because it was thought to have been formed by volcanic action in the moon's geological past. Previous astronauts had not visited such a terrain. The Apollo 16 crew consisted of one veteran, John W. Young, who had already orbited the moon, and two rookies, Charles M. Duke, Jr., and Thomas K. Mattingly II. Young was the flight commander, Duke the lunar module pilot, and Mattingly the commander of the command module. The code name Mattingly chose for the latter module was *Casper*, after a cartoon ghost, while Young and Duke named their lunar module *Orion*.

The flight was launched at 12:54 P. M. (EST) on April 16, 1972, and entered lunar orbit on April 19. A serious problem arose as *Casper* prepared to reascend to a higher orbit: monitors indicated that the module's back-up control system might not work properly if called upon. It took Mattingly and mission control four hours to decide not to abort the mission in the face of this potential hazard, and *Orion* finally set down on the rocky Descartes plateau six hours late, at 9:23 P. M. (EST) on April 20.

The tired Duke and Young slept before going out on the lunar surface. Young set foot on the moon at 11:58 A. M. on April 21. Because of a balky antenna, picture transmission did not begin until Duke came out and set up a high-gain antenna on the surface. Thereafter the two men went about the task of setting up an array of scientific experiments similar to that of Apollo 15 and including a miniature astronomical observatory. Unfortunately, at one point Young tripped over and broke a cable leading to an expensive device for measuring heat flow from the lunar interior, but otherwise all went well. The astronauts returned to Orion for a rest period at 6:58 P. M. after a sample-collecting tour in their lunar rover.

The second EVA, on April 22, lasted 7 hours and 23 minutes. Duke and Young drove up the slopes of nearby Stone Mountain to a height some 750 feet (230 meters) above the landing site. Making several stops, they collected samples that did not seem to be the volcanic-type rocks that scientists had expected. On the third EVA, of 5 hours and 40 minutes, on April 23, the men took their lunar rover northward to North Ray Crater, a hilly landscape strewn with boulders.

That evening, at 8:25 P. M., *Orion* blasted off the moon in view of the television camera, taking with it 215 pounds (97 kg) of rocks and soil. The return proceeded with few further problems, and on April 25, Mattingly took a "walk" in space to retrieve film cassettes from a panoramic camera and a mapping camera at the rear of the service module. Splashdown occurred at 2:45 P. M. on April 27, some 215 miles (346 km) southeast of Christmas Island.

Apollo 17. The last lunar landing mission of the Apollo program was undertaken by astronauts Eugene A. Cernan, Ronald E. Evans, and Harrison H. Schmitt. After a delay of almost three hours, they blasted off on Dec. 7, 1972. On Dec. 10, their Apollo 17 spacecraft entered lunar orbit. The next day Cernan and Schmitt landed the lunar module *Challenger* in the Taurus-Littrow valley, the planned target area where they hoped to find some form of volcanic ash. While Cernan and Schmitt explored the lunar surface by riding in the lunar rover vehicle and by walking, Evans remained in the command module *America* and made moon observations. The most startling discovery of the mission was made by Schmitt, who found a layer of orange-colored soil and suggested it might be evidence of past vulcanism on the moon.

On December 14, Cernan and Schmitt rose from the lunar surface in *Challenger* and rejoined Evans and *America* in lunar orbit. They then set off for earth, taking about 275 pounds (125 kg) of lunar rocks and soil with them. The astronauts splashed down in the Pacific on December 19.

Apollo-Soyuz Mission. The first joint international manned space flight occurred in July 1975, when Russian cosmonauts Aleksei Leonov and Valery Kubasov were launched on July 15 in Soyuz 19 from Kazakhstan, USSR, and astronauts Thomas Stafford, Vance Brand, and Donald Slayton were launched on the same day in an Apollo spacecraft from Cape Canaveral, Fla. They came together on July 17 over the Atlantic Ocean and remained docked for two days while the men moved from one vehicle to the other.

Space Shuttle. The first U.S. Space Shuttle, *Columbia*, made its first orbital flight in 1981. The second shuttle, *Challenger*, made its maiden flight in 1983. See SPACE SHUTTLE.

