THE NINTH

DR. ALBERT PLESMAN MEMORIAL LECTURE

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The Dr. Albert Plesman Memorial Lecture has been initiated by the International Air Transport Association (IATA) in 1954 in memory of Dr. Albert Plesman (founder and president of KLM and one of the founders of IATA). It was decided that this Memorial Lecture on scientific development of air-transportation should be given at the Delft University of Technology, which presented Dr. Albert Plesman a honorary degree in 1947.

JESSE W. MOORE

BIOGRAPHY

Mr. Jesse W. Moore is currently the Associate Administrator for Space Flight at NASA Headquarters in Washington, D.C.

He came to NASA Headquarters in 1978 as the Deputy Director of the Solar Terrestrial Division in the Office of Space Science. He was the Director of the Spacelab Flight Division until December 1981, at which time he assumed the position of Director, Earth and Planetary Exploration Division, in the Office of Space Science and Applications, where he remained until being appointed to the position of Deputy Associate Administrator for Space Flight in February 1983 and Acting Associate Administrator for Space Flight in April 1984. He was appointed to the position of Associate Administrator for Space Flight on August 1, 1984.

Prior to these assignments, he was employed at the Jet Propulsion Laboratory (JPL) beginning in 1966 where he worked in a variety of areas, including guidance and control, advanced programs, and flight projects. His last assignment at JPL was as the Science and Mission Design Manager for Project Galileo.

Mr. Moore graduated from the University of South Carolina in 1964 with a Master's Degree in Electrical Engineering. He joined General Dynamics immediately after graduation and worked in guidance systems development for naval missiles.

Mr. Moore is a member of the American Institute of Aeronautics and Astronautics and is a senior member of the American Astronautical Society.

He is married to the former Brenda Kay Polson, and they are the parents of two children. Mr. Moore and his family reside in Vienna, Virginia.

ADDRESS OF WELCOME AND INTRODUCTION

BY PROF. IR. B. P. TH. VELTMAN
RECTOR-MAGNIFICUS, VICE-CHAIRMAN OF THE EXECUTIVE BOARD OF DELFT UNIVERSITY OF TECHNOLOGY

Your Excellencies, My Lords, Ladies and Gentlemen,

It is a privilege for me to welcome you all on behalf of the Executive Board of the Delft University of Technology, on the occasion of the Ninth Dr. Albert Plesman Memorial Lecture.
We are pleased that so many guests have accepted the invitation to attend this lecture today.

On the initiative of the International Air Transport Association (IATA), the Delft University of Technology commemorates with this Memorial Lecture the late Dr. Albert Plesman, paying tribute to his contributions to the world's civil aviation from the foundation of the Royal Dutch Airlines KLM in 1919 until his death on December 31, 1953, at the age of 64. Dr. Plesman's contributions to civil aviation and to the Netherlands' society in general, were honoured by the Delft University of Technology in 1947, when the Honorary Doctors Degree was granted to him.
On several occasions Dr. Plesman challenged the scientific world to discover better ways to conquer the gravitational force in order to create improved vehicles for air transportation.
Since his death the world's civil aviation has expanded enormously, mainly by the introduction of the large high-speed subsonic jet aircraft. And although we have not found the anti-gravity matter Cavarite, as described around 1900 in H. G. Wells' story "The first Men in the Moon", we have now even mastered the gravity barrier by sending unmanned and manned vehicles into space from the earth.

With these thoughts in mind, the Organizing Committee for the Memorial Lecture found it appropriate to devote the Ninth Dr. Albert Plesman Memorial Lecture to the development of space flight.

All of us know that the National Aeronautics and Space Administration, NASA, has played a dominant role in the conquest of space since its foundation in 1958. And we are pleased that, by the kind offices of the Ambassador of the United States of America in the Netherlands, Mr. L. Paul Bremer III, we were able to invite a distinguished lecturer from NASA Headquarters.
The Delft University of Technology is deeply honoured, that you, Mr. Moore, have accepted our invitation to present a lecture on the intended subject and I extend a special welcome to you.

After his graduation at the University of South Carolina in 1964 and a period in industry, Mr. Moore joined NASA in 1966. Before his assignment to NASA Headquarters in 1978, Mr. Moore was employed at the Jet Propulsion Laboratory, where he worked in a variety of areas, covering guidance and control, advanced programmes and space flight programmes. At NASA Headquarters he served on several prominent positions in the Space Science and Space Flight Divisions. On August 1, 1984, he has been appointed Associate Administrator for Space Flight.
Indeed, the outstanding career of Mr. Moore in space science and space flight makes him a most qualified lecturer on the subject of the future of space flight.

May I now call upon you, Mr. Moore, to deliver the Ninth Dr. Albert Plesman Memorial Lecture.

"THE FUTURE OF SPACE FLIGHT"

BY JESSE W. MOORE

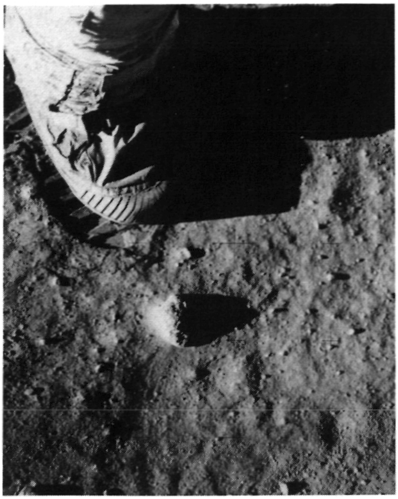
I. INTRODUCTION

"Here man from the planet earth first set foot upon the moon, July 1969 A.D. We came in peace for all mankind." As I read these words, I still stand in awe at our accomplishments. They remind me of the past and bring to mind our dreams of the future.

With the Space Shuttle a reality and a space station in the not too distant future, it is not too difficult to see us mining the asteroids, manufacturing drugs and metals in space, establishing a permanent presence on the moon, and visiting Mars. Looking back, I see those prophets and miracle workers of the past, Von Braun, Goddard, and Tsiolkovsky, and have difficulty realizing that all of these accomplishments have taken place in only the last fifty years of man's life here on earth, and they all have taken place in my short lifetime. I continue to marvel at what our children will see.

We did not begin our efforts with a trip to the moon. In the beginning, it was enough to send a small satellite carrying a few instruments into the weightless vacuum of space.

It was just over 25 years ago that NASA was formed, and we began our first steps in the conquest of space. But there were others before us that experienced the triumph and the seemingly insurmountable failures that



APOLLO 11 MOON FOOTPRINT

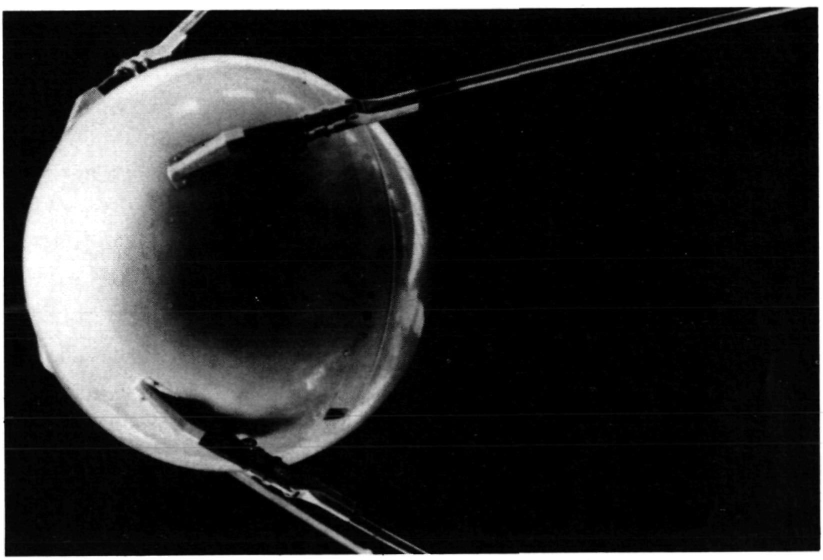
ASTRONAUT ALDRIN ON MOON

were to lay the foundation for our later successes. They may have expected the accomplishments of the last quarter century. I did not, at least, in such a short period. Instrument-laden spacecraft have visited the five nearest planets and the moon and have sent back data that has enriched our understanding of our universe, men have walked on the moon and brought back pieces of it for our scientists to study, scores of satellites circle the globe, mapping our earth, letting us see and talk with each other instantaneously, helping rescue ships at sea, and revealing new knowledge about our world and cosmos at an ever-expanding rate. More importantly, men and women are flying into space routinely on a reusable spaceship, working there to benefit us all and helping to push further back the frontiers of space and to push forward our knowledge about ourselves and our world.

II. HISTORICAL PERSPECTIVE

Although rockets were reportedly used by the Chin Tartars in 1232 in fighting off a Mongol assault, it was not until the 20th century that a clear understanding of the principles of rockets emerged and the technology of large rockets began to evolve.

The space age, as we know it today, was made possible by the pioneers of liquid fuel rocket propulsion. From the work of Tsiolkovski, Oberth and Goddard, Von Braun and Dornberger, and Von Karman in the first half of the 20th century, emerged the basis for the developmental work in both the United States and the Soviet Union after the second World War.



SPUTNIK ON DISPLAY AT PARIS AIR SHOW

Any recent history of space flight must begin with Sputnik. It provided the impetus and the challenge that led to our landing men on the moon and marks the beginning of the space age. Without it, NASA may never have been born.

III. NASA PROGRAMS

At 2:55 a.m., October 11, 1958, a 27 meters-tall Thor rocket was launched with Pioneer I, a 38-kg satellite filled with all the radios and instruments it could hold. It was a critical first step for NASA on the road to space exploration. But the complexity of rockets, even in 1958, left little margin for error. The bad news came 16 hours later. Thor's engines had not delivered full power. Pioneer I climbed to just over 114,000 km, sending back 43 hours worth of data, then fell back toward the Earth.

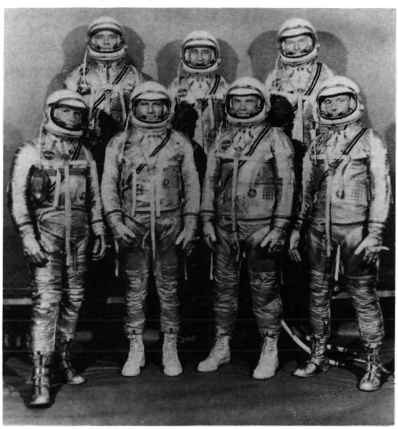
That beginning marked NASA's ventures into the new frontier. While the beginning was inauspicious, things would get better. Four months later, the United States orbited its proposed International Geophysical Year satellite, Explorer 1. The satellite carried instruments which detected the Earth's radiation belts – now named after the principal investigator on that first U.S. satellite, Dr. James Van Allen. Later spacecraft would orbit the earth. Others would explore the moon and the planets. And, in the most successful effort of all, man would fly into space. Each of the ensuing programs was separate, yet each resulted in new knowledge and built upon its predecessor's successes and learned from its failures.

A. Mercury

Even as NASA was being organized, plans were developed to put one man alone into a tiny, bell-shaped spacecraft and orbit him around the earth. In 1959, after an exhaustive search, NASA selected seven test pilots to become our first astronauts. Because no one knew what dangers a human being would face from zero gravity, radiation, or the still-unknown secrets of orbital flight, their training was intense.

