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A STUDY OF NASA UNIVERSITY PROGRAMS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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A STUDY OF NASA UNIVERSITY PROGRAMS

Prepared by
Task Force to Assess NASA University Programs

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FOREWORD

This paper has been prepared as a summary report to Mr. Francis B. Smith, Assistant Administrator for University Affairs, by the Task Force to Assess NASA University Programs. It is based on the analysis of information gathered throughout NASA and the university community covering many different grants, contracts, disciplines, programs, and projects wherein NASA and universities have interacted. Obviously, the information collected about so complex a relationship can never be complete, but the Task Force has sought to make it representative. It is believed to typify NASA university programs with reasonable accuracy.

The Task Force wishes to acknowledge the contributions of time, thought, and effort to this study by many people both within and outside the National Aeronautics and Space Administration. It particularly wishes to thank the administrators, faculty, and students of the universities which generously hosted its representatives during their campus visits.

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PRECIS

This study examines the results of the total NASA university program. It is an assessment of the program based on goals publicly expressed by NASA managers as recorded in the literature and correspondence with universities. Foremost among the goals has been the intent of NASA to accomplish its aeronautics and space mission while at the same time strengthening the universities involved; NASA-sponsored research was to be conducted in the traditional atmosphere of instruction and learning in order to maximize the indirect returns from the mission-oriented programs. The study was approached through selected sampling of NASA-university interactions by interviews, university visits, and in-depth case studies. The significant limitations of the study are those imposed by the lack of sufficient time to collect and analyze data on such a huge and diverse program. However, the Task Force believes this report to be indicative of the total NASA university program.

Impact on NASA, Universities, and the Nation

The returns from all NASA university programs fall into the categories of new knowledge, trained people, or new capability for research, education, and service. The major impact of these returns is upon the participants. However, since NASA and universities are both parts of the Nation, anything that affects them also affects the Nation. The results of programs that affect the Nation outside the immediate areas of the participants generally are too obscure to be identifiable. Therefore, the emphasis of this study is on the new knowledge, trained people, and new capability that have impacted NASA and universities and, through them, the Nation.

General.- NASA's university programs have made major contributions to the aeronautics and space program. Research sponsored by university programs has generated new concepts, has developed new technology, and has created unique facilities for further education and research. Over 50 percent of all experiments flown on NASA satellites have been generated by university programs. Universities have awarded at least 500 graduate degrees and provided continuing education opportunities to thousands through NASA employee graduate training programs. Even management of the aerospace program has been influenced, since university consultants have given policy, scientific, and engineering advice to NASA at all levels. These contributions demonstrate that NASA university programs have been successful in their first and most important objective - obtaining the expertise of the university community to help meet the aeronautics and space goals of NASA and the Nation.

NASA university programs have had a significant impact on the university community. About 250 universities have been responsive to opportunities to become involved in the aeronautics and space program made available by NASA.

They have welcomed NASA support and have used it to strengthen and build research and education capability. Centers of excellence exist that were created with NASA support. Entire departments and graduate degree programs have grown out of NASA involvement, many new courses have been developed, and countless science and engineering courses have had their content altered by NASA programs. The national capability for education and research has been both broadened and strengthened.

In general, universities have not taken advantage of the opportunities offered by NASA to innovate in research management, multidisciplinary research, and government-industry-university relations. There is little evidence that the long-range goals of NASA university programs, such as the development of a university capability to respond as an institution, capability for multidisciplinary research, concern with societal problems, and acceleration of technology transfer, are being achieved. The examples that were identified - an Urban Laboratory at UCLA, the Industrial Development Division at the University of Michigan, Cornell's new Department of Environmental Systems Engineering, etc. - are only loosely tied to NASA programs. Sometimes they were unknown to, or unrecognized by, the scientists administering the NASA grants. It should be pointed out, however, that the dollars NASA has used to encourage change have come mostly from the Sustaining University research and facilities programs and have amounted to less than 1 percent of the total Federal support to universities. From this perspective, the changes that NASA university programs have stimulated in universities appear more significant.

NASA's university programs have built up a reservoir of good will within the university community toward the agency. University administrators generally perceive that NASA is sensitive to their needs and has undertaken a program to assist them with facilities, graduate student support, and institutional support grants. Generally, faculty members appreciate the opportunities for research and education that have been made available to them.

Industry has benefited from NASA university programs through the increased availability of trained people, new knowledge, and new capability. For the most part, however, industry-university relations do not appear to have been altered by NASA programs. Little evidence was found that universities are working harder at transferring technology to industry or have been successful in increasing industry support for university research.

Although NASA's stated policy is to conduct its programs in such a manner as not to draw faculty away from teaching, some of the research institutes, centers, and laboratories in universities have very few graduate students involved in the ongoing research. Some have full-time staffs of research professionals who neither teach nor supervise graduate students. Most universities that have such special research groups are aware of the problem and are attempting to find mechanisms to bring research closer to the educational process. Some are successful; some are not. Significant numbers of groups with little educational involvement still exist. NASA violates its own policies when it supports groups that continue to divorce themselves from the educational function of the university.

Project research.- About 70 percent of NASA funds obligated to universities has been by the project research method. This system of supporting the research of principal investigators within universities is serving both NASA and the universities well. Abuse of the system sometimes occurs (e.g., overcommitment by an agressive university researcher, demands for industrial-type response by a NASA contract monitor, or too little educational involvement). However, on balance, these are excellent programs that have contributed directly to the aerospace objectives of NASA. Project research also involves large numbers of faculty and graduate students and generates about three out of four of the space-science publications from all NASA programs. A large amount of education at all levels - undergraduate, graduate, and postdoctoral - is supported by these NASA programs. More than 10 percent of all funds supporting project research have been invested in equipment, which is available in university laboratories for further education and research.

Small project grants, which involve only one or two faculty members and their graduate students, have often led to productive interactions with NASA center personnel. Research on optimal control of nuclear rockets at the University of Arizona and ablation-material research at Louisiana State University are examples of projects through which NASA has received new concepts and techniques, the university has improved curricula and research and increased the number of publications, and technology is being transferred from universities to other segments of society. Larger project research grants, while producing valuable research, do not seem to foster development of as close a tie to the ongoing NASA program.

Space-science flight experimentation represents an area of significant accomplishment in NASA university programs. University scientists have been eager to take advantage of the opportunities made available by NASA to conduct experiments in space. More than 98 percent of balloon-borne experiments, more than 40 percent of sounding rocket experiments, and more than 50 percent of satellite experiments flown on NASA vehicles had principal investigators or coinvestigators in universities. For the satellite experiments, this is five times the level of participation of industry and about the same as the participation of all government laboratories. For the Orbiting Geophysical Observatory program alone, 50 percent of the flight experiments and almost two-thirds of the early scientific publications came from universities. A large share of the significant discoveries in space science were made in university-originated experiments.

Although the university community appears to have an effective voice in flight programs and selection of experiments through advisory committees, some university people complain about favoritism in the selection of flight experiments. Another continuing problem with university participation in flight experiments is involvement of graduate students. Long lead times and project uncertainties limit the suitability of flight programs for thesis projects. Universities have adopted various approaches to circumvent the difficulties, but NASA must continue to be aware of them and continue to seek administrative mechanisms that encourage participation of graduate students.

A university research program in R. & D. management and socioeconomics in aerospace-related areas has been NASA's only significant support of the social science disciplines. This program has been quite productive as measured by publications and involvement of faculty and students. Capability for research on management of large technological programs has been created in several universities and is now available to the Nation. However, few if any management or policy decisions or processes within NASA appear to have been influenced by the research. While some of the research may have had potential usefulness, NASA has no mechanism for utilizing its results. The program has had no centralized direction or policy and almost no involvement of the centers where many management problems occur. It may be significant that NASA has sponsored a university research program in these disciplines without a corresponding in-house research capability - a position it has carefully avoided in engineering and physical-science disciplines.

Sustaining University Program.- The Sustaining University Program, which provided about 30 percent of NASA funds obligated to universities and provides support to institutions rather than to principal investigators within universities, has generally been successful. Its short-range objectives - increasing the supply of trained manpower, increasing university involvement in aeronautics and space, broadening the base of competence, and consolidating closely related activities - have been achieved. However, the long-range goals that require innovation and change by universities - capability for multidisciplinary research, university concern with the technology-transfer process, increased university involvement with community and societal problems, developing capability for institutional response - have not been successfully attained. There are a few indications of change in the direction of long-range goals that may lead to future developments.

The aims and operation of the Sustaining University Program are poorly understood within NASA outside the Office of University Affairs. Only in the Office of Space Science and Applications, which formerly directed the program, are they reasonably well understood and felt to have value to NASA as a supplement to project research. In other Headquarters offices and in the Centers, no benefit to NASA is seen in the program. The Sustaining University Program grants are viewed as giveaways to help universities. The quality of research sponsored by the program is regarded as not good enough to obtain support in open competition. The impact on both NASA and universities would have been greater if the in-house managers had been involved and committed to the programs.

The Sustaining University Program has made grants for multidisciplinary space-related research to 50 universities. These grants were about 10 percent of the total research funds provided to universities by NASA. The grants achieved the objective of broadening the base of involvement and capability in aerospace research. They have contributed to the establishment of new departments (e.g., aerospace engineering or space sciences) and strengthened old ones (e.g., astronomy). Capabilities were nourished that have since successfully competed for research support from NASA project research and other Government agencies.

The multidisciplinary aspect of Sustaining University Program research grants has generally not been taken seriously by universities. The universities perceive the grants as institutional support in a conventional sense that does not require innovation in the administration of research. A contributing factor to this attitude is the lack of "systems" administrators in universities with broad views of real-world problems and the capability for breaking problems into small subsystems for attack by individual researchers. A small amount of multidisciplinary research that involves physical and life scientists and engineers is supported, but little of it was initiated under the grants. Research involving individuals from multiple disciplines, including social sciences, jointly attacking a multidisciplinary problem is nonexistent.

NASA has encouraged universities to involve social scientists in their research with little response. The small amount of social-science involvement that does exist is usually on a subproject that does not interact with other research.

Many of the individual researchers supported by Sustaining University Program research grants have no direct contact with NASA. If they know their counterparts in NASA, it is only by chance. While some of the scientists and engineers relish independence, many would welcome closer relations with NASA peers. Examples of interactions in project research illustrate the benefits that close relations could have for both universities and NASA.

A Sustaining University Program research grant in a university gives a focus to its aeronautics and space program that is not present in universities without such a grant. The steering committee which administers the grant seems to give identity and visibility to the total NASA program. The existence of this committee appears to give credence to NASA's concern for doing its business in a way that strengthens the university and is a step toward interdepartmental cooperation for multidisciplinary research. Key members of these committees tend to dominate the direction of the program for the total university.

The Sustaining University Program predoctoral traineeship grants to 152 universities accounted for about 15 percent of total NASA obligations to universities and have supported more than a thousand students who have earned Ph.D. degrees in space-related areas. By 1970, over 4,000 doctorates will have been earned by trainees. More than half of these highly trained scientists and engineers are remaining in universities and will contribute to the Nation through education and research for years to come. About a third of the former trainees are seeking industrial careers. Many of their skills are transferable to areas other than aerospace and will continue to benefit society and science whether or not they engage in aerospace research. Some evidence exists that traineeship grants have accelerated (as well as increased) the production of doctorates, but it is not conclusive except in the obvious cases of students who otherwise would have held part-time jobs.

The trainees tend to be isolated from NASA and have little opportunity to identify with the Agency. Since the program is administered by the individual universities, not even the stipend checks come from NASA. The Agency has overlooked an opportunity to communicate with the students, which is reflected by the statistic that only 1 percent of the Ph.D. recipients have been hired by NASA. This indicates very little direct impact on NASA by the traineeship program.