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6. The Future of Space Exploration

One of the problems facing space mission planners is where to place priorities. The solar system is huge, containing not only 34 principal bodies (the sun, the eight other planets, 22 moons with diameters of more than 150 miles, or 240 km, and the three large asteroids Ceres, Pallas, and Vesta), but numerous smaller bodies. It must be decided what percentage of available resources should be expended on research from earth orbiting satellites, on studies of the moon, and on investigations of the planets. It must also be decided whether to emphasize manned or unmanned exploration and when to change the major portion of effort from one target of exploration to another. Decisions have to be made that reflect a realistic assessment not only of scientific objectives but also of the state of technology, government policy, and public support. The latter are not always predictable, since they depend both on internal conditions and aspirations and on international events.

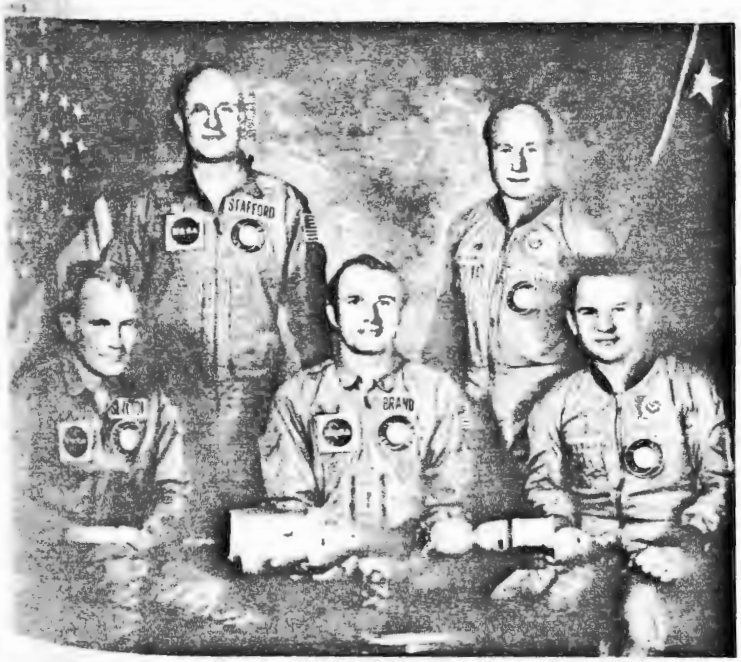


The American and Russian spacecraft preparing to dock on July 17, 1975, as depicted by an artist. The U. S. Apollo, at the left, maneuvered slowly and carefully toward the Soyuz.

APOLLO-SOYUZ JOINT SPACE MISSION

The first joint international space flight was completed by the United States and the Soviet Union in July 1975. On July 15, cosmonauts Aleksei Leonov and Valery Kubasov were launched aboard a Soyuz spacecraft, and astronauts Thomas Stafford, Vance Brand, and Donald Slayton were sent into orbit in an Apollo spacecraft. The two vehicles docked on July 17 over the Atlantic Ocean and remained joined for two days while the crews moved from one spacecraft to the other.

The Apollo-Sayuz crews, shown before their historic flight. (*Seated, l. to r.*) Astronauts Slayton and Brand, and cosmonaut Kubasov. (*Standing*) Astronaut Stafford and cosmonaut Leonov.



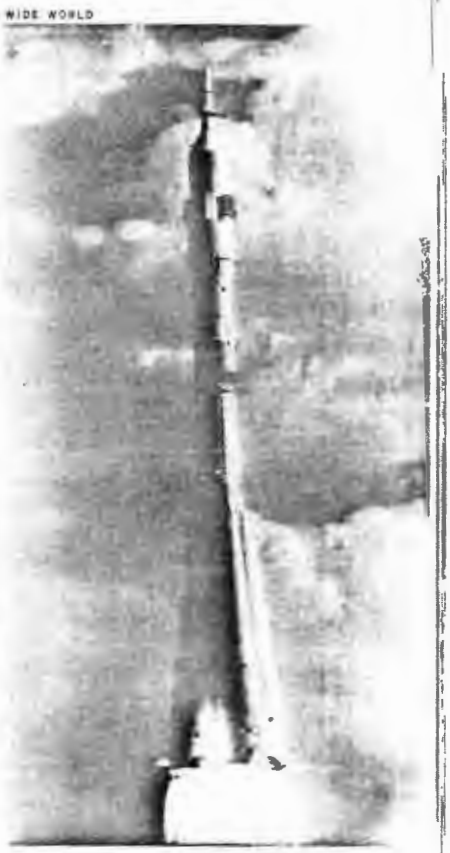


UPI

The Apollo astronauts are sent into orbit from Cape Canaveral, Fla., aboard a Saturn 1-B rocket.