The Mercury capsule was tested aboard Little Joe and Atlas Launch Vehicles, and the decision was made to test the system with a chimpanzee. On January 31, 1961, the chimpanzee, Ham, rode inside the Mercury aboard a Redstone missile on a 16-minute ballistic test flight from Cape Canaveral. The spacecraft and launch systems worked perfectly and Ham was safely returned to Florida. Ham left the space program to live in North Carolina at the Asheville Zoo, where he lived quite contentedly until January 1983, when he died of natural causes at age 25.

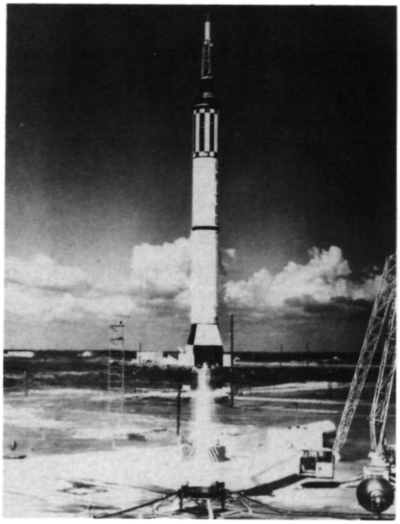
Following this successful flight, NASA continued testing the Mercury



FIRST ASTRONAUT TEAM

"HAM" – THE FIRST CHIMPANZEE TO EVER RIDE INTO SPACE

ALAN SHEPARD/MERCURY CAPSULE

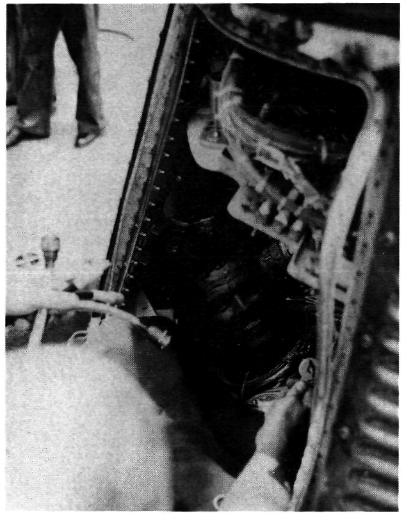


LAUNCH OF FIRST MAN IN SPACE
ON THE MERCURY-REDSTONE III
MAY 5, 1961

capsule on both Redstone and Atlas vehicles. This testing continued through April and, on May 5, 1961, Alan Shepard, America's first man in space, was secured into the cramped spacecraft, Freedom 7, beginning a 15-minute suborbital flight and ending in a splashdown in the Atlantic Ocean. It was a brief flight, but it paved the way for the others that were to follow.

In February 1962, John Glenn entered the history books by orbiting the earth three times in Friendship 7. In the next 15 months, other astronauts followed. Each flight advanced NASA's knowledge of the space environment and taught us how better to survive in orbit. The final Mercury mis-

ASTRONAUT JOHN GLENN



ASTRONAUT GORDON COOPER ABOARD “FAITH 7”

sion, with Gordon Cooper aboard, lasted 34 hours and 20 minutes – 22 times around the world! NASA had proven both the concept of manned flight and the procedures which were to later assist in the Apollo landings.

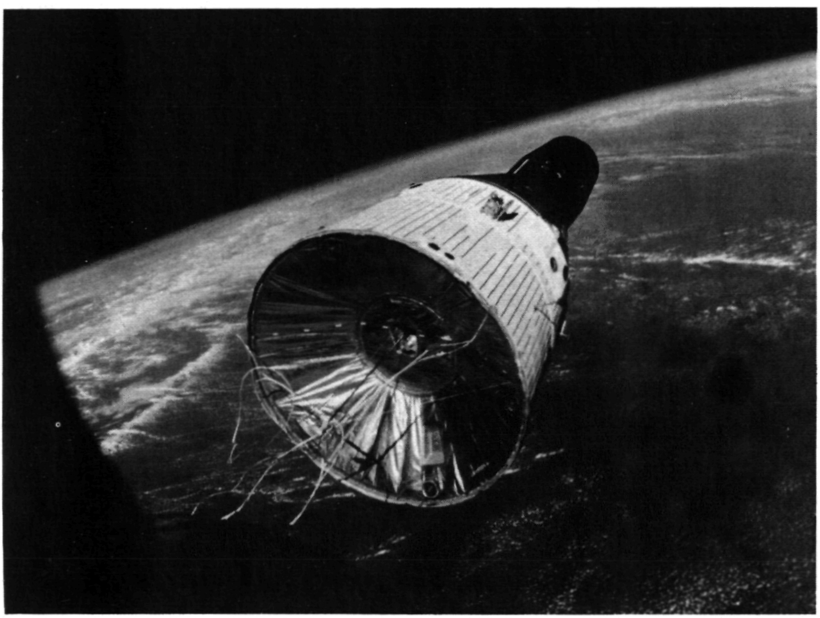
B. Gemini

Following Project Mercury, NASA proposed a two-man spacecraft to orbit the earth. It would perform extended missions, test the techniques of maneuvering in space and rendezvousing with another craft, and test the endurance of men against the still undefined hazards of space travel. During a period of 16 months, NASA used the larger Titan rocket to hurl a dozen Gemini craft into space. Ten spacecraft carried two-man astronaut crews.

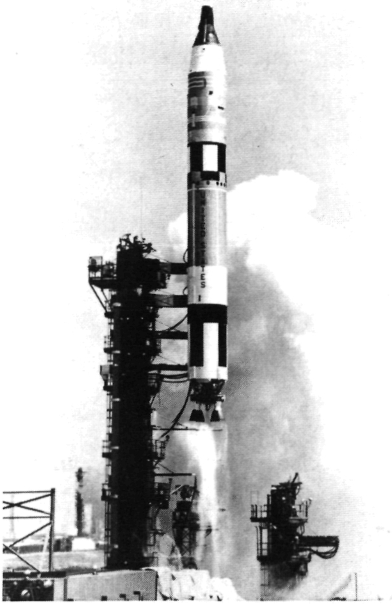
C. Apollo

On May 25, 1961, President Kennedy recommended to a joint session of Congress the most dramatic project undertaken by humankind, which may in future history books be compared to the early explorations of the New World, America, by the European explorers such as Columbus, Henry Hudson, and others.

"I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth," President Kennedy told the Congress.



SPACE RENDEZVOUS "GEMINI 6" – "GEMINI 7"



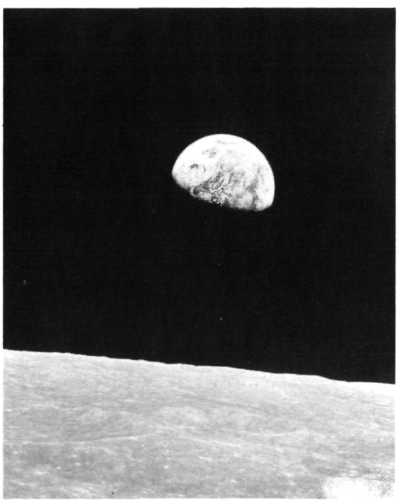
JUNE 3, 1965 LIFTOFF OF
GEMINI IV SPACECRAFT
CAPE KENNEDY, FLORIDA

DR. WERNER VON BRAUN
APOLLO SATURN V

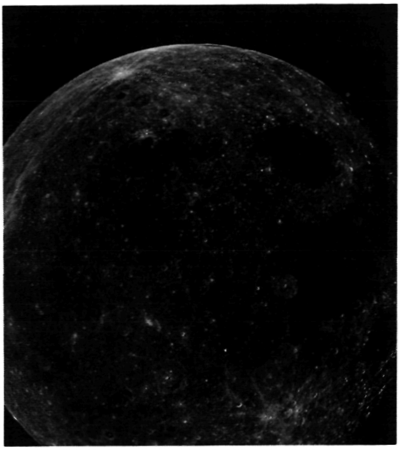
The Apollo plan called for two spacecraft to land on the moon, a command module carrying three astronauts, and a lunar module which would carry two of the astronauts to the moon's surface while the third astronaut remained in lunar orbit. The two astronauts would return to rendezvous in lunar orbit with the waiting third crewman. But the mission could not succeed without giant rockets. Through the mid-sixties, under Von Braun's imaginative leadership, NASA's Marshall Space Flight Center designed and tested the Saturn rockets that would send man to the moon. When the first Saturn V rocket, the largest in the world, was launched with an unmanned payload, the ground shook three miles away. Developed under the leadership of Werner von Braun, the rocket, with over 39,000,000 newtons of thrust, performed flawlessly.

In autumn 1968, the Apollo 7 mission tested the command module with a three-man crew orbit. Then, in December 1968, Apollo 8 crossed the long miles toward earth's nearest neighbor. Looking back, the astronauts photographed the earth as a gleaming blue and white globe against the blackness of space. The photos they took changed forever our view of the earth.

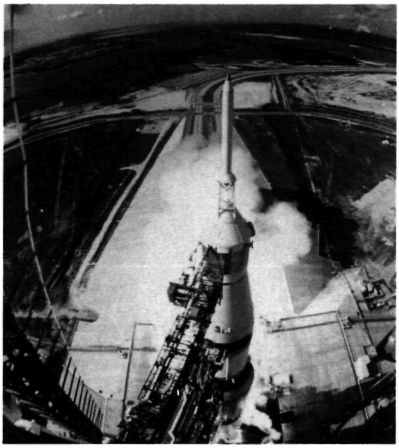
ASTRONAUTS CUNNINGHAM, SCHIRRA AND EISELE "PRIME CREW" FOR FIRST MANNED APOLLO MISSION



APOLLO 8 EARTH VIEW



APOLLO 8 MOON VIEW



APOLLO 11 LIFTOFF

On Christmas Eve, Apollo 8 disappeared behind the moon. We all waited anxiously.

"Houston, be advised. There is a Santa Claus!" The words came from astronaut James Lovell as Apollo 8 climbed above the lunar horizon and reestablished contact with earth. For the first time, representatives of the human race orbited the moon.

Less than seven months later, when Neil Armstrong stepped out of the lunar module Eagle, the world heard the first words from a person standing on another planetary body: "That's one small step for man, one giant leap for mankind."

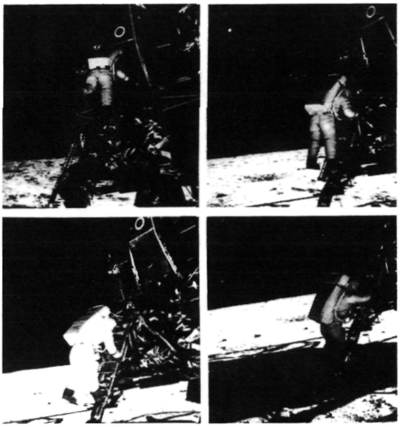
The Apollo goal was achieved on July 20, 1969. A few days later, Apollo 11 splashed down in the Pacific Ocean, and the challenge was fully realized. The astronauts had returned safely to earth. They brought with them a treasure of lunar geology samples. In the next two and one-half years, five more astronaut teams landed on the moon. They left scientific stations to radio new knowledge about the moon, and they brought hundreds of pounds of samples home for study.

