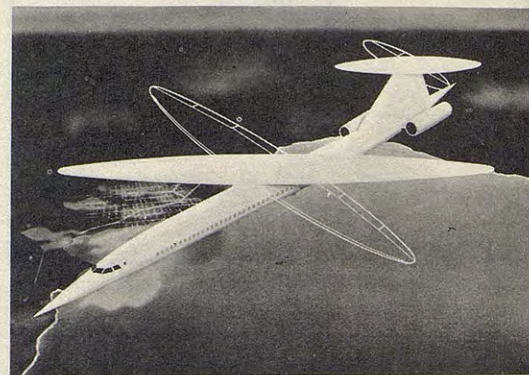


miles flown per gallon of fuel, resulting in potential economies to the user public.

The NASA-developed supercritical wing design has completed the first phase of its flight-test program, including over 75 flights in a two-year program. The initial flight tests have demonstrated that the new shaped wing makes it possible for aircraft to operate approximately 15 per cent more efficiently.

The supercritical wing would enable aircraft to fly faster and farther without increasing thrust or fuel consumption, thus potentially shortening trip times for hurried travelers. It would also enable aircraft to carry more cargo over a set distance with the same amount of fuel or the same amount of payload with less fuel.



Antisymmetrical wing.

Another significant NASA design innovation is the antisymmetrical wing. This wing crosses the airplane's fuselage at a right angle for takeoff and landing and pivots to cross the body diagonally for high speed flight. Preliminary studies indicate the wing would enable an airplane to operate more quietly and use much less fuel than current delta-wing jets during takeoff and landing and would add substantially to fuel mileage at cruising altitudes of 40,000 feet. At supersonic speeds up to Mach 1.2, an antisymmetrically winged plane would not produce a

sonic boom on the ground. As stated earlier, reduction of aircraft noise will result ultimately in more convenient passenger service.

NASA is also developing and testing composite materials—combinations of metal and plastic—for aircraft. Composites show promise for lengthening service life and also for reducing weight by more than thirty percent. They thus have potential for effecting substantial savings in aircraft operating costs and for increasing payloads.

NASA has supported the FAA in the development of systems to prevent mid-air collisions. One system detects infrared radiation from a Xenon flashing strobe lamp, installed on an aircraft, at much greater distances than the flashing light can be seen. Another pilot-warning indicator uses computers in conjunction with UHF radio waves. The Doppler shift (change in apparent frequency of radio signals transmitted by an approaching or departing object) would indicate the closing rate of the other aircraft.

NASA's remedy for wet-runway skidding problems is not only contributing to increased safety for air travelers but also for travelers on the nation's highways. NASA research determined that skidding is frequently due to hydroplaning. This occurs when a vehicle, rolling across a wet surface, reaches a speed where hydrodynamic pressures lift tires clear of the pavement so that the tires travel on a thin film of water. NASA tests have shown that as little as one-tenth inch of water on the ground can cause hydroplaning.

NASA research determined that increased tire pressure and ribbed treads raise the speed at which hydroplaning is likely to start. More important, grooved and roughly textured pavements significantly reduce hydroplaning, through removal of water from the tire contact areas.

Both runways and highways grooved

as suggested by NASA research have demonstrated greatly improved traction in both wet and dry weather. Grooving does not harm runways, highways, nor vehicles.

Snow or slush also creates problems on runways. Slush can prevent aircraft from reaching flying speed. NASA is studying ways of redesigning landing gear to reduce slush drag. In the meantime, its studies have led to an FAA rule forbidding jet takeoffs in more than one-tenth inch of slush.

Fog at airports costs airlines more than \$100 million yearly and airline passengers much inconvenience in delayed or cancelled flights. Working with private organizations and other Government agencies, NASA is conducting tests to find and perfect means of reducing fog hazards at airports.

Another important aviation technology that NASA is advancing is a satellite air traffic control and communications system. NASA's Applications Technology Satellite program is conducting experiments that are potential forerunners of satellite air traffic control systems of the future.

A National Academy of Sciences study of traffic control and navigation over oceans concluded that satellite systems offer the best means of handling the traffic on the overcrowded air and sea lanes expected in the coming decades. The Academy noted that present systems from time to time cannot handle transoceanic traffic without costly diversions. A satellite system, however, could provide instant, continuous, and automatic plotting of flights and communication with pilots over vast ocean areas.

Among other potential benefits of satellite air traffic control and navigation are precise and frequent position fixing, reliability, all-weather operation, and improved safety. Such a system may be indispensable for the convenience and safety of the more than 500 airplanes expected to be flying

over the Atlantic simultaneously by 1980.

General Aviation aircraft, which include all but certified air carriers, fly more mileage than commercial transports. The nearly 140,000 domestic general aviation planes range from corporate jets to home-built craft. NASA technology is focussed not only on making general aviation flights safer but also increasing their performance and keeping them superior to foreign competition.

NASA is concentrating on the prevention of stalls and spins, primary factors in about 35 per cent of general aviation fatalities. Other programs are aimed at making landings easier and more precise; studying methods for improving traffic patterns at airports that do not have control towers (such airports serve only general aviation); and developing acoustically treated engine fans and propellers to reduce general aviation engine noise. And new airfoils under study by NASA would decrease weight of such airplanes, increase lift-to-drag ratio enabling them to fly more efficiently, and help prevent stalls.

In these and many other activities, NASA continues to improve air transport for the benefit of the traveler, shipper, operator, and others whose lives are affected by the airplane. And these include a good part of mankind.

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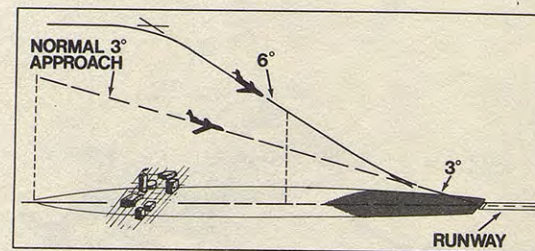
NASA AERONAUTICS

passenger comfort
convenience
economy



Comfortable, convenient, safe, and economical air travel in a time of increasingly crowded skies, steadily rising costs, and growing fuel scarcities are some of the vital challenges that NASA programs in Aeronautics are helping to meet. Meeting these challenges continues more than fifty years of NASA aeronautical research—research that has contributed significantly to United States world leadership in the development of civil and military aircraft. This leadership continues to make a major contribution to America's balance of trade through aircraft sales abroad.

NASA research on jet engines is helping to decrease substantially the noise levels of aircraft to make them better neighbors, so that airports can be built nearer to city centers. Door-to-door travel time for airline passengers can thus be shortened significantly.



Two-segment landing approach.

NASA is also experimenting with steeper aircraft landing approaches which keep the airplane higher over populated areas, thus lessening the noise reaching communities located near airports. The NASA-developed "two-segment landing approach" is being evaluated in regular airline passenger service. In practice, the aircraft descends on a steeper glide path during the initial landing approach and then assumes the normal path for the final approach and landing. It is anticipated that a 67 per cent reduction in the ground area impacted by objectionable noise during landing of the 727 jet transport aircraft will be achieved by the NASA two-segment approach.

NASA is paving the way for development of safe, clean, quiet, and efficient jet V/STOL (Vertical and Short Takeoff and Landing) aircraft for commercial airline service. Such V/STOL airplanes would require only small runways (or none at all), and thus could reduce substantially the congestion and associated passenger delays plaguing major U.S. airports and the critical need for additional large jetports. They would also permit fuller utilization of the present large metropolitan jetports for transcontinental and transoceanic airliners. Smaller, less congested V/STOL airports could be employed or developed for intercity flights of less than 500 miles. Such flights presently account for about eighty per cent of all air travel and are expected to triple in the coming decade.

V/STOL Quietports could be designed into community town areas, providing a welcome convenience for air travelers by reducing their travel time to and from airports. NASA is conducting wind tunnel tests, noise reduction studies, powerplant development, and flight operations research for V/STOL aircraft.

Among VTOL research projects is a joint NASA-Army Rotor Systems Research Aircraft. NASA is developing technology to increase helicopter performance, safety, reliability, and strength and to reduce noise, maintenance requirements, and vibrations. NASA is also preparing a flight program with a large helicopter (CH-53) to demonstrate use of current technology in reducing passenger compartment noise levels and vibrations to facilitate civil application of helicopters in feeder line transportation.

Another program involves automatic landings. NASA research engineers and pilots have achieved the first fully automatic landings at a predetermined spot by a full-scale manned helicopter. The landings were performed with laboratory-type equipment in a research environment to study performance

requirements for automatic VTOL aircraft operations in all-weather city-center-to-city-center service.

At a predetermined range from the landing point, the helicopter began automatic deceleration to zero ground speed, coming to a hover 15.2 meters (50 feet) over the landing spot. It then descended vertically to an automatic landing.

The accomplishment marked a major milestone in a continuing research program aimed at enabling helicopters and future VTOL aircraft to fly routine missions under poor visibility conditions—conditions which today cause flight delays, cancellations, and passenger inconvenience.

There have been a number of NASA studies on combining into one craft the cruising characteristics of the conventional airplane and the vertical lift and landing features of the helicopter. These include fan-in-wing and tilt-wing designs. The fan-in-wing model used rotors located in the aircraft's wings for takeoff and landing and regular propellers for cruising. The tilt-wing craft tilted up the entire wing for vertical takeoff and landing, and tilted forward for horizontal flight.

NASA recently initiated development of a tilt-rotor research aircraft for use in a joint NASA/U.S. Army "proof-of-concept" flight research program. The tilt-rotor aircraft concept uses large motors mounted at the aircraft's wing tips for vertical takeoff and landing like a helicopter. Once airborne, these same rotors are tilted forward to provide cruise propulsion like conventional turboprop airplanes. The combination of longer ranges and higher speeds [potentially in excess of 400 knots (460 mph)] with the utility of the helicopter shows considerable promise for improving U.S. short-haul air transportation by reducing airport congestion.

In STOL research, NASA is experimenting with new propulsive-lift

concepts whereby a jet engine's exhaust is used to add to the lift normally provided by airflow over the aircraft wings and flaps. High lift is a key to slower takeoffs and landings and use of shorter runways at smaller, more conveniently located airports. The slower terminal area speeds also enhance safety and permit bad weather minimums, which restrict airplane flights, to be safely lowered.

Another important NASA STOL goal is to make STOL aircraft good neighbors, environmentally acceptable, while providing convenience to air travelers. This program calls for development of new quiet, clean, short-haul engine technology for STOL aircraft.

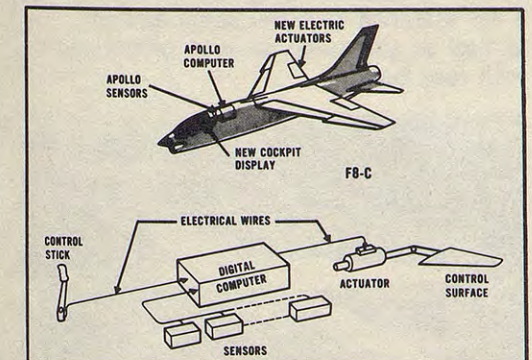
NASA's Terminal Configured Vehicle and Avionics Program uses a Boeing 737 as a "research support flight system" aircraft in research on present and future airport environments. The program is studying more efficient and quieter air paths in airport terminal areas and is investigating aircraft performance requirements, automatic systems, and displays to minimize pilot workload in the terminal area. The program is part of the efforts to provide better public transportation services by solving such problems as aircraft noise, airway and airport congestion, and the lack of all-weather operations capabilities.

NASA scientists are investigating the use of lasers in systems to warn pilots of two invisible menaces: trailing vortices (circular winds trailing from the wingtips of aircraft) and clear air turbulence. All flying aircraft generate trailing vortices, but large aircraft produce stronger ones.

For the present, the FAA requires a five-mile spacing between large and small aircraft approaching terminals for landings to allow time for crosswinds to break up the trailing vortices. This spacing restricts flight operations at major airports and contributes to passenger delays caused by airport congestion.

Clear air turbulence is caused by naturally occurring tempestuous air currents. These can unexpectedly add bumps to an aircraft's and passengers' rides even though the sky is cloudless. NASA has developed a laser system that detects clear air turbulence ahead of the aircraft, somewhat like radar is reflected off solid objects. With such early warning, airline pilots can steer clear of the turbulence.

The rising demand for and price of fuel make imperative development of aircraft technology that will increase flight miles per gallon. One design under NASA test uses an Apollo spacecraft electronic flight-control system, called fly-by-wire.



Design implications of fly-by-wire control systems.

Fly-by-wire is a fast-reacting computer-controlled electronic system that provides the exact amount of aircraft control response to soften the bumps, sways, and lurches of aircraft in turbulent air, resulting in safer, more comfortable passenger travel at high speeds.

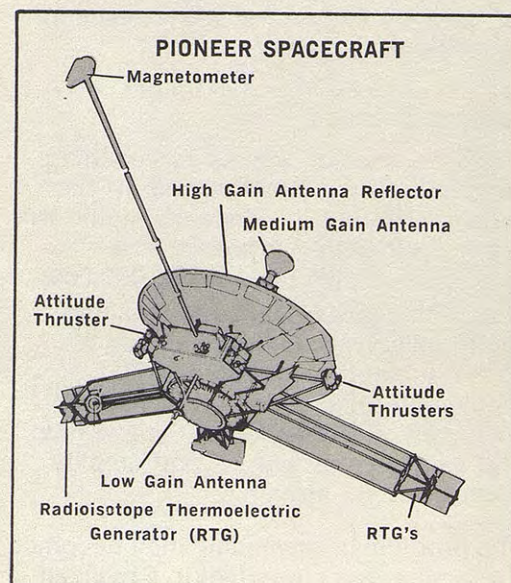
Because of its responsiveness, the fly-by-wire control system can be used in indirectly reducing aircraft loads and structural weight. Additionally, light weight wires replace the heavy system of metal rods, hinges, and hydraulic lines that previously translated the pilot's signals from the aircraft control stick to the control surfaces. This combined reduction in aircraft weight results in increased payload and

that Pioneer's radio signals, which like all radio signals travel at the speed of light, will take 45 minutes to come from Jupiter. This means that commands to Pioneer must have a lead time of 45 minutes and that any information requested from Pioneer takes 1½ hours to obtain. Lead time periods lengthen as Pioneer 10 cruises farther out into space.

If all goes well, Pioneer's voice will still be heard by NASA's supersensitive Deep Space Network stations with 64-meter (210-foot) diameter dish antennas when Pioneer crosses the orbit of Uranus—some 3.2 billion kilometers (2 billion miles) from Earth.

Spacecraft Description

Measured from its farthest ends, from the horn of its medium-gain antenna to the tip of its omnidirectional antenna, Pioneer 10 is 2.9 meters (9½ feet) long. Its widest cross-wise dimension, exclusive of booms, is the 2.7-meter (9-foot) diameter high gain antenna. Pioneer weighs 270 kilograms (570 pounds).



The spacecraft carries 11 instruments that gather data on atomic particle and other radiation, magnetic fields, temperatures, and meteoroids, and on chemical elements. In addition, two experiments will be carried out using the spacecraft and its communications system. One will help to refine estimates of Jupiter's, and perhaps Io's, atmospheric densities. The other will add to knowledge about Jupiter's mass, distance from Earth, and orbit around the Sun. Pioneer's electronic imaging system will telecast to Earth the first close-ups of Jupiter.

Pioneer 10 is the first NASA spacecraft to draw its power entirely from nuclear-fueled generators. Pioneer is cruising where sunlight is too dim for the practical use of solar cells which convert sunlight into electricity. Solar cells have been the primary source of power for most United States unmanned spacecraft to date. Pioneer has four radioisotope thermoelectric generators that turn heat from decaying plutonium 238 into electricity. The nuclear fuel is adequate to continue to supply more than 100 watts of power five years after launch. Pioneer carries at least one item that no previous unmanned spacecraft has had. Considering that Pioneer will leave the solar system and the possibility, however remote, that it might be captured by intelligent beings of another planetary system, scientists attached a special plaque to Pioneer 10. Diagrams, sketches, and binary numbers etched into the 152 × 229 millimeter (6 × 9-inch) gold-anodized aluminum plaque indicate when, where, and by what kind of creatures Pioneer 10 was launched.

Launch Vehicle

The launch of Pioneer 10 marks the first use of the Atlas-Centaur as a three-stage launch vehicle. The Atlas-Centaur

basically consists of an Atlas first stage, propelled by refined kerosene and liquid oxygen, and a Centaur second stage with super high energy liquid hydrogen as the fuel and liquid oxygen as the oxidizer. Attached to the forward section of Centaur for this launch was a solid-propellant third stage. The added stage was required to rocket Pioneer 10 to the speed of 51,810 kilometers per hour (32,400 mph) needed for a flight to Jupiter. This made Pioneer the fastest manmade object to leave Earth, fast enough to pass the Moon in 11 hours and to reach Mars orbit, about 80 million kilometers (50 million miles) away, in just 12 weeks. It took Mariner 9, the spacecraft assigned to study Mars from orbit, more than five months to reach Mars.

Among the many interesting observations announced during a Pioneer 10 press conference on June 8, 1972, were the following.

- The Gegenschein, a faint glow in the sky at a point directly opposite the Sun as seen from Earth, was ruled out as an Earth-associated phenomenon. It appears to be derived from sunlight reflected from small particles of matter in interplanetary space.

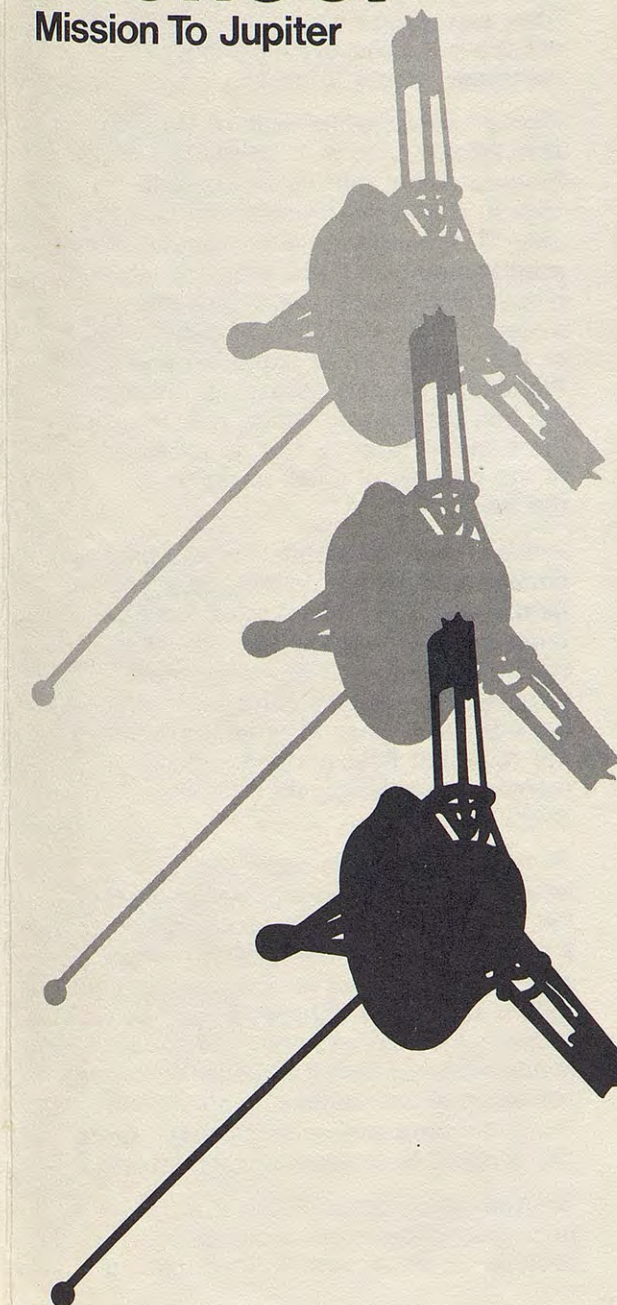
- A decrease in meteoroid hits on Pioneer as the spacecraft passed the orbit of Mars has tentatively confirmed the theory that there is a substantial planetary "sweeping" of matter in a planet's path. This theory holds that dust and larger particles near a planet's orbit are literally "swept up" by the planet's gravitational pull.

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Pioneer

Mission To Jupiter



Pioneer 10, launched from Kennedy Space Center, Fla., on March 2, 1972, is the first spacecraft assigned to probe the cosmic debris forming the asteroid belt and to observe at close range the colorful giant of the planets, Jupiter. After sweeping by Jupiter, Pioneer will escape our solar system—the first manmade object to do so.

Pioneer reached the orbit of Mars on May 25, 1972. Once beyond Mars orbit, Pioneer sailed into an unexplored region. It entered the asteroid belt on July 15. Among the perils it encountered are the innumerable fast-moving bits and pieces of asteroids which are either a stage in the formation of a planet or the residue of an exploded planet. Pioneer is helping assess the hazards the belt presents to spacecraft. It is also increasing the accuracy of estimates of the number of small particles in the belt.

In the vicinity of Jupiter, Pioneer may be endangered by the Jovian radiation field which is estimated to be a million times as intense as Earth's Van Allen Radiation Region. If Pioneer is not crippled by radiation damage, it will provide additional information about the radiation field and significantly increase knowledge about Jupiter itself.

Pioneer 10 will also send back information about interplanetary space up to the limits of the spacecraft-Earth communications system, which extends to the orbit of Uranus, about 3.2 billion kilometers (2 billion miles) away. Pioneer may also sample interstellar space matter, which is believed to invade the solar system beyond Jupiter, where the solar wind and solar magnetic fields are thought to weaken considerably.

Between the planets, Pioneer is providing information on nuclear particles such as cosmic rays rushing

into the solar system from interstellar and intergalactic space at speeds near that of light. Nuclear accelerators used on Earth in nuclear particle experiments can never match these speeds. Pioneer is also contributing to the study of the Sun's magnetic fields and how they link the atomic particles of the solar wind (mostly protons of the hydrogen atom) into a collisionless ionized gas, or collisionless plasma. When man can apply the process on Earth, he may be able to produce vast supplies of electric power without polluting the environment.

Jupiter—Giant Planet of the Solar System

Jupiter's mass is 318 times that of the Earth and more than twice that of all the other planets combined. Because it is mostly composed of hydrogen and helium, its comparative volume is even greater—about a thousand times the Earth's.

Jupiter appears to radiate four times the heat that it receives from the Sun, and scientists speculate that the heat may be derived from continuing gravitational collapse and radioactive elements in the planet's core.

Hydrogen—the most abundant element of the Universe and of the Sun—is also the most abundant element of Jupiter. Also identified are the simple compounds methane (hydrogen and carbon) and ammonia (hydrogen and nitrogen). Scientists believe that helium and oxygen are also present because they say Jupiter is a primitive planet and still contains all of the elements identified on the Sun. Another assumption is that Jupiter's oxygen combines with its abundant hydrogen to form water.

Scientists concluded years ago that life forms on Earth first appeared in the

planet's primitive environment of water, hydrogen, methane, and ammonia. In laboratory experiments on Earth, this kind of mixture, subjected to electric discharge, heat, or ultraviolet radiation, generates organic molecules. Vast discharges of electricity (lightning) probably occur on Jupiter; the planet radiates heat; and thus, a life-generation situation exists in Jupiter's environment.

The temperature of Jupiter is believed to climb steadily from -130°C (-200°F) at its cloud tops to an estimated $11,000^{\circ}\text{C}$ ($20,000^{\circ}\text{F}$) at its core. Between the two extremes, temperature, moisture, and atmospheric conditions may be hospitable for life forms. These conditions could occur somewhere within the dense clouds of Jupiter, and life forms may float or swim about.

Jupiter is blanketed by dense clouds with bands in bright hues of yellow-orange and blue-gray. The cloud bands appear to be visual evidence of atmospheric currents comparable to those on Earth. Detailed study of the cloud bands, made possible by Pioneer and future spacecraft, can increase

insight into the circulation of Earth's atmosphere and contribute to understanding of and accuracy in forecasts of weather and of changes in climate.

The circulation of the Earth's atmosphere is partially affected by the Earth's rotation which, at the equator, is at the rate of about 1600 kilometers per hour (km/hr) or 1000 mph. Jupiter's rotation is about 22 times as fast (35,200 km/hr or 22,000 mph.). Jupiter, despite its vast size relative to Earth, has a 10-hour day. Jupiter's fast rotation can theoretically provide, in a short time, a time-lapse picture of weather changes comparable to those during a longer period on Earth.

An intriguing feature of Jupiter is its mysterious Great Red Spot that drifts about and sometimes nearly disappears. Its nature may be determined by Pioneer and other spacecraft that make close-range observations.

The Jupiter Flyby and Beyond

In December 1973, Pioneer 10 will reach Jupiter, passing over two thirds of the planet during a hundred-hour flyby

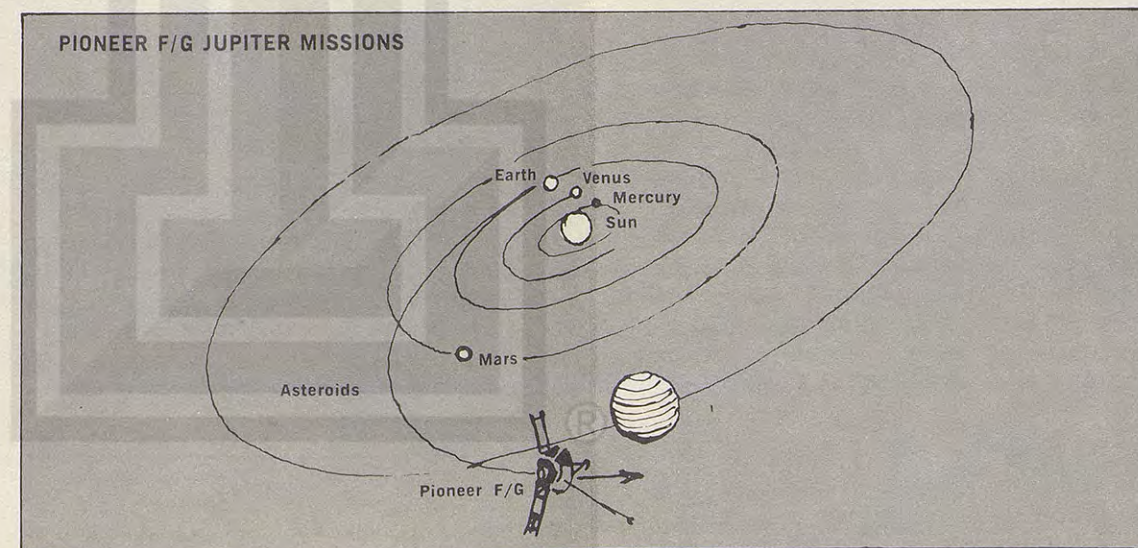
that will bring it as close as 140,000 kilometers (87,000 miles) to Jupiter's cloud tops. If flight directors can adjust its orbit properly, Pioneer will also pass behind the Jovian satellite, Io. Io, about as big as Earth's Moon, is orange colored and may have an atmosphere. Its shadow on Jupiter seems hotter than the surrounding sunlit areas, and its passage around Jupiter is marked by massive electric discharges (lightning) in Jupiter's atmosphere. As Pioneer goes behind Io, its radio waves will be affected by the satellite's ionosphere, if any. Analyses of the changes in the radio waves will tell whether and perhaps what kind of atmosphere Io has. A similar technique will be used to analyze Jupiter's atmosphere.

Jovian gravity will accelerate Pioneer from an approach speed of 33,000 km/hr (20,000 mph) relative to Jupiter to 126,000 km/hr (78,000 mph). The swingby of Jupiter will eventually leave the spacecraft with a speed of 41,400 km/hr (25,700 mph), enough to escape the solar system. In 1987, Pioneer is expected to cross the orbit of Pluto and journey among the star systems of the Milky Way galaxy.

Keeping In Touch

Pioneer's mission makes far-reaching demands on communications. At the distance of Jupiter, Pioneer's signal will reach Earth with a power of one-quadrillionth ($1/1,000,000,000,000,000$) watt. If this power were accumulated for 19 million years, it could light a $7\frac{1}{2}$ -watt electric light bulb for a thousandth of a second. But NASA's Deep Space Network can receive this and even fainter signals and amplify them to useful strength.

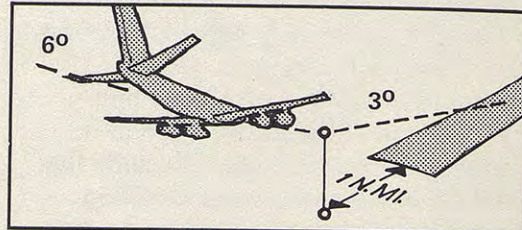
The problem of communication becomes even more complex when it is realized



highways and airports should be designed to operate.

A parallel effort involves the redesign of aircraft jet engines currently in use to reduce noise. The engine fan is undergoing design modifications which can reduce engine noise output. Noise can be further reduced by installing the engine in an acoustically treated nacelle. This program is intended to demonstrate that engines in airline-use today can be refitted to achieve significantly reduced noise levels.

Another project is seeking to reduce the impact of aircraft noise on the community by developing improved



flight approach procedures—the two-segment landing approach. The aircraft initially descends at a steeper angle as it approaches the airport. Landing noise levels are thus reduced by keeping the airplane higher when over populated areas. For engines of the future, NASA is developing technology for quieter propulsion systems.

Aircraft engine emissions cause air pollution problems in the vicinities of airports. NASA is conducting research aimed at markedly reducing polluting emissions such as nitrogen oxides, carbon monoxide, unburned hydrocarbons, and smoke. The goal is a 75 percent reduction in the levels of oxides of nitrogen, carbon monoxide, and unburned hydrocarbons produced by modern jet engines.

The possibility of using hydrogen as a fuel in some applications is also under study. This would eliminate carbon monoxide and hydrocarbons and, in addition, probably reduce oxides of nitrogen.

Applying NASA Technology

NASA technology used in aeronautical and space projects is being considered for use in developing advanced automotive propulsion systems and cleaner burning engines. Research is also being conducted on adapting liquid metal power conversion techniques for use in electrical power plants. These techniques could increase plant efficiency 10 to 15 percent and reduce fuel requirements and emissions by 25 to 40 percent. Such results would significantly conserve natural resources and reduce pollution.

In a joint project with another Government agency, NASA is investigating the concept of a modular utility system for an urban or community complex. The system would integrate power generation, water processing, and waste management. It would also recover some of the energy normally wasted in generating electricity and use it for heating, air conditioning, and solid and liquid waste treatment. The result will be lower water and fuel requirements, reduced combustion products, and less thermal pollution—all ecologically desirable.

NASA's work on water and waste recycling derives from programs which provide life support systems for manned spacecraft. Among its activities are systems experiments to reduce residential water and sewage

requirements and work on a process to convert sewage sludge to charcoal for fuel.

To manage the quality of our environment, we must be able to observe and measure pollution locally, regionally, and globally. The equipment and the technology for remote measurement of pollution are being developed and perfected by NASA, using spacecraft and aircraft. Sophisticated instruments on the Earth Resources Technology Satellite are already proving their capability to provide vital information for use and for continuing research. This research includes efforts to establish identifying characteristics of pollutants, to select sensing techniques, and to develop instruments. A project concerned with local measurements of pollution is investigating the use of a laser device to monitor smokestack emissions from a short distance. Such equipment would enable environmental agencies to observe and measure air pollution from industrial plants—which are responsible for 50 percent of the particulate and gaseous air pollution—without the need to enter the plant.

The activities discussed here are all part of NASA's environmental effort. They will be continued, and others will be initiated in a continuing research and development program to enhance the quality of life for all mankind.

improving our environment



National
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and
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

An increasing world population, rising standards of living, and a highly industrialized society are making demands on the environment which it may be unable to tolerate. The price of progress includes its by-products—polluted air and water, wasted materials and energy, crowding, and excessive noise. All detract from the quality of life and cause deterioration of the environment. However, we have become aware of the danger and of the need for action.

Our awareness of the importance of the environment was heightened by the Apollo astronauts view of the Earth. From their spacecraft, they saw "spaceship Earth" as a lovely blue planet traveling through space with all of mankind. Like Apollo spacecraft, spaceship Earth has its own environment and resources. The view from space made it clear that Earth's life support system is limited and fragile, and, therefore must be conserved and protected. Fortunately the knowledge and the technology to help protect the environment were already available in the space program.

Unmanned Spacecraft

In the early phases of the space program, before men were sent out to explore space, instrumented satellites studied the near-Earth environment. Data from these satellites led to the discovery of the Van Allen radiation belt, helped determine the shape of the Earth's magnetic field, provided counts and measurements of particles in space, and helped refine knowledge of the shape of the Earth. These and other discoveries

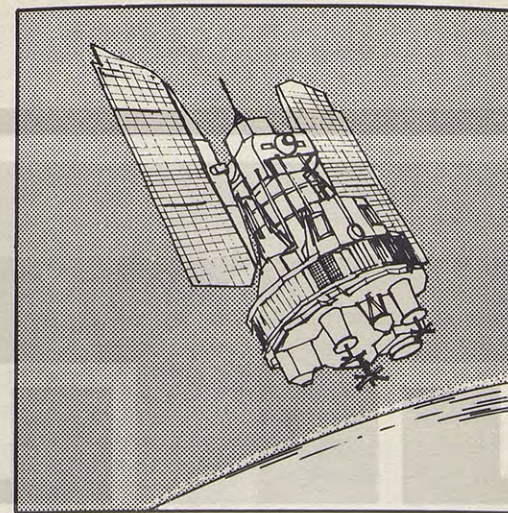
continue to help us better understand the forces that affect our environment.

Other satellites have returned information about the Sun and solar flares, about the solar wind, and about the relationship of Sun cycles to events on Earth. These have contributed greatly to our understanding of why our weather is affected by the cycles of activity on the Sun and why and how magnetic storms in space influence or interfere with communications here on Earth. Data from satellites also helped develop the theory that weather phenomena on Earth are influenced by solar particles injecting energy into the upper atmosphere.

Interplanetary spacecraft such as Mariners have provided close-up views of Mars and Venus that have drastically changed our concepts of these planets. In addition, interplanetary exploration is helping to increase our understanding of our own planet. One observation of significant interest to those concerned about Earth's environment was derived from the colossal dust storm which enveloped Mars when Mariner 9 arrived in mid-November 1971. The dust absorbed the Sun's heat, sharply dropping Martian surface temperatures.

The resulting data are being analyzed to determine what increase in particulate (for example, smoke and smog) pollution in Earth's atmosphere could trigger another disastrous Ice Age. Scientists already know that a seven-degree-Fahrenheit drop in average atmospheric temperature on Earth is enough to cause an Ice Age.

In addition, problems that complicate weather forecasting on Earth, such as the seasons, Earth's rotation, and



the world oceans, can be isolated and studied on other planets. Venus rotates slowly; has no oceans; and is covered thickly by clouds. Mars has no oceans, but its rotation and seasons are like Earth's. Jupiter's cloud bands resemble largely invisible atmospheric currents on Earth. Study of the atmospheres of these and other planets can be applied to increase knowledge about Earth's atmosphere and changes in Earth's weather and climate.

Earth resources satellites—spacecraft orbiting the Earth for long periods and providing images of its surface at regular intervals—are producing great quantities of usable information about our environment. Currently, ERTS-1 (Earth Resources Technology Satellite-1) is giving us a comprehensive view of our planet and the events on its surface. Launched in July 1972, the spacecraft circles the globe 14 times a day, viewing virtually the entire surface of the Earth once every 18 days.

The performance of ERTS-1 has far exceeded all expectations in its

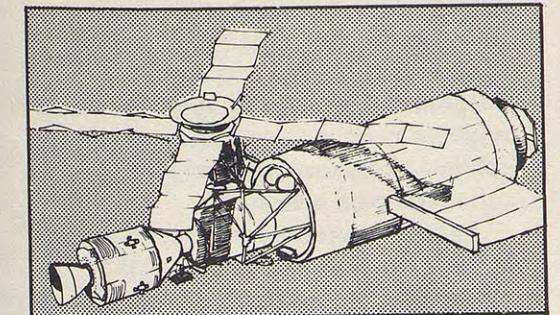
comparatively short lifetime. For example, it has discovered air pollution sources in urban industrial areas, some of them previously unknown to pollution-control authorities. ERTS-1 has also photographed water pollution, identified strip mines, and provided pictures from which land-use maps of cities and states can be prepared. The information ERTS is transmitting on natural resources has proved highly satisfactory. The satellite has recorded crops and croplands, provided data to refine a geologic map of petroleum provinces of Northern Alaska, and given indications of mineral deposits in other countries. Farmers will benefit from information derived from the ERTS color photographs which make it possible to identify crops and crop diseases, soil erosion, damaged or dead forests, and fertile, productive soils. Cartographers are already finding the mapping capabilities of ERTS valuable in saving time and money and in increasing accuracy of certain map types.

Skylab

Skylab is another major step in remote environmental research. This manned Earth-orbiting research laboratory is collecting information and conducting experiments to improve life on Earth. During its eight-month operational period, Skylab is being manned by three different crews. Duration of the first manned mission was 28 days, while the second and third are about eight weeks each.

The three-man crews live and work in an area about the size of an average

house with facilities for eating, sleeping, washing, exercising, and recreation. Working in a shirtsleeve environment, they conduct experiments in Earth observations, spacecraft environment, solar astronomy, stellar astronomy, space physics, geophysics,



biomedicine, zero gravity biology and zero gravity technology. Skylab objectives are to enrich scientific knowledge of the Earth, the Sun the stars, and cosmic space; to study the effects of weightlessness on living organisms, including man; to develop processing and manufacturing techniques which take advantage of the absence of gravity; and, perhaps most important, to devise methods of gathering information about the Earth's surface that will enhance the well-being of mankind.

Pollution

NASA also conducts research on such forms of pollution as aircraft noise and engine emissions. The noise studies are concerned with the effect of noise on people, human reactions to various levels of noise and ways of setting standards for measuring noise levels. Standards would enable communities to develop policies regarding noise levels at which

the Space Shuttle. Healthy individuals will be able to withstand the mild forces of acceleration and deceleration experienced when the shuttle is launched and reenters the atmosphere. In addition, the shuttle will be built and pressurized so that passengers such as scientists, engineers and others will be able to ride in ordinary clothing, as in an airliner. Also by lowering the cost of space operations, the shuttle will encourage more nations to participate in space activities. Such joint experiments, joint environmental monitoring, and perhaps other joint enterprises will contribute toward making the benefits of space exploration available to all people.

The shuttle will be launched vertically. The orbiter will separate from

its booster and go into orbit under its own power. When it accomplishes its mission, its pilots will fire its rockets to slow it down, fly it through the atmosphere, and land it like an airplane on a jet size airstrip.

The delta-winged manned orbiter will be about the size of a DC-9 airplane. The cargo compartment, which can accommodate experiments and passengers, will be about 4½ meters (15 feet) in diameter and up to 18 meters (60 feet) long. The orbiter will be able to carry cargo and/or passengers weighing in total as much as 29,500 kilograms (65,000 pounds).

The shuttle orbiter crew will consist of two pilots and two flight engineers. Maximum G forces on launch

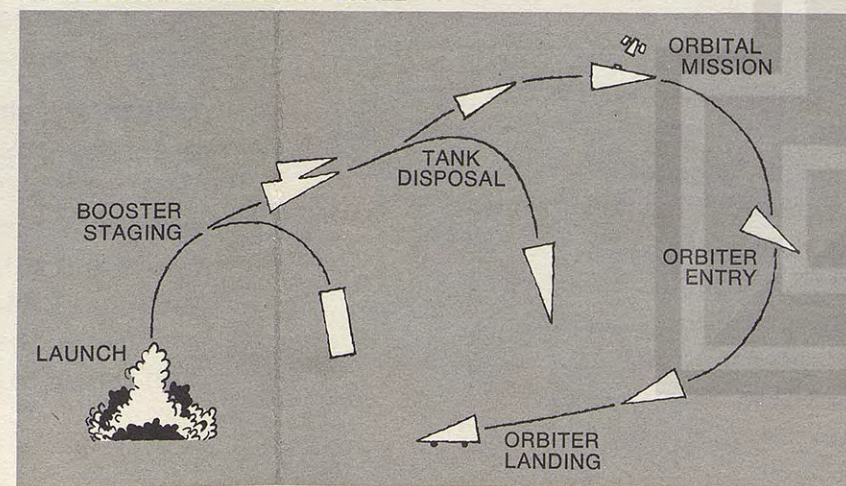
and reentry will be no more than a mild 3G.

The shuttle after entry will not have to follow a ballistic trajectory to the ground. It will be able to maneuver right or left some 1760 kilometers (1100 nautical miles). Each orbiter will be designed for reuse up to a hundred times.

The Space Shuttle is expected to be ready to play its major role in space by the end of this decade. It will then be used to launch all but the very smallest and very largest payloads. It will send some spacecraft into orbit from which the spacecraft's own rockets would send them into higher orbits or toward the Moon and other planets.

The shuttle represents an investment in mankind's future. It can provide dividends that will continue for decades to come.