The Soyuz spacecraft, atop a Russian rocket, leaves the Baikonur Cosmodrome in Kazokhstan.

WIDE WORLD



The U.S. space program formally began in 1955, when President Dwight D. Eisenhower reluctantly approved a minimum satellite development, Vanguard. This was part of the U.S. contribution to the International Geophysical year (IGY) program of scientific research.

The Soviet Union's Sputnik, launched on Oct. 4, 1957, caught the U.S. public unawares and bestowed great prestige on international communism as a progressive force. The U.S. Congress created NASA in response, but it was still struggling to launch a wide range of programs when the Soviets orbited Yuri Gagarin in Vostok 1 on April 12, 1961. Worldwide awe at that feat convinced President John F. Kennedy, with strong congressional backing, to commit the United States to the multibillion-dollar Apollo lunar landing program.

Despite its ultimate triumph many people saw the Apollo program as an extravagance. By 1966 it had strong opposition in Congress. That opposition kept NASA to virtually a flat budget in the 1970's and quenched plans for another fiery decade on the Apollo order. The Skylab and Apollo/Soyuz programs used up remaining Saturn rockets and Apollo hardware. The space agency gained approval in 1971 to embark on the Space Shuttle development. That held together its central engineering teams and prepared the way for a new era in space transportation and manned space operations. A set of planetary spacecraft and astronomy satellites carried out the great space missions of the 1970's—making an excellent visual record of the planets from Mercury to Saturn; exploring Mars, the planet that looms largest in the public imagination; and opening the X-ray universe with startling discoveries by a series of high-energy astronomical observatories, one named after Copernicus. But all this, and much more, was done with a budget constrained by public dubiousness about space spending.

Meanwhile, quietly, space communications and military space developments had independently become vast enterprises. By the end of the 1970's commercial space communications, independent of NASA, had become a billion-dollar business, headed for revenues estimated in the tens of billions by the 1990's. Military space developments, not in weapons but in reconnaissance, attack warning, communications, navigation, and weather, equaled the NASA budget by the beginning of the 1980's. These portended a great surge later in the decade, riding a tide of futuristic developments in directed-energy weapons and other large satellite systems made possible by the Space Shuttle, and anticipated advanced space launch vehicles.

Whatever its limits, the decade of the 1970's was a period both of great achievements in space exploration—the grand unveiling of the planets and the high-energy universe—and of gestation of mighty works to come. Many of these works will compete for dollars and engineering interest with scientific and other exploratory objectives.

The great payload capacity of the Space Shuttle will motivate the creation of a new generation of earth satellites, in good part for the lucrative business of space communications but also for earth-resource surveys, navigation, meteorology, manufacturing, atmospheric and space science, astronomy, and military operations. Much of the drive for new space systems will come from businesses and institutions other than NASA. Table A gives some idea of prospective satellite services in the decades ahead.

A major objective of the space agency will be the creation of a large manned space station able

Table A: SPACE APPLICATIONS SUMMARY WITH RISK ESTIMATES, 1980's AND 1990's
(Risk categories in increasing uncertainty with IV the greatest)

COMMERCIAL APPLICATIONS	Risk Category
Personal Applications	
Personal Communications Wrist Radio	I
Emergency/Rescue Wrist Beacon	I
Personal Navigation Wrist Set	II
Voting/Polling Wrist Set	I
Civil Applications	
Disaster Communications Wrist Radio	I
All-Aircraft Traffic Control	I
Urban/Police Wrist Radio	I
Car Speed-Limit Control	I
Industrial Applications	
Burglar Alarm/Intrusion Detection	I
Vehicle/Package Locator	II
3D Holographic Teleconferencing	III
Advanced TV Broadcast	I
Advanced Resources Pollution Observation	I
Space Processing	I/II
International Applications	
Nation-Nation "Hot Lines"	I
Multinational Air Traffic Control Radar	II
Small Terminal Intelsat Network	I
Earth Resources Data Sharing	I
Energy Distribution Relay	IV
UN Truce Observation Satellite	I

