NASA SP-122

Summary Report on the NASA Western University Conference

JET PROPULSION LABORATORY

NOVEMBER 8-9, 1965

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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NASA Program for Cooperation with Western Universities

JET PROPULSION LABORATORY
NOVEMBER 8-9, 1965

by Donald E. Cunningham
Adelphi University

Scientific and Technical Information Division
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Washington, D.C.

PROGRAM

November 8

Conference Chairman: WILLIAM H. PICKERING, Director, Jet Propulsion Laboratory

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The NASA Advanced Research and Technology Program
ALFRED J. EGGERS, Deputy Associate Administrator for Advanced Research and Technology, NASA

The NASA Manned Flight Program
WILLIS B. FOSTER, Director, Manned Flight Experiments, Office of Space Science and Applications, NASA

JPL Flight Projects
JACK N. JAMES, Acting Assistant Laboratory Director for Lunar and Planetary Projects, Jet Propulsion Laboratory

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W. I. LINLOR, Chief, Electrodynamics Branch, Space Sciences Division, Ames Research Center, NASA
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JPL University Program
ROBERT V. BARTZ, Manager, University Office, Jet Propulsion Laboratory

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JOHN E. LEVEEN, Chief, Employee Development Branch, Ames Research Center, NASA

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ELLIOTT C. LEVINTHAL, Research Physicist, Department of Genetics, Stanford University
URNER LIDDEL, Assistant Director and Chief Scientist, Lunar and Planetary Programs, Office of Space Science and Applications, NASA
G. DALE SMITH, Manager, Experiments and Life Support Systems, Project Biosatellite, Ames Research Center, NASA
HERBERT G. TROSTLE, Manager, Space Instrument Section, Division of Space Sciences, Jet Propulsion Laboratory

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T. L. K. SMULL, Director, Office of Grants and Research Contracts, NASA

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FOREWORD

The NASA Western University Conference was held at the Jet Propulsion Laboratory, Pasadena, California on November 8 and 9, 1965. This conference was the first of a series of regional conferences that NASA is planning to hold to emphasize the work going on in the NASA Centers that is of potential interest to the colleges and universities in these regions.

The participants in this conference were drawn from the western colleges and universities. In addition to presenting a comprehensive picture of the NASA program and a description of the mechanisms through which faculty members can participate in these activities, particular attention was given to the activities of the NASA installations on the west coast—the Jet Propulsion Laboratory, the Ames Research Center, and the Flight Research Center.

Speakers from these three installations discussed the scientific research being undertaken and the means available for NASA university cooperation. The overall NASA organizational structure and the entire breadth of its university program were also discussed and explained.

This summary of the conference is an attempt to digest the proceedings and to present them in brief but usable form. It has the further purpose of making available to all colleges and universities the essence of the program originally directed toward the western universities in the expectation that there will be national as well as regional interest in developing increased NASA university relationships.

T. L. K. SMULL
Director, Office of Grants and Research Contracts, NASA

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INTRODUCTION

The first regional university conference of the National Aeronautics and Space Administration was held at the Jet Propulsion Laboratory, Pasadena, California, on November 8 and 9, 1965. The participants were drawn from universities of the Western states—Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Two nationwide NASA University Conferences had been held previously, the first in Chicago (November 1962) and the second in Kansas City (March 1965). The NASA Western University Conference resembled more the Chicago meeting than the Kansas City Conference in that NASA personnel presented discussions on what NASA has done, is doing, and is planning. In the Kansas City meeting, the colleges and universities described their participation in NASA programs.

There are always at least two levels on which a conference of this type takes place. The first level is that of organization—how the administrative structures of educational institutions and of NASA can effectively be brought together and used to attain a high degree of interaction. The second level is that of research substance—how an investigator knows what real science and engineering NASA is pursuing so that he may know whether his own research interests are in some way parallel or interrelated with those of NASA. Both levels are important. NASA university relations are especially important. The growth of NASA has been rapid and the problems of adequately performing the requirements of its mission have sometimes required internal organizational changes which in turn have affected the focus of interaction with both universities and individual researchers.

In this summary material drawn from the NASA Western University Conference is presented in a highly edited form—a compromise inherent in all attempts at summary. The first of the three parts outlines the general administrative structure of NASA with appropriate identification of each unit's basic program. In short, it is an organizational look at NASA. The second part is concerned with the face presented by NASA to the universities—a rather complicated face to be sure as it involves both organizational and research substance relationships. The third part is a presentation of research areas in which the western field centers of NASA—Ames Research Center (Moffett Field, Calif.), the Flight Research Center (Edwards Air Force Base, Calif.), and the Jet Propulsion Laboratory (Pasadena, Calif.) have deep commitments and responsibilities.

In what is necessarily a condensed version of the 2-day proceedings much pertinent information has been omitted. Many tables and figures containing valuable information do not appear. The only justification is that an attempt has been made to retain the essence of what was said, and if this attempt is successful, the information contained will be useful in identifying people and organizations through which NASA may be approached. The growth, development, and interaction of research people in NASA and in the universities will of necessity depend on the individual participant's understanding of NASA's mission, how it relates to the universities, and how, at a personal level, working relationships may best be developed. From the tone of the conference, it is apparent that NASA feels a need of deeper and more extensive university participation in meeting its goals and, therefore, accomplishing its mission. NASA and the universities share the belief that this cooperative involvement can be carried on with no deleterious effects on the integrity of either. And finally, NASA has, through its Office of Grants and Research Contracts, attempted to assure that relationships of mutual benefit will be encouraged and preserved.

It would be remiss in a summary not to mention the thoughts and feelings of many of the university people that have direct implications to meaningful university participation in the Space Program. These center around the traditional role of the graduate student in performing research. It is clear that at present if a student is to "fly" an experiment, there is a certain delay time. This delay time exists in any type of experiment, but in space experiments there also arises the necessity for developing the idea of the experiment, the need for engineering skill to make the experiment "flyable," and the vehicle availability to allow it to fly. The possibility of a launch accident also exists. According to present estimates, some 30 months elapse between idea and data retrieval, assuming no accidents. Considering that a student usually does not begin thesis work immediately upon entering graduate school, the minimum time period corresponds to the time required to achieve the Ph.D. degree. Failure of any part of the complicated research and development program along the way may introduce delay which in turn is reflected directly in the time to a degree. The time to a degree is of vital concern to the university, as it is to NASA. How best to match a program aimed at the exploration of space to the needs and abilities of the individual student continues to be puzzling and difficult. Many universities have succeeded in meeting the problem (ref. 1), but it is by no means easily solved.

Another important, if nonmeasurable, aspect of the conference was the opportunity presented for individual university faculty and NASA personnel to meet and exchange views. Some 158 faculty members from 51 institutions attended the sessions. Personal contacts brought about by the conference should help both NASA and university participants to understand each other's position, and thus be in a position to provide mutual help.

PART I
The Administrative Structure of NASA

PART I: THE ADMINISTRATIVE STRUCTURE OF NASA

In the first session of the conference, representatives of each of the three main Program Offices of NASA discussed the roles of their divisions. Figure 1 shows the Office of Space Science and Applications (OSSA), headed by Homer E. Newell, the Office of Advanced Research and Technology (OART), headed by Mac C. Adams, and the Office of Manned Space Flight (OMSF), headed by G. E. Mueller.

Dr. Newell discussed the work of the Office of Space Science and Applications; Alfred J. Eggers discussed the Office of Advanced Research and Technology; and Willis B. Foster discussed the Manned Flight Program.

OFFICE OF SPACE SCIENCE AND APPLICATIONS (OSSA)

The Office of Space Science and Applications, as Dr. Newell pointed out, has two basic objectives:

(1) The extension of human knowledge and understanding of the Earth and space.

(2) The application of space knowledge and technology to practical uses.

In meeting the first of these objectives, certain questions must be asked and answered about the solar system and the Earth itself.

(1) What are the origin, composition, and structure of the atmosphere?

(2) What are the nature and behavior of the ionosphere and the magnetosphere?

(3) What kinds of seismic and volcanic activity are present?

(4) What are the physical, chemical, and topographic characteristics?

(5) What are the subsurface characteristics?

(6) How has life originated and developed?

Meeting the second objective requires analysis of the answers obtained to the above questions and the determination of

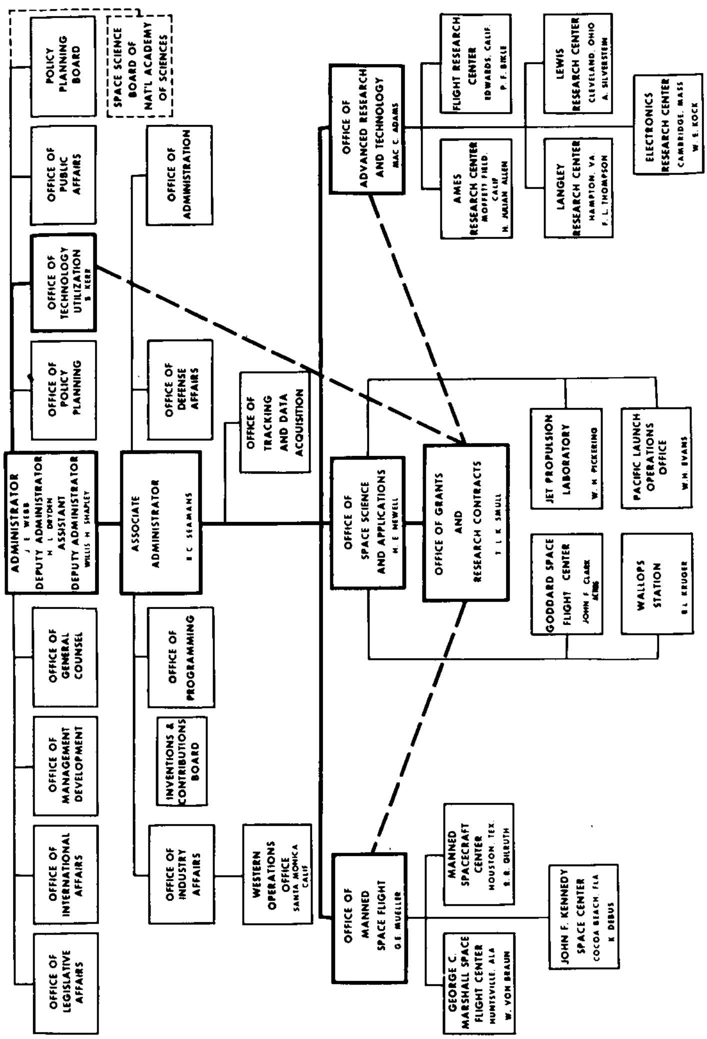

Figure 1.—University view of the National Aeronautics and Space Administration.

where and how the capabilities that have been developed can be translated into practical applications.

Some applications have already been made. In particular, meteorological satellites such as the Tiros series have provided global data-gathering ability and have greatly refined weather forecasting. Synchronous meteorological satellites as well as the development of experiments to provide vertical atmospheric structure data are being planned.