SPACE SHUTTLE MISSION PROFILE

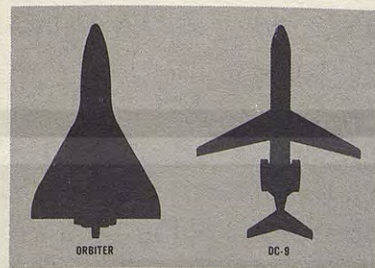


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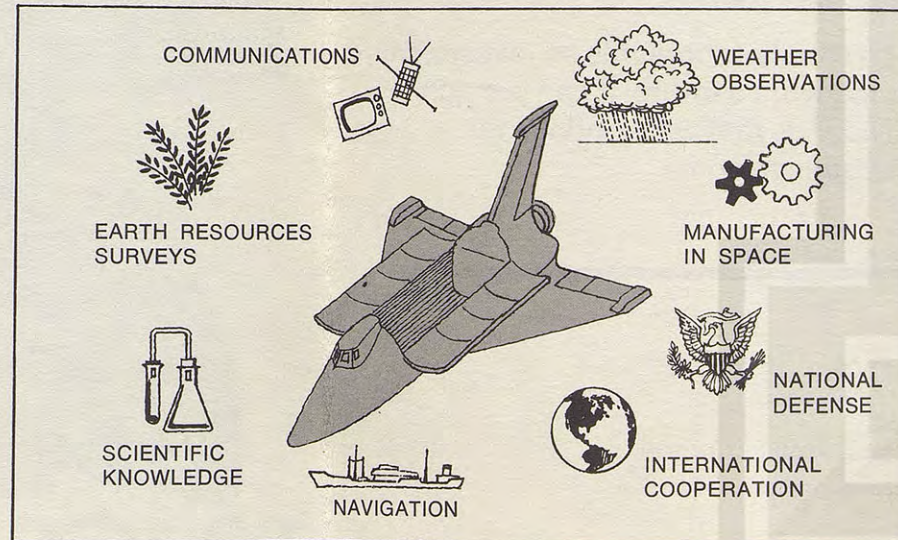
The Space Shuttle will be a space transportation system designed to carry out various missions in Earth orbit at a fraction of the cost of present systems. It will consist of two stages, a booster for launch from Earth, and an airplane-like manned reusable orbiter for flight into orbit where it will conduct space missions. Then, the orbiter will be flown back to land at a conventionally sized airstrip.

Four main reasons why the space shuttle is important have been presented by Dr. James C. Fletcher, NASA Administrator.



First, the space shuttle is needed to do useful things. The shuttle will be able to send most unmanned applications spacecraft into orbit; for example, communications, weather, navigation, Earth resources observation satellites and military spacecraft.

SPACE SHUTTLE USES



The uses of the space shuttle will include launching of unmanned spacecraft into orbit for missions such as those indicated.

It will also launch scientific spacecraft for study of space near and far. With the shuttle, men will supervise the launch and placement of the satellites and will be able to service and repair them as needed. Thus, launch vehicle and satellite failures, which require the construction of a whole new satellite, will become things of the past.

“The United States should proceed at once with development of an entirely new transportation system designed to help transform the space frontier of the 1970’s into familiar territory, easily accessible for human endeavor in the 1980’s and 1990’s . . . The continued pre-eminence of America and American industry in the aerospace field will be an important part of the shuttle’s payload.”

President Richard M. Nixon, January 5, 1972.

Second, the space shuttle is needed to make space operations less complex and less costly. Today, NASA has to mount an enormous effort for a space mission. And the costly launch vehicle is used but once. The space shuttle will launch payloads into Earth orbit at costs substantially less than the expense of current space operations.

The key to this cost reduction is that major parts of the shuttle system are reused rather than thrown away. Such a next step in space is appropriate and logical. After all, a trans-continental airliner is not discarded after a single trip. The shuttle will greatly reduce the cost and difficulty of preparing payloads because of its easier environment, its volume and weight capacity and its capability for retrieval and repair.

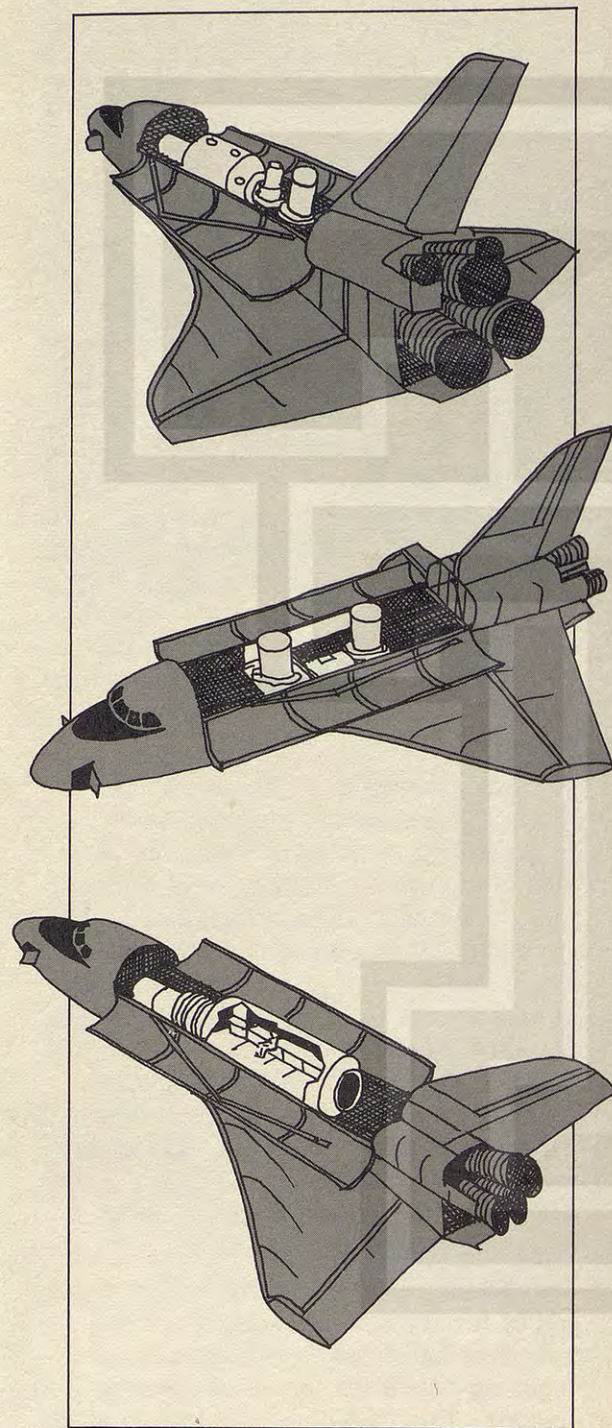
Third, the shuttle is the only meaningful new manned space program which can be accomplished on a modest budget. Man has worked hard to achieve freedom of mobility on land and sea, and in the air. In the past dozen years, he has gained the freedom of space. The Space Shuttle will extend man’s ability to do useful work in space while contributing to economy of space operations. The Space Shuttle will make launching of payloads into Earth orbit a virtually routine event.

Fourth, the shuttle will encourage far greater participation in space flight. With the shuttle’s easy and routine access to space, scientists, engineers and astronauts will be able to go into orbit to supervise and check on their space experiments. You don’t have to be an astronaut to ride

Earth Surveys. Comparisons of observations of the Earth's surface taken simultaneously with a variety of instruments yield information which is useful to meteorologists, oceanographers, and geologists and can be applied to such commercial activities as transportation, fishing, farming, and prospecting. While there will be immediate use of some Earth resources information gathered, the Spacelab will primarily provide for testing and developing instruments and sensors. Later, the perfected sensors and instruments would be installed on projected unmanned spacecraft for placement into orbit by Space Shuttles.

Astronomical Observations. Observations of transient celestial events, such as a comet passage, aurora borealis, and novae, as well as sustained study of the solar system and the universe are substantially improved above the Earth's obscuring atmosphere. Supplementing larger permanently orbiting instruments, the Spacelab missions offer the advantages of quicker response to opportunities and the use of simpler instruments which can be repaired or modified for subsequent flights.

Biomedical Applications. The extremely stable, gravity-free environment of a space laboratory should be ideal for several types of highly delicate separation methods used to isolate specific biological materials. Such methods may be used to obtain preparations of particular types of cells of high purity for transplantation, to prepare concentrated antibodies for treatment of specific diseases, or to purify materials such as vaccines to eliminate contaminants that can cause undesirable side effects. These techniques will be developed on a small scale initially to



support medical research, but if materials identified in such research are needed for large-scale use, they might be processed in space.

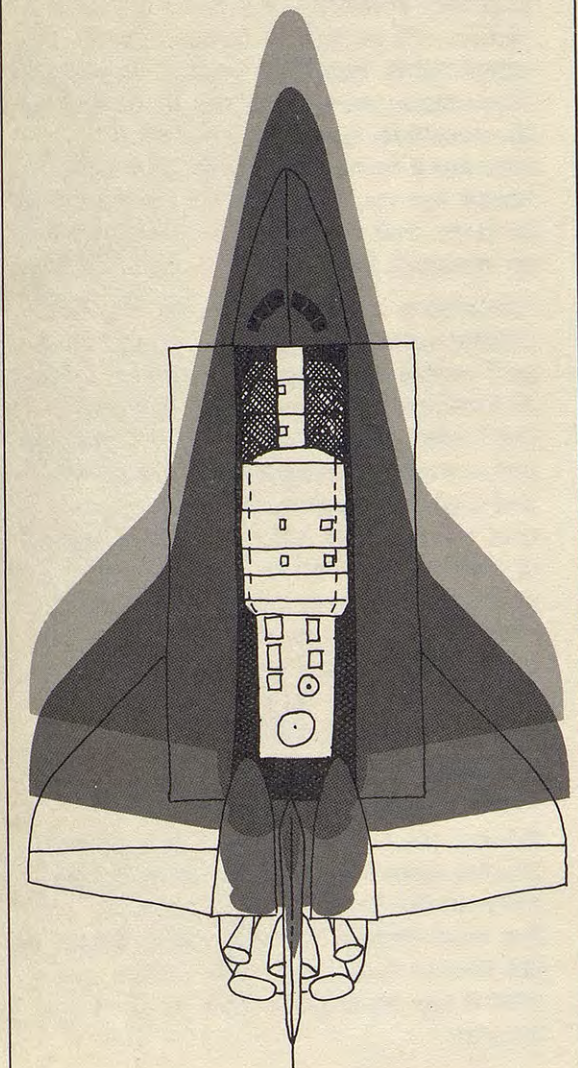
The Spacelab program lays a basis for greatly expanded international space participation. NASA and the European Space Agency (ESA) are continuing to make the benefits and the future availability of the Spacelab known to potential users in the international community. Furthermore, the Spacelab is being designed and built by European contractors, under program management by ESA, to combined European and United States requirements.

NASA's responsibilities for technical support of ESA in its development of the Spacelab are directed by the Marshall Space Flight Center in Huntsville, Alabama. Operation of Spacelab will be a United States responsibility.

A new and economically feasible mode of conducting orbital research with increased opportunities for mankind's benefit is soon to be at hand. The Earth Resources Technology Satellite (ERTS), Nimbus, and other automated satellites have tapped some of these potential benefits. Skylab missions with astronauts cross-trained in scientific disciplines have uncovered many new possibilities. With the Spacelab launched and recovered routinely as part of the Space Shuttle system, researchers from a wide variety of fields will be able to apply their own creative talents in orbit for the benefit of the world community.

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SPACELAB
SPACELAB



In the next decade, non-astronaut scientists, engineers and technicians will be able to conduct space experiments requiring in-orbit supervision. This unique opportunity will be offered by the reusable Spacelab, a spaceborne laboratory being built by the European Space Agency. Spacelab will be transported to Earth orbit by the NASA Space Shuttle for missions lasting 7 to 30 days.

Spacelab is a major element of the Space Shuttle system being developed to transport people and material more economically and routinely between the ground and Earth orbit. Improving on the technologies and operational experience of the Apollo and Skylab programs, the Shuttle concept substantially reduces costs of space operations by repetitive use of most of its major components. It also saves money for the experimenter because his instrumentation and equipment can be returned to Earth for reuse or repair rather than be abandoned in orbit.

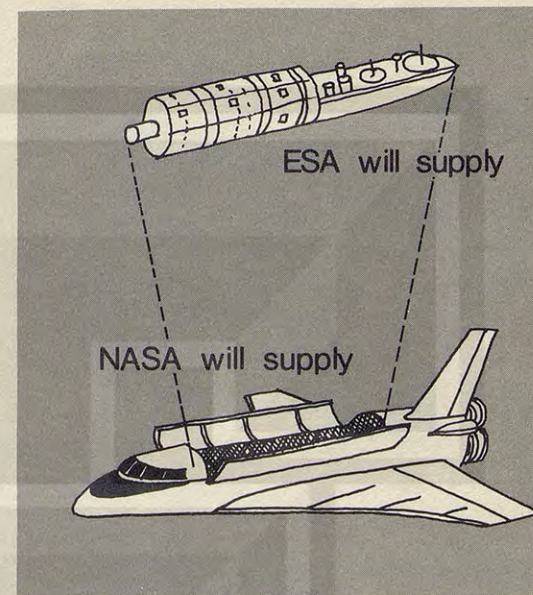
Spacelab will be transported in the 4.5x18-meter (15x60-foot) cargo bay of the Orbiter, the orbiting element of the Space Shuttle system. Upon completion of each mission, the three astronaut pilots will fire retro-rockets to lose orbital speed, fly the Orbiter through the atmosphere, and land it like an airplane on a jet-sized airstrip.

Spacelab will have facilities and equipment similar to laboratories on Earth but adapted for zero gravity. In any of several configurations to meet specific experiment requirements, it will provide a shirt-sleeve environment, like that in a passenger airliner, for both male and female experimenters. Spacelab will remain attached to the Orbiter, where the experimenters will eat and sleep, throughout the mission. On return to Earth, Spacelab will be removed from the Orbiter and outfitted for its next assignment.

The Shuttle/Spacelab relationship is analogous to the large tractor-trailer combinations seen on the nation's highways. While the several trailers (Spacelabs) are in various stages of preparation for use, a relatively few tractors (Shuttles) are needed to transport the assembled payloads, thus assuring maximum utilization of the more intricate transportation (Shuttle) stage. The Spacelab can be outfitted at the user's facilities. It is more likely, however, that individual experiments will be brought to a central location and integrated into a particular Spacelab.

Spacelab is conceived as having two main elements: the pressurized laboratory module and an external instrument platform, or pallet, for large man-directed instruments such as telescopes or antennas requiring direct exposure to space or a broad field of view.

Pallet-mounted instruments normally will be supplied and controlled from within the pressurized module but could be attended from the Orbiter cabin in a "pallet-only" mode. The pallet, of course, can accommodate a variety of experiments where manned attendance is unnecessary but certain services, such as temperature control and electrical power, are needed.



Both the pressurized portion of Spacelab and the pallet are modular in concept so as to be able to adjust to varying demands.

To meet a variety of experimental needs within the pressurized module, each Spacelab will include such features as: standard laboratory instruments; equipment racks; work benches; windows; data recording and processing equipment; and extendable booms for remote positioning of experiments requiring special placement. Several kilowatts of electrical power in both AC and DC form will be available. Continuous voice and data transmission capability is contemplated to allow experimenters to maintain contact with colleagues on the ground for consultation and rapid reorientations.

The research people who fly on Spacelab will be healthy men and women of many nations, qualified in their field, and requiring only a few weeks of specialized training. This training will include briefings

on flight plans and procedures; familiarization with zero gravity; exercises in space-flight housekeeping and emergencies; and total system simulation.

Because these researchers will be conducting their own experiments in orbit, the quality and reliability of the results are expected to be high. In many cases, the experimenters will be able to go home with the acquired data immediately after landing. As many as four research people may staff a Spacelab mission.

There will be many uses for Spacelab. Among them are the following:

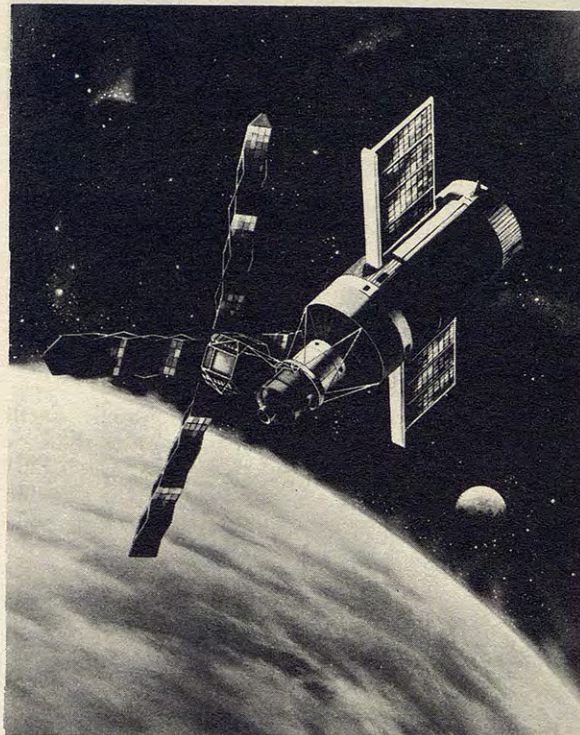
Zero-g studies in life sciences. Space flights to date, by isolating the effects of gravity, have indicated interesting changes in man and suggested that there are metabolic and associated changes in plants and animals. Repetitive studies of these phenomena will add to knowledge of medicine and contribute to the advancement of understanding of fundamental mechanisms in life processes.

Materials Science and Technology. The absence of gravity in an orbiting laboratory will open new vistas for applied research on materials and orbital manufacturing operations. For example, ultrapure metals, semiconductors and glass may be produced, by processing free of contact with containers, for research use and applications in such areas as electronics, laser technology, and optical products. Greatly improved crystals may be produced for computers, communications, and other electronics uses. New types of composite materials with increased strength at high temperatures may be produced, and new knowledge about materials may be acquired to advance processes used on the ground.

Astronomy

The Earth's obscuring atmosphere has limited the effectiveness of astronomical observations since Galileo's time. By transferring observation equipment to space, outside Earth's envelope, man has acquired the capability to investigate celestial mechanisms which affect life on this planet.

Astronomers have discovered additional X-ray emissions from various regions of space, detected ultraviolet and soft X-ray energies coming from the Sun, and discerned radio waves emanating from Earth that resemble waves which appear to be coming from Jupiter.



Subsequent space projects will further assist astronomy by carrying instruments of larger size and enhanced capabilities. From this research and investigation will come a better understanding of the Universe, and the Earth-Sun-Moon relationships which affect our lives.

Earth Resources

A new and comprehensive view of Earth's resources is offered man for the first time from space. Every chemical element reflects or radiates a

distinctive signature across a spectrum of wave lengths, not unlike the fingerprints of man. Photography by film sensitive to these radiations provides hitherto unavailable information concerning natural resources. Thus with the proper use of this information, a pattern of resource supply can be matched with resource demands.

Through space-borne observation, our geologic knowledge investigates Earth's composition, structure, stratigraphy and history. Geologic features can be mapped regionally. Eventually, with the help of laser reflectometers carried to the Moon by Apollo, we can develop methods for monitoring and predicting natural disturbances such as earthquakes and volcanic upheavals.

Mineral resources — iron, copper, gold — and non-metallic deposits — sand, gravel, limestone, oil and gas — can be detected and measured from space.

Electromagnetic energy and the electrical properties of rocks and terrain are even more effectively observed from space than from the limited height of aircraft observation. Gemini and Apollo photographic observations provided the first, all-inclusive views of the Himalayas and the Andes, the practical applications of locating new oil deposits in Australia, and a photo mosaic of Peru more accurate than any map.

Oceanography

Two-thirds of Earth is covered by oceans. They can be seen in their vastness only from a distant point in space. Just such a view can be utilized to increase our understanding of the oceans, to utilize them as a medium of transport, to detect their influence on weather and climate, and to evaluate them as food sources.

Several techniques of collecting oceanic data by satellite are in use or development:

State of the sea — relationship between wave height and wind force

Thermal conditions and temperature of the sea surface

Sea ice — one of the first oceanographic features pictured by the first U. S. meteorological satellite, TIROS, in 1960

Location of currents and water masses by thermal characteristics and coloration

Mapping coastal areas — an aid in detection of shifts in shoreline resulting from flood and storm

Movement of biological phenomena in the oceans, discernible by heat or color, implies a possible relationship between concentrations of fish and marine organisms — of great value to commercial fishing and the wise use of resources.

Bonuses

The spinoff of space technology runs the gamut from new industries to better smoking pipes.

Medicine has been one of the biggest beneficiaries of space research. The merging of bioscience and engineering forced by the demands of adapting man to space created many new medical devices and techniques.

Dry, spray-on electrode techniques permit taking an electrocardiogram in the ambulance enroute to a hospital. Sensors smaller than the head of a pin can be inserted into a vein to measure blood pressure without interfering with circulation. An automatic living cell analyzer can produce almost instantaneous blood counts. A switch can be operated by the eye movement of a paralyzed patient. A telemetry unit monitors cardiac patients in intensive care.

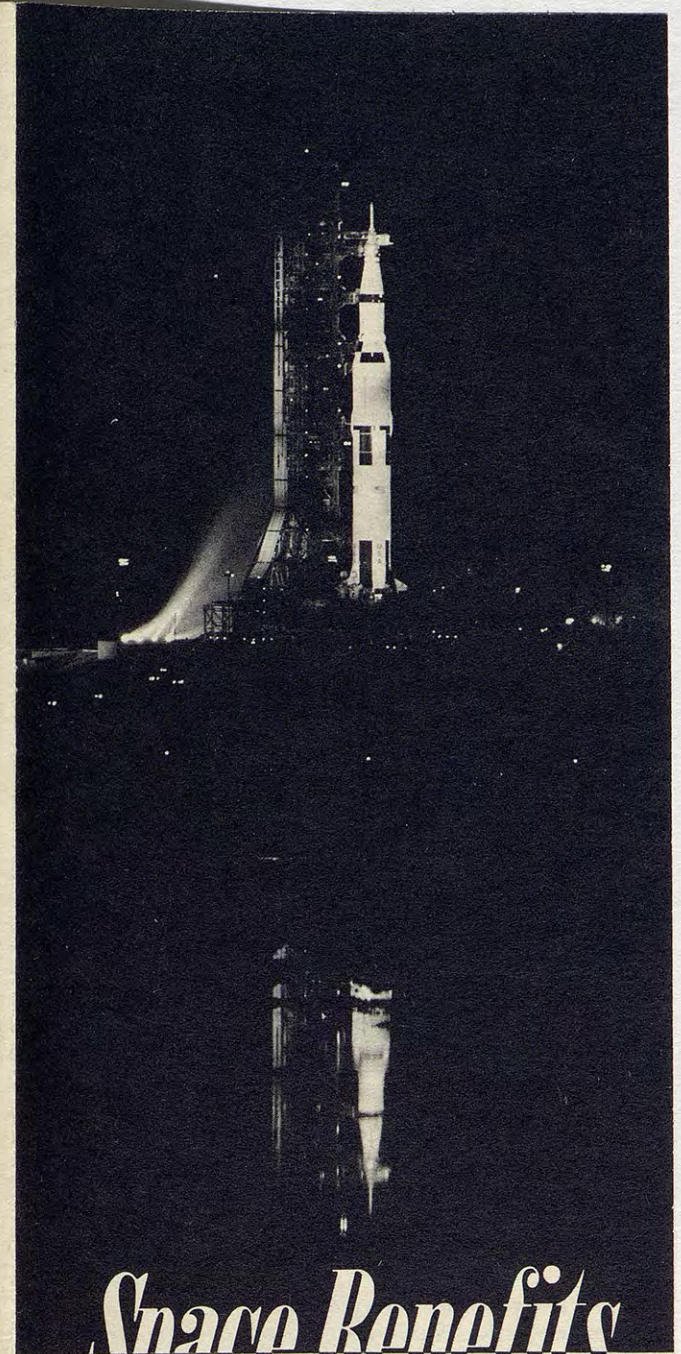
A new type of pipe, built of plastic mortar, reinforced with fiberglass, is light, thin-walled, non corrosive and virtually indestructible. A polyurethane spray foam is used to insulate the hull of a tuna ship. An aluminized plastic half a thousandth of an inch thick becomes an emergency blanket.

An electromagnetic hammer is used to build ships and autos. There is a new plastic material for packaging meat. Foamed resins have been used to refloat sunken ships. Better adhesives bond auto trim. A fire resistant material transforms into soft and resilient garments. Semi-conductors three-sixteenths of an inch thick contain more than 1,000 circuits. An anti-skidding device has been applied to trucks. Computer programming has been adapted to such diverse uses as an instant flight and reservations system for airlines and the rapid handling of stock market transactions.

Other and less tangible spinoffs from space have been catalogued. Basic knowledge has been enriched in many fields — in biosciences, physics, geology, astronomy, and engineering. Space has been our best salesman abroad. It has demonstrated our capabilities, our good will, and enhanced U. S. prestige throughout the world.

The transfer of new knowledge derived from space exploration continues both by intent and coincidence. The possibilities exceed our ability to predict them.

NATIONAL AERONAUTICS
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Space Benefits
today and tomorrow

"The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind."

Section 102 (a)
National Aeronautics and Space Act of 1958

Why is the United States Exploring Space?

The Space Act of 1958 adopted by the Congress and signed by President Dwight D. Eisenhower determined that the nation would develop and utilize space transportation systems for the acquisition of knowledge, for national defense, and in the interest of peace.

The law established the foundation for a two-fold program. One is conducted by the Department of Defense and is related to protecting the nation from attack through space. The other is conducted by the National Aeronautics and Space Administration in the pursuit of knowledge and the application of that knowledge to benefit mankind.

Our progress today, as in the past, depends upon exploration of unknowns.

What Has the United States Accomplished?

The charge placed upon Defense and NASA by the Congress in 1958, and supported by succeeding Administrations and Congress since then, required the development of rockets, engines, launch facilities, guidance systems, data acquisition systems, tracking and communications systems, and spacecraft which could perform effectively in a largely unknown environment over vast distances, and some of which in combination could transport men and their Earth environment to and from the Moon.

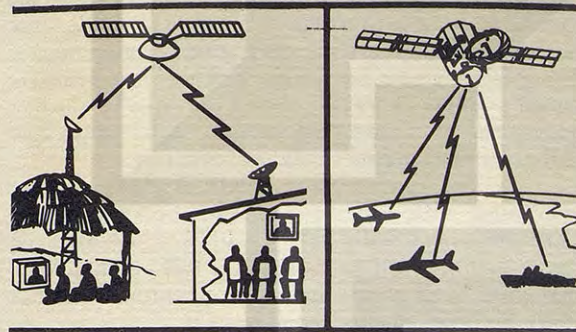
All of these things have been accomplished by the integrated efforts of Government, science, and U. S. industry.

New Tools for Mankind

The prodigious research, development and manufacturing effort harnessed by Government under the terms of the Space Act has spawned many tools useful to mankind and placed at man's disposal new technology which will be applied here and abroad to produce novel and better products for society. Advances in computers, miniaturization, electronics, exotic materials, and many other by-products have become part of our way of life almost without recognition.

Communications

The Earth-revolving communications satellite has within a decade progressed from novelty to an operational tool. Every television viewer knows that he sees and hears events occurring across continents and oceans because of satellite relay. One communications satellite transfers 9,000 phone calls, 12 color television programs, or any combination, between North and South America, Europe and Africa. Relay costs approximate \$4,000 per channel per year compared with \$25,000 per year by submarine cable.



Seventy-six nations own the International Telecommunications Satellite Consortium, for which NASA places satellites in orbit. The network has 42 ground stations in 29 countries, leases 2,000 circuits full time and relays 1,000 hours of television around the world every year. Its financial success alone demonstrates the commercial potential of space.

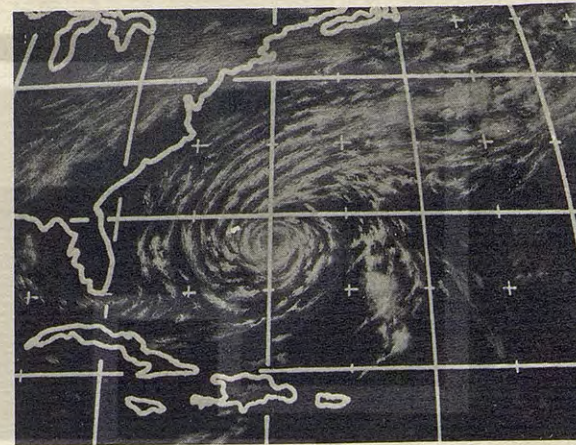
Weather

The most significant advances in weather reporting of this century, perhaps even since the invention of the barometer, were achieved through progressive development of meteorological satellites to a fully operational system which supplies data to the National Weather Service.

Global weather reporting through international participation has been expanding for 75 years, but, until the advent of weather satellites, the weather information came from less than 20 percent of Earth. The other 80 percent, primarily the oceans, was covered only by scattered observations.

In the early 1960s, the weather satellite made possible observation of the entire surface of Earth on an all-encompassing basis. What the satellite saw and measured was immediately transmitted to ground stations, permitting the expert interpretation of data on a timely basis. Today's orbiting spacecraft, equipped with cloud cover cameras, enable man to observe the atmosphere continuously and to track severe

storms. Four satellites, properly spaced above and around Earth, would monitor nearly all of Earth's cloud cover all the time.



Fifty nations use the information provided by the network of U. S. satellites, launched by NASA for the National Oceanographic and Atmospheric Administration. During the next decade, advanced satellites and computer networks will provide reliable long range weather predictions of two weeks or longer. Eventually the weather satellite could be one of several devices which will make possible weather control and modification. The satellites observe air pollution as well and can become an invaluable tool in reporting the transport and diffusion of pollutants and the effects of weather and climate in its creation and dissipation. Land, sea, air and space transportation operations will proceed with enhanced safety and efficiency because of timely and reliable weather data.

Navigation

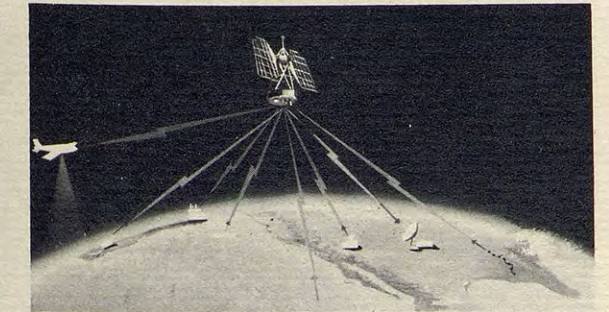
Navigation of ships and aircraft requires the determination of exact position, the direction and rate of movement from one point to another, and the ability to communicate that information. Navigation via satellite fills this need admirably.

Satellite navigation systems can provide global coverage and are practically invulnerable to weather, available day or night, and provide instantaneous response.

Earth orbiting satellites discern ship and aircraft positions much more accurately than earlier systems. Such a capability is vital for traffic control in today's fast-moving environment of air traffic. With satellite assist, ground controllers can pinpoint a jet liner's position within approximately one mile.

Agriculture

Aerial photography ushered in a new era of crop and forest observation, but its capabilities were limited when compared to those of the satellite. The orbiting device permits regular, periodic observation in routine operation from distant, all-inclusive views which can make use of multi spectral scanners, infrared sensitive film, television and conventional photographic techniques.



With the aid of satellites and their remote sensors, man can better manage crop and timber resources. He can monitor the state of their health, determine the best time to plant and harvest for maximum yields, detect potential damage to crops from blight or infestation, help improve land use, inventory crops during growth, and have advance warning of drought, erosion and floods.

NASA is forging ahead in developing Earth resources sensing systems in cooperation with the U.S. Department of Agriculture, the U. S. Geological Survey, and many State Governments. The possible applications of satellite observation cover a wide field:

Range surveys	Crop disease and insect detection
Forest fire detection	Agricultural development projects
Land use changes	Watershed and hydrologic studies
Crop identification	Forest disease and insect invasion
Soil classification	Crop acreage control programs
Natural vegetation	Forest species identification
Flood control survey	Recreation site evaluation
Wildlife habitat	Irrigation development



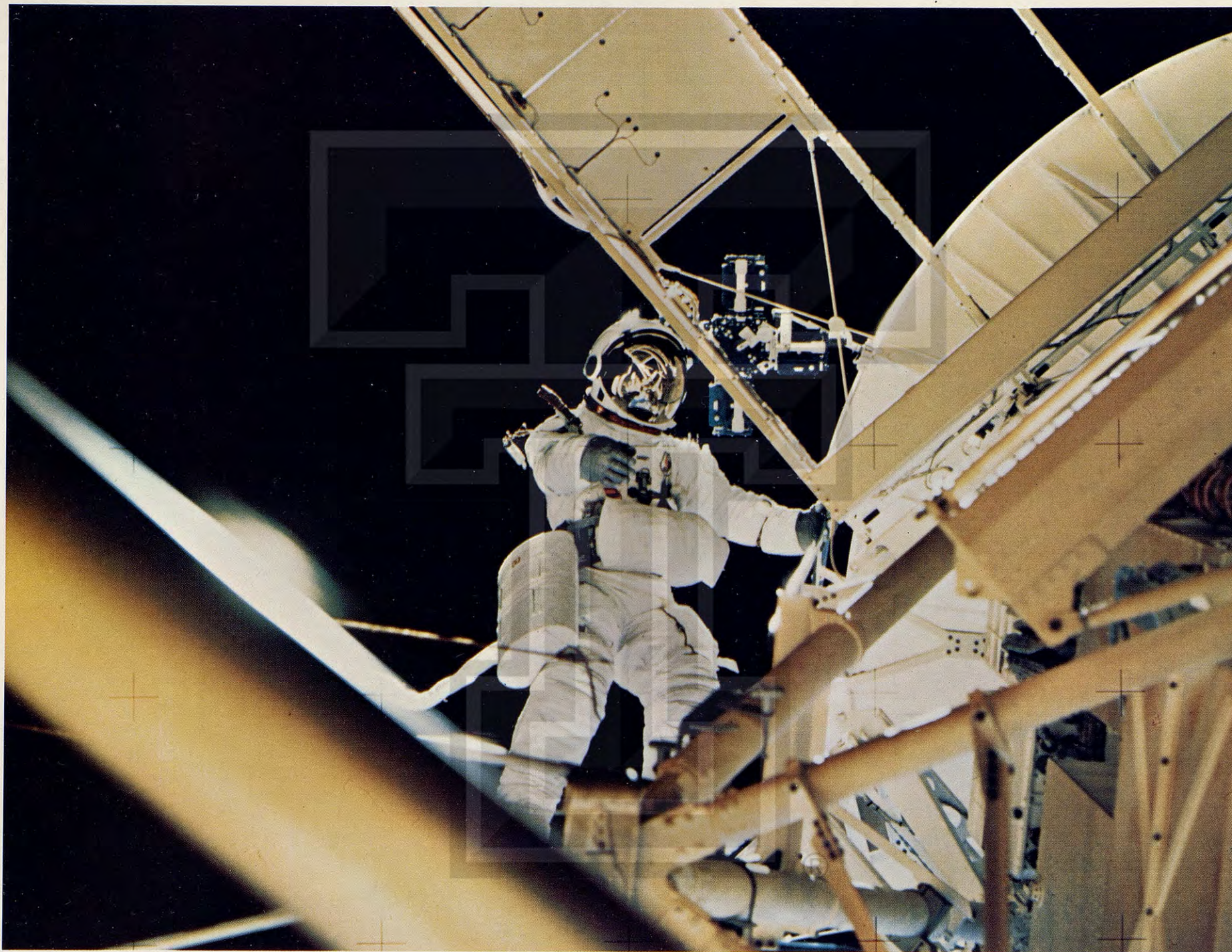
PRIME CREW OF THIRD MANNED SKYLAB MISSION
Gerald P. Carr Edward G. Gibson William R. Pogue



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THIRD MANNED SKYLAB CREW—These three astronauts are the prime crew of the third manned Skylab mission. They are, left to right, Gerald P. Carr, commander; Edward G. Gibson, science pilot; and William R. Pogue, pilot. Skylab will evaluate systems and techniques designed to gather information on Earth resources and environmental problems. Solar telescopes will increase man's knowledge of our Sun and the multitude of solar influences on Earth environment. Medical experiments will increase knowledge of man himself and his relationship to his earthly environment and adaptability to space flight. Additionally, Skylab will experiment with industrial processes which may be enhanced by the unique weightless, vacuum environment of orbital space flight. The third manned Skylab mission will last up to 56 days.





ASTRONAUT GARRIOTT PERFORMS SKYLAB 3 EVA



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SKYLAB 3 EVA PHOTO—Scientist-Astronaut Owen K. Garriott, Skylab 3 science pilot, is photographed performing extravehicular activity at the Apollo Telescope Mount of the Skylab space station in Earth orbit. Garriott had just deployed the Skylab Particle Collection S149 Experiment. The experiment, the blue panels, is mounted on the rim of the ATM, directly above Garriott's head. The purpose of the S149 experiment is to collect material from interplanetary dust particles on prepared surfaces suitable for studying their impact phenomena. Earlier during this EVA Garriott assisted Astronaut Jack R. Lousma, Skylab 3 pilot, in deploying a twin pole solar shield.

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JSCL-114



COMET KOHOUTEK FROM ASTRONAUT SKETCHES AND DESCRIPTION



MSFC - 74 - SL-7200 - 401B

HOW COMET KOHOUTEK LOOKED TO SKYLAB 4 CREW



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KOHOUTEK PROGRESS — A composite of six drawings made from astronaut sketches and descriptions illustrating the progress of the Comet Kohoutek. The Skylab 4 crewmen monitored the comet during their mission in Earth orbit. Sketches by the crewmen accompanied by their commentary helped ground-based scientists better understand the status of Kohoutek. The Comet Kohoutek passed the Sun on December 28, 1973 (perihelion) at a distance of about 20,800,000 kilometers (13 million statute miles). The date appears along with each of the six sketches. The National Aeronautics and Space Administration with its "Operation Kohoutek" studied the comet with an extensive array of electronic eyes from the ground, Skylab, high-flying aircraft, unmanned spacecraft and sounding rockets.



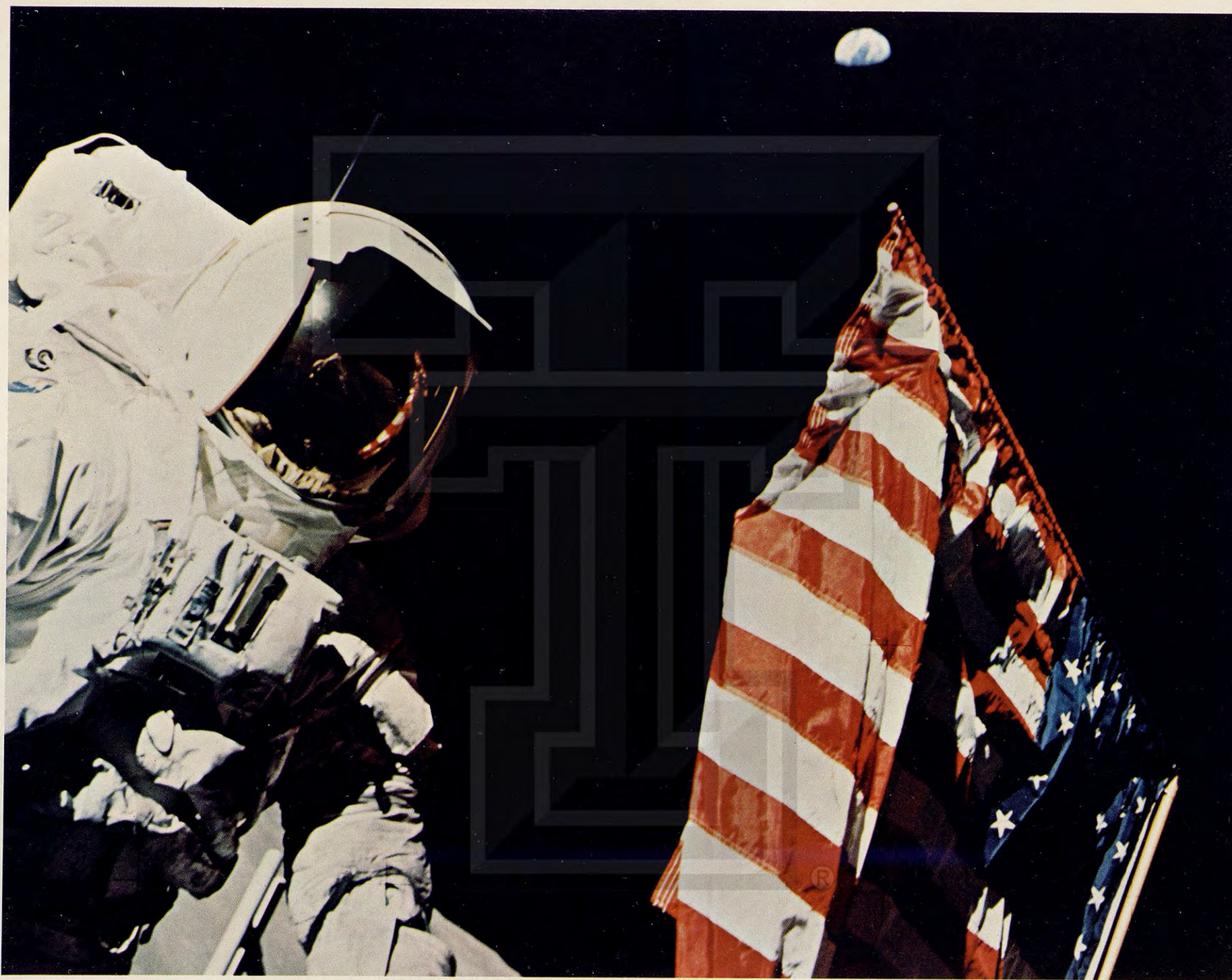


SKYLAB SPACE STATION AS SEEN FROM SKYLAB 4 CSM



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SKYLAB 4 ON-BOARD PHOTO — An overhead view of the Skylab space station in Earth orbit as photographed from the Skylab 4 command service module during the final fly-around by the CSM. The space station is contrasted against a cloud-covered Earth. One of the Orbital Workshop solar array system wings is missing. A solar shield was deployed to cover a portion of the OWS where a micrometeoroid shield was torn off. The damage to the space station occurred during the Skylab 1/Saturn V launch on May 14, 1973. Aboard the Skylab 4 CSM when this 70mm Hasselblad picture was taken were Astronauts Gerald P. Carr, Edward G. Gibson and William R. Pogue. Note the small white area in the sail which was recently opened. This area is representative of the material before exposure to the solar rays and atmospheric conditions.