GOVERNMENT APPLICATIONS	Risk Category
Communications	
Voting/Polling Wrist Set	I
Electronic Main Transmission	I
Border Surveillance	II
Nuclear Materials Locator	I
Library Data Sharing	I
Observation	
High Resolution Resources/Pollution Observatory	II
Water Level and Fault Movement Indicator	I
Atmospheric Temperature Profile Sounder	III
Forest Fire Detection	I
Ocean Resources Location	I
Support	
Passive Coastal Anti-Collision Radar	II
Night Illuminator	II
Energy Delivery and Distribution	IV
Energy Consumption Monitor	I
Aircraft Laser Beam Powering	IV
Nuclear Waste Disposal	II
International Applications	
Astronomical Super-Telescope	IV
Interplanetary TV Link	II
Atmospheric Temperature Profile Sounder	III
Ocean Resources and Dynamic Sensor	I
Water Level and Fault Movement Indicator	

SOURCE OF DATA: IVAN BEKEY, DIRECTOR, ADVANCED PROGRAMS, NASA [illegible]

Table B: PROSPECTIVE SOLAR SYSTEM EXPLORATION 1980-2000

Name	Remarks	Launch Year
Galileo	Jupiter orbiter w/probe	1985
International Solar Polar Mission	Solar mission out-of-ecliptic plane	1986
Halley's comet intercept	Close flyby of Halley nucleus	1985
Venus orbiter imaging radar	Venus polar orbit, mapping	1988
Comet Faye rendezvous	Solar electric propulsion	1988
Mercury orbiter	Solar electric propulsion	1989–1992
Venus lander	Surface exploration	1990
Asteroid(s) rendezvous	Solar electric propulsion	1991–1993
Saturn orbiter dual probe	Orbit Saturn, probes of Saturn Titan	1992
Uranus orbiter/probe	Jupiter gravity assist	1992–1993
Close solar probe	Jupiter gravity assist (to 0.03 AU)	1992–1995
Mars aeroscience/ geoscience orbiter	Detailed map of Mars from polar orbit atmosphere and surface composition	1994
Mars sample return	Series of two to four sample return missions in successive opportunities	1996–2000

to serve both as a research center and as the hub of a space construction base.

Military and civil space operations will support construction of a dozen Space Shuttles. The traffic and complexities of joint civil and military space operations may motivate creation of a space transportation business outside NASA akin to the airlines. In the face of this surge of earth-orbital engineering, planetary missions will have a secondary role, although a prospectively important one, as Table B shows.

Deep space, the moon, the planets, and asteroids will all motivate important government missions and perhaps private ventures involving colonization, as argued by Gerard K. O'Neill in his imaginative book *2081—A Hopeful View of the Human Future*, published in 1981.

Space has become a richly diverse and dynamic sphere of human activity. Economics will play an increasingly important role in choosing space activities. But all the factors outlined above come into play, making the field a heavy mixture of politics, economics, science, and adventurism.

In this light, deep-space, lunar, planetary, and interstellar missions deserve comment.

EXPLORING THE MOON

The first crews landing on the moon were able to accomplish limited geological and photographic work and to gather samples to be brought back to earth. Subsequent missions in the Apollo series provided the astronauts with more generous work periods, enabling them to make topographical, geological, and geophysical surveys of extended areas. A mobile surface vehicle was developed that permitted them to move much further away from their landing vehicle.

NASA's broader goals in the Apollo program include development of a better understanding of the moon, the interaction of the moon and the earth, and the place of the earth-moon system in the solar system. It is also necessary to establish what role the moon will play, not only in future scientific investigations but in other astronautical endeavors. For instance, the moon may one day serve as a major communications center for controlling spaceflight operations throughout the solar system. From its surface, manned spacecraft may take off for planetary targets, taking advantage of its airless and low-gravity conditions. Another objective, almost inevitable as governments supporting such efforts, is to develop space capabilities in direct support of national interests and national prestige.

There are countless scientific objectives in manned exploration of the moon. These include determining the nature of gross topographical features, such as craters, and studying the rock units on and immediately below the surface to ascertain their shape, age, and relationships. The structure of the interior, its relationship to the surface, and the geological history and origin of the moon are also major areas of investigation. Since earth's erosional agents such as water and wind do not operate on the moon, and sediments are not deposited by such agents, the surface and subsurface should be much closer to primordial conditions than anywhere on earth.