D. Skylab

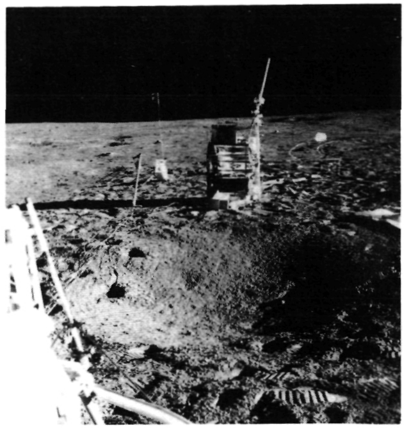
When the decision was reached to terminate the Apollo program upon the completion of Apollo 17, permission was obtained to modify the left-over hardware from the Apollo program to place a "Skylab" in earth orbit.

Three Skylab missions kept astronaut crews in an orbiting space laboratory for increasingly longer flights in 1973 and 1974. In these missions, NASA demonstrated that humans could survive and lead active, healthy, and useful lives during prolonged space flight. Nine men, three crews of three, stayed in Skylab a total of 168 days. The science results of Skylab surpassed all expectations. Using a special solar telescope, astronauts studied the sun and recorded vital new data about its activity and how it affects earth. They used a sophisticated camera and other sensors to study earth itself, making new discoveries in geology, hydrology, weather patterns, and more.

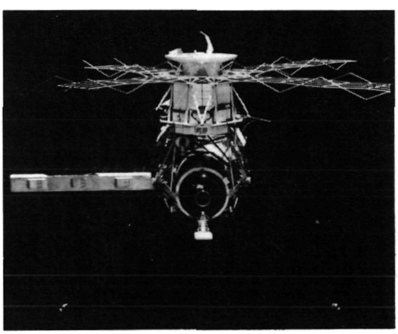
The Space Shuttle program was approved at about the same time that the Skylab program was started. The expectation was that the Shuttle would be used to tend Skylab, which would become a permanent manned Space Station. Unfortunately, the Shuttle was late in flying and, because of higher sun spot activity than expected, atmospheric resistance caused the Skylab to come back to earth in 1979. Thus, the first plan for a "Space Station" based on Apollo hardware was not realized.



APOLLO 11 ASTRONAUTS ALDRIN AND ARMSTRONG LEAVING SPACECRAFT FOR "WALK ON THE MOON"



VIEW OF CENTRAL STATION OF APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE (ALSEP)



SKYLAB SPACE STATION CLUSTER IN EARTH ORBIT AS SEEN FROM SKYLAB 4 COMMAND AND SERVICE MODULE

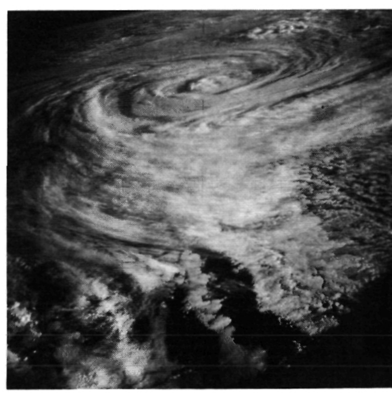


PHOTO TAKEN DURING SKYLAB 4 MISSION – LARGE VORTEX OF A TYPHOON IN SOUTH CENTRAL PACIFIC OCEAN

E. Apollo-Soyuz

During the final manned mission of the seventies, United States astronauts flying an Apollo command module joined up with cosmonauts in a Soyuz craft to meet in space and work together, proving the efficacy of space rescue missions.

F. Science and applications

While astronauts explored the space close to earth and walked on the moon, other NASA spacecraft explored the planets. NASA made equally important strides in practical, scientific, and observatory spacecraft that remained in earth orbit.

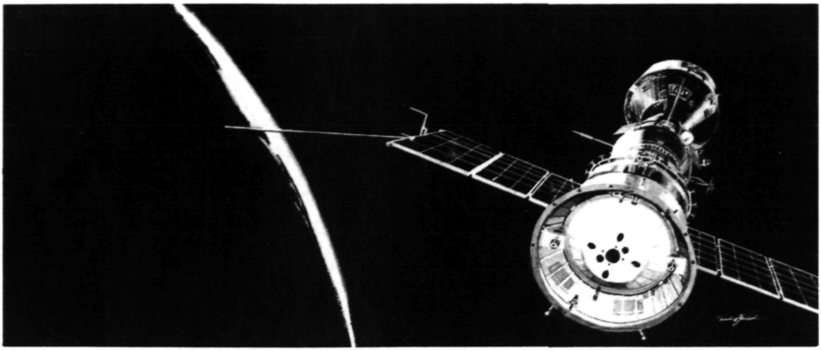
The agency developed the technology for communications and weather satellites that are now commonplace in our daily lives. Communications satellites alone represent a multibillion dollar business today that began with NASA's pioneering thrusts.

Scanning the earth itself has been one of the most effective uses of space technology. Landsat's sensitive cameras and instruments reveal mineral deposits, track the growth of crops and forests, and monitor snowfall and water resources.

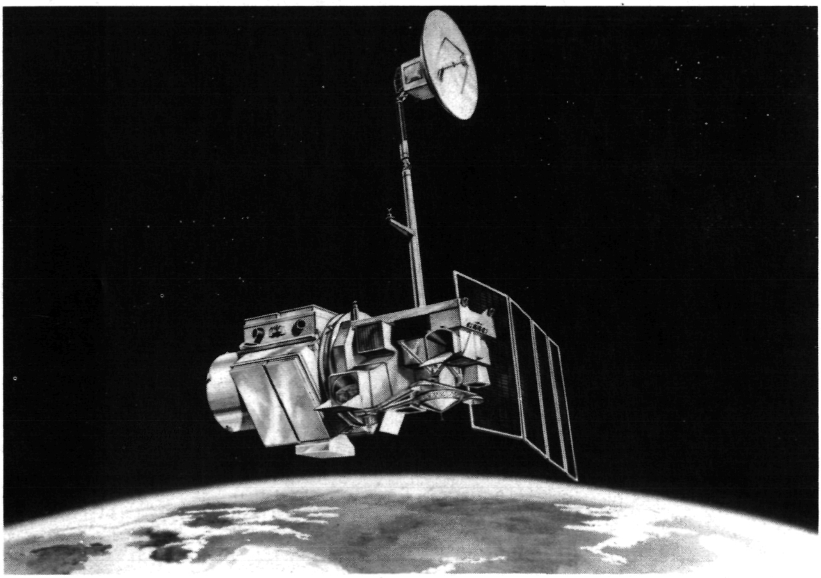
Other spacecraft have provided new knowledge for the sciences. Solar observatories studied the sun. Astronomical observatories scanned the heavens. Instrument-laden satellites aimed their sensors at earth's atmosphere and the near-space regions. The High-Energy Astronomical Observatory spacecraft brought new understanding to how stars are formed and how the universe is aging.

The highly successful Infrared Astronomical Satellite (IRAS) is helping expand our knowledge to the edge of the universe. Many years of collaborative efforts between the U.S., the Netherlands and the U.K. culminated in a successful launch on January 25, 1983. IRAS has surpassed all expectations. Exciting discoveries from IRAS observations include observations of proto-stars in the very early stage of formation, observations of a previously unobserved long tail on a comet, and the discovery of a halo of particles around the star Vega. It will take years to fully analyze the data collected by IRAS.

AMERICAN AND SOVIET PRIME CREWS OF APOLLO-SOYUZ TEST PROJECT (ASTP)



APOLLO-SOYUZ TEST PROJECT "DOCKING"



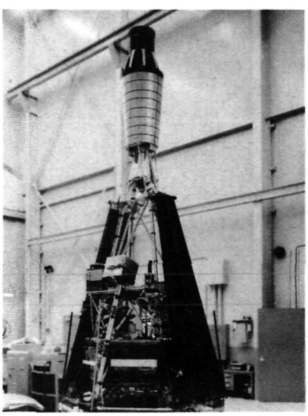
LANDSAT-D
FOURTH IN A SERIES OF EXPERIMENTAL SATELLITES DESIGNED TO EXPLORE EARTH FROM MORE THAN 640 KILOMETERS

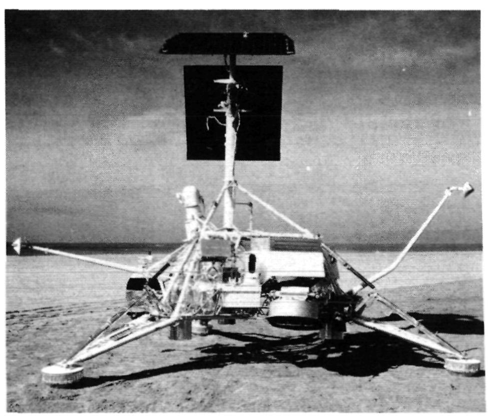
IRAS is the second cooperative satellite project which NASA and NIVR have undertaken together, building upon the success of the Netherlands Astronomical Satellite (ANS).

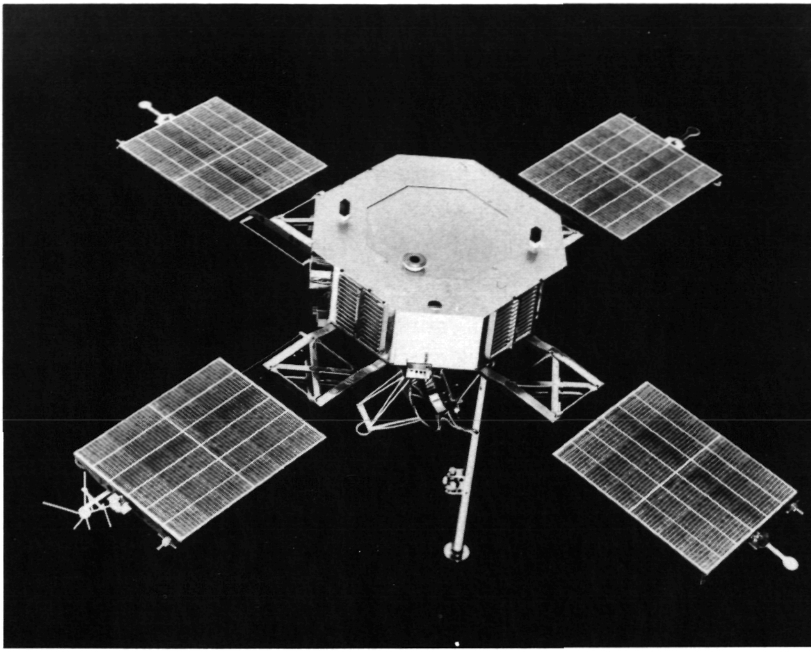
In developing machines capable of surviving in space, NASA advanced the state of the art in the area of new materials, such as composites, polymers, ceramics, and metallics, as well as nondestructive testing, fracture, and fatigue.

Space Science and Applications Spacecraft included:

1. *Ranger*
NASA and industry experts used the Ranger program in the early and mid-sixties to solve the difficult engineering and navigational problems of reaching a distant body.


RANGER II SPACECRAFT


SURVEYOR SPACECRAFT



MARINER E SPACECRAFT

2. *Surveyor*

The Surveyor Program showed that a robot spacecraft could be safely landed on another planet.

