NASA SP-81

Summary Report on the NASA University Program Review Conference

KANSAS CITY, MISSOURI
MARCH 1-3, 1965

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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by Donald J. Montgomery
Michigan State University

Scientific and Technical Information Division 1965
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C.

RROGRAM

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K. G. PICHA, Director, School of Mechanical Engineering, Georgia Institute of Technology

CHESTER N. WINTER, Planning Officer, University of Colorado

ANDRE G. BUCK, Chief, Research Facilities and Equipment Division, NASA Ames Research Center

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FOREWORD

The purpose of the NASA University Program Review Conference was to describe the nature of the Program, the manner in which it is being conducted, the results that it is producing, and the impact it may be having. The presentations, except for some expository papers by NASA officials, were made by members of the university and nonprofit community.

The present report is an attempt to reflect the burden of the Conference message as it has come to me, a university professor spending a year in making a study of NASA-University relations under a NASA contract with my institution. In preparing the report, my guiding principle has been to try to maximize its usefulness by making it accurate, brief, and prompt. These qualities are largely incompatible, and I am sure that the result of my search for an optimum compromise will please no one. Open editorializing is mainly confined to a brief section constituting my Evaluation of Program.

The complete transcript will shortly be available, to stand as the authoritative source for statements that anyone may wish to attribute to the speakers.

DONALD J. MONTGOMERY
Research Professor of Physics,
College of Natural Science; and
Professor of Engineering Research,
College of Engineering,
Michigan State University

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INTRODUCTION

The National Aeronautics and Space Administration, like other technical Governmental activities, takes from the universities and gives to the universities. It takes from them some of their output in training and some of their output in knowledge — most of this product being the return from earlier investment by other sectors of society, either public or private. NASA gives to the universities public funds in substantial amount and opportunities for scientific investigations considered visionary less than a decade ago. It brings to the academic world, moreover, a current of freshness and inspiration to be joined or resisted, according as the energies and the constraints of university faculties and administration allow.

Is NASA's consumption of the university product commensurate with its input to the universities? Arbitrary as any answer to such a question must be, decisions will be made and resources allocated on the basis of what Congress, the Administrator, and the universities think it is. One can rather easily find NASA numbers as to how much money goes where, and NSF numbers as to how many scientists and engineers do what. But it is much harder to say how efficaciously the expenditures have been made and how properly the responsibility for producing and utilizing trained manpower has been allocated. Yet we must do what we can to shrink the area of our ignorance on these matters.

One input into the information pool is the report of the universities themselves about the impact, or lack thereof, of NASA support. (The corollary and grave question about NASA nonsupport must be reserved to another occasion.) Not merely to provide a feedback to NASA, but also and perhaps more significantly to provide information to the university world, NASA — in the seventh year of its existence, and the fourth year of its Sustaining University Program — arranged a conference to review its program with the universities. Speakers were chosen with a view to describing representative activities over a spectrum of institutions. The audience consisted of about 500 university representatives, about 50 NASA employees, and perhaps 25 representatives of other Government agencies, foundations, and the technical press. The present summary report and a complete account of the proceedings are being made available to interested members of the professional communities.

NASA's university-oriented activities divide themselves into two classes that are most easily understood in terms of the motivation in the parts of NASA that control them. One part has the straightforward task of extracting from the universities such information and services as contribute directly to the accomplishment of some fairly specific and identifiable assignment in the space program. Clearly the offices charged with this task will strive to procure the information or service from whatever source they consider best, be it university, industrial, research-institute, or in-house at a NASA Center. Only indirectly, if at all, do there enter such issues as development of capabilities, equitability of geographic distribution, and so on. In dollar volume, roughly half of NASA funding to universities is in this category. The various program offices in the several divisions of NASA are charged with the responsibility for allocating this portion of NASA money. Although the return to the universities is great in this part of NASA's activity, one must always keep in mind that its primary purpose cannot be the welfare of the universities.

On the other hand, NASA's self-interest requires that it not impoverish the sources of an important part of its activity. To this end NASA has set up its Sustaining University Program. Here the principle is straightforward, though the application is complex and, in the eyes of some, even curious at times. The controlling ideas are that society in general and the universities in particular are unable or unwilling to divert their resources in an amount sufficient to the needs of the space effort; it is therefore the responsibility of NASA to supplement these resources by providing adequate space-oriented personnel, laboratories, and long-range studies. In dollar volume, roughly one-half of NASA funding to universities is in this class. The Office of Grants and Research Contracts has, among other activities, the responsibility for allocating these funds. A discussion of the nature and objectives of the NASA University Program by the director of the Office of Grants and Research Contracts is given in reference 1.

The structure of the conference is to be understood against the background just outlined. Much of the program-mission work is of quite general interest to the university community, but it is not characteristically different from the back-up basic-research effort of other Government activities, such as the Atomic Energy Commission or the Department of Defense. No special effort was made at the conference to describe this work, although some of it was mentioned in almost every paper in describing its interleaving with the Sustaining University Program activity; indeed, one paper in Session III was devoted completely to it. Two items in the program-mission work, however, are of unique interest, namely, the space flight experiments, and the schemes for transfer of technology from the space laboratories and shops to the rest of the scientific and technological community. Session IV was devoted to description of flight-experiment programs, with attention to program management as well as to scientific results. Session V described NASA's technology-utilization program, with emphasis on the university role. This program is much wider than university project-type research, and we are to some extent forcing it into the project-type mold.

The other four sessions were occupied mainly by the activities of the Sustaining University Program. This program has divided its activities into Training (development of personnel through education), Facilities (provision of laboratory space), and Research (development of knowledge of long-range significance, and development of space-related competence through research experience). The Training activity, of major importance in the Sustaining University Program budget, was described in Session I of the Conference. The Facilities activity, of lesser importance in the budget but of special interest to the university community, was described in Session VI. The Research activity of the Sustaining University Program formed the subject of most of Sessions II and III.

To familiarize the participants with NASA missions and methods, the three after-luncheon talks were delivered by representatives of the three main divisions of NASA: for the Office of Advanced Research and Technology, Associate Administrator Raymond L. Bisplinghoff; for the Office of Space Science and Applications, Associate Administrator Homer E. Newell; for the Office of Manned Space Flight, Samuel C. Phillips representing Associate Administrator George E. Mueller. To help put the NASA-university interaction into perspective on the national and international scale, Administrator James E. Webb introduced the Honorable Stuart Symington, Senior Senator from Missouri, and member of the Aeronautical and Space Sciences Committee, as the after-dinner speaker, on the second day of the conference. Senator Symington's topic was "The NASA University Program — A Two-Way Street." Digests of these talks are given as an appendix to the present report.

An added attraction was offered on the first evening of the conference: some motion pictures from Ranger VII, and the latest still pictures from Ranger VIII. This spectacular accomplishment of NASA's University contractors, particularly the Jet Propulsion Laboratory of California Institute of Technology, was presented and described by Professor Gerard Kuiper, Director of the Lunar and Planetary Laboratory at the University of Arizona.

TRAINING

NASA's predoctoral training program has become a significant source of support in the production of doctorates in engineering and in the physical and biological sciences. In the fall of 1965 over 3100 predoctoral trainees will be working towards their doctorates under this program, in 142 universities throughout the 50 states. The maximum number of traineeships awarded in 1 year to a single institution is 15, the minimum, 2; in 1965 the average number was 9. Each grant provides an allowance to the institution in addition to the stipend for the students. Since the traineeships are renewable for a period up to 3 years, as many as 45 trainees may be studying at a single institution. The average number is currently 22. The traineeships are granted to the institution, which by its own procedures selects students of demonstrated promise who wish to pursue studies in a space-related field in which the institution has a Ph.D. program. The institutional allowance is commonly used to defray cost of instruction and to strengthen the institution's program in the space-related sciences.

How does it work out? As judged by presentations and discussions at the Conference, very well indeed. The NASA traineeships are desired by students, in all likelihood because of the relatively generous stipends and the 3-year tenure, and because of prestige attendant upon the method of selection — the traineeships, in principle, go to the best students, regardless of the particular space-science discipline in which they happen to work. NASA trainees appear to be among the best graduate students, at both large and small institutions. The 3-year tenure presumably leads to rapid completion of the degree requirements, saving 6 months to a year (although such times are difficult to estimate meaningfully, since the better students tend to get the better fellowships, and presumably tend to finish early anyway).

The primary effect of the NASA training program is that it encourages students to plan for a career in science or engineering and permits them to enter and complete their graduate studies quickly. At the larger schools the NASA grants do not seem to be viewed a great deal differently from other student-support funds, though they are still much appreciated. At the smaller schools, particularly at those just beginning their science and engineering doctoral programs, the grants are especially esteemed for their effect in giving prestige to the institution, and in permitting the attraction and retention of students who might otherwise go to more fashionable or more affluent institutions. Moreover, in these emerging institutions the NASA trainee program permits a significantly faster growth of the graduate enrollment and thereby a quicker development of the university.

The secondary effect of the NASA predoctoral training program is that the utilization of the institutional allowance tends to encourage participation in the space effort. No pattern, however, seems to have evolved for use of these funds; almost always an important part goes for general instructional costs — but the rest may be prorated into departments, or allocated in block amounts to some of the departments having special needs, or spent towards new faculty positions or for common-use equipment.

Comment seems to be universally favorable, with the feeling that the training program is of vital importance in helping meet the increasing demands of both NASA and the rest of the Nation for scientific and technical personnel. For the older and larger institutions, the predoctoral training program seems primarily to play the role of an appreciated supplement to other funds. For the emerging institutions, the program appears to have both qualitative and quantitative effect in speeding their development.