Lunar Bases. Longer-lasting missions that require permanent bases and outposts are certain to be necessary, if for no other reason than to reduce the cost of bringing moon explorers back to earth every few days or weeks. In locating and establishing such bases and outposts, factors to be considered include scientific interest in the surrounding area; environmental conditions, including the angle of the sun, temperature extremes, and radiation flux; availability and accessibility of local resources, including underground water; nature of the local terrain; availability, size, cargo capacity and speed of surface of over-the-surface supply vehicles; and the size and cargo capacity of spaceships dispatched from earth and the frequency of their arrival.

Early base structures will probably be made from materials brought from earth, but processed lunar resources may be substituted later. However constructed, bases must provide facilities for living, power generation, waste disposal, air production and conditioning, communications, observation, and, ideally, farming. In the long run, it will be impractical to bring from earth all the food consumed by base inhabitants.

A variety of proposals have been made as to how plants, and even animals, may be raised in airtight structures on the moon, making use of the abundant sunlight during the long daytime periods. Suitably enriched moon soils may be developed, or hydroponics may be pursued.

DEEP-SPACE PROBING

Pioneer 10, launched on March 2, 1972, became the first man-made object to leave the known solar system when, on June 13, 1983, it crossed the orbit of Neptune, the most distant known planet. Voyager 1 and 2 spacecraft also were programmed to leave the solar system, as will Pioneer 11 and other deep-space probes to come.

These spacecraft have revealed the tremendous reach of solar-system processes. Pioneer 10 recorded the sun's atmosphere and magnetic envelope at a distance of at least 30 astronomical units—"far beyond the point predicted by many scientists," according to the principal Pioneer investigator, James A. Van Allen of the University of Iowa. (Van Allen's crude radiation counter flew on Explorer I in 1958 and discovered the earth's radiation belts.) Van Allen believed that the solar envelope reached beyond Pluto. Pioneer 10 should discover the border between the sun's atmosphere and interstellar space, the so-called "heliopause." Such findings help explain the character not only of our solar system but also of other stars and their planets.

Table B shows complementary deep-space missions scheduled for the latter half of the 1980's. Two International Solar Polar Mission (ISPM) spacecraft will obtain the first stereoscopic view of the sun from latitudes high above the ecliptic plane to provide new insights into the three-dimensional structure of the interplanetary medium. Simultaneous measurements by OPEN's (Origin of Plasmas in Earth's Neighborhood) Interplanetary Physics Laboratory (IPL) will establish an inecliptic benchmark for out-of-ecliptic data from the ISPM. The data can be interpreted and related to the more familiar perspective of the sun and solar wind.

During the same period, the UARS (Upper Atmosphere Research Satellites) program will conduct a global study of the chemistry and dynamics of earth's mesosphere and stratosphere (the altitude range extending from about 10 miles, or 15 km, to about 50 miles, or 85 km). OPEN's Polar Plasma Laboratory (PPL) will measure the entry of solar-wind plasma into the dayside polar cusp. An Equatorial Magnetospheric Laboratory (EML) will measure the near-equatorial storage of energy, mass, and momentum, and a Geomagnetic Tail Laboratory (GTL) will survey conditions in the magnetotail. Simultaneous measurements by these spacecraft will yield the first coordinated results on the coupling and transport of solar-wind plasma and energy through the magnetosphere and the effects of that energy transfer on the upper atmosphere of the earth.

Gerard K. O'Neill of Princeton University expected the relative cheapness of lunar materials for building space colonies to motivate lunar bases. NASA summer studies in 1976 and 1977 explored this use of the moon and the design of large space colonies. O'Neill presented his ideas and the nub of the findings of these and other studies in his prizewinning books *The High Frontier* and *2081—A Hopeful View of the Human Future*. If his predictions are correct, people will be living throughout the inner solar system, from the orbit of Venus to the asteroid belt, by the end of the next century.

In this connection, the first manned flight to Mars takes on the coloration of the Apollo program inasmuch as it signifies the opening of the colonization wave. Space-station developments under way in the USSR and those about to be activated by the United States will lay the groundwork for both lunar bases and manned planetary flight in the 1990's. By then several propulsion options should be available.