3. *Mariner*

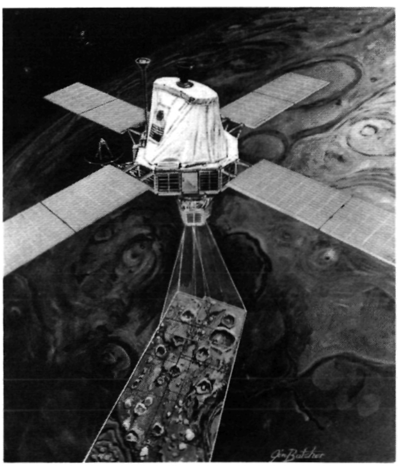
Mariner spacecraft flew past Venus and Mercury, obtaining closeup views of the innermost planets. Other Mariners crossed to Mars, precisely fired their engines, and went into orbit.

In twin missions, each having an orbiter and a lander, Viking spacecraft were precisely navigated to Mars. The first of them landed on July 20, 1976. From widely separated landing zones, the two Viking Landers provided us our first on-the-ground look at our neighbor.

Cameras showed a rock-strewn rusty red terrain and a pinkish sky. Samples of martian soil were analyzed in one small part of the Viking Lander. A 0.35 cubic meter unit, a marvel of engineering that contained miniaturized instruments that would fill a laboratory on earth, analyzed the soil for signs of life. But it found no life.

4. *Pioneer*

An unbroken series of successes put Pioneer spacecraft into far-distant space where they studied the sun, the solar winds, and the radiomag-



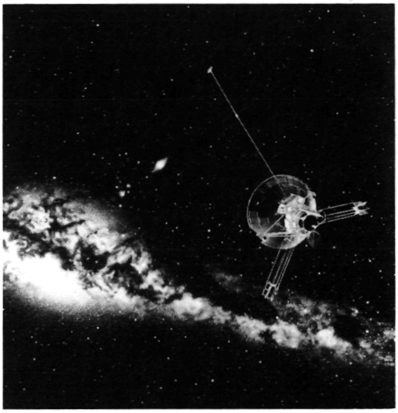
VIKING I

VIKING I LANDER
PICTURE TAKEN ON SURFACE OF MARS

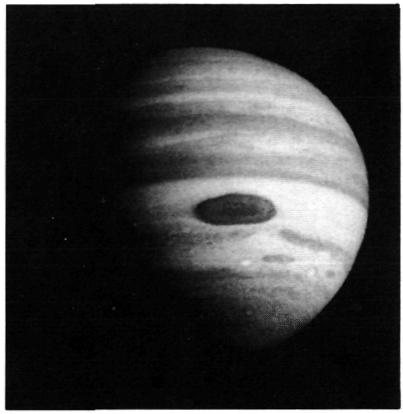
VIKING 2 ON MARS' UTOPIAN PLAIN

netic phenomena. More than two years before Viking reached Mars, two Pioneer spacecraft, launched one year apart, flew past Jupiter obtaining color images of Jupiter, showing bands of multicolored clouds and strange spots and swirls in the jovian atmosphere. Scientists had a closeup look at the Great Red Spot.

In December 1974, the spacecraft began a five-year journey to its next goal, Saturn. Pioneer 11 entered the Saturnian system in early September 1979. The spacecraft's imaging system gave earth a closeup look at



VIEW TOWARDS THE SUN FROM PIONEER 10



JUPITER'S GREAT RED SPOT AS VIEWED FROM PIONEER 11

Saturn's fabled rings and its banded cloud patterns. Observers saw a never-before-seen ring, the F ring, girdled Saturn, and that its broader rings actually had many components. Instruments recorded new data on interplanetary magnetic forces, radiation, and weather.

Another pair of Pioneer-class spacecraft headed for Venus. Thought to be a watery planet, Venus was shown to be a parched furnace, its landscape dry and hot beneath the weight of an atmosphere more than 90 times as dense as earth's. Data which we obtained about the greenhouse effect that traps heat within a planet's atmosphere may have vital significance for the future of earth.

5. *Voyager*

With their high-resolution cameras and other instruments, Voyager found an unsuspected ring around Jupiter and revealed that Saturn's rings are not a few, but thousands of glimmering bands composed of icy chunks and embedded moonlets.

Voyager 2 is scheduled to reach Uranus in 1986. A subsequent flyby of Neptune in 1989 is a strong possibility.

G. Space Shuttle program

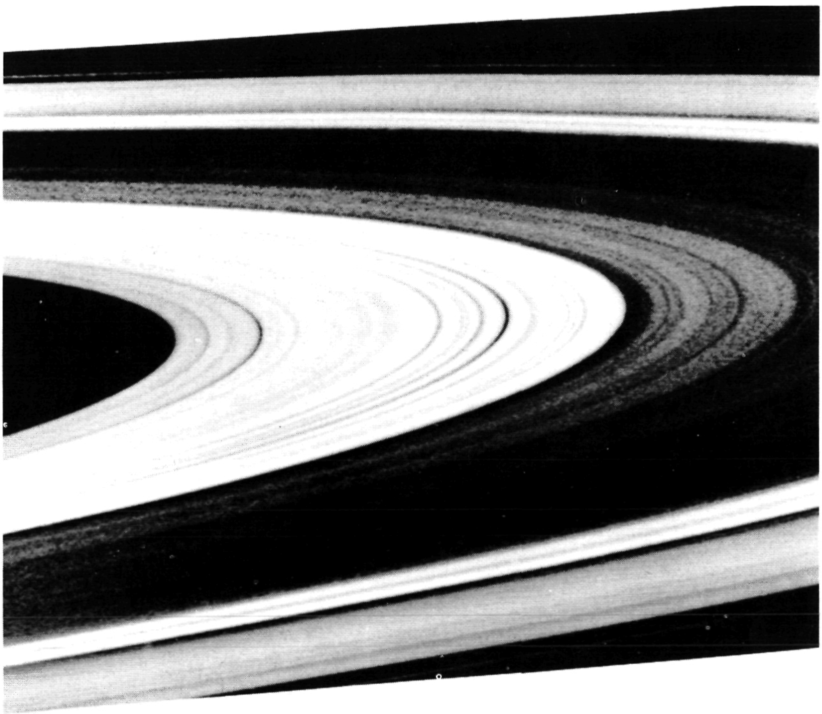
1. *Past*

In 1952, in an article for Collier's Magazine, Werner von Braun restated the ideas of Oberth and Tsiolkovsky and asserted that the new rockets that were being conceived at the time would eventually make space travel possible. He also suggested the idea of a reusable spaceship which he called a "space taxi" but which we now know as the Space Shuttle.

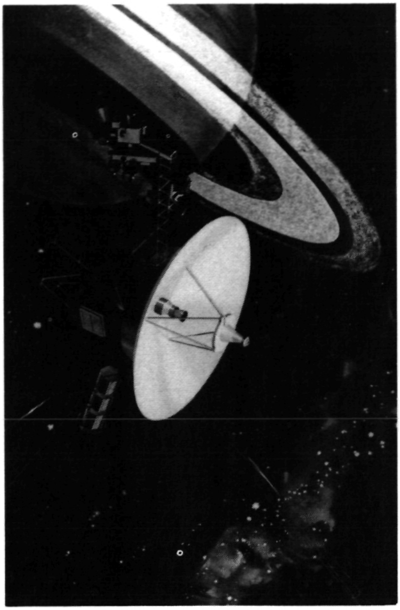
Von Braun thought that it would be important to create a new transportation system to carry things and people back and forth to a Space Station. This transportation system would consist of completely reusable rocket ships (or rocket airplanes) that would "shuttle" back and forth between the ground and the Space Station. He foresaw that a Space Station would generate enormous traffic in space and that the reusable "Space Shuttle" would eventually be the most economical way to handle the traffic.

Shortly after the successful lunar landings in 1969, NASA proposed building a Space Station and an associated Space Shuttle. Only the Space Shuttle was approved. Although the construction of the Space Station was the ultimate objective, the Space Shuttle was technically more difficult to develop. NASA would concentrate on the Shuttle and defer the construction of the Space Station until after the Shuttle was available. Shuttle operations would demonstrate the potential value of the Space Station and show how it could enhance future space operations.

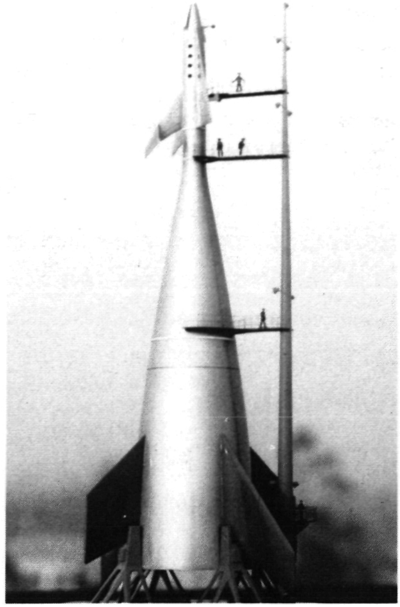
The proposed cost of a totally reusable system was $ 12 billion in "then year" dollars. Money of this kind was not available. Thus, the original



VIEW OF SATURN RINGS – PERSPECTIVE SEEN BY VOYAGER 1
AT A RANGE OF 717,000 KILOMETERS



VOYAGER SATURN ENCOUNTER



DR. VON BRAUN'S CONCEPT OF "SPACE TAXI"

design was changed, and the familar configuration we use today was substituted. In February 1972, we planned to build a reusable space ship for $ 6.5 billion (in 1972 dollars) which would be capable of putting 29545 kg in near-earth orbit in 1979.

It took a decade to make our dreams a reality.

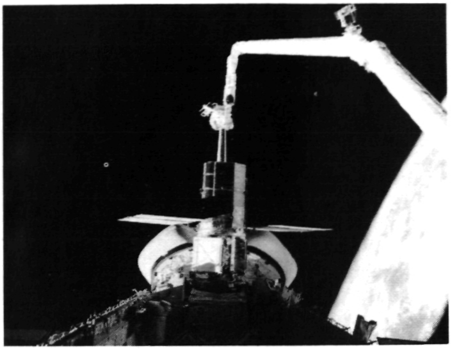
The Space Shuttle orbiter "Columbia" flew for the first time on April 12, 1981. By the end of 1982, the Shuttle was declared operational, and a new era of space flight began with men and women routinely going into orbit.

Since that historic first flight of Columbia in April 1981, we have flown 10 highly successful Shuttle flights. From the historic first flight and the return of our astronauts to a landingstrip in California, the first flight of a reusable space vehicle, the flight of the Spacelab, the deployment of the Long Duration Exposure Facility through the flight of the Manned Maneuvering Unit and the Solar Maximum Repair Mission, the Space Shuttle has proven that it is the most versatile space transportation vehicle ever built.