The traineeship-grant program has had little impact on large established graduate schools. Ten or 12 additional traineeships tend to get lost in universities such as Cornell or Michigan. However, traineeships were awarded to 152 universities, most of whom do not have the size or reputation of the two universities just mentioned. The grants have enabled the smaller and less well established universities to recruit more and better graduate students and to strengthen their graduate education programs.

The Sustaining University Program has made 35 facilities grants to 32 universities that have already resulted in 27 completed laboratories. The grants account for over 6 percent of NASA obligations to universities. The facilities are enabling universities to participate in aerospace programs more effectively by providing working space and by consolidating aerospace-related activities. They are being used to house interdisciplinary activities, usually in the form of an aerospace-related institute, center, or laboratory. Little evidence was found that technology-transfer processes or university interaction with the local or regional community had been stimulated by the facilities visited.

Little evidence was found that the Memorandums of Understanding associated with Sustaining University Program facilities grants have led to anything but talk. Usually only a few administrators within a university even knew about the Memorandum. They had not attempted to use it as a tool to induce changes in procedures or attitudes; they did not regard it as requiring them to do anything new or different. The major criticism which must be made is that universities have not made "energetic and organized" efforts to implement the Memorandums, which they clearly agreed to do.

Personnel development programs.- The temporary in-residence faculty programs (NASA-ASEE summer faculty fellowships, NASA-NRC resident research associates) are among the most rewarding of NASA university programs. NASA managers feel that the participants bring new talent and ideas into NASA projects and develop continuing relationships with NASA after they return to their schools. The participants like the programs for the exposure to real problems, for new ideas for research, and because they often provide a sponsor for their own research. Almost a thousand NASA-ASEE summer faculty fellows have spent 10 weeks during the summer working on real-world problems at a NASA center. More than 300 NASA-NRC postdoctoral research associates have had the opportunity to conduct research in a NASA center for at least 1 year. These programs have led to new research projects, curriculum modifications, and the creation of new centers of excellence. The acoustics program at North Carolina State University is just one outstanding example of impact on NASA, the university, and the Nation resulting from participation in these programs.

The employee training program has contributed in a major way to upgrading the capabilities of NASA personnel. Employees have earned about 400 master's degrees and 100 Ph.D. degrees by this method in recent years. Simultaneously, in meeting training needs, NASA centers have strengthened old departments and accelerated the creation of new departments in nearby universities. The graduate program in physics at the College of William and Mary is one example of stimulation of regional graduate-education capability to meet Langley Research Center's graduate training needs.

Alternatives for Future Consideration

The results of the study suggested many changes in procedures, policies, or approaches that would lead to more effective university programs. Many of these involve operational details and have been called to the attention of appropriate NASA managers. Only those of broad scope and general interest will be discussed here.

A substantial portion of Government-supported R. & D. management research within the country has been sponsored by NASA. However, NASA is not reaping full benefit from it because there is no mechanism for translating research into applications. In physical-science and engineering disciplines, university researchers interface with research-oriented NASA personnel who know how to disseminate and use their results. In the R. & D. management area, university researchers interface with NASA management practitioners with whom the researchers have difficulty communicating. Research-oriented management-science groups within NASA would be one approach to improving utilization of the sponsored research.

The Memorandums of Understanding associated with facilities grants have been ineffective in accomplishing change. The facilities may be a permanent symbol and reminder of NASA support, but NASA loses all leverage once the grant is awarded. Memorandums of Understanding might be more effective in inducing change if used in conjunction with institutional or multidisciplinary grants that have a renewal feature. University administrators could then use the threat of failure of renewal to influence faculty. NASA has recently begun to experiment with Memorandums associated with research and training grants and their effectiveness should be carefully evaluated.

Many NASA-university interactions have demonstrated that synergism occurs when personnel are in close communication. The element of close working relations has been missing from research sponsored by the Sustaining University Program. Therefore, the benefits to both NASA and universities from this research would be increased by closer ties with ongoing NASA programs. Individual researchers in universities need to communicate with their NASA peers and university administrators need more data on real NASA problems for decision-making in allocating grant resources. Therefore, centers and program offices should be participants - not advisors - and share responsibility in administration of Sustaining University Program research grants.

The mechanisms that have been established for bringing university faculty into NASA on a temporary basis are valued highly by NASA managers and by the participating university people. It is noteworthy that equivalent mechanisms permit NASA employees to enter the university community on a short-term basis but are not widely known or used. Many highly qualified NASA scientists, engineers, and managers could make significant contributions to universities in research, education, and administration, as well as increase their own understanding of university problems, if mechanisms could be developed for them to spend 6 months or a year as active participants - not students - in university programs. Exchange programs between universities and NASA should be encouraged.

Employee graduate-training programs should be considered as another method for meeting the Nation's need for highly educated scientists, engineers, and managers. Innovations in these programs could help offset the reduction in Ph.D. production that will come after 1970 as a result of decreases in Sustaining University Program traineeships. If the employee graduate-training programs could be expanded, NASA would benefit from the services of highly motivated and capable employees while at the same time giving them educational opportunities. In addition, if NASA's requirements for employee graduate training at nearby universities are large, financial support to the universities for facilities and faculty augmentation should be considered.

A requirement that annual reports on all grants and contracts summarize numbers of graduate students given full or partial support, theses supported, technical reports published, curriculum changes, facilities acquired, and degrees earned by students being supported would emphasize to universities NASA's desire to support research in an educational environment and would provide data to assess the program.

Continuous feedback on the effectiveness of university programs is needed by NASA management at all levels. A better management information system and reporting of educational impact of NASA programs would satisfy many requirements. However, periodic use of ad hoc groups, university consultants, and regularly scheduled conferences of the Office of University Affairs, Centers, and Program Offices will probably all be required.

INTRODUCTION

The National Aeronautics and Space Administration is a mission-oriented agency created by the Congress to achieve the national goals specified in the Space Act of 1958. To achieve them, NASA has involved and utilized all appropriate elements of our society. Since aeronautics and space programs involve the newest and most sophisticated sciences and technologies, universities were one of the components of society that had to participate. In addition, the space act specifically directed NASA to "arrange for participation of the scientific community." Since the scientific community and the university community overlap, and since the expertise within universities was essential to the accomplishment of its mission, NASA has cultivated relationships with universities from its inception.

A NASA university program is not a program per se, but a multifaceted set of complex interactions. Relationships have evolved among offices, programs, and centers of NASA, and the various institutions, administrations, faculties, disciplines, and students that make up the university community. They have been continuously modified, expanded, or contracted as the program has matured, immediate objectives have changed, or funding levels have been altered. However, the NASA-university interface has three distinguishable types of relationships. The first of these is the well-established project system of Government-university interaction whereby a Federal agency supports the work of a principal investigator within a university. A second type of relationship is represented by NASA's Sustaining University Program, most of which provides support to universities as institutions rather than to individuals within the university. The third type of NASA-university relationship involves the movement of people across the Government-university interface for training, consulting, and transfer of knowledge. In combination, these relationships make up <u>the</u> NASA university program.

Elements of the NASA university program are reviewed and assessed periodically as standard NASA management practice. For example, a training report is issued annually on accomplishments in upgrading employee abilities through graduate education in universities. Similarly, progress of research in universities is examined during annual reviews by cognizant NASA program offices. The mechanism of ad hoc groups has been used for in-depth examination of portions of the program - for instance, the committees which examined the response of universities to the Memorandum of Understanding associated with NASA facility grants. In addition, NASA management has utilized university consultants to provide feedback on university relationships. However, because of the magnitude and scope of the programs as well as their diffusion throughout NASA, a comprehensive assessment of university programs has not been attempted previously.

In order to evaluate the total university program, the Assistant Administrator for University Affairs appointed the Task Force to Assess NASA University Programs. The Task Force included representatives from most NASA centers and program offices, as well as consultants from the university community. Its objectives were (1) to determine returns to NASA, the universities, and the Nation from NASA university programs, (2) to assess these returns quantitatively and qualitatively, and (3) to determine alternatives to current NASA-university relationships that would increase the benefits accruing to each party. The basis of the Task Force's assessment was the goals of NASA university programs as expressed by its top managers. These goals have been recorded in the literature and in correspondence with universities. The study was carried out by selected sampling of NASA-university interactions through interviews, university visits, and case studies. Its findings are indicative of the total NASA university program and are summarized in this report.

CHAPTER I

SCOPE OF NASA UNIVERSITY PROGRAMS

The National Aeronautics and Space Administration interacts with the university community at every level of its organization. Nearly all major programs are influenced by concepts, problem solving, advice, or direct participation of university people. The entire national aeronautics and space program ultimately relies on professionals trained in universities to carry out its scientific, technological, and managerial tasks.

Relation to Total Federal University Support

Any assessment of the impact of NASA university programs must consider the NASA input to universities relative to the total Federal support. From the university viewpoint, NASA is one of many Federal agencies that provide dollars. Generally, all Federal dollars look alike. Figure 1 presents the data for four recent years. Although the number of NASA dollars increased from $75 million to $126 million during the period, NASA's relative contribution declined from

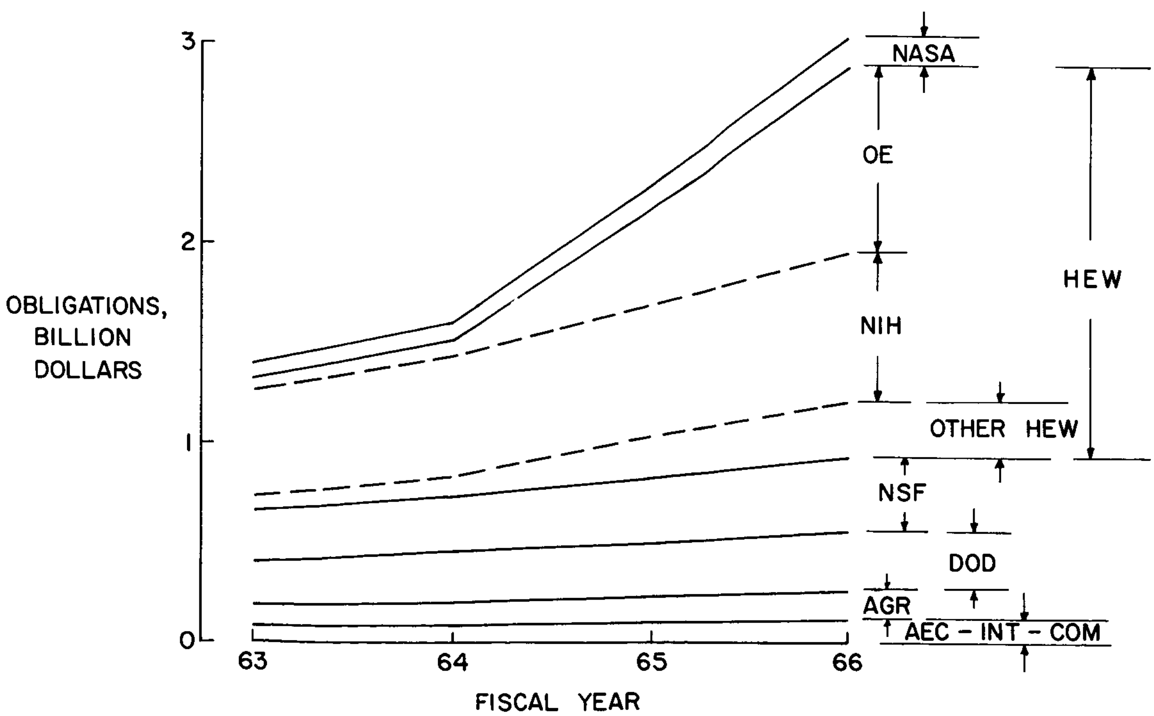

Figure 1.- Total Federal obligations to universities. (From table 2 of "Federal Support to Universities and Colleges, Fiscal Years 1963-66," NSF 67-14, National Science Foundation, 1967.)