JOHN NEWBAUER
Editor in Chief
"Astronautics and Aeronautics"

SPACE LAW, a branch of international law concerned with the regulation of activities in outer space. The ability to penetrate beyond the earth's atmosphere, demonstrated in 1957, gave rise to intense speculation about the nature of the legal order under which outer-space activities would take place. From the outset, statesmen and scholars agreed that the bulk of the pertinent rules of international law, which govern relations between nations on earth, would apply to human activities beyond the atmosphere—that, in fact, there was no "legal vacuum" in space. Space law has been modeled in part on the agreements concerning the peaceful use of the oceans and Antarctica.

International Agreements. Most of the present pattern of space law originated with UN General Assembly resolutions, adopted unanimously in 1961 and 1963, and the 1963 Nuclear Test Ban Treaty. The UN resolutions called for international cooperation in outer space; the treaty prohibited nuclear testing there. Answers to many legal questions were provided by the general outer-space treaty of 1967, a 1968 agreement on astronauts, and a 1972 treaty on liability.

Broadly paraphrased, the nations are in agreement that each has equal legal rights of access to outer space for peaceful activities; that no nation may claim sovereignty in outer space or to a celestial body; that international law, including the UN Charter, applies to activities in space, and that nuclear testing, the stationing of nuclear weapons in space, and the placing of military bases on celestial bodies are barred. The nations have also agreed that astronauts and space vehicles remain under the jurisdiction of their state of nationality and astronauts are to receive every assistance in case of accident.

States are to consult together before undertaking potentially hazardous activities. In addition, states are generally responsible for national spacecraft and have agreed to accept absolute responsibility for damage caused by their space vehicles to persons, property, or aircraft on the earth's surface, including airspace, and to accept liability, based on fault, if another spacecraft or its occupants are harmed. Thus, an embryonic but rather extensive regime for cooperative peaceful space activities exists.

Unresolved Questions. A number of legal questions remain, including a definition of the outer limit of national airspace, in which states have absolute sovereignty. The U.S.–Soviet contention over the flying of military "spy" satellites largely disappeared by the late 1960's, when it became clear that both states were using them. But the development by the United States of civilian resource-sensing satellites raised questions about the right to "view" possibly unwilling nations and about the processing and ownership" of such information. Questions about specific right to use and even to "mine" areas of the moon and about national (or private) claims of ownership of materials brought from the moon also have arisen.

HOWARD J. TAUBENFELD
Coauthor of "The Law Relating to the Activities of Man in Space"

SPACE MEDICINE, the branch of medical science that studies the hazards faced by man in the environment of space and develops the means by which he can survive in that environment. SPACE EXPLORATION—*Man in Space.*

Vol. 25

Shuttle Launching Delayed Again Over Weather Fears

By WILLIAM J. BROAD
Special to The New York Times

CAPE CANAVERAL, Fla., Jan. 26— A forecast of threatening weather forced space agency officials to postpone this morning's scheduled launching of the shuttle Challenger until 9:37 A.M. Monday.

It was the second weather-related postponement of the launching of the Challenger and its crew of seven, one of whom is a New Hampshire schoolteacher. The first came Saturday when poor weather in North Africa, the location of two emergency landing sites, forced the launching to fall back from Saturday to this morning.

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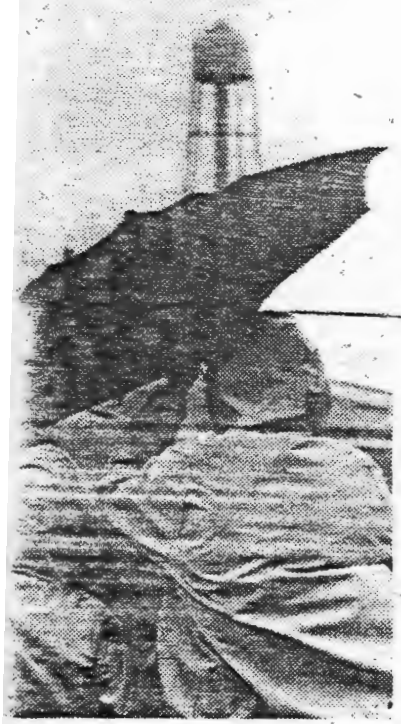
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The New York Times/Keith Meyers

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