Besides the predoctoral trainees, the NASA Training Program supports several institute activities. The summer undergraduate institutes are an experimental program concerned with some of the problems of undergraduate education as posed by new developments in space science and technology. A principal goal is to acquaint upper-division undergraduates with the substantive problems of space science and engineering. The techniques adopted by the different institutes (at Columbia University, California Institute of Technology, University of California at Los Angeles, University of Miami) represent a variety of approaches to the educational problems resulting from space developments. For example, planetary physics demands a high level of attainment in physics and mathematics, and imposes strains on institutions where the staff is not prepared in the appropriate subjects. As an illustration of one approach, at UCLA (under the direction of MacDonald) the first 5 weeks of a 10-week program was centered on lectures about four selected problems: determination of the gravitational field about a body by observations on a satellite moving around the body; escape of an atmosphere from a planet; lifetime of particles trapped by the Earth's magnetic field; origin of the solar wind. Two weeks was then spent at the California Institute of Technology to study observational methods of planetary and space physics, including inspection of radio and planetary telescopes, and laboratory work in constructing instrumentation for space vehicles. The final 3 weeks was spent in experimental research programs of the students' choice. The Columbia program (under the direction of Jastrow), the CalTech-JPL program (under the direction of Sechler), and the Miami program (under the direction of Singer) differ considerably from one another and from the UCLA program, as a consequence of the geographical location of supporting resources and the interests of the directors.

The students performed superbly. Most went on to graduate work in geophysics or astrophysics. Evidently the institutes have interested a number of the ablest undergraduates in the country in the problems of space physics. The program could probably be expanded fruitfully, since at present only very well <u>prepared</u> students, typically from the larger institutions, can be accepted; a large number of apparently equally <u>able</u> students, especially from the smaller colleges, have to be turned down because they lack sufficient background in mathematics or physics. As judged from the enthusiasm of the directors, the reactions of the students, and response of the Conference audience to Professor MacDonald's paper, this program is an exciting and interesting experiment, well worth extending.

Another flower in NASA's training basket is the ASEE-NASA Summer Faculty Institute program. Here the rationale is that the contribution of the university community to our national effort in space exploration depends strongly on the degree to which engineering and science professors keep up with the rapid developments in our NASA Centers. One avenue is to give interested faculty members an opportunity to become directly involved in the research in progress at the various NASA laboratories. The Space Engineering Committee of the American Society for Engineering

Education (ASEE) proposed a series of summer institutes to be directed jointly by one or more universities and a nearby NASA Center. These institutes provide opportunity for engineering and science educators to engage actively in research in a NASA laboratory for a summer and at the same time attend advanced university courses and seminars related to the research. The NASA centers select suitable research topics and suitable research advisers for each faculty participant; the codirecting universities organize and teach special courses and seminars. The participants, designated as Faculty Fellows, normally are young engineering or science teachers, with a minimum of 2 years' teaching experience at the college level, who are U.S. citizens, with a scholastic background equivalent to a Ph.D., and with some competence in research. Each Fellow's institution is supposed to furnish a statement setting forth the benefits to be realized by the institution as a result of the candidate's participation. The stipend is commensurate with the Fellow's academic salary. Travel allowances are granted.

The 1964 ASEE-NASA Institutes were the following: Case Institute of Technology with Lewis Research Center (Cleveland); University of Virginia, Virginia Polytechnic Institute, and College of William and Mary with Langley Research Center (Langley Field); Stanford University with Ames Research Center (Moffett Field). About 15 Fellows participated in each program. The research staff at each NASA center wholeheartedly endorsed the programs, and at their conclusion, the comments of the Faculty Fellows, the research supervisors, and the codirectors were uniformly enthusiastic.

Encouraged by the success of the first three summer institutes, NASA decided to expand the program to a total of six institutes by adding the following sets: University of Houston and Texas A & M with Manned Spacecraft Center (Houston); Auburn University and the University of Alabama with Marshall Space Flight Center (Huntsville); University of Maryland and Catholic University of America with Goddard Space Flight Center (Greenbelt). The three pilot institutes emphasized different scientific aspects of the aerospace effort; the new institutes offer in addition opportunities for various types of engineering and systems-analysis research. It is hoped that the faculty members will return to their universities with new ideas for future research and increased capacity to stimulate interest among their students in aeronautics and space exploration. Evidently most of the participants were able to be genuinely useful in the NASA laboratories, as judged by their research advisers' reactions, and in many cases by their demonstrated production.

RESEARCH: SUSTAINING UNIVERSITY PROGRAM

As contrasted with the motivation for funding of project-type research — namely, the intention to support directly and immediately the specific requirements of on-going NASA programs — the motivation for funding under the Sustaining University Program lies in support and development of competence and productivity in basic research of long-range significance. For the continued vigor of the space program, both kinds of funding are essential. The specific methods of implementing the long-range objectives offer a wide choice. SUP represents a novel scheme, tied together — sometimes a little forcedly — by the concept of multidisciplinary effort. On this basis some 30 universities throughout the country are currently recipients of SUP research grants. They have in common a multidisciplinarity of some kind or other, and a long-term security for their effort achieved through step-funding. Beyond these factors, there are as many kinds of activity under the grants as there are institutions receiving them. The results, nevertheless, turn out to have much in common.

The crucial advantage of the SUP research grant is that the allocation of funds is controlled locally in the university rather than remotely in the agency. Hence, speed and flexibility are attainable in carrying on the research. In particular, an unestablished investigator need demonstrate his abilities only to his colleagues, who know him directly, rather than to some remote panel members or Government officers, who know him either indirectly or not at all. And a senior investigator wishing to develop a new idea need expose himself only to his colleagues instead of to the world at large, and he need not have his enthusiasm fade while he waits 6 months to a year for a decision. In any case, if an idea started with SUP support develops well, it may engender direct support, and free the SUP money for another fledgling project.

The complete scope of NASA's SUP-type research cannot be learned from the Conference, but a representative fraction of it can. The patterns are too diverse to make classification very useful, and specific examples at different types of institutions may serve best to illustrate the way of working. Consider the SUP grant at a large land-grant privately-operated institution that is very active in the space program, the Massachusetts Institute of Technology. Here the SUP research grant supports many small projects in a sort of "seeding" program. About 40 individual tasks are under way, filling in the gaps between the larger research projects under program-office sponsorship. Work includes topics in astrophysics, exobiology, and social sciences. The larger research projects, perhaps six, are in communication sciences, solid-state energy conversion, physiobiology, space-navigation systems, and space physics. The SUP research activity benefits from the proximity of a laboratory for undertaking actual experiments in space, for example, preparation of an interplanetary plasma probe for Mariner and a gamma-ray telescope for an orbiting astronomical observatory (OAO). The detailed catalog of projects is impressively long. The characteristic contribution of SUP is the promptness with which it can initiate support, and its fill-in function between fields or segments of fields where support from conventional sources is not appropriate.

Another large activity, of quite different nature, is that of the Theoretical Chemistry Institute at the University of Wisconsin, a large land-grant state-supported institution. Here the SUP grant makes possible the stable existence of a sizable group of scientists studying quantum mechanics and statistical mechanics of molecules. Theoretical chemistry is a natural focal point for interdisciplinary research. In relating macroscopic properties of bulk matter to the microscopic properties of the individual molecules, the theoretical chemist serves as the middleman for the theoretical physicist in his dealings with the practical engineer and the applied scientist. Theoretical understanding of the individual molecules and their interactions is especially important when predictions have to be made about the unusual environments and the extreme conditions characteristic of space science. The current research — conducted by chemists, physicists, and computer scientists — is concerned with new approaches to solving the complex equations occurring in quantum chemistry and to analyzing nonequilibrium gaseous transport phenomena in statistical mechanics. The characteristic feature of SUP support here is its continuing character, which provides stability enough to attack the research barriers that require continued effort over a long period. The NASA grant, as managed at Wisconsin, helps break down the departmental barriers that tend to segregate scientists into narrow compartments. The existence of a sizable group permits broad training for students in the application of theoretical physics to practical chemical and physical problems; and it permits colleagues to get help from one another.

At the University of Maryland, another large land-grant state-supported institution, the unifying theme of the SUP-supported research activity is computing science. The Computer Science Center both uses modern high-speed digital computers to solve space-related problems over a broad spectrum of sciences and studies the computer-science aspects of the projects. Representative problems in the space sciences are concerned with molecular physics, plasma physics, radioastronomy, psychometric testing, and atmosphere models. Some of the computer-science aspects analyzed are computer-programing systems, numerical analysis, automatic image processing, mechanical languages, and information storage and retrieval. The success of the program demonstrates the value of bringing together computer scientists and research investigators in order to stimulate and broaden the work of both.

At the University of Denver, a medium-size private institution, the SUP research grant is used almost exclusively as seed money, primarily to support new investigators in amounts of several thousand dollars per project. The program is administered by a University-NASA Awards Committee consisting of three deans, three professors at large, and the director of the Denver Research Institute at UD. An application for support is reviewed by a three-man ad hoc committee of senior scientists and engineers, to whom the applicant must make a written and an oral presentation. The permanent committee makes final decision as to acceptance and level of funding. Representative subjects of investigations among the 19 supported so far are sound waves in plasmas, mechanical properties of plasmas, applied mathematics, quantum chemistry, high-velocity impact, solid-state physics, and geophysics. The great value of the grant is its stimulus to the professional development of junior faculty. Without such support available to them locally, their inability to get grants from distant agencies where their potentialities cannot be known would result in discouragement and eventual withdrawal from research. Ancillary values reside in the experience that applicants get in preparing and defending their research proposals, and in the fact that the reviewers, who are often in other departments or off-campus, develop interest in the investigator and his problem and frequently visit the laboratory with profitable interaction.