5.3 percent to 4.2 percent. NASA has consistently ranked fifth behind Health, Education, and Welfare; National Science Foundation; Department of Defense; and Department of Agriculture as a source of university support.

The sudden increase in Office of Education obligations during the period tends to distort the relative positions of the agencies. If OE funds were omitted, NASA would still rank fifth, providing about 6 percent of the total support.

Total University Community Involvement

Total NASA obligations to universities are presented in table 1 for fiscal year 1959 through December 31, 1967. These data are from the NASA Status of Contracts and Grants (SCAG) ADP system. They show that NASA obligated over $660 million through its university program during the period. More than $194 million of this (29 percent) was through Sustaining University Program grants, which will be discussed subsequently. The remaining $472 million (71 percent) was obligated for project research and institutional support. (As used here, institutional support indicates such expenses as tuition, seminars, colloquia, and duplication of papers.) Less than 1 percent was obligated to foreign universities.

Two additional obligations shown in table 1 are not usually considered to be part of NASA's university program. The first is $1,325 million to the California Institute of Technology for operation of the Jet Propulsion Laboratory.

TABLE 1.- NASA OBLIGATIONS TO UNIVERSITIES

[FY 1959 through December 31, 1967]

SUP training	$101,905,135		
SUP facilities	42,633,992		
SUP research	49,621,329		
Sustaining university program grants		$194,160,456	
Project research - U.S. universities	467,440,226		
Project research - Foreign universities	5,095,885		
Total project research and institutional support		472,536,111	
Total university program			$ 666,696,567
JPL operations through CIT			1,325,100,000
Apollo guidance system through MIT			87,560,000
Total university expenditures			$2,079,356,567

The second is for $87 million to the Massachusetts Institute of Technology for design of the Apollo guidance and navigation system by the MIT Instrumentation Laboratory. These expenditures appear because the money passes through a university for activities usually referred to as Federal Contract Research Centers. They pay for services that usually fall outside the purview of universities and will not be examined in this study.

The decentralization of university business within NASA is illustrated in table 2, which shows the accumulated university obligations by its operational elements. More than 60 percent of the funds were obligated by Headquarters and about 11 percent by the Western Operations Office. The Goddard Space Flight Center, with its large program of university flight experiments, has obligated

TABLE 2.- DISTRIBUTION OF OBLIGATIONS TO UNIVERSITIES WITHIN NASA

[FY 1959 through December 31, 1967, excluding foreign universities]

Source of funds	Number of grants and contracts	Amount obligated	Percent of obligations
NASA Headquarters	3,942	$404,719,738	61.2
Western Operations Office	582	72,715,941	11.0
Ames Research Center	475	19,787,851	3.0
Lewis Research Center	322	5,889,472	.9
Langley Research Center	584	14,865,568	2.2
Flight Research Center	64	53,204	---
Electronics Research Center	233	6,664,187	1.0
Space Nuclear Propulsion Office (D.C.)	19	1,092,070	.2
Goddard Space Flight Center	992	84,925,182	12.8
Wallops Station	38	3,151,508	.5
Marshall Space Flight Center	1,074	23,337,233	3.5
Manned Spacecraft Center	656	23,805,243	3.6
Kennedy Space Center	98	593,485	.1
Total	9,079	$661,600,682	100.0

about 13 percent of the total funds. None of the other field centers has spent more than about 3.5 percent of the total. More than 9,000 contract or grant actions were involved in the program for an average of $73,000 per action.

Table 3 presents a further indication of the diversification of the program. The number of active grants and contracts as of December 31, 1967, are shown for all the centers and offices. Also shown are the number of universities holding these agreements. For example, the Office of Advanced Research and Technology had 279 grants or contracts with 98 different institutions. Of the more than 1,600 active grants and contracts, 1,063 (63 percent) were awarded by Headquarters offices. The large Headquarters offices are each sponsoring research in about 100 universities while a typical large center sponsors research in 40 or 50 institutions.

TABLE 3.- DISTRIBUTION OF ACTIVE GRANTS AND CONTRACTS WITHIN NASA

[December 31, 1967]

Program office or Center	Number of grants and contracts	Number of institutions
Headquarters, general	28	22
Advanced Research and Technology	279	98
Space Science and Applications	447	115
Manned Space Flight	12	11
University Affairs	251	156
Technology Utilization	44	21
Tracking and Data Acquisition	2	2
Total for Headquarters Offices	1,063	
Ames Research Center	86	49
Electronics Research Center	67	39
Flight Research Center	2	2
Goddard Space Flight Center	144	70
Kennedy Space Center	2	2
Langley Research Center	98	50
Lewis Research Center	48	36
Manned Spacecraft Center	89	40
Marshall Space Flight Center	74	29
Space Nuclear Propulsion Office (D.C.)	7	7
Wallops Station	4	4
Western Operations Office	2	2
Total	1,686	[a]218

[a]Column does not add to total because of duplications.

Individual Programs

Individual university programs have developed to meet both specific and general needs of NASA and the universities. They will be discussed in three categories, although there is considerable overlap.

Project research program.- The project research system is used to support investigations into a single problem or several closely related problems associated with some concept or phenomenon of concern to NASA in conducting the aeronautics and space program. Grants or contracts are awarded to a university for the research of a designated principal investigator. Table 1 indicates that over two-thirds of all obligations to universities were of this type. It includes supporting research and technology in disciplines such as engineering and physical, life, social, and management sciences. It also includes contract support for developing space-flight experiments and for services involving spacecraft tracking and data acquisition and technology utilization.

While this type of program is aimed primarily at obtaining the expertise of university people for aeronautics and space research, elements other than research become involved. For instance, research projects often require that specialized facilities be acquired, which remain in the university for further research or educational activities. In some cases, surplus NASA equipment, such as analog computers and even wind tunnels, have been transferred to universities. A vast amount of training is also accomplished through the project system, since much of the actual research is carried out by graduate students. In addition, postdoctoral study, which has become almost a requirement for serious research in some physical and life sciences, is largely financed in this manner.

Sustaining University Program.- The Sustaining University Program was designed to broaden the base of participation in the aeronautics and space program, to meet special needs of universities already heavily engaged in aeronautics and space research, and to achieve long-range objectives of NASA. It consists primarily of three types of grants (training, facilities, and research). The total investment by NASA is shown in table 1. Training grants totaling 5,414 three-year predoctoral traineeships in space-related disciplines have been awarded to 152 universities at a cost of more than $100 million. Thirty-five facilities grants have been awarded to 32 universities at a cost of about $43 million to build specialized and general-purpose space-research facilities. The research component of SUP has invested about $50 million in 50 grants to institutions for multidisciplinary research activity. The research grants differ from project research grants in that they are given to an institution, rather than to a principal investigator, and permit the university to manage the grant with freedom to approve individual projects and allocate resources.

Personnel programs.- People move in both directions through the Government-university interface for education, consulting, and transfer of knowledge. For example, employee training programs take advantage of the educational services of universities to upgrade and update staff qualifications. NASA employs large numbers of undergraduate and some graduate cooperative students. NASA sponsors four 6-week Summer Institutes in Space Science and Technology for nationally selected undergraduates in universities each year. Postdoctoral study is encouraged through the Resident Research Associateship program, administered by the National Academy of Sciences-National Research Council, for resident research at NASA centers and the post-M.D. program in aerospace medicine at Ohio State or Harvard University. The Summer Faculty Fellowship Program, administered by the American Society for Engineering Education, brings young faculty members to NASA centers for 10 weeks of research or engineering-system study each summer.

Many additional interactions have evolved to meet specific needs. Consulting relationships fall in this category, as do scientific advisory groups. The Space Science Board is the most prestigious example. NASA relies upon the Board for outside advice and feedback. Conversely, NASA employees often become adjunct faculty members at nearby universities, teaching and directing research of graduate students. Personnel move in both directions to give seminars and colloquia and, more recently, NASA is opening its doors to university researchers who wish to use it as a laboratory for research in management and organizational behavior. Such programs have significant impact upon the agency and universities because of the large numbers of people involved.

CHAPTER II

APPROACH TO THE STUDY

Four approaches were used to assemble data on the impact and accomplishments of NASA university programs. First, existing numerical data from NASA sources were compiled. Then qualitative information was collected in interviews with NASA managers and visits to the university community. Finally, case studies were developed to focus sharply on specific portions of the university program. The data were assessed on the general basis of the goals of NASA university programs as publicly expressed by NASA managers and as recorded in the open literature and correspondence with universities.

Compilation of Available Data

Much information on university programs that exists within NASA program offices has never been specifically identified as university data and brought together. Such data can provide answers to questions about the involvement of university faculty and graduate students, equipment purchased for use in universities, participation in flight experiments, numbers of publications, and numbers of graduate students supported. The data exist on computer tapes, in project files, and in private files of program chiefs and technical monitors. While it was impossible to collect all such information, selected samples were collected that indicate the magnitude of university involvement with the aeronautics and space program.

Management Interviews

The second approach to the assessment of university programs was interviews with NASA managers. Unstructured interviews 1 to 2 hours long were held with about 55 senior and middle managers in 40 separate sessions. They were conducted by three Task Force members, singly or in two-man teams, in order to provide continuity between interviews. The discussions during the interviews ranged over the entire spectrum of NASA-university relationships in order to determine perceptions of existing university programs; returns from these programs to NASA, universities, and the Nation; and attitudes toward universities as an element of the aeronautics and space program. Managers interviewed were from NASA Headquarters, Goddard Space Flight Center, Langley Research Center, and Manned Spacecraft Center, and represented a wide range of disciplines and functions. Numerous informal discussions with other NASA personnel also contributed to the picture of in-house attitudes and perceptions that emerged.

University Visits

Much of the data about NASA university programs can be obtained only within the universities themselves. Five universities were visited by a team representing the Task Force. The five were the Universities of Arizona, California at Los Angeles, Cornell, Florida, and Michigan. They were selected as representative of universities heavily involved in the aeronautics and space program (each has received more than $5 million of NASA support) and covering a range in academic standing, geography, size, and total Federal support. All five universities had received facilities and traineeship grants from the Sustaining University Program, but only three had received multidisciplinary research grants. One university had been visited by a NASA assessment committee 2 years previously. Four of the universities were public institutions; one was operated privately.

The visiting team comprised three Task Force representatives, one of whom was from a university, and a staff member of the National Academy of Public Administration. The team spent 2 days at each university seeking qualitative data on the impact of NASA university programs from administrators, faculty, and graduate students. Topics such as impact on faculty and curricula, graduate student support, multidisciplinary research, university response to the Memorandums of Understanding, and capability for research on societal problems were discussed.

Case Studies

The case studies were intended as in-depth examinations of portions of the total NASA university program. They were individual efforts by Task Force members and varied widely in methodology and coverage. Four studies examined the impact of NASA university programs on particular disciplines; they were space power and electric propulsion, fluid mechanics, astronomy, and socio-economic research. The two case studies that covered employee training programs and in-residence programs brought together the relevant NASA-wide statistics and then focused particularly on one NASA center. Another case study focused on the Orbiting Geophysical Observatory (OGO) program as an example of NASA-university interaction in the flight experiment area. Another compiled data on the Apollo guidance and navigation contract with the Instrumentation Laboratory of MIT. The summary report draws heavily on data from these in-depth studies.