Communication satellites (Echo, Telstar, Relay, and Syncom) have performed their functions well. These systems, now operative, were only vague plans in 1958.

Typical of the results of the programs so far is the journey of Mariner IV to Mars and its observations of that planet. Dr. Newell described the mission as follows:

"The spacecraft and its experiments had to remain operative for two-thirds of a year while traveling from Earth to Mars. At the time of encounter, the spacecraft was at a straight-line distance from the Earth of 135 million miles. It took 12 minutes to send the actuating signal to the spacecraft and another 12 minutes to receive the response. In addition, the spacecraft continued to function after the planetary encounter and sent back pictures obtained during the flyby. It is now beyond earshot, so to speak, although signals are still being transmitted. In 1967 the spacecraft should again be close enough to be heard.

"The instruments aboard Mariner IV showed that the ionosphere on the afternoon side of the planet was at a height of about 125 kilometers and contained about 10^5 electrons per square centimeter. Such an ionosphere would permit radio signals at the frequencies used for spacecraft telemetry to be sent to Earth from the surface of Mars itself. The atmosphere was found to be very thin at the surface—less than one-thousandth that of the Earth; no radiation belt was detected.

"Most spectacular were the 22 photographs of the surface of Mars, of which 15 were useful. They covered about 1 percent of the Martian surface and included both light and dark areas, as well as regions where the so-called canals had been reported. The surface looks very much like that of the Moon, with both large and small craters. Now the question must be settled whether the surface being viewed is billions of years or only hundreds of millions of years old. On this rests the matter of whether great quantities of water may at one time have existed on the planet. All of this has a bearing on the design of equipment to investigate possible life on Mars."

It should be noted that even in its early stages the manned space program has yielded valuable scientific data. Results ranged from the effect of space flight on human blood cells to very excellent pictures of the faint zodiacal light thought to be caused by solar radiation reflected and scattered by material dispersed through interplanetary space. The Manned Space Flight Program promises to be more productive of results as its progress continues.

Dr. Newell described future programs as follows: "We have literally only begun and the future is full of promise. Radio-astronomy, atmospheric, and interplanetary Explorer satellites are being prepared for flights during the coming year. One of these will be put in orbit about the Moon to investigate the far reaches of cislunar space and particularly to investigate the tail of the Earth's magnetosphere. Rice University is preparing a 'University Explorer,' a radiation belt satellite called OWL, to be launched by a Scout rocket. Another Orbiting Geophysical Observatory has been prepared and will be ready for launching in the near future. After 5 years of exceedingly difficult development work, the first Orbiting Astronomical Observatory is ready for launch. This undertaking has severely pressed the current state-of-the-art in both spacecraft and instrumentation, and its completion marks a significant advance in both areas.

"The new series of Pioneers will explore the regions ahead of and behind the Earth, between the orbits of Venus and Mars. The first Lunar Orbiter is scheduled for flight in 1966. Its mission is to photograph more than 1 million times the surface area covered in the last Ranger photographs, and at nearly the same resolution. Selection of areas to be photographed will take into consideration the maximum support to be provided to Project Apollo, which will follow. The first Surveyor, by far the most difficult mission that has yet been undertaken in space science and applications, will attempt a soft landing on the Moon's surface. Farther in the future is Voyager, which it is hoped will explore Mars in 1971.

"The first Biosatellite flight is scheduled for 1966. More and better experiments will be performed by man in space. Scientific experiments for Earth and lunar orbiting missions are being defined in which, for example, remote sensing at visible, infrared, and radar wavelengths play an important role.

"The Tiros Operational Satellite (TOS), based on technology from the Tiros and Nimbus programs, will be launched soon. In one version, TOS will be capable of world photographic coverage through interrogation and readout at United States command and data acquisition stations. Another version will yield cloud photographs covering 1700-mile by 1700-mile areas surrounding local receivers, either in the United States or elsewhere.

"The particular value of TOS is in strengthening the 1-day weather forecasting capability. Farther in the future is the provision of basic data for the computation of long-range weather forecasts for 1 to 2 weeks in advance.

"During 1966, flight of the first Applications Technology Satellite is planned to further the advanced technology of gravity-gradient and spin stabilization techniques, antenna research, and the determination of environmental effects on components.

"Paralleling these scientific and technological enterprises is a continuing program to develop improved launch vehicles to make flights more effective and reliable. During 1966, the first operational Centaur will be ready for the first engineering test of Surveyor, and the development of the basic Centaur stage will be completed."

The essence of Dr. Newell's presentation is clear. With increasing weight and performance capability in space, more basic research on the characteristics of the space environment and more practical applications will be possible. Further university participation in space research and development is vital and necessary if full utilization of these advances is to be realized.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

The prime objective of NASA's Office of Advanced Research and Technology (OART), discussed by Dr. Eggers, is to provide the technical base for attractive future missions in the air and in space.

To illustrate these activities, Dr. Eggers chose two studies now being performed. The first, concerned with air missions, was the hypersonic transport. The second, a space mission, was a manned journey to Mars. The problems in each mission are formidable, and the need for experimental and theoretical work to make the missions possible is evident.

Concerning the hypersonic transport, Dr. Eggers pointed out that the X-15 research aircraft program has been producing valuable hypersonic-flight data for some years. The result of this and other information derived from Air Force and NASA programs indicates that hypersonic transports may some day be economically worthwhile. "Consequently, a significant part of our advanced research is focused on accumulating the data and know-how that will make design of a hypersonic transport possible. Present calculations indicate that hydrogen fuel can make a highly efficient hypersonic transport feasible."

For a detailed evaluation, various factors must be considered. Among these is flight efficiency. It would appear that hydrogen-fueled hypersonic transports may have very attractive cruise efficiencies. Currently, however, research is needed to establish a firm base from which to design such transports. According to Dr. Eggers, current NASA research is vitally concerned with developing a better understanding of the factors, including speed, that influence lift-drag ratio and engine performance in hypersonic flight. The fundamental nature of many of the problems is such that they should be of interest to university researchers. They are encouraged to participate in the solution of these problems.

Trajectory, too, must be taken into account. Not only rise time, climb rate, and initial acceleration must be considered, but also the problems of noise, sonic boom overpressure, maximum dynamic pressure, engine inlet pressure, and airframe surface temperature affect the final transport configuration and characteristics.

The skin friction at high speeds imposes conditions of temperature for which at present no suitable materials exist. Even at the lower end of the temperature ranges of interest, materials as strong as those currently being used in slower aircraft are not available. This means that a premium is to be gained by using more efficient structures, such as sandwiches and honeycombs. Additional development is required, however, to achieve structures with the required reliability from the best superalloys. Many of the best superalloys are currently available in only cast or forged forms.

At the higher temperatures, it is indicated that refractory metals or ceramics must be used. Both of these categories of materials are unfamiliar to most structural engineers and involve formidable problems. One of the most difficult is protecting the refractory metals from rapid and destructive oxidation. Over the past two decades, a vast amount of research has gone into the development of both oxidation resistant alloys and protective coatings. Yet, today, the best coatings are adequate only for short-flight, one-shot vehicles, not for long-time, multimission, high-reliability airplanes. Much work remains to be done in this area. NASA is, for example, working on an iridium coating which looks promising. The present technology of refractory metals compels designers to think in terms of refurbishing the highest temperature parts after each flight, or possibly just a few flights. It is necessary to advance the technology to eliminate this awkward and very costly procedure. Moreover, the promising possibilities of ceramics deserve the most careful continuing attention.

With regard to the propulsion system, more research is necessary. Initial calculations show that in hypersonic flight internal drag in engines becomes significant. For example, an engine capable of providing 50 000 pounds of internal thrust would have internal drag of 40 000 pounds, leaving a net thrust of only 10 000 pounds.

Langley Research Center plans to study these problems using a small hypersonic ramjet engine carried on the X-15. While this research would provide some vital answers, extensive ground-based propulsion research will also be required. Consequently, Lewis Research Center has initiated studies to determine the facilities required for a ground-based research program and the characteristics of the "boilerplate" engines required. Such facilities are difficult to design and construct; there is an opportunity for new approaches. One such approach being studied is to make synthetic air by first bringing nitrogen to a very high temperature with a graphite pebble bed heater and then combining it with oxygen to obtain the proper proportions and final temperature.

Although the promises of hypersonic flight are great, so are the problems that must be overcome through research.

The type of research that must be carried out before advanced space missions can be realistically considered was illustrated by a description of a proposed manned mission to Mars. The particular case considered was an eight-man crew using a Mars orbital rendezvous technique similar to that to be used in the Apollo excursion module on the Moon. In the return to Earth, atmospheric braking is used, and, finally, a flyby of Venus on the journey is considered.

Once these boundary conditions are imposed, choice of appropriate propulsion techniques from Earth surface to orbit and subsequently to Mars and back must be made. Some of these considerations were described.

"Large launch vehicles promise a substantial reduction in the high cost of delivering payloads to orbit. Their use could also substantially reduce the complexity of manned planetary space missions. Consequently, various candidate post-Saturn launch vehicles have been studied by NASA. One concept is an adaptation of the 'single stage to orbit' launch vehicle with solid propellant assist units. The basic liquid-oxygen—liquid-hydrogen "core" stage with two to eight solid assist motors can deliver between 1.2 and 2.8 million pounds of payload to orbit. One or perhaps two of these should be sufficient for lofting all the payload required for a manned mission to Mars. Solid motor strap-on units appear attractive for use with large post-Saturn launch vehicles since they provide an easily achieved growth potential for the basic core vehicle.

"The Mars spacecraft departing Earth orbit may very well be propelled by solid core nuclear rockets. In present concepts a cluster of four modular nuclear rockets would be used. Three of these modules would be discarded after propelling the spacecraft to above escape velocity for its trip to Mars. The remaining module(s) would be used to decelerate the spacecraft to Mars and place it in a suitable Mars orbit. Later, after the exploration party has returned to the orbiting spacecraft, the third stage nuclear rocket propulsion module would provide the escape propulsion from Mars, accelerating the return portion of the spacecraft into its path back to Earth. In these studies, each of these engines can be the same size, and a single engine (and perhaps a single propulsion module system) may be a suitable building block to satisfy all the requirements of the mission."

The present nuclear rocket program is aimed at achieving these objectives, and significant progress has been made. Alternately, electric propulsion might be used from Earth orbit to

Mars. Meanwhile, progress has been made on the feasibility of the electric thrustor itself. Last year a flight experiment was conducted to resolve a basic uncertainty on the use of ion propulsion in space. The SERT I (Space Electric Rocket Test) flight launched from Wallops Station on July 20, 1964, was the first successful flight test of an ion engine.

During the SERT I flight an ion engine was operated with and without electrons injected into the exhaust stream to determine whether the electrical charge in the exhaust could be neutralized. This question could not be resolved by ground tests because of the unknown influence of the test chamber walls on the results. The flight conclusively demonstrated that neutralization can be achieved in space and further demonstrated that the performance of an electric engine in space can be closely correlated with the data obtained from ground tests.