At Montana State College, a smaller land-grant state-supported institution, the SUP research grant has aided the institution to develop first-class main-stream physics in areas that support, and are supported by, other research programs on campus. The areas of activity are atomic and molecular physics, solid-state physics, and astrophysics. The use of NASA funds as seed money has established a viable graduate research program in physics. The College is developing other departments, notably electrical engineering, botany, bacteriology, and chemistry. The characteristic contribution here is the development of research competence and the strengthening of graduate programs.

At Texas A & M University, a medium-size land-grant state-supported institution, the SUP research grant is likewise used primarily as seed money, but in larger and fewer blocks than at most other institutions. Many of the projects undertaken have led to developments of actual or potential interest to NASA, in topics such as plasmas, solid state, polymer physics, cosmic rays, aerospace structures (in particular impact-attenuation devices, shell structures, aerospace materials), non-Newtonian fluid flow, radiation damage, and activation analysis.

At the University of California at Los Angeles, a large state-supported institution, SUP grants in training, facilities, and research are administered by a single body. UCLA believes that it can contribute best to the space effort by doing its main job, that is, educating. Thus, the NASA program must be an integral part of the graduate educational program. UCLA, which has the only fully developed tax-supported graduate school in Southern California, considers that it has a special responsibility to the space program, in view of its location in the area of greatest concentration of aerospace industry in the whole Nation. Graduate education in science and engineering depends strongly on the quality of the research; hence, the opportunities provided for research to a considerable degree determine the quality of graduate education. The university needs some sort of grant that provides flexibility in order to be able to take advantage promptly of the surprising new developments that occur in space-related research. With a flexible grant, a new faculty member, whether junior or senior, can be supported for the year or so that his first grant applications are being acted on, in effect having a year added onto his research life. Some 50 grants have been made as seed money in 3 main scientific and technological areas and in the field of business administration. A small expenditure of a different type goes to making arrangements for scientists to visit UCLA, for 1-day conferences or extended stays. The SUP multidisciplinary grants in no way replace project grants; in fact, only the project grants are large enough to allow the immediate missions to be carried through, and without them as a goal, there would be no point in having seed money. Some of the developments at UCLA are a magnetically shielded room for testing magnetometers, a high-energy plasma torch, a 24-inch telescope available to graduate students, crystal-growing apparatus, high-pressure apparatus, and much biological work.

At the University of Pennsylvania, a large private institution, the SUP research grant has made possible the creation of a small institute with well-defined objectives and methods of working — the Institute for Direct Energy Conversion. It sets an example for other institutions desiring to enter the space program, but for one reason or another on a scale lower than the Michigan-MIT-UCLA-Princeton one. The primary purpose of the Institute is to provide engineering graduate students with an opportunity to obtain a broad background in the area of direct energy conversion, with students performing their research in a common laboratory to stimulate their interest in other disciplines and to facilitate free communication, at the same time that they are meeting the requirements of their parent departments for the doctoral degree. A few postdoctoral research people facilitate continuity and help the students make the transition to experimental research. Senior staff members, obtained from the permanent faculty, develop and present a sequence of courses in the broad area of direct energy conversion. The range of topics needed — thermodynamics, solid-state physics, plasma physics, thermionics, magnetohydrodynamics, fluid dynamics, electrochemistry, physical chemistry — cannot be covered by ordinary course work in an acceptable length of time. Hence, the staff is forced to work together to compress all this knowledge into a coherent whole. Through NASA the support for this program was obtained. The Institute now has three major groups, one working in plasma engineering, one in electrochemical engineering, and one in materials science. By persistence and persuasion, the Institute has managed to get basic scientists to come to work on engineering problems.

The College of William and Mary, for over two centuries a private school and for half a century now a state-supported one, is a small institution that is evolving to a university. The SUP research grant here has gone in minor part to the biology department for a laboratory of population ecology, and in major part to the physics department to help obtain equipment for visible and infrared spectroscopy, for upper-atmosphere research, for plasma physics, and for high-energy physics. This last-named activity began as a consequence of the cooperation of the College of William and Mary, the University of Virginia, and Virginia Polytechnic Institute in forming the Virginia Associated Research Center to manage and operate the 600-MeV proton synchrocyclotron at the Space Radiation Effects Laboratory of the NASA Langley Research Center. A high-energy physics group has been set up, and for the first time in its history in any field the College has been authorized to grant the Ph.D. degree. Present research is concentrated in low-energy muon and pion physics, in particular the muon-capture interaction in some 50 elements. A substantial amount of instrumentation development is carried on simultaneously. The combination of the SUP research grant and the Langley accelerator has resulted in an increased rate of evolution of a traditional liberal arts college towards a modern university.

At Washington University, a medium-size private university with long-standing but not major involvement with the space program, the SUP research grant shows its greatest value in much the same way that it does at UCLA — that is, in providing speed in setting up new research or in changing the direction of old, in establishing a young researcher as a capable investigator, and in providing a facility or service that several related small projects cannot. The multidisciplinary grant has been limited to the physical sciences and engineering, because the health-related biological sciences are not suffering at the moment from a national shortage of project-type research funds. The decisions on specific allocations are made by scientist members of the administration who are not themselves competitors for the research funds that they are dispensing. With a policy of giving priority to establishing new faculty members in their research, and to shifting research directions in combination with criteria of relevance to space sciences, the decisions have been reasonably clear cut and relatively uncontested. Some topics are hot silicon radicals, paleomagnetism, X-ray fluorescent spectroscopy, cryogenic detectors, low-temperature ultrasonic detectors, noise reduction in lasers and masers, and impinging jets with large temperature gradients.

RESEARCH: PROJECT-TYPE

The complete scope of NASA's project-type research was not intended to be displayed at the Conference; but, even so, some idea of its extent may be inferred from the variety of topics mentioned in the individual papers describing the SUP activities.* Two sessions, namely, IV — Space Flight Experiments, and V — Technology Utilization, were

*Details of NASA's space-science program may be obtained by examining "A Review of Space Research," a publication which, though dated, remains valuable (ref. 2). This is the report of the Summer Study conducted under the auspices of the Space Science Board of the National Academy of Sciences at the State University of Iowa in 1962.

devoted completely to project-type research. Sessions II and III, Research, though emphasizing SUP activity, contained nevertheless many references to project-type research, and indeed one paper describing only project work.

This work, described by Professor Summerfield of Princeton University, exemplifies the breadth and depth of the aerospace activity at a single university, admittedly strongly participating but still of only medium size. The participation is in astrophysics and in aerospace propulsion. In astrophysics a broad program of astronomical observations is under way with telescopes placed above the Earth's atmosphere to get better photographic definition and to make measurements in spectral regions where the atmosphere is opaque. A 36-inch telescope is lifted to 80,000 feet by balloons — above atmospheric water vapor and atmospheric twinkle but not above atmospheric ozone. Hence observations may be extended to the infrared, but not to the ultraviolet. For this region, a satellite at say 500 miles altitude can be used. An orbiting astronomical observatory (OAO) carrying a payload selected by Princeton is being constructed under subcontract, with instrumentation and data-transmission system also being carried out under subcontract. Advance experience in above-atmosphere measurements is gained with Aerobee sounding rockets.

On the engineering side, Princeton has a diverse program of research and graduate education in the aerospace propulsion field. Investigations are undertaken with chemical rockets powered by solid propellants, liquid propellants, and combinations of liquid and solid propellants; and with nuclear rockets having solid, liquid, or gaseous cores. Problems are attacked also in the area of high-speed atmospheric propulsion systems, from turbojet to hypersonic ramjet; and in low-thrust electric-propulsion engines based on electrostatic-ion or electromagnetic-plasma acceleration systems.

Flight Experiments

Only torpor or indisposition can keep a scientist from catching the excitement of directly exploring the regions outside the thin shell of the Earth to which he and his instruments have been bound until today. The NASA space flight program is a research program in the basic environmental sciences, designed to explore regions hitherto inaccessible and environments hitherto unattainable. Its general objective is stated in the National Aeronautics and Space Act of 1958 as the expansion of human knowledge of phenomena in the atmosphere and space. The specific objectives come from the space scientists themselves. Every individual flight has its own particular scientific objectives that are the direct result of suggestions by members of the scientific community. (Ref. 3 provides an overview of the space-flight program and refs. 4 and 5 furnish additional details on certain aspects of the flight program.)

Selection of experiments for flight is made with the scientific advice of subcommittees reporting to the Space Science Steering Committee (SSSC), and with the engineering advice of the NASA center that manages the project. SSSC is composed of senior scientists and engineers within the Office of Space Science and Applications (OSSA) in NASA. The subcommittees are made up of scientists from universities, Government laboratories, and NASA Headquarters. A subcommittee covers each of the disciplines: astronomy, bioscience, ionospheres and radio physics, particles and fields, planetary atmospheres, and solar physics. Final decision is made by the Associate Administrator for OSSA, acting upon the advice of his staff through the subcommittees, the committee, and the program directors.

Research funds are available to develop an idea or an instrument and to provide supporting theoretical, laboratory, or ground-based observational research. Sometimes balloons or sounding rockets are furnished for testing instruments, or for giving experience to newer experimenters. Examples of Earth-orbiting satellites in which universities have experiments are Explorers, small vehicles designed by a single organization to carry a specific set of experiments into orbits selected for the set; Orbiting Observatories, large direction-stabilized vehicles to carry out extensive measurements for different experimenters over a wide scientific area (e.g., OAO —Orbiting Astronomical Observatory; OSO —Orbiting Solar Observatory; OGO —Orbiting Geophysical Observatory); and Biosatellites, recoverable vehicles carrying experiments with plants and animals.