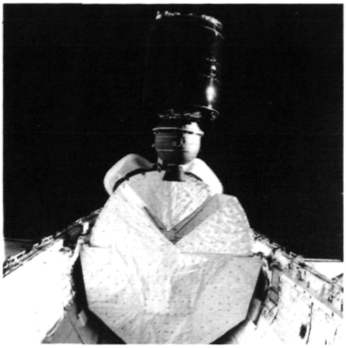
The Space Shuttle has demonstrated its flexibility in meeting customer requirements despite encountering some technical difficulties and some schedule delays. The inaugural flight of Discovery, STS 41-D, and the actions that were taken in combining the cargos from two flights to fly

ASTRONAUTS CRIPPEN AND YOUNG
FIRST SPACE SHUTTLE CREW

41-C ON-BOARD SCENE RELEASE
OF LONG-DURATION EXPOSURE
FACILITY (LDEF) SATELLITE



STS-5 SATELLITE DEPLOYMENT -
"SATELLITE BUSINESS SYSTEM
(SBS-3)



SOLAR MAXIMUM MISSION
SATELLITE (SMMS) REPAIR –
41-C MISSION

on 41-D, have strengthened our confidence in the flexibility of the Shuttle team and its ability to respond to unforeseen circumstances. The Shuttle has been successful in the deployment of nine communications satellites, including the deployment of satellites for Telesat Canada, Indonesia, and India.

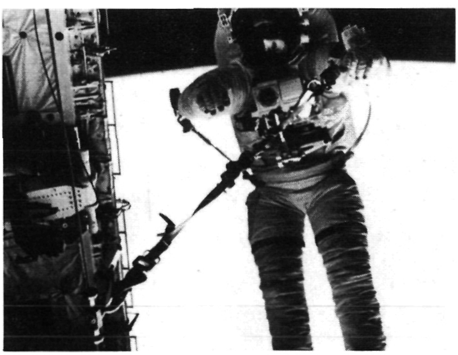
On the STS-6 flight, two mission specialists took the first space walk for the U.S. since the Skylab program. While tethered to the orbiter, the specialists conducted exercises to improve our ability to use tools and perform equipment handling techniques in the cargo bay. The successful test of astronauts, their spacesuits, and the untethered Manned Maneuvering Unit on the recent 41-B mission demonstrates an additional EVA capability that shows great promise for repairing satellites and extending their lifetime.

The Canadian-built Remote Manipulator System performance during the

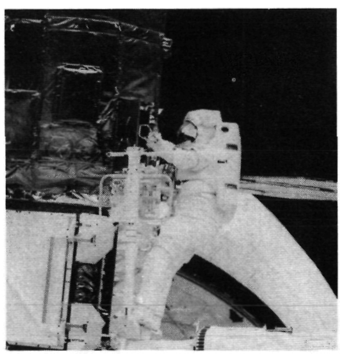
STS-7 mission was flawless as it achieved the first deployment and retrieval of a spacecraft, the West German Shuttle Pallet Satellite (SPAS-01), from the cargo bay. It was this spacecraft, which served as a pallet for several scientific experiments, that gave us the first pictures of the orbiter in flight.

While the Shuttle flights have been demonstrating a large number of engineering accomplishments, the capabilities of the Shuttle to provide outstanding scientific benefits have also been illustrated. The greatest example of this was the resounding success of the first Spacelab mission on STS-9. This joint NASA-European Space Agency (ESA) mission, flown last November, was an immense success, demonstrating the versatility and broad applicability of this new space research facility.

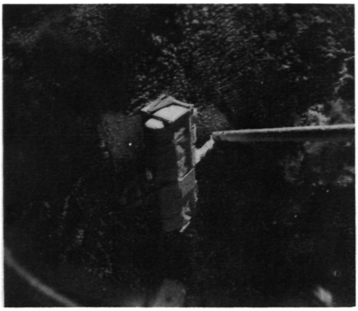
This historic flight represented the fruition of an international effort of individuals representing a broad spectrum of governments, industry,



STS-6 EXTRAVEHICULAR ACTIVITY (EVA)



41-C MISSION SPECIALIST, JAMES VAN HOFTEN, MAKING NEEDED REPAIRS ON SOLAR MAXIMUM MISSION SATELLITE



SPACE SHUTTLE REMOTE MANIPULATOR ARM GRASPS SHUTTLE PALLET SATELLITE, SPAS-01, DURING PROXIMITY OPERATIONS

STS-9/SPACELAB ON-BOARD SCENE – ULF MERBOLD, SPACELAB 1 PAYLOAD SPECIALIST

and the scientific community over a ten-year period. More than 100 investigators from 11 European nations, Canada, Japan, and the United States, provided over 70 experiments in seven scientific disciplines. Never before has so much scientific data been brought back from a Shuttle flight. All of Spacelab's verification objectives were accomplished. For the first time during a flight, principal investigators were able to communicate directly with the crew, monitor real time data, and give instructions for their experiments through the Payload Operations Control Center. Once again, the flexibility of manned space flight operations was demonstrated by the STS-9 crew's ability to modify experiments, improvise, and even make dramatic equipment repairs.

Additional scientific experimentation was accomplished on STS-7 with NASA's Office of Space and Terrestrial Applications payload (OSTA-2) which remained fixed inside the payload bay to perform materials processing experiments. These four instrument packages, developed by

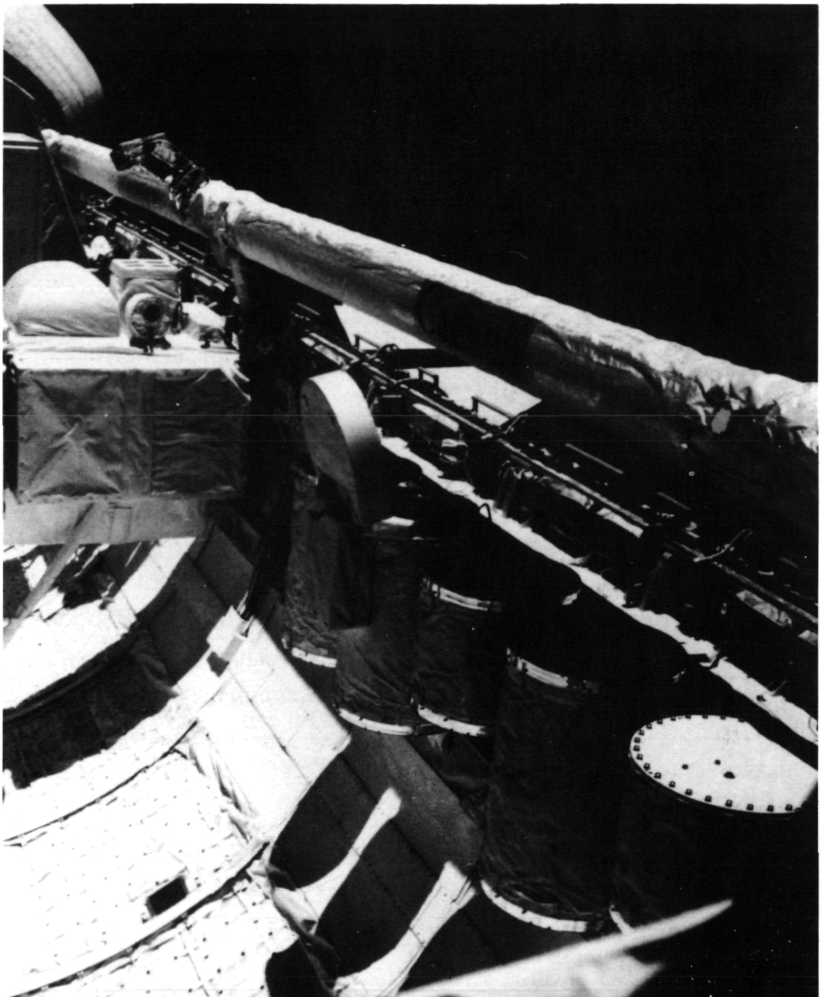
U.S. and West German scientists, investigated the mixing, melting, and crystallizing of such substances as metal alloys and glass.

Because of its reliability and flexibility, and in accordance with the President's space policy, the Shuttle is the primary launch system for U.S. government missions and will be used for a number of exciting missions in the near future, including the retrieval mission in November to return the Palapa-B and Westar communications satellites which failed to achieve their planned geosynchronous orbits.

With all of the successes of the Shuttle, we are deeply committed to assisting our customers and their suppliers in any way possible using all of the technical expertise we have developed in over 25 years in the space business, enhancing our ability to provide customer services and ensuring that the capability is available to meet not only our nation's needs but also those of our customers.

We are looking at ways we can continue to reduce costs, improve quality, increase productivity, ensure greater customer satisfaction, and explore avenues to enhance commercial opportunities in space.

The Shuttle revolution has also made it possible for us to offer space experimentation opportunities to new classes of investigators through our Small Self-Contained Payload Program – better known as Getaway Specials (GAS). Over 400 reservations for these Specials have been booked and, during the past year, 19 experiments have been carried on Shuttle missions. The investigations have included experiments with plants, seeds, metals research, snow crystals, ants, and soldering, to name a few.



STS-7 ON BOARD SCENE – VIEW OF FIVE GETAWAY SPECIAL AND STUDENT EXPERIMENTS IN THE PAYLOAD BAY

The mid-deck of the Orbiter also offers experimental opportunities for the science community. We have performed mid-deck experiments on monodisperse latex spheres, studies of lightning associated with thunderstorms, and plant experiments.

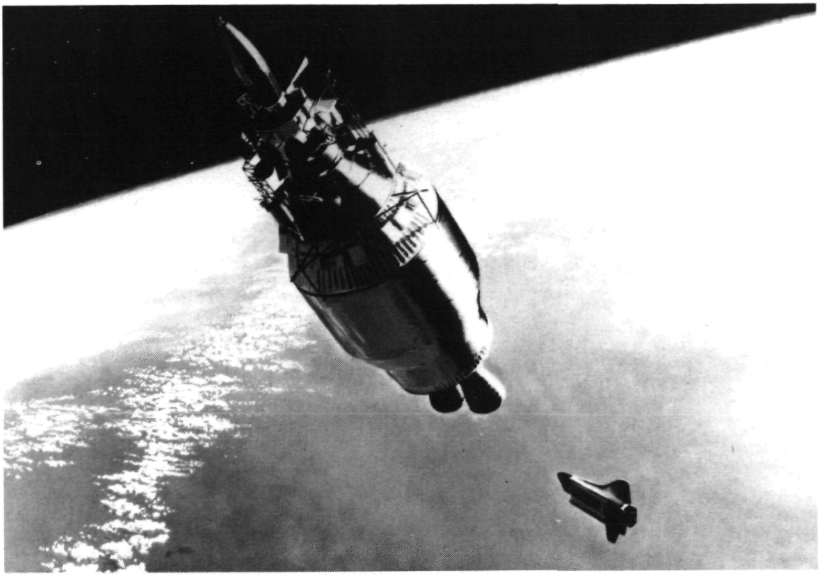
On the last five flights we have sent up 27 crew members who performed their duties with a level of excellence that has again and again proven the value of having people in the loop to conduct mission activities and to initiate corrective action when necessary. This brings the number of crew members who have participated in Shuttle missions to 42, including 20 astronauts, 19 mission specialists (including the first female and the first two blacks), and the first three payload specialists – two from the United States and our first from Europe – Ulf Merbold. It also includes the first commercial endeavor payload specialist.

We will continue to expand opportunities for space flight both within and outside the United States. Several countries are currently conducting their own selection procedures for payload specialists to fly on missions carrying their country's spacecraft and experiments.