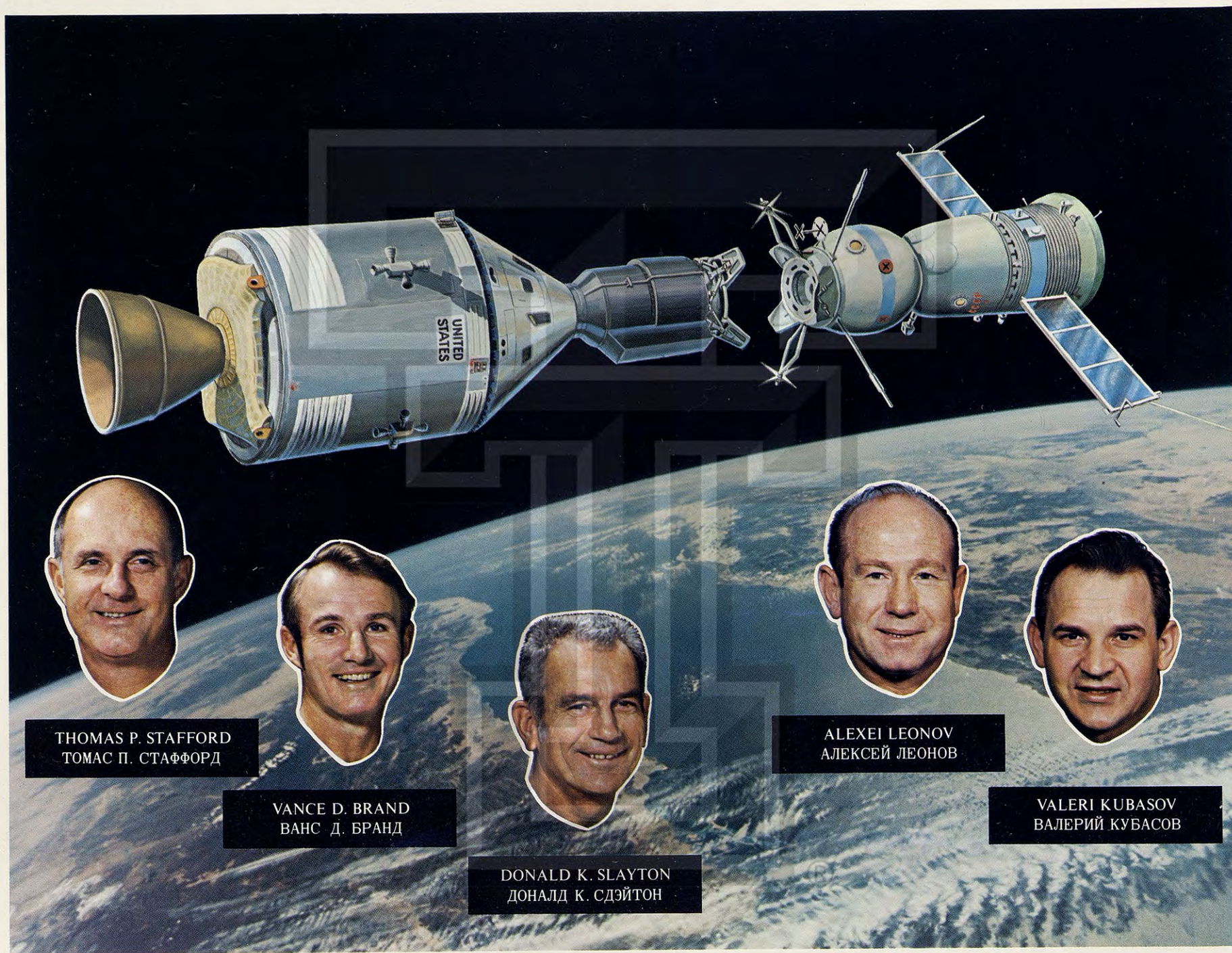


U. S. FLAG "POINTS" TOWARD EARTH



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APOLLO 17 EVA PHOTO—Scientist-Astronaut Harrison H. “Jack” Schmitt stands next to the deployed U. S. flag during lunar surface extravehicular activity at the Taurus-Littrow landing site. The highest part of the flag appears to point toward the Earth in the far distant background. This picture was taken by Astronaut Eugene A. Cernan, Apollo 17 commander. Schmitt is the mission’s lunar module pilot.



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ВАЛЕРИЙ КУБАСОВ

CREWS FOR APOLLO SOYUZ TEST PROJECT
ЭКИПАЖИ ЭКСПЕРИМЕНТАЛЬНОГО ПОЛЕТА АПОЛЛОН/СОЮЗ



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CREWS FOR APOLLO SOYUZ TEST PROJECT

ЭКИПАЖИ ЭКСПЕРИМЕНТАЛЬНОГО ПОЛЕТА АПОЛЛОН/СОЮЗ

Apollo Soyuz Test Project, a joint manned space flight between the United States and the Soviet Union, is scheduled for mid-1975. A Soyuz spacecraft will be launched into Earth orbit from the Soviet Union with a two-man crew; 7 1/2 hours later, an Apollo spacecraft from the United States with its three-man crew will be launched and will rendezvous and dock with the Soyuz spacecraft.

The mission objective is to test the compatibility of systems for rendezvous and docking future manned spacecraft and stations and thus improve future space rescue capability.

Prime crew for the Soyuz spacecraft of the USSR consists of Alexei Leonov, Commander, and Valeri Kubasov, Flight Engineer. Leonov was born in 1934 in the village of Listvyanka in the Kemerovo region. He was in the first group of Soviet cosmonauts and on March 18, 1965, he stepped from the Voskhod-2 to become the first man to "walk in space." Valeri Kubasov, born in 1935, in the town of Vyazniki in the Vladimir region, will be the flight engineer. He was a crew member of the Soyuz-6, in October 1969, and conducted a successful series of experiments that included welding material in space.

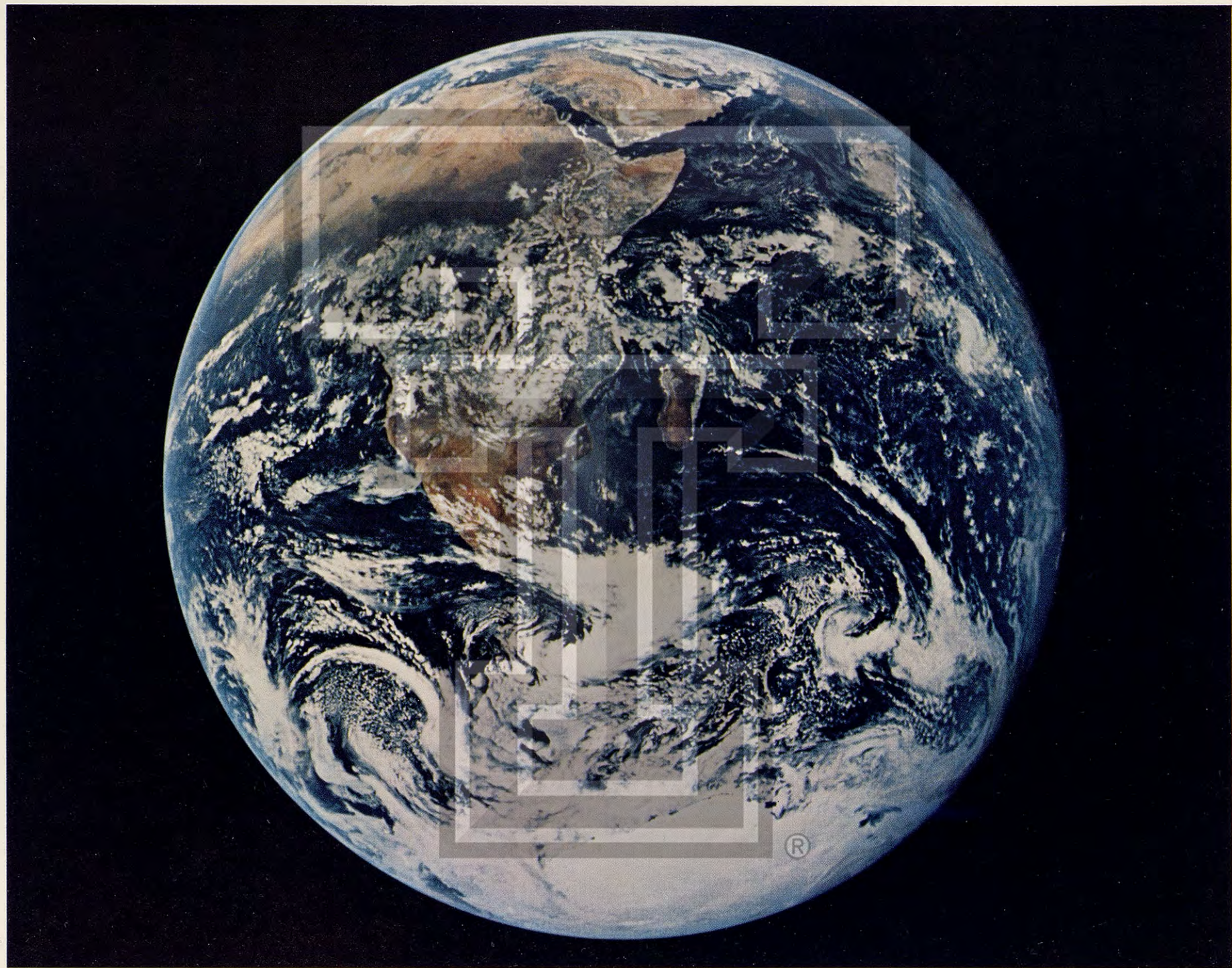
The Apollo prime crew will include Thomas P. Stafford, Commander; Vance D. Brand, Command Module Pilot; and Donald K. Slayton, Docking Module Pilot. Stafford, born in Weatherford, Oklahoma, September 17, 1930, was in the second group of astronauts chosen in 1962. He has made three flights into space on Gemini 6, Gemini 9, and Apollo X. Vance D. Brand, Command Module Pilot, from Longmont, Colorado, was born May 9, 1931. He was selected in April 1966 as one of 19 astronauts chosen at that time. Although he served on backup crews for the Apollo flights, this will be his first trip into space. Donald K. Slayton was born March 1, 1924, in Sparta, Wisconsin. He was one of the original seven astronauts chosen for the Mercury Program in 1960. He served as Director of Flight Crew Operations at the Johnson Space Center from 1963 through 1973 and was responsible for flight crew training and crew procedures for all US Mercury, Gemini, Apollo, and Skylab flights during this period. This will also be his first space mission.

Экспериментальный пилотируемый полет космических кораблей "Аполлон" и "Союз", совместно проводимый США и СССР, состоится в Июле 1975-ого года. Из Советского Союза будет запущен на орбиту космический корабль "Союз" с экипажем состоящим из двух космонавтов; 7 1/2 часов спустя, из Соединенных Штатов космический корабль "Аполлон", с экипажем состоящим из трех членов, будет доставлен на орбиту, где он встретится с Союзом и состыкуется с ним.

Основной задачей экспериментального полета является испытание совместимости систем управления маневрами сближения и стыковки будущих пилотируемых кораблей и космических станций чтобы, следовательно увеличить возможность в будущем оказывать помощь кораблям находящимся в космосе.

В состав первого экипажа корабля "Союз" вошли, командиром - летчик-космонавт Алексей Леонов и борт-инженером - Валерий Кубасов. А. А. Леонов родился в 1934-ом году в городе Листвянка, Кемеровского района. Он состоял в первой группе Советских космонавтов и 18-ого Марта, 1965 года вышел из космического корабля "Восход-2" чтобы стать первым человеком, кто познал что такое плавание в открытом космосе. Второй член экипажа борт-инженер Валерий Кубасов, родился в 1935-ом г., в городе Вязники, Владимирского района. В Октябре 1969-ого года он совершил полет на корабле "Союз-6", и во время полета осуществил успешные сварочные работы в космосе.

В состав первого экипажа корабля "Аполлон" вошли Томас П. Стаффорд, командир; Ванс Д. Бранд, пилот командного модуля; и Доналд К. Слэйтон, пилот стыковочного модуля. Стаффорд родился в городе Уэдерфорд, штата Оклахома, 17-ого Сентября 1930-ого года. Он был членом второй группы astronauts назначенной в 1962-ом году, и с тех пор совершил три космических полета на кораблях "Джемини 6", "Джемини 9" и "Аполлон X". Ванс Д. Бранд родился 9-ого Мая 1931-ого года в городе Лонгмонт, штата Колорадо. Он был членом группы 19-и astronauts, выбранных в Апреле 1966-ого года. Экспериментальный Полет Аполлон Союз является его первым выходом в космос, однако он состоял членом второго экипажа нескольких полетов корабля "Аполлон". Доналд К. Слэйтон родился 1-ого Марта 1924-ого года в городе Спарта, штата Уисконсин. Он был одним из первых astronauts выбранных для проекта "Меркурий", в 1960-ом году. В Центре имени Джонсона, Слэйтон служил Директором работ летных экипажей с 1963-его по 1973-ий год, и за это время руководил подготовкой всех astronauts на все полеты кораблей "Меркурий", "Джемини", "Аполлон" и "Скайлэб". Предстоящий полет также является его первым личным ознакомлением с космосом.



APOLLO 17 VIEW OF EARTH



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 17 VIEW OF EARTH—This fantastic view of the Earth was seen by the Apollo 17 crewmen during their journey toward the Moon on their lunar landing mission. This outstanding translunar coast photograph extends from the Mediterranean Sea area to the Antarctica south polar ice cap. This is the first time the Apollo trajectory made it possible to photograph the south polar ice cap. Note the heavy cloud cover in the Southern Hemisphere. Almost the entire coastline of the continent of Africa is clearly delineated. The Arabian Peninsula can be seen at the northeastern edge of Africa. The large island off the southeastern coast of Africa is the Malagasy Republic. The Asian mainland is on the horizon toward the northeast.

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

MISSION CONTROL CENTER

"Houston, Tranquility Base here. The Eagle has landed."

Those words, of course, came from the first men on the Moon. They were broadcast to the entire world, but the call sign "Houston" to which the message was addressed designates the control center for United States manned space flight.

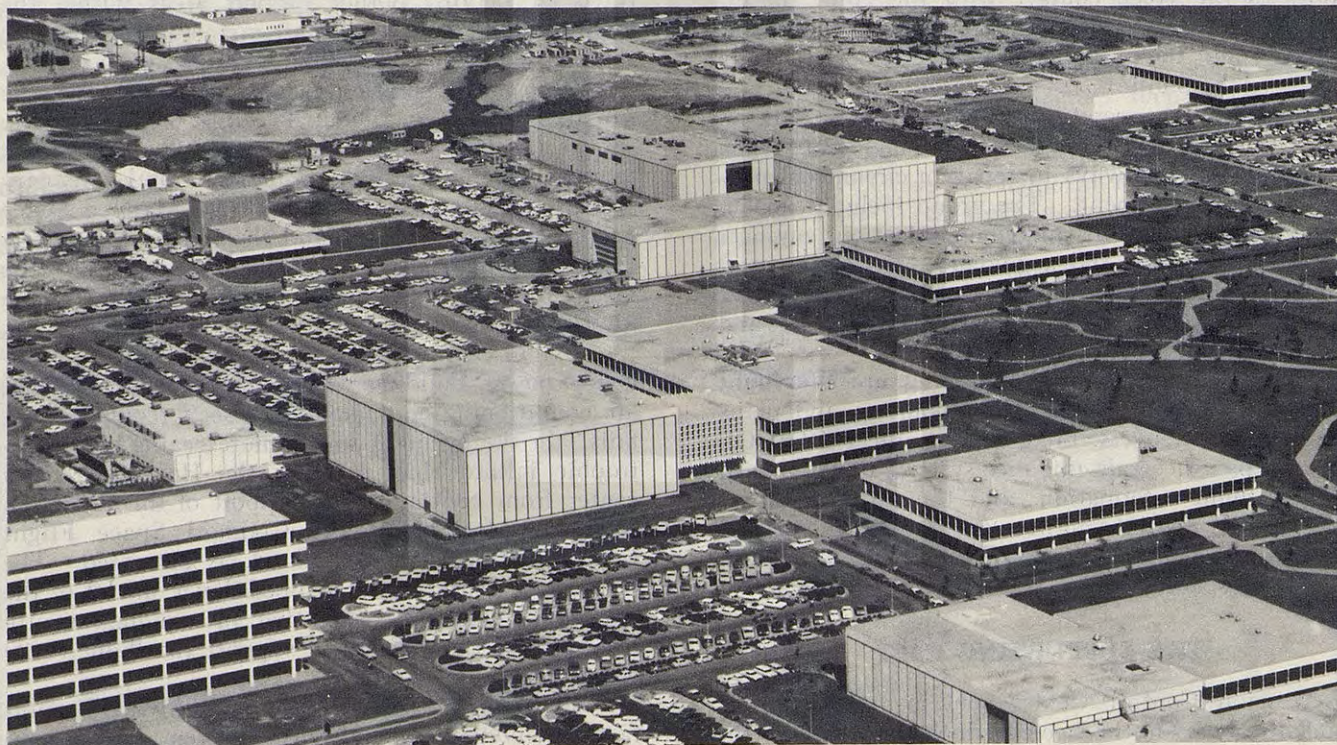
Mission Control Center is a three-story building at the NASA Johnson Space Center. In it is some of the most sophisticated communication, computer, data reduction, and data display equipment available. Operating it — 24 hours a day during manned space flights — are hundreds of engineers and technicians with a wide scope of specialized skills. And from it come the decisions that can mean mission success or failure.

Focal point of the Mission Control Center is the Mission Operations Control Room (MOCR)

where flight controllers get information from television-like screens on the consoles where they work, or from projected displays that fill the wall at the front of the room. The MOCR (pronounced as though it were a word spelled "moker") provides working space for three basic operating groups of flight controllers: mission command and control, systems operations, and flight dynamics.

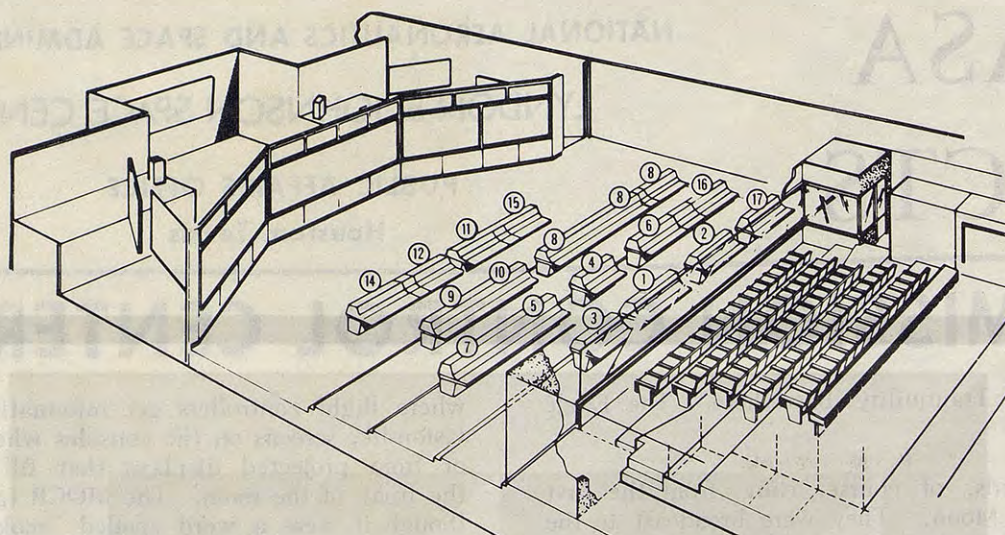
Mission command and control positions are: the mission director, who is responsible for overall mission conduct; flight operations director, representing Johnson Space Center management; flight director, who is responsible for operational decisions and actions in the MOCR; and the assistant flight director.

Others in the command and control group are: the flight activities officer, who develops and coordinates the flight plan; the Department of Defense (DOD) representative coordinates and directs DOD



Mission Control Center, in the center of the picture, is also the center of attention during manned space flights, when it hums with activity

24 hours a day. The Mission Operations Control Room is located in the windowless west wing of the three-story building.



This layout of a Mission Operations Control Room shows the visual display wall, the flight control consoles, and the viewing area for official observers. Console assignments vary landing mission would be: (1) the Flight Operations Director; (2) Mission Director; (3) Public Affairs Officer; (4) Flight Director; (5) Assistant Flight Director; (6) Flight Activities Officer; (7) Communication Systems Engineer, and Opera-

tions and Procedures Officer; (8) Vehicle Systems Engineer (two for the command module, two for the lunar module); (9) Flight Surgeon; (10) Spacecraft Communicator; (11) Flight Dynamics Officer; (12) Retro-fire Officer; (14) Booster Systems Engineer; (15) Guidance Officer; (16) Network Controller, and (17) Department of Defense Representative.

mission support; the network controller is responsible to the flight director for Mission Control Center and for operations relating to the Manned Space Flight Network; the surgeon monitors the crew's medical condition; the spacecraft communicator, referred to as "Capcom" (from early manned flight, when Mercury was called a capsule rather than a spacecraft), is the voice contact with the crew; the experiments officer coordinates mission experiments activity; and the public affairs officer reports mission events to the public.

The systems operations group monitors data on the spacecraft and the launch vehicle and, when necessary, suggest ways to repair or circumvent malfunctioning equipment. The group includes an environmental, electrical, and communications engineer for each spacecraft and a guidance, navigation, and control engineer for each. Other positions are booster systems engineers, communications engineer, and operations and procedures officer.

In the flight dynamics grouping are the flight dynamics officer (FIDO), who monitors and plans spacecraft maneuvers, the guidance officer (GUIDO), who keeps spacecraft guidance systems updated with current flight information, and the retrofire office, who plans deorbit maneuvers for earth orbital flights, or calculates reentry trajectories for return from deep space.

THE SUPPORTING CAST

Mission Control Center contains two identical MOCRs, one on the second floor and one on the third. Either can be used for mission control, or they can be used simultaneously to control separate flights. At times, one team of flight controllers

has conducted an actual flight while a second team is going through a make-believe mission to prepare for a future operation.

But the MOCR occupies only a relatively small portion of the Mission Control Center. Each operating group is assigned a nearby staff support room where data on the mission are monitored and analyzed in detail. Other support areas within the facility include the Spacecraft meteorological Room, the Spacecraft Planning and Analysis (SPAN) Room, the Recovery Operations Control Room, and the Lunar Surface Experiment Package Support Room.

On the first floor of the Mission Control Center are the communications, command, and telemetry system for processing data from the Manned Space Flight Network stations, and the real-time computer complex, which converts the flight data into the visual displays used by the flight controllers in the MOCR.

Mission Control Center is supported by an emergency power building which houses generators and air conditioning equipment for use if regular power fails. In the event of some unforeseeable but catastrophic failure that prevents the Houston control center from continuing its support of the flight, an emergency facility at the Goddard Space Flight Center in Greenbelt, Maryland, is activated. The emergency center is a stripped-down model of the one in Houston, incorporating just enough equipment to let the controllers support the flight to its conclusion.

One of the most interesting of the MOCR support facilities is the display/control system, which uses the front wall of the room as a projection screen for displays ranging from plotting charts that show the spacecraft's location, to actual television pictures

such as the display unit as elapsed before a man

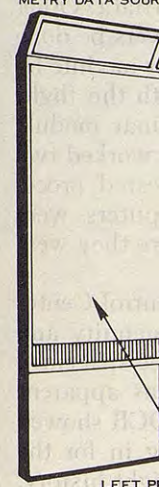
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such as the scenes from the Moon's surface. Other display units built into the wall show such things as elapsed time after launch, or time remaining before a maneuver or other event.

The information displayed, and on which the flight controllers base many of their decisions or recommendations, can be telemetry and tracking data relayed from Manned Space Flight Network stations and processed through the real-time computer complex, or it might be information — predicted time of upcoming events, for instance — derived through the computer, or even stored reference data based on simulated flights conducted as practice for the actual mission.

The consoles at which the flight controllers work in the MOCR, and those in many of the support rooms, include one or more TV screens and the necessary switches to let the controller view a data display on a number of different channels. He may view the same display being shown on the large projection screens on the front wall, or he can "call up" data he is especially interested in just by changing channels. A library of prepared reference data is available to display static information, while digital-to-television display generators provide dynamic, or constantly changing, data.

BEHIND THE SCENES

The Mission Operations Control Room, with its rows of consoles and its large display screens, is a familiar sight to many television viewers around the world, for a view of the busy MOCR during peak-interest periods of United States manned space flights has become almost a standard scene in video coverage of the mission.

But other equally busy areas of the Mission Control Center are just as important to the success of the flight. One such area is the communications, command, and telemetry system (CCATS) on the first floor. The CCATS processes incoming digital data and distributes it on a real-time basis to the facilities associated with the MOCR and support

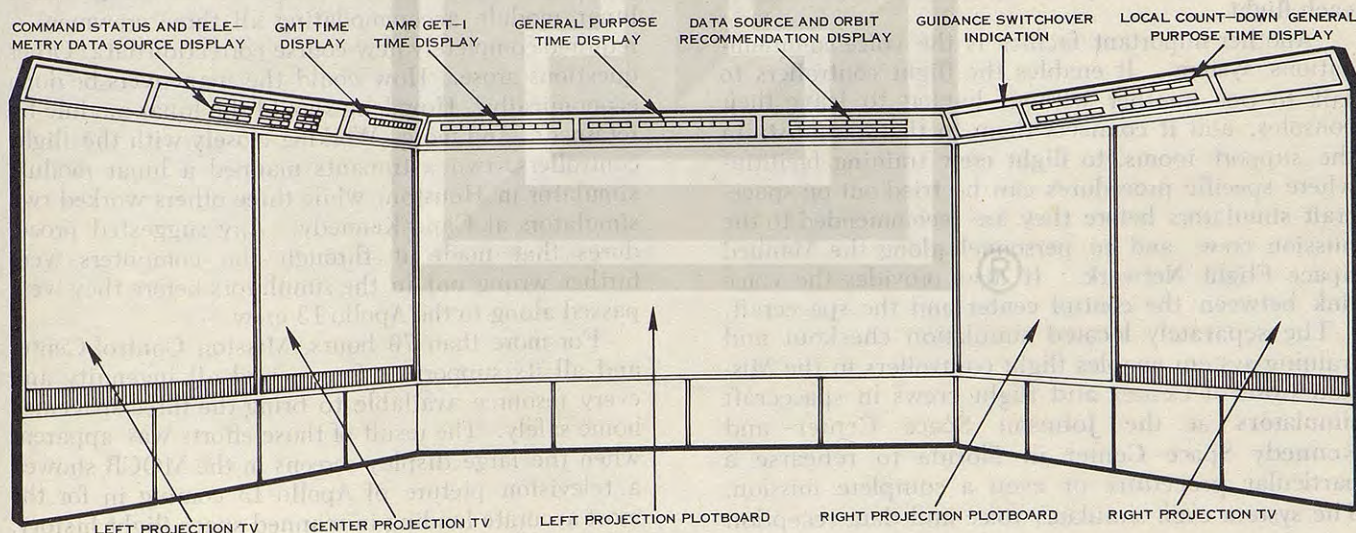


The view from the Flight Director's position takes in the other control consoles, as well as the visual displays on the front wall. The picture of two astronauts is coming live from the Moon and is beamed onto a special screen (right projection screen in the diagram below).

room displays. The system also handles the digital command signals to the spacecraft — the up-data link which lets Mission Control do such things as keep the spacecraft guidance computer's facts and figures up to date.

The real-time computer complex (RTCC), also on the first floor, processes incoming tracking and telemetry data and compares actual mission conditions with predetermined parameters — simply, it compares what is happening with what should be happening. Often, it does not even bother displaying the information unless something is going wrong. As the system evaluates factors such as spacecraft position and velocity, it also computes what maneuvers should be made to correct any shortcomings.

The RTCC, as its name implies, computes and evaluates on a real-time basis: through the high-speed electronic data from the worldwide network of tracking stations, the real-time computer complex





One of many unseen and unsung support areas of Mission Control Center, this is the television color converter that turns video signals from the Moon into the color picture seen on home sets around the world.

“sees” what is happening at almost the instant it happens; its computations are fast enough to correct a situation as it develops. Using this same data, the RTCC also predicts where the spacecraft will be at any given time in the flight.

Further, the computers are used to give acquisition information that helps the tracking stations point their antennas at the spacecraft. And the RTCC is used to monitor and evaluate telemetry information from the spacecraft to be sure that personnel and equipment are performing normally.

Of the five primary computers in the real-time computer complex, two are used to support one MOCR and two the other, where a second live mission can be controlled or a simulated flight conducted to train additional teams of flight controllers. The fifth serves as a backup for any of the first four, or it can be used separately to help develop and perfect the many computer programs used in each flight.

Another important facility is the voice communications system. It enables the flight controllers to talk to one another without having to leave their consoles, and it connects them to the specialists in the support rooms, to flight crew training facilities where specific procedures can be tried out on spacecraft simulators before they are recommended to the mission crew, and to personnel along the Manned Space Flight Network. It also provides the voice link between the control center and the spacecraft.

The separately located simulation checkout and training system enables flight controllers in the Mission Control Center and flight crews in spacecraft simulators at the Johnson Space Center and Kennedy Space Center in Florida to rehearse a particular procedure or even a complete mission. The system even simulates voice and data reception

from the far-flung stations of the Manned Space Flight Network.

THE SYSTEM IN ACTION

The Mission Control Center probably never was exercised so much nor demonstrated its value so well as during the flight of Apollo 13. While being far from a typical operation, it can be considered a classic one insofar as Mission Control Center doing what it was designed to do — and then some.

The spacecraft was 200,000 miles from Earth when an oxygen tank in the service module exploded. The accident wiped out the command module's main supply of oxygen, electrical power, and propulsion. Mission Control cancelled the scheduled landing on the Moon and started working toward getting the crew home alive.

While the crew powered-down as many systems as possible and took up residence in the attached lunar module, Mission Control mobilized all its available personnel, as well as those of the companies that built the spacecraft. They went to work to determine how best to make a “lifeboat” of the lunar module, a spacecraft with its own power and oxygen supply but not designed to reenter the Earth's atmosphere.

Maneuvers to put Apollo 13 on the proper path back home were computed and simulated on the ground. Since the lunar module engine was to do the thrusting, its burn had to be tailored to a greater mass and different center of gravity than that for which the system was designed.

Computation of available consumables — oxygen, electricity, and water (for cooling electronic equipment rather than for drinking) — pointed up the desirability of another maneuver that would shorten the time of return. The computers and the simulators were exercised again to demonstrate that the lunar module engine could, in fact, stand up under the additional strain.

Now the crew was on its way back. But the strange spacecraft — the dead service module, the powered-down command module, and the two-man lunar module accommodating all three crewmen — required completely new course correction data. Other questions arose. How could the maneuvers be done economically? How long should the lunar module be retained? And more. Working closely with the flight controllers, two astronauts manned a lunar module simulator in Houston, while three others worked two simulators at Cape Kennedy. Any suggested procedures that made it through the computers were further wrung out in the simulators before they were passed along to the Apollo 13 crew.

For more than 70 hours, Mission Control Center and all its supporting forces used all ingenuity and every resource available to bring the three spacemen home safely. The result of those efforts was apparent when the large display screens in the MOCR showed a television picture of Apollo 13 coming in for the most accurate landing in manned space flight history.

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE
Houston, Texas

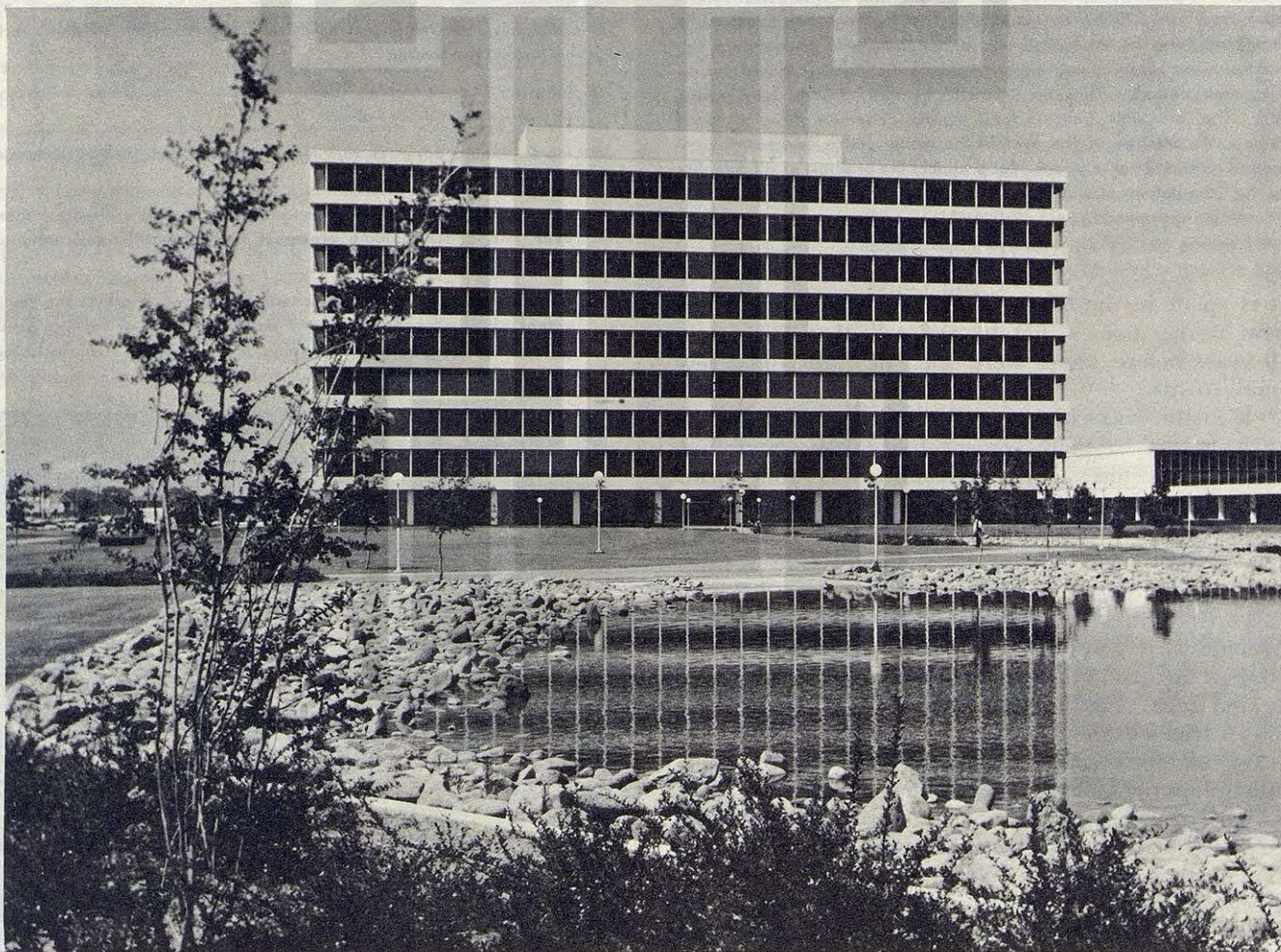
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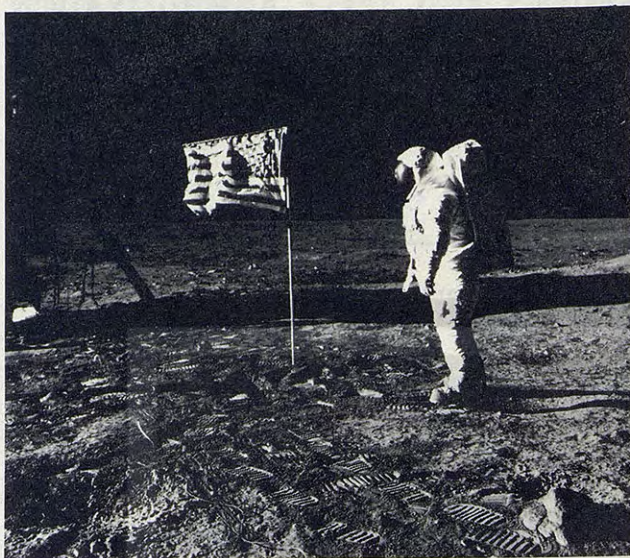
The NASA Lyndon B. Johnson Space Center (JSC) opened for business at its 1620-acre site 25 miles southeast of downtown Houston in September 1963. The Center's responsibilities include: design, development, and testing of the spacecraft and associated systems for manned flight; selection and training the astronauts; planning and conducting the manned missions; and extensive participation in the medical, engineering, and scientific experiments that are helping man understand and improve his environment.

Although a manned space flight starts at a launch pad a thousand miles away from JSC and ends on the deck of a ship even more distant, the JSC Mission Control Center is the astronauts' link with

Earth from lift-off to splashdown. The space crew's return to JSC completes a cycle begun months earlier. Mission planning and preparation involves several thousand JSC personnel, elements of NASA headquarters and other centers, and employees of American industry throughout the nation.

The JSC employs some 4,000 engineers, technicians, scientists, secretaries, mathematicians, managers, clerks, photographers, writers, instructors, administrators, and . . . astronauts. Another 7,000 contractor personnel work at or near the Center to help test spacecraft systems, work out computer programs, or just keep the Center running smoothly. The total combined payroll adds more than \$150 million a year to the Houston area economy. Much of





The July 20, 1969, Moon landing and the safe return to Earth of the Apollo 11 crew signified the successful accomplishment of a goal set 8 years earlier. But the initial lunar landing, and those that followed, are just the obvious fruits of a nationwide mobilization without precedent. Historically, the most rapid technological advances are forced by war; peacetime benefits from the new technologies generally develop more slowly and, at times, unpredictably. When President Kennedy called for a national effort to land an American on the Moon before the end of the '60s, he mobilized the country's talent and purpose as they never had been, short of war. The program cost Americans less than \$20 billion up to that first landing; they spent more than four times as much on liquor, better than twice as much on cigarettes, more on parimutual betting, and more on foreign travel during the same period. Tangible "spinoff" benefits already form a long list. The intangible interest from Apollo dollars is America's self-esteem, its prestige in the eyes of the world, and a new path to improved international relations. But probably the greatest of all benefits is the stimulation of basic research and technological development already being applied to help solve problems on Earth.

it is spent in the Clear Lake business community — new stores, homes, hotels, and schools where, only 10 years before, there were open pastures and a few small towns.

Houston was chosen as site of the JSC after an investigation of many prospective locations around the United States. The selection was announced in September 1961. Personnel began moving to offices in Houston from Langley Field, Virginia during October 1961. JSC construction started in April 1962.

The facilities were designed and built to house the wide variety of technical and scientific disciplines required for JSC's mission. JSC was organizationally divided into several directorates, where each directorate was responsible for a specific function — spacecraft development, astronaut training, or space flight planning, for example. The system is flexible, and the directorates are frequently realigned to keep pace with the changing directions and dimensions of manned space flight. Some of the original JSC directorates have reorganized, merged, or split into separate groups; new directorates are created as needed.

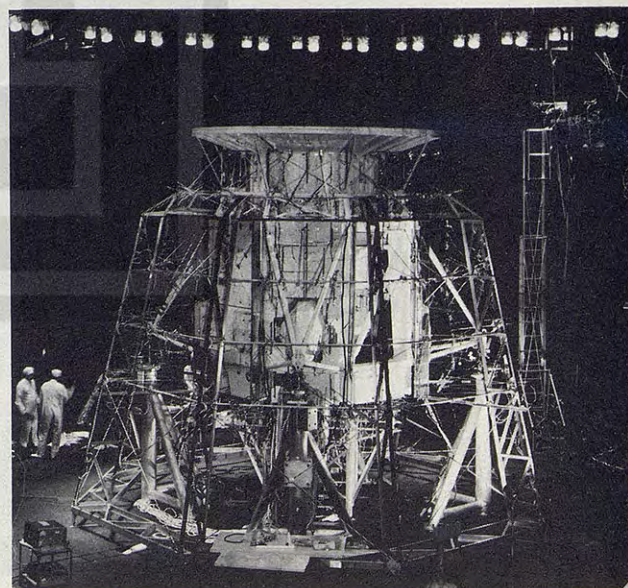
The JSC program offices direct or coordinate the efforts required locally, elsewhere within NASA, or by the industrial contractors to fulfill the JSC's specific program responsibilities. The Skylab Program Office, for instance, deals with such JSC Skylab tasks as development of a modified Apollo command/service module spacecraft and of crew-support items, mission planning and evaluation, and selection and training of flight crews.

Directorates and program offices are responsible to the Center Director who, in turn, is responsible to the Office of Manned Space Flight at NASA Headquarters in Washington, D.C.

The Center is situated near Clear Lake on a 1620-acre site, much of it donated to NASA by Rice University. It is made up of about 100 different buildings of sizes and uses that range from

The broad field of developing and analyzing spacecraft systems, the materials and techniques that go into them, and the equipment and methods of testing them — tasks of the Engineering and Development Directorate at JSC — accounts for many of the new and improved products that make everyday living easier, better, or safer:

- cookware that goes from freezer to oven without cracking and which can be cleaned easily;
- pressure-sensitive fasteners and closures;
- fire-retarding paint and flameproof materials;
- electronics for radio and television sets that are smaller, work better and last longer;
- tungsten fiber-reinforced nickel superalloy four times as strong as previous nickel-base alloys;
- more reliable batteries with longer lifetime and greater rechargeability;
- new thermosetting polyurethane plastics that are stronger than ever, and better molding processes that strengthen conventional plastics; and
- a shock absorber capable of softening a 60 mph shock to the equivalent of 5 miles an hour, and better methods of sealing, packaging, inspecting, testing, designing, measuring, and manufacturing items equally at home in space or on Earth.