Turning to the trajectory to be used in going to and from Mars, one recent advance is the discovery that the gravitational field of Venus can be used to reduce the need for propulsion for trips between Earth and Mars. This was recognized at least 50 years ago, but it was only last year that it was discovered that opportunities to do this kind of thing occur frequently enough to make them practically useful.

One important net effect of a Venus swingby is to make the approach velocity vector more nearly tangent to the orbit of Earth on return from Mars. This means that the velocity of the spacecraft as it nears Earth is not so much higher than the velocity of Earth. Accordingly, atmospheric entry velocities may be considerably reduced at Earth, thereby considerably reducing the heat shielding problems (or the retrorocket requirements). Similar benefits appear to derive from using the Venus swingby mode on the outgoing leg to Mars, and all aspects of this interplanetary flight mode are now under careful study.

NASA is actively engaged in both theoretical and experimental study of the problems of heating in reentry. Communication capability, too, is under investigation. These studies have led to the conclusion that optical communication systems may be required for real-time television transmission from Mars.

One step in the study of optical communication techniques is the use of lasers between ground and spacecraft. During 1965, Goddard Space Flight Center conducted the first flight experiments aimed at the use of laser technology for tracking. The

Explorer XXII satellite is equipped with an array of small corner reflectors designed to reflect a laser beam transmitted from the ground. Explorer XXII was launched October 10, 1964, by a Scout booster from the Western Test Range. The laser transmitter and receiver were located at the Goddard Space Flight Center in Greenbelt, Maryland. Tracking was accomplished through a computer which alined the laser beam with the predicted satellite position. The laser pulse started a counter that was stopped when the reflected pulse was received.

Explorer XXII has provided an opportunity for other experimenters in laser tracking. The Air Force Avionics Laboratory, General Electric Company, Bell Telephone Laboratories, and Air Force Cambridge Research Laboratories, as well as France and Great Britain, have all directed laser beams at Explorer XXII.

Although much remains to be done, it is believed that laser tracking and communication offer promise for the future. Calculations indicate that better than a tenfold improvement in tracking accuracy is possible over the best techniques in use today. This possibility, together with the promise of improved communications, particularly over very long distances, has prompted increased efforts in laser technology; and, again, this is an area where university research would be particularly helpful.

The large distances involved in planetary exploration also result in very long trip times, and, in turn, these long trip times introduce major problems in the area of life support for manned missions. It appears that for long duration missions some form of regenerative life support system will be required. The development of such a system will involve a major research and technology effort.

Finally, adequate electrical power must be provided. Planetary missions will involve a number of different component vehicles or modules. These may well include mission modules, planetary excursion modules, unmanned probes and landers, and Earth-atmosphere-entry modules. Among these modules there are requirements for widely varying power levels because of the different uses and operational life times. For the mission module, the power supply will be operated during the entire trip and the electrical power levels required appear to be in the range of 6 to 12 kilowatts continuous, and up to 25 kilowatts peak. The excursion vehicle operates for perhaps a month with power levels of some 2 to 4 kilowatts continuous, and 5 to 7 kilowatts peak. The unmanned landing probes may operate for any period from about 1 month to 1 year with power levels of about 50 watts continuous and perhaps 200 watts peak. The Earth-entry vehicle is used for the order of 1 day, and its load is about 1/2 kilowatt continuous, and 2 to 4 kilowatts peak. From these few requirements alone, the need for power systems clearly is widely varied. Any application of electric thrustors for primary propulsion involves much greater power levels—into the megawatt class—than those just cited. Planetary missions may thus impose requirements for research and development in power systems at nearly all levels.

Work is being done on a number of space power systems such as photovoltaics, advanced batteries, fuel cells, thermionic systems using solar and nuclear energy, and dynamic systems using solar and nuclear energy. In the last category is the Snap-8 project, a 35-kilowatt electric power system using the Rankine thermodynamic cycle with mercury as the working fluid. A 10 000-hour life is aimed for, and during the last year significant progress was made in endurance testing of components.

In the large variety of energy conversion processes, there are many challenging research problems of possible interest to universities. For example, more knowledge is needed about the radiation and temperature degradation of photovoltaics, and about methods of increasing the efficiency of photovoltaics, particularly thin-film cells. In addition more knowledge is required of: electrochemical processes in fuel cells and batteries to increase their power capabilities and to extend life and reliability; the operation of thermionic converters at very high temperatures in nuclear reactors; plasma physics as related to energy conversion processes; and materials and their behavior in high temperatures and in corrosive environments. These are but a sampling of the great challenges that exist in the energy conversion field.

OFFICE OF MANNED SPACE FLIGHT

Following a brief review of the progress of NASA's Manned Flight Program to date, Willis B. Foster focused his discussion on the Apollo program, in which the first manned flight of the system in Earth orbit is scheduled for 1967. This flight will use a Saturn IB rocket as launch vehicle. The first unmanned flight of the Apollo-Saturn V space vehicle, which will later be used for lunar flights, is planned for the same year.

The first object of the Apollo mission is the landing of astronauts on the Moon. In the summer of 1965, a group of 100 specialists in six scientific disciplines recommended a 10-year program of lunar exploration following the initial Apollo landings. They also suggested that the highest scientific priority be assigned at first to the return of lunar samples to Earth for analysis. Other important recommended scientific objectives of early Apollo flights are the emplacement of an instrument package to transmit data to Earth following the astronauts' departure and the conduct of geological traverses in the area surrounding the point of landing. The report of this group is given in reference 2.

The Apollo Applications Program (AAP) will be the next stage of the manned exploration of space. The program has four major objectives. Mr. Foster described these and a typical lunar mission.

"The first group, space technology and operations, is fundamental to the others. Capability must be developed for extravehicular activity, assembly of large structures, emplacement and adjustment of instruments, and, eventually, maintenance, repair, space rescue and ground landing.

"In the second group, a significant and complex package of experiments is planned in astronomy. The program also includes experiments in several other disciplines. Two areas in the second group—atmospheric science and technology and communications and navigation/traffic control—might well be combined with the first in the third group—Earth sciences and resources. In each of these we are talking about potential benefits to man on Earth.

"Finally, the Lunar Orbiter survey, using the same remote sensing instruments with which we survey the Earth, and lunar exploration enable us to fulfill the recommendations of the summer conference to begin a comprehensive program of lunar exploration."

An extended Apollo lunar surface mission, as presently conceived, consists of a lunar flight to deliver an unmanned Lunar Excursion Module (LEM)-shelter to the lunar surface, in conjunction with another flight with a LEM-taxi to execute a manned lunar landing and subsequent surface operations. Such a mission would permit the astronauts to work on the Moon for about 2 weeks as compared with approximately 1 day for Apollo. Their work could also become more efficient through the inclusion in the payload of a mobility aid such as a small roving vehicle or a rocket-powered flying vehicle.

During the lunar stay, the crew would be able to conduct geological and geophysical experiments, survey nearby areas, sample the lunar material with a core drill, and set up an unmanned emplaced scientific station which will remain to operate for long periods of time.

The LEM-shelter serves both as living quarters for the crew and as a laboratory for preliminary sample analyses, preparation, and packing. Several hours a day could be spent monitoring data gathered by the emplaced scientific station. This station would require 1 or 2 days to set up and would then operate unattended for perhaps a year. Examples of possible instruments for the emplaced scientific station are:

Gravimeters	Radiation detectors
Seismometers	Solid particle detectors
Mass spectrometer	Television
Magnetometer	Borehole probes

The roving vehicle envisaged for the extended lunar mission should be able to carry an astronaut in his space suit and also some scientific equipment through an immediate area of approximately 6 miles in radius.

A great deal of time can be spent by astronauts in carrying out extensive geological and geophysical surveys over relatively small areas. The information can then be extrapolated to larger areas through the use of orbital observations.

In addition to lunar missions, of which the above is typical, other scientific missions not strictly of a lunar character are planned. Mr. Foster discussed one of these, a hypothetical but reasonable astronomy mission.

"Such an astronomy mission might have as its goal the performance of both radio and optical astronomical observations at orbital altitudes above the impeding layers in the Earth's atmosphere and ionosphere. The orbital vantage point would allow optical astronomy free of atmospheric distortion. It would also allow radio wavelength observations to be extended below 1 centimeter, where atmospheric absorption due to oxygen and water vapor begins, and above about 30 meters, where reflection of longer waves in the ionosphere takes place.

"The payload for the astronomy mission might contain an optical telescope with suitable filters, cameras, and related equipment to operate in both an imaging and spectrophotometric mode; a radio telescope to measure radio-wave flux and spectral properties at wavelengths of 1 centimeter or less; a low frequency antenna for measurements at wavelengths of 30 meters or greater; and a space radiation telescope to measure cosmic and gamma ray flux and energy spectra. A typical astronomy mission would be in an Earth-synchronous orbit of altitude 19 350 nautical miles and inclination 0°. The duration is 45 days with a crew of three."

This mission has been planned primarily for astronomical experiments which will obtain spectral and photometric data in the X-ray, visual, and infrared portions of the spectrum from various points of interest throughout the celestial sphere. These points consist of either discrete stellar sources or diffuse patterns of interstellar media, plus a group of Earth-oriented experiments for conjugate aurora observations.

There has also been included a secondary array of experiments consisting of observations of living organisms exposed to the space environment, a deployable maneuverable satellite and extendable antenna rod for radio-astronomy measurements, and a deployable communications satellite (passive) in the form of a solar sail. The selection of the secondary experiments was based on their lack of definite pointing requirements. Hence, any conflict with the pointing requirements of the primary astronomical experiments will be minimized.

In order to achieve the most advantageous viewing conditions throughout the 45-day mission for the primary astronomical experiments, the spacecraft is injected into a synchronous orbit (19 350 n. mi. altitude) and positioned over ground facilities compatible with the requirements of the mission. One day is given to set up various experiments. Extra Vehicular Activity is necessary for retrieval of the micro-organism specimens and "redocking" of the small maneuverable satellite.

"The space vehicle consists of a Saturn V launch vehicle, an extended Command Service Module (CSM), and a LEM-laboratory with ascent and descent stages. Nominal spacecraft attitude is inertially oriented. Attitude is held within a deadband of $\pm 0.5^{\circ}$, except during experiment periods having specific pointing and stability requirements. Experiment pointing and stability requirements exceeding CSM capability are accommodated by installing the experiment telescopes on gimbaled mounts and providing fine guidance and control systems within the telescope.

"The astronomy experiments are all alined parallel to the longitudinal axis of the spacecraft and are controlled from an astronomer's console on the right side of the LEM forward cabin. Access to the telescope and coronagraph is provided from inside the LEM for readily changing cameras, magazines, and spectrographs. A common television viewfinder and two boresight star trackers provide inputs for orientation and control. Spacecraft pointing accuracy for these experiments is $\pm 0.5^{\circ}$. The telescopes, coronagraph, and conjugate aurora experiments are gimbaled, and incorporate fine-error sensors to meet individual requirements.