The complexity, ruggedness, and reliability required of a flight instrument necessitates a long time for construction and testing. Moreover, the integration of the instrument into the spacecraft and the scheduling and the interaction of the components of the mission stretch the leadtime even farther. Hence, an investigator planning a new experiment should be prepared to wait about 3 years from the date of proposal submission until the actual flight occurs. Even after launch, the experimenter may wish to postpone analysis of results until the end of the useful lifetime of the satellite, frequently 6 months or more. By the time the data are reduced, analyzed, and interpreted, and the scientific reports are prepared and published, 5 years may easily elapse.

This background information was given by Dr. Clark at the opening of Session IV. Professor Winckler of the University of Minnesota then described the way in which space flight experiments fit into the graduate physics program at his institution. He pointed out that so far as university activity is concerned, the space effort will not be thoroughly embraced unless challenging and exciting problems in space science become available as thesis topics for graduate students. Surely the most exciting problems are those that can be solved only by direct investigation in space. Such investigation demands the instrumentation and flight of space vehicles. But the extraordinary requirements on such instrumentation and the exigencies of vehicle scheduling put severe strains on traditional graduate-study patterns and on traditional university services.

A student working in space physics is no less a professional physicist than one working in any other specialty. Hence the basic training for a space-physics student should be the same as that for a student in any other specialty, commonly a strong and diverse basis in undergraduate physics, followed by a standard set of graduate courses. The specialization for the thesis proceeds as with any other subdiscipline, the student ideally choosing the field according to his own desires. Among the factors consciously or subconsciously influencing this choice are the likelihood of finishing the Ph.D. within a finite time span, and the fashionability of the field. The student gains from diverse sources, notably other students, a pretty good notion of the image of the field. It is a fact of life that if the field is not adapted for furnishing good Ph.D. problems, this informal method of choosing a thesis topic will not provide competent students in the field, and the area will suffer.

A student who is ready, willing, and able to work on a space experiment must make his decision and begin his investigation early in his graduate career if he hopes to complete an experimental problem utilizing a space vehicle. The student must be given full warning of the risks involved in choosing such a problem. After the years of planning and preparation, the rocket may end up in ocean instead of in orbit, and he may have to wait a full year for a repeat. As partial insurance, another experiment may be prepared, to be fired in some other rocket at lesser delay.

Professor Winckler believes that a student must become a master in understanding every phase of the work — the electronics and the mechanical equipment, the physics of the radiation encountered, the characteristics of the spacecraft, and the workings of the data system. (The student must, of course, have professional support for the actual execution of the experiment.) Another member of the staff believes, however, that a student should not work on satellites and space probes at all, because of the long leadtimes and the difficulty in performing follow-up experiments to test his ideas. (For another system of managing graduate-student participation in flight experiment programs, see Professor Simpson's description of the University of Chicago program, in the FACILITIES discussion.)

Examples of the kinds of work carried out in flight programs were given by Professor Petersen, University of California at San Diego (X-ray and gamma-ray astronomy); Professor Bowhill, University of Illinois (ionosphere physics); and Professor Brown, University of Pennsylvania (bioscience).

Professor Petersen, in order to study cosmic photons in the 10-keV to 10-MeV range, must get his apparatus away from the effects of air absorption by use of balloons and satellites. With a set of gamma-ray telescopes on the first OSO he obtained a 2-month coverage of the latitude dependence of high-altitude photons. Unexpected and extraneous effects occurred in the NaI crystal detectors owing to radioactivity induced in them by inner-belt radiation. To untangle the relations among terrestrial, extraterrestrial, and extraneous gamma-ray signals, balloon flights were needed. Such flights seem ideally suited for graduate students, in that they provide experience in flight instrumentation without being subject to the long leadtimes and complexities of satellites and deep-space probes.

Professor Bowhill, in order to study the lower ionosphere, must work with sounding rockets, since the region around 160 kilometers is too high for balloons and too low for satellites. He began a small, self-contained study of the upper atmosphere with a sounding-rocket program, which he finds largely free from the dissatisfactions of satellites and probes. For example, with sounding rockets, the time and place of launching can be controlled, elaborate launch facilities are not needed, and the information feedback occurs quickly. His program has yielded much insight into the C, D, and E layers of the ionosphere.

Professor Brown pointed out that the scientific objective of the biosatellite program is to exploit rather than explore the space environment; that is, the objective is to make use of those features of the space environment that render possible experiments that can be performed only in space, rather than to find out something about life in space. The biosatellite series offers six recoverable, unmanned, automated space platforms, which form unique laboratories for providing gravitational fields different from that at the Earth's surface over extended times, and for freeing organisms from the periodicity of the Earth's rotation to allow study of circadian rhythms. The current program has three phases: (1) demonstration of absence of synergistic effects between weightlessness and exposure to radiation; (2) identification of effects of weightlessness on growth, development, and rhythmic behavior of organisms and organismal systems; (3) study of primate physiology, with 30-day flights carrying a monkey as test animal. Launches will be made from Cape Kennedy at a 30°-inclination and 225-mile orbit, with recovery being made by air snatch. Biologists are impressed by the team nature of the research engendered by its multidisciplinarity; by the heavy involvement with engineering; and by the costliness. Some of the difficulties in biological-science experiments are the same as those in physical-science experiments — long leadtimes; need for adherence to schedules; reduction of experimenter's responsibility for his own experiment, with decisions made by default or by someone else; troubles in working with a new agency. Others seem to be somewhat peculiar to bioscience work — bioscience space research has an unfavorable image; the reasons are many, and the image will be corrected only as results of space experiments appear in the established journals. Ames Research Center is relatively not so prestigious as centers with which it will naturally be compared, such as those of N.I.H.

Technology Utilization

Technology utilization, with respect to NASA's mission, means the transfer of the scientific and technological results of the space effort over to nonspace use. The Space Act requires that NASA make its information available in efficient and useful ways. An important part of this activity is carried out in conjunction with universities. Both analysis and experience show that the dissemination of information is best established on the basis of local-user orientation. NASA works with a number of universities and other institutions in seeking through pilot projects to find the best means of disseminating information. The reason for including the universities is that they have natural interest in collecting, storing, and distributing information, and that they have the breadth and the professional capacity to attempt the task of developing methods of transferring knowledge. Beyond these points, however, is the realization that the utilization (as contrasted with the mere acquisition) of technical information requires a close interaction between the supplier and the user. The universities are in good position to extend the work beyond bare supplying of information, up to the further investigation that will lead to fruitful application. From a very broad point of view, the development of regional information-handling centers such as those at universities constitutes part of, and adds strength to, the body of national technical resources.

NASA's Technology Utilization Program began in the fall of 1961, as recounted by President Kimball of the Midwest Research Institute (MRI) in the opening paper of Session V, when his institution undertook a pilot study in order to find and stimulate Midwest potential for participation in space science and technology, both in universities and in industry.

Fifteen universities in six Midwestern states were studied, with active cooperation of administration and faculty. Few scholars were aware at that time of NASA's interest in science, even in universities having large Government-sponsored programs. The important university role in NASA's research, particularly in identifying problem areas where an extension of fundamental knowledge is needed, has proved to be a difficult conceptual problem for some scholars accustomed to working in traditional subjects. The MRI role in finding and stimulating potential would appear to be successful, in that 13 of the 15 universities studied are now involved in NASA programs in contrast to the 4 in 1961, and that NASA is supporting an extension of the study to 17 institutions in the Southwest.

For the industry part of the program, a series of briefings by MRI people was presented in 21 Midwest cities to a total of about 3000 people representing more than 400 companies. The briefings were conducted by MRI senior technical people, selected for their ability to communicate technical information in language comprehensible to industry. Previously they had studied at NASA centers a vast array of NASA's findings, discoveries, experiments, inventions, and patents. They reported that the udiences exhibited deep interest in NASA's work in new manufacturing echniques, quality control, reliability, and new materials.

Within NASA are two highly developed activities supporting the Technology Utilization Program, namely, the Scientific and Technical Information Division (STID) and the Technology Utilization Division (TUD). STID assembles and analyzes the formal written output of NASA, in a sense constituting NASA's passive vocabulary. TUD tries to make this passive storehouse an active one for groups having specific interests, by selectively collecting and packaging information in the region of concern.

Even so, the actual application of existing knowledge to new uses seems to take place rapidly only upon the close personal contact accompanying localization of the dissemination service to the point where it can be selective with respect to the industry's problems, and can be available locally for quick response to requests for additional information. It turns out that technology transfer is less a method of distributing documents than it is of solving problems. A regional instrumentality is needed to show how the information in the documents is applicable to the local problem. As examples — each one small, perhaps, but imposing in the aggregate — MRI has helped in the application of NASA-developed technologies to units for electric-power conversion for railroad equipment (NASA-developed heat-sink techniques for power transistors); transistorized digital read-out devices (NASA work on soldering techniques); electronic cell logging equipment (NASA methods for making electrical connections); protection of rotary kilns for a wallboard producer (low-cost inorganic coatings developed by NASA for passive temperature control in satellites); ore-washing equipment (NASA-designed air bearings); precision meter movements (NASA-designed gas bearings in high-speed jewelers' lathes); electronic seals (NASA-developed ceramic-to-metal seals); setting up of precision cutting tools (NASA-created tools for alining space-vehicle parts); telemetry (NASA solid-state amplifier circuit); stainless-steel high-pressure vessels (NASA-developed methods of high-energy-rate forging and electron-beam welding).

The real barriers to technology transfer seem to be neither technical nor financial. They lie

(1) within corporate management: absence of adequate mechanisms to deal with new products, new processes, new concepts; unwillingness to take risks, to do anything that might render existing plant or personnel obsolete; ignorance of government as a fruitful source of technical information.