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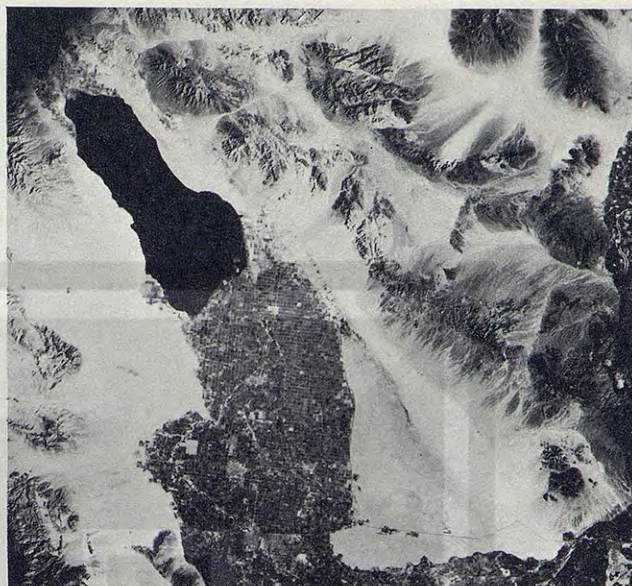
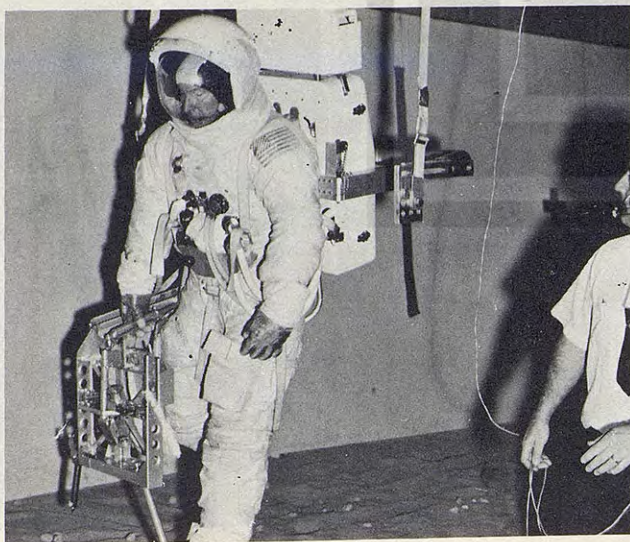
the nine story Project Management Building to the tiny traffic-control booths at each entrance. While many of the Center's structures are devoted to office space, others are uniquely designed to accomplish special tasks. Some are open to the public for self-guided walking tours, and others can be seen on specially arranged guided tours.

The building probably most familiar to the public is Building 30 Mission Control. TV networks around the world show the activity in Mission Control several times during each manned flight — the flight controllers at rows of consoles, studying the data that helps them make mission decisions.

But Building 30 contains much more than just the Mission Operations Control Room (MOCR). It actually contains two identical MOCRs, one on the second floor and one on the third, which can be used simultaneously to control two missions or to practice procedures for a future flight while the current flight goes on.

The Medical Research and Operations Directorate at the Johnson Space Center is responsible not only for helping man to stay alive, healthy and active in space, but also to help find how the knowledge from space flight can help man on Earth. Many hospitals and specialized medical facilities already use space-age products:

- blood pressure or heart monitoring sensors so small they can be inserted by a hypodermic needle rather than surgery;
- contamination control procedures to keep operating and recovery rooms infection-free;
- remote monitoring equipment that lets one nurse keep a continual check on 64 patients at once;
- equipment to send an electrocardiograph by radio or telephone from the accident or illness site;
- a motorized wheelchair that is controlled by only the eye movements of a paralysis victim;
- a lunar gravity simulator used to train Apollo crews, modified to help rehabilitate handicapped or bedridden patients;
- transducers used to measure spacecraft splashdown impact incorporated into a device for precision fitting of artificial limbs; and
- many more products are still being developed.



The view of Earth from space is not only spectacular, but informative. Photographs such as this one from Apollo 9 can help survey the natural resources of the world. Work being done by JSC and other NASA centers may help establish more efficient management and use of Earth's commodities. Projects involving unmanned and manned spacecraft, as well as specially equipped airplanes, have already shown the value of remote sensing — observation and measurement from a distance. Coupled with ground data, remote sensing will help maintain an up-to-the-minute picture of the world's farmlands and forests; identify areas of availability, pollution, or waste of Earth's dwindling fresh water supply; globally prospect for new deposits of minerals and petroleum, resources which are now threatened with depletion; and survey the oceans that cover 70 percent of the globe to determine how best to benefit from this source of untapped wealth. Observation from space, being perfected and extended in NASA's Earth Resources Survey Program, has proven most beneficial so far in the science of weather forecasting. Satellite tracking of the 1969 killer hurricane Camille prompted early evacuation of 70,000 people from the area of predicted impact; many of the 324 dead or missing had stayed behind in spite of the warnings.

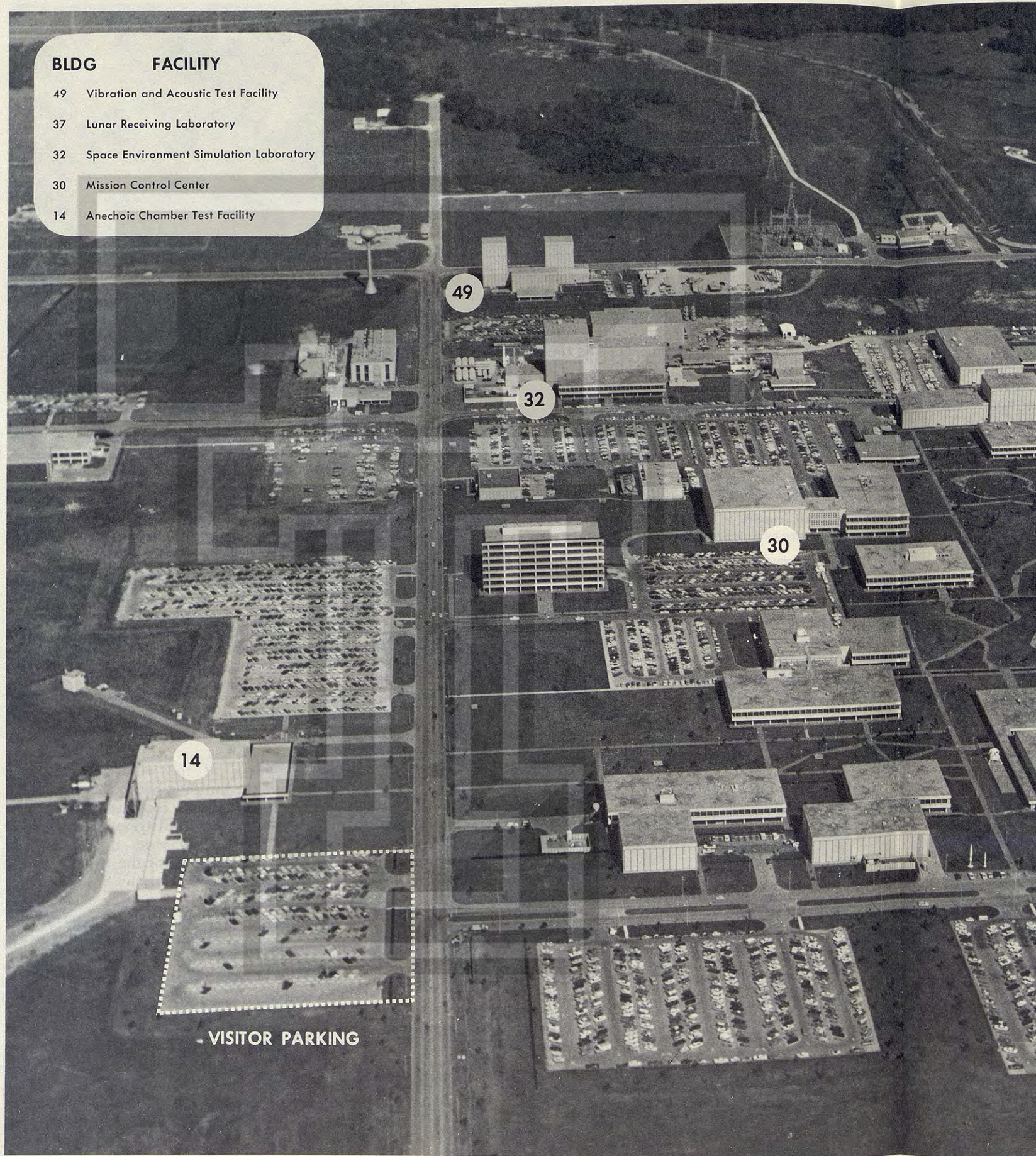
On the first floor of the windowless Mission Operations half of the building house the computers, processors, control panels, tape recorders, test boards, wiring, displays, controls, and distribution equipment needed to support the activity on the second and third floors. The second half of the first floor, the more conventional-looking Operations Support wing, contains mostly office space.

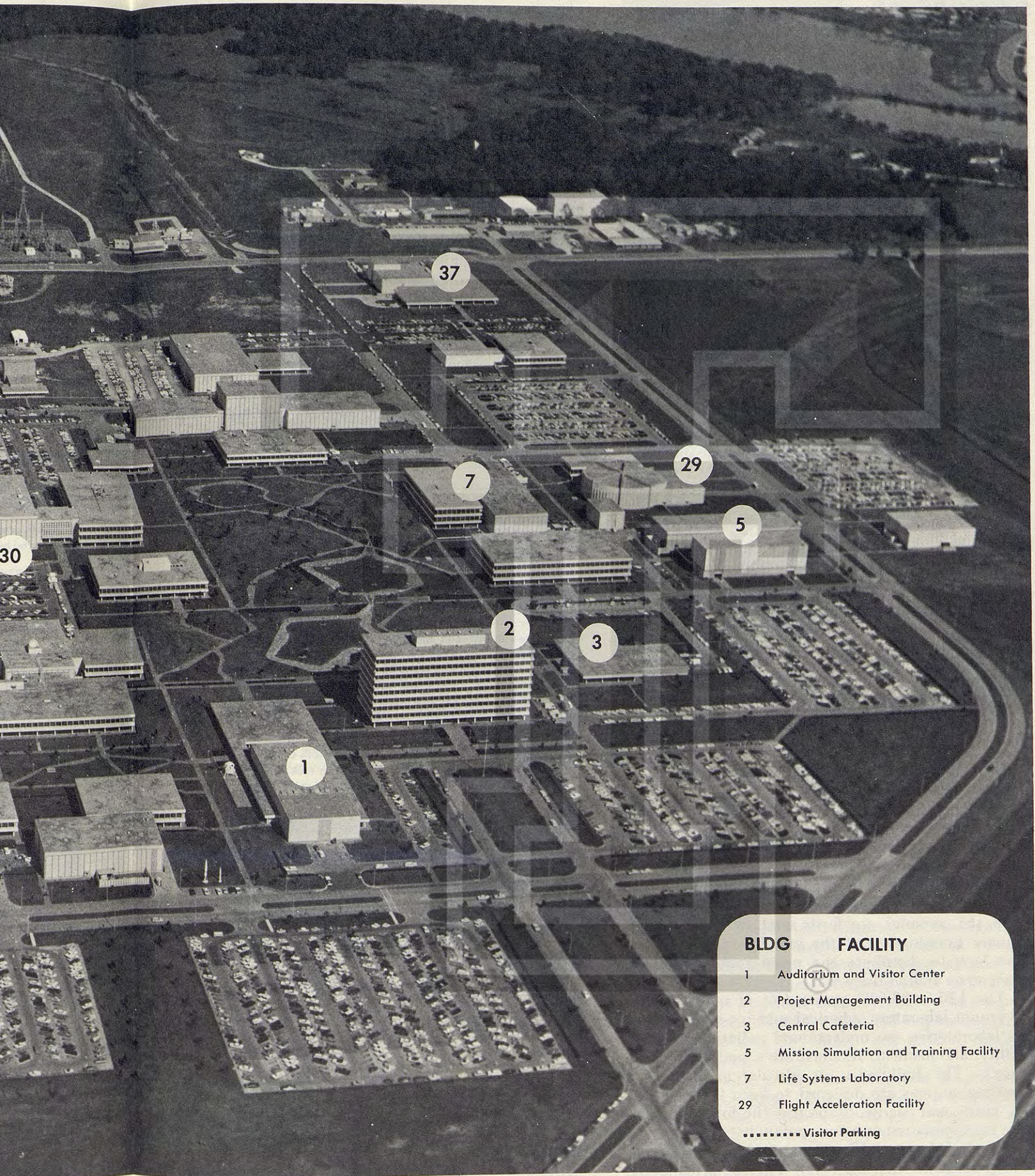
Through space-age electronics, a doctor in Houston can monitor a heartbeat a quarter-million miles away. A systems engineer can tell whether life-sustaining oxygen is flowing at the right rate, or if a switch is in the proper position. And a man can sit in his own home and marvel at the communications systems that bring mankind closer together.

If Building 30 is the center of attraction during a space flight, its postmission counterpart is Building 37, the Lunar Receiving Laboratory (LRL). One original basic purpose of the LRL was to keep crew, spacecraft and samples in quarantine on their return from the moon, while doctors, technicians, and scientists looked for anything that could contaminate

BLDG **FACILITY**

- 49 Vibration and Acoustic Test Facility
- 37 Lunar Receiving Laboratory
- 32 Space Environment Simulation Laboratory
- 30 Mission Control Center
- 14 Anechoic Chamber Test Facility

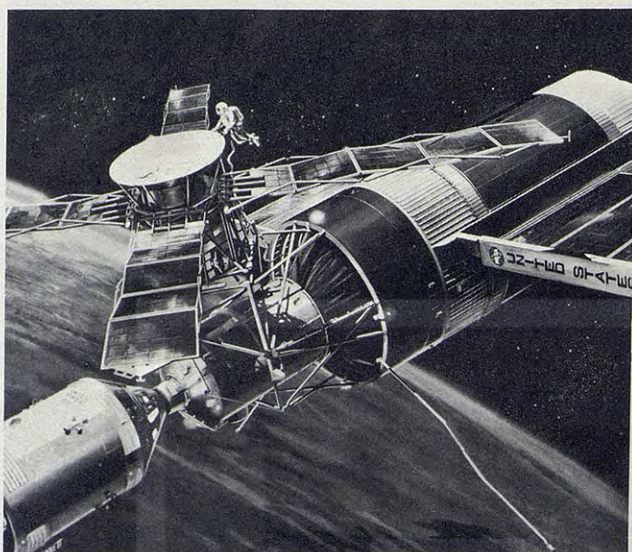




BLDG	FACILITY
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- | | |
|----|--|
| 1 | Auditorium and Visitor Center |
| 2 | Project Management Building |
| 3 | Central Cafeteria |
| 5 | Mission Simulation and Training Facility |
| 7 | Life Systems Laboratory |
| 29 | Flight Acceleration Facility |

..... Visitor Parking



Two manned space programs, one active and one in the study stage, represent some of the planning for logical steps beyond current capability. Skylab is the active program, and Space Shuttle is the program under study. Skylab, perhaps a forerunner of large permanent space stations, is a workshop from which long-term scientific experiments can be conducted. The lab and living quarters are in the empty third stage of a Saturn V rocket, which is equal in volume to a three-bedroom house. The lab will be boosted into a 260-mile earth orbit. Three-man crews will spend 28 to 56 days in the lab studying ways of checking Earth's resources, making astronomical observations not possible from the ground, and seeing how the human body reacts to the increase in flight duration. Space Shuttle is the reusable launch vehicle and spacecraft needed to reap the benefits of space more economically — both launcher and spacecraft would make airplane-like landings. Some anticipated Shuttle missions are: in-flight repair and maintenance of orbiting satellites; and the launching of new satellites. The Shuttle will be used to carry nonastronaut scientists up to Skylab where they will carry out experiments in space. With NASA and Russia studying compatible docking facilities on Skylab, and several nations ready to put technical skills and money into Shuttle, international harmony in space is growing.

Earth — lunar bacteria, for example, that might be immune to any known treatment.

But careful analysis of man and materials from the first lunar landings turned up nothing alarming, and the other activities of the LRL are beginning to be more publicized. These further purposes of the LRL are to preserve and protect the lunar samples, to perform investigation that must be done while the samples are fresh, and to make a preliminary examination of the samples to help determine how to distribute the moon rocks and dust to scientists around the world.

The LRL's 83,000 square feet of space include a vacuum laboratory, physical and bio-science sample laboratories, an underground radiation-counting facility, and medical, administrative, and lab-support areas. The building's air circulation and waste handling systems are designed to keep the laboratories clean and sterile to protect the lunar samples from contaminating or being contaminated.

Many of the special facilities of JSC are designed to help determine that spacecraft systems and materials

can stand up against the rigors of space flight. One such is the Space Environment Simulation Laboratory, Building 32. It contains two vacuum chambers, one 120 feet high by 65 feet in diameter and the other 43 feet high by 35 feet in diameter. A complete spacecraft or individual components can be subjected not only to a space-like vacuum, but to temperature extremes from 280° F below to 260° F above zero. Near by, in the Building 49 Vibration and Acoustic Test Facility, space hardware is buffeted by equipment which simulates the shakes and sounds the spacecraft will experience in flight. In contrast, complete silence is found in the Anechoic Chamber Test Facility, Building 14, where foam-covered walls, floor, and ceiling soak up stray signals during spacecraft communication system tests.

Just as unique are some of the specialized facilities used to test and train the men who fly the spacecraft.

The Flight Acceleration Facility, in Building 29, is another area open to the public as part of the JSC self-guided tour. A 50-foot centrifuge with a 12-foot-round gondola at the end spins up to

The scene in Mission Control is a familiar one to TV audiences around the world. What is not shown is the preparation for a space flight — the months of planning and analysis, programming, and practice by Flight Operations Directorate personnel and the thousands of other NASA, Department of Defense, and contractor personnel who support each flight. When Neil Armstrong reported his "giant leap for mankind" to Mission Control, his words went around the world through facilities set up by 2,000 newsmen gathered at the Center to follow the Apollo astronauts' historic flight. The technology which let Mission Control see Armstrong's image and hear his words, check his heartbeat and respiration rate, keep tabs on fellow Moon explorer Edwin Aldrin, and monitor the status of the lunar module "Eagle" as well, is proving beneficial on Earth. Right now, the capability to monitor remote functions and events is helping many hospitals run more efficiently. Tomorrow's applications may not yet have been thought of. Nuclear Physicist Dr. Edward Teller once remarked "When Columbus took off, the purpose was to improve trade relations with China. That problem has not been solved to this very day, but just look at the byproducts." The byproducts of space flight are just beginning to emerge.



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iences around space flight — and practice by and of other el who support leap for man- world through nter to follow ich let Mission his heartbeat Edwin Aldrin, ell, is proving r remote func- efficiently. To t of. Nuclear mbus took off, That problem e byproducts." ge.



impose g-forces even greater than those experienced by the astronauts during launch or reentry. The facility also is used to help develop equipment that will survive the acceleration stresses of space flight.

Most of the time spent in training an astronaut for a specific mission is logged in simulators — training devices that duplicate spacecraft equipment and control panels, or even the entire spacecraft cabin. The most sophisticated of these, called "mission simulators," include projections onto screens where the spacecraft windows would be. The scenes are those the crew will see during the real mission. These trainers in the Mission Simulation and Training Facility can be tied in with the Mission Control communication system so that crews and flight controllers can practice the entire mission many times before the actual flight.

Other specialized facilities at the Center include a photography processing laboratory, a technical services shop, printing plant, cafeterias, fire department, dispensary, and a Visitor Orientation Center that houses spacecraft which have flown in three American manned space programs — Mercury, Gemini, and Apollo.

JSC's Flight Crew Operations Directorate includes some of the best known people in the world, but the astronauts' jobs are not necessarily filled with glamour and adventure. Like the personnel who work with them, the astronauts put in a full 5-day workweek — and then some — to make manned space flight efficient, safe, and productive. A flight crew spends a year or more in preparation for a mission. Training devices such as the mission simulator are so realistic that many astronauts say the weightlessness of space is the only difference between the practice flights and the actual one. Similar equipment is being used to train airline pilots, and an automobile simulator gives driving trainees a sense of assurance and safety before they actually take to the highway. Other items developed for crew training or for space flight also find application to nonspace activity. Fireproof material used in the spacesuits is worn by firefighters, while full-protection garments, including a breathing system, let the fireman walk right into the flames. Lightweight, flexible insulation that protects spacemen from extreme heat and cold is featured as new outdoor wear and an emergency rescue blanket. Space food research is being turned toward easy-to-fix and more nutritious food for the home.



The Lunar Receiving Laboratory, an element of the Science and Applications Directorate, is NASA's cataloging and distribution point for the samples Apollo astronauts bring back from the Moon. One of many lunar sample tests conducted to date indicates that moon dust may be a sort of super fertilizer, containing elements that help Earth plants grow bigger faster. Techniques used within the directorate to increase the detail and clarity of Lunar Orbiter photographs of the Moon have proven useful in enhancing X-ray pictures of humans. The picture's composition is broken down electronically, then put through a computer to clean up and sharpen the image. This technique significantly increases the capability of X-ray examination of deep, inaccessible areas of the body. The scientific activity within NASA carries over into the community. Between 1965 and 1971, NASA awarded grants and research contracts for 1,640 programs to 223 universities and colleges in all 50 states and the District of Columbia. Of the money spent on the space program in the decade 1959-1969, nearly \$3 billion went to schools. A NASA grant to the National Academy of Sciences helped set up the Lunar Science Institute next door to the Center. JSC works closely with the Institute and its owner, Rice University.

The JSC also maintains airplanes for astronaut training, research programs, and administrative travel at nearby Ellington Air Force Base, and it operates the White Sands Test Facility in New Mexico.

JSC PROGRAM MANAGEMENT

One important function of the National Aeronautics and Space Administration is management. By the time NASA began the second 10 years of its existence, it had conducted manned and unmanned space programs involving some 20,000 contractors from American industry, and — at the peak period of the mid-1960's — 420,000 employees, 35,700 of them working for NASA, and federal funds of about \$40 billion.

Hundreds of contractor companies helped build the space program. These companies are located throughout the United States and range in size from small several-man shops to corporations employing tens of thousands of people. The task of

managing these efforts — bringing everything together in the proper place at the right time with confidence it will work as planned — is monumental.

The JSC's largest contribution to program management is in the design and construction of manned spacecraft. Apollo is an example of the job's scope: the command module, which carries the astronauts to the Moon and then back to Earth, is manufactured in California; the lunar module, which makes the actual Moon landing, is built on Long Island, New York; the guidance and navigation hardware contractor for both spacecraft is located in the Midwest. Several hundred additional subcontractors and suppliers have important inputs to the program.

JSC overcomes the distance problem by assigning resident managers to the spacecraft contractors' plants where they work closely with the development, manufacturing, and testing activities. Regular reviews and progress reports go into status charts which show whether all phases of the program are moving smoothly ahead. Program management defines and controls the many interfaces between systems to assure compatibility of crew, spacecraft, and launch vehicle; and it establishes quality control and reliability standards, along with the appropriate checkout and test procedures.

Similar management functions are performed by NASA centers responsible for other aspects of the program — the launch vehicle at Marshall in Huntsville, Alabama; tracking and communication systems at Goddard in Greenbelt, Maryland; and launch facilities at Kennedy in Florida. The total effort is coordinated by NASA Headquarters to a precise schedule with rigid standards. Yet, it is flexible enough to take advantage of new technology or to bounce back from failures.

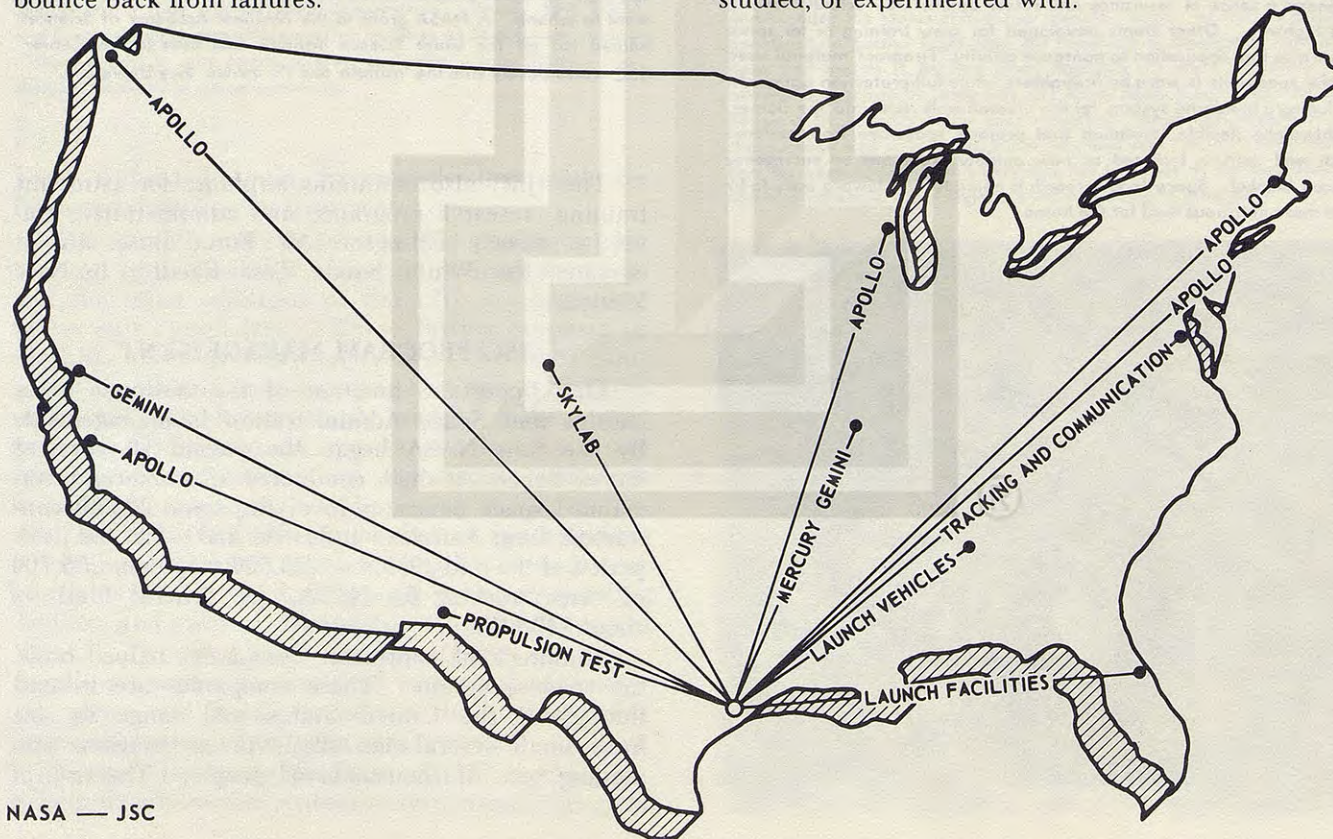
The success of NASA's management techniques was confirmed July 20, 1969, when Apollo 11 Commander Neil Armstrong announced "The Eagle has landed!"

Eight years earlier, when President Kennedy was preparing to declare the lunar landing as a national goal to be accomplished within the decade, NASA management estimated that it could be done, and done at a cost of "\$20 to \$40 billion." After Apollo 11 and follow-on Moon landings with increasingly extensive exploration, the final cost of the Apollo Program is pegged at about \$25 billion.

The management techniques which enabled the National Aeronautics and Space Administration to fulfill such an ambitious commitment — plans for the lunar landing were presented publicly before any human had flown in space — are being applied to help solve some of the growing problems of America's large cities. The City of Los Angeles was among the first, using NASA-perfected procurement and source-evaluation procedures to start updating the city's overworked police, fire, and ambulance services.

An increasing number of businesses, big and small, are taking advantage of NASA-sponsored data banks, which are another spinoff benefit from management's in-depth documentation of the space program. The data centers are located at several universities around the country. They stock nearly a million documents on technical research and development. A subscribing business can get a computer search that will turn out condensations of every technical report ever recorded on the subject in question.

Meanwhile, other beneficial uses of these management techniques and tools are being proposed, studied, or experimented with.



NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

MOST-ASKED QUESTIONS ABOUT SPACE

Thank you for your letter. Each month we receive 7,500 like it from people all over the world. To respond more quickly to your inquiry, we have listed these most-asked questions with brief answers. More detailed discussion of aspects of manned space flight can be obtained from the Public Affairs Office, Johnson Space Center. Material on space and the solar system also is available in your school or community library.

1. Why explore space? New technology developed to let man work safely and efficiently in space is being applied to let him live better on Earth. Until the space program, the one great stimulus to extensive and rapid technological development was war.

2. Why not spend the money here on Earth? Every penny of space money is spent on Earth — to buy materials and skills to put men and equipment into space. In the late 1960's, about 420,000 Americans worked in the space program. They spent their paychecks on homes, food, cars, education, and entertainment — all here on Earth. And they paid taxes.

3. What about the things you leave in space (on the Moon, etc.)? Space hardware — paid for on Earth with Earth money — is abandoned for several reasons: no feasible way to bring it back, or to increase crew safety, or to replace it with something more valuable scientifically. Though some feel this is space-age litterbugging, we have no other practical solution. However, because the date and composition of much space debris is recorded on Earth, such discards could prove historically and scientifically valuable in the future.

4. What does a TV camera cost (or a spacecraft, suit, launch rocket, etc.)? There is no valid way to price a spacecraft or its separate pieces the way a car is priced. A figure can be determined by dividing items built into contract dollars. But included in the contract are intangibles — research, development, and testing — that make costs on single units appear unrealistically high even for "custom built" spacecraft.

5. Then how much does the space program cost? In NASA's first decade (1959-1969), the cost totalled \$35 billion, or about 2-1/2 percent of all federal spending (\$1.4 trillion) over the same period. Apollo, through the first landing on the Moon, cost about \$19 billion; its final cost is set at \$25-26 billion.

6. But what does it cost me as an individual? The 1971 space budget was about 1.6 percent of the total

federal budget or, roughly \$15.00 per person per year. (Americans spend per person: \$400 on health, education and welfare; \$400 on defense; \$35 on alcoholic beverages; \$17 on tobacco; and \$16 on cosmetics.)

7. Why not use the money to feed the hungry (or cure cancer, end pollution, etc.)? Ideally, spaceage technology will help such problems. The money, rather than buying food to merely lessen hunger today, will pay for research that could wipe out hunger tomorrow.

8. Why send men into space when unmanned spacecraft are cheaper? Man's ability to observe, reason, and act accordingly, make him important in space. Today's manned flight is largely a proving ground to develop future programs in which man will be essential as a scientist or an astronomer or even a space mechanic who can prolong the useful lives of other orbiting satellites.

9. How can I help? NASA cannot accept financial or material donations from private citizens or organizations, nor can we accept volunteers for space flight or other experiments. You can help by learning of the benefits — past, present, and future — from space exploration and by making your friends and acquaintances aware of them.

10. How can I become an astronaut? The astronaut of today has a college education beyond a bachelor's degree — often a doctorate — in engineering or a science, has good eyesight and hearing, keeps in shape physically, and does not mind hard work or long hours. Because physical standards for each recruitment are subject to change, your best preparation is an advanced education. Experience in flying will not hurt. No new astronaut recruiting is pending, but when a call is issued, the specifics will be listed by most news media.

11. Will we ever have women astronauts? Probably, but not in the immediate future — after Apollo there are four definite flights (three Skylab and the U.S.-Russia flight) and about three times as many astronauts as openings. There have been women applicants, but they and several thousand male applicants did not make the final selection. Race, religion, or national origin have no bearing on qualification or selection.

12. What manned programs follow Apollo? Skylab, the Apollo-Soyuz Test Project (a 1975 mission in which an Apollo command and service module and a Russian Soyuz spacecraft will rendezvous and dock long enough for the crews to visit each other's craft and to conduct

some basic space experiments), and Space Shuttle, for which firm missions have not yet been designated.

13. Will these spacecraft land on water or land? Skylab and Apollo-Soyuz Test Project will land on water because they will utilize the Apollo command module that was designed to land normally in water as a weight-saving device — see No. 27 to learn the importance of weight. Soviet spacecraft are built to land on land. Space Shuttle, however, is designed to land on land, much as an airplane does, and to be reusable.

14. Will there ever be additional moon exploration? Obviously, much of the moon remains to be explored, and exploration sometime in the future certainly is probable. However, even without definite plans for further lunar visits, scientists on Earth have enough samples and data to keep them busy for years. Also, much of the material already returned to Earth is being stored in the certainty that future generations will have even better instruments and techniques with which to study the samples.

15. How was the name "Apollo" chosen (or Mercury, etc.)? The way names for almost anything usually are chosen: people in charge of a program consider various names and finally agree on one. Sometimes the names are very descriptive (Skylab, Shuttle, even Gemini, which is Latin for "twins" and refers to the two men in the spacecraft). Other names, such as Mercury and Apollo, are more symbolic than descriptive.

16. What happens to used spacecraft? They undergo a post-flight checkout that yields additional information on the ship's performance. Some then go on public display — the Johnson Space Center has several — and some back into other space programs.

17. Can I have a spacecraft (helmet, moon rock, flight plan, crew insignia patch, etc.)? No. Hardware and other items that have no further direct value to the program usually go to public institutions or museums — the Smithsonian Institution in Washington, D.C., for instance — for display so people all over the world can see a portion of the space program. Flight plans, transcripts, and other printed matter are prepared in limited quantity for distribution to the newsmen who tell the story of each flight to the public.

18. But can't I buy some space things? Not from NASA. Visitors to Houston or other NASA centers find souvenir items in many stores in the area, and many merchants throughout the country stock articles that pertain to space flight. Charts and booklets on space can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

19. Can I visit the Johnson Space Center? Yes, the center is open to the public from 9 a.m. to 4 p.m. seven days a week except on federal holidays. There is no charge and no need for advance reservations. Guided tours are available to groups on weekdays by advance arrangement with the JSC Office of Public Affairs.

20. Will I see an astronaut? Possibly, but you may

not know it unless he is pointed out to you. Astronauts do not walk around the center in spacesuits, and they are not much different in appearance from many other busy people you will see.

21. Where do the astronauts live? Anywhere they want to. Most of them choose — along with many other JSC employees — to live within several miles of the center.

22. Can I get an astronaut to speak to my class (club, meeting, convention, etc.)? Astronaut appearances must be limited. Otherwise, crews would have no time to train or to keep up with changes in space technology. Generally an astronaut will take part in national meetings or scientific and technical groups or youth groups, and will make appearances in the astronaut's home town. Requests should be addressed to the Astronaut Office at the Johnson Space Center. Inquiries on talks by other JSC representatives should be sent to the Office of Public Affairs.

23. How much are the astronauts paid for going into space? An astronaut's pay is determined by his civil service grade (a pay scale for government employees) or, if he is in a military service, by his rank. Like other government workers away from home temporarily on official business, the astronaut gets a predetermined food-and-lodging allowance. Since meals and quarters are furnished by the government, the allowance during a flight is just a few dollars a day. He gets no extra pay for space flight.

24. Do the astronauts in space really eat or drink the food the advertisements say they do? The companies that prepare and package food for space also produce food you can buy at the grocery. These companies usually let NASA check their advertisements to be sure they are technically accurate or do not claim NASA uses something it doesn't. This does not necessarily mean the astronauts use such products at home or that they think you should. You have to decide that for yourself.

25. How does an astronaut go to the bathroom in space (or scratch an itch, blow his nose, etc.)? He uses a hose-and-bag device (sometimes called a "motorman's friend") for urinating, and a plastic sack for defecating. The motorman's friend was used by streetcar operators who were unable to make rest stops; the space-age version can empty the collected liquid into space, where it vaporizes. The sealed fecal bags, containing a germicide for sanitation, are stored for disposal back on Earth. Itch-scratching or nose-blowing in a pressurized suit is not feasible, but the astronaut no longer wears his spacesuit full time.

26. How can I write an astronaut? Address your letter to him at Astronaut Office (CB), Johnson Space Center, Houston, Texas 77058. But please remember that astronauts are very busy and cannot always personally answer as many letters as they would like to.

27. How much does a spacecraft weigh (a launch rocket, back pack, spacesuit, etc.)? In space, everything is weightless; on the Moon, it weighs about 1/6th its Earth

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weight. The significant question to spacecraft designers is "How can we make it weigh less?" The Saturn V takes about 60 pounds of propellant for each pound of spacecraft it sends to the Moon, so a little extra weight in the spacecraft adds a lot to the launch vehicle.

28. How much propellant does it take to go to the Moon? That's like asking how much gasoline it takes to drive cross-country — what route are you taking, what vehicle are you driving, how fast are you going, and how big a load are you carrying? For a nominal Apollo moon landing flight, launch vehicle and spacecraft weigh about 6,400,000 pounds at liftoff. Some six million pounds of that is propellant.

29. How far from Earth are spacecraft when orbiting? After the burn toward the Moon, most Apollo missions would have reached an apogee (the highest point of an orbit) of about 320,000 miles if there were no gravitational pull from the Moon. Presently, there are no planned manned Earth orbital programs with such extreme orbits. Skylab will be in a 260-mile circular orbit with a lifetime of 3 to 5 years. Studies of six- and 12-man space stations mention a 300-mile, 10-year orbit.

30. What is a launch window? A variety of conditions — most of them remote from the launch site — sometimes restricts a launch to certain days or times of day. This precise period in which liftoff must occur ranges from seconds to hours, depending on the mission, and is called the "launch window." Generally, a launch window is required when a spacecraft is to rendezvous with another object already in orbit.

31. How is the window determined? A rendezvous with the Moon, for example, begins with the lunar landing site. Acceptable sunlighting occurs just 16 hours each month. Figuring backward — calculating the time from the Earth to the Moon gives the day of launch. The hour is determined largely by the azimuth (direction) of launch from Cape Kennedy, and the expected location of the Moon when the spacecraft gets there. The result is a window of about 4 hours twice a day. Other considerations: daytime launch (one of the two daily windows occurs at night), lunar landing phase tracking and communications from Goldstone, California (only about 12 hours a day), and earth splashdown in daylight (a function of the Moon landing site).

32. Where are the lunar landing sites? Apollo 11 landed in the Sea of Tranquility at coordinates 0 degrees, 41 minutes, 15 seconds North latitude by 23:26:00 East longitude. Apollo 12 landed in the Ocean of Storms at 3:12:32 South by 23:23:09 West. Apollo 14 landed at Fra Mauro, 3:40:27 South by 17:27:58 West. Apollo 15 landed at Hadley-Apennine, 26:06:04 North by 3:39:10 East. Apollo 16 landed at Descartes, 8:54:13 South by 15:30:48 East. Apollo 17 landed at Taurus-Littrow, 20:09:50 North by 30:46:19 East.

33. How long will the flags left by those flights last? Barring destruction by a meteoroid impact or deterioration from some presently unexpected chemical reaction,

they should withstand solar radiation and extreme temperatures for many years. These flags are made of 100 percent nylon and are 30 by 48 inches on a two-piece 8-foot aluminum staff.

34. How hot or cold does it get on the Moon (in space)? In the space around the Earth, including the Moon, objects in sunlight heat up to about 250 degrees F, in shadow about minus 250 degrees. An astronaut, in his protective suit or in the spacecraft cabin, experiences a steady 70 to 80 degrees as long as his thermal control systems are in order.

35. Can an astronaut smell anything on the Moon? Even if flowers grew on the Moon, the astronaut would not be able to smell them; he would be isolated from them by his life-sustaining spacesuit. Other "Can you on the moon?" questions include: Fire a gun? Yes, because the cartridge itself contains an oxidizer. If fired parallel to the surface, the bullet would travel about six times further than it would on Earth. The muzzle velocity would be the same as that on Earth, but the bullet would remain at peak velocity longer. See the Great Wall of China? No, nor any other manmade object. Cloud formations, the oceans, and the land masses are visible.

36. Are there germs or bacteria on the Moon? None have been found so far. An Earth organism — streptococcus mitis — was discovered to have survived 30 months on the Moon in a piece of Surveyor III gear brought back by Apollo 12. Quarantine of returning crews was determined unnecessary after Apollo 14.

37. Have the Moon rocks told us anything? They have resolved some questions about the Moon: its apparent age, that there was no evidence of water, and that the maria or "seas" were formed by flowing lava. The samples also have stimulated many new questions. Examination of the rocks and of data from experiments left on the Moon will continue for years.

38. Why go to the Moon? The most accessible of the bodies formed at or about the same time as Earth, the Moon may be the best undisturbed record of the solar system's formation and history. Understanding why and how Earth evolved could help man make better use of the world's resources. Or it might tell how life began, knowledge some scientists feel is a major step toward such goals as a cure for cancer.

39. Isn't \$25 billion a lot of money just for a few boxes of rocks, though? Apollo is much more than just a few boxes of rocks. The quest for those rocks forced technological developments that already are contributing to a better life.

40. Just what benefits have we received from the space program? Tangible benefits derived from the space program or that emerge sooner as a result of space activities are too many to list here. These benefits do not include intangibles, such as new technology, stimulus to learning, national pride, world harmony, and potential scientific discoveries. Some you might encounter each day, however, are: fireproof fabrics and paint, smaller

and longer lasting radios and TVs, tougher plastics, stronger glues, hospitals in which larger numbers of patients can be cared for better by fewer nurses, live television coverage of events around the world, safer air traffic control and better ground traffic management, long-range weather forecasting that contributes to saving lives and crops, lightweight super-insulated sleeping bags, a heart monitor inserted through a hypodermic needle rather than by surgery, computer technology, longer-life flashlight batteries, et cetera.