"Supporting electronics and spares for experiments are carried in the aft equipment bay of the Ascent Stage. Structural modifications to the LEM Ascent Stage are limited to the incorporation of an airlock below the floor panel in the forward cabin to accommodate the coronagraph. The telescope airlock is designed to mount in the existing ascent engine hatch. The Descent Stage structure must be reworked to accommodate the coronagraph."

While this summary could not include all the projected and possible missions, it is hoped that the two above are representative. What is clear is that we are entering a period where there will be the ability to do large amounts of research and applications work and, thus, a major opportunity for university participation.

PART II
NASA University Relations

PART II: NASA UNIVERSITY RELATIONS

The broad general objectives and interests of NASA described in part I would be impossible to reach without a plan for enlisting the assistance of colleges and universities, their faculties and staffs, and their general intellectual resources. In particular, the responsibility for the development of effective working arrangements has been delegated to the Office of Grants and Research Contracts (OGRC). T. L. K. Smull, director, described the general activities of this office. It should be noted that although central responsibility for university relationships lies in the Office of Grants and Research Contracts, NASA field organizations deal with universities and colleges on a daily basis. Robert Bartz, Manager of the University Office of the Jet Propulsion Laboratory, discussed JPL's activities in this area, and Ray Sutton and John Leveen commented on the activities of the Ames Research Center (ARC). Again, this summary will present a broad general description of the content of these discussions. More detailed information may be obtained from reference 3.

NASA UNIVERSITY PROGRAM

The Office of Grants and Research Contracts is organizationally located in the Office of Space Science and Applications (as shown in fig. 1). Its responsibilities, however, are agency-wide, and it also serves the Office of Advanced Research and Technology and the Office of Manned Space Flight.

Dr. Smull emphasized that the basic principle underlying all NASA policy regarding relationships with universities is that "NASA wishes to work within the structure of the university in a manner that will strengthen the university and will at the same time make it possible for NASA to accomplish its mission. While NASA is anxious to reap the benefits to be gained by developing the research potential in the universities, NASA wants to support research in the traditional atmosphere of instruction and learning from research that results from keeping the research activities surrounded by students. NASA is keenly aware of the need for an ever increasingly supply of highly trained personnel if NASA and, in fact, the Nation as a whole, is to carry out its goals successfully and reap the maximum benefits from the Nation's space program. NASA is not interested in the creation of institutes that tend to draw university faculty away from the educational aspects of their research. The university is the only segment of the team undertaking the space program that produces manpower rather than consumes it, as do the other two partners in this enterprise—industry and Government. It is for this reason that NASA hopes to conduct its joint activities in a manner that will preserve and strengthen the university's educational role. This basic theme is interwoven in the policies and procedures of NASA's support of training, research, and research facilities."

One other fundamental policy of considerable significance in NASA's university activity is the effort to assure wherever possible the long-term, reasonably stable funding so essential to the successful conduct of research. NASA has pioneered the use of a funding mechanism known either as "step funding" or "forward funding" to provide the stability most desirable to those university programs known to be of several years' duration. Under this arrangement funds in the amount of 100 percent of the agreed level of effort are made available during the first year. Funds in the amount of two-thirds of the agreed level of effort are programed for the second year, and one-third of the agreed level of effort would be paid during the third year. When the initial grant is made, these funds are set aside by NASA and are paid to the university, on demand from the university, on a quarterly basis. During the course of the investigation, and based on its continual review, NASA will supplement the grant annually with a grant of funds in the amount of the agreed-upon level of effort. These supplements are scheduled to be paid in accordance with the university's demand. Thus, the university always has funds for an additional 2 years at a reduced rate should NASA decide to withdraw its support, or should Congress fail to appropriate funds for this purpose. This permits the university to fulfill any obligations which it may have incurred over a 2-year period. Although this type of funding is not appropriate for all research, it is desirable for the greater part of the research activities that NASA supports, because it creates stability and thereby increases research productivity. Every effort is made, when appropriate, to use this funding technique.

While NASA engages in many different types of activities with universities, the largest single activity is the support of project-type research. This research is that which is either an integral part of or in direct support of rather specific requirements of on-going NASA programs. As a mission-oriented agency, the NASA organization has been arranged in such a manner as to support most effectively the conduct of its mission, and "mission oriented" does not imply that NASA's mission is limited to putting a man on the Moon. In fact, the first objective of NASA, as stated in its enabling legislation, the National Aeronautics and Space Act of 1958, is "The expansion of human knowledge of phenomena in the atmosphere and space...." This certainly covers a broad spectrum of activity from research of a very basic nature to the most sophisticated applied research and development.

Project-type research covers a wide variety of activity from purely theoretical studies through conventional laboratory-based experimental studies to the very complex project research associated with the NASA space flight program. Experiments conducted in space require the application of very sophisticated technology, and also involve a long lead time which makes it extremely difficult to integrate them into a university's normal academic program. Although extremely difficult in execution, these experiments represent our attack on the most fundamental and important problems confronting our understanding of the basic nature of space.

Participation of universities is essential if we are to reap the greatest gains possible in this program. Many university scientists have had experiments flown on the various tools employed for space research—airplanes, balloons, sounding rockets, satellites, and deep space probes. There are extensive opportunities for this type of participation. Information regarding opportunities to participate in the space flight program may be found in reference 4 which is issued semiannually.

In 1961 NASA's university relationships were confined almost exclusively to project-type research. In that year, however, a change in approach resulted in the establishment of the Sustaining University Program. Its main goals are:

(1) An increase in the production rate of highly trained people

(2) More adequate laboratory facilities in which to conduct research in support of NASA's mission

(3) Removal of interdisciplinary barriers in research and fostering of genuine cooperation between workers in collateral fields

(4) An increased awareness by universities of their national responsibilities in the attainment of national goals

(5) Application by universities of their unique and extensive talents to an understanding of the interrelationship of space research and technology, academic processes, industry, commerce, and society in general.

To accomplish the first objective NASA set up a number of predoctoral traineeships. "It is NASA's belief that by making funds available that permit a student to pursue his graduate studies on a full-time basis, the time required to achieve the Ph.D. degree will be shortened and the number of Ph.D.'s produced annually will increase. Although these graduate fellowships may be held by a student for 3 years if his progress is satisfactory, there is no preconceived notion that the doctoral degree can, or necessarily should, be attained in a 3-year period, but rather that it is appropriate for NASA to support a student for that period of his graduate studies. NASA's goal is to aid in the production of 1000 Ph.D.'s annually, a goal which the program, now in its fourth year, shows promise of meeting."

In addition to the Predoctoral Traineeship Program, NASA also conducts a Summer Faculty Fellowship Program. The program began in the summer of 1964 at three locations and in 1965 was conducted at seven locations (fig. 2). The Summer Faculty Fellowships are, in essence, a group of institutes sponsored jointly by NASA and the university in the immediate vicinity of seven of the NASA Centers. They offer the opportunity for faculty members to acquire first-hand research experience with the pressing problems of space science and technology by spending some time actually engaged in research at one of the Centers and concurrently participating in seminar activity conducted by the university on some space-related topic. Fifteen new Fellows are selected annually to participate in the program at each of the Centers. Provision is made, and it is encouraged, for each Fellow to return for a second summer. This program has been

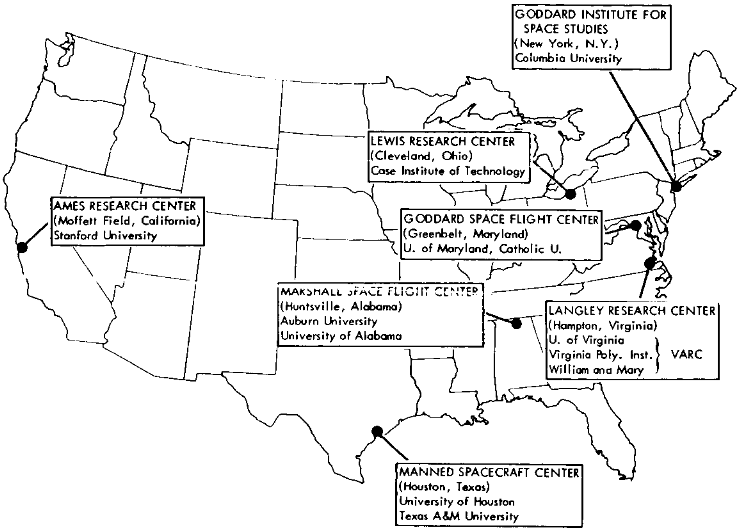

Figure 2.–NASA Summer Faculty Fellowship Programs.

developed and carried out largely with the cooperation of the American Society of Engineering Education. For this reason, the majority of the participants have been principally, but not exclusively, engineering faculty members. The programs are 10 weeks long. The participants receive stipends geared, in general, to faculty salaries, as well as modest relocation costs. The programs shown in figure 2 are to be repeated in 1966. Information may be obtained from the Centers or the American Society for Engineering Education.

The complete NASA training program includes:

(1) Predoctoral Training—3132 three-year trainees at 142 universities

(2) Summer Faculty Fellowships—12 universities cooperating with 7 NASA Centers in 10-week programs in science and engineering for 150 young faculty participants

(3) Summer institutes in Space Science and Technology—6-week sessions at 3 universities for 150 gifted undergraduates

(4) Training in Aerospace Medicine and Environmental Health—specialized postmedical training in Aeromedicine for 6

people at 2 institutions; Sterilization and contamination training for 4 people at 1 school

(5) Resident Research Associateships—75 postdoctoral associates at 6 NASA Centers

(6) International Fellowships—50 foreign nationals, sponsored by home countries, doing graduate and postdoctoral work at 20 United States institutions

(7) Miscellaneous—symposia, seminars, and conferences related to NASA's mission.

The training activities are supplemented by broader than project-type research support. "Three types of approaches have been employed in the past. The first supports broad multidisciplinary research investigations in the space-related sciences. The second supports research or technology of a generally coherent type in order to establish new research groups in these areas. Evidence of latent competence and desire to work with NASA are necessary ingredients in these grants. Third, grants are used to facilitate and coordinate research projects in related scientific areas. This type of grant is useful where adequate support for a single project is not possible, but where by tying several projects together as, for example, in the use of a particular specialized instrument, the group of projects can be pursued more effectively. Thirty-one universities now are involved in this type of program."

Finally, the overall NASA University Program is concerned with supplying research facilities to those universities deeply engaged in the space program. These facilities are a necessary ingredient to the successful performance of this specialized research. Making available these important facilities is felt to be a NASA responsibility.