(2) within the scientific community: scientists who cannot communicate, or have little understanding of or motivation towards economics; inadequate appreciation of management's skill and functions.

(3) within the society's institutions: inadequate supply of venture capital; out-dated building codes; automation disputes in labor negotiations; lack of rapport between industry and universities.

(4) within the human mind: failure to learn how to provide the climate that motivates creativity, to develop the ability to match the needs and wants of society with our vast ability to do.

President Kimball concluded by pointing out that the role of the universities must be reappraised if they are to take their part in technological utilization.

Provost Terman of Stanford University, in drawing upon his observations at his own institution as well as at others, stated that for a university to make a major direct contribution to technology utilization, it needs faculty with the proper qualities, leadership on the academic side, and hard and persistent working at the job. The contribution can be traced to individual faculty members who are creative, who are recognized as authorities in some area of specialization, and who have broad interests extending into the practical world; and they must get genuine personal satisfaction out of doing useful things. In addition to having suitable faculty, the university must have members of the administration who help keep up the push to have the institution interact strongly with the industrial community. The stimulating effect of the university in accomplishing technology utilization is not self-sustaining until habits of interaction are established, and until many participants are involved. The administration must help sustain the effort over many years.

The first NASA-supported technology-utilization university program began at Indiana University in the spring of 1962. The general premise on which the work was based was to set up effective working relationships with business firms. At present 39 companies of various sizes are associated with the IU Aerospace Research Applications Center (ARAC). One part of the program is sending short summaries of TUD-furnished information to member companies. A second part is selectively disseminating information of high-priority interest to member companies. A third part is bringing together member-company personnel with NASA personnel, and a fourth is bringing them together with university scientific and management personnel. A fifth part is long-range managerial planning in technical areas. So far as benefits are concerned, there have been general expressions that research and development programs have been started earlier, and have enjoyed greater resources commitments, because the management has been assured that there is indeed not enough information currently available, and the search for new knowledge is therefore justified. There have been in addition some specific illustrations of benefits, for example, in tungsten inert-gas welding, paint removal, electronic rectification, magnetic-core materials, and microencapsulation. A different kind of benefit lies in semiannual meetings sponsored by ARAC for industrial representatives, Government officials, and university people. Here problems and ideas are discussed on an informal basis, and the resulting interactions have been found to be valuable. The list of activities is completed by computerized document searches for people both at the IU campus and at other campuses.

Wayne State University is situated in the heart of the major metropolitan region of southeastern Michigan, with its diverse heavy industry; hence its technology-utilization program can be expected to be different from those at MRI and IU. Vice President Whaley pointed out that technology utilization is simple neither to define nor to understand, that it does not occur by chance, that it affords an urgent problem. The output of information is enormous, but our ability to utilize it in fields not related to those in which it is generated is not. WSU, through its Center for the Application of Sciences and Technology (CAST), is seeking a means whereby an academic institution can appropriately contribute to an understanding of the process of transfer, whereby pilot mechanisms within the institution can be developed, and whereby experiments can be undertaken to contribute to a revitalization of some academic programs of teaching and research. For the initial stages CAST has limited itself to NASA-generated aerospace-related technology. During the first year of operation starting in spring 1964, CAST was established and organized, with two principles obtaining: that by policy and practice, the operation must be locked into the academic mission of the university, which is education in the broadest sense; and that the elements that make transfer of aerospace technology into nonspace industry a fact must be discovered. CAST has a director reporting to the vice president for graduate studies and research, with a university advisory board and an industrial advisory board. It has two divisions, information services and application services. Through the latter, contact is made with industries by means of CAST applications engineers, who are professional engineers and usually faculty members. Graduate students serve as interns on part-time employment.

The information so digested and transmitted leads to applications that rarely bring forth a new product, but most often produce solutions to problems in manufacturing processes, reduction of costs, reduction of losses, or improvement of the product. Almost always the utilization is directed toward improvement of a product or a process for which the company already has a market. Sometimes the transfer of information helps in opening up a new area of research, and CAST with its storehouse of information as interpreted and transmitted by its applications engineers is of significant value in corporate planning and in arriving at decisions relative to research efforts. CAST relates to the academic responsibility of the university in the following ways: new courses related to technology utilization have appeared; a workshop has been cosponsored by CAST and the WSU Institute for Applied Chemistry and Physics; faculty who serve part-time as applications engineers are modifying what they teach, sometimes using CAST as a source of thesis topics.

The University of Maryland has created an Office of Industrial Applications (OIA) to undertake a study of conditions underlying the transfer of technical knowledge to the industry. The study seeks to identify factors which may impede or which may facilitate the transfer of technology to industry. It appeared that it would be valuable to develop some quantitative guide to divide new technology into that portion which might tend to become profitable commercially, and that portion which would tend to remain only as laboratory exercises. Such a guide is not easy to develop, for a small specially qualified group cannot evaluate ideas over all areas; and calling upon outside groups in the form of scientific panels will not work because the crucial criteria are marketability and profitability, matters in which the scientific panel is not likely to be knowledgeable. Evidently, industrialists themselves must be consulted. Hence it was decided to contact individual companies to obtain an evaluation of the commercial significance of a particular development, in terms of the company's reaction to the development, or the company's estimate of its potential destination in industry. The company was, of course, invited to use the development. The selection of the developments to be presented to the companies naturally had to be made critically — the right material must go to the right companies in the right form. So far, some 7500 combinations of company-by-innovation have been tried, following drastic preselection of innovations from the total store by the OIA; some 300 combinations were judged to be not without practicality. They have varying prognoses for ultimate utilization. Experience with the program will, it is hoped, permit quantification of the effectiveness of various aspects of technology utilization.

FACILITIES

Federal participation in providing research facilities, i.e., buildings or parts thereof, is very recent: National Institutes of Health, 9 years, $330 million; National Science Foundation, 6 years, $100 million; NASA, 3 years, $29 million; Office of Education, just entering with $60 million. Each program is designed to help achieve the unique mission of the particular agency, and special attention is given to coordination among the agencies so that the programs become complementary rather than competitive. NASA is concerned with the expansion or provision of research laboratories at those institutions that are heavily committed in space-related activities. For this purpose $29 million has been spent in 27 grants to as many institutions to provide nearly 1 million square feet of urgently needed laboratory space.

NASA's first facilities grant was made in the fall of 1962 to Rensselaer Polytechnic Institute to aid in establishing its Materials Research Institute. As related by President Folsom, RPI received $1.5 million from NASA without requirement for matching funds, for 56 000 square feet gross, and $0.5 million from NSF with $0.6 million matching funds, for 40 000 square feet gross, to give a total of $2.6 million for 96 000 square feet, equivalent to a cost of $27 per square foot including fixed laboratory furniture. A major source of funding for the Materials Research Institute is NASA's Materials Research Branch in OART. This office has been step-funding the Institute at the rate of $300 000 per year. The materials research program is interdisciplinary, with several disciplines under one roof active in problems of developing new materials, specifically in solids — ceramics, metals, polymers, and composites of these. The laboratory is always open to industrial representatives who may wish to visit it and discuss the RPI research activities. Besides this contact with industry there is strong interaction with NASA laboratories. This facilities grant has been an important factor in strengthening particular research areas, through permitting addition of professorial staff and increase in number of graduate students.

Chancellor Litchfield of the University of Pittsburgh spoke about the memorandum of understanding signed by him and Administrator Webb upon acceptance of the facilities grant at his institution. He accepts as an obligation of the institution that it build up its capabilities on an interdisciplinary basis, that it aid in exploitation of "spin-off", that it help the public understand the academic, economic, and social significance of the space program, and that it bring a wider degree of private support to the space effort so that it is not purely a Governmental activity. To fit these commitments into the role of the large complex university in today's society implies a new part for it to play. In the past the university had the opportunity and responsibility of providing teachers with the chance to teach, and academic people with the chance to do research. The end product was an increasing number of better educated people, who knew and discovered more things. The university was satisfied that it was doing its job if it provided teachers and classrooms and laboratories and libraries, and if it maintained a tradition of free inquiry. As an institution the university seldom regarded itself as having definable problems that it had a responsibility to solve. Consequently, university organization developed very loosely, and extensive means of communication within the university did not develop.

The anatomy of institutional life that has developed around the traditional concept of the university is not one that suggests real organization. We lack a philosophy of the way in which the university should relate to the Government, to corporations, and to other defined institutions within our society. Now one sees the emergence of a belief that something must be done to define a university role beyond the traditional values. Two major considerations are: (1) the realization that a large and complex university has a unique opportunity in society because it has the capability of integrating a broad spectrum of knowledge, or in other words, that it can carry out meaningful interdisciplinary activities; (2) a new awareness of the acceleration of the process of knowledge accumulation, in whose generation and dissemination the university has a key role. These two factors give the universities the responsibility to enlarge their role in our society. It is a kind of demand for partnership with Government and with industry. The university must fully and frankly acknowledge that in addition to its traditional functions it has the role of serving as a comprehensive vehicle for social action. It must acknowledge the existence of problems, must dedicate itself to doing something about those problems, must organize itself to implement that dedication, and must staff itself with reference to the problems.

Unless the university acknowledges such a responsibility, it cannot reconcile itself to the commitment it has made to involve its faculty in space-related fields. The University of Pittsburgh is undertaking deliberately to influence the direction in which the faculty will go, rather than following the traditional course of leaving it to the faculty itself. The University of Pittsburgh has accepted the redefined role of the university and welcomes participation with NASA and other forces for this kind of commitment. Here, the space-related disciplines have been strengthened by adding 130 people in the relevant faculties; new buildings have been created for engineering, natural science, and radiation studies. In technological utilization, UP has joined with other institutions in the area to build an industrial research park adjacent to the campus. A Knowledge Availability Systems Center has been formed to store, retrieve, and disseminate information. A well-developed program exists to allow scientists from industry to visit the campus for extended periods. Television films have been developed for the public, and programs have been designed for the secondary schools. Private citizens have become interested, with corporations and foundations contributing to the program. In the long run, this pioneering effort in forcing and encouraging the universities to play a new role will mean a great deal — far beyond the specific space activities — in extending the basic role of academic institutions in contemporary life.