41. Will the United States and Russia explore and colonize other planets? Yes, but not necessarily together. Both nations already have sent various unmanned probes to several planets, but neither has announced any firm program of manned planetary flight. Colonization of the Moon or planets probably is in the distant future. Most likely, it will be a scientific research colony such as maintained in Antarctica, rather than a populating colony intended to start a new world. Questions about Russia's space program should be directed to the Russian Embassy in Washington, D.C.

42. How far away are the planets (Moon, stars, etc.)? This is the type of question you can answer from general or special reference books in your library. Schools often carry texts of varying depths, from an elementary course on the solar system (or physics, rocketry, aeronautics, medicine, etc.) to comprehensive studies at the college level. You can pursue the subject as extensively as you wish.

43. What planets would we investigate? Probably all of them eventually. But only Mars is being considered seriously for manned landing. Conditions on the other planets seem too extreme. Inquiries should be made to Jet Propulsion Laboratory at Pasadena, California 91103. JPL develops unmanned lunar and planetary spacecraft. Earth orbiting satellites are developed by Goddard Space Flight Center at Greenbelt, Maryland 20771.

44. Will we use atomic energy on those flights? The Apollo Lunar Surface Experiments Package already uses nuclear energy in the SNAP 27 generator for electrical power to gather scientific data and transmit it to Earth. Nuclear propulsion systems for very long-duration flight have undergone extensive development, as have advanced electric generating systems. Inquiries to: AEC-NASA

Space Nuclear Propulsion Office, Washington, D.C. 20545.

45. Will you send animals to the planets first? Maybe. NASA currently uses various insects and animals for in-flight and laboratory experiments. They are handled in accordance with established humane standards. Perhaps the most famous space animal is the chimpanzee Ham, who made a 16-minute suborbital flight in a Mercury spacecraft January 31, 1961. Ten years after that flight, Ham was still alive and well in the National Zoo, Washington, D.C.

46. In space flight so far, have you seen UFOs? Some unidentified objects have been seen, but most later were proven or surmised to be such prosaic items as water droplets, material from the spacecraft or launch vehicle, or man-made satellites. Wally Schirra did report a UFO during his December 1965 flight of Gemini 6, but that turned out to be Santa Claus. No "flying saucer" has been sighted. Inquiries on UFOs: National Investigating Committee on Aerial Phenomenon, 1730 Rhode Island Avenue N.W., Suite 801, Washington, D.C.

47. What work is NASA doing...? NASA's research at this time does not include the subject you ask about. Perhaps your local library (school or state university) can help you find additional information.

48. Will you put me on your regular mailing list? Because so many people are interested in the space program, we try to make best use of our limited funds by restricting our regular distribution of material to places it will be available to many people — school classrooms and libraries in an eight-state region served by the Johnson Space Center in Houston, Texas.

49. Will NASA help us form (name, fund, etc.) our club? You may name your club anything you wish, of course, but if you decide to incorporate, you will be subject to state laws governing existing names and titles. NASA does not have funds or facilities to support private organizations. Similarly, NASA cannot sponsor education, travel, or housing for individuals.

50. Will you publish my poem (critique my story, comment on my theory, etc.)? Again, NASA does not have funds or facilities to study and formally acknowledge the many good submissions we receive or the fine personal achievements that are brought to our attention, but we sincerely appreciate your interest.

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE
Houston, Texas

SPACE BENEFITS

IN THE BEGINNING . . .

Galileo's observations of the Moon through a telescope in 1609 provided our first accurate picture of the Moon as a planet with mountains, valleys, and plains. Before Galileo reported his observations, scientists, including Aristotle, Copernicus, and Ptolemy, had developed only vague and inaccurate concepts of the Moon. With little more than the naked eye and a scientist's intuition as a basis for lunar studies, these earlier scientists depicted the Moon as a smooth crystalline sphere or as a lantern-like body lighted by internal fires which showed through openings in its surface.

For 300 years after Galileo and his contemporaries opened the door for modern lunar studies, our knowledge of the Moon grew only gradually as scientists obtained bigger and better telescopes.

Not until 1959, when the Soviet Union's Luna 3 first photographed the side of the Moon facing away from Earth, did we discover that that side of the Moon, never before seen by men, was strikingly different from the side of the Moon which always faces Earth. The large, dark-colored, circular basins which dominate the near side of the Moon are very rare on the far side of the Moon, which appears much rougher and generally lighter than the lunar near side.

The unmanned Orbiter satellites, which photographed potential landing sites for Apollo missions, exhibited unexpected orbital variations when flying around the Moon. Scientists attributed these changes in orbit to dense pockets of material on the Moon and to irregularities in the Moon's shape which exerted differing gravitational pull on the spacecraft, causing it to speed up and slow down at various places over the lunar surface. Subsequent studies have shown these curious gravitational variations are related to the large circular mare basins which dominate the front side of the Moon.

Discovery of these large collections of dense materials, called mass concentrations or "mascons," raised many new questions and posed some difficult problems for scientists attempting to explain the formation of the Moon and the nature of its interior. Did the Moon have a crust like the Earth's? they wanted to know. And, if so, how thick would such a crust have to be and how could it be formed to support the mascons?

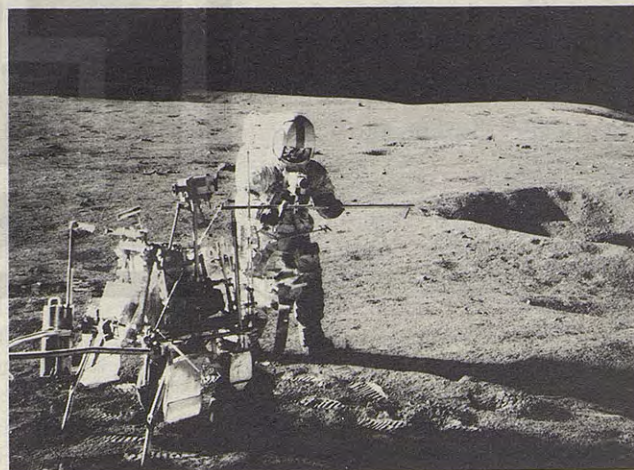
NEW ANSWERS

These were only some of many unanswered questions about the Moon at the time Neil Armstrong and Edwin Aldrin landed their spacecraft "Eagle" in the Sea of Tranquillity in July 1969.

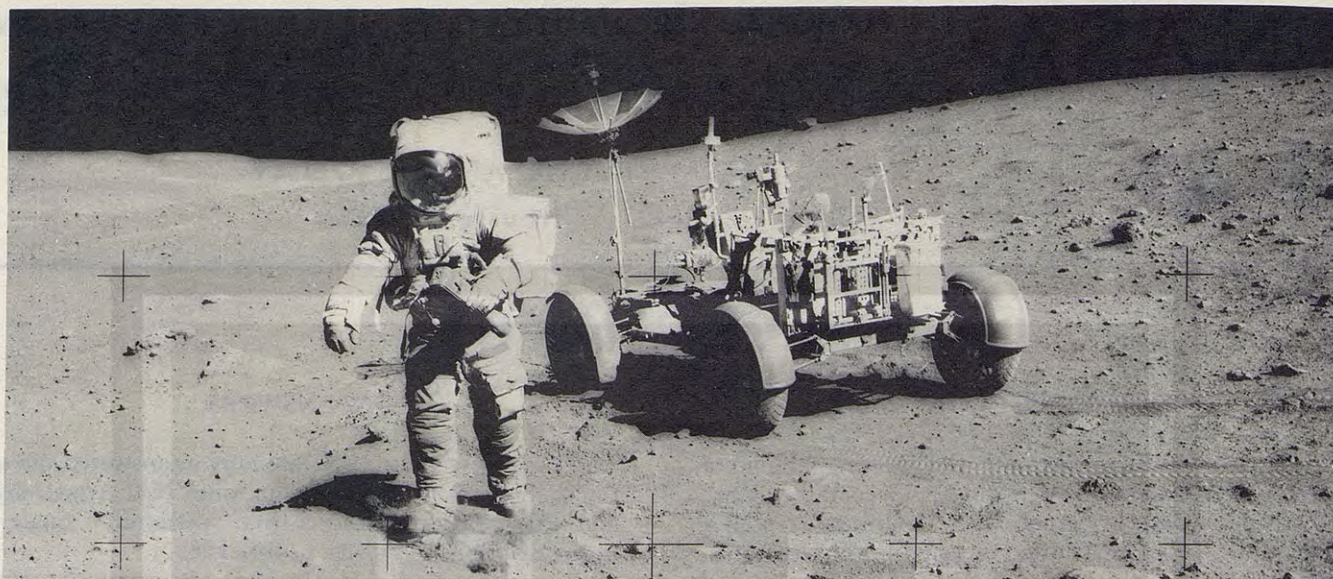
Before the Apollo 11 landing, one group of scientists believed there had once been abundant water on the Moon. Like the astronomers of Galileo's time who named the dark areas on the front side of the Moon mare (the Latin word for sea), this group believed that the flat lunar maria represented the accumulation of sediments brought into the mare basins by running water and that these basins were once seas or lakes. This same group thought that the sinuous rilles that appear as canyons on the lunar surface represented stream channels along which water had flowed.

Another group suggested that the mare areas of the Moon were filled by volcanic processes and consisted largely of lava flows. There was also much speculation before the Apollo 11 landing whether volcanic processes or meteoritic impacts were the major process forming the Moon's cratered surface.

Not only were the origins of the maria and of lunar craters in debate, but also the age of different areas on the surface. Some scientists believed the



The scientific equipment set up on the Moon, and the rocks and soil brought back from it, will help man learn more about Earth — what it has been, what it is, and what it might become.



Surface transportation, such as the electric lunar rover, extends the capability for scientific investigation of the Moon. The Apollo 15 crew

covered about 17 miles in 3 days and came home with about 170 pounds of samples.

Moon was a primitive body which had changed little since it formed some 4.6 billion years ago. Others believed the Moon had a more active earth-like history and speculated that features such as the maria were formed relatively recently — a few hundred million years ago rather than several billion years ago.

And, of course, fundamental to all these debates and still not answered are the questions of how and where was the Moon formed.

LUNAR SCIENCE

From samples of the Moon returned by Apollo astronauts, from instruments they set up on the lunar surface, and from experiments they conducted in lunar orbit, scientists are assembling the framework of new theories which can answer these questions about the Moon and which eventually will tell us much about our own planet.

Looking at the Moon from Earth on a clear night, one sees a large, dark-colored circular area which dominates the upper left quadrant of the lunar disk. This feature, known to scientists as Mare Imbrium — the Sea of Rains — was formed early in the Moon's history when an asteroid-size body about 100 kilometers or 60 miles in diameter crashed into the Moon with an explosion that lifted material from deep beneath the lunar surface and scattered it over much of the lunar front side. Much later, the crater left by the explosion was filled with lava, giving the area its oceanlike appearance.

Mare Imbrium is a most important feature in understanding lunar history because its formation affected such a large part of the lunar surface. By studying samples returned from the Moon, scientists have determined not only that the mare basin was formed by a collision with an asteroid and that the

crater was filled with lava and not ocean sediments, but they have also determined that the collision occurred about 4 billion years ago or about half a billion years earlier than any known geologic event on Earth. The lunar material where the crater was formed is obviously even older and may, in part, date back to the formation of the Moon and the planets of our solar system.

Many other lunar features are covered by rays and blankets of material thrown out of the Imbrium Basin and thus contain rocks that are also older than 4 billion years.

MOON CHRONOLOGY

By dating this one major feature, scientists are able to piece together relative and absolute ages for many other lunar features, and a chronology of major events on the Moon is gradually taking shape.

A network of scientific stations set up on the Moon by Apollo astronauts has detected quakes or movement about 700 kilometers (more than 400 miles) beneath the lunar surface — as deep or deeper than quakes which occur on Earth. The stresses which cause quakes can accumulate only in rigid structures. Thus, scientists believe the Moon has a crust and rigid mantle as thick or thicker than Earth's. Furthermore, the size and pattern of certain small lunar quakes suggest they are caused by stresses associated with planetary interiors where there are significant temperature differences rather than with a cold, dead planet.

Despite these apparent similarities of the Moon and Earth, Apollo lunar orbital experiments, coupled with laboratory studies of samples, suggest that the Moon may not have formed from the same chemical building blocks as Earth or the rest of the solar system.

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Other studies of lunar minerals show that there was little or no water present when the rocks crystallized and that Moon rocks have not been exposed to water since the time of their formation.

The apparent total absence of water, the very low carbon content of lunar materials, and the absence of organic compounds are convincing evidence that life never began to evolve on the moon.

MORE QUESTIONS

Though our knowledge of the Moon, and consequently our knowledge of planets in general, has increased immensely as a result of Apollo exploration, many important questions about the Moon have yet to be answered.

Why are most of the lunar maria on the side facing Earth? What was the source of the heat which appears to have melted much of the lunar surface? And when did the surface cool to form the crust which is still evident in the lunar highlands or mountain areas? What is the internal composition and structure of the Moon? And is there water vapor — a common gas in the interior of planets — deep beneath the surface of the Moon?

The geologic record once contained in Earth's crust has been largely worn away by the effects of our planet's atmosphere, and we know little of Earth's surface history beyond about 3.5 billion years ago. The Moon, by comparison, has almost no atmosphere and its surface features erode very slowly. As a result, rocks barely an arm's length beneath the lunar surface remain relatively unchanged for 100 million years; while on Earth, in this same period of time, water, ice, and wind will wear down an entire mountain range and begin to deposit it as sediment at the bottom of the sea.

The Moon, perhaps more than any other body in the solar system, can be a Rosetta stone for interpreting the early history of our Sun and its planets. Scientists can read, in the Moon's rocks and soil, records etched by high-speed particles emitted by the Sun when it was still a young star. They can view this record as it changed over the eons, showing how the Sun developed and released its life-giving energy. Our growing knowledge of the Moon's surface and its early formation will allow us to infer things about the structure and history of our own planet's crust, from which we draw nearly all the resources that support human life and progress.

SCIENTIFIC BONANZA

Of the six lunar-landing missions which end the Apollo Program, the final three flights offer by far the greatest potential for scientific return. The first of these second-generation Apollo missions, Apollo 15, showed that, with a lunar car to give them mobility, with improved spacecraft and life-support systems to double their time on the lunar surface, and with the base of knowledge provided by previous missions, astronauts could achieve scientific

results on a single mission equivalent to three previous missions combined. The remaining Apollo missions are thus the most important of the program and the most likely to provide answers to some of our remaining questions about the Moon, the Earth, and the solar system.

Our knowledge of Earth has advanced steadily over the past three or four hundred years, whereas our knowledge of the Moon and of the early history of the solar system has moved forward with the great bursts of learning associated with the development of the telescope in the early 1600's and with the development of space technology in our own time. Though the final achievements of Apollo lunar exploration remain to be seen, we can be sure from the scientific results already obtained that future generations will remember our generation as the one that first understood the early history of the solar system.

PRACTICAL BENEFITS

While it is not always clear at first just what the full results and practical benefits of new knowledge and exploration will be, history can provide some interesting clues.

Early experiments with electricity, nuclear energy, automobiles, airplanes, and rockets were generally considered novel and interesting but of little practical



The lunar samples — rocks and soil from on and under the Moon's surface — hold clues to the formation of our solar system. Scientists the world over are taking part in the effort to find those clues.



Space technology is being applied to Earth needs, such as finding and keeping track of pollution sources. The area pictured is a part of the Houston Ship Channel, but airplanes and satellites can monitor any area in the world.

value at the time they were performed. Daniel Webster complained that the great American West encompassed in the Louisiana Purchase was a howling wilderness Americans could never occupy. The purchase of Alaska from Russia at a cost of \$7 million was derided at the time as "Seward's Folly." And the electric motor, which has revolutionized our society, found little practical use for 100 years after it was invented.

It is interesting to compare the delayed payoff from these previous investments and enterprises with the almost-immediate returns we have gotten from the space program and with the clear promise of future benefits which space activities offer.

Communications satellites have already more than repaid the cost of developing and launching them and, in fact, have become commercially profitable. This new benefit from the space program is obvious to TV viewers. The Olympics were first televised internationally in 1968 from Tokyo and were viewed instantaneously by U.S. audiences. The largest audience in world history — over half a billion people, one-sixth of the world's population — saw man's first steps on the Moon.

In 1960, one could not send live TV across the Atlantic; by 1965, it was possible but expensive; by 1969, as a result of the space program, the quality had been improved and the cost reduced to one-fifth of the 1965 rate. At present, communications satellites are used largely for transoceanic traffic, providing economical links across the Atlantic, Pacific, and Indian Oceans. Before satellites, a West Coast-to-Japan cable circuit cost \$15,000 per month; today the Communications Satellite Corporation offers the same service at a charge of \$4,000 per month.

It is becoming apparent that satellites will soon handle domestic communications as well as transoceanic traffic. In 1960, there were fewer than 75 million phones in America. We now have about 120 million. In 1960, Americans made about 18 billion calls; this year, we will make about 200 billion. We are rapidly reaching the point where cables will not be able to handle the entire communications load in this country.

LOWER COSTS

The recent decision by the Federal Communications Commission to entertain suggestions for a U.S. domestic satellite system opens a whole range of potential new services, including low-cost message, data, and television transmissions coast to coast — and anywhere in between. The feasibility of using satellites to supplement and, in some cases, to replace cables and microwave circuits for domestic communications has been well demonstrated; and the response from industry to the Federal Communications Commission invitation shows that satellites have great potential for national as well as international communications.

Weather satellites have yielded almost immediate practical returns from our investment in space research and now provide constant daily information to the U.S. Weather Bureau. Tiros III gave advance information on Hurricane Carla and resulted in the greatest mass evacuation ever to take place in the United States. Over 350,000 people moved from the path of the storm. **There is no way to determine how many lives were saved.**

The continual improvement in techniques of interpreting data from this type of satellite and the improvements in the satellite itself offer the possibility of accurate forecasting of weather over vast regions. An accurate 5-day forecast of weather conditions over the United States alone would provide an estimated annual savings of \$6.75 billion when applied to agriculture, lumber business, surface transportation, retail marketing, and water-resources management. This savings alone would be more than any single year's cost of the nation's total space program.

GREATER SAVINGS

Weather satellites survey the ice fields of the Gulf of St. Lawrence with an estimated savings to the United States and Canada of \$1.7 million each year by more accurately predicting the opening of shipping on the Great Lakes.

Space observation of weather patterns on a global scale offers the only hope of understanding weather movement, global temperature, and global wind patterns, which is necessary for long-range forecasts.

The National Research Council of the National Academy of Sciences has estimated that accurate long-range forecasts would lead to savings of at least \$70 million annually from flood and storm damage, \$1 billion a year to the construction industry, \$500

million a year, \$500 million and \$450 million.

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million a year to fuel and electric power industries, \$500 million a year to fruit and vegetable producers, and \$450 million annually to livestock producers.

Although national pride, international goodwill, and a nation's prestige cannot be measured in dollars and cents, these are real and tangible benefits resulting from the space program. The Associated Press recently reported that a survey of high school student leaders in the United States showed this country's landing on the Moon was one of the things of which students were most proud.

In 1960, a worldwide poll showed the majority of the world believing that the dominant force in international affairs would be the Soviet Union. In 1970, after the Apollo 11 landing on the Moon, the same survey indicated the majority of the world's people believed that the United States was and would continue to be the most powerful and influential country in world affairs.

STABILIZING FORCE

Former NASA Administrator Thomas O. Paine described space as a major "stabilizing force in world affairs," which he said has given both America and the Soviet Union a unique opportunity to demonstrate before the entire world their national will, the strength of their institutions, the quality of their people, and the vision of their leaders.

In a hearing before the U.S. Senate Committee on Aeronautical and Space Sciences, the State Department's U. Alexis Johnson cited as examples of international cooperation fostered by the space program the Treaty on Outer Space, which, among other things, states that no nation can claim sovereignty to outer space and forbids the stationing of nuclear weapons on celestial bodies or in space; and an Agreement on Rescue and Return of Astronauts.

More than 50 countries benefit from the automatic picture-taking systems on U.S. weather satellites, which allow them to view daily weather patterns over their own territory. Teams of scientists in 39 institutions, representing 14 foreign countries, have received samples of lunar rock and soil collected by U.S. astronauts. At the same time, the United States and the Soviet Union have exchanged lunar samples and have conducted a series of meetings aimed at developing compatible spacecraft docking equipment so that U.S. and Soviet spacecraft can link up in space in a future joint manned mission.

MORE ECONOMY

Much of the potential use of space as a new resource to benefit man depends, of course, on the cost of transporting man and his machines into space. In 1958, the first U.S. satellite, Explorer I, cost more than \$100,000 a pound to place in orbit. When we use the largest present launch vehicles, the cost now is less than \$1,000 a pound. But we can do much better than that.

The United States has developed more than 20

different launch vehicles for manned and unmanned space programs. Each has required development cost, special support equipment, separate production facilities, and specially trained ground personnel, all for one launch in which the vehicle — successful or not — is destroyed.

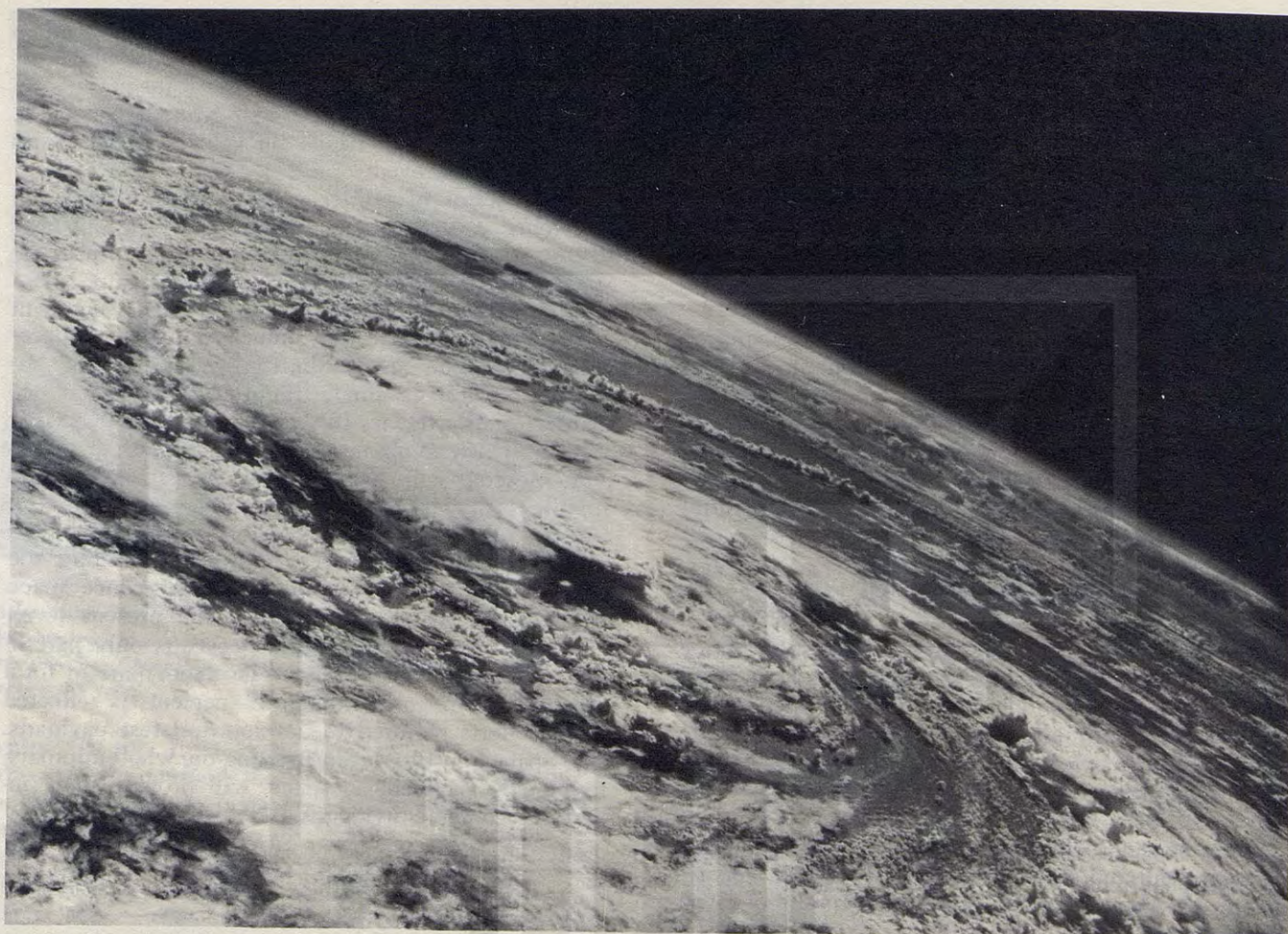
As a result of our experience with manned and unmanned programs, space technology has advanced to the point where it is possible to return entire space vehicles from orbit and use them again. NASA and industry teams have begun design and development work on a new-generation launch vehicle and spacecraft called the Space Shuttle, which will not be discarded after a single flight but will be flown many times during its 10-year lifetime. This versatile vehicle, which combines the features of both airplanes and rockets, will be designed to carry men and supplies and unmanned spacecraft into orbit. It will be piloted like a commercial airliner and will land on conventional-type runways, avoiding the cost of recovery at sea; thus, it should reduce space flight costs to about one-tenth the present level.

The reduction of operating costs is only part of the savings to be realized. The major part of total space program costs, about 80 percent, is reflected in the efforts required to develop and test payloads. The Space Shuttle, revolutionizing our whole approach to placing payloads in space, will provide such important economic dividends as:

1. Drastic reduction of payload development costs
2. Less risk of failure in placing payloads in orbit
3. A capability for routine, economical operations in space



High-altitude and orbital photography of farmlands and watersheds is being applied to programs to preserve and improve the Earth's resources. This photo, taken on black-and-white film through a green filter, shows the mouth of the Colorado River as it looks from 140 miles overhead.



More accurate, longer range weather tracking and forecasting is one of the benefits of the space program. Quicker detection of weather

Economies also are anticipated in the use of the Space Shuttle as a "test bed" for instrument development. Spacecraft found inoperable or erratic upon deployment could be returned to the launch site for further work before final placement into orbit. Thus, the operation of the Shuttle should virtually eliminate the risk of total failure in spacecraft operations.

INCREASED BENEFITS

As space flight becomes more economical and as it becomes easier for men and machines to operate in space, the potential uses and benefits of this new environment are almost unlimited. The immediate and substantial returns from communications and weather satellites demonstrate the value of space to man, and similar gains are waiting to be achieved in numerous other areas.

Potentially, the most useful of all the applications of space flight is to observe and measure the resources of Earth, to help manage them properly, and to deal with the problems of the environment. As with weather satellites and communications satellites, the value of space to Earth-resources studies is the

systems, such as Hurricane Gladys, can help save lives and property.

ability it gives man to view his planet from a perspective other than standing on its surface or looking down on it from only a few thousand feet in the air.

Every object on Earth, its subsurface strata, its atmosphere, and its oceans reflect distinctive electromagnetic characteristics which can be detected from a distance by specialized sensors. Vegetation has a different and recognizable reflective "signature" from water or bare earth. And a diseased crop will appear different from a healthy crop.

Coupling this knowledge with the synoptic view of Earth which space provides will allow us to capitalize on our previous investments in space in a practical and immediate way.

As an example of how this new space tool can be used, it is possible to detect, measure, and map water pollution, detect and determine the size of oil slicks at sea, and monitor worldwide air pollution. Off the coast of Iceland, airborne infrared sensors located the Gulf Stream, which meanders a considerable distance. This could enable fishermen to continue hauling in good catches.

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The Space Shuttle
more economical

POLLUTION CONTROL

It is significant that a sudden worldwide interest in controlling pollution and protecting Earth's environment has appeared just as we are developing the means to assess and monitor Earth's ecology on a global scale, for ecologists agree that only by dealing with the problem on a worldwide basis will we be able to save our oceans and atmosphere from being destroyed by pollution.

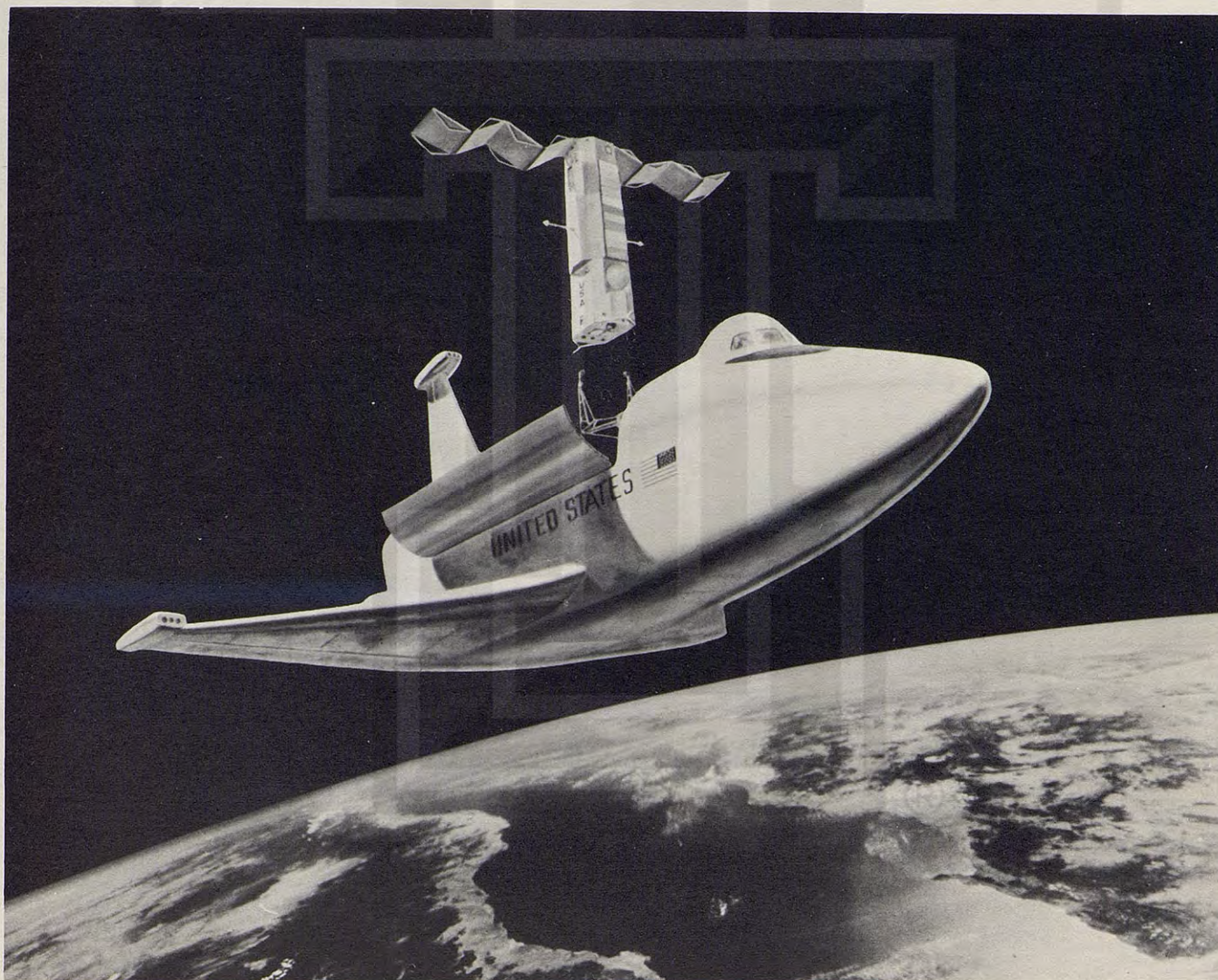
Infrared scanners, for example, can detect thermal pollution in water — both day and night. Conventional photographs from space can show discoloration and patterns in bodies of water for tracking and controlling pollutants. Other sensors can monitor the atmosphere to get the information on large regional distributions and cross-country movements of polluted air to help determine the sources of pollution and its extent.

By providing improved cropland surveys, space

sensing could aid both the farmer and the ecology. Crop diseases and insect infestations often begin in a localized area, perhaps within a single field, and then spread to the rest of the crop. It is common practice today for farmers to protect crops through large-scale preventive application of pesticides, which all too often are washed off the fields by rainfall and into streams, lakes, and oceans where they endanger wildlife and eventually work back in the food chain to man himself. But, if crop disease could be detected early, before it had spread to an entire field or crop, the farmer could apply only that pesticide needed to control the specific disease or infestation and only at the location where it was required. And both the farmer and the ecology would benefit.

UNLIMITED POTENTIAL

Seldom has a national investment yielded quicker or more substantial returns, offered clearer potential



The Space Shuttle is designed to make working in space easier and more economical. The spacecraft will fly many times, not just once,

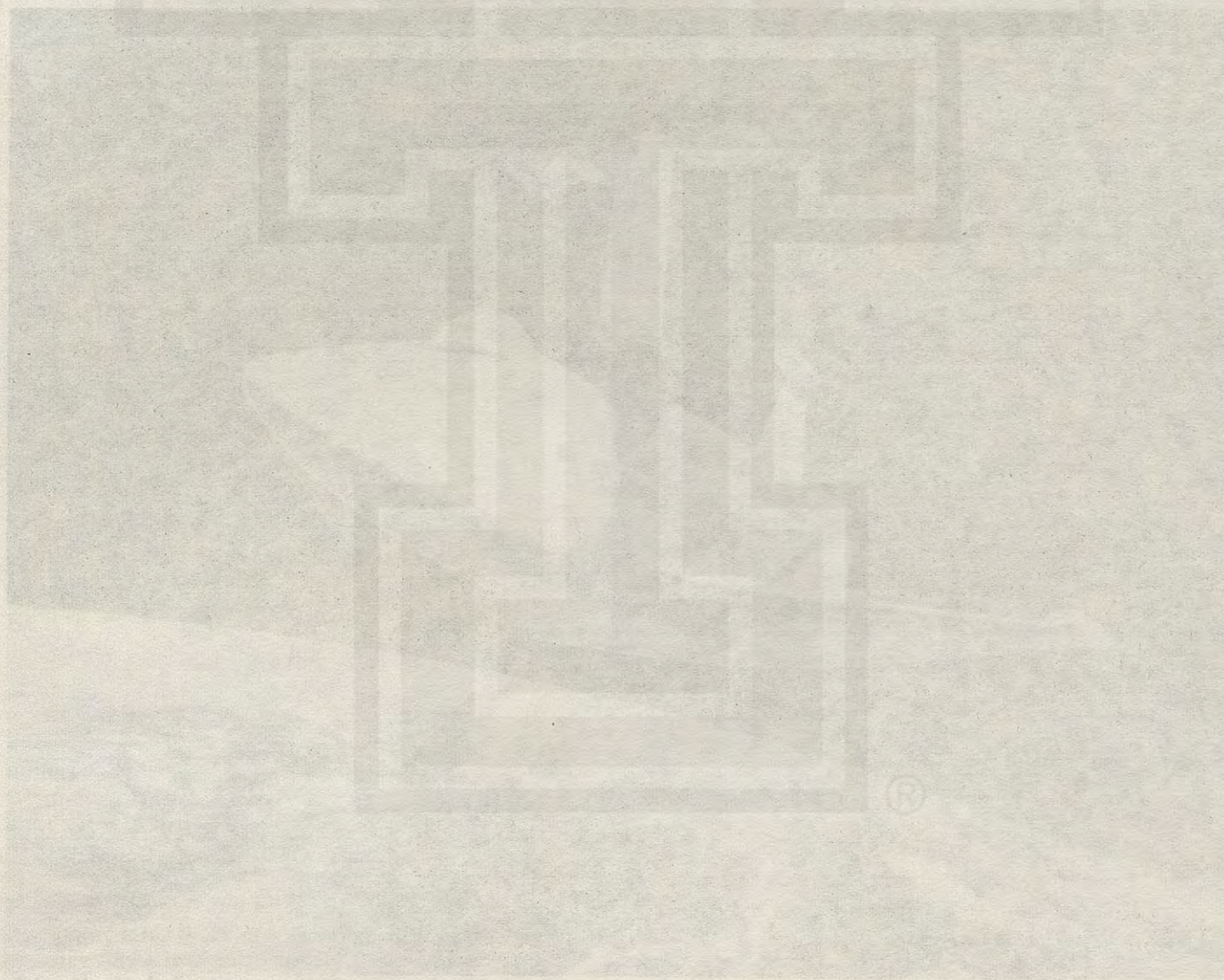
and can be used for many purposes — launching or retrieving unmanned satellites, for instance.

benefits for the future, or stimulated more effective and creative use of human and natural resources than has the space program.

The dividends from our investment in space have continued even as we made major reductions in the money and manpower committed to space research and exploration, prompting a European finance minister to estimate that each dollar the United States invested in space research over the past 10 years is returning \$4 today.

Speaking to the United Nations Conference on the Exploration and Peaceful Use of Outer Space

in Vienna recently, an Italian delegate noted that, "Very often, the expenditures borne by the most advanced countries for space activity are criticized as luxury in the face of the pressing needs of large sectors of mankind. But satellite educational transmissions would almost magically close a circuit through which money spent for the most sophisticated technology returns manifold benefits to a large number of less privileged peoples." And he said, "There can be no more dramatic confirmation of the sometimes-obscured truth that technological progress assures the progress of all humankind."



NASA FACTS

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LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE
Houston, Texas

JSC 08003

FIRE UNDER CONTROL





To demonstrate the ability of a lightweight foam and paint fire-retardant system to delay heat and flame penetration of aircraft compartments, salvaged aircraft fuselage sections were subjected to a jet fuel fire that reached 1800 degrees F (inset). The treated section would have given passengers a survivable environment for the 6 to 10 minutes required for firemen to subdue such a fire and rescue the inhabitants. A similar-looking but untreated section occupying the spot just beneath the inset photo above was completely consumed by the fire. Another awesome flame test, front page, saw Houston Fire Department volunteers walk up to a pit of burning jet fuel to demonstrate the protection of prototype ensembles developed at NASA's Johnson Space Center.

The tragic Apollo spacecraft fire of January 27, 1967, took the lives of three men, stunned the world, and threatened the future of space flight itself.

But from the ashes rose a flameproofing and fire-control program based on the most extensive scientific fire safety research ever conducted by man.

Available today to government and industry are fire prevention and protection techniques and materials that might never have been discovered or developed but for the launch pad fire. *They are the legacy of a tragedy.*

Fire safety always is a top-priority item in aerospace design. Obviously, however, the best efforts were not good enough. The mandate after the Apollo fire was threefold:

- Substitute wherever possible with completely fireproof material;
- If suitable substitutes do not exist, develop them;
- If any item cannot be made fireproof and if it cannot be deleted from the spacecraft, cover it with fireproof material.

Fireproof meant nonigniting in an atmosphere of 100 percent oxygen at 16 psia pressure — the greater the concentration of available oxygen and the higher the atmospheric pressure, the more readily a flame ignites and the quicker it burns (under the maximum test conditions,

which duplicated those experienced in the Apollo fire, even stainless steel fabric will burn on exposure to a spark or flame).

The materials were tested not only for fire resistance but for nontoxicity (death of the Apollo crew was from asphyxia from inhaling the toxic gases of combustion; thermal burns were only contributory).

Along with being fireproof and nontoxic, the material had to be functional. That is, it had to stand up under a variety of severe conditions it would meet in space.

Some 27,000 different material tests conducted in the months following the fire cut the number of acceptable materials that would not burn in oxygen at high pressure to just five:

- The glass-like material called Beta-fabric manufactured by Owens-Corning Fiberglas Company of Ashton, Rhode Island;
- A metallic fabric of nickel and chromium fibers made by the Brunswick Metal Products Company under the trade name Karma;
- An asbestos-like material manufactured by Rex Asbestoswerke in Schwabisch-Hall, Germany, and by National Carborundum Company in the U.S., among others;

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- The organic polybenzimidazole, or PBI developed by the Celanese Corporation under Air Force contract;
- A fluorocarbon, hexa-fluoropropene-vinylidene-fluoride copolymer, manufactured by 3M Company as Fluorel and subsequently modified by the Raybestos-Manhattan Company of North Charleston, South Carolina.

Those five materials were not developed by NASA, nor were many of the other materials important to the developing home and industrial fire safety program. But all were evaluated and cataloged for flammability, toxicity, and wearability in NASA's exhaustive search for a fireproof spacecraft.

The success of that search is evidenced by Apollo's record.

What fell into the category of "other materials" were those that did not make it into space because they were somewhat flammable in the oxygen-rich test chambers, although fireproof in the 14.5 psia 20 percent oxygen atmosphere that most humans know.

A data bank full of painstaking research into the qualities of those materials was available, information turned up in many cases only because of the requirement for a fireproof spacecraft.

Rather than see the data go unused, a small group of Johnson Space Center personnel asked and got support through NASA's technology utilization program to publicize the flammability tests and their results.



That fireproofing does not require a sacrifice of utility or beauty is shown in commercially available articles such as bedspreads (above) and draperies (below) made from glass fiber material. General use of materials tested or developed in NASA's spacecraft fireproofing program could cut significantly the losses of life and property in home and industrial fires.

The group planned and conducted a series of seminars, lectures, and demonstrations. A 15-minute film produced in support of the program is available on loan for group showings in nonsponsored public affairs or educational and industrial programs.

The film is "Fire Under Control" MSC-558 (1972). It is available at no charge from NASA Johnson Space Center, Photographic Technical Lab, Audiovisual Office, Code JL-13 Houston, Texas 77058.