Limitations

The major limitations of the study are those imposed by the constraints of time and people for collecting information on such huge and diverse programs. Sample sizes were small. In addition, records from the early years are incomplete, and valuable background information has been lost through personnel transfers.

The five universities visited may not be representative of the approximately 250 universities with which NASA has interacted. Noticeably absent from the sample of universities are smaller universities and universities that have developed close ties with NASA centers. A number of special university relationships, such as the Goddard Institute for Space Sciences and the Virginia Associated Research Center, are not included in the study.

The disciplines and technology areas selected for case studies certainly do not cover the complete spectrum of involvement. For example, it would have been desirable to have covered at least one life-science discipline. And numerous individual interactions, such as consulting, lecturing, and service on advisory and study committees, which have great influence on policies and execution of the aeronautics and space program and enrich the campus activities of the participants, have not been adequately covered.

No attempt has been made to assess the Technology Utilization Program. While that program has been partially implemented through university-operated centers, it is a study in and of itself.

No special consideration has been given to foreign universities in this study. However, there is considerable interaction with them even though the amount of money involved is not large. Part of this interaction is through the project research system and involves flight experiments and sponsored research. Another part of the interaction is through two personnel exchange programs administered for NASA by the National Academy of Sciences. One, the International Fellowship Program, brings foreign nationals to American universities for graduate and predoctoral study in space sciences. The other, the Resident Research Associateship Program, involves postdoctoral studies in NASA centers. It is not primarily an international program but, in practice, about two-thirds of the associates have been foreign nationals.

CHAPTER III

PROJECT RESEARCH PROGRAMS

About two-thirds of the money that NASA has invested in universities has been through the project system. The project system is characterized by grants or contracts to individual faculty members by a Federal agency for investigations of a single problem or several closely related problems associated with some concept or phenomenon. Some of the results from these types of interactions, including indirect returns to universities and society, are discussed in this chapter.

Goals

Project-system grants and contracts have been designed to enlist the expertise of the best scientific and technical minds in the country in solving problems of aeronautics and space exploration and to create opportunities for universities to participate in space experimentation. It would be impossible for NASA to achieve its objectives, as stated in the National Aeronautics and Space Act of 1958, for "the expansion of human knowledge," for "the preservation of the role of the United States as a leader in aeronautical and space science and technology," and for "the most effective utilization of the scientific and engineering resources" without the participation of university scientists and engineers. However, it has also been the policy of NASA, as stated repeatedly by its administrators, to accomplish its aeronautics and space mission in such a way as to strengthen the universities with whom it dealt. Therefore, a NASA goal has been to sponsor research in the traditional atmosphere of instruction and learning, while keeping the research surrounded by students.

Research Grants and Contracts

Research grants and contracts, sponsored by every office and center of NASA, involve a variety of disciplines and vary in purpose from basic research to routine services.

Perceptions of university programs.- The NASA managers who use university grants and contracts perceive them in many ways. The most obvious attitude is that of the space scientists who consider themselves to be part of the academic and scientific community. They see university programs as a way to build and retain ties with their peers in universities. They regard the university research environment as ideal. Research is viewed as an attack on the frontiers of knowledge in which university and NASA scientists participate as equals.

The attitudes of NASA project and operations personnel are quite different. They regard universities as simply another group with which to do business. A university is seen as a resource to be used in accomplishing a job and is expected to conform to NASA requirements for schedule and performance.

The attitudes of engineers and technologists lie between those of the other groups. They see universities as a source of competence that can sometimes be helpful in solving problems. Although universities are regarded as being different from other sources of competence, they should be utilized within the context of the NASA mission or NASA research program.

Indicators of returns from research.- There is no simple way to assess returns from research. However, there are indicators that give an idea of the impact of NASA-sponsored research in universities, such as faculty and student involvement, equipment purchased, publications, graduate degrees earned, and curriculum changes.

Various approaches have been used in this study to evaluate results. For example, table 4 presents aggregated expenses reported by 151 educational

TABLE 4.– UNIVERSITY USE OF FUNDS FROM NASA GRANTS AND CONTRACTS[a]

Use	Charges	Percent of total
Materials and supplies	$ 38,492,854	15.0
Travel costs	5,858,987	2.3
Other expenses	15,751,203	6.1
Personnel services[b]	112,535,958	43.9
Equipment	29,733,178	11.6
Subcontracts	11,733,108	4.6
Overhead	42,310,520	16.5
Total	$256,415,808	100.0

[a]These data are aggregated from a sample of 1500 Financial Management reports from 151 separate educational institutions.

[b]Nineteen institutions did not report man-months charged. However, if charges for personnel services are used as a basis for extrapolating the reports of the other 132 institutions, the $112 million was paid for 11,500 man-years of effort.

institutions from about 1,500 Financial Management reports for the years 1964 through 1967. Almost 12 percent of the $250 million reported ($30 million) was used to purchase equipment ranging from voltmeters to computers. This represents a significant capital investment in laboratory equipment available for further research and education. Forty-four percent of the money paid salaries for about 11,500 man-years of effort by faculty members, postdoctoral fellows, graduate and undergraduate students, full-time professional staff, and technicians.

A more detailed examination of a smaller sample of grants and contracts was made at the Ames Research Center. The results (table 5) show that more

TABLE 5.- GRANTS AND CONTRACTS AT AMES RESEARCH CENTER

Number of grants	80
University staff involved	114
Students involved	216
Reports published	448
Total investment	$14,320,000
Invested in equipment	$ 1,468,000

TABLE 6.- SIGNIFICANT SPACE SCIENCE PUBLICATIONS, BY DISCIPLINE

[1958 through half of 1967]

Discipline	Publications from universities	Total publications	Percent from universities
Astronomy	178	225	79
Solar Physics	95	143	66
Particles and Fields	234	333	70
Ionospheres and Radio Physics	147	198	74
Cometary Physics and Dust	23	38	60
Planetary Atmospheres	94	216	43
Planetology	119	233	51
Meteorology	76	216	35
Bioscience	1,376	1,571	88
Total	2,342	3,173	74

TABLE 7.- SIGNIFICANT SPACE SCIENCE PUBLICATIONS, BY YEAR

Year	Publications from universities	Total publications	Percent from universities
1958	7	16	44
1959	21	38	55
1960	34	69	49
1961	52	102	51
1962	109	171	64
1963	211	295	72
1964	321	483	67
1965	513	663	77
1966	708	861	82
1967 (half)	366	475	77
Total	2,342	3,173	74

than 10 percent has been invested in equipment. About two students were working on the grants for every university staff member. And more than five papers per grant have been published.

The number of publications resulting from a research effort is one method of ascertaining productivity. Tables 6 and 7 show "significant publications" in space sciences from the Space Sciences and Applications Program during the period 1958 through June 1967 by discipline and by year. A "significant publication" is defined as one cited in the OSSA series, "Significant Achievements in Space Science," and thus reflects the judgment of the discipline program chiefs. University papers accounted for about one-half the publications in 1958, but by 1967 more than 75 percent originated in universities. While the significance of the number of papers may be questioned, the rate of university publication in space sciences increased by two orders of magnitude during the period. Thus, it may be concluded that the objective of increasing the involvement of university scientists in the aeronautics and space program has been achieved.

Space power and electric propulsion research.- Research on the technology of space power and electric propulsion was selected for detailed study as representative of a group of grant and contract relationships. Total input to this research program has been about $183 million, of which $111 million (60 percent) was obligated through Lewis Research Center. Only $8 million (less than 5 percent) was spent through 84 university grants and contracts. Lewis Research Center obligated $3 million (less than 3 percent) in this technology area to universities. About 60 percent of the total resources supported industry contracts, and 35 percent was spent for in-house projects.

An assessment of the 29 grants and contracts funded by Lewis Research Center revealed that almost 15 percent of the funds went into equipment. An average grant or contract was for $110,000 and lasted about 2.5 years. It involved two faculty members, a research associate, and five students. About 1.5 master's and 1.2 Ph.D. degrees were earned by students who were at least partially supported by the grant or contract. More than seven publications were produced. Table 8 summarizes the findings.

The technical monitors reported that NASA-university interaction had been beneficial to NASA on 70 percent of the grants and contracts; that is, the research had influenced or redirected in-house research or development. Only five of the grants and contracts were felt to have made no impact on other NASA work.

TABLE 8.- SPACE POWER AND ELECTRICAL PROPULSION GRANTS AND CONTRACTS

SPONSORED BY LEWIS RESEARCH CENTER

	Number	Funding
Grants	24	$2,233,426
Contracts	5	978,680
Total	29	$3,212,106
Equipment purchased		$ 473,326

University involvement:	
Universities	21
Faculty (including 4 ASEE summer faculty fellows)	59
Research associates	28
Students	151
Degrees earned:	
Ph.D. degrees	35
Master's degrees	42
Publications (excluding progress reports)	218
Interaction with NASA:	
Good	21
Moderate	3
Poor	0
None	5

A more comprehensive assessment was made of seven of the 29 grants and contracts. In five cases, the technical monitors were able to point to specific contributions, other than a general increase in knowledge, made to NASA programs. In six cases, equipment (much of it unique) was purchased or constructed that remains in the university laboratory. Nearly all the research was considered to be of high quality. One of the recipients of a Ph.D. degree supported by one of the grants is now an Electronics Research Center employee.

One of the seven grants examined in detail was to American University and has contributed substantially to a new graduate degree program in electrochemistry. The grant funded a research professor for his first year, led to two new courses in electrochemistry, and provided research support for the initial group of master's degree candidates. The technical monitor reported that the research became increasingly sophisticated as the grant progressed. This appears to be a substantial contribution to the development of new capability for education and research.

Fluid dynamics research.- University research in the technology of fluid dynamics was also examined. The total NASA investment through grants and contracts is shown in table 9. The current annual level of NASA investment in fluid dynamics is about $11 million, of which approximately $5 million is for research and development. Of the $11 million, 9 percent ($1 million) is in university research, 73 percent ($8 million) goes for in-house activities, and the remainder is contracted to non-university laboratories.

The views of university faculty members and NASA managers active in fluid dynamics research were solicited. The program managers point out that individuals with creative, timely ideas are supported regardless of institutional affiliation. Thus, university research is not regarded as a separate entity within the program. They also point out that the fluid dynamics research

TABLE 9.- GRANTS AND CONTRACTS FOR FLUID DYNAMICS RESEARCH

Source of funds	Number of grants and contracts	Number of universities	Cumulative obligations
NASA Headquarters	70	40	$8,456,000
Ames Research Center	5	5	200,000
Langley Research Center	7	5	455,000
Lewis Research Center	2	2	386,000
Marshall Space Flight Center	2	2	18,000
Total	86	[a]46	$9,515,000

[a]Column does not total to 46 because of duplications.

program is directed toward problems relevant to the future needs of NASA. Other fluid dynamics research has been performed under the Sustaining University Program which is not necessarily directed toward problems relevant to NASA's needs and is not included in the above totals. Although the SUP research has helped train students, NASA project-research managers do not think it has contributed significantly to NASA research goals in the fluid dynamics area.

Many contributions to NASA goals are reported for the directed research program. For example, a relatively new program of basic fluid-dynamics research into the sonic-boom phenomena has already generated new concepts. Research on explosions, combustions, and combustion instability conducted at the University of California at Berkeley, University of Michigan, University of Wisconsin, and Princeton University has contributed to the understanding of the behavior of acoustic liners of rocket engines and to a practical new concept in the use of rocket-engine acoustic absorbers. Noteworthy contributions in the fluid dynamics of planetary entry have been made by university researchers over the past decade, also. Just one example is University of Maryland research on intermolecular potentials, which was needed to understand energy transport mechanisms between a hot gas cap and the surface of an entry vehicle.