Professor Simpson took the use of the facilities grant at the University of Chicago as a point of departure for describing the functioning of a strong space-science activity at a university. He stated that a major question facing experimental science in the universities is how to retain the essentially individualistic role of the faculty, both as investigators and teachers, in the face of increasingly complex demands for technical support required for first-rate research. Even more difficult is the question of participation of graduate students in on-going research, so that they can grow into scientists rather than supertechnicians. There must be innovation within the universities to meet the challenge of the changing conditions of scientific research with support from Federal funds.

Our Government, through NASA, has provided the scientific community with an impressive array of opportunities to enter directly into space research and exploration. The machinery for accomplishing this entry is a national resource, which because of its magnitude must reside within the Government. Consequently, investigators must recognize that their initial decisions to undertake experiments in space will be followed by detailed and continuing collaboration between themselves and the administrative and technical staffs concerned with the overall success of a spacecraft and its mission.

Space research is almost always intrinsically multidisciplinary; almost any area of investigation involves knowledge in a combination of fields, such as particle physics plus astronomy plus atomic physics plus atmospheric physics. The simplicity and unity of classical fields, and the departmental administration of them, have broken down. These dramatic differences in the pursuit of experiments in space require administrative and technical innovation on the part of the university and of the senior staff and the students, with the objective of retaining their responsibility for the experiment and their associated drive for scientific excellence. At Chicago, the general picture emerges of individual faculty members supported by small professional staffs whose purpose is to assist in the preparation of experiments for space flights and to maintain the communication channels necessary in providing the interface with NASA. The graduate students may, before their dissertations, assist in the theory, design, and preparation of experiments. They may assist also in the analysis of data, and in preparation of computer programs. At the dissertation level, students trained previously in experiment and analysis are frequently made co-experimenters in new experiments. Because of the long leadtime for a major experiment, most students can participate in the preparation of an experiment that will fly only long after the thesis preparation. Therefore, for their thesis work, they participate in an already on-going experiment having similar objectives.

For the universities, there must be a rethinking of their role in providing support for faculties and students with administrative provision of technical personnel. For NASA, there must be a recognition of the essentially fragile nature of the intellectual spirit that must be maintained in the research areas of the universities. NASA Headquarters has recognized this, but NASA Centers have diverse policies and are only gradually learning not to treat universities as industries. The main point of the discussion with respect to the facilities grant is, however, that the pursuit of scientific excellence and the training of future scientists require a unifying of disciplines and of support staff within a suitably designed physical facility. At Chicago, without such a facility the efforts would have remained fragmentary, and U.C.'s present ability to sustain experiments conducted in space would be severely limited.

Some relevant subjects that are worthy of further consideration are:

(1) The increasing complexity and sophistication of missions, particularly planetary ones. Some way must be found through the serious problems imposed by the constraints of complex missions if the universities are not to drop out of participation.

(2) Schemes of participation by small groups at institutions not yet heavily committed to space-science activity. Perhaps the NASA Centers or the larger university groups should encourage the smaller groups to join them.

(3) Implementation of block assignments in well-developed spacecraft, whereby university groups would be responsible for the entire payload. In this fashion the enormous amount of time and effort consumed

in exchanging technical information relevant to component interfaces can be minimized.

(4) Patience in public release of data following a space experiment. At universities, it is graduate students who are normally engaged in such work, which consequently proceeds somewhat more slowly than in a group whose members can work full time on the data.

Following Professor Simpson's paper, Professor Nier monitored a panel discussion by members representing diverse aspects of research administration and conduct. Professors Kuiper and Levinthal illustrated some of the research activity that provision of facilities allows. Professor Kuiper stressed the importance of student training in connection with space-oriented programs, and the need to balance ground-based astronomy with spacecraft-based astronomy. He asked for university scientists to assist NASA in ascertaining the proper balance, and for university administrators to understand the demands of NASA participation on the time of scientists. Professor Levinthal pointed out that exobiology will have no results until 1970 or so, and that interest in such a field must be maintained through relevant terrestrial experiments in related disciplines, such as quantitative assay of functional presence of enzymes, and microsampling for mass spectrometry. Director Picha showed how the Space Sciences and Technology Center at Georgia Institute of Technology developed in response to activity in energy conversion, materials processing, systems engineering, nuclear processes, and transport phenomena. He asked whether the Federal Government might not streamline its approaches to funding of facilities. Planning Officer Winter talked about the value of having a basic written document containing guidelines for architects, administrators, and scientists concerned with a particular project; such a document will save the university and the architect from false starts. To get from planning to completion requires collaboration, with specific definition of responsibilities, and realistic formulation of schedules. Mr. Buck, Chief of Research Facilities and Equipment Division at Ames Research Center, in discussing square footage, speed, and utilization and return, emphasized that research facilities are but a means to an end, a tool with which to increase knowledge. No set rules can apply to dollars per square foot; the only meaningful rule is to get the most that is possible within a given funding for a given occupancy and use. Urgency is real, to keep the long time from inception of the idea of the building to its occupancy just as short as possible.

Chairman Holmes, in concluding Session VI, remarked that whatever success the NASA facilities program has had is to be credited to people at many levels in NASA Headquarters and Centers, up to and including the Administrator; and to people at many levels in the universities, up to and including the presidents.

EVALUATION OF PROGRAM

In March 1965 it became clear that the U.S. space effort had come of age. Ranger IX and Gemini GT-3 spectacularly demonstrated our progress in technology. The NASA University Program Review Conference in its own quiet way showed NASA's growing maturity and vision in discharging its responsibilities in science. Out of the mass of detail arose a picture of far-sighted and imaginative provision of the sinews of science — men and women, supplies and services, buildings and equipment.

The scientific aspects of the space program are so broad that NASA cannot hope to maintain in-house competence across all fields. Even if it could, its responsibility in managing its resources as a national trust requires that it give all the Nation's scientists opportunities and encouragement to participate in space research. Other Government agencies, industrial laboratories, research institutes, and the universities are to become NASA's partners. Each sector makes a substantial and characteristic contribution. This conference reviews that of the universities; in terms of funding, this activity is represented by an item of $109 million out of NASA's total budget of $5100 million (all figures for Fiscal Year 1964).

NASA provides support of people with respect to both training and research. The current budget for training is $25 million. The major item is the predoctoral-trainee program, in which an educational institution is granted money to support a specified number of outstanding students in space-related fields. The institution has the responsibility for selecting the students according to whatever procedures it thinks best, in keeping with NASA policy of providing university authority to discharge university responsibility. The Conference showed that this feature is much appreciated by almost all institutions. The adequate stipend and the 3-year tenure of the traineeships, plus the prestige attached to them, make them attractive to students. Evidently the NASA trainees are first-rate performers, and there is certainly no lack of qualified candidates. NASA's other training programs, principally summer space-science institutes for undergraduates and for faculty members, have met with enthusiasm on the part of both trainees and trainers. The evolution of the training program has apparently been both sound and dynamic. It has been, and shows every sign of continuing to be, a wise investment for the future of NASA.

NASA provides support of university research, which consumes people, supplies and services, and equipment, under its mission-program offices for project-type activity ($42 million) and under its Sustaining University Program for multidisciplinary activity ($8 million). Accomplishments under the project-type support, even when seen only fragmentarily in this conference, are impressive evidence of both the breadth and the depth of space-related research. In the project-type research, flight experiments are especially fascinating, and the service rendered to the universities by the NASA Centers is mighty in this area. Yet the execution of these experiments by the universities is fraught with problems. The complexity of the apparatus and the demands for reliability thereon, together with great expense and tight scheduling, force a strict management that is usually outside the experience and sometimes beyond the comprehension of university researchers and officials. Nonetheless, only through collaboration between university people and NASA Center people will the best space science get done, and ways must be found to keep this interaction fruitful so that the flight-experiment program is not merely viable but actively flourishing.

Less glamorous yet of great potential value to the community at large is another effort, the Technology Utilization Program, which has settled down from the fanciful notions of spin-off that most of us had at the beginning of the space effort, into a day-to-day, unostentatious, evolving operation. NASA has created a mighty store of knowledge, but useful information can be extracted from it only by deliberate and skilful effort. The key element in utilization of technology appears to be provision of technical liaison personnel who know the problems of local industries as well as the mechanisms of NASA's information services. The useful output of the program seems to be made up primarily of items more or less minor in themselves, yet together building up into a substantial aggregate.

NASA's support of university research by its multidisciplinary grants may turn out to be its most far-reaching contribution to itself and to the universities. The characteristic feature of such a grant is that it puts responsibility on the institution (1) to prove that it has potentialities for effective participation in the space effort; (2) to identify locally activities that could contribute effectively if supported; (3) to evaluate locally the merits of locally proposed activities, and allocate locally the funds so as to maximize the effectiveness of the program. As is to be expected, each institution has its own methods of managing its grant and has its own diverse set of activities. The characteristic advantages result from the flexibility of the grant, for example: supplying a research-support start to young investigators who are respected locally but have not yet reached national prominence; letting new research ideas be pursued immediately without the delays attendant upon submission, evaluation, negotiation, and transmission of formal proposals handled by a nonlocal agency; and supporting research not clearly lying within the boundaries of traditional disciplines. These grants are not intended to, and they do not, supplant project-type grants; rather they supplement them, often serving for stimulation of activities that grow into research appropriate for project-type support.