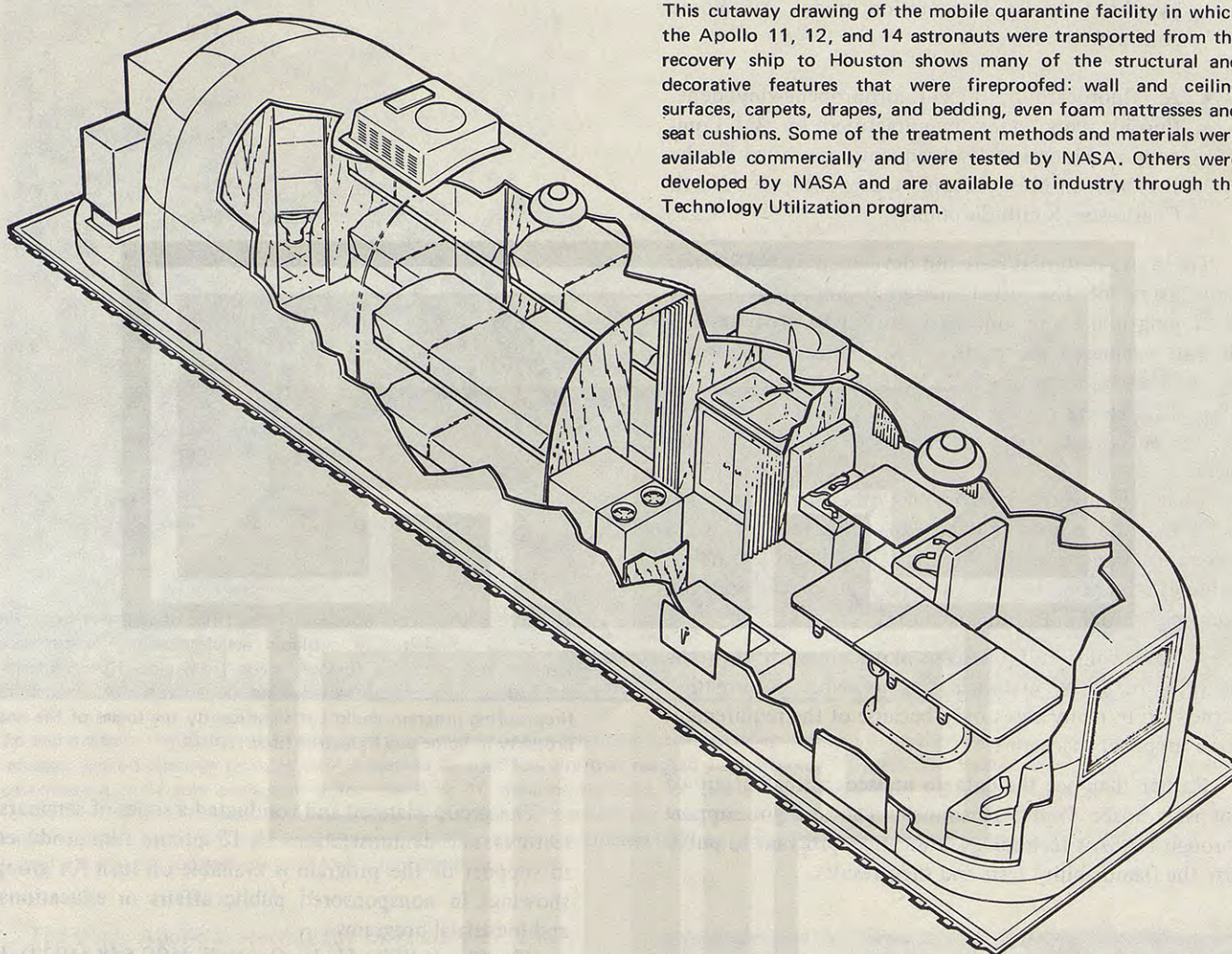
The first major seminar was conducted May 6-7, 1970. Called the "Conference on Materials for Improved Fire Safety," the seminar was attended by nearly 600 representatives of foreign and domestic industry and of city, state, and Federal government agencies.

The NASA Administrator, in a message to the conference, said "It is well known that for more than a decade NASA has been discovering new things about the Earth ... and the universe itself.

"Not nearly so well known, however, is ... that NASA has been discovering new things about human beings, materials, and equipment.

"Some of the agency's most significant and satisfying work in recent years has been directly concerned with the control or elimination of fire hazards.

"Recognizing that maximum benefit can be obtained from space research only when our discoveries are widely shared ... we hope you will find ways of adapting some of the many varied findings presented here to relieve and reduce the hazards of fire in everyday working and living — in housing, hospitals ... cars, aircraft, theaters ... wherever people and their valued possessions may be."



This cutaway drawing of the mobile quarantine facility in which the Apollo 11, 12, and 14 astronauts were transported from the recovery ship to Houston shows many of the structural and decorative features that were fireproofed: wall and ceiling surfaces, carpets, drapes, and bedding, even foam mattresses and seat cushions. Some of the treatment methods and materials were available commercially and were tested by NASA. Others were developed by NASA and are available to industry through the Technology Utilization program.

Those "findings presented here" were 27 papers that described the testing procedures and results, development of new materials, applications to the spacecraft, and continuing research — then and now — into fire prevention.

A publication of those papers is available under the title cited, reference NASA SP-5096 or Stock Number 3300 0390, for \$2.25 from **Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.**

Specific projects undertaken to apply and demonstrate the knowledge gained included refurbishing two Air Force and two NASA aircraft with nonflammable interiors, and similarly fireproofing the interior of the mobile home used as a transportable quarantine facility for the first three Apollo Moon-landing crews.

Development of families of items for multiple applications, such as nonflammable foams, films, fabrics and paper, even surface and wall treatments and paints, was conducted.

One of the more appealing projects is the development and manufacture for testing of fireman's protective clothing, a program being supported by the International

Association of Firefighters, the International Association of Fire Chiefs, the Bureau of Standards, and municipal fire departments nationwide.

Early testing was done with the help of the Houston Fire Department. For field tests and evaluation, the Johnson Space Center distributed prototype protective ensembles to departments in various parts of the country.

NASA's role in such a program ends with development of a final specification, which is turned over to the National Bureau of Standards for implementation.

Continuing developments in fire-protection, as well as in other areas of public interest or safety, are put into the public domain regularly.

In late 1972, for instance, NASA published abstracts on more than 1800 NASA-owned inventions available for licensing. The 880-page "NASA Patent Abstracts Bibliography" (NASA PAB) SP-7039 comes in two sections and is available at \$6 per section from **National Technical Information Service, Springfield, Virginia 22151.**

NASA Technology Utilization Publications describe science or technology of interest to commercial and other nonaerospace users and are available through **National Aeronautics and Space Administration, Code KT, Washington, DC 20546.**

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

SPACECRAFT DESIGN

A spacecraft's job is to provide transportation and services in space. As long as spacecraft requirements for both tasks are kept to a minimum, spacecraft design is comparatively straightforward. For instance, the United States' first orbital spacecraft, Explorer I, furnished only the propulsion to establish orbit and the communications service to relay data gathered by its experiment package passenger. The vehicles that followed grew progressively sophisticated — they could be commanded from the ground to perform various activities in space, for example, turning equipment off and on, changing attitude to point instruments in different directions, or even slightly altering the flight trajectory; but today, those early vehicles are thought of as "satellites" or "space probes."

What is more accurately called a "spacecraft" evolved as scientists decided they should retrieve the instruments they were sending into space. Next, they orbited animals and brought them back to Earth. These experiences enabled man to enter space and safely return to Earth.

To stay alive in space, man must be isolated from the vacuum. He needs oxygen to breathe and must be conditioned against the extremes of heat and cold of space. If his trip lasts longer than an hour or so, additional services are required: water to drink, food to eat, as well as a system for managing the resultant body wastes. For really long-duration flights, considerations of physical comfort grow in importance.

The designer's job is to put crew support and spacecraft operation systems together in a safe, workable package. The package, of course, is restricted in weight and size by the lifting power of the launch vehicle.

PROJECT MERCURY DECISIONS

If a spacecraft is to function only in space, it can be any shape suited to the job it is designed for; during its launch, it can be covered by a streamlined shell to protect it from the heat of atmospheric friction. But the requirement to come back to Earth means the craft must be shaped for stable, controlled flight and shielded against the metal-melting heat generated during reentry into the atmosphere.

In the mid-1950's, discussions of manned orbital flight established many of the basic design concepts

of United States manned spacecraft to date. For instance, designers studied both the rounded blunt body and the flattened lifting body concepts as potential spacecraft shapes, and ablating heat shields and radiating heat sinks. Reentry techniques were so new and so important, both to space flight and to military missile warheads, that President Dwight D. Eisenhower went on television in November 1957 to display the first experimental reentry body to survive its fiery trip and be recovered.

The blunt, nonlifting ballistic shape was selected for the first manned spacecraft as the quickest and safest approach to orbital flight. But design of the heat shield to cover the blunt end followed two paths, ablation and heat sink designs. The ablative heat shield gets rid of heat as the shield material chars and flakes off, while the heat sink shield absorbs heat and radiates it into space. Both types of shields were studied, but the lighter, more efficient ablation shield was finally selected for manned flight. The blunt-body Gemini and Apollo/Skylab spacecraft also use ablation shields.

SPACECRAFT SYSTEMS

To leave orbit and reenter the atmosphere, a spacecraft must reduce the velocity that keeps it in orbit. Control over time and place of deorbit requires a system of braking rockets and an attitude control capability to decelerate in the right direction. Equipment to measure and display spacecraft attitude and velocity therefore is necessary.

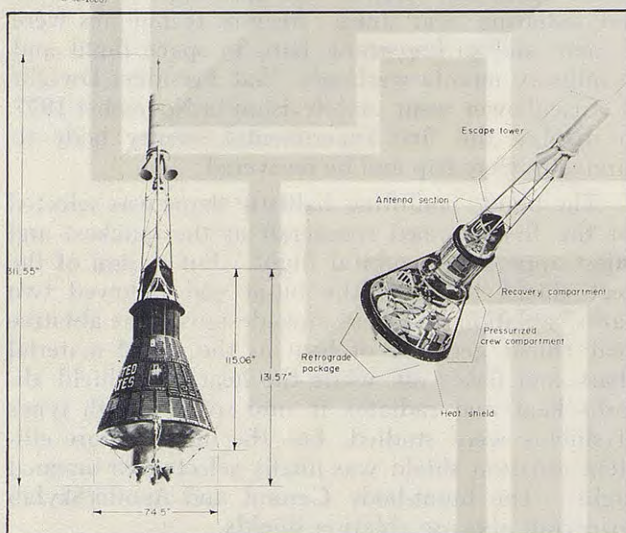
The blunt body shape requires landing assistance, such as a parachute; a lifting body, as proposed for a space shuttle, is designed to "fly" its way from space to a landing on Earth. In either case, and for extraterrestrial landers like the Apollo lunar module, structural design must take landing dynamics into consideration.

Up to this point, the spacecraft — with instrumentation to monitor its systems, and communications to link it with flight controllers on Earth — could be put through a successful flight by remote control. In fact, Project Mercury systems were designed to do just that because there was no experience to indicate a man's ability to function under space conditions, particularly weightlessness. (Mercury proved man a very desirable, in some cases necessary, addition to the system.)

MAN IN SPACE

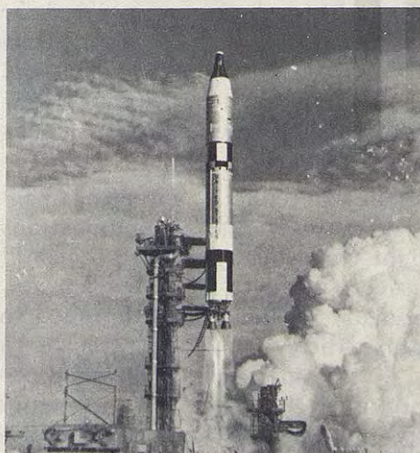
The systems are designed not only to be safe and reliable as possible, but to have one or more redundant (or backup) modes of operation that offer an alternate way to get the job done. Spacecraft designers employ the concept of redundancy whenever possible.

The fundamental workings of a life support system remain much the same from spacecraft to spacecraft: it gives man oxygen to breathe, cools and heats him as necessary, and generally helps him go about his business in space as efficiently and comfortably as possible. Design changes in environmental systems tend to take advantage of, rather than cause, spacecraft shape and structure changes.



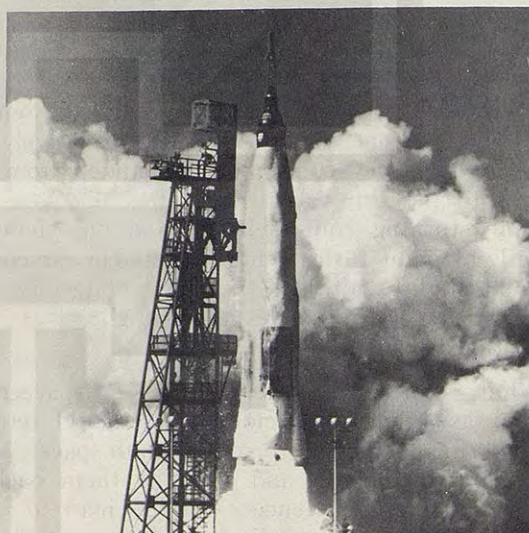
MERCURY spacecraft and its launch vehicle (above) pioneered United States spacecraft design. The large, blunt end is covered with a heat shield to protect the astronaut and the spacecraft systems from 3,000-degree reentry heat. The astronaut sat in a couch specially fitted to his body, was surrounded by spacecraft equipment, and had little room to move about. The Mercury spacecraft was built by

McDonnell Douglas Corporation
Post Office Box 516
St. Louis, Missouri 63166

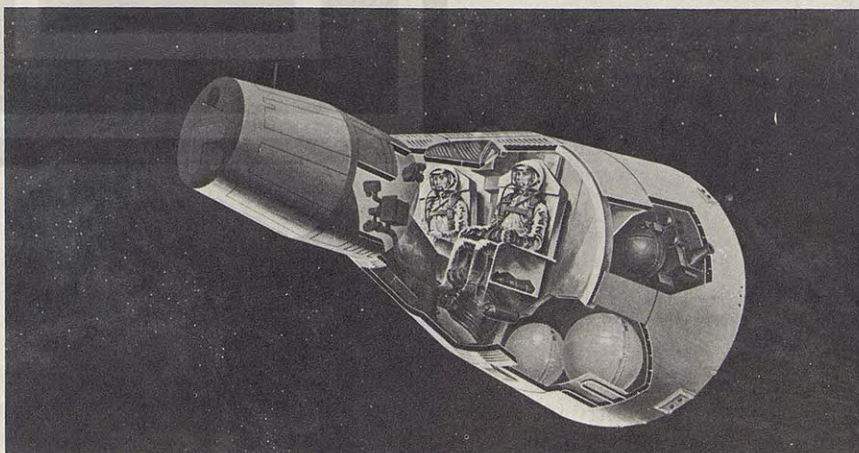


In the Mercury spacecraft, the astronaut had room enough to do little more than turn his head and move his arms. Gemini was only a bit more spacious, but Apollo crews were given room enough to move a few feet in several directions. They also ate hot meals and had more comfortable sleeping facilities in the Apollo spacecraft. Skylab has even more conveniences.

Major concept and hardware changes probably are on the way. Larger, permanent space stations, for instance, will be designed to be fabricated in space and provide living conditions more like those on Earth. The proposed space shuttle system will bring back the "airplane look." Future prospects of flight to the far-off planets promise spacecraft designs that truly will be out of this world.



GEMINI, below, the second United States manned spacecraft, also was built by McDonnell Douglas Corporation. In some respects, the two-man craft was an enlargement of the bell-shaped Mercury with its ablation heat shield. But experience told designers that much equipment, not needed for reentry, could be put outside the pressurized cabin and left behind at reentry. This increased the cabin volume and let the astronauts stretch their legs on long orbital flights. Gemini's design also included propulsion systems that permitted orbit changes and reentry maneuvers that could refine the splashdown trajectory.



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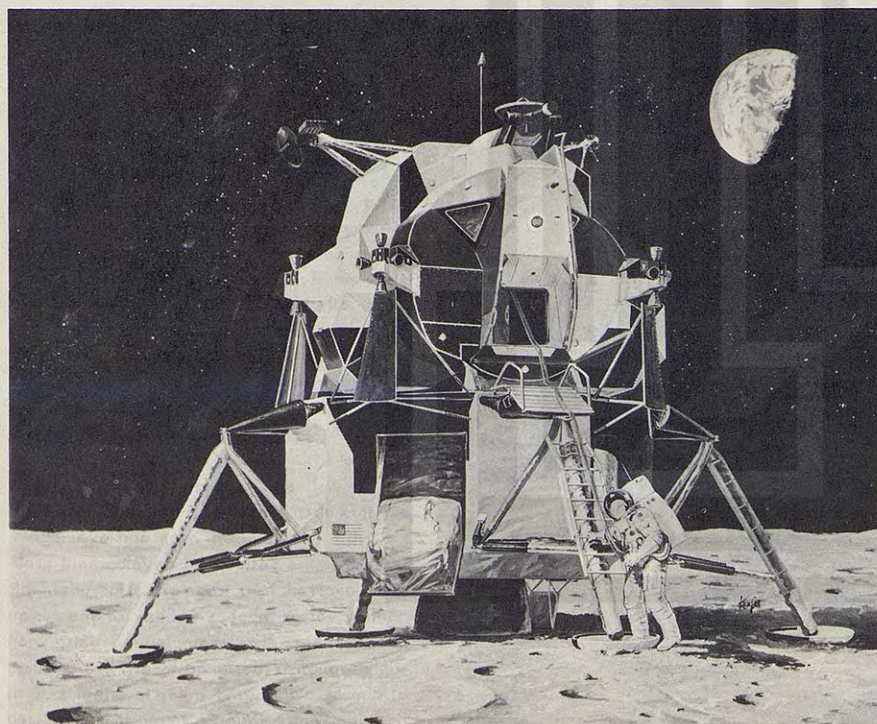
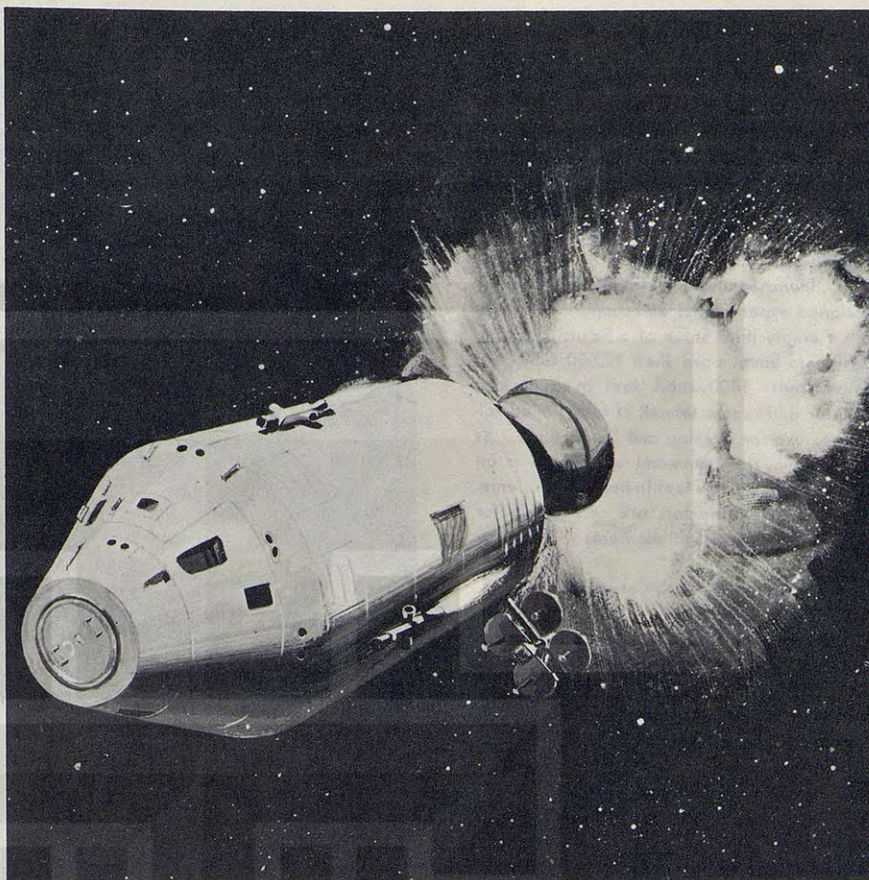


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APOLLO command and service modules extend the Gemini concept where the main propulsion system, electrical power, and oxygen supplies not needed for reentry, are located in an unpressurized service module. The blunt shape and ablation heat shield used on the Mercury and Gemini spacecraft were kept. The increased cabin volume allowed design with more comfortable facilities, such as, hot water for food preparation and hammocks for sleeping, for example. Both Apollo modules were built by

North American Rockwell Corporation
Space Division
12214 Lakewood Blvd.
Downey, California 90241



APOLLO lunar module represents the first true manned spacecraft — a vehicle that operates only outside the atmosphere. Its shape is dictated by its job of landing on the Moon, not by having to come back to Earth. The airless space and lunar environments offer no resistance that would heat the angular surfaces, and the 1/6 gravity on the Moon's surface lessens propulsion and structural requirements. Prime contractor for the lunar module is

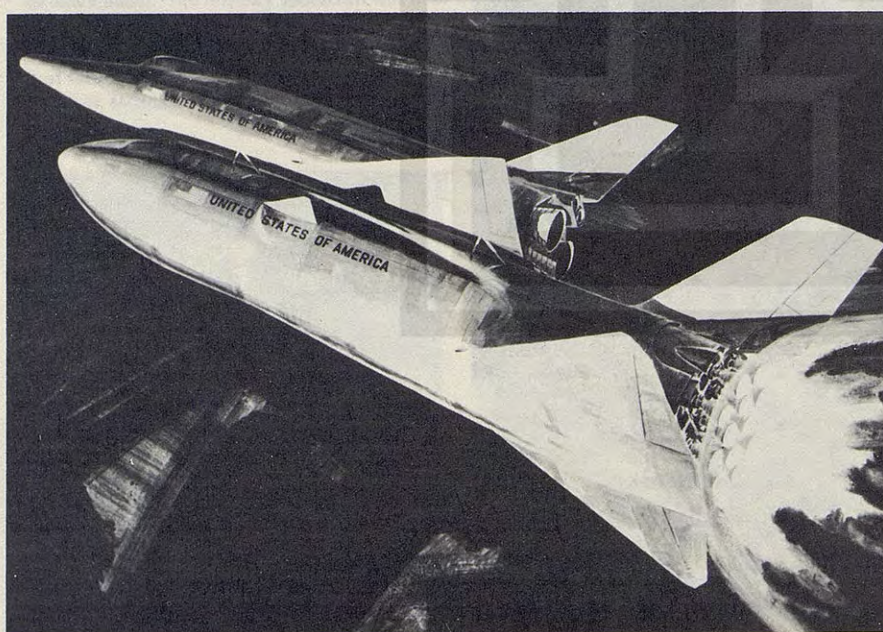
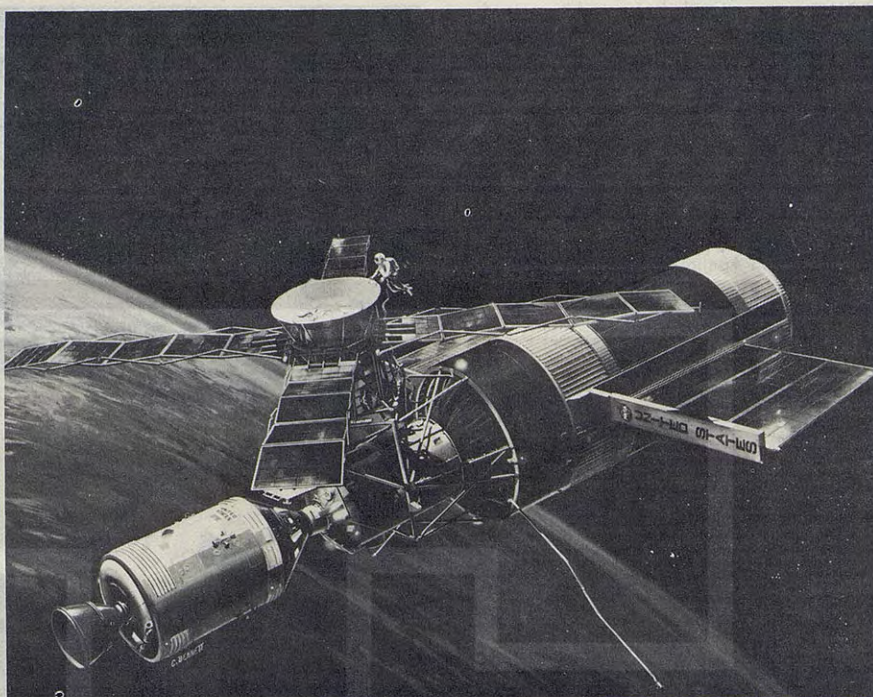
Grumman Aerospace Corporation
Bethpage, New York 11714

SKYLAB is a forerunner of long-life, complex space stations in which men can work or from which they can journey further into space. The program makes much use of available hardware and systems for economical study of future space projects. Skylab utilizes the Apollo command module, redesigned to support an orbital lifetime of 3 months, as the spacecraft taxi that takes men and supplies to and from the so-called "workshop". The "workshop", launched unmanned along with specially designed experimental and support hardware, is the empty third stage of a Saturn V rocket. Designers have more than 10,500 cubic feet (plus almost 1800 cubic feet in a docking adapter and access tunnel) of conditioned volume to use for working and living space. By comparison, the command module is a bit more than 200 cubic feet in habitable volume. Three prime contractors are responsible for the various spacecraft elements. They are:

North American Rockwell Corporation
Space Division
12214 Lakewood Blvd.
Downey, California 90241

McDonnell Douglas Corporation
Missiles and Space Systems Division
5301 Bolsa Avenue
Huntington Beach, California 92646

Martin Marietta Corporation
Denver Division
Post Office Box 179
Denver, Colorado 80201



SPACE SHUTTLE is a system of reusable launch vehicles and spacecraft. The idea is to economically meet the future requirements for a wide variety of space missions involving a number of different payloads. As envisioned, the shuttle will be able to put satellites into or retrieve them from orbit, ferry crews and supplies to and from space stations, even perform space rescue missions. Many aerospace industrial firms have submitted shuttle studies to NASA. They include designs of several types of lifting bodies that will let the boosters, as well as the orbiting spacecraft, maneuver to aircraft-like horizontal landings. Thus, the craft can be used over and over again. Typical of the design and development problems involved is a trade-off of aerodynamic heating versus maneuverability of one design over another. For example, the delta wing configuration is designed to achieve a range of almost a thousand miles to either side of its initial entry trajectory, but it is subjected to severe heating from atmospheric friction; while the straight wing shape reduces heat protection design requirements because of its reentry attitude, but cross-range capability is also reduced. Flight testing of such a reusable shuttle might be expected 3 to 5 years after design and development work is begun.

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

FOOD FOR SPACE

More and more, dining in space is becoming enjoyable. By the time the three-man Skylab crews are ready to spend 4 to 8 weeks at a time in orbit, they will be able to select varied menus from food not too different from that at home. Thanks to years of laboratory research and in-flight experience, the good-tasting meals also will meet exacting nutritional standards.

When man first ventured into space, it was for short periods of time. Hunger was no particular problem — the astronaut had eaten a hearty pre-launch breakfast, and he could expect an equally tasty meal on the recovery ship. Nor was his workload sustained to the point that, hungry or not,

he needed nourishment to keep his performance up to par.

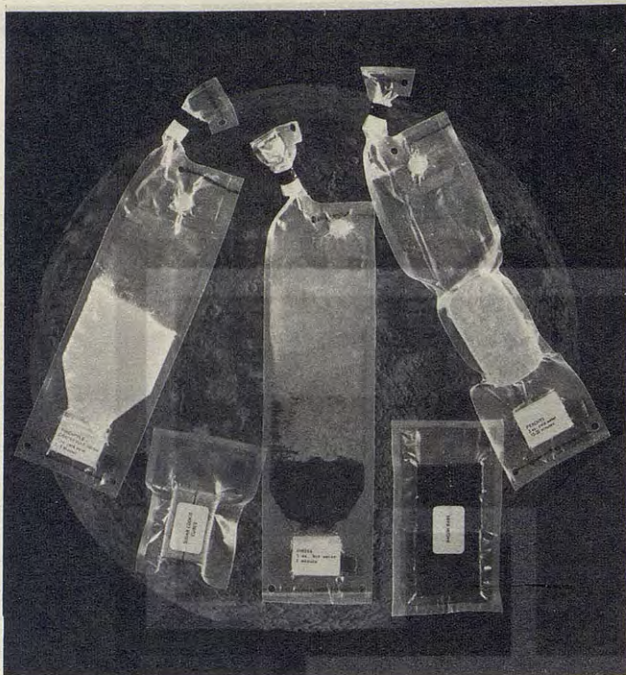
Even so, the requirements and problems of feeding man during the inevitable longer-duration space flights were investigated from the beginning. Each of the orbital Mercury capsules carried food of one kind or another — bite-size cubes (Scott Carpenter reported that his were crumbling, the crumbs floating freely around the cabin), freeze-dried foods (Gordon Cooper experienced difficulty in rehydrating his), and semi-liquids in aluminum tubes to be squeezed out like toothpaste.

None of the pilots described the food in glowing terms. But — problems of crumbs, unappetizing



Before it is sent into space, astronauts' food undergoes lengthy research and testing, some of the most important of which is taste-testing by the men who will have to eat it. Skylab meals, for in-

stance, were sampled by astronauts and program officials as well. The compartmentalized food trays are the same type that will be used in the orbiting Skylab to heat the food and eat from.



Man's first meal on the Moon was made up of rehydratable and dry bite-size foods — pineapple-grapefruit drink, sugar cookie cubes, coffee, bacon squares, and peaches. These items are refinements of processing and packaging developed in the Mercury and Gemini programs.

taste and texture, difficulty in adding water to the dried food, and a general lack of hunger notwithstanding — each found the actual act of eating in space to be relatively easy.

By the time Gemini spacecraft began flying, some of the dietary rough spots had been smoothed out. The aluminum squeeze tubes were done away with because the bulk of their weight came from the container rather than the contents (weight control is one of the most critical items of spacecraft design). The bite-size cubes of fruit, meat, bread, or desert foods were coated with an edible gelating to control the crumbling experienced in Mercury. Rehydratables in improved plastic packs added variety to menus strictly regulated to give an astronaut 2800 calories a day as 16 to 17 percent protein, 30 to 32 percent fat, and 50 to 54 percent carbohydrate.

The meals were nicely packaged. The cubes were vacuum sealed in clear plastic. The rehydratables came in laminated plastic bags with a one-way valve at one end and a tube at the other — the procedure was to insert the nozzle of a gun-type dispenser into the bag and add a squirt or two to the dry contents, then knead the mixture to a puree that could be squeezed through the tube into the astronaut's mouth.

The items in each meal were chosen before the flight by each astronaut in the crew. The meals were packaged separately in plastic and aluminum foil laminate that served as a litterbag for leftover food and empty wrappers.

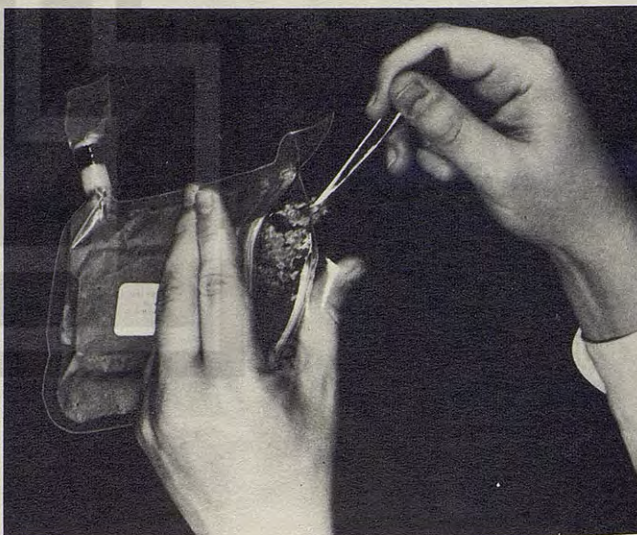
The packs then were labeled as to what meal to be eaten on what day by which crewman, and the packages were put into the spacecraft storage compartment in the order in which they were to be used. A typical meal would include shrimp cocktail, chicken and vegetables, toast squares, butterscotch pudding, and apple juice. Thanks to a varied menu from which they selected the food, the astronauts faced the repeat of any particular meal only about every fourth day.

From engineering and biological standpoints, these meals were about perfect. Not only did they yield high nutrient and energy values with low residue, they also stood up well under the shocks of launch, weightlessness, the vacuum of space, and the pure oxygen atmosphere of the spacecraft.

But the men who had to eat the food still were unimpressed. The appearance of most items was not especially appetizing, nor was the method of eating the food natural. Preparation of rehydratable meals was time-consuming, and the result was a thick lukewarm soup.

The biggest improvement early in the Apollo program was the addition of colder and hotter — about 50 degrees F from the chilling unit, 150 degrees from the heater compared to a range of 80 to 100 degrees in the Gemini spacecraft. Otherwise, the food was pretty much the same from one program to the other — until Christmas 1968.

The Apollo 8 crewmen, during man's first in-person look at the Moon, opened a surprise package: gravy-covered chunks of turkey, cranberry applesauce, and a spoon to eat with. It was the first authorized "home-cooked" meal on a United States space flight. Once Apollo 8 demonstrated space-food can be eaten in a more natural way, with a spoon rather than through a tube, further improvements were made.



The spoon-bowl package, with its wider opening than used in earlier rehydrating packages, permits foods with larger chunks of meat and vegetables. As the name indicates, the food can be eaten with a spoon.

Rehydratable packs. After food, pressure of the pack out. The lack of food for cocktail. A bread and se

The free space food — shelves — is frozen foods. Heat is applied to the water in solid state (liquid state). Leaving behind the flavor, n

Skylab n foods:

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Rehydratables were put up in "spoon bowl" packs. After hot water is added to the freeze-dried food, pressure-type plastic zipper along one edge of the pack is opened and the contents spooned out. The larger opening makes possible larger chunks of food for meals such as beef stew and shrimp cocktail. Another welcome addition was slices of bread and several flavors of sandwich spreads.

The freeze-drying process used to prepare the space food — and many new products on supermarket shelves — is a relatively simple one. Raw or cooked frozen foods are placed in vacuum chambers, and heat is applied to melt the ice. Under vacuum, the water "sublimes" or changes directly from the solid state (ice) to a gas without going through the liquid state. The vapor is drawn from the chamber, leaving behind a dried food that still has much of the flavor, nutrition, and appearance of the original.

Skylab meals will feature four different types of foods:

- Ready to eat rehydratable foods such as cream

of tomato soup, scrambled eggs, salmon salad, beverages, and deserts;

- Pre-cooked, thermally stabilized or fresh food with moisture content reduced to intermediate range (20 to 45 percent), such as dry roasted peanuts, cookies, or bacon wafers;
- Pre-cooked or thermally stabilized food with 50 to 80 percent moisture content — turkey and gravy, meat balls with sauce, or pudding;
- Pre-cooked or fresh food kept frozen at below zero temperature until it is prepared for eating, including prime rib of beef, filet mignon, shrimp cocktail, and lobster Newburg.

A correctly designed diet is necessary to maintain an astronaut's health at the desired level. Experience gained from Gemini indicated that less energy is needed to work in weightlessness, so daily calorie intake was reduced to between 2300 and 2500 during Apollo. Skylab menus will vary from 2000 to 2800 calories a day.



The addition of bread and sandwich spreads, such as these used by Apollo 14 crew, was a welcome one to the space menu, with each astronaut having a selection of white, rye and cheese-flavored bread

and peanut butter, jelly, or cheddar cheese spreads, or ham, tuna, or chicken salad.

Crew members have experienced weight loss on almost every space flight. Just how much and how directly this effect is related to food and water intake is being carefully studied, and the findings could mean even more changes to the space menu.

The psychology of eating in space also is being viewed with interest. The spoon-bowl packs and sandwiches already have contributed to making dinner in space seem more natural and, therefore, enjoyable. Skylab will go a step further with a special tray being developed to let each astronaut heat his own meal. The tray, 13-1/2 by 15 by 4-1/2 inches, has individual recessed compartments with built-in heating elements. The heated food is eaten with conventional utensils right from the tray compartments.

Understanding how much food an astronaut

needs, and making every attempt to have him actually eat what is planned for him, is important not only to astronaut ability to perform certain tasks in space, but to the conduct of the overall mission. On flights of a year or more into deep space, for instance, even a slight overcalculation of daily food requirements could mean excessive weight and volume penalties to the spacecraft. On the other hand, an underestimate could be disastrous.

The science of space-age nutrition still is too young to have greatly changed eating habits and preferences on Earth, but new nutritious and convenient food items created and packaged with space nutritious and convenient food items created and packaged with space program techniques already are available in the neighborhood grocery store.

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

SPACE SUIT

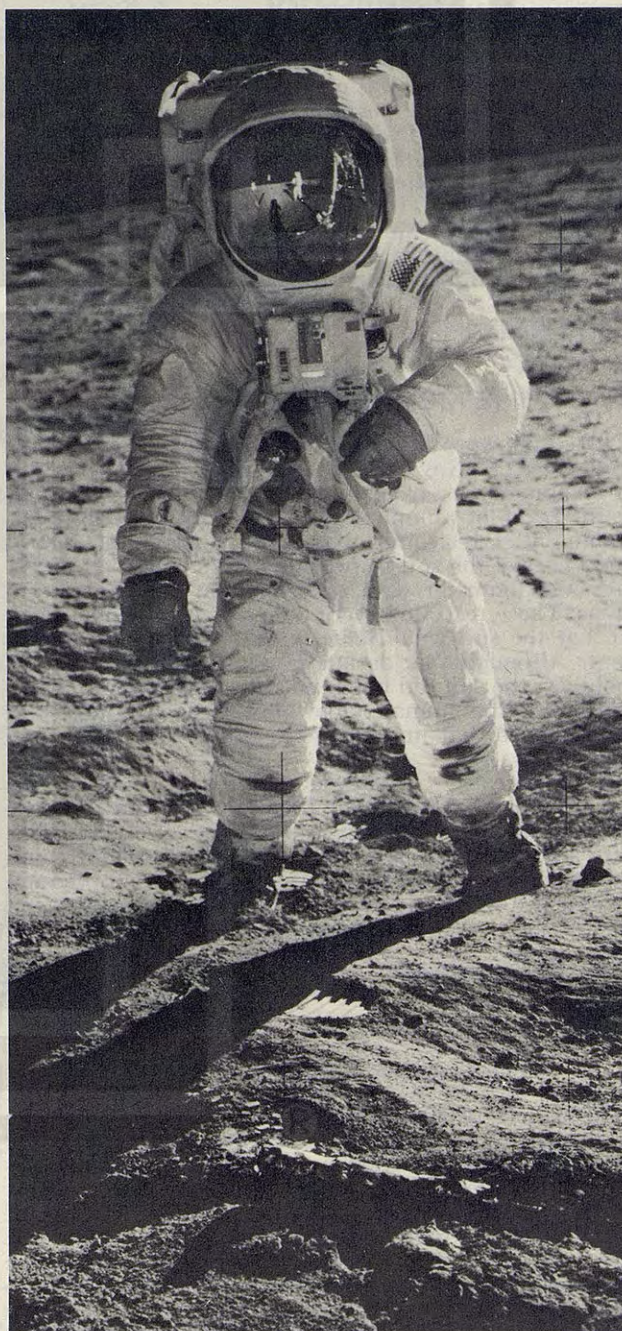
For many people, a space suit epitomizes the whole business of space exploration — toy manufacturers market pint-size space suits and helmets, cartoons show space pilots in the most unlikely places garbed in space suits, and space suits have even had an impact on women's fashions and on airline stewardess uniforms. While the space suit is a popular symbol for man's ventures into space, little is known, except by those directly involved, about what goes into the design and construction of these garments — which really are a sort of personal spacecraft that separates man from the hostile and deadly environment of space.

If an astronaut were to step onto the moon unprotected, the gases in his body would expand and his body liquids would boil. Death would result quickly as oxygen flowed out of lungs, blood, and body tissues. Furthermore, in sunlight, he would be scorched by temperatures as high as 250 degrees Fahrenheit; and, if he stepped into a shadow or if night fell, the temperature would quickly drop to 100, 200, or even 250 degrees below zero!

Fortunately, space suits that protect against these dire consequences can readily be designed. Neoprene-coated nylon will form a gastight layer which will hold oxygen at a pressure of 3.5 pounds per square inch, producing sufficient force against an astronaut's body to maintain blood as a liquid, to retain gases in body tissue and fluids, and to allow normal breathing. Additional layers of a very thin, plastic-like film, coated with silvery aluminum and separated by layers of glass-fiber cloth, will provide superinsulation to protect against a wide range of heat and cold.

If protection against the vacuum and temperature extremes of space were the only function required of a space suit, the job of designing such a suit would be quite simple. Unfortunately for space-suit designers, astronauts must also be able to move about freely and must be able to perform intricate operations, often with the added handicap of weightlessness.

Edwin Aldrin on the lunar surface in protective space suit and helmet with gold over-visor. Square package on back is portable life support system.



EARLY PRESSURE SUITS

Wiley Post, aviation pioneer of the early 1930's, was among the first to discover the problems of movement in a pressurized suit. Post proposed to make some cross-country speed runs in the "Winnie Mae" aircraft and believed he would be most successful flying at altitudes above the weather. He contacted the B. F. Goodrich Company and proposed a man-shaped gas-bag, which could be pressurized from his aircraft supercharger. Early attempts at producing such a suit failed when Post discovered that his suit became rigid and immobile as soon as it was pressurized.