The impact of fluid dynamics research support upon the universities involved has been different in each case. In the universities having strong, long-established programs, NASA support has helped shape curricula and research, but has not impacted the university otherwise. At universities that lacked a strong fluid dynamics program, the effect has been marked. The research requires an interdisciplinary approach that has led to a completely revised academic course structure. During the past decade, fluid dynamics curricula have changed from conventional aerodynamics and heat-transfer courses to course work in atomic and molecular physics, chemically reacting boundary layers, quantum mechanics, radiative gas dynamics, hypersonic flow, kinetic theory, plasma dynamics, and experimental plasma physics, which reflect the needs of NASA research. The transformation has been so complete that in some universities the graduating student is well grounded in aerophysics but deficient in conventional aeronautics. Since the emphasis is shifting back toward aeronautics problems, it appears that universities may have been too responsive to NASA's needs. Reorientation of their research and curricula may again be necessary.

Some multidisciplinary working arrangements have been instigated by fluid dynamics research support, although results are spotty. Stanford University has increased interdepartmental cooperation by the establishment of the Institute for Plasma Research, incorporating three laboratories from three departments. Similar relationships exist at Cornell and Princeton. However, at some universities such arrangements are reported to be only marginally successful; at still others, interdepartmental cooperation has not been obtained at all.

Generally, NASA's university record in fluid dynamics is good. Suggestions from a principal investigator at MIT closed with the comments, ". . . NASA has done its job well and enjoys a good reputation on campus for knowledgeable support of research. It has a clear idea of its needs and is willing to support good research which helps it meet those needs. It also says 'No' and 'Stop' when the research is no longer of interest. I know of no shoddy research which NASA has supported. It is hard to be critical of such a record."

Research in astronomy.- NASA university programs have influenced the science of astronomy in three main areas. First, NASA funding has had a significant effect on graduate school enrollment and Ph.D. production. Second, NASA support for astronomical research in universities has resulted in a general stimulation of activities leading to scientific advances, raised the prestige and status of astronomy research in the university community, and developed new applications for astronomy research. Finally, NASA support has brought significant advances in at least two new areas - X-ray astronomy and infrared astronomy.

The space program generally appears to have contributed to an increase in graduate school enrollment in astronomy apart from specific NASA funding. Table 10 presents the results of a survey of four representative astronomy departments, which show an uneven but rising trend in graduate school enrollment beginning in 1961-62. Presumably this increase can be traced to the stimulation of undergraduates by Sputnik in 1957.

A major factor in increased graduate student enrollment and Ph.D. production is the financial assistance available to graduate students in astronomy through NASA university programs. During the years 1964-1967, NASA project grants supported an average of 77 graduate students per year engaged in research in astrophysics or astronomy. If the average time required to earn a Ph.D. degree is 4 years, this level of graduate student support corresponds to a Ph.D. production rate of 19 per year in 1966-67. In addition, seven doctorates in astronomy resulted from the Sustaining University predoctoral traineeship program in 1966-67. Thus, by 1966-67, NASA university programs were supporting 26 new Ph.D.'s per year in astronomy. The national annual production of doctorates in astronomy and astrophysics, based on National Research Council data, is shown in figure 2. Prior to 1961, the average

TABLE 10.- GRADUATE STUDENT ENROLLMENT AND Ph.D. DEGREES AWARDED

IN ASTRONOMY AND ASTROPHYSICS AT FOUR UNIVERSITIES

Academic year	Univ. of Indiana		Harvard University		Univ. of Michigan		Univ. of California at Berkeley	
	Graduate students	Ph.D. degrees	Graduate students	Ph.D. degrees	Graduate students	Ph.D. degrees	Graduate students	Ph.D. degrees
1955-56		2	24	4	15	0	20	4
1956-57	15	1	21	8	18	1	20	3
1957-58		0	22	1	16	4	22	1
1958-59		3	19	6	20	3	18	5
1959-60	23	0	25	1	22	1	21	1
1960-61	27	0	27	2	27	0	23	0
1961-62	24	2	36	2	24	4	31	2
1962-63	25	2	34	5	26	3	37	1
1963-64	24	2	39	1	33	2	41	6
1964-65	33	2	46	7	35	6	44	4
1965-66	29	2	42	5	34	3	42	4
1966-67	29	2	47	3	35	4	42	10

national output was about 16 Ph.D.'s per year. By 1967, this output had more than quadrupled, although the 26 students that NASA supported account for only about one-half of the increment in output.

The sources of support for all new astronomy Ph.D.'s in 1966-67 are shown in table 11. NASA university programs have supported almost 40 percent of the Nation's new Ph.D.'s in astronomy. However, the rate of Ph.D. production increased around 1961, as shown in figure 2, before the direct effects of NASA support could have influenced output, since 3 to 5 years are required to earn a Ph.D. degree. Therefore, much of the increased output must be credited to stimulation of interest in astronomy by space activities, and not directly to NASA programs per se.

NASA support of astronomy research has generally stimulated astronomy departments. In particular, new and vigorous research efforts developed where astronomical facilities were fully or partially supported by NASA; e.g., the University of Texas, University of Arizona, University of Michigan, UCLA, and Columbia University. In addition, a new dimension has been added to astronomical research in universities by providing astronomers with opportunities to fly instruments on high-altitude aircraft, balloons, sounding rockets, and satellites.

X-ray astronomy received its impetus from the original discovery of X-ray sources through sounding-rocket experiments funded by NASA in 1960 through 1962. Since the energy emitted by X-ray sources is strongly absorbed by the atmosphere, only observations made from the uppermost fringes of the atmosphere or from satellites are meaningful. Thus, a major portion of knowledge in X-ray astronomy is a direct result of space experiments stimulated and funded by NASA.

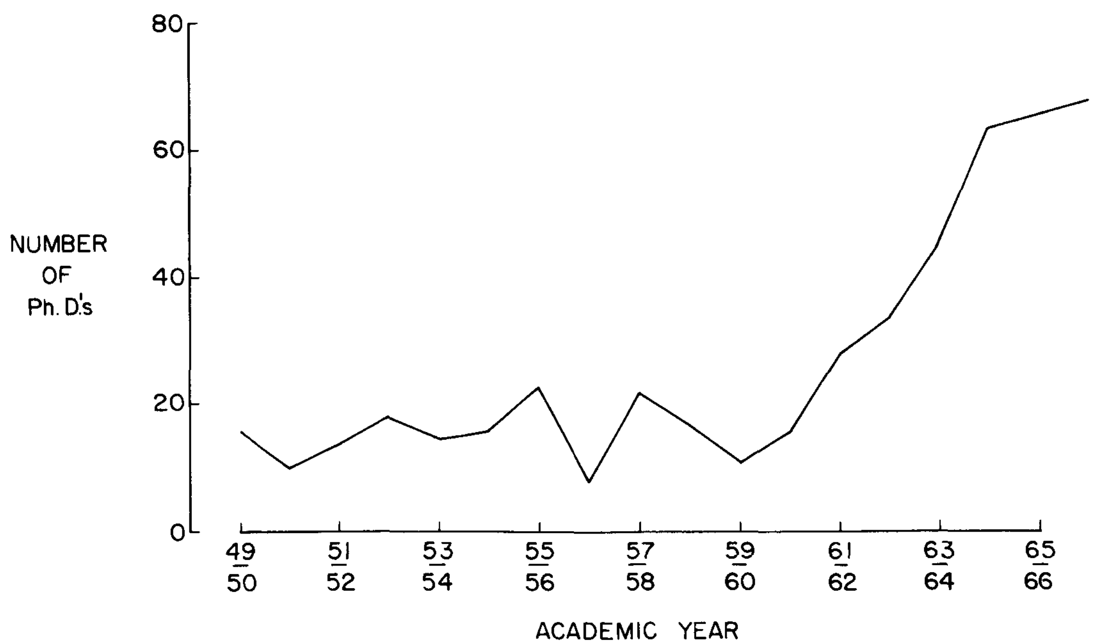

Figure 2.- Annual production of Ph.D.'s in astronomy in the United States.

TABLE 11.- SOURCES OF SUPPORT FOR ALL CANDIDATES RECEIVING

Ph.D. DEGREES IN ASTRONOMY IN 1966-67

NASA	26
NSF	20
USAF (estimated)	5
U.S. Navy	9
Carnegie	4
Other (estimated)	2
Total	66

(The Air Force, Navy, and NSF have funded research in this area, also.) The discovery of X-ray sources has since led to the search for optical counterparts and interaction between ground-based and flight-based astronomy.

Since satellites have the greatest potential for gathering data on infrared sources, NASA activity and funding have helped to open up and develop the new field of infrared astronomy. NASA has also supported ground, aircraft, and balloon measurements where spectral windows permit adequate observations in the infrared. Since quasars emit most of their energy in the infrared, the study of these significant objects has been particularly stimulated. Another example of a discovery in infrared astronomy, partially supported by NASA and illustrating the scientific importance of the new field, is data showing that infrared energy radiated from Jupiter is greater than that received from the Sun. The explanation of this phenomenon will shed new light on problems of planetary formation and history. A final example is the discovery of a large region of infrared emission surrounding three red giant stars, including Betelgeuse, the brightest of the red giants. These regions are about 10 times the diameter of the solar system, and some of the major puzzles of stellar evolution may be resolved through their study.

R. & D. management and socioeconomic research.- NASA has sponsored research at a number of leading universities in research and development management and socioeconomics. About $4.75 million has been invested in this research since the first grant to MIT in 1962. It is the only sizable NASA program of sponsored research in the social sciences. Its rationale is that management of large and complex research and development activities is as important to success as technical performance. Examples of the projects sponsored are research into the R. & D. management process itself; socioeconomic studies of the impact of technological programs in general, and the space program in particular, on the national economy; and studies of applications of NASA management techniques to nonaerospace endeavors. The programs represent the first attempt by a Government agency to involve the university community in research and analysis on the complex managerial and policy issues confronting the agency. The research has been supported and directed by NASA Headquarters; the centers have not been involved, except as the loci for particular studies by some of the university researchers.

TABLE 12.- R. & D. MANAGEMENT AND SOCIOECONOMIC RESEARCH GRANTS

[Through December 31, 1967]

Grant	Institution	Cost	Period	Number of researchers		Productivity			Ratio of graduate students to faculty members	Ratio of dollars to publications
				Faculty	Graduate	Reports and books	Master's degrees	Ph.D. degrees		
NSG-727	George Washington University	$1,551,000	5/65-8/70	16	11	67	[a]5	12	0.70/1	23,000/1
NSG-243-63	University of California, Berkeley	1,110,000	2/63-1/70	20	44	92	11	17	2.2/1	12,000/1
NSG-235	Massachusetts Institute of Technology	921,000	1/62-1/68	24	122	92	[b]100	12	5/1	10,000/1
NSG-342	Washington University, St. Louis	450,000	6/63-6/68	12	30	50	3	4	2.5/1	9,000/1
NGR-05-003-125	University of California, Berkeley	223,000	1/66-7/68	8	19	12	9	10	2/1	18,000/1
NSG-495	Northwestern University	220,000	8/65-7/69	5	36	70	15	5	7.2/1	3,000/1
NSG-237-62/ NGR-05-007-090	University of California, Los Angeles	125,000	7/63-6/68	8	35	25	23	12	4.3/1	5,000/1
NGR-23-005-116	University of Michigan	74,000	12/65-10/67	6	3	7	0	1	0.5/1	10,500/1
NGR-22-004-116	Boston University	50,000	9/66-12/67	1	(c)	(c)	0	0	(c)	(c)
NSG-498	University of Michigan	29,000	7/63-8/66	.5	1	6	0	1	2/1	5,000/1
Total		$4,753,000		100.5	301	421	166	74	3.0/1	11,000/1

[a]Includes 3 LL.B. degrees.