An important consideration in making a research facilities grant is an agreement which culminates in the signing of a Memorandum of Understanding between NASA and the institution by the Administrator of NASA and the principal executive officer of the institution, which states in part:

> *It is the policy of the National Aeronautics and Space Administration to support research in space-related science and technology at nonprofit scientific and educational institutions. Where additional research facilities are urgently needed to conduct such research in support of the national space effort, and the institution involved has demonstrated its intent to seek ways in*

which the benefits of this research can also be applied to the social, business, and economic structure of the United States, NASA may supplement research support with funds necessary for the construction of such facilities. The National Aeronautics and Space Administration is particularly desirous that the environment in which space research is conducted and its full benefits realized will be characterized by a multidisciplinary effort which draws upon creative minds from various branches of the sciences, technology, commerce, and the arts. The desires of the university are in conformity with this policy, and the institution tends to foster and conduct research in all areas of space-related sciences, bring to bear on this research the efforts characteristic of a major university, and seek ways in which both the direct and indirect benefits of such research can contribute to the economic, social, and general well-being of the nation.

Of special significance is a portion of the last sentence which states that the university will "...seek ways in which both the direct and indirect benefits of such research can contribute to the economic, social, and general well-being of the nation." Implicit in this statement is NASA's expectation that the university will go beyond the more conventional role of teaching, seeking new knowledge, and serving as custodian of knowledge by seeking new ways to accelerate the flow of this knowledge to, and its potential uses by, the community.

"Discussion of this portion of the Memorandum of Understanding touches on merely one aspect of the whole subject of technology utilization. In such a large scientific and technological endeavor as the space program, NASA would be delinquent in its responsibilities if it did not make a concerted effort to see that the knowledge brought about by this program serves not only the interests of the program itself, but is usefully applied in improving national welfare. To this end, NASA, several years ago, established its Office of Technology Utilization. The program of this office involves NASA, the universities, industry, and the community. There is a very important role for the universities, and they are playing an ever-increasing part in seeking ways to speed the flux of recently acquired scientific and technological information into our civilian economy."

JET PROPULSION LABORATORY UNIVERSITY PROGRAM

Robert Bartz pointed out that the Jet Propulsion Laboratory, in common with other major NASA-supported facilities, places high value upon its relationships with the university community. These relationships make not only very direct contributions to the Laboratory and to the NASA program as a whole, but reciprocally contribute to the health of education, especially engineering education, and therefore to the Nation. Large research and development establishments must lean heavily upon the universities for staffing needs, for the pursuit of the most basic knowledge, and for assistance with the continuing professional development of staff at all levels. Looking at these university relationships from the standpoint of the engineering educator, it is to be hoped that the professional environment afforded by several of the major national laboratories would be conducive to professional growth at any stage of a faculty member's career.

A University Office has been established at JPL to stimulate and, where necessary, coordinate every appropriate means of implementing these ideas. JPL enjoys such a diversity of university relationships that it would be unwise to attempt to centralize the control of this area, and such is not the intent of the Office. Nevertheless, the Office is ready to guide faculty members with respect to any opportunity or problem for which they would like aid from the Laboratory.

Some of the cooperative possibilities were described by Mr. Bartz. Residencies at JPL by faculty members and students can often match well the professional needs and the other circumstances of the individual and the program requirements of the Laboratory. A new Resident Research Associates Program for JPL, financially supported by NASA, has been established under the aegis of the National Academy of Sciences and the new National Academy of Engineering. It is intended normally for residencies of up to 1 year. Applications for the program should be submitted to the National Academy of Sciences, although informal contact beforehand with the Laboratory is not inappropriate. The program is designed primarily for university faculty, especially engineering faculty.

Other arrangements, for faculty or students, are possible for short-term residencies at JPL, particularly including summer employment; the University Office is prepared to receive initial inquiries in this regard.

JPL has many contractual ties with universities through its Office for Research and Advanced Development for specific research assignments. The relevant technical interests of this kind are generally covered in references 5 and 6.

Significant opportunities exist for academic institutions to sponsor special institutes on the space program for faculty and students (drawn from other universities). These are exemplified by the Space Technology Summer Institute of the California Institute of Technology (1964), the University of California at Los Angeles (1965), and the University of Southern California (planned for 1966), and by the 1965 Summer Institute in Space Biology at UCLA. For each of the institutes named, the Laboratory provides substantial planning and instructional assistance.

Technical conferences for university faculty are regarded as an especially effective means of interchange on subjects of increasing scientific or engineering importance, as might be illustrated by the topic of electrical properties of high polymers. University faculty are encouraged to propose such meetings for which JPL would be the logical host.

The Laboratory is able to maintain a certain level of seminar participation by its staff on campuses throughout the western region of the country and, under appropriate circumstances, to finance such activity. Participation of this kind enables faculty and students to come abreast of objectives and current developments in the space program, and often directly influences the educational program or the research-interest orientation of faculty members. The Laboratory is happy to entertain requests for such university visits by its staff.

A wide variety of report material and other aids, such as films, covering the space program as a whole and the Laboratory program in particular, are available to interested university personnel. Distribution is generally without charge. A form available from the University Office indicates what is available and from what sources.

Mr. Bartz concluded by emphasizing that the mutual dependency of the university community and the Jet Propulsion Laboratory is fully recognized, and the extension of this involvement in better fulfillment of the many inherent opportunities is encouraged.

AMES UNIVERSITY PROGRAM

The relationships that have developed between colleges and universities and the Ames Research Center were discussed by

Ray Sutton and J. E. Leveen. Mr. Sutton's emphasis was on the research-oriented phase of the relationships and Mr. Leveen's on the academic phase.

Ames sponsored about $5.5 million of research during the past year. These funds were in support of approximately 125 projects at colleges and universities throughout the country. The largest supporter of research at Ames is the Life Sciences Directorate. Research has concentrated on several phases of human and animal experimentation, including the effects on man of varied atmospheres, acceleration, and radiation.

Mr. Sutton also described the four general areas in which research is supported. The first, aeronautics, includes studies of heat transfer characteristics in boundary layer flow associated with hypersonic flight, methods for analyzing high energy plasma flow, new ideas for filter theory for control system and analysis, and advanced theories of stabilization and control. In life sciences, of particular interest are cardiovascular stress responses and circulatory function, new concepts in bioinstrumentation leading to reliable and effective means for better assessment and quantitation of the physiological response of man and animals under stress conditions. Biological closed life support systems require much more attention and effort, as do advanced subsystems for life support, such as water electrolysis systems.

The third area, space sciences, includes investigations of the chemical composition and physical structure of solid matter in the solar system. Of principal interest are: (1) impact cratering and the effects of shock waves in rocks and minerals and (2) chemistry of extraterrestrial materials. The impact studies have particular significance on the interpretation and understanding of the lunar surface. Research on meteorites and cosmic dust provides important clues to the origin of the planets and solar system.

In electrodynamics, Ames space science people are investigating particles and fields in space with particular emphasis on the interaction with earth's magnetosphere.

In astronautics, interest is directed toward the investigation and understanding of the flows in the shock layer of vehicles as they enter the atmosphere at high speeds, the understanding of the heat transfer problems on entry bodies, the behavior of materials in the space environment during atmosphere entry, and the identification and development of satisfactory materials for these hostile environments.

Mr. Leveen described the academic activities of Ames, including graduate study programs established in neighboring universities, fellowships and traineeships held by college and university staff and students, and teaching by Ames personnel at colleges and universities in the vicinity of the Center.

Of particular interest to western universities is the fellowship and traineeship activity. There are three general types available:

(1) Research Associates selected by the National Academy of Sciences. These positions are of 1-year's duration. Applicants submit their research proposals to the National Academy of Sciences, Washington, D.C. The proposals are then reviewed in terms of appropriateness to NASA's overall mission and, if accepted, result in a 1-year appointment.

(2) Summer Faculty Fellowships (which were described previously). In this program Stanford University and Ames combine in selecting young engineering and science faculty members to spend 10 weeks at Ames. The Fellow has the option of returning a second summer if he wishes. Application forms are sent to all college and university science and engineering departments.

(3) Traineeships. These traineeships are available during the summer to graduate and undergraduate science and engineering students. Students are exposed to space and aeronautical research as practiced at Ames. The program is open to students who have completed at least 3 years of college study.

PART III
Research Programs

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PART III: RESEARCH PROGRAMS

After a discussion of organization techniques and methods by which universities and NASA can develop mutually productive relationships, the subject of actual research programs underway was considered. It is very difficult to describe these projects adequately because of their diversity and the limited time investigators had to discuss their work. In a sense, this report is a summary of a summary, and hence resembles a listing more than a comprehensive treatment. This is perhaps not altogether a failing in that the development and matching of complementary research programs are more detailed and personal tasks than the understanding of broad institutional relationships. Such matching is more likely to stem from personal contacts than from published reports.

For this reason this section of the summary may be more brief than it deserves to be, but it will at the same time be sufficiently informative for those planning research in the general areas of interest to NASA.

Some of the research programs of the Ames Research Center, the Flight Research Center, and the Jet Propulsion Laboratory are described. The Ames report was presented by Manley Hood, J. Lloyd Jones, Jr., Victor Stevens, Norman Johnson, W. I. Linlor, and Harold P. Klein. De E. Beeler described the Flight Research Center technical programs. Jack N. James, Frank Goddard, and Eberhardt Rechtin spoke for JPL.

AMES RESEARCH CENTER

Mr. Hood began the session with a brief description of the Ames Research Center, an installation located 25 miles south of San Francisco. The total staff numbers over 2 000, of whom 800 are research professionals.

After this brief introduction, J. Lloyd Jones spoke on the general area of aeronautics. The work in aerodynamics conducted at Ames is concerned with three main areas of research:

theoretical and analytical studies; experimental research in wind tunnels; and flight and flight simulation activities. The principal subdivisions of research and development include fluid mechanics, lift and drag studies, stability and control, aerodynamic heating, and structural and dynamic aspects of propulsion system aerodynamics. The studies are carried out for subsonic, supersonic, hypersonic, and reentry velocities.

Victor Stevens discussed the problems of atmospheric entry by space vehicles. The basic problem is how a spacecraft may dissipate in a controlled and nondestructive manner the great amount of kinetic energy it possesses. One of the most straightforward means is using the atmosphere of a planet to brake the spacecraft. Although simple in concept, many different mechanisms of energy dissipation must be understood before the technique can be used successfully.

Prevention of undue heating and maintenance of stability and control during entry are difficult problems in analysis. So, too, is the development of ground-based experimental equipment to simulate in the laboratory what will happen in the upper atmosphere. Ames has been interested in this sort of problem for more than 15 years and continues its extensive work in theoretical and experimental analysis of entry problems and of the related problems of stability and control dynamics during entry.

Mr. Johnson described current programs in flight mechanics, navigation, guidance, control, and stabilization. These areas are being investigated as they relate to manned space vehicles, unmanned space vehicles, and aircraft. For manned vehicles, thought is being given to ways for allowing astronauts to navigate in a primary role or as backup to the control systems. Of particular interest to the Ames group is the application of modern control filtering theory to lunar and planetary midcourse navigation tasks.

As the space program has progressed, so has interest in piloted reentry guidance and control systems. Studies have been made to determine the effects on these systems of vehicle acceleration, heating, actual entry velocity, lift-to-drag ratio, and various control techniques.