Our goal is to make the Space Transportation System fully operational and cost effective in providing routine access to space for all users. Our primary concern and objective is that each mission is safe and successful. As NASA's Aerospace Safety Advisory Panel reported, our safety record has been 100% so far, and the Shuttle has performed superbly during each mission.

2. *Future*

The Shuttle flight rate is scheduled to increase to 24 flights per year by



GALILEO DEPLOYMENT FROM SPACE SHUTTLE CARGO BAY

1989 with a four-orbiter fleet and includes 6 flights in 1984 with 13 planned in 1985. An important milestone in the program is expected to be reached in October 1985 with the first flight from the Vandenberg launch facility. In 1986, we plan to launch 14 flights. 1986 will be a particularly significant year for the STS, as we will launch our first two Centaurs on the Shuttle for Galileo and Ulysses in May 1986 and, later in August, place the Space Telescope in orbit.

We are in the middle of a period of evolution from Space Shuttle research and development activities to full operational status. The full 29545 kg cargo capability will be demonstrated at KSC in May 1986 with the Galileo mission.

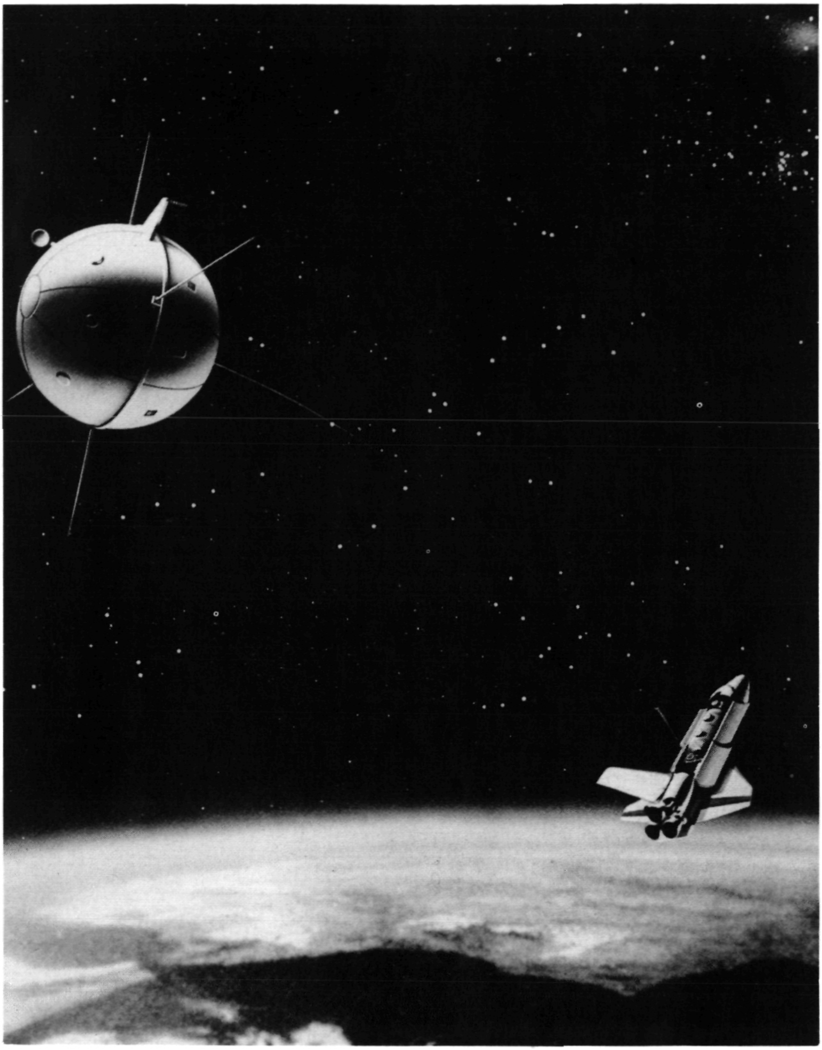
We will conduct a few inexpensive, but vital, flight experiments to demonstrate new Shuttle capabilities aimed at developing customer confidence in connection with satellite services and orbital operations with large structures.

Our major emphasis in advanced programs will be placed on satellite services, tethers and platforms, advanced transportation systems, crew systems, and proving generic new space systems capabilities.

Detailed definition of Shuttle-derived launch vehicles will be initiated to define a potential evolutionary capability for earth-to-orbit payloads which may capitalize on the STS facilities. We will complete concept definition (Phase A) studies, begun in 1984, for a proposed reusable space-based Orbital Transfer Vehicle to be defined in conjunction with the Space Station requirements for refueling and refurbishment. The next step, our system definition studies, will be completed next year.

The development of a Tethered Satellite System, in cooperation with the Italian government, will provide a new facility for conducting space experiments at distances up to 100 kilometers from the orbiter. We will continue the hardware design and development through the Preliminary Design Review and the Critical Design Review early in 1986 with an engineering verification flight in December 1987.

The Space Shuttle will, of course, play a vital role in the development and eventual operation of the Space Station. In the near term, we will use the Shuttle's research capabilities to gain experience and insight into designs and systems that are essential elements of any Space Station concept. Since the Shuttle will be the primary vehicle that will allow us to



TETHERED SATELLITE SYSTEM

carry personnel and equipment to build and maintain a Space Station, those of us connected with the Space Shuttle have a special incentive to insure routine and reliable space transportation, both now and for the future. We are proud of our contributions and the Space Shuttle's role in the revolution in space that is clearly underway, and proud of our friends, especially here in Europe, who are assisting in this revolutionary undertaking.

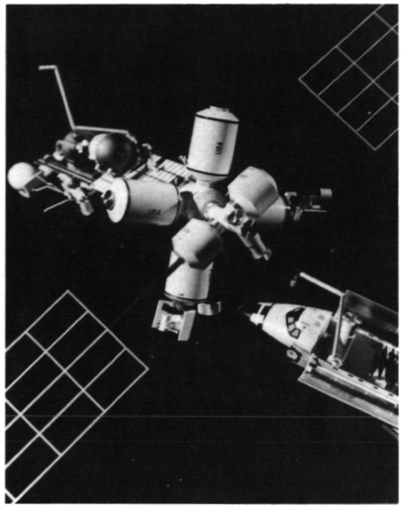
H. Space Station

On January 25, 1984, in his annual State of the Union message, President Reagan announced a new national commitment to take the next important step in space operations. The President directed NASA to develop plans for the establishment of a permanently manned orbiting Space Station to be deployed within the decade. He also invited our friends and allies around the world to join with the United States in this new venture. This initiative marks the beginning of the next new era in space.

Although the Space Station proposed by President Reagan is very modest, it will give us the ability to expand our operations in space and will eventually lead to larger-scale activities, such as developing automated manufacturing processes in space and, ultimately, the use of extraterrestrial materials for these factories.

The Space Station is not a new idea. In 1869, a Boston clergyman, Edward Everett Hale, wrote a story that appeared in the *Atlantic Monthly* called "The Brick Moon". The story is a fantasy about the creation of a large earth-orbiting sphere, built of brick, 61 meters in diameter, in which people lived and worked. Decades later, the idea was picked up by Kon-

VON BRAUN SPACE STATION
CONCEPT



SPACE STATION DESIGN
CONFIGURATION

stantin Tsiolkovsky (1903) and Hermann Oberth (1924). In the early years of this century, both speculated extensively on space travel and on orbiting Space Stations. Their work had a decisive influence on two young engineers, Robert H. Goddard in the United States and Werner von Braun in Germany, who developed the concepts on which all of the liquid-fueled space booster rockets in use today are based. It was Goddard, Von Braun, and their followers who produced the propulsion systems that make the Space Shuttle possible and, with the Shuttle, the Space Station.

During the Apollo program, a number of studies were conducted by NASA on the subject of Space Stations. Late in 1968, a committee was established to look at the future of NASA and to develop a "Post-Apollo" program. The early plans for Apollo called for a staging from earth orbit. A small orbiting plans for Apollo called for a staging from earth orbit. A small orbiting station would be placed into earth orbit, and the vehicle destined to go to the moon and back would be launched from this station. In addition to being a feasible way to go to the moon, this method of "earth orbit rendezvous" had the advantage that it could evolve to the construction of an earth-orbiting Space Station. However, the "earth orbit rendezvous" method was more expensive and would take longer to achieve than the alternative of the "lunar orbit rendezvous" proposed by Dr. John Houbolt of the NASA Langley Research Center. Dr. Houbolt proposed that the lunar landing ship go to the moon from a small "station" placed in orbit around the moon and then return to the lunar orbiting station for the trip back to earth. Because of the pressures imposed by a tight time schedule and limited funding, the more time-efficient method recommended by Dr. Houbolt was adopted by NASA in the summer of 1962.

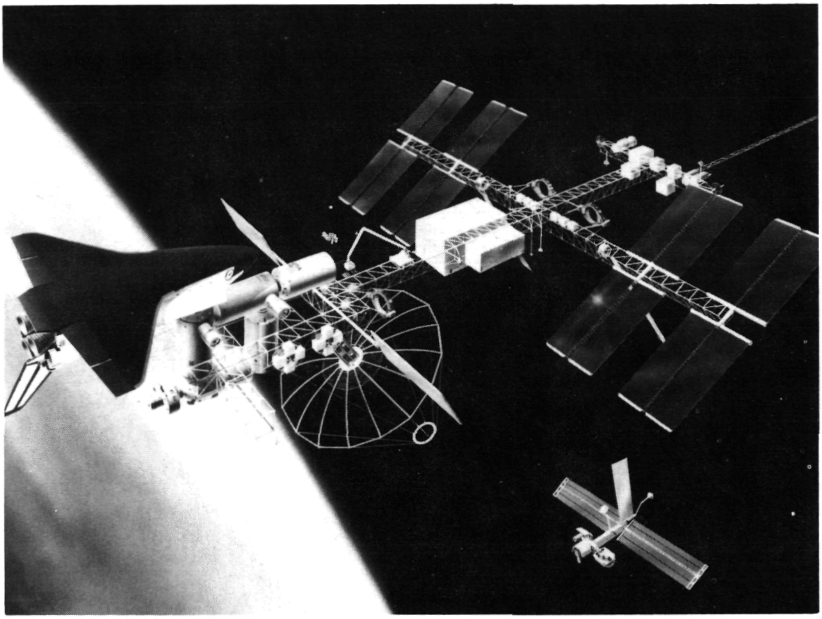
There are three compelling reasons to construct a Space Sation:

(1) A Space Station is a laboratory in earth orbit on which a great many scientific experiments can be performed that would be impossible to do on the ground. Included among these are biological experiments to determine the reaction of living things to zero gravity; certain chemical, physical, and fluid processes that can be carried out only in zero gravity; and many astronomical and astrophysical observations for which the absence of an atmosphere is an advantage. We have had considerable experience now in conducting experiments in space with the Skylab, the Shuttle with Spacelab, and the Salyut. There is no doubt that very

valuable scientific work will be done on the Space Station on this experience.

(2) A Space Station is a repair and maintenance base from which important satellites could be reached, retrieved, and maintained or repaired. The United States now has deployed in earth orbit well over 150 satellites, many of which perform missions of great importance to our national security and others that are scientifically or economically very important. Right now, all of these satellites are eventually discarded when they run out of fuel or when various components reach the end of their lifetimes. The Space Station and the associated orbital transfer vehicles will eventually make it possible to maintain and service all of these satellites while they are in orbit. Satellites will evolve into "permanent orbital facilities" that will be repaired, maintained, and upgraded as required. The Shuttle flight conducted this April, during which a failed satellite "Solar Max" was retrieved, repaired, and redeployed foreshadows, in a small way, the kind of operation that will become routine once the Space Station is completely operational.