Because any inflated shape tends to form a sphere, Post's suit bulged tightly; and the arms, legs, and torso became so rigid that it was nearly impossible for him to bend. The problem, which has plagued pressure-suit designers ever since, was overcome by patterning Post's suit in a nearly fetal position, which allowed him to sit in the Winnie Mae with his arms extended stiffly toward the controls and his legs on the rudder bars.

Pressure suits improved in mobility gradually during the next 30 years. However, jet pilots, and even astronauts in Projects Mercury and the Gemini Program, were tightly confined in the cockpits of their craft and had little need for leg and torso mobility.

THE MERCURY SPACE SUIT

The suit worn by Mercury astronauts was adapted from the U.S. Navy MK-IV pressure suit. It consisted of an inner layer of neoprene-coated fabric and a restraint layer of aluminized nylon fabric. Inelastic circumferential restraints were sewn around the elbows and knees of the suit to provide places where the cross-sectional diameter was less than that of the adjacent areas. These restraints were then tied together laterally so that the suit would bend when, say, the elbow was bent. Although this design provided a fair degree of mobility, the suit did not bend with the sharp hingelike motion of the human elbow but instead followed a gentle curve that limited the degree to which the arm could bend.

A good deal of energy was required to bend the suit joints, which folded in on themselves, reducing overall volume and increasing internal pressure. The Mercury suit was worn as a backup to the spacecraft cabin and would have been pressurized only if cabin pressure had been lost. (It never was.) The mobility shortcomings of the suit, when pressurized, were therefore less significant.

THE GEMINI SPACE SUIT

Designers used a different approach for the space suit worn by Gemini astronauts. Instead of providing flexible joints, they used a combination bladder/link-net construction in an effort to make the whole suit flexible when pressurized. The bladder was made of lightweight, neoprene-coated nylon in the general shape of a man. The gastight bladder was covered with a layer of nylon or slippery Teflon strands woven into a net and patterned to the shape of the body. Because the net had a surface area less than the area of the

inflated gas bladder, the net became the load-bearing structure when the suit was pressurized. The same principle is used to shift the load in an automobile tire from the inner tube to the tire casing. This construction improved arm and shoulder mobility and made the suit more comfortable when it was worn unpressurized for long periods of time.

THE APOLLO SPACE SUIT

For the Apollo Program, astronauts needed a suit which would allow them to climb through the small hatch of the lunar module, descend a ladder to the lunar surface, bend over to pick up lunar samples, and walk over the rugged lunar terrain. Designers recognized that the major problem in providing a more flexible space suit was to come up with a joint which could bend without compressing the gases in the suit. If, for example, one tries to bend a sausage-shaped balloon, he will find that it requires a surprising amount of force. As the balloon bends, it folds in on itself, reducing its inside volume and compressing the gas inside. If a joint which does not change in volume can be built, it can be bent quite easily.

Applying this principle, designers selected a constant-volume, bellows-like joint for the Apollo suit. When the joint is bent, it compresses on one side and expands on the other, maintaining a more or less constant internal volume. When properly constructed and balanced, a constant-volume joint will follow the astronaut's natural body movements freely and comfortably, even when the suit is fully pressurized.

In addition to affording astronauts much greater mobility, the Apollo suit had to protect them against micrometeoroids—tiny particles hurtling through space, which, unimpeded by a lunar atmosphere, strike the surface of the moon at speeds five to six times the velocity of a rifle bullet. It must also operate over a wide temperature range, in reduced gravity, and in intense ultraviolet radiation, which could permanently damage an astronaut's eyesight. It must also be compatible with a portable life support system carried on the astronaut's back to provide breathing oxygen and cooling for the astronaut and to remove carbon dioxide and water from his breathing oxygen. The Apollo space suit is designed to satisfy these requirements and to permit astronauts to explore the lunar surface in spite of its hostile environment. The complete suit system required to do this job is called the extra-vehicular mobility unit.

A liquid-cooling garment is the first layer of the space-suit assembly. The garment resembles a pair of long johns with a network of spaghetti-like tubing sewn into the fabric. Cool water is circulated through the tubing to transfer metabolic heat from the astronaut's body. Progressing outward from the liquid-cooling garment, the Apollo suit has a comfort layer of lightweight, heat-resistant nylon called Nomex, a gastight bladder layer of neoprene-coated nylon which maintains the pressure of the suit, a nylon restraint layer which prevents the bladder from ballooning, a lightweight super-insulation consisting of alternating layers of very thin plastic-like Kapton and glass-fiber cloth, several layers of Mylar and spacer material, followed by protective outer layers of Teflon-coated glass-fiber Beta cloth and Teflon cloth.

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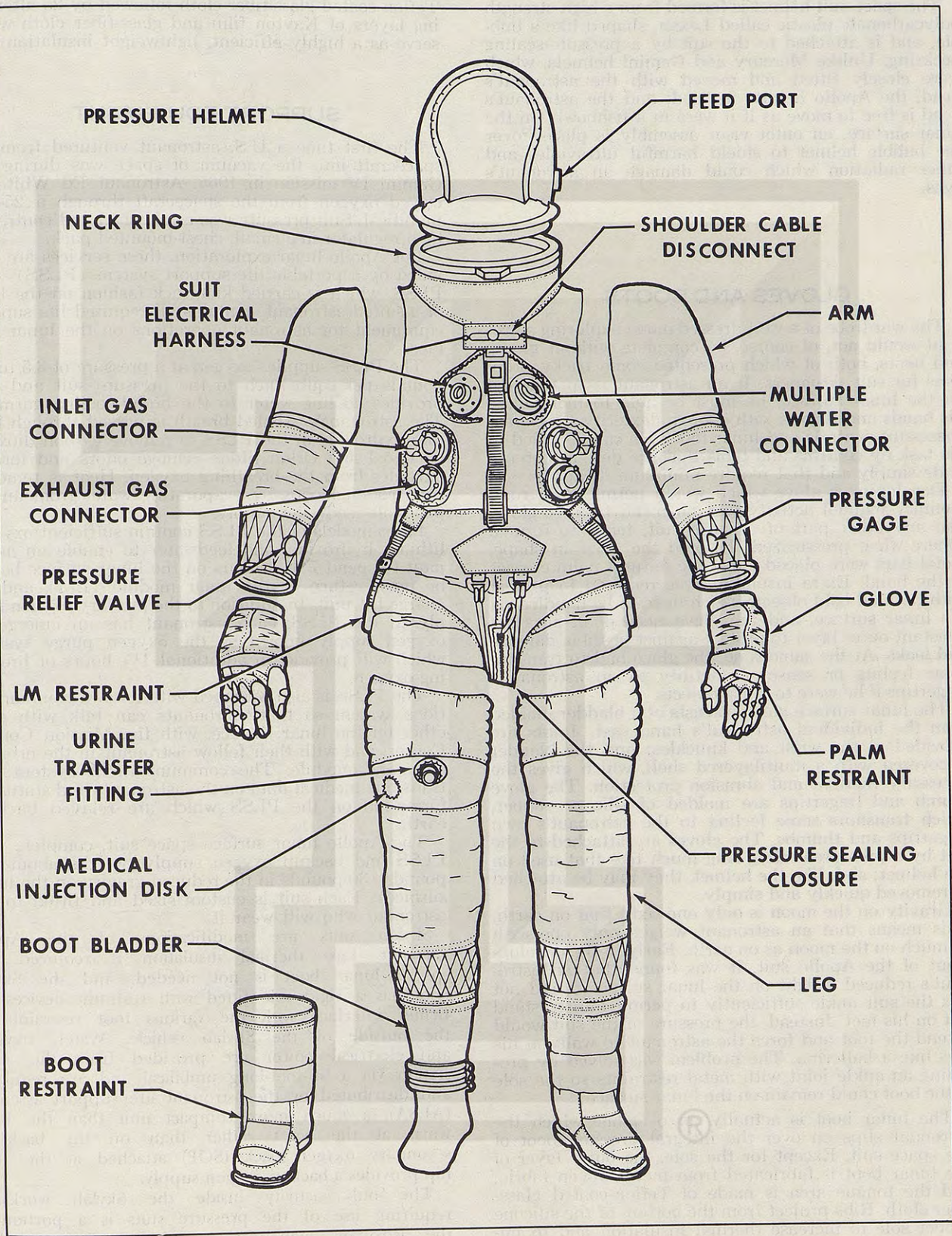
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APOLLO SUIT MODEL A-7L

The space-suit helmet is formed from a high-strength polycarbonate plastic called Lexan, shaped like a bubble, and is attached to the suit by a pressure-sealing neckring. Unlike Mercury and Gemini helmets, which were closely fitted and moved with the astronaut's head, the Apollo helmet is fixed; and the astronaut's head is free to move as if it were in a fishbowl. On the lunar surface, an outer visor assembly is placed over the bubble helmet to shield harmful ultraviolet and other radiation which could damage an astronaut's eyes.

GLOVES AND BOOTS

The wardrobe of a well-dressed moon-exploring astronaut would not, of course, be complete without gloves and boots, both of which presented some tricky problems for suit designers. If an astronaut is to function on the lunar surface, he must be able to manipulate his hands and fingers with enough dexterity to operate space-suit controls and lunar tools. He can be aided in his task by controls and tools that are designed to operate simply and that require minimum dexterity.

Developing a glove which would permit even rudimentary manual activity was no mean task. A glove, like any other part of a space suit, tends to form a sphere when pressurized. To hold the glove in shape, metal bars were placed along the natural palm creases of the hand. Extra insulation was required to protect both hot and cold objects which have to be handled on the lunar surface, and the glove needed an abrasion resistant outer layer to protect against possible damage and leaks. At the same time, the glove had to transmit some feeling or sense of tactility to an astronaut's fingertips if he were to grasp objects.

The lunar surface glove consists of a bladder molded from the individual astronaut's hand cast. Joints are provided at the wrist and knuckles; and the bladder is covered with a multilayered shell, which gives the necessary thermal and abrasion protection. The glove thumb and fingertips are molded of silicone rubber, which transmits some feeling to the astronaut's own fingertips and thumbs. The gloves are attached to the suit by a pressure-sealing ring much like that used on the helmet; and, like the helmet, they may be attached or removed quickly and simply.

Gravity on the moon is only one-sixth that on earth. This means that an astronaut weighs only one-sixth as much on the moon as on earth. Early in the development of the Apollo suit, it was found that an astronaut's reduced weight on the lunar surface would not flex the suit ankle sufficiently to permit him to stand flat on his feet. Instead, the pressure of the suit would extend the foot and force the astronaut to walk on his toes like a ballerina. The problem was solved by providing an ankle joint with metal restraints so the sole of the boot could remain on the lunar surface.

The lunar boot is actually an overshoe which the astronaut slips on over the integral pressure boot of the space suit. Except for the sole, the outer layer of the lunar boot is fabricated from metal woven fabric; and the tongue area is made of Teflon-coated glass-fiber cloth. Ribs project from the bottom of the silicone rubber sole to increase thermal insulation and to improve traction. The inner layers of the boot consist of

Teflon-coated glass-fiber cloth followed by 25 alternating layers of Kayton film and glass-fiber cloth which serve as a highly efficient, lightweight insulation.

SUPPORT EQUIPMENT

The first time a U.S. astronaut ventured from his spacecraft into the vacuum of space was during the Gemini IV mission in 1965. Astronaut Ed White received oxygen from the spacecraft through a 25-foot umbilical. Suit pressure was established and controlled by a regulator in a small, chest-mounted pack.

For Apollo lunar exploration, these services are provided by a portable life support system (PLSS). The PLSS, which is carried knapsack fashion on the back of a suited astronaut, contains all required life support equipment for astronaut operations on the lunar surface.

The PLSS supplies oxygen at a pressure of 3.5 to 4.0 pounds per square inch to the pressure suit and also provides cooling water to the liquid-cooling garment. The astronaut's exhaled breath is passed through lithium hydroxide in the PLSS to remove carbon dioxide. Charcoal and Orlon filters remove odors and foreign particles from the breathing oxygen. Heat is removed from cooling loops by evaporating water from an expendable feedwater supply.

Later models of the PLSS contain sufficient oxygen, lithium hydroxide, and feedwater to enable an astronaut to spend 7 or 8 hours on the lunar surface before he must return to the lunar module (LM) and recharge the unit. In addition to the primary oxygen supply in the PLSS, each astronaut has an emergency oxygen supply known as the oxygen purge system, which will provide an additional 1½ hours of breathing oxygen.

The PLSS is also equipped with its own communications system so that astronauts can talk with each other on the lunar surface, with the Mission Control Center, and with their fellow astronaut in the orbiting command module. The communications system also transmits medical data on the astronauts and status information on the PLSS which are relayed back to earth.

The Apollo lunar surface space suit, complete with PLSS and backup oxygen supply, weighs about 180 pounds (30 pounds in the reduced gravity on the lunar surface). Each suit is custom sized and fitted to the astronaut who will wear it.

Skylab suits are modifications of the Apollo garment. Less thermal insulation is required, the special lunar boot is not needed, and the Skylab boot has a rigid sole fitted with restraint devices for firmer interface with the various foot restraints on the outside of the Skylab vehicle. Water, oxygen, and electrical power are provided from the space station via a 60-foot-long umbilical and are regulated and distributed by the astronaut life support assembly (ALSA), a much more compact unit than the PLSS worn at the waist rather than on the back. A secondary oxygen pack (SOP) attached at the right hip provides a backup oxygen supply.

The only activity inside the Skylab workshop requiring use of the pressure suits is a portion of the astronaut maneuvering unit experiment; otherwise, a "shirtsleeve" mode is standard.

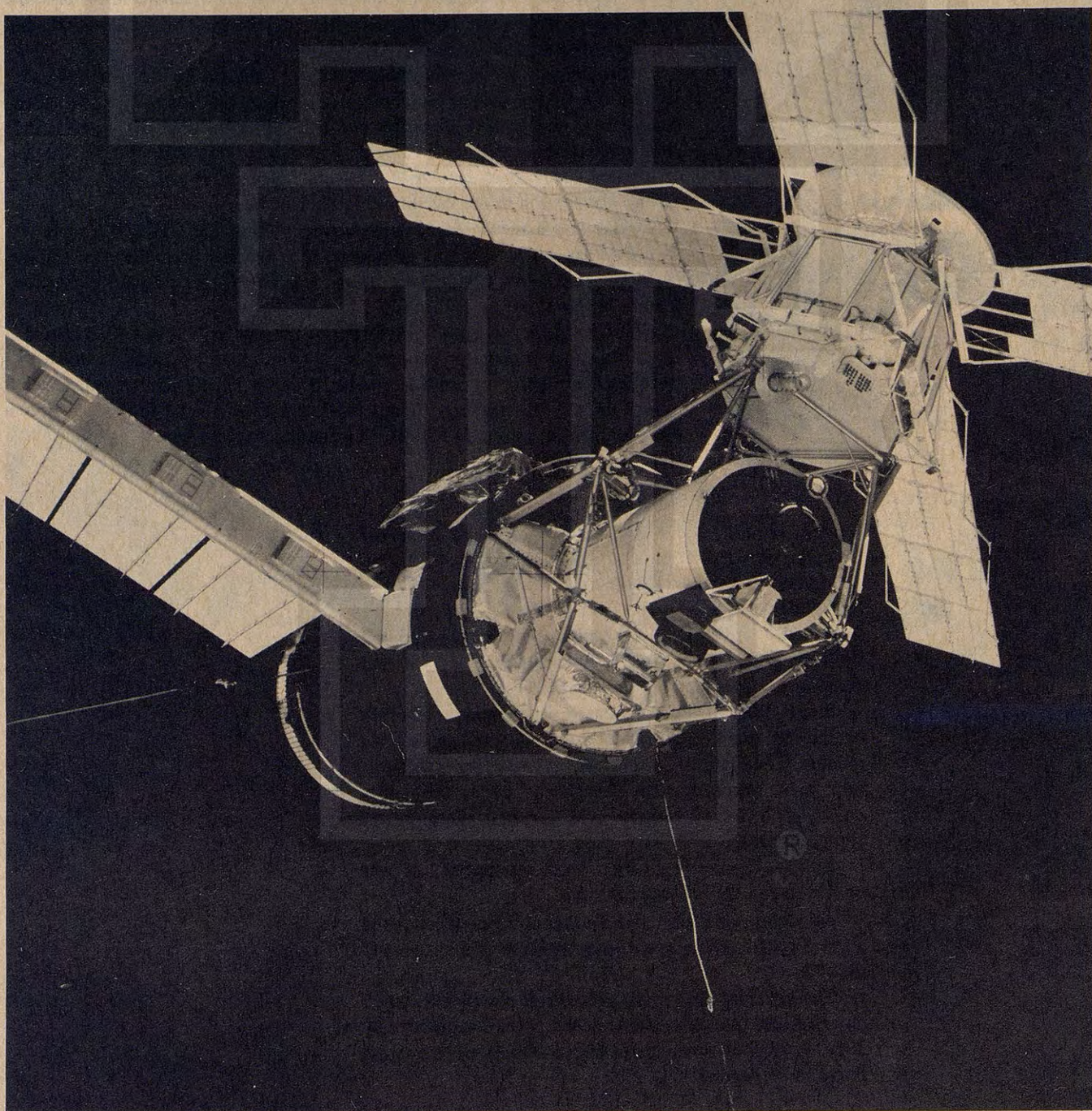
NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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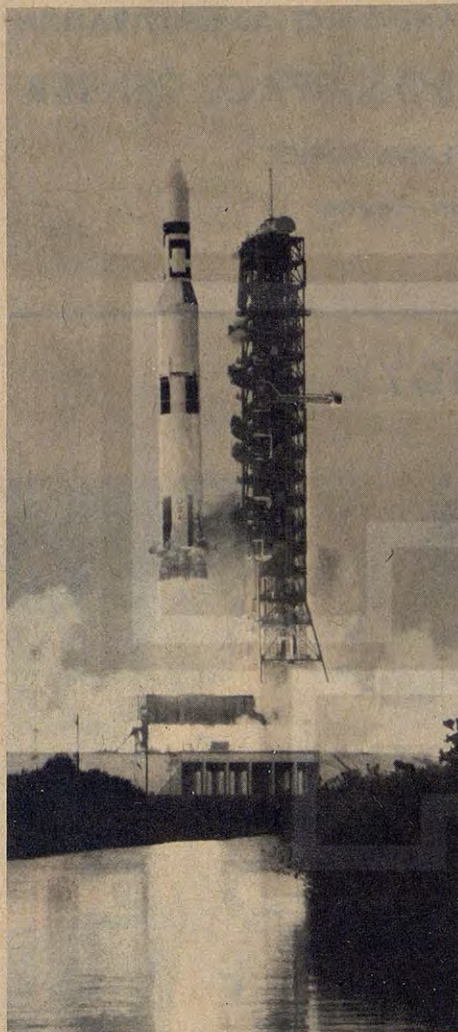
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Houston, Texas

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SKYLAB — 1973 - 1974



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The unmanned Saturn Workshop was launched May 14 at 12:30 p.m. Central Daylight Time (1730 Greenwich Mean Time) atop a Saturn V launch vehicle from Pad A of Launch Complex 39 at Kennedy Space Center, Florida.

The workshop's initial orbit was 269 miles circular with an inclination to the equator of 50 degrees.

An hour after launch, ground controllers still were waiting for confirmation that the workshop's solar arrays had deployed, a signal they never received.

Analysis of launch data showed a failure of the meteoroid shield some 63 seconds into the flight. Slight deployment of one of the two solar array wings, which provided about half of the electrical power used in Skylab, also was indicated.

The board appointed to investigate the failures reported on July 19 "Of several possible failure modes of the meteoroid shield . . . the most probable . . . was internal pressurization of its auxiliary tunnel which acted to force the forward end of the meteoroid shield away from the shell of the workshop and into the supersonic air stream.

"The breakup of the meteoroid shield, in turn, broke the tie downs that secured one of the solar array systems . . . Complete loss of this solar array system occurred at 593 seconds when the exhaust plume of the S-II stage retro-rockets impacted the partially deployed solar array system."

In the hours after launch, NASA and contractor personnel worked to salvage the mission in the face of mounting trouble.

Skylab was maneuvered so its telescope mount solar arrays faced the Sun to provide as much electricity as possible. But in this attitude Skylab, without the meteoroid shield that was to protect against solar heating as well, got too warm — up to 126 degrees F inside.

Several NASA centers designed various thermal shields of reflective cloth to protect the workshop's exposed areas from direct sunlight. Three shields were decided upon — a parasol type to be deployed through an experiments airlock in the lab was the primary device, a "sail" to be drawn up over a twin-pole frame, and a similar sail to be deployed from the command module were alternatives.



CONRAD



KERWIN



WEITZ

Pete Conrad, Joe Kerwin, and Paul Weitz lifted off Complex 39's Pad B on a Saturn 1B at 8 a.m. CDT May 25 after twice being rescheduled.

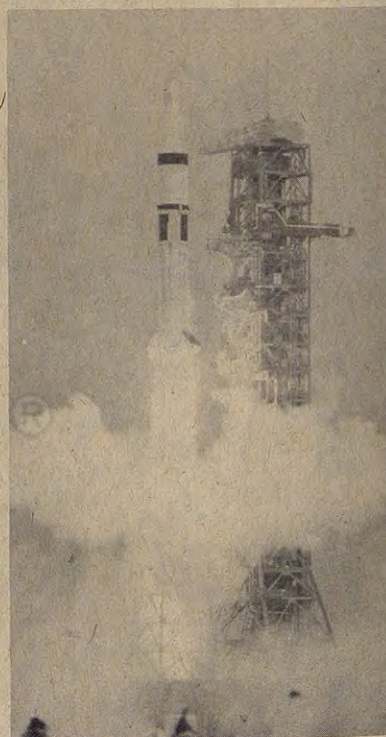
Rendezvous was in the fifth revolution and, after an hour and a half of station keeping, the crew docked and finished preparations for a fly-around inspection and stand-up extravehicular activity (SEVA).

Weitz stood in the open hatch while Kerwin held him by the legs and Conrad maneuvered the command-service module. The scientific airlock was reported free of debris, one solar array system completely gone, the other deployed 5 to 10 degrees and jammed there by an aluminum strap.

In the 75-minute SEVA, Weitz attempted but was unable to cut or pry loose the strap.

At 10:50 p.m., after five attempts, the crew redocked with Skylab. They spent the night in the command module.

The next day, following procedures completed only 2 days before, the crew deployed the parasol sunshade. By June 4, temperatures inside the orbital workshop were down to 75 degrees.



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Another power problem occurred May 30 when four of 18 battery packs in the telescope mount power supply system showed they were taking less than one-half charge from the solar arrays, a result of overheating during the unmanned period.

While the crew continued a power-limited schedule of experiments and observations, mission support personnel worked out and tested procedures to free the jammed solar wing.

Radioed to Skylab one day, practiced inside the workshop the next, the procedures were used on Day 14 of the mission, June 7.

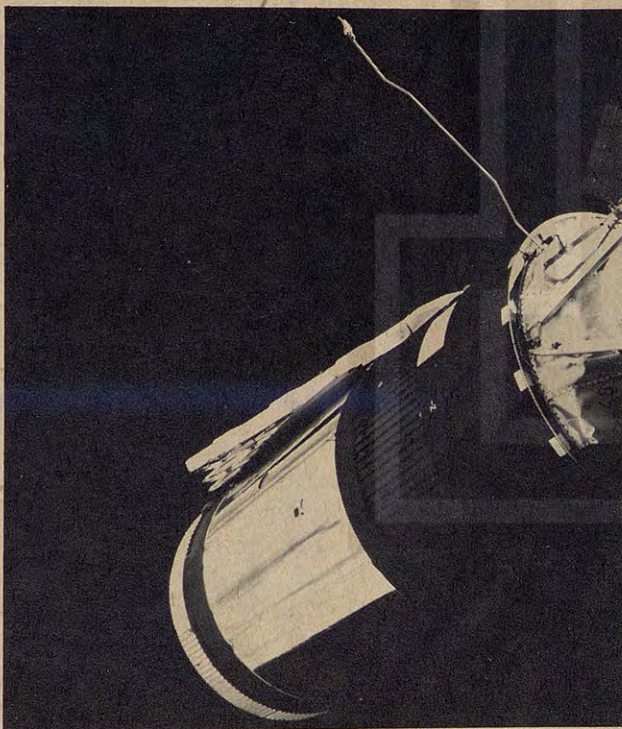
Conrad and Kerwin spent about 4 hours and 10 minutes in extravehicular activity. They freed the array, and within hours the electric power supply was such that a mission close to the original plan was authorized.

On June 19, the 26th mission day, Conrad and Weitz went EVA for 96 minutes to retrieve film from the telescope mount. Conrad also reactivated a battery regulator relay — he tapped the case with a hammer.

Splashdown came at 28 days 50 minutes, June 22, some 830 miles southwest of San Diego, California.

When the three crewmen emerged from their spacecraft on the deck of the recovery ship U S S Ticonderoga, they appeared wobbly but well, dispelling fears that the human body could not function after 4 weeks in the weightlessness of space.

Kerwin, the medical expert in the crew, said in a postflight press conference "It was a continuous and pleasant surprise to me to find out how easy it was to live in zero g, and how good you felt."



CONRAD: "Okay, Houston, it looks like the meteoroid shield at the upper thick panel on the SAS plank has wrapped around it just slightly. Now my guess is that our easiest thing to do is just go to the end and try and deploy it."



KERWIN: "In the lower body negative pressure device, we all experienced some degradation objectively on the measurements of our ability to pool blood . . . in the lower extremities, which is what lower body negative pressure does."

The first Skylab crew recommended increased exercise for those to follow.

In spite of the problems encountered, the first manned mission successfully accomplished most objectives established for it.

- Some 80 percent of planned solar data was obtained, with a major scientific accomplishment in the monitoring of a solar flare.
- 11 of 14 planned Earth resources data runs were accomplished.
- Data were taken on all scheduled experiments except those involving the scientific airlock (through which the sunshade had been deployed) or those curtailed by power or weight limitations.
- All 16 medical experiments were conducted, and the time history of man's adaptation to zero g was obtained for the first time.
- Data were obtained on five student investigations, with two others rescheduled for the second visit.

Skylab experiments data and film were delivered to the appropriate principal investigator for analysis or processing at his direction. In many cases, complete analysis of data may require years; however, significant findings are released to scientific journals and the news media as they occur.

Sources of photographic prints from experiments film or from the general mission photography are listed on the last page of this report.



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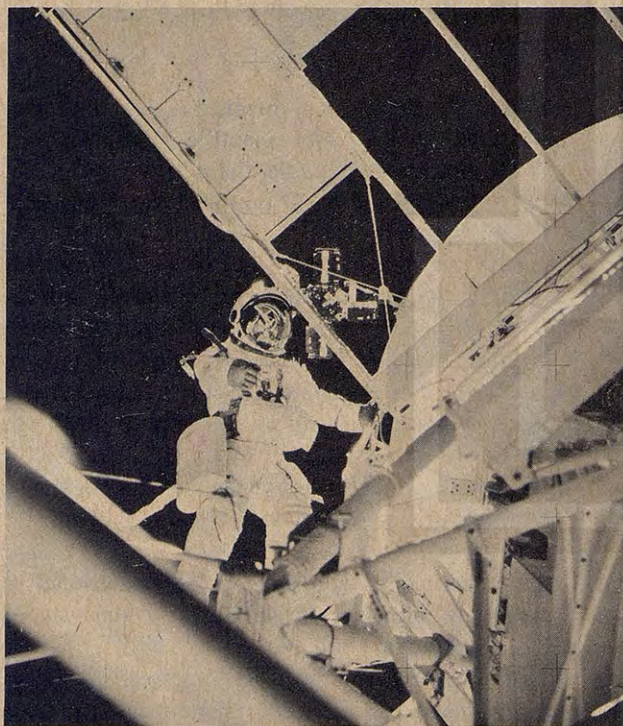


GARRIOTT



LOUSMA

The crew did experience one situation not encountered by the first crew — motion sensitivity. It bothered them for the first few days of the mission but, as they adapted to weightless flight, the astronauts recovered with no after-effects.



LOUSMA: "Owen's really the EVA record holder. . . . We worked a long time. We took our time. We did not get tired at any time, even when we didn't have water cooling to assist us."

The second Skylab manned mission lifted off at 6:11 a.m. CDT July 28 with a crew of Al Bean, Owen Garriott, and Jack Lousma. The trio splashed down 59 days 11 hours and 9 minutes later, September 25, near the U S S New Orleans, 225 miles southwest of San Diego.

Between those two events was a list of conducted experiments that exceeded the planned workload by 50 percent. The crew also experienced hardware difficulties beyond those that had plagued their predecessors.

Early in the mission, one cluster of four reaction control system rockets, then a second, developed leaks and had to be deactivated. The RCS quads are used to "steer" the command-service module in flight. The problem potentially was serious enough that around-the-clock activity was ordered to prepare a modified command module for a rescue mission. But when the two remaining quads stayed healthy, and simulations on the ground demonstrated that adequate control was available with just the two units, rescue preparations were curtailed.

Three EVA sessions were undertaken — the first a marathon 6-hour 31-minute excursion to deploy an experiment, install solar telescope film, and augment the parasol with the twin-pole sunshade. The second was 4 hours 31 minutes to change film, deploy experiments, and replace the faltering rate gyro "6-pack" with a new unit. Garriott and Lousma conducted those EVAs, the first on August 6 and the second on the 24th.

Garriott and Bean spent 2 hours and 45 minutes outside the workshop on September 22, retrieving film and experiment samples. The film canisters plucked from the telescope mount contained some 77,600 pictures of the Sun. And fresh film loaded into the solar cameras during that last EVA enabled 3 experiments — S052 White Light Coronagraph, S054 X-Ray Spectrographic Telescope, and S055 UV Scanning Polychromator Spectroheliometer — to operate through the 6 weeks of unattended operation, just as they had between the first two missions.

By the 10th mission day, the crew was putting in about 19 man-hours a day on scientific experiments, but a week to 10 days later they were doing 27 to 30 man-hours of experiments each day.

Their output was such that where 26 Earth resources experiment passes had been planned, they actually accomplished 39. Data included the developing and decaying stages of tropical storm Christine, drought-stricken areas of Africa, and the active volcano Etna. The crew took a look at an incipient severe storm over Oklahoma, at a fishing operation in the Gulf of Mexico, and at an Arizona ecological test site.

Some 206 hours of solar viewing had been planned, 305 were logged. Those viewing sessions took in two major solar flares and numerous coronal transients.

In an already ambitious medical experiment program of 327 planned runs, 333 were accomplished. Six more corollary experiment runs than the planned 158 were carried out, including the first orbital demonstrations of astronaut maneuvering equipment.

Although student investigations ran behind schedule — 12 planned, 10 conducted — it was one of the high school student proposals that introduced two new space personalities. Arabella and Anita, a pair of common cross spiders, were orbited to demonstrate their ability to spin a web without the influence of gravity assisting them.

After a number of shaky starts, Arabella produced an Earth-like web of creditable symmetry. Anita adapted more quickly and spun good webs after just a few false starts. Anita died in space, apparently of starvation, and Arabella was found dead of unknown causes after her return to Earth.

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While the web formation investigation, one of seven student experiments assigned to the mission, was conducted for one person — a 17-year old Massachusetts girl whose proposal was among 25 selected from 3,400-plus submissions by high school students over the Nation — other experiments involve substantial numbers and types of organizations and people.

In Skylab's earth resources experiments alone there are some 100 American and 42 foreign academic investigators, industrial investigators, and state, Federal, and foreign government agency representatives.

At Skylab lift-off, more than 270 scientific and technical investigations were scheduled for one or more of the three manned missions and even, in some cases, for unattended operation between missions.

Flight experience brought additional experiments and scientific demonstrations, some of which used such easy-to-obtain hardware as a coiled spring toy, a small gyroscope, and some paper airplanes.

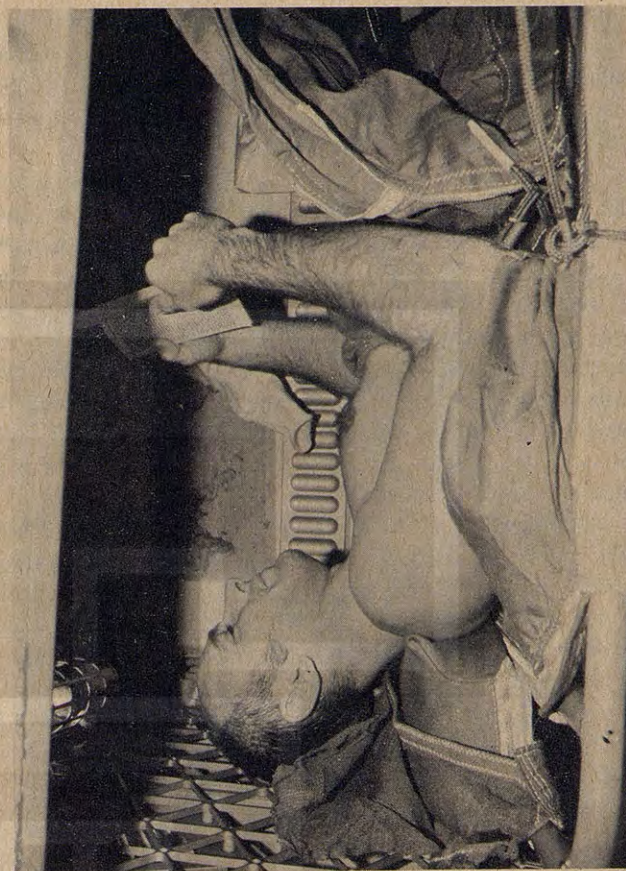
Details on most experiments are contained in "Skylab Experiments Overview" (Stock No. 3300-0461) available through the Government Printing Office for \$1.75.

Accounts of each mission in greater depth than in this necessarily brief summary can be found in weekly news magazines on file in most public and many school libraries.

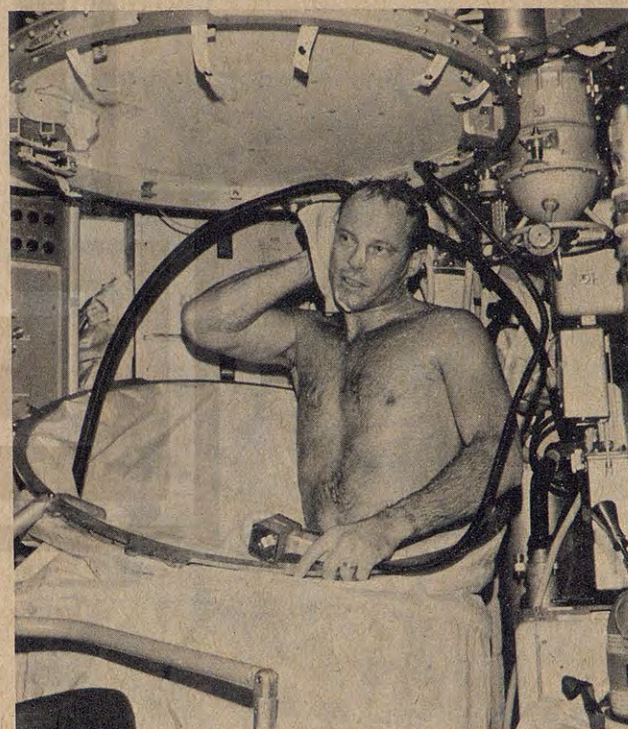
For a full report on the missions, inquiry should be made to the Government Printing Office and the National Technical Information Service (see back page) on the availability and purchase price of "Mission Report" and "Preliminary Science Report" publications for a given mission.



GARRIOTT: "Here's a view of Arabella. I guess she received a little more publicity than we expected. . . . This is one of her webs. I'm not sure what day it was, but she actually spun more symmetrical and better-shaped webs than this."



GARRIOTT: "Al's customary sleeping position was with his head on the floor and his feet on the ceiling . . . he took the light off the fixture at the top and mounted it down on the floor. . . ."



LOUSMA: "It took quite a long time to take a shower. We had a whole 3 quarts to do it with — warm water . . . but it was a pleasant experience, although it was time-consuming."

The third and final manned mission in the program got underway at 8:01 a.m. Central Standard Time (1401 GMT) November 16 after a 6-day delay to replace cracked stabilizing fins on the launch vehicle. With the experience of the successful first two Skylab missions to guide them, crewmen Gerald Carr, Ed Gibson, and Bill Pogue were prepared to stay as long as 84 days in space, nearly as long as those previous missions combined.

One task assigned Skylab 4 was observation and documentation of the newly discovered Comet Kohoutek. Because the comet never achieved the size or the brightness predicted for it, many Earth-bound viewers were disappointed. But the astronauts had a different reaction.

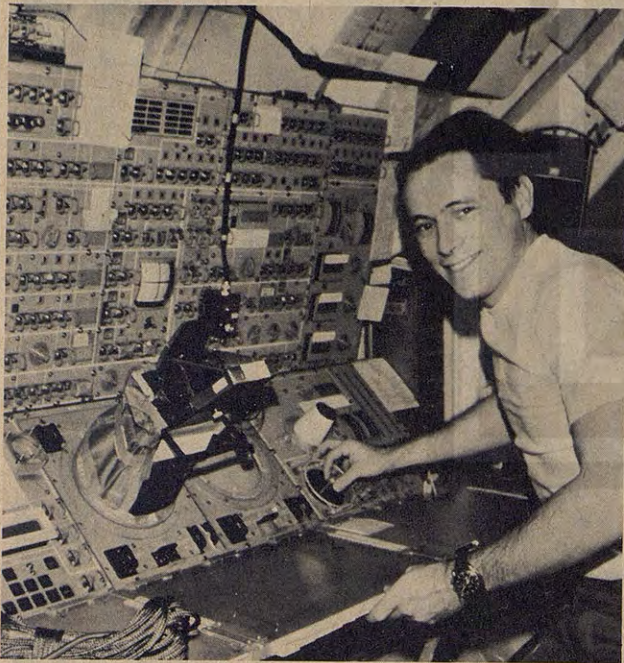
"Hey, I see the comet! There's the tail. Holy cow!" That was Gibson as he began his spacewalk of December 29 to photograph Kohoutek. Carr, outside too, agreed. "Beautiful!" The comet had looped around the Sun the day before and, at that time, Dr. Lubos Kohoutek used the Houston communication facilities to ask that the crew try to observe certain characteristics of his namesake. "The comet's got a spike and a tail," Gibson confirmed. "That spike is very evident. It is not 180 degrees out from the tail, but more like 160 degrees. It is yellow and orange . . . just like a flame. It seems to be the same distance out as the tail, and there is a diffuse amount of material which goes out and joins up with the tail."

The December 29 EVA by Carr and Gibson lasted 3 hours and 28 minutes. On Christmas Day, Carr and Pogue conducted a 7-hour 1-minute walk in space to carry out several experiments, to retrieve some equipment and film, and to photograph the comet as it approached the Sun.

The first extravehicular activity by the crew also occurred on a holiday, Thanksgiving Day, November 22, when Pogue and Gibson put in 6 hours and 33 minutes to deploy experiments, load fresh film into the cameras, and repair a jammed antenna. On February 3, Carr and Gibson teamed up again to retrieve the last of the film and experiments in a 5-hour 19-minute EVA.

The crewmen of the third manned mission experienced two kinds of growth, spiritual and physical, during the 84 days of their flight.

During a 30-minute space-to-Earth news conference on January 2, they spoke of changes of "almost a spiritual nature" in their attitudes toward themselves and their fellow beings, even in their views on possible life elsewhere in the universe.



GIBSON: "I have not had a chance to work the ATM panel this morning, but as of last night that region was still fairly bright . . . it looked as though something was happening, but I guess . . . there is no sunspot."



CARR



GIBSON



POGUE

Carr said "I think this mission is going to . . . increase my awareness . . . of what else is going on besides what I'm doing."

In Gibson's view, "Being up here and being able to see the stars and look back at the Earth and see your own Sun as a star makes you . . . realize the universe is quite big, and just the number of possible combinations . . . which can create life enters your mind and makes it seem much more likely."

Pogue felt that "I now have a new orientation . . . of almost a spiritual nature. My attitude toward life is going to change, toward my family it's going to change. When I see people, I try to see them as operating human beings and try to fit myself into a human situation instead of trying to operate like a machine."

Their views reflected those of others who have flown in space.

The physical growth also had been experienced, though almost unnoticed, by previous crews, but this was the first flight on which proper measuring devices were flown. The height increase — each man gained 1 to 2 inches — was accompanied by a loss of some muscle mass as the body adjusted to zero-gravity, and body fluids were redistributed accordingly.

In the weightless environment, the body's calves and thighs reduce in size as fluids move up from the legs; without the pull of gravity, the spinal column stretches and the chest and abdomen reduce, but the slim-and-trim look does not last. Carr, Gibson, and Pogue lost most of it on their return to Earth and were completely back to normal several days after splashdown.

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Before they left the laboratory, the crew configured it for a possible revisit "by somebody in the future whether that be ASTP (Apollo-Soyuz Test Project), or Soviets, or green men, or what-have-you" in the words of the mission director.

Because any possible revisit will be to inspect the external condition of the space station and to retrieve samples, the crew was directed to leave in the multiple docking adapter a bag containing:

- Samples of four types of photographic film and eight camera filters;
- Three of each of five types of food — rehydratable, thermostabilized, bread, pudding, and beverage;
- A sample of material from any piece of clothing and from any wrist or waist tether, and a surgical glove;
- One roll of teleprinter paper and four samples from a flight data book;
- A heater fan, short lengths of electrical cable, a fire sensor control unit, and a crewman communications umbilical control head.