In addition, research is conducted at Ames to determine the performance of various stabilizing systems, including those utilizing inertial methods and those using the gravity gradient approach.

An active and continuing program of nonspace aircraft guidance and control studies at Ames includes work on:

(1) Zero-zero landings
(2) Control concepts for V/STOL aircraft
(3) Study of inertial guidance for the SST
(4) Variable stability and control systems for research aircraft.

Turning to space sciences, W. I. Linlor described what is currently known about the composition of interplanetary space.

The Sun emits an essentially space-charge neutralized stream of ions and electrons. Numerically the ions are approximately 95 percent protons, 5 percent alpha particles, and a very small percentage of other nuclei. This flux, aptly called the "solar wind," has an ion velocity of 300 to 500 kilometers per second and a direction mostly within a few degrees of the radius vector. The intensity is of the order of 3×10^8 ions per square centimeter per second. The corresponding density is about 10 ions per cubic centimeter.

Accompanying the solar wind and permeating it is a magnetic field having an intensity of the order of 10^{-4} gauss—very weak compared with that of the Earth.

The interplanetary environment includes photons from the Sun and stars whose spectra range from infrared to high-energy gamma rays. The intensity at 1 astronomical unit is about 0.1 watt per square centimeter.

Also in the interplanetary environment are cosmic rays, whose numerical abundance is similar to that of the solar wind. The spectrum is energy-dependent. Particles with energies as high as 10^{19} electron-volts have been observed.

Another constituent of interest is interplanetary dust, consisting of solid particles with dimensions ranging from a few centimeters down to a few tenths of a micron. Each observational technique covers only a small portion of the size range, making intercomparison of results somewhat difficult. The flux intensity depends on mass. As an example, for a mass of 10^{-10} grams, a flux of one particle per square meter per second is observed. Roughly speaking, this means a density of one such particle per million cubic meters. The interaction of the solar wind with the terrestrial magnetic field is shown in figure 3.

The magnetic field lines in certain regions act as a magnetic bottle for charged particles. The well-known Van Allen

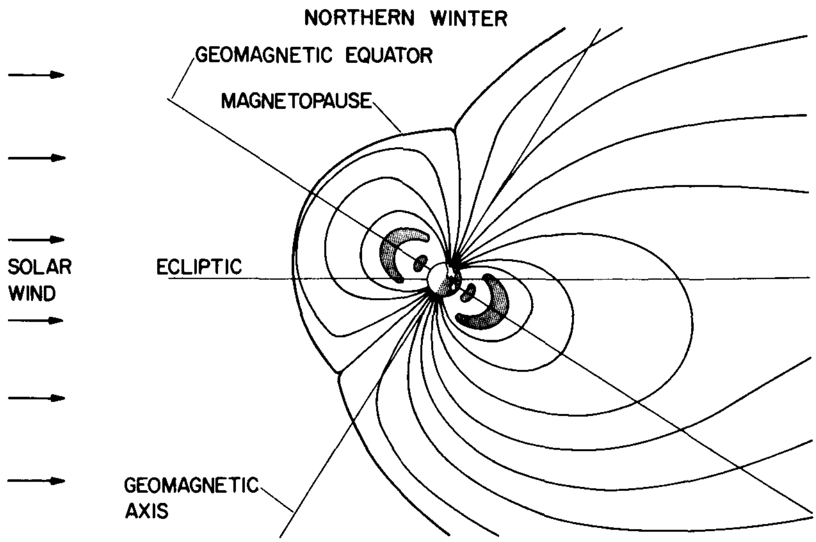

Figure 3.–Interaction of the solar wind and the Earth's magnetic field.

radiation belts are indicated, the characteristic distance being about 3000 kilometers. Closer to the Earth is the ionosphere, at a distance between about 200 to 1000 kilometers. This has a varying electron density whose peak value is about 10^6 electrons per cubic centimeter.

To achieve greater understanding of the space environment, Ames research programs are grouped into several sections:

- Theoretical studies of astrophysical plasmas and fields, planetary interiors, and planetary and stellar atmospheric physics
- Planetology
- Atmospheres and astrophysics
- Electrodynamics
- Space technology
- Experiments for spacecraft, including plasma probes for Pioneer A, B, C and D, the interplanetary monitoring platform (IMP), and the orbiting geophysical observatory (OGO), and magnetometers for Pioneer C and D and the anchored IMP.

The Life Science program was discussed by H. P. Klein. The Life Science group consists of the Exobiology Division, the Environmental Biology Division, and the Biotechnology Division.

Within these divisions are the various subgroups shown in figure 4. These divisions funded 188 research projects this year, 39 in the form of grants to universities.

In addition to the functional description presented, Dr. Klein also discussed certain experiments being performed at Ames. One of these involves laboratory simulation of a primitive planet used in studies on chemical evolution. Methane, ammonia, and water are subjected to various disturbances (electrical and heat) to determine what effects occur. In a second class of experiment, the effect of chronic and acute acceleration on animals is studied. The observations of these test animals include analyses of livers of the accelerated specimens and an extensive look at endocrine functions. Research on centrifuged human beings is also being carried on.

Thus, the work at Ames is broad and varied. Much is performed with university help, either at Ames or at the university. There appear to be areas where more collaboration and interaction are possible.

A summary of this type cannot be of great use except as an indicator of areas of interest. For more comprehensive information, the appropriate Center or Laboratory should be contacted.

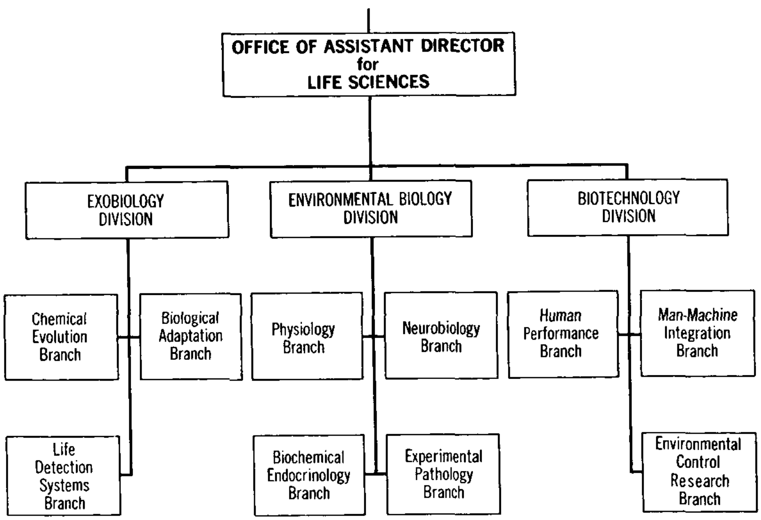

Figure 4.–Organization of Office of Life Sciences, NASA Ames Research Center.

FLIGHT RESEARCH CENTER

The activities of the Flight Research Center, Edwards Air Force Base, California, were described by De E. Beeler. This center has been active in the actual flying of research vehicles, including the X-15, and the testing of various types of experimental aircraft.

The organization of the Flight Research Center is shown in figure 5. Of interest are the areas of aerodynamics and propulsion in which programs range from studies of the noise caused by "sonic booms" to inquiry into the best shapes for reentry vehicles. The X-15 has proved to be of great value as a research vehicle. One example of its use is indicated in figure 6. Data based on theory and data derived from experiments on the X-15 are shown. The decrease in uncertainty is dramatic and is of vital use for experimenters and scientists in the design of flight vehicles.

JET PROPULSION LABORATORY

Jack N. James described the Jet Propulsion Laboratory's activities in the flight experiment area. His discussion included consideration of the Ranger, Mariner, Surveyor, and Voyager projects, all unmanned investigations of the Moon, the planets, and the interplanetary medium. A rather complete history in some cases and future plans in others are given in figure 7. The

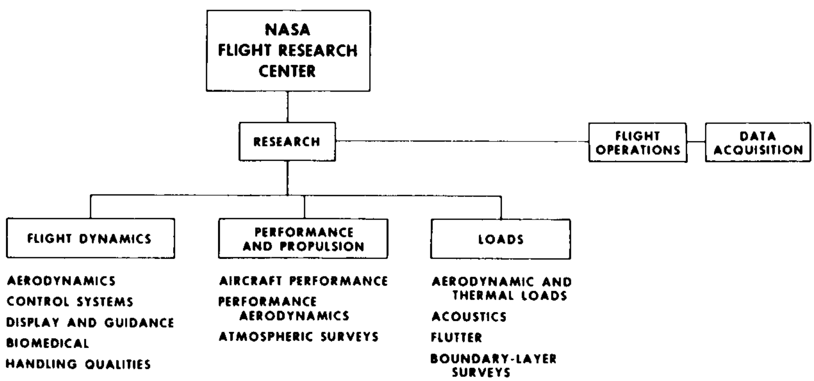

Figure 5.–Technical organization of Flight Research Center, Edwards AFB, Calif.

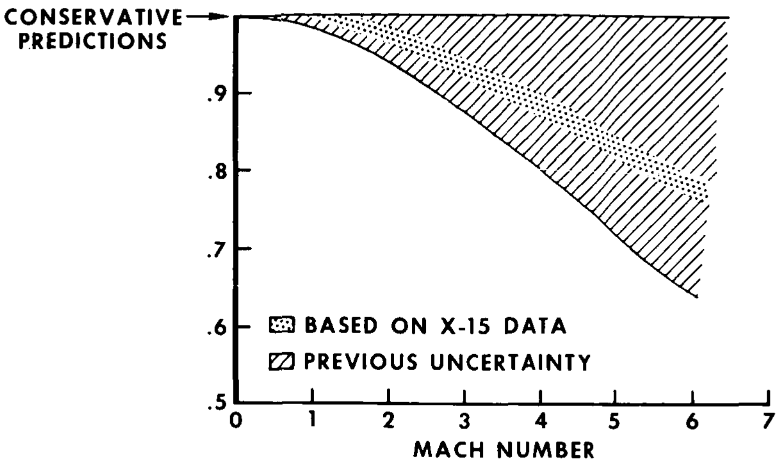

Figure 6.–Boundary-layer research: heat transfer, skin friction, and noise.