NASA, in all its research sponsorship, attempts to provide continuity through "step funding," whereby support tapers off rather than ceases abruptly when a grant or a contract cannot be renewed. Apparently all investigators and their institutions consider step funding desirable, many extremely so.

NASA aids in provision of equipment only insofar as the equipment constitutes an item to be funded under a specific research activity, or as it constitutes part of the permanent installation in a NASA-funded facility. The NASA facilities program funds about 10 buildings or parts of buildings each year (FY 1964 budget, $9 million), in order to enable institutions to carry out space-science activities that would be precluded or seriously hampered otherwise. One characteristic feature of these grants is that matching funds are not required, a crucial point in avoiding distortion of the institution's overall purpose through diversion of scarce non-Federal funds into Federally encouraged activities. The private universities appreciate this feature in view of the shrinking of their capital-fund sources; the public ones, in view of higher-priority claims on capital funds for building classrooms to meet the rapid growth of the student body. A second characteristic feature of a NASA facilities grant is the signing of a memorandum of understanding between the principal executive of the university and the Administrator of NASA. Here the university agrees essentially to enlarge its role in the society, serving as a comprehensive vehicle for social action. With few exceptions, the creation of a space-science facility seems to have had a marked impact on campuses, but in strikingly different ways from one institution to another.

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The conference reflects a challenging, on-going major activity that has caught the imagination of the Nation, and of a large number of its universities. NASA appears as a maturing agency, not yet a sea of tranquility but no longer an ocean of storms. The conference brought out the virtues of the NASA University Program, and they are many; it was not, however, a medium for making evident the program's shortcomings. The activities described were intended to be representative of the entire program, but emphasis was placed on the program's strengths rather than its weaknesses. All this is to be expected, and can readily be taken into account whenever necessary. Harder to identify are the sins of omission in the NASA University Program — deserving students left unsupported, sound research proposals turned down, promising flight experiments unflown, needed buildings unbuilt. As in all thriving organizations, some individuals within NASA undoubtedly were guilty of poor judgment, but overwhelmingly it is the scarcity of NASA funds for university support that is responsible.

At the conference it would have been easier to learn about the program's deficiencies and possible remedies therefor if more time had been available for discussion from the floor. Some of the papers contained extensive detailed material that surely could not have been of value to most listeners. Its deletion would have permitted more substantial participation from the floor, and would have allowed the scheduling of, say, a panel of noncaptious university critics and nondefensive NASA officials, to examine responsibly questions such as grants-versus-contracts, procedures for proposal evaluations, delays in decision and notification concerning NASA's actions, and inflexibility in university business procedures. Such a panel might have enlightened both Government personnel and university personnel about the limitations under which the other operates.

But it is unlikely that a recital of the defects would have changed importantly the impression that the conference gave of the program. True, the NASA offices, and indeed the universities themselves, need attention to improving the mechanics of current procedures, and foresight in dealing with their collaborating institutions, as novel and complex interactions develop in the NASA University Program. Yet, all in all, NASA appears within the boundaries of its mission to have demonstrated a firm grasp of principle, to have displayed energy and imagination in application of that principle, and to have been rewarded with output both copious and significant.

APPENDIX – DIGESTS OF RELATED PAPERS

THE NASA UNIVERSITY PROGRAM–A TWO-WAY STREET

Stuart Symington
United States Senate

We can take justifiable pride in the accomplishments of the universities, the Government, and industry during the 6-1/2 years of NASA's existence. In little more than 4 years our first man-in-space project, Mercury, was initiated and completed. Our second manned-space-flight program, Gemini, is now underway. Thus we see that our programs with manned spacecraft are proceeding dramatically. Meteorological satellites Tiros and Nimbus advanced the state-of-the-art in weather forecasting. Communications of satellites Relay, Telstar, and Syncom proved the feasibility of space vehicles as a base for global communications. We have demonstrated our ability to explore space through the success of such programs as the Ranger series to photograph the Moon, the Mariner series to investigate the planets, and the Explorer series to explore terrestrial, lunar, and interplanetary space. We may be proud of many of our other developments, such as the Saturn I launch vehicle, our 1.5-million-pound thrust rocket.

But up to the present we have proceeded almost entirely on the base of relatively old concepts and even old technologies. Yet for the ambitious goals of the space age we need new knowledge. We must widen the scope of man's imagination and stimulate to their fullest potential the mental powers of young Americans. Neither the Government nor the universities nor industry can do the job alone. The Government supports university participation, but NASA's striving to give full play to the local initiative of its grantees places the space-age responsibility in the hands of the university people.

From the universities must come the future leaders of science and technology, as well as a vast portion of the ideas demanded by the technological revolution in general and the space program in particular. By participating in the NASA programs, the universities are placing themselves in better position to provide support to the industrial complex at large and to their local communities. In this regard, transmission of knowledge must go beyond classroom and laboratory teaching. The universities need to develop more rapid means of communicating new knowledge to industry and the community.

Industry needs closer liaison with the university community, in particular to acquaint university researchers with various industrial problems. The university is a largely untapped reservoir of ideas, technology, and even techniques. Industrial inputs into this reservoir will naturally broaden the scope of university investigation. Industry can profit by acquiring new science and technology growing out of university research for which it has not had to bear the financial burden. In this connection NASA is undertaking its Technology Utilization Program to accelerate the flow of technical information from space research into nonspace applications.

In summary, the NASA University program provides assistance to students who want to make space their career; it supplements the space-research efforts carried on in government and industry; and it encourages the university community to meet its responsibility to the Nation by accepting its role in the challenge of space. The give and take of the program — the two-way street — will strengthen the Government, the universities, and the industrial complex. It represents further progress in the teamwork that has made this Nation the strongest and the most prosperous in world history.

NASA'S PROGRAM IN ADVANCED RESEARCH AND TECHNOLOGY

Raymond L. Bisplinghoff
Associate Administrator
Office of Advanced Research and Technology, NASA

Preeminence in aeronautics and space will depend not only on current aeronautical and space operations, but also on our ability to organize and extend the underlying body of science and technology; that is the reason for having our Advanced Research and Technology Program.

We may divide technologies according to three steps: from Earth surface to Earth orbit; from Earth orbit to Moon; from Moon to planets. The first two steps rest on technologies that are already familiar, but the third demands performance and reliability that are orders of magnitude higher. NASA's Advanced Research and Technology Program is devoted to improving reliability in all three steps, and in conceiving and developing the new concepts required for the third step.

The technological fields of chief interest in the program are the following:

Energy conversion. — Chemical rocketry will continue to serve for parts of planetary missions; the principal new requirements for deep-space applications are fuels with high specific impulse and high density that are capable of long-duration storage with little loss. Deep penetration with large payloads for long times, however, will require nuclear energy. The nuclear stage may be augmented by electrical propulsion to achieve extremely high velocities. Significant success has been attained recently in chemical (e.g., fluorine-hydrogen), nuclear (e.g., NERVA solid-graphite-core reactor), and electrical (e.g., SERT-1A ion engine) propulsion.

Electrical power is needed for space missions. For selected applications chemical and solar power can be used as primary sources, but the generation of large quantities of electrical power for long periods of time in space will rest eventually upon nuclear energy. During the past year, a nuclear-electric system (the 35-kW Snap 8) was successfully tested. An attractive step for the future would be a magnetohydrodynamic device, linked with gaseous containment of the fission process.

Materials.— The demands on materials are exceptionally severe for the Moon-to-planets step. Materials are needed that will resist burning and oxidation, remaining compatible with new propellants while retaining their mechanical properties for thousands of hours in the presence of high vacuum and solar radiation. The emergence of such materials depends on our progress in achieving a fuller understanding of the forces binding atoms together in solids. Some recent developments are encouraging —for instance, our success in making certain polymer films useful up to 1100° F.

Guidance and Control.— One of the most important branches of space technology is the process of measuring the flow of energy and continually using the result to control it ("feedback"). Significant advances over present-day capability are required for the future, particularly with regard to precision in pointing and in attitude —for example, in directing the antennas of synchronous communications satellites, in orienting orbiting solar observatories, and in laser communications satellites. Besides stellar, solar, and horizon sensing, we need to consider visible airglow, ultraviolet radiation, and radiofrequency radiation as bases for sensing.

Communications.— Transmission of information is fundamental in space science. Present technology permits high rate of information transmission (e.g., 5×10^3 bits/sec for intelligible voice communication, 10×10^7 bits/sec for high-quality television) between points on the Earth's surface and in near space. But because the data-rate capability for any system ultimately falls off as the square of the distance between the transmitter and the receiver increases, the rates attainable for deep-space vehicles are very small. For example, Mariner transmitting from Mars has a rate of only 0.2 bit/sec. With the microwave systems in current use, the data rate can be increased by raising the operating frequency, the receiving-antenna aperture, and the transmitting power, and by lowering the noise in detectors. Yet all the improvements foreseeable in these factors within the next 5 years will not permit the capabilities of the Mariner system to be raised above 5×10^3 bits/sec, far short of the rate needed for real-time television from Mars. Millimeter-wave or optical-wave systems must be developed. Successful flight experiments with a passive laser system were conducted last fall with Explorer XXII.

The NASA Centers can become effective creators of new technology only when they are coupled with the enormous strength and vitality of the Nation's universities and industrial firms. As an example, reentry technology shows the interaction of laboratories in universities, industry, and government. Together they have shown how to handle the speeds characteristic of Earth-orbital return and lunar return; the Project Fire spacecraft reentered the Earth's atmosphere at the fastest controlled reentry speed yet managed, over 7 miles/sec. But for unbraked reentry into the Earth's atmosphere from interplanetary missions, much more needs to be known about heat transfer, materials, and configurations. For entry into the atmosphere of Mars and Venus one needs of course to know the properties of their atmospheres.