[b]Includes 52 M.S. degrees awarded Sloan fellows.

[c]Figures unavailable.

The results of research in this area were examined by means of interviews with NASA technical monitors, questionnaires to most principal investigators, and searches of the official grant files. In addition, interviews were conducted with people within NASA and the university community who are knowledgeable about the content and scope of the program. The study covered only those grants where there was large involvement of both NASA and the university. It did not include the few grants that were essentially the work of one man with little or no involvement of the university as an institution. The Sustaining University Program research grants have also produced a few management-oriented studies, which were not covered.

Returns from the grants are summarized in table 12. Six of the grants were monitored by the Office of Policy, three by the Office of Technology Utilization, and one by the Office of University Affairs. The average grant in this program has received about $475,000 over a 4-year period. It involved 10 faculty and 30 graduate student researchers, who produced more than 40 publications, while providing partial support to students who earned over 16 Master's and 7 Ph.D. degrees. Since one-half of the grants spanned at least a 5-year period, relatively stable funding has been provided. The 3 to 1 ratio of graduate students to faculty demonstrates that there was a high degree of student involvement in the research.

A number of key NASA personnel, both in Headquarters and in Centers, were asked to rank six of the major grants along two dimensions: impact on the university and relevance to (or impact on) NASA. While these rankings are subjective, they provide an indication of how responsible NASA officials view the results and value of the work done:

	Impact on the university		Relevance to (impact on) NASA
1.	George Washington University (NSG-727)	1.	Washington University, St. Louis (NSG-342)
2.	Washington University, St. Louis (NSG-342)	2.	Northwestern University (NSG-495)
3.	Massachusetts Institute of Technology (NSG-235)	3.	George Washington University (NSG-727)
4.	University of California, Berkeley (NSG-243-63)	4.	University of California, Los Angeles (NSG-237-62)
5.	University of California, Los Angeles (NSG-237-62)	5.	Massachusetts Institute of Technology (NSG-235)
6.	Northwestern University (NSG-495)	6.	University of California, Berkeley (NSG-243-63)

The rankings show that the most balanced grants are those at George Washington University and Washington University, St. Louis. It should be pointed out, however, that the George Washington University ranking was based more on promise than accomplishment, while the Washington University program was judged solely on accomplishments.

As a multidisciplinary approach to research, the effort at the University of California at Berkeley under NSG-243-63 is perhaps the strongest, followed by the George Washington University and UCLA grants in that order. The George Washington University grant has been most effective in involving the university as a whole in its research. None of the other grants really involved the entire university to any substantive degree.

The administration of the R. & D. management and socioeconomic research program has been inadequate. There has never been a single point of contact or a home for this program within NASA Headquarters. A number of organizations have sponsored or monitored particular grants, but no one organization has attempted to establish a coherent policy. Although much of the direction came from the Administrator's Office, the agency did not establish guidelines for the program. As a result, several of the principal investigators complained of a gap between policies and direction expressed by the Administrator and the resulting administration of grants by technical monitors. One investigator felt that lower level NASA organizations were too concerned with short-term relevance to NASA rather than with long-range impact on the Nation.

There has been only limited and sporadic involvement of the NASA centers in this program. Since about 90 percent of NASA's funds are distributed by the centers, it could be assumed that a proportionate number of management problems and innovations would be found at that level. However, this apparently has not been recognized by either NASA or universities in the program.

Only Northwestern, George Washington University, and, to some extent, MIT have based their programs on field research. Other universities have missed opportunities to conduct real-time research on the operations and organizations of the space program. (The Washington University effort is an exception in that its research did not need to be tied to NASA organizations.) Both NASA and the universities would probably have benefited from additional interaction between their personnel.

Most of the reports and data emanating from R. & D. management and socioeconomic grants do not find their way to line and program managers within NASA. No technique for identifying interested in-house managers or for disseminating research data in this area has been developed. Even when information reaches managers, little is communicated because of the difference in outlook of the researcher and the manager. A research-oriented management-science group within NASA could be one approach to the communications problem. It is significant that NASA has attempted a university research program in this area without an in-house research capability - the antithesis of its approach to engineering and to physical and life sciences.

In summary, the R. & D. management and socioeconomic research program has benefited universities by training faculty members and supporting graduate students. Society as a whole has benefited, in that capability has been created in several universities for R. & D. management research programs. However, NASA appears to have given more than it has received. Few, if any, management or policy decisions or processes in NASA have been influenced, aided, or improved as a result of research by universities. In certain cases, particularly with respect to George Washington University work at Headquarters and Northwestern University research in centers, potential exists for future impact.

Individual research grants and contracts.- There are many examples of grants and contracts that illustrate impact on both NASA and universities. One such grant, at the University of Arizona, is "Application of Modern Automatic Control Theory to Nuclear Rockets." The principal investigator reports a valuable two-way exchange resulting from the grant. He spends about a month in NASA centers each summer to stay abreast of latest problems and market his techniques. His students have also been able to obtain summer employment with NASA so that their educational experience is enriched by close contact with real research problems. Computer programs developed during the research have been applied to design problems by both the Jet Propulsion Laboratory and Lewis Research Center, and three companies are using the programs to design reactor control systems for the Jet Propulsion Laboratory. The techniques have broader application, too. The principal investigator was able to assist Lewis in an SST inlet-duct configuration control problem. At least six Ph.D. and eight master's degrees were earned by students partially supported by the grant during its first 3 years. At one time, five faculty and 10 graduate students were involved in the research. Among the publications resulting from the grant are two textbooks, 10 papers, and three monographs. Thus, a highly motivated individual has used a project grant to obtain support for students and strengthen their education; build ties among the university, NASA, and industry; accelerate the transfer of technology; and further his own research and professional development.

Another example of the impact of research grants is the development of optical replica gratings, which was undertaken by Goddard Space Flight Center with most of the research performed at the College of the Holy Cross, Old Dominion College, and the College of William and Mary. Goddard held seminars and conferences, and provided coordination. The program has successfully developed replica gratings which are in use on satellites with a reduction in cost of about 90 percent. In addition, capability has been created in these relatively small universities for research in a highly specialized area. First-class facilities for vacuum-ultraviolet spectroscopy have been established at Holy Cross and Old Dominion that can be used for other studies of space environment, as well as more general solid-state and plasma research. Both undergraduate and graduate students have been involved in an active and important research program. The faculty members have also been able to develop important new contacts with outstanding scientists from the United States, Europe, and Japan and enhance their own professional standing. Five papers have been presented to the Optical Society of America by faculty researchers.

It was apparent in discussions with NASA managers that some grants and contracts, considered to be high-risk investments, were thought to be justified because they helped train graduate students, increased faculty competence, or developed a unique facility. Managers and technical monitors have readily adopted these long-range goals, usually associated with the Sustaining University Program, for grants in their technical areas of responsibility. An example of this attitude is a grant to Texas A. & M. University for the simulation of atmospheric processes in a wind tunnel. The university had done no previous relevant work but was supported in order to build competence in low-speed aeronautics. If the project is successful, a unique facility for further research and training in low-speed aerodynamics will exist at the university. Meanwhile, the school has hired an internationally known British aerodynamicist, partially through the influence of the NASA grant, to strengthen its faculty in this area. Through the research, graduate students are already being trained. This is a good example of a successful "seed" grant that is not uncommon in project research.

A multidisciplinary research grant.- The Institute for Direct Energy Conversion at the University of Pennsylvania is an example of the use of research grants to create new capability for research and education. Although a large part of the research funds came from the Sustaining University Program, this grant is not considered to be a multidisciplinary SUP-R grant because it is for research in relatively narrow disciplines and is made to a principal investigator instead of to an institution.

The Institute was established to provide graduate engineering students with a broad background in direct energy conversion. The students meet the doctoral requirements of their parent departments but perform their research in a common laboratory to stimulate interest in and communication with other disciplines. An Institute ground rule is that all doctoral candidate research must be suitable for a thesis and involve at least two disciplines. A few postdoctoral researchers are provided for continuity of research. The senior staff members are obtained from the permanent university faculty, continue their normal teaching activities, and devote about 20 percent of their time to Institute activities. The initial senior staff consisted of professors of mechanical engineering, electrical engineering, metallurgical engineering, material science, and electrochemistry. (As projects are completed or new interests develop, the composition of the senior staff may change.) Each senior staff member supervises at least one Ph.D. candidate from his parent department and has absolute control over the suitability of research topics. The senior staff members have also cooperated in developing an interdisciplinary curriculum to prepare the students for their research. The Institute has remained small, with a goal of producing about four Ph.D.'s per year, and has involved industrial researchers as advisers at monthly meetings when graduate students report their progress.

A NASA grant in 1962 provided the initial support which the Institute needed to become organized and established. Additional funds were supplied for 5 years so that, with step funds, the Institute will have received NASA support for a total of 8 years. Technical advances credited to it include a new approach to direct energy conversion in the area of boiling fuel cells and techniques for forming new materials. About 60 major publications (10 per year) constitute another indicator of technical contribution. These include a textbook suitable for teaching solid-state energy conversion. The Institute has helped train 15 Ph.D.'s who have gone into industry or academic life. One is teaching direct energy conversion at the University of Delaware. Another is on the staff of the University of Tehran. The latter undoubtedly influenced a recent request for the Institute to assist Iran in the development of a power system for remote areas of the country. Two companies have been established as a result of Institute activities, including one by a former staff member.

The capability that NASA support has helped create is now being applied to other national problems. The director of the Institute was a participant in the electric automobile study sponsored by the Department of Commerce. The Institute also planned a joint program between the University of Pennsylvania and General Motors to study terrestrial travel and subsequently established a multidisciplinary team with expertise in such areas as traffic, economics, city planning, environments, pollution, and operations research, in addition to the Institute's capabilities in energy conversion. The team has received a $300,000 grant from the Department of Housing and Urban Development.

It is evident that the NASA grant has not only produced technical advances and trained people, but has also led to multidisciplinary research capability, to research on societal problems other than space, to increased associations with and technology transfer to industry, and to involvement with real-world problems.

Flight Experiments

In-flight science experimentation is conducted on a variety of vehicles including aircraft, high-altitude balloons, sounding rockets, satellites, and manned spacecraft. Conducting these experiments requires a major interaction between NASA and the university community.

University participation.- University scientists participate in and contribute to nearly all flight programs. Their guidance to NASA management in planning the programs is accomplished through a group of advisory bodies such as those shown in table 13. Three out of every four science advisors are from

TABLE 13.- NASA SCIENTIFIC ADVISORY GROUPS

WITH NON-NASA CHAIRMEN

Advisory group	Total membership	University membership	Percentage of university members
Science and Technology Advisory Committee for Manned Space Flight	13	12	92
Physics Advisory Committee	9	7	78
Lunar and Planetary Missions Board	18	12	67
Astronomy Missions Board	14	11	79
Ad Hoc Science Advisory Committee	13	9	69
Bioscience Panels (AIBS)	36	27	75
Total	103	78	76

universities. University scientists help select flight experiments and advise on the conduct of science and applications programs by serving on the subcommittees of the Space Science and Applications Steering Committee. As shown in table 14, almost half the membership of these committees comes from the university community.

A large portion of the experiments flown on NASA vehicles are originated by university scientists. NASA scientific balloon launchings for recent years are shown in table 15. All but five of the 246 launches (98 percent) were for university experimenters. Table 16 shows the organizational affiliation of the principal investigators on sounding rocket launches. In recent years, more than 40 percent have come from universities.