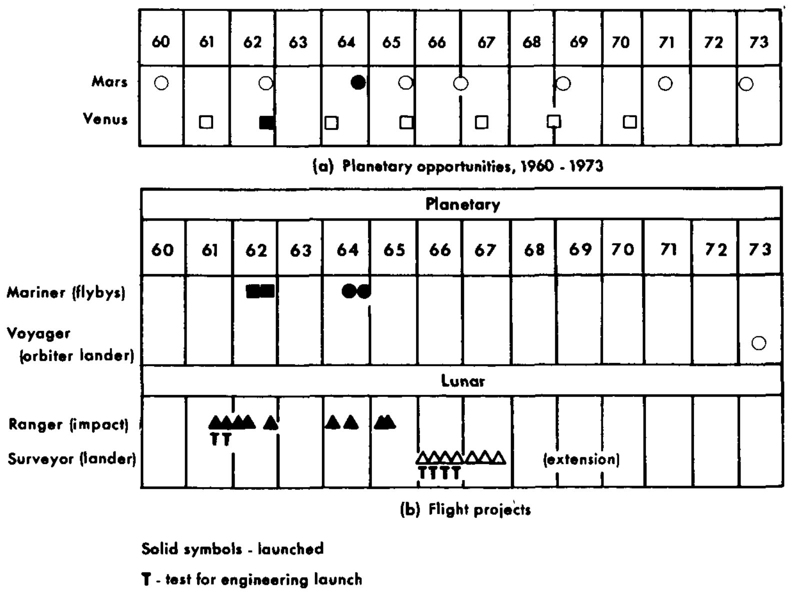

Figure 7.–Launch opportunities and JPL flight projects.

plans as presented are, of necessity, tentative and dependent upon the availability of funds and trained manpower, the rate of development of necessary components, and the capability of available launch vehicles to allow meaningful missions to be completed.

A description of each of the projects gives a good idea of areas of prime interest.

First, the Ranger project has obtained excellent photos of the Moon's surface. Among the observations made were: there are apparently no cracks or fissures on the Moon's surface and apparently no large rock masses and boulders are present. In addition, two distinct types of craters have been observed—those caused by high velocity impact and those caused by low velocity impact of lunar fragments. As a result of the Ranger successes, data have also been obtained on the slopes and surfaces of parts of the Moon—data which will be valuable in selecting sites for the Surveyor vehicle landing.

The Mariner II flight surveyed Venus and the Mariner IV surveyed Mars. A summary of the results of those two missions is given in table I.

The first Surveyor launch is planned for 1966. Included in the scientific packages to be soft-landed on the Moon's surface are television cameras for horizontal and downward observations of the Moon's surface character and texture; a seismometer; a micrometeorite data detector; a surface sampler using techniques involving the manipulation of the surface in the view of television cameras; an alpha particle backscattering experiment aimed at chemical analysis of the surface; and various engineering instrumentation used to analyze the dynamics of the vehicle during touchdown. This instrumentation is planned only on later Surveyor flights, the first four being engineering flights.

The Voyager mission, while still not precisely defined, will aim at orbiting and landing on the planets. The first target will be Mars in the 1970's. Plans call for using the Saturn V launch vehicle being developed for the Apollo missions as launch vehicle for the Voyager instrument package. Saturn V has the capability for sending 40 000 to 50 000 pounds to Mars. Soft landings are planned, although much further research and development work and data will be needed to determine how best to accomplish this goal.

Table I.—Mariner Results

	MARINER II	MARINER IV
Launched	August 27, 1962	November 28, 1964
Planetary encounter	December 14, 1962	July 14, 1965
Accomplishment	First successful Venus mission	First successful Mars mission
Days of flight data	129	307
Distance at closest approach	21 600 miles	6118 miles
Range at encounter	36 000 000 miles	135 000 000 miles
Planetary findings	Limb darkening High surface temperature, same on dark as on light side Clouds cold—no breaks Negligible magnetic field No radiation belt detected No dust belt detected Mass of Venus determined	Craters on Mars 5-10 millibar atmosphere No ionospheric communication problems in Mars atmosphere Negligible magnetic field No radiation belt detected No dust belt detected Mass of Mars determined
Interplanetary findings	Little dust. 2 hits Radiation ≈ 3 roentgens Character of solar plasma Character of magnetic fields	215 hits. Dust increased to 1.36 AU, then dropped off Radiation ≈ 30 roentgens Character of solar plasma Character of magnetic fields

JPL Research and Development Program

The JPL Research and Development Program was described by Frank Goddard. The responsibilities and program areas studied included topics ranging from spacecraft and capsule development to considerations of planetary quarantine—an area of considerable and deep interest. Basic research has been undertaken in those areas usually thought of as pure physics, chemistry, and mathematics as well as investigations of materials and their properties. JPL has available the specialized facilities (e.g., large vacuum chambers, wind tunnels, etc.) to undertake these studies. These specialized facilities are also made available to college and university investigators in cases where mutual interests exist.

In spacecraft and capsule development, facilities are available to simulate the space environment and near-Earth environment. The studies undertaken include such problems as environmental control and the structure and dynamics of the spacecraft itself.

Investigations are also underway to determine the applicability of chemical, thermionic, and photovoltaic techniques to space power. In electronics, projects are being carried on in the areas of guidance and control, communications, data handling instrumentation, and matching of components and techniques. A result of this particular program is the television transmitter and scanner used in photographing Mars. Chemical and electric propulsion techniques which allow greater flexibility and performance are also being studied in searches for new concepts and mission needs.

An active program in bioscience is also underway. Here, the subject areas under consideration include research in bioscience, development of appropriate instrumentation, and work on the Automated Biological Laboratory (ABL).

The mission studies being carried on by the JPL group concern possible missions to Mars, Jupiter, Venus, and Mercury with both orbiting and flyby vehicles. For the Mars study, thought is being devoted to landing and maneuvering on the surface.

The Deep Space Network Program

Eberhardt Rechtin concluded the Jet Propulsion Laboratory presentation with a description of the Deep Space Network program. He discussed the economics of antenna design—how much an antenna installation costs as the antenna size is increased from a 10-foot diameter to 1000-foot diameter. The results of these studies are shown in figure 8. On the basis of these

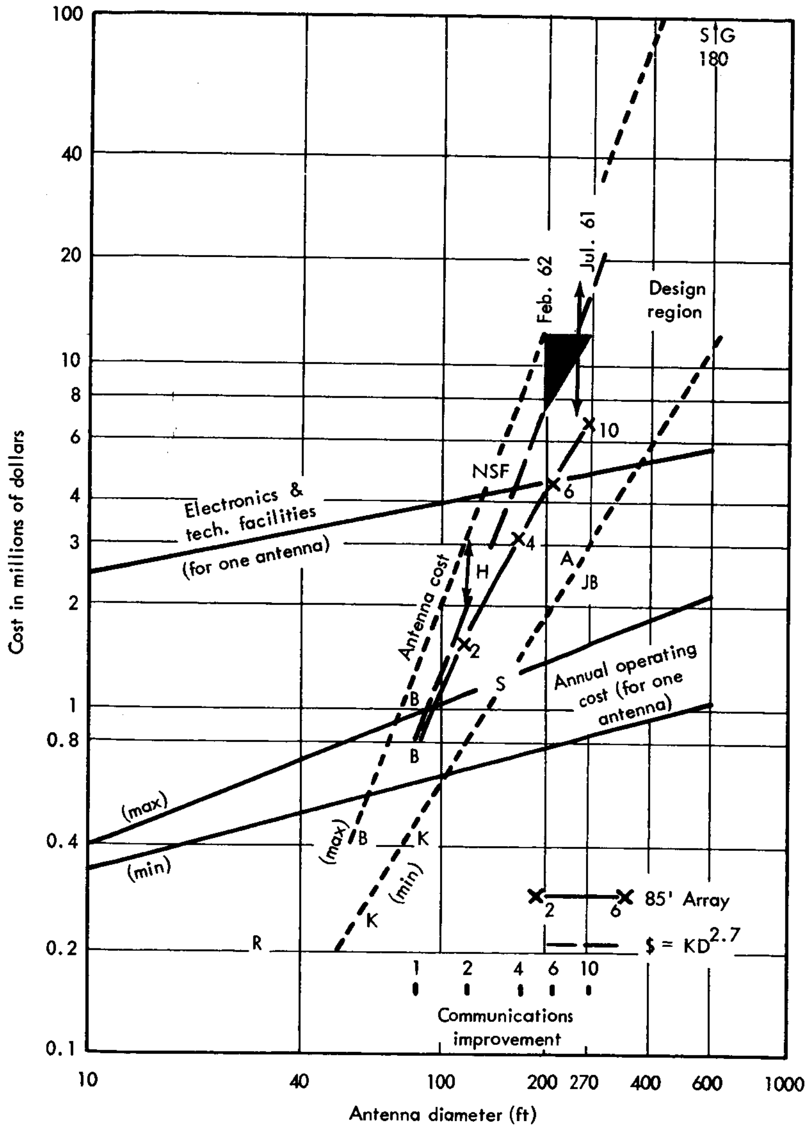

Figure 8.–Economics of antennas: 1962 JPL study.

considerations, JPL has now designed and built an essentially complete 210-foot-diameter antenna. The entire subject of possible tradeoffs in information passage with given power and range and given receiving capability have been examined.

JPL has been concerned with both the Ranger and the Mariner projects. Pictures of the surfaces of the Moon and of Mars are examples of what can be done with advanced communication systems in space. Less spectacular, perhaps, but also of great scientific interest are the measurements of temperature and magnetic fields obtained in the 1962 Mariner flight to the vicinity of Venus.

In addition to the Mariner and Ranger series, radar probes of Mars, Venus, and Mercury have been carried out with ground-based equipment. A typical result, the radar signal returned from Venus, is shown in figure 9. The narrow spread indicates that the planet's rate of rotation must be very slow.

This work has had great scientific return in the past and is continuing.

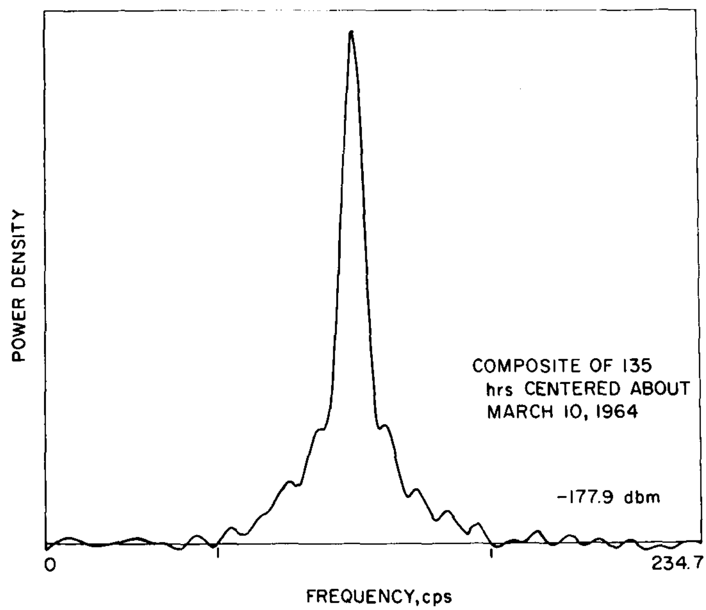

Figure 9.–Narrow spectral return from Venus; composite of 135 hours centered about March 10, 1964.

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6. Anon.: Supporting Research and Advanced Development. Vol. IV, Space Program Summary, Jet Propulsion Laboratory, California Institute of Technology.