The universities can make characteristic contributions in research, particularly in enhancing depth of understanding in the underlying physical phenomena, through the processes of unhurried thought by individuals; yet the most important contribution of the universities is developing people with creative and imaginative talent.

NASA SPACE SCIENCE AND APPLICATIONS PROGRAM

Homer E. Newell
Associate Administrator
Office of Space Science and Applications, NASA

The many motivations behind the creation of NASA can be summarized in its intent to establish and maintain the Nation in a strong position in the Space Age. To this end NASA has undertaken to develop a broad capability such that in space matters this Nation will have strength and security, flexibility and freedom of choice. An essential part of this effort is the use of spacecraft to advance knowledge of the Earth and of space, and the development of practical applications for this knowledge. This program has come to maturity in half a dozen years, with applications missions carried out by 18 satellites in interleaf with scientific missions executed by 32 satellites and 5 deep-space probes.

In the applications missions we are attempting to maximize practical benefits from our developing space capabilities. Significant success has come in two areas, weather and communications. In the weather-satellite program, Tiros (Television Infra-Red Observation Satellite) has led to the spacecraft technology to be used on our first operational weather-satellite system, Tos (Tiros Operational Satellite). Nimbus, an instrumented meteorological unmanned satellite, represents the next generation of weather satellites. This part of the space program provides the global data-gathering capability needed to match and stimulate advancing theory, moving us, it is hoped, to the day when long-range weather forecasting will be successful. In the communications-satellite program, the sequence consisting of Echo (passive satellite in 700-mile orbit), Telstar (active satellite in elliptical orbit, 3500-mile apogee, 600-mile perigee), Relay I (active satellite in elliptical orbit, 4600-mile apogee, roughly 1000-mile perigee), and Syncom (active satellite in 23 000-mile synchronous orbit) has laid the groundwork for an operational communications system.

NASA does not assume operational responsibilities in applications. It performs the necessary research and development and provides supporting services in launching the spacecraft and in tracking and monitoring it in orbit. NASA continues to search for other potential applications of space technology. In conjunction with other interested agencies, it is investigating navigational satellites, with special attention to the possible contributions to air-traffic control.

Space science is not separate from the rest of science, but rather is an extension of the rest of science made possible by the availability of sounding rockets, Earth satellites, and deep-space probes. The space program has led to a tremendous broadening of the horizons of many branches of science. The geophysicist, for example, finds on the one hand that the space vehicle is a new tool for investigating classical problems such as the shape of the Earth, and on the other hand that the results from flights bring him new problems such as the origin of the radiation belts. And soon the geophysicist will reach new domains in the form of selenophysics and planetophysics. The astronomer, likewise, gains the ability to observe from a new vantage point above the absorbing, distorting atmosphere, and hence to study and then explain new wavelength regions, especially the ultraviolet and X-ray. The physicist has in interplanetary space a laboratory where matter and fields exist under conditions unattainable on the ground; and the solar wind, together with its interaction with the Earth's magnetosphere, constitutes an important problem and laboratory in plasma physics. In fact, geophysics, astronomy, and physics are drawing closer together as they attack first the problem of Sun-Earth relationships and then the broader problems of the whole solar system.

The impact of the space program on biosciences is still developing. Exobiology, the search for and study of extraterrestrial life, is fascinating, though we have some time to wait for the first results to come in from lunar and planetary missions. In the meantime, biologists are carrying out exciting terrestrial experiments on the chemical synthesis of compounds of the type associated with living organisms. In recoverable near-Earth satellites, other kinds of experiments are planned wherein living material can be studied free from net gravitational field and from normal diurnal rhythms.

The space vehicles will be only as useful as they are made to be, by having competent people interested in and involved with the effort. At present, the Space Science and Applications Program involves about 58 000 people, of whom 15 000 are engineers and scientists. Among these technical personnel are 700 leading scientists serving as principal investigators or co-investigators in about 2000 separate tasks concerned directly with flight experiments or indirectly with the supporting research.

In space science, NASA regards as a national trust the resources made available to it, to be managed in such a way as to draw from our national capability the very best. We believe the most effective way to get the best is to carry out the program in a way that strengthens the universities. NASA makes available the opportunities for scientists to pursue their ideas in solving problems which they judge to be of scientific importance. NASA tries to support space research in association with the teaching of new talent. Space flight experiments are not easy for a university to conduct, yet important benefits do accrue to science and education from university participation in flight programs. Hence NASA provides engineering support, either from a Center or from a contractor, for universities that desire it.

NASA also recognizes the need to assume some share of the burden of supporting research in areas pertinent to the NASA program. Its program offices support a sizable amount of ground-based research, occasionally providing special instruments such as telescopes and computers. NASA's Sustaining University Program provides support for predoctoral training, for some laboratory buildings, and for some multidisciplinary seed-money and space-capability-development grants. NASA policy encourages long-term funding wherever practical and encourages placing responsibility within the university. NASA insists on open publication of results, in the literature appropriate to the discipline concerned or at scientific gatherings. It seeks the advice of the scientific community in deciding upon the scientific objectives of the flight missions and in selecting the experiments and the experimenters for the program. NASA's approach is designed to uphold the integrity of science and scientists by enabling the scientific community to undertake solution of scientific problems of challenge and importance according to proved scientific tradition.

On this point, let us recall that the overall space program has many motivations and many objectives. Some are scientific, many are not. The Nation, through its representative democratic processes, has chosen to embark upon the venture of moving into space. The Nation is going forward with vigor and determination in developing its space capability. It is the responsibility of the Government to make it possible for the space program to contain the best science that the Nation is capable of and a responsibility of the scientific community to see that such science is indeed carried out in all of our space vehicles.

RESEARCH OPPORTUNITIES IN MANNED SPACE FLIGHT

Samuel C. Phillips
Director, Apollo Program
Office of Manned Space Flight, NASA

NASA recognizes the universities as the fountainhead of our national strength in science and technology. NASA values the universities for providing counsel, for conducting research, and for training people. (General Phillips showed a 32-minute color film, "Apollo Mission Profile," to exemplify the broad range of technologies supporting manned flight and to suggest opportunities for experiments on the Apollo flights.)

Why is man of value in space? His attributes as a subsystem of a manned spacecraft system are: he is a relatively lightweight, versatile, and mobile computer, with intelligence, judgment, and ability to anticipate events and make decisions. He can translate perceived data into relevant information, in part through his ability to correlate, to systematize, and to recognize patterns. He can selectively communicate this information. But he is delicate, and he must be given a structure to provide for his comfort and safety. He must be furnished food, water, and oxygen, and he must have his waste products removed. Many pounds of payload are needed to make these provisions, and these pounds increase the complexity of the spacecraft, the power of the launch vehicle, and concomitantly the cost. In each space mission we must ascertain whether the benefits provided by man's presence justify the additional expense.

To aid in deciding this issue, analyze man's abilities according to his ability as (1) a sensor; (2) a manipulator; (3) an evaluator; and (4) an investigator.

As a sensor, he adds little or nothing to automatic equipment. Instruments are available with greater abilities to see, hear, touch, feel warmth or cold, smell, or even taste. Only in event of mishap is man's sensing ability needed.

As a manipulator, man can be valuable in piloting spacecraft through his operation of controls and in conducting research through his ability to assemble, operate, and repair equipment. The replacement of man by a robot manipulator would be difficult, but not impossible. For deep-space missions, manipulation in real time by remote control from the Earth becomes impossible because of the limit on the speed of interaction, that is, the velocity of light. Even at the Moon, a device controlled remotely from the Earth cannot react in less than 2.6 seconds, the round trip time for a radio signal.

As an evaluator, man is valuable in translating meaningful data into useful knowledge through his ability to remember, recall, reflect, analyze, compare, contrast, and induce. His ability to evaluate, in combination with his ability to sense and manipulate, gives him substantial self-reliance in controlling what he perceives and how he reacts. Devices can evaluate only in a fashion rudimentary as compared with man.

As an investigator, man is valuable in responding creatively to unexpected situations, in postulating hypotheses, and in devising and initiating systematic measurements. Almost by definition, devices cannot fulfill this function.

From this analysis there appears the need to give current astronauts some scientific education to develop their evaluative ability, and to consider as future astronauts some full-fledged scientists in order to exploit their investigative ability. Programs for both activities are under way.

NASA is currently studying and planning missions that utilize Apollo developments for programs other than the initial manned lunar-landing program. With the Saturn IB as launch vehicle, the basic Apollo spacecraft can be placed in a low Earth orbit with provision of experimental payloads up to 2000 pounds in nearly 210 cubic feet of unpressurized volume. Orbit durations up to 4 weeks could be achieved with a three-man crew. With Saturn V as a launch vehicle, durations up to 90 days are possible, with greater payloads and more volume, in orbits offering special viewing possibilities.

A manned station with such capabilities offers the opportunity to perform experiments in space science, to develop Earth-oriented applications, and to support space exploration. In science, astronomy and astrophysics gain access to new regions of the spectrum heretofore cut off by the atmosphere; in physics and chemistry, phase-interface effects free from gravitational influence can be investigated as well as the effects of exposure of materials to space environment. In applications, meteorology will get synoptic views of cloud cover; and geographers will get Earth-mapping surveys. In space exploration, a direct detailed investigation of the lunar surface and subsurface will be valuable in understanding the origin of the Moon and nature of the solar system.

In all these programs, NASA welcomes suggestions and comments from the universities, not only in the research-oriented endeavors, but also on any other aspects of the program to which they can contribute.

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