(3) A Space Station is a necessary staging base for more ambitious missions that will be carried out in the future. In the coming years, we will definitely want to return to the moon. It has been speculated that we will establish a small permanent colony on the moon before the year 2000 and will want to conduct more ambitious missions such as sending people to explore Mars and possibly to visit some asteroids. Such missions can be executed much more easily if the starting point is a Space Station that permits refueling and resupply before the journey to Mars or some other distant objective actually gets underway.



SPACE STATION CONCEPT - CREW MEMBER SHOWN PERFORMING EXTRAVEHICULAR ACTIVITY (EVA)

IV. INTO THE 21ST CENTURY

We have explored many options in an attempt to predict what the future will likely hold in the next century. It has been speculated that our activities in space will advance in three phases:

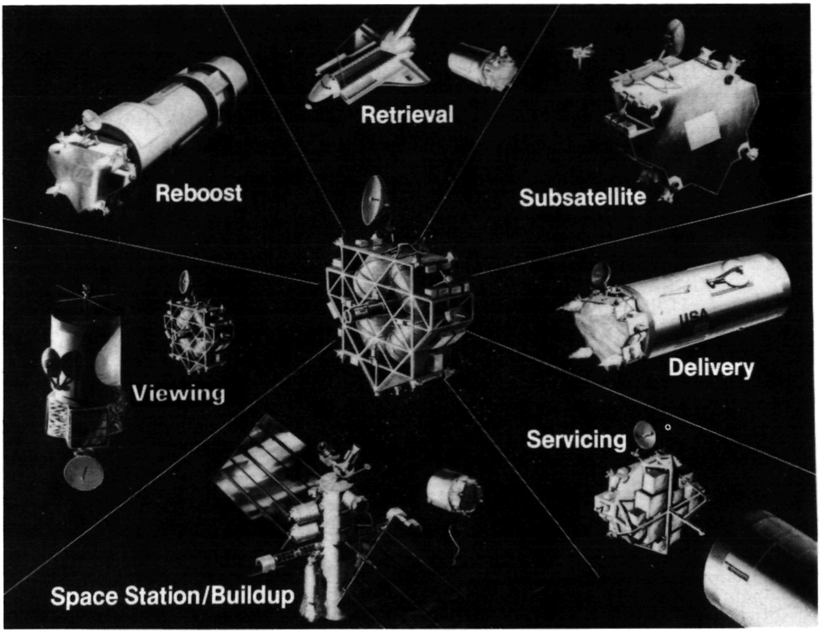
1. easy access to and return from space,
2. permanent presence in low earth orbit, and
3. limited space-based self-sufficiency of man in space.

We feel reasonably certain that we will have assembled an advanced Space Station in low earth orbit, have begun launching serviceable commercial communications satellites, have an orbital maneuvering vehicle for servicing and refueling satellites, have an orbital transfer vehicle to deliver communications satellites to geosynchronous orbit from low earth orbit, and may have placed a manned platform in geostationary orbit.

Flight crews will operate not only between earth's surface and low earth orbit, but also at geostationary orbits, between orbits, and, later on, at lunar and planetary distances.

The orbital maneuvering vehicles and the orbital transfer vehicles will provide the necessary mobility to support the necessary satellite servicing functions from the Space Shuttle and the Space Station including deployment, on-orbit assembly of some elements, retrieval, orbit change (including reboosting the satellite), replenishment, and repair.

In addition to delivering communications satellites to geosynchronous orbit, orbital transfer vehicles can deliver large structures such as space platforms to higher orbits. Orbital transfer vehicles may be used for transportation for a lunar base and for planetary projects such as those recommended by the Solar System Exploration Committee of the NASA Advisory Council. These include a recommended core program with a Venus Radar Mapper, Mars Geoscience/Climatology Orbiter, Comet Rendezvous, and Titan Probe missions. Additional possible planetary missions such as Mars Surface Science, Mars Sample Return, and Comet Sample Return would also benefit from the orbital transfer vehicle.

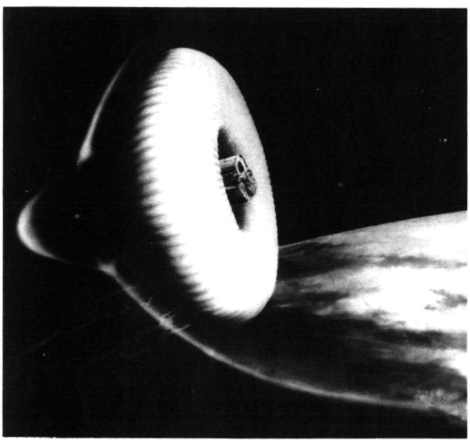


ORBITAL MANEUVERING VEHICLE (OMV)

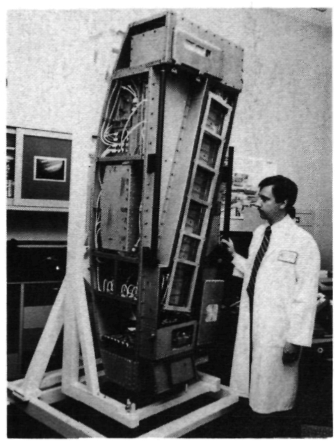
By the end of this century, there will be a need for routine operation of unmanned earth to low earth orbit vehicles with larger payload capability than now exists. Processing materials, such as pharmaceuticals, high purity advanced semiconductors, and unique glass materials and metals in space is expected to become a major contributor to the betterment of life here on earth and will result in relatively large manufacturing facilities in space.

I believe that commercial space enterprises may be just over the horizon. Perhaps the best example is the zero gravity continuous flow electrophoresis experiment that has been carried out on several Shuttle flights by the McDonnell Douglas Corporation and a subsidiary of the Johnson and Johnson pharmaceutical house. The continuous flow electrophoresis process works much more effectively (by more than a factor of a thousand) in zero gravity than it does on the ground. Certain very valuable materials, which probably would not otherwise be available, could be made in commercially significant quantities in space.

I can foresee that with the help of our international partners, by the turn of the century, our space programs could include a complex of advanced and very large scientific and industrial facilities in low earth orbit, permanently manned scientific and communications facilities in geosynchronous orbit, a permanent base on the moon, and a manned expe-



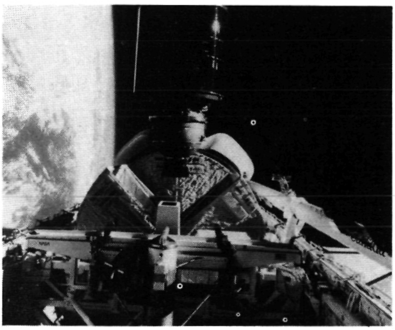
AEROASSIST ORBIT TRANSFER VEHICLE - WOULD CARRY PAYLOADS TO ORBITS HIGHER THAN THE SHUTTLE IS CAPABLE OF REACHING



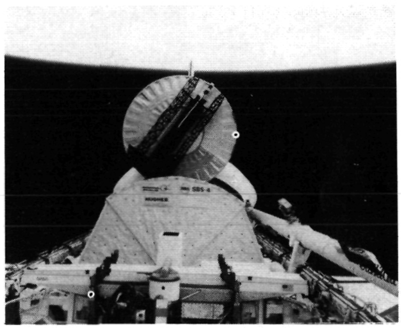
CONTINUOUS FLOW ELECTROPHORESIS SYSTEM - FIRST EXPERIMENT BY A COMMERCIAL FIRM CARRIED ON STS-4 dition to Mars. Routine checkout, refueling, repairing, and upgrading of space facilities, as well as debris removal in all orbits, and other innovative Shuttle uses and missions such as large space tether applications for power generation, nonpropulsive transportation, and satellite constellations, are easily possible.

Many space developments will be very expensive and will require international cooperation in space ventures because the costs are so large that, unless several nations participate over a relatively long period of time, the project could be postponed almost indefinitely or never started. Cooperation will be essential for some of the more expensive projects.

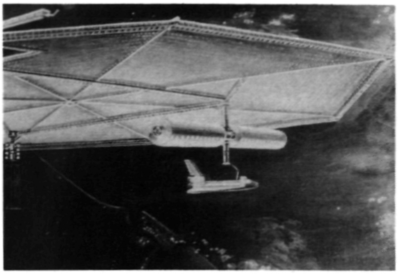
The establishment of a manned lunar base during the early years of the decade after the year 2000 could well become a major goal of this nation and its partners in space for a number of persuasive economic, sociopolitical, cultural, and philosophical reasons. There are very attractive scientific reasons for returning to the moon. There are also indications that mining operations on the moon's surface may be more economical



SBS-4 DEPLOYMENT



SYNCOM DEPLOYMENT



ARTIST'S CONCEPT –
LUNAR SUPPLY BASE

CONCEPT – CHEMICAL
PROCESSING PLANT IN SPACE

in terms of outfitting or refueling a geosynchronous spacecraft or Space Station than comparable earth-based operations.

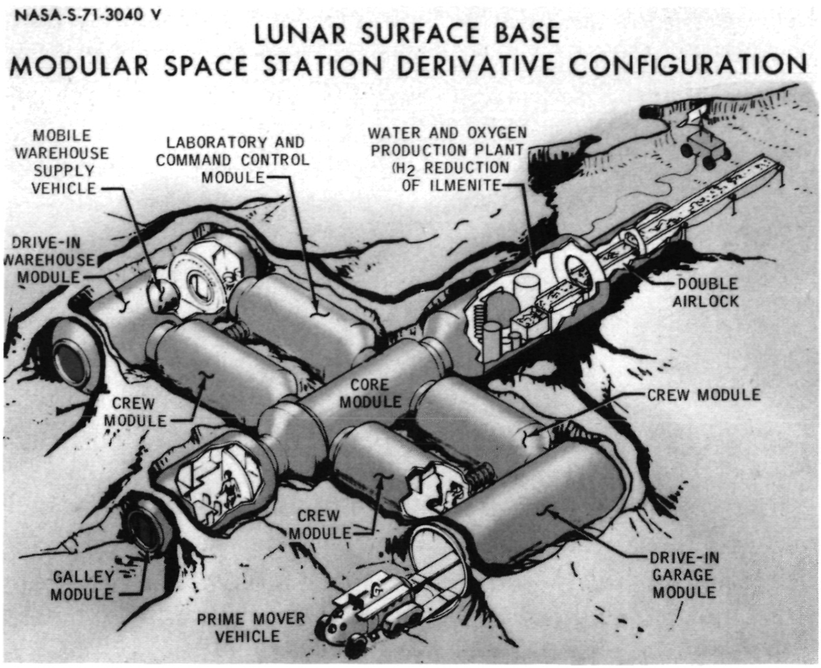
The moon provides very low gravity isolation from earth, particularly earth-based radio frequency interference and atmospheric diminuation, very low magnetic field, large temperature excursion, long day-night cycle, and unique geologic features. The moon would be not only a base for scientific studies which would include radio and possibly optical and other photometric astronomical observations, but would be the subject of intensive study itself. The origin of the moon remains a very puzzling question, despite our many visits there. A scientific base on the moon would be as fruitful as our Antarctic science stations and would offer the additional advantages of opening up this new locale for other scientific uses.