APPENDIX
Organization Charts of the National Aeronautics and Space Administration

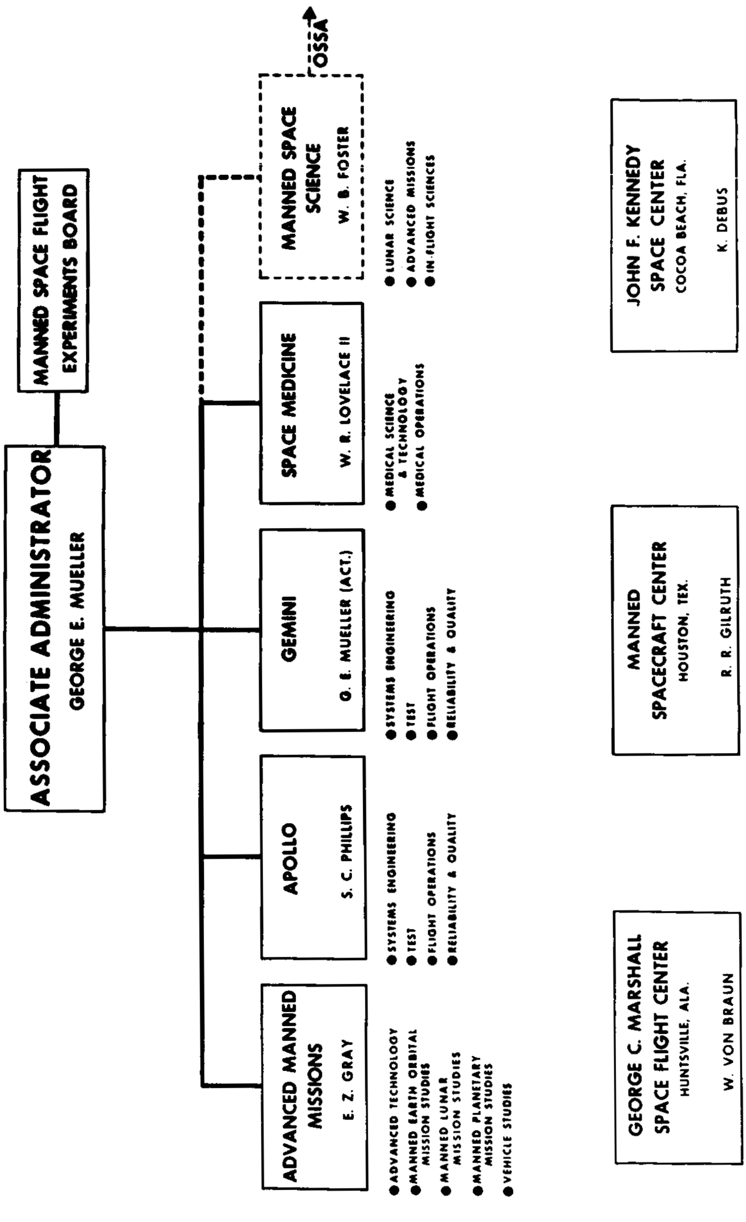

Figure A-1.—Partial organization of the Office of Manned Space Flight.

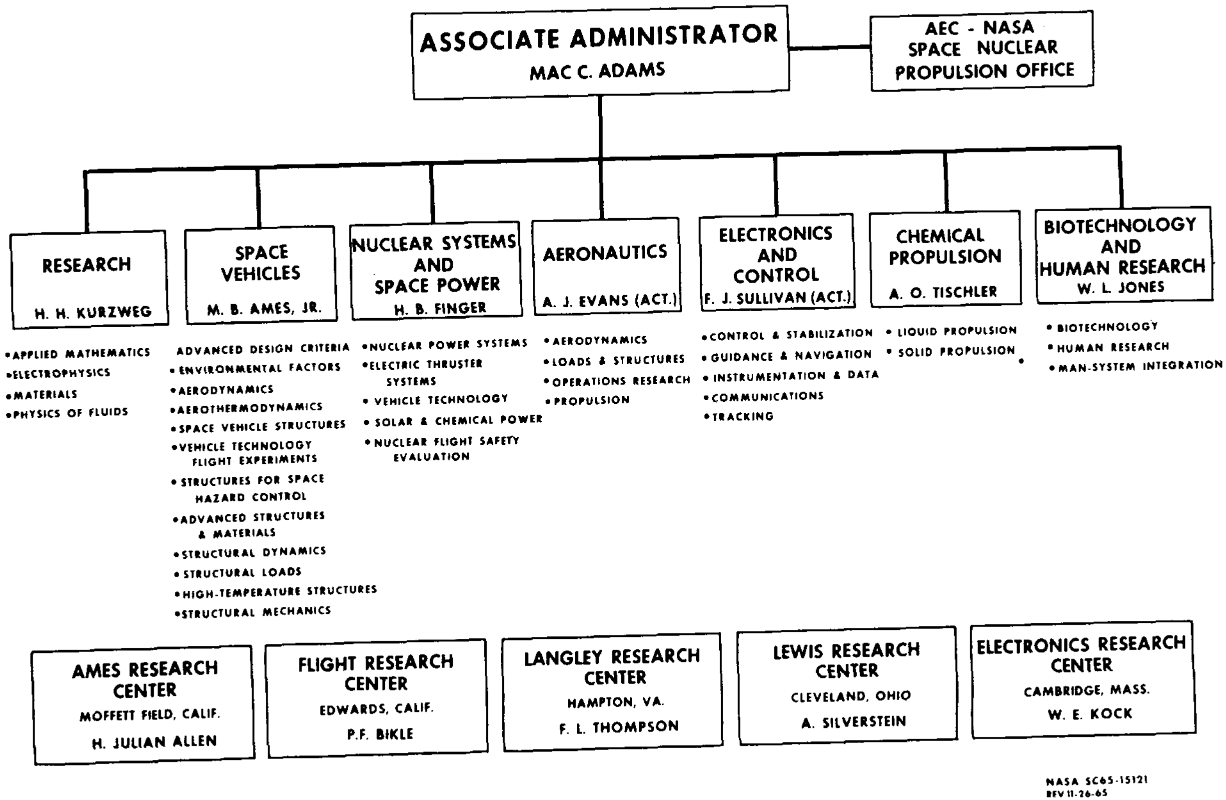

Figure A-2.—Partial organization of the Office of Advanced Research and Technology.

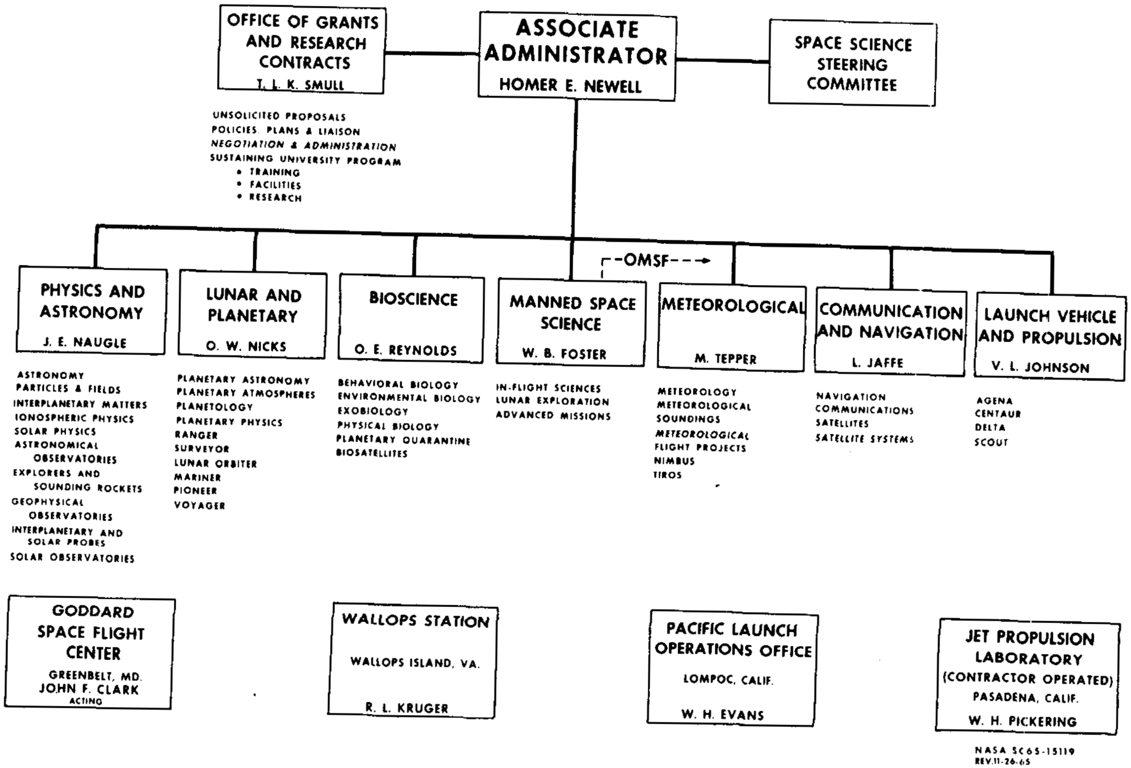

Figure A-3.—Partial organization of the Office of Space Science and Applications.

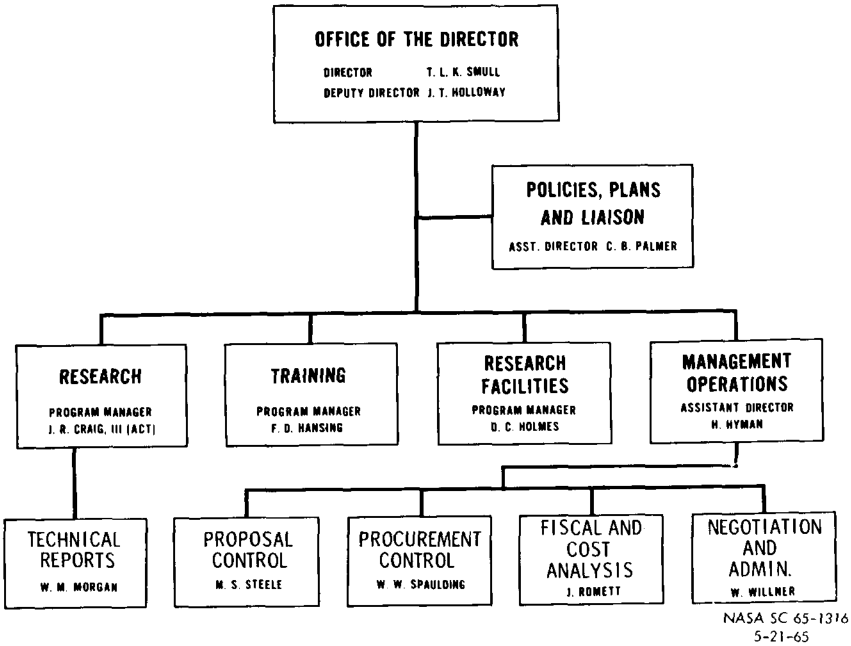

Figure A-4.–Organization of the Office of Grants and Research Contracts.

NASA-Langley, 1966

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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