Experimentation on satellites or spacecraft offers unique opportunities for participation in the space program. Table 17 is a listing of organizational affiliations of principal investigators or coinvestigators for 268 experiments being flown in 15 different programs. More than one-half of the experiments were from universities and, if foreign universities are included, more than 60 percent had at least a university coinvestigator. Table 18 shows the large number of universities providing experiments for 28 spacecraft in the bioscience,

TABLE 14.- COMPOSITION OF ADVISORY SUBCOMMITTEES OF THE SPACE SCIENCE AND APPLICATIONS STEERING COMMITTEE IN 1968[a]

Subcommittee	Membership					
	Total	University	Not for profit	Industry	Government	GSFC[b]
Astronomy	12	4	2	0	6	2
Communications	5	1	1	2	1	0
Earth Resources Survey	7	4	1	0	2	1
Geodesy and Cartography	11	6	1	0	4	1
Ionospheres and Radio Physics	13	7	0	0	6	3
Meteorology	9	2	1	1	5	1
Navigation	9	6	1	0	2	1
Particles and Fields	14	9	1	0	4	2
Planetary Atmospheres	10	3	1	0	6	1
Planetary Biology	11	5	2	0	4	1
Planetology	13	4	3	1	5	1
Solar Physics	14	5	3	0	6	2
Space Biology	12	8	1	0	3	0
Total	140	64	18	4	54	16
Percent of total	-	46	13	3	38	11

[a]Excludes chairmen, vice chairmen, and secretaries, who are NASA personnel.
[b]Included in "Government" column also.

TABLE 15.- OSSA SCIENTIFIC BALLOON LAUNCHINGS

Discipline	1965	1966	1967 (to Nov.)
Planetary atmospheres	19	21	11
Particles and fields	44	37	42
Astronomy	16	27	29
Total	79	85	82

planetary, and physics and astronomy programs. Thirty-two universities are supplying 55 percent of the experiments. An additional 6 percent come from five foreign university investigators.

The OGO program.- The Orbiting Geophysical Observatory (OGO) program is a good example of the interplay between universities and NASA in the field of flight experimentation. The OGO is a large satellite that provides common service facilities to a large number of instruments for making observations and measurements of the earth's environment. The selection of the experiments on the five satellites was based upon the scientific advice of the discipline subcommittees of the Space Science and Applications Steering Committee. As mentioned above, about one-half of the subcommittee members are from universities. The origin of the experiments for the five spacecraft is shown in table 19. Forty-four percent of the 105 experiments originated in universities. If foreign universities are included, one-half of the experimenters are university

TABLE 16.- PRINCIPAL INVESTIGATORS FOR FLIGHT EXPERIMENTS IN

OSSA SOUNDING ROCKET PROGRAM

Source	1960	1961	1962	1963	1964	1965	1966
NASA Centers	40	39	25	31	42	47	33
Other Government agencies	0	2	3	6	10	2	8
Industry	8	7	15	20	21	9	7
International	0	1	8	9	13	17	11
Universities	7	8	13	16	32	63	40
Total	55	57	64	82	118	138	99
Percent from universities	13	14	20	20	27	46	40

TABLE 17.- INVESTIGATORS ON FLIGHT EXPERIMENTS[a]

Project	Total experiments	Source of experiments[b]					
		Universities		Not for profit	Industry	Government	
		U.S.	Foreign			Total	GSFC
OGO	90	46	7	2	10	46	28
OAO	8	3	2	-	1	3	2
OSO	31	12	9	-	2	11	3
ATS	11	5	-	-	4	2	2
Mariner	13	12	-	-	2	8	1
Lunar Orbiter	4	-	-	-	-	4	-
Surveyor	6	7	1	-	-	5	-
Injun V	4	3	-	-	-	1	-
IMP	12	7	-	1	2	6	6
OWL	10	10	-	-	-	-	-
Explorers	22	6	2	1	-	15	11
Pioneers	12	10	-	4	1	5	2
RAE	3	-	-	-	-	3	3
Nimbus	22	3	2	1	-	19	16
Biosatellite	20	19	-	-	4	5	-
Total	268	143	23	9	26	133	74
Percent	-	53	9	3	10	50	28

[a]Source: Space Science and Applications Program, NHB 8030.2A, October 1967, covering actual and planned launches subsequent to August 1965.

[b]Includes principal investigators and coinvestigators, so totals exceed number of experiments onboard.

TABLE 18.- UNIVERSITY FLIGHT EXPERIMENTS FOR CALENDAR YEARS 1967 AND 1968 IN BIOSCIENCE, PLANETARY, AND PHYSICS AND ASTRONOMY PROGRAMS[a]

[From Report to the Space Science Board on the Space Science and Applications Programs, November 1966]

University	Number of experiments
United States	
Rice University[b]	22
State University of Iowa	10
University of California, Los Angeles	9
Graduate Research Center of the Southwest	7
Stanford University	7
University of California, Berkeley	7
California Institute of Technology	6
University of Chicago	6
University of Colorado	6
University of Minnesota	6
Massachusetts Institute of Technology	4
Temple University	4
Dartmouth University	3
University of Maryland	3
Brigham Young University	2
Harvard University	2
University of New Mexico	2
University of Southern California	2
Bowling Green University	1
Colorado State University	1
Emery University	1
North Carolina State University	1
Princeton University	1
Rutgers University	1
Texas Woman's University	1
University of California, La Jolla	1
University of New Hampshire	1
University of Pennsylvania	1
University of Rochester	1
University of Texas	1
University of Virginia	1
University of Wisconsin	1
Total	122
Foreign	
University College, London	5
University of Paris	4
University of Leicester	2
University of Bologna	1
University of Southampton	1
Total	13

[a]28 spacecraft; total experiments, 222; total university experiments, 135.

[b]Two OWL spacecraft account for 20 experiments.

based. Table 20 shows that 14 U.S. and three foreign universities contributed 51 experiments.

The proposals from which the individual flight experiments were chosen were most often an outgrowth of a project research grant from NASA. After an experiment is selected for flight, the investigator is funded to produce working instruments and to analyze the data for a period of 2 years after launch. (For foreign universities, these costs are borne by the sponsoring agency in the foreign country.)

The principal investigator (1) establishes the investigation and functional requirements for the instrumentation, (2) insures that an adequate research program is conducted to minimize the possibility of ambiguous data, (3) develops and constructs the instrumentation, (4) participates in mission operations as required, and (5) analyzes and publishes the results and findings.

Of the five OGO satellites launched, four are returning usable data in 1968. This fact, plus the fact that it takes from 1 to 2 years to analyze and publish the findings, makes an assessment of the scientific results of the program premature. However, a recent count of scientific papers resulting from the OGO program is shown in table 21. More recently, at the American Geophysical Union meeting in April 1968, about 240 papers were presented on satellite experiments or in areas of science closely related to satellites. Twenty-three of the papers related to the OGO satellites. Of these, 15 (65 percent) were from universities.

TABLE 19.- SOURCES OF EXPERIMENTS FLOWN IN THE OGO PROGRAM

Spacecraft	Total experiments	Number of experiments[a]						
		University	Industry (profit)	Not for profit	Government			Foreign
					Non-NASA	Total NASA	GSFC	
OGO-I	20	7	0	1	3	10	8	0
OGO-II	20	11	0	2	3	10	7	1
OGO-III	21	10	0	1	4	9	7	0
OGO-IV	20	11	0	3	3	7	6	1
OGO-V	24	7	2	1	2	8	6	4
Total	105	46	2	8	15	44	34	6
Percent	-	44	2	8	14	42	32	6

[a]Includes principal investigators and coinvestigators, so totals exceed number of experiments onboard.

TABLE 20.- UNIVERSITIES PARTICIPATING IN FLIGHT EXPERIMENTS IN THE OGO PROGRAM

University	Number of experiments
United States	
University of Michigan	7
University of Chicago	6
University of Iowa (and State U. of Iowa)	5
University of Minnesota	4
Stanford University	4
University of California at Los Angeles	4
University of California at Berkeley	3
University of Colorado	3
Massachusetts Institute of Technology	2
Dartmouth College	2
Rice University	2
California Institute of Technology	2
Temple University	1
University of Illinois	1
Total	46
Foreign	
University of Paris	3
University College of London	1
University of Southampton (U.K.)	1
Total	5
Total, U.S. and foreign	51

TABLE 21.- SCIENTIFIC PAPERS FROM THE OGO PROGRAM

[As of April 1967]

Source	Number of papers	Percentage of total
Universities	60	57
GSFC	26	25
Others	19	18
Total	105	100

At this stage of the OGO program, contributions to the results can be assigned roughly as follows:

Observatory concept	Primarily NASA
Measurement objectives . .	Large university input
Payload selection	Large university input via subcommittees of Space Science and Applications Steering Committee
Investigations	Over 40 percent from universities
System management	NASA
Operations	NASA - responsive to investigator needs
Scientific results	Large university contribution

Universities and NASA have been in partnership at all stages of the program. NASA has obtained the services of some of the most talented scientists in the nation, who otherwise might not have been available. Open competition for the opportunity to experiment aboard the spacecraft has strengthened NASA's in-house competence. In turn, universities have been able to participate in research on the frontiers of knowledge - to experiment in space without the responsibility associated with designing, building, launching, and operating a complex space vehicle. Students have "learned by doing"; by direct involvement in the space program. The rigid demands of the program have forced university people to adopt modern management, cost control, and scheduling practices. Another major contribution to the universities has been the financial support for their flight experiments, which has indirectly supported faculty, students, and staff and has paid for new equipment (such as computers for data analysis) which is still available in university laboratories for other purposes.

The competitive factor.- A criticism frequently voiced within the university community is that NASA gives its own scientists an unfair advantage in the keen competition for space aboard NASA spacecraft. NASA administrators are aware of the criticism and have established a system of peer evaluation for all flight programs. This practice does not satisfy some critics who point out that NASA scientists still fly proportionally more experiments aboard spacecraft than their university peers. They feel that they should not be competing with men in the very agency that administers the program. Of course, the only way to alleviate that criticism is to eliminate in-house scientific capability, which is obviously directly contrary to NASA policy. In the final analysis, the competition that results between in-house and university scientists may very well lead to better experiments and faster dissemination of the findings.

Impact on curricula.- Participation in space-flight experiments has had a strong influence on the educational opportunities within universities. The space-science departments in universities such as UCLA and Rice would not exist without a background of 10 years of national space experimentation. Other universities have developed specialized courses (e.g., instrumentation) primarily to train graduate students for space research projects. A good example of a new degree program is the development of the Department of Aeronomy at the University of Michigan. It started with interdisciplinary experimentation on sounding rockets, which led to a summer short course in aerophysics for practicing engineers and then to a seven-course graduate-level curriculum. Two of the three successful Ph.D. candidates so far are Langley Research Center employees and four of seven master's candidates are Air Force Officers. Employees from the Goddard and Marshall Space Flight Centers are among the applicants waiting to enter the program. Participation in flight experimentation has enabled the university to build a center of excellence, which is now educating a new generation of professionals.

Involvement of students.- Participation in space-flight experimentation requires a university researcher to deliver flight hardware on a rigid time schedule. The sophistication of the hardware often requires competence beyond that available in graduate students. As a result, universities in many instances have built up full-time professional staffs to support principal investigators. In addition, the uncertainties endemic to flight programs and the long lead times (over 5 years from concept to flight) required of some experiments make them unsuitable for thesis research. In some cases, students have been involved with only the most routine parts of the project. One principal investigator on OGO admitted that he had no graduate student involvement because none of the work was suitable. He suggested that students might become involved in analysis of the flight data, which he was now accumulating.