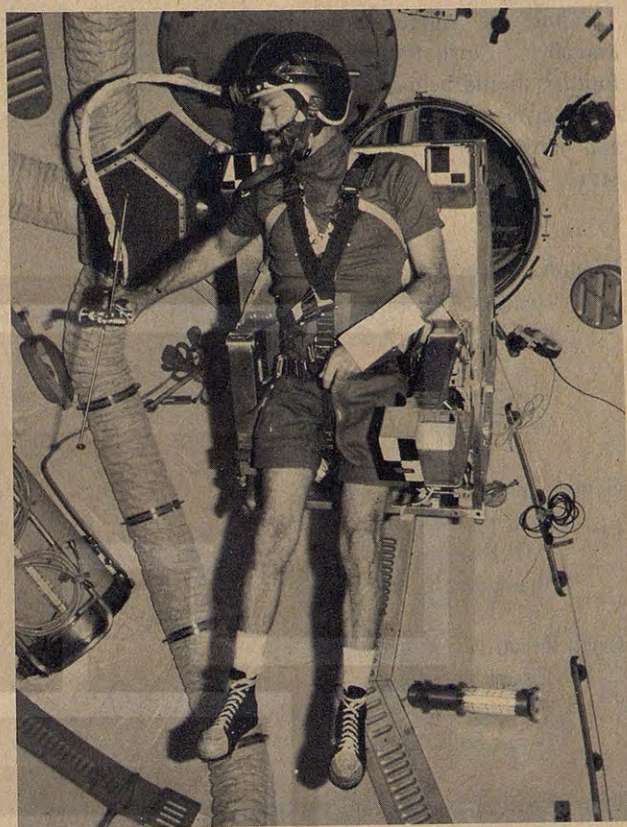
Then a service module reaction control system burn nudged Skylab into an orbit about 280 miles high with a nominal 10-year lifetime, and the third manned mission ended in its 1214th revolution of Earth — the second crew turned 858 revolutions, the first 404.

(Although distance traveled in orbit is not especially significant in itself, those who want such data can use an average orbital velocity of 17,090 miles per hour to determine mileage for any phase of the mission.)

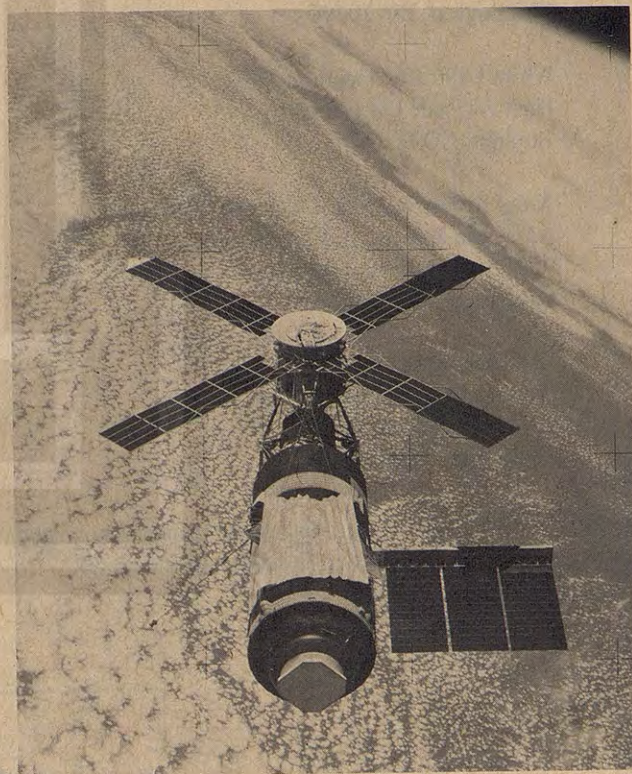
Splashdown was at 10:18 CDT February 8 after 84 days, 1 hour, and 17 minutes. The crew was recovered some 155 miles southwest of San Diego by the USS New Orleans.



CARR: "Right up here is where it all started . . . Merritt Island . . . Cocoa Beach. Right there is Patrick Air Force Base. We never failed to take a picture of where it all started any time we got over it."



CARR: "I think we've got it now . . . the bird flies real well, and I think it will be a real pleasure to work from now on, and we'll get the kinks worked out of the procedures."



CARR: "We got one fold in the sail . . . that apparently has opened up recently, and it's a whole lot lighter color, a lot whiter than all the rest of the folds in the accorian pleats in the sail."

These are sources of information and materials not available through the NASA centers involved in Skylab. Inquiry should be made directly to the appropriate source to determine availability, time required to fill, and price and method of payment — never send cash for any mail order.

Mission reports and preliminary science reports:
National Technical Information Service
Springfield, VA 22151 and/or

Government Printing Office
Washington, DC 20402

General mission photography:
Space Photographs
P.O. Box 486
Bladensburg, MD 20710

Earth Resources photography:
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

Solar experiments data and photography:
X-ray/UV Solar Photography Experiment
S020, Coronal Spectroheliograph S082A
and Chromospheric Spectrograph S082B
U.S. Naval Research Laboratory
Washington, DC 20390

White Light Coronagraph S052
High Altitude Observatory
Boulder, CO 80302

X-ray Spectrographic Telescope S054
American Science and Engineering
955 Massachusetts Avenue
Cambridge, MA 02139

H-Alpha Telescopes
Harvard College Observatory
60 Garden Street
Cambridge, MA 02138

Audio tape highlights of air-to-ground transmissions (the conversation between Mission Control and the crew):

NASA Headquarters
Washington, DC 20546
Attn: Code FP

The Office of Manned Space Flight, NASA Headquarters, Washington, D.C. 20546 directed, integrated, and evaluated the overall Skylab program.

Responsibilities assigned to NASA centers were:

The worldwide tracking and communications network.

Goddard Space Flight Center
Greenbelt, MD 20771

Development of the modified Apollo command and service modules; development of assigned experiments, crew systems, medical equipment, food, and other crew-support hardware; crew training and mission planning; mission control.

Johnson Space Center
Houston, TX 77058

Launch facilities and operations, and prelaunch checkout.

Kennedy Space Center
FL 32899

Development of orbital workshop, airlock module, multiple docking adapter, Apollo telescope mount, and payload shroud; development and integration of assigned experiments and support systems; Saturn launch vehicles, and overall systems integration.

Marshall Space Flight Center
Huntsville, AL 35812

Support in the areas of recovery, weather reporting, communications and bioastronautics were provided by

Manned Space Flight Support Operations
Department of Defense
Air Force Eastern Test Range
FL 32925

Major contractors for the Skylab program were

The Boeing Company
Seattle, WA 98124

Chrysler Corporation
New Orleans, LA 70129

Martin Marietta Corporation
Denver, CO 80201

McDonnell Douglas Corporation
St. Louis, MO 63166

Rockwell International Corporation
Downey, CA 90241



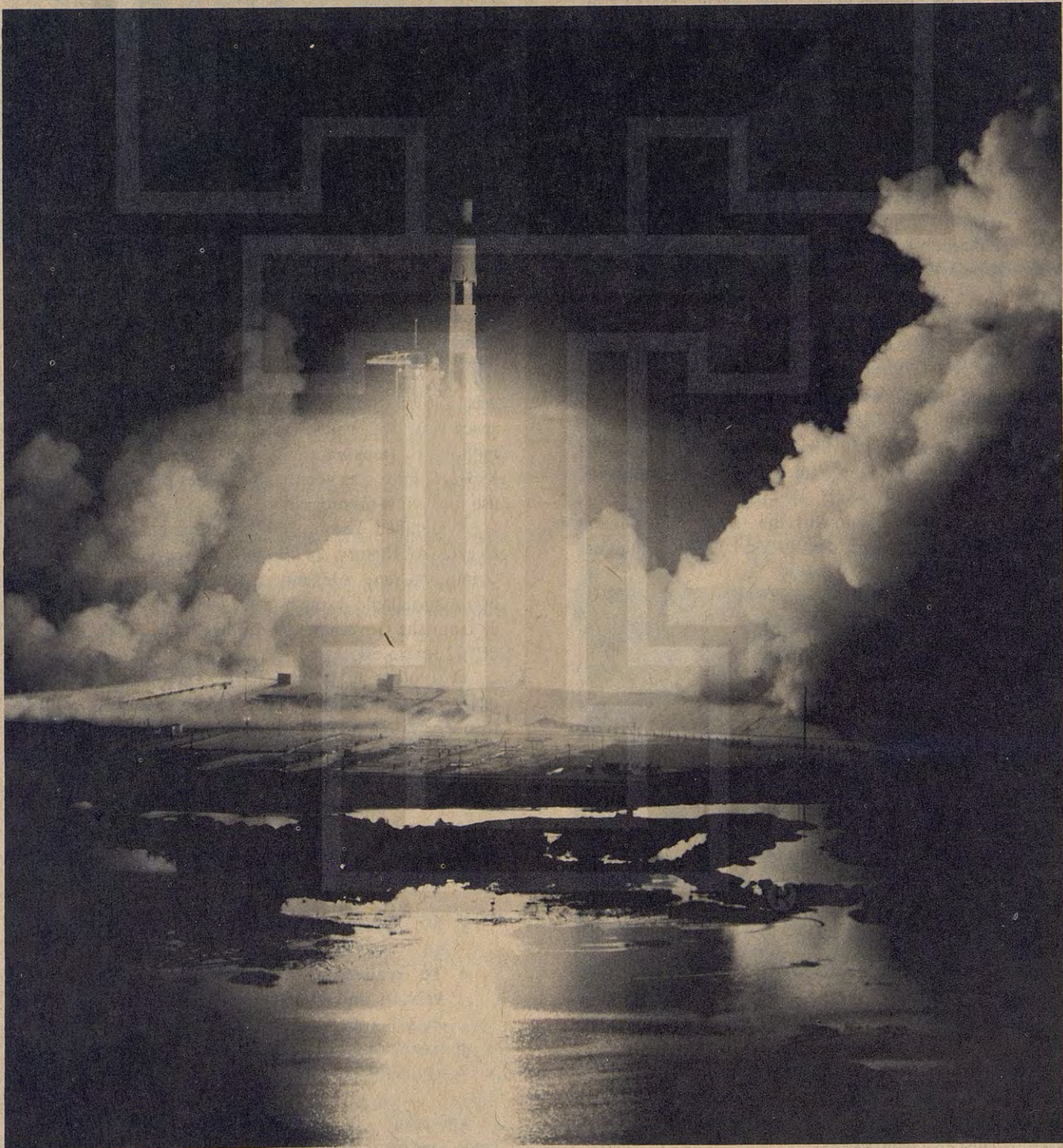
NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE
Houston, Texas

JSC 08062

MANNED SPACE FLIGHT-THE FIRST DECADE



Printed on recycled paper

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THIS FOOTPRINT may be the most famous in the world, for it represents man's first step onto the surface of a body other than Earth. The print was left in the dust of the Sea of Tranquility when Neil Armstrong took his "Giant Leap for Mankind" on Apollo 11.

problems began to impact the program. Some 40 medical and scientific experiments and photographic projects also were completed in the 10 manned Gemini missions.

Gemini costs totaled \$1.29 billion: \$790.4 million for spacecraft, \$417.4 million for launch vehicles, and \$82.3 million for program support.

A complete text on the program is "Project Gemini: A Chronology" by Grimwood and Hacker with Vorzimmer, 1969, NASA SP-4002, GPO \$2.75.

When President Kennedy called for a manned lunar landing and safe return by the end of the decade, he characterized the effort as "... a clearly leading role in space achievement, which in many ways may hold the key to our future on Earth."

Apollo's goals beyond landing Americans on the Moon and returning them safely to Earth were:

- To establish the technology to meet other national interests in space;
- To achieve preeminence in space for the United States;
- To carry out a program of scientific exploration of the Moon; and
- To develop man's capability to work in the lunar environment.

The program required development of two new spacecraft, one of them capable of landing on and taking off from the Moon. It also required a launch rocket that could lift 7.5 million pounds, a package of complex scientific experiments that could be deployed by two men, and a vehicle to extend the surface exploration.

At the peak of the effort, in the mid 1960's, the total of NASA and contractor personnel engaged in Apollo climbed to 420,000.

Then the January 27, 1967, launch pad fire that killed astronauts Grissom, White, and Chaffee brought the program to a standstill. The inquiry lasted 2-1/2 months, involved 1500 persons.

An exhaustive materials test and development program resulted in a fireproof spacecraft; the findings were also applicable to home and business. A new quick-opening hatch cover and other design and procedural changes also were called for.

Little more than a year and a half after the first manned Apollo was to have flown, Apollo 7 performed a flawless qualification mission. Two months later, man reached the Moon; in another 7 months, he landed on it.

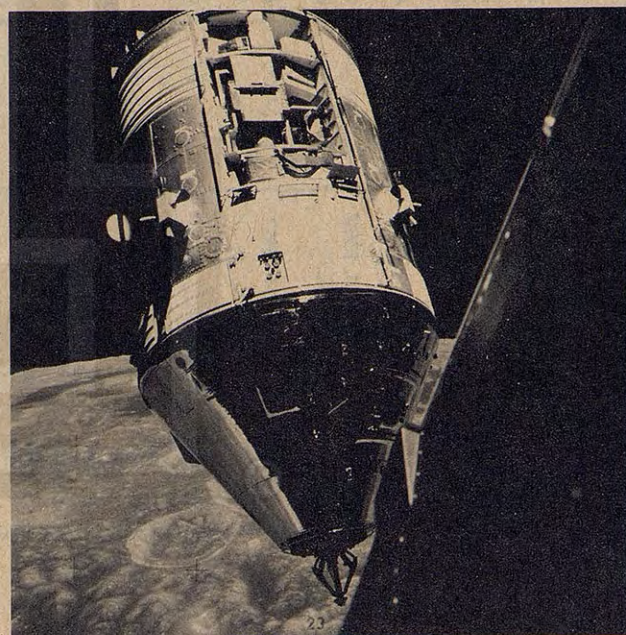
The national goal established by President Kennedy in 1961 was met. Twice before the end of the decade, man explored the lunar surface.

Those two landings and the four that followed in the early 1970's gave lunar scientists around the world a variety of sample material, photographs, and electronic data that will keep them busy for years unlocking the secrets of the universe.

Five of the six scientific stations left on the surface still were transmitting data when the Apollo follow-on manned flight program — Skylab — was launched.

The 12 Americans who left their footprints in the lunar dust totaled 166 man-hours of surface exploration. They traversed almost 60 miles and brought about 850 pounds of rock and soil samples back to Earth. They left

(Continued on back page.)



SCIENCE IN ORBIT and on the lunar surface provided volumes of data to keep scientists busy for years unlocking the secrets of the universe. The complex equipment carried around the Moon in the Apollo service module was but a forerunner of orbiting scientific packages designed to help man improve his own planet.

Mission	Crew	Date	Duration hr:min:sec	Remarks
Mercury-Redstone 3	Shepard	May 5, 1961	00:15:22	Suborbital flight — first American in space. USS Champlain, Atlantic recovery (A). Spacecraft call sign Freedom 7.
Mercury-Redstone 4	Grissom	July 21, 1961	00:15:37	Also suborbital; successful flight but spacecraft sank, astronaut rescued. USS Randolph (A). Liberty Bell 7.
Mercury-Atlas 6	Glenn	Feb. 20, 1962	04:55:23	Three-orbit flight; first American in orbit; retropack retained when erroneous signal indicated heat shield possibly loose; capsule landed 40 miles uprange. USS Noa, (A). Friendship 7.
Mercury-Atlas 7	Carpenter	May 24, 1962	04:56:05	Also three-orbit mission; yaw error at manual retrofire caused 250-mile landing overshoot. USS Pierce (A). Aurora 7.
Mercury-Atlas 8	Schirra	Oct. 3, 1962	09:13:11	Six-orbit flight; capsule landed 4-1/2 miles from recovery ship USS Kearsarge, Pacific (P). Sigma 7.
Mercury-Atlas 9	Cooper	May 15 and 16 1963	34:19:49	Twenty-two orbits to evaluate effects on man of 1 day in space; landed 4-1/2 miles from USS Kearsarge (P). Faith 7.
Gemini-Titan III	Grissom, Young	March 23, 1965	04:53:00	Three-orbit demonstration of the spacecraft; maneuver over Texas on first pass changed orbital path of a manned spacecraft for first time; landed about 50 miles uprange. USS Intrepid (A). Molly Brown (only Gemini named).
Gemini-Titan IV	McDivitt, White	June 3 to 7, 1965	97:56:11	Four-day flight with White first American to walk in space in 20-minute extravehicular activity (hatch open 36 minutes); after 62 revolutions of Earth, landed 50 miles uprange from USS Wasp (A).
Gemini-Titan V	Cooper, Conrad	Aug. 21 to 29, 1965	190:55:14	First use of fuel cells for electric power; evaluated guidance and navigation system for future rendezvous missions; incorrect navigation coordinates from ground control resulted in landing 90 miles short; 120 revolutions. USS Lake Champlain (A).
Gemini-Titan VII	Borman, Lovell	Dec. 4 to 18, 1965	330:35:31	Longest-duration Gemini flight; provided rendezvous target for Gemini VI-A; crew flew portions of mission in shirtsleeves for first time; 206 revolutions; landed 6.4 miles from target. USS Wasp (A).
Gemini-Titan VI-A	Schirra, Stafford	Dec. 15 and 16, 1965	25:51:24	Rescheduled to rendezvous with Gemini VII after original target Agena failed to orbit; VI-A launch postponed 3 days when launch vehicle engines automatically shut down 1.2 seconds after ignition; completed first space rendezvous; after 16 revolutions, landed within 7 miles of target to initiate series of pinpoint landings by Gemini spacecraft. USS Wasp (A).
Gemini-Titan VIII	Armstrong, Scott	March 16, 1966	10:41:26	First docking of one space vehicle with another; about 27 minutes after docking, Gemini-Agena combination began to yaw and roll at increasing rates; emergency procedures included undocking, deactivation of malfunctioning spacecraft control system, activation of reentry control system; mission was terminated and, midway through 7th revolution, spacecraft landed 1.1 miles from planned landing point in secondary recovery area in western Pacific; destroyer USS Mason picked up crew 3 hours later.
Gemini-Titan IX-A	Stafford, Cernan	June 3 to 6, 1966	72:21:00	Rescheduled to rendezvous and dock with augmented target docking adapter after original target Agena failed to orbit; ATDA shroud did not completely separate, making docking impossible; three different types of rendezvous were completed; Cernan carried out 2 hours 7 minutes of EVA; 44 revolutions; 0.38 miles from target. USS Wasp (A).

Gemini-Titan X	Young, Collins	July 18 to 21, 1966	70:46:39	First use of Agena target vehicle's propulsion systems; spacecraft also rendezvoused with Gemini VIII target vehicle; Collins had 49 minutes of EVA standing in hatch, 39-minute EVA to retrieve experiment from Agena VIII; 43 revs; 3.4 miles, USS Guadalcanal (A).
Gemini-Titan XI	Conrad, Gordon	Sept. 12 to 15, 1966	71:17:08	Gemini record altitude (739.2 miles) reached using Agena propulsion after first-revolution rendezvous and docking; Gordon fastened Agena-anchored tether to Gemini docking bar, and spacecraft later made two

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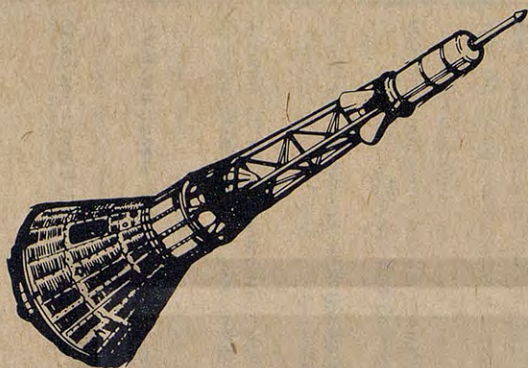
June 3 to 6, 1966

Stafford, Cernan

Gemini-Titan IX-A

72:21:00

Gemini-Titan X	Young, Collins	July 18 to 21, 1966	70:46:39	First use of Agena target vehicle's propulsion systems; spacecraft also rendezvoused with Gemini VIII target vehicle; Collins had 49 minutes of EVA standing in hatch, 39-minute EVA to retrieve experiment from Agena VIII; 43 revs; 3.4 miles, USS Guadalcanal (A).
Gemini-Titan XI	Conrad, Gordon	Sept. 12 to 15, 1966	71:17:08	Gemini record altitude (739.2 miles) reached using Agena propulsion after first-revolution rendezvous and docking; Gordon fastened Agena-anchored tether to Gemini docking bar, and spacecraft later made two revolutions of Earth in tethered configuration; Gordon 33-minute EVA and 2-hour 5-minute standup EVA; 44 revs; 1.5 miles, USS Guam (A).
Gemini-Titan XII	Lovell, Aldrin	Nov. 11 to 15, 1966	94:34:31	Final Gemini flight; Aldrin logged 2-hour 29-minute standup EVA, 55-minute standup EVA, and 2-hour 6-minute EVA for Gemini record total of 5 hours 30 minutes of extravehicular activity; 59 revs, 2.6 miles, USS Wasp (A).
Apollo-Saturn 7	Schirra, Eisele, Cunningham	Oct. 11 to 22, 1968	260:09:03	First manned flight of Apollo spacecraft command-service module only, 163 revolutions; USS Essex (A) — all Apollo spacecraft splashed down within 10 miles of predicted landing point.
Apollo-Saturn 8	Borman, Lovell, Anders	Dec. 21 to 27, 1968	147:00:42	First flight to the Moon (command-service module only); views of lunar surface televised to Earth; 10 revolutions of the Moon; USS Yorktown (P).
Apollo-Saturn 9	McDivitt, Scott, Schweickart	March 3 to 13, 1969	241:00:54	First manned flight of lunar module; spacecraft call signs for communications identification when undocked: CSM "Gumdrop" and LM "Spider"; Schweickart 37-minute EVA from LM; 151 revs; USS Guadalcanal (A).
Apollo-Saturn 10	Stafford, Young, Cernan	May 18 to 26, 1969	192:03:23	First lunar module orbit of Moon; call signs Charlie Brown and Snoopy; 31 revs of Moon (4 revs by undocked LM); USS Princeton (P).
Apollo-Saturn 11	Armstrong, Collins, Aldrin	July 16 to 24, 1969	195:18:35	First lunar landing; call signs Columbia and Eagle; lunar stay time 21 hours 36 minutes 21 seconds, Armstrong and Aldrin EVA (hatch open to hatch close) 2 hours 31 minutes 40 seconds, lunar surface samples 48.5 pounds; 30 revs; USS Hornet (P).
Apollo-Saturn 12	Conrad, Gordon, Bean	Nov. 14 to 24, 1969	244:36:25	Yankee Clipper and Intrepid; stay time 31 hours 31 minutes, Conrad and Bean EVAs 3 hours 56 minutes and 3 hours 49 minutes, lunar samples 74.7 pounds plus parts from Surveyor 3 unmanned spacecraft; 45 revs; USS Hornet (P).
Apollo-Saturn 13	Lovell, Swigert, Haise	Apr. 11 to 17, 1970	142:54:41	Odyssey and Aquarius; mission aborted after service module oxygen tank ruptured; using lunar module oxygen and power until just before reentry, crew returned safely to Earth; USS Iwo Jima (P).
Apollo-Saturn 14	Shepard, Roosa, Mitchell	Jan 31 to Feb 9, 1971	216:01:57	Kitty Hawk and Antares; stay time 33:31, Shepard and Mitchell EVAs 4:48 and 4:35, samples 96 pounds; 34 revs; USS New Orleans (P).
Apollo-Saturn 15	Scott, Worden, Irwin	July 26 to Aug 7, 1971	295:11:53	Endeavour and Falcon; first use of lunar roving vehicle; stay time 66:55; Scott standup EVA 33 minutes, Scott and Irwin EVAs 6:33, 7:12 and 4:50, Worden trans-Earth EVA 38 minutes, samples 170 pounds; 74 revs; USS Okinawa (P).
Apollo-Saturn 16	Young, Mattingly, Duke	April 16 to April 27, 1972	265:51:05	Casper and Orion; stay time 71:02; Young and Duke EVAs 7:11, 7:23 and 5:40, Mattingly trans-Earth EVA 1:24, samples 213 pounds; 64 revs; USS Ticonderoga (P).
Apollo-Saturn 17	Cernan, Evans, Schmitt	Dec. 7 to Dec. 19, 1972	301:51:59	America and Challenger; stay time 75:00; Cernan and Schmitt EVAs 7:12, 7:37 and 7:15, Evans trans-Earth EVA 1:06, samples 243 pounds; 75 revs; USS Ticonderoga (P).



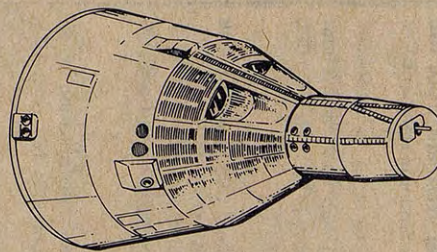
Mercury

Mercury set the trend for U.S. spacecraft design in the first decade. The one-man capsule was 6 feet 10 inches long (26 feet with its launch escape tower) and 6 feet 2-1/2 inches in diameter. It weighed about 2990 pounds in orbit. The blunt end was covered with an ablative heat shield to protect against 3000-degree reentry heat. The capsule was built by McDonnell Douglas Corp.

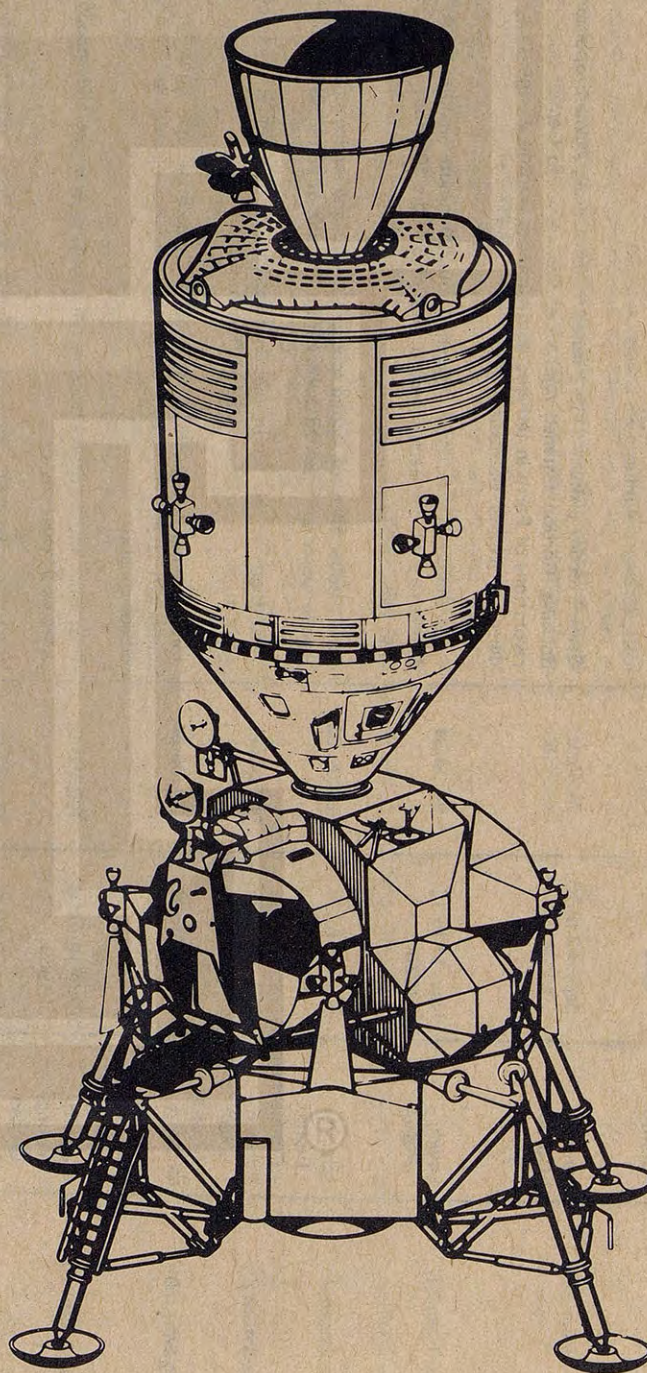
Gemini also was built by McDonnell Douglas. The two-man craft was an enlargement of the Mercury vehicle, but experience had shown that much equipment could be placed outside the pressurized cabin and left behind at reentry. Gemini propulsion systems allowed changes in orbit, as well as reentry maneuvers for pinpoint landings. The spacecraft was 19 feet long, 10 feet in diameter, and weighed about 8400 pounds.

Apollo command and service modules bridge the first decade of American manned space flight with the second; they served both Skylab and Apollo/Soyuz Test Project planners. The service module extends the Gemini concept of locating in a separate package the equipment and supplies not needed for reentry, and the three-man command module retains the ablative heat shield of Mercury and Gemini. The command module is 10 feet 7 inches high (to top of apex cover) and 12 feet 10 inches in diameter; its 33-foot launch escape tower is jettisoned before orbital insertion. The service module is 24 feet 9 inches by 12 feet 10 inches. Both modules are built by Rockwell International.

Apollo lunar module (LM) operated only outside the atmosphere. Its shape therefore was dictated by its job of taking two men safely to and from the Moon's surface. The LM was 22 feet 11 inches high with legs extended, 31 feet in diameter (measured diagonally across extended landing gear). Nominal Earth orbit weight of the three Apollo modules was 100,600 pounds. Grumman Aerospace Corp. built the lunar module.



Gemini



Apollo

Drawings indicate relative sizes of spacecraft.

Saturn V
feet by 33 feet
Rockwell, 81
stage (S-IVB)
pounds of the
spacecraft and

Saturn IB
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Drawings indicate



Mercury-Redstone

Saturn V NASA-developed three-stage launch vehicle; first stage (S-IC) by Boeing, 138 feet by 33 feet, RP-1 and LOX for 7.76 million pounds of thrust; second stage (S-II) by Rockwell, 81.5 feet by 33 feet, LH₂ and LOX for 1.15 million pounds of thrust; third stage (S-IVB) by McDonnell Douglas, 59.3 feet by 21.7 feet, LH₂ and LOX for 230,000 pounds of thrust; instrument unit by IBM, 3 feet by 21.7 feet; with adapter, Apollo spacecraft and launch escape system, Saturn V stands 363 feet high.

Saturn IB NASA-developed two-stage launch vehicle; first stage (S-IB) by Chrysler Corp., 80.3 feet high and 21.4 feet in diameter, burns RP-1 and LOX to produce 1.6 million pounds of thrust; second stage (S-IVB) by McDonnell Douglas, 58.4 feet high and 21.7 feet in diameter burns liquid hydrogen and LOX for 200,000 pounds of thrust; instrument unit by IBM is 3 feet high, 21.7 feet in diameter; with aft interstage, Apollo spacecraft and launch escape system, Saturn IB stands 224 feet high.

Gemini-Titan modified Air Force missile manufactured by Martin Company; two-stage rocket 10 feet in diameter and 90 feet high (109 feet with spacecraft) burning Aerozine 50 and nitrogen tetroxide to produce 430,000 pounds of thrust in the first stage, 100,000 pounds of thrust in the second.

Mercury-Atlas modified Air Force missile manufactured by General Dynamics; stage-and-a-half rocket 10 feet in diameter (16 feet at base) and 67.3 feet high (95.3 feet with capsule and escape tower), burning RP-1 and LOX to produce 308,000 pounds of thrust from the booster engines (2) and 57,000 pounds of thrust from the sustainer engine.

Mercury-Redstone modified Army ballistic missile manufactured by Chrysler Corp., single-stage rocket 70 inches in diameter and 59 feet high (83 feet with capsule and escape tower) burning alcohol and liquid oxygen to produce 78,000 pounds of thrust.

Drawings indicate relative sizes of launch vehicles.



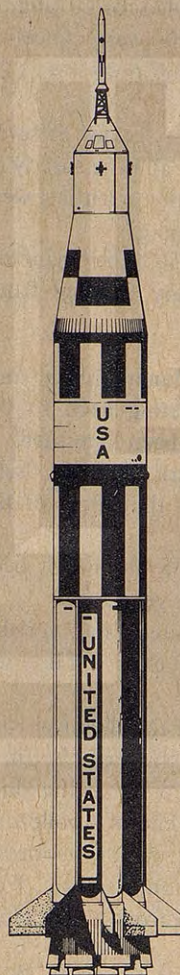
Mercury-Redstone



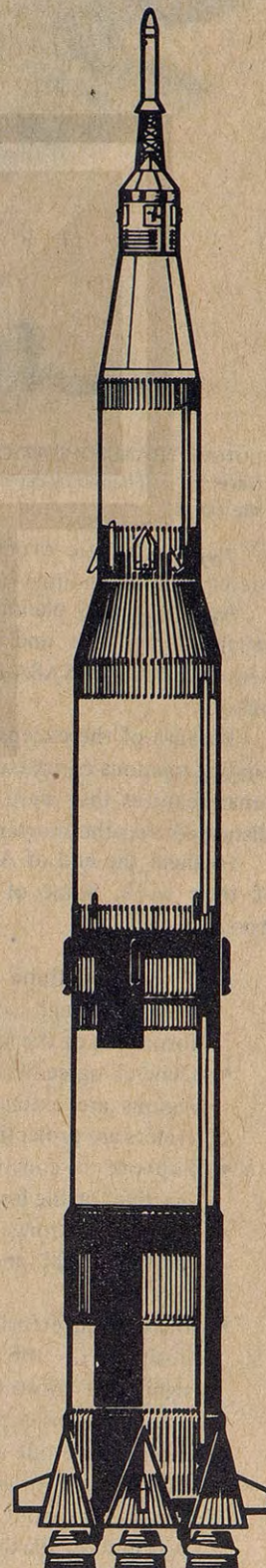
Mercury-Atlas



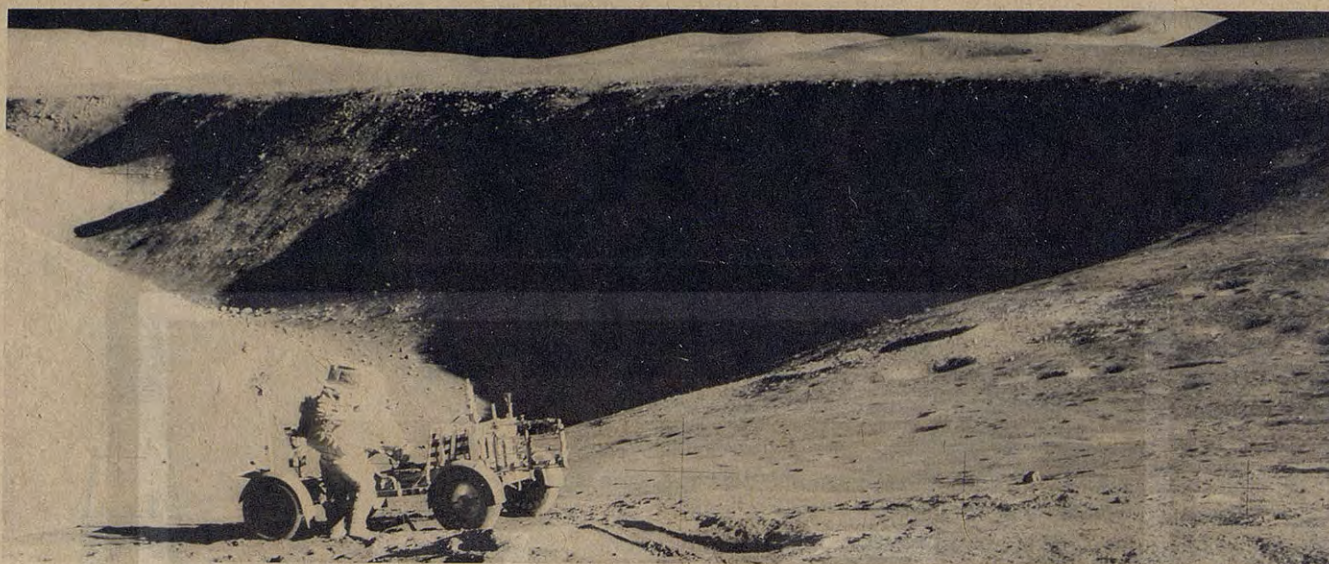
Gemini-Titan



Saturn IB



Saturn V



LUNAR TRANSPORTATION in the form of an electric car gave the last three Apollo crews a wider range for their geological and scientific traverses. The moonscape views transmitted to Earth by a television system mounted on the vehicle were seen in almost every country of the world.

60 major scientific experiments on the Moon and conducted 34 more in lunar orbit.

Apollo, in early planning, was scheduled for 10 landing attempts; but one and then two more were cancelled because of cuts in NASA funding. Apollo's final cost: \$25 billion.

Because of the exceptional success — six out of seven landing missions completed flawlessly — and the variety of lunar features that were investigated, few scientists were dismayed over the shortened flight program.

To them the end of Apollo was still just the beginning of their work. Some of the preliminary findings from Apollo:

- A rather definite and reliable lunar history time scale, although so far rocks dating back to the formation of the Moon have not been identified;
- General agreement that the dark mare or "sea" regions are extensive lava flow, that most of the craters are projectile impacts;
- Support of conclusions that the Moon has been inactive for the last 2 to 3 billion years;
- A much stronger than expected and variable magnetic field, and a hotter than expected interior; and
- Distinct differentiation between the chemical composition of the Moon and that of Earth, a significant constraint on the theory that the Moon originally was a part of Earth (end-of-Apollo data did not rule out any of the three major theories on the Moon's origin — separation, capture from circumsolar orbit, or formation from a dust cloud surrounding Earth).

Apollo's other legacy, and that of the first decade of manned space flight, is a spinoff of technology and materials that is being applied to the betterment of man's everyday life.

No other program of technological and scientific exploration ever has been so compelled or perhaps so able to justify its existence on the basis of the immediate tangible and sometimes unrelated benefits it yielded.

Ironically, though such spinoff gains were envisioned, they were not considered as justification for or goals of space exploration when it was conceived.

Apollo also bridged the first two decades of man in space. Its launch vehicles and spacecraft were key elements in the planning of the 1973 Skylab and the '75 Apollo/Soyuz Test Project.

The former is the logical next-step application of all that was learned in Mercury, Gemini, and Apollo. It explores man's reaction to even longer duration space flight. And it utilizes him as a scientist, an astronomer, and an ecologist.

The latter is a move toward international participation and cooperation in space, a necessity not only to expanded exploration of space but to peaceful coexistence on Earth as well.

By the end of the second decade, the emphasis in manned space flight will be on economy. The Space Shuttle is planned as a reusable spacecraft that will carry out a variety of assignments at about a fifth the current cost per pound of payload.

When he approved Shuttle early in 1972, President Richard Nixon foresaw it as going far toward delivering "... the valuable spinoffs from space efforts into the daily lives of Americans and all people."

"The Apollo Spacecraft: A Chronology" by Ertel and Morse (Vol. I) and Morse and Bays (Vol. II), NASA SP-4009, is available at \$2.50 a volume from GPO. The first volume covers the program through November 7, 1962, the second from November 8, 1962, through September 30, 1964. Continuation volumes will be released as available.

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION LYNDON B. JOHNSON SPACE CENTER

PUBLIC AFFAIRS OFFICE
Houston, Texas

NASA CAREERS

A common characteristic of America's astronauts is that each has acquired a high level of academic achievement and professional experience.

Astronaut jobs are very scarce, but other equally important and rewarding positions are available in the manned space program — and they all call for good education or strong experience, or both. The young man or woman considering a career with the Lyndon B. Johnson Space Center, or with any of the other NASA centers, should strive first for all the schooling possible.

Many jobs in the aerospace industry are common to those in other businesses — personnel specialists, bookkeepers, labor relations personnel, secretaries, and the like — while others are unique. NASA refers to its jobs in the engineering and scientific fields as “positions in aerospace technology.”

Aerospace technology positions cross traditional academic disciplines because NASA work is not channeled in the usual manner. The job may require a combination of talents — mechanical and electronic engineering, for example.

Because of the newness of the work being done, a new occupational group terminology was created:

1. Space Sciences, including such exotic-sounding specializations as aeronomy, ionospheres, lunar and planetary studies, fields and particles, and meteoroid studies;

2. Life Studies, the study of life and how to live in space, includes psychological and physiological study, neurobiology, exobiology, biochemical processes, and radiobiology; and

3. Other major groups such as Fluid and Flight Mechanics, Materials and Structures, Propulsion Systems, Flight Systems, Measurement and Instrumentation Systems, Data Systems, and Experimental Facilities and Equipment.

The work of these engineering and scientific

positions is tied together by professional management personnel. Aerospace technology specialties for this include Technical Management and Project Management.

All of the engineering and scientific positions under the broad term “aerospace technology” have a positive education requirement. That is, in order to qualify basically, it is necessary to have at least a bachelor's degree in engineering, mathematics, or physical sciences from an accredited institution. For the Life Studies group, the requirement is at least a master's degree.

Administrative positions in areas such as personnel, financial operations, budget management, public information, procurement and contracts, and others are filled through the Federal Service Entrance Examination, the same as for other federal installations.

Because jobs, and the qualifications required of people in those jobs, change as the space program moves forward, this discussion is general in nature. Obviously, preparing oneself with the proper background is the first big step toward a career in the space program.

Most schools have a career guidance counselling program designed to help the student select his career and formulate the educational schedule he needs to reach the goal. Many high schools invite college representatives to explain the various specialized subjects offered undergraduate and graduate students. And many colleges and universities, through their placement offices, set up on-campus interviews between students and representatives from industry and government. These are good sources from which to gain information concerning career fields and requirements.

Jobs with NASA are covered under the rules of the U.S. Civil Service Commission. Information on Civil Service jobs, including how to apply, is available at most post offices and at Federal Job Information Center offices in most major cities.





JSC

HOUSTON, TEXAS

Lyndon B. Johnson Space Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



1960-1963
MERCURY



1963-1966
GEMINI



1966-1971
APOLLO



1971-1974
SKYLAB



1974-1975
APOLLO-SOYUZ