The moon is also a prime source of oxygen, silicon, and aluminium, as well as other metals and bound gases. For some time, NASA has been studying the prospect of using these ores in some fashion, either to extract the oxygen and other elements or to use the material to produce building materials and fuels for the lunar base. There have even been some extremely imaginative suggestions as to how we would go about these operations, including launching the finished materials off the surface of the moon using an electromagnetically driven "mass driver" with an orbital "catching net" near our geosynchronous Space Station.

It is not difficult to imagine that the initial revisit could establish a small lunar staging operation, probably of no more than two or three persons with geoscience instruments who could conduct some preliminary mining experiments. Such a lunar base would be the first permanent human activity on another natural body in space, a landmark in human history, and could be the foundation for a much larger lunar scientific colony and mining operation.

While not a necessary part of a lunar transportation system, a manned geosynchronous orbit Space Station could be highly beneficial to a subsequent lunar program concerned with generating lunar material resources of value such as oxygen in gaseous and liquid form. Because of its high orbital energy, a geosynchronous facility would generally tend to become an important transportation node for missions to and from cis-lunar and heliocentric space. The availability of a nonterrestrially supplied resource such as liquid oxygen could substantially reduce its operational costs and increase its effectiveness.

In addition to geosynchronous orbit, a number of other peculiar orbits in cis-lunar space appear to hold promise.These include pseudo-geosynchronous orbits (for high-inclination coverage of earth), long lifetime orbits for waste storage, high sunlight orbits outside earth's shadow, and orbits passing through various portions of the plasma sphere.



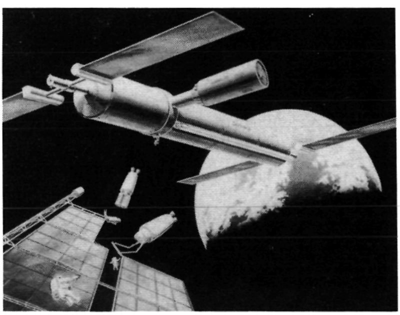
LUNAR SURFACE BASE

Another potential goal in the post-2000 era would be a manned Mars landing mission.

Mars offers the least severe environment of all the planets for man due to its atmosphere, its accessible surface, its possible availability of water, and its relatively moderate temperatures (−120 °C to +20 °C). It appears to be the most habitable of all planets other than the earth. Its resources include materials that could be adapted to support human life: air, food, fuels, fertilizers, and building materials. In addition, Mars could be an excellent gateway to the asteroid belt, facilitating the scientific exploration of asteroidal bodies by man in the next century and the eventual use of asteroidal resources such as water, oxygen, iron, nickel, and carbon.

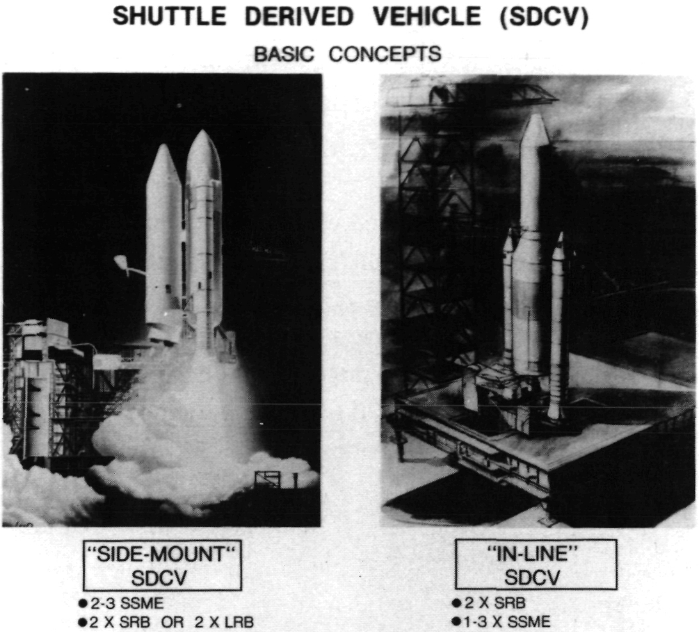
Even more important in its long-range benefits, with a mission as large and challenging as a manned Mars expedition, international participation on a large scale would be encouraged. Its scientific, technical, and sociological benefits, as well as its ultimate value, would undoubtedly be unprecedented in scope and magnitude.

A manned Mars landing scenario would use the Space Shuttle as well as *the Shuttle-derived launch vehicle envisioned for the year 2000 era,* to assemble an all-chemical multistage mission vehicle in earth orbit. Total mass in earth orbit of the expeditionary ship at departure would depend on the particular earth-Mars constellation chosen, that is, on the year of departure. For some of the options after year 2010, these mass requirements are on the order of only 3.2 million kg for a chemically propelled spacecraft delivering six crew members to Mars and landing three of



GEOSYNCHRONOUS ORBIT
SPACE STATION

MARS LANDING



SHUTTLE-DERIVED LAUNCH VEHICLE

them on the planet's surface. After a 60-day stopover, the entire crew would return to earth orbit for rendezvous with the Space Station. Total mission duration would be 600–700 days. Much like the first Apollo lunar landing, this scenario assumes a one-flight exploration mission, leaving no usable infrastructure in orbit around Mars or on the surface. It does not exclude, however, subsequent visits in the further course of time, with the eventual establishment of a seasonal base camp on Mars.

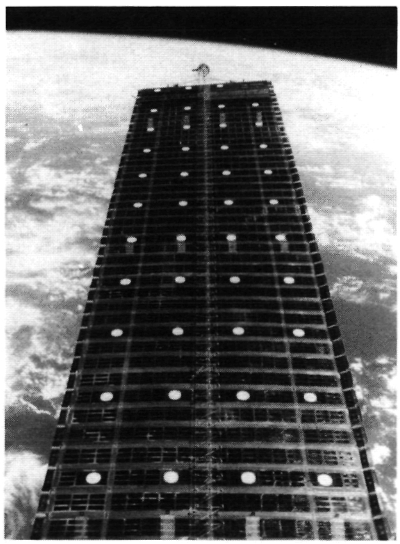
Other planetary and solar system exploration missions beyond the year

2000 we feel worth considering include:

- Multiple main asteroid belt rendezvous missions with sample return
- Mercury surface rover
- Venus balloons
- Unmanned Venus surface station
- Jupiter aircraft and atmosphere balloon
- Advanced orbiters, landers, and rovers on the moons of Jupiter and Saturn, especially nitrogen-rich Titan.

Some candidate future large space initiatives that have been studied include: satellite power systems for providing energy to space-based users and, perhaps, also to earth; nuclear waste disposal in space; large automated deep space/planetary missions such as an automated Titan

ASTEROID RETRIEVAL MISSION



SOLAR PANEL

Probe and an Interstellar Space Explorer; space settlement; asteroidal mining; and others.

"Human" industries in space (such as medical, clinical, and biogenetic research); space science and space-based educational centers; space hospitals and sanitariums; as well as activities in areas such as entertainment and the arts are all long-range possibilities that will eventually be brought within our grasp. Orbital vacation centers may also be somewhere in the future, adding a whole new dimension to space tourism. NASA's Space Flight Participant Program, announced by President Reagan in August, is really the beginning of the space tourism industry.

The opportunity for the growth of new worlds in space with all of the advantages that humans have gained from fresh starts appears to be among the most intriguing of all the potentials of space.

We are at the threshold of a new frontier. The space program has the potential of demonstrating that there are no tangible limits to humanity's future in the universe. Helping to demonstrate this apparently limitless potential could be our most important contribution to the future.

VOTE OF THANKS

BY PROF. IR. H. WITTENBERG,
PROFESSOR IN AEROSPACE ENGINEERING, VICE-DEAN OF THE DEPARTMENT OF AEROSPACE ENGINEERING OF DELFT UNIVERSITY OF TECHNOLOGY

Mr. Moore,
On behalf of all present here, and of those who will read the text of your lecture afterwards, I thank you very much for your interesting and challenging presentation.

As your lecture clearly shows, already today space activities of all kind are playing an important role, not only in the world of the scientists and the engineers, but even in everybody's life, as is well illustrated by communication services through satellites.
Compared with aviation, space flight is still in the years of its adolescence, but your lecture has indicated ways along which it will grow to become a mature part of the human society. Many applications of space science and technology will serve mankind's needs on Earth. But on longer terms, your outlook makes it clear that we can still compare our present space activities with Columbus' journey to discover a New World, which will lead to the exploration of our solar system and its resources. I do hope sincerely, that your lecture will inspire many of us in our own small country to participate in the great efforts to make use of all the possibilities which the era of space flight offers.

Until now, the Netherlands have taken an active part in space science and technology. Not only by participation in the international programs of the European Space Agency, ESA, but also by the development and operation of two scientific satellites you have referred to: the Astronomi-

cal Netherlands Satellite ANS and the Infra-Red Astronomical Satellite IRAS. I am pleased to recall here the fine cooperation of our scientific and technological community with NASA on these projects.
Your lecture challenges us to continue our efforts in space activities. Many of us here are convinced with you, Mr. Moore, that taking part in these activities is of the utmost importance for every country which scientific, economic and cultural health largely depends on its participation in advanced fields of science and technology.

The Delft University of Technology wishes to thank all guests, both from our country and from abroad, who have shown their interest this afternoon. May I especially mention in this respect the younger ones among us, on which the space activities in the Netherlands will depend in the years ahead.

In closing this Ninth Memorial Lecture I thank Mr. Moore again for sharing his views on the future of space flight with us and I wish him and the NASA organization great success in all space projects to come, culminating in the manned space station and its transport system in the nineties.
All those, who have known Dr. Albert Plesman personally, will be convinced that should he be alive today, he would have fostered a keen interest in all possibilities of space flight to the benefit of mankind. We are grateful that this Dr. Albert Plesman Lecture enables us to pay tribute to the memory of this great pioneer in Dutch civil aviation.

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THE FUTURE OF SPACE FLIGHT

BY JESSE W. MOORE

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PREVIOUS LECTURES

1955 J. D. Pearson
Managing Director, Aero Engine Division, Rolls Royce Limited
The development and future of turbine engines for civil aircraft

1957 Arthur E. Raymond
Vice-President Engineering, Douglas Aircraft Company
The oceans of the air

1959 Hall L. Hibbard
Senior Vice-President and Vice-President Engineering, Lockheed Aircraft Corporation
Supersonic flight

1961 Georges Héreil
Président du Sud Aviation – Président Fondateur de l'AICMA
La coopération européenne en matière de recherche, de développement et de production en aviation et en astronautique

1966 Edward C. Wells
Vice-President – Product Development – The Boeing Company
Some economic aspects of air transport design

1969 Frits Besançon
Deputy-President of KLM, Royal Dutch Airlines
Airline industry heading for 2000

1973 Emile van Lennep
Secretary General of the Organisation for Economic Co-operation and Development
Aviation needs and public concerns

1979 Knut Hagrup
Former President of Scandinavian Airlines System
The World Airline- and Aerospace Manufacturing-Industry