Most universities are aware that such research can lead to the exclusion of graduate students and seek mechanisms to avoid it. For instance, experiments on sounding rockets, related to the satellite experiments, are sometimes used in conjunction with thesis projects. Other principal investigators have given their graduate students responsibility for a portion of the complete experiment, which can become an acceptable thesis. However, a great amount of postdoctoral education is accomplished through participation in satellite experiments. Still, the flight experiment part of NASA's project research has been least successful of all NASA-sponsored research in meeting the objective of graduate student involvement.

University Explorers.- The University Explorer series of satellites illustrates the flexibility shown by NASA in delegating responsibility to universities. It was an attempt to give researchers more responsibility by awarding a university a contract for the entire spacecraft as well as the experiments. The principal investigator assumed responsibility for the complete payload in addition to his science instruments. Some university researchers who have participated in the program now believe that other methods may be preferable, since complete control of the spacecraft brings with it a host of detailed responsibilities unrelated to their science interests. NASA managers have admitted their disappointment with results from the programs, such as failure to involve more than one department of the university, poor schedule performance, and inadequate engineering. However, they maintain that indirect benefits have accrued through exposure of university scientists to real-world technological and managerial problems. Some are optimistic and would enter into such arrangements again, assuming that the management experience that has been gained could be transferred to the new programs.

Unresolved problems.- Administrators and faculty in universities are concerned that principal investigators on large flight experiments tend to become project managers. Since instrument hardware must be either built in the university or subcontracted, the scientist finds himself devoting an inordinate amount of time to project administration at the expense of his teaching and research. Although a researcher may conduct an excellent program, he can hurt his university, with NASA's acquiescence, by committing himself to too much responsibility.

Some university people feel they are performing a service for NASA when they undertake a flight experiment. Since, as discussed above, experiments do not always make good thesis topics, they feel that NASA has an obligation to provide additional support for basic research that can be used to train graduate students. The merit of the argument, it appears, depends on the individual case.

University Research Centers, Institutes, and Laboratories

Student involvement in research, mentioned in connection with flight experiments, becomes a more general problem in the research organizations variously called centers, institutes, or laboratories that have evolved in universities. The problem is the tendency for such organizations to lose their ties with the educational function of the university and to become almost wholly research oriented. They have full-time staffs of scientists, engineers, technicians, and administrators. The faculty members tend to become full-time researchers and managers, neither teaching nor directing the research of graduate students.

In two of the five universities visited, the Task Force found organizations they they felt had less graduate student involvement than was possible. The groups were excellent research teams with successful charismatic leaders. They can point to students working in their laboratories and cite all the advantages of "learning by doing," exposure to real-world problems, and scientific apprenticeship. However, many of the students are engaged in routine activities at the technician level, such as assembling electronic hardware, with little exposure to research. At best, it can be said that these students are being exposed to the state of the art in electronics and are receiving financial support.

Not all research organizations are neglecting their educational function. Many universities are successfully carrying out graduate education within their institutes and centers. The Task Force saw many more instances of success than of failure. However, the potential for withdrawal from education is present, and sensitivity to it by the university is required. NASA's project research system contributes to this potential. The desire of project managers to obtain the best and most timely research can lead to support of organizations that have full-time professional staffs and little student involvement. In fact, the dynamic and aggressive nature of the leaders of such groups has made it possible for some of them to control a sizable portion of SUP research funds in their universities, further strengthen their research capability, and thereby obtain more project support.

NASA facilities grants have also made it possible for such groups to drift away from graduate student involvement. Since the facilities do not include classroom space, they tend to be occupied by full-time researchers. In fact, one young professor reported that he lost very valuable contacts by being in the Space Science Building away from his academic department. He felt that the disadvantages of being in the Space Science Building just about offset any advantages the facility provided.

The extreme case of limited graduate student involvement occurs in the Federal contract research centers, such as the Jet Propulsion Laboratory and Lincoln Laboratory. This report does not argue for or against such centers. As a basic policy, NASA has generally avoided the contract center approach, although the Apollo guidance, navigation, and control contract relationship with the Instrumentation Laboratory of MIT has been considered to be of this type and is examined here.

About $94 million was spent at the Instrumentation Laboratory from 1961 through June 1968. It initially purchased design, assembly, test and checkout software for the Apollo guidance, navigation, and control system and later provided software support for operational activities. (Hardware was produced by industry under contract to NASA.) These activities are essential to the Apollo program and NASA managers feel that the depth, breadth, and quality of effort was the best that could have been obtained anywhere. The secondary results of the contract include an impressive list of spin-off activities and applications of technology to other programs in which the Instrumentation Laboratory is active. It also includes a long list of new technology items being reported through NASA's Technology Utilization Office.

The impact on education and the university is less clear, but 384 graduate and undergraduate students and six part-time faculty consultants have been involved. More than 250 formal papers, including 12 B.S., 38 M.S., and nine Ph.D. theses have been produced. Curriculum impact included a new course in astronautical guidance, a revised computer design course, and added strength in many other courses, particularly in electronics. The university sees as an intangible benefit the invaluable exposure of astronautical and aeronautical students to experiment and hardware.

To place these figures in perspective, the involvement with education can be compared with that of one of NASA's own research laboratories. Langley Research Center has about 1,200 professional employees, compared with about 800 in the Instrumentation Laboratory. However, only about a quarter of the IL employees are now working on NASA projects, so that about 200 professionals might be considered as NASA-related. Langley's publication rate of more than 500 per year generated about 3,000 papers from 1961 to 1967. Only one-sixth of these (500) may be compared with the IL production (250) because of the difference in professional employees. Langley has an undergraduate cooperative program and many of its professional employees were candidates for advanced degrees in an employee graduate training program. One-sixth of these students, over 100, is less than the 384 claimed by IL. However, the center's employees have earned 205 master's and 37 Ph.D. degrees in the 6-year period, one-sixth of which, 40, again compares favorably with the 47 master's and Ph.D. degrees earned in the IL work. In addition, six part-time faculty consultants is not a very large faculty involvement on a $100 million project; many industrial companies rely more heavily on faculty consultants.

This example of a federal contract research-center operation indicates that the indirect returns in terms of trained people, student involvement, new knowledge and technology, and faculty involvement are not significantly different from what may be expected of federal laboratories.

Research and development in such centers must be judged on its own merits and cannot be justified on the basis of indirect benefits to the university. The smaller research groups in universities, which choose to conduct their research under the academic umbrella but divorced from the educational role, should be supported only on the same basis - the quality of the research being performed. It is deceptive to support such groups on any other basis.

CHAPTER IV

SUSTAINING UNIVERSITY PROGRAM

Almost a third of the funds NASA has invested in universities has been through its Sustaining University Program. Such support is more general than that provided by the project system in that grants are made to institutions rather than to principal investigators within the institutions.

Goals

The Sustaining University Program augments and complements project system research and other NASA activities in universities. Its goals tend to be longer range than those of project research, although they were intended to have a common goal of strengthening universities. The broad goals include acceleration of the transfer of technology between segments of the economy, development of a capability for multidisciplinary research on societal problems, development of sensitivity to real-world problems, and development of a capability to respond institutionally to societal problems. The program also sought to involve universities as institutions in the planning, management, and assessment of research as one route to achieving the other goals.

The SUP has consisted of training, facilities, and research with more specific operational objectives than the generalized goals above.* The emphasis between objectives has tended to change with time. The training component has aimed at increasing the number of scientists and engineers in space-related disciplines. The Gilliland Report to the President in 1962, which forecast the Nation's needs in graduate education, provided the rationale for a specific NASA goal of 1,000 new Ph.D.'s per year by 1970. In addition to increasing quantity, this program has attempted to accelerate the production of doctorates in science and technology by shortening the time required to earn the Ph.D. degree.

The SUP facilities program was intended to help universities provide urgently needed facilities for aeronautics and space research. The facilities were to provide reasonably adequate working space for universities already heavily engaged in scientific and technical activities supported by NASA and make possible new research groups with combinations of disciplines relevant to NASA objectives.

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*Dryden, Hugh, L.: The Role of the University in Meeting National Goals in Space Exploration. NASA-University Conference on the Science and Technology of Space Exploration, Chicago, Ill., Nov. 1, 1962, NASA EP-5, pp. 87-91.

The research element of the SUP had multiple objectives. The primary purpose, however, was to encourage creative multidisciplinary investigations that required team research on broad, space-related problems. It also sought to expand the base of research capability by developing groups with latent competence and potential for contributions in an area of importance to NASA. Still another aim was to coordinate related projects in a university by providing a base for small projects and lessening the impact of fluctuations in support.

Perceptions of the Sustaining University Program

NASA managers (outside of the Office of Space Science and Applications) are largely uninformed about the objectives and content of the Sustaining University Program. It is difficult to find anyone who can even discuss the program knowledgeably. Managers with a little knowledge tend to regard it as a program designed solely to help universities and from which NASA can expect little tangible return. Probably more managers are aware of the research component than of the facilities or training components (because they have reviewed proposals) and they regard it as a haven for research of less than top quality or of marginal interest, which they would not support in their own programs. Those few who are aware of the traineeship program regard it as a failure because it has proved to be a poor recruiting tool. (The SUP training program did not have recruitment for NASA as a goal.) Within OSSA, from which the program was managed until early 1967, managers have considerably more knowledge of the SUP and regard it as a valuable adjunct to their own programs. They see its contributions as being the general support for buildings, students, equipment, etc., which has made their own project research more effective.

Within universities, the Sustaining University Program is much more favorably regarded. NASA's liberal and innovative policies are appreciated and applauded. Its procedures are even imitated; Cornell modeled a new fellowship program in Highway Safety after the NASA traineeships. The SUP research program is seen as institutional support; NASA's insistence upon multidisciplinary aspects is regarded as a gimmick. The SUP facilities program is also viewed as general institutional support; the Memorandum of Understanding associated with the grant is seen as a legality. The institutional allowance associated with traineeship grants is also viewed as general support. The general perception is that the SUP is designed to help universities while broadening the base of space-related science and technology and that it requires nothing in return except education and research in the traditional manner.

Predoctoral Traineeship Program

The predoctoral traineeship program of the Sustaining University Program has obligated about $100 million since 1962. In this program, grants have been made to the university instead of to individual students. The university is responsible for selecting high-quality students for predoctoral study in a space-related discipline. Each grant provides support for a specific number of students for 3 years of full-time study. Universities may select either new graduate students or students who have partially completed degree requirements, and they have authority to replace a student who completes his Ph.D. or withdraws before the 3 years of support is consumed. Consequently, there are more graduate student participants during the tenure of a 3-year grant than the number of traineeships awarded the university. An institutional allowance, approximately equal to the trainee stipend, is awarded the university with each traineeship. This allowance is not overhead reimbursement, but is intended to strengthen the graduate education program of the school. The university administers the allowance and is free to use it for such things as faculty augmentation, library acquisitions, laboratory equipment, and guest lecturers.

The number of traineeships that have been awarded in the program is shown in table 22. The extent to which more students receive training than traineeships are awarded has been examined by analyzing the first 2 years of the program. In 1962 and 1963, the 886 traineeships that were awarded supported 1,378 different students. About 500 students held their traineeships for the full

TABLE 22.- PREDOCTORAL TRAINEESHIPS UNDER

SUSTAINING UNIVERSITY PROGRAM

Year	Number of traineeships
1962	100
1963	786
1964	1,071
1965	1,275
1966	1,335
1967	797
1968	50
Total	5,414

3 years, but another 500 had less than a year of support. Of the 1,378 students supported, 558 had received Ph.D. degrees by May 1968. Another 519 students were still in school and expected to earn doctorates. Only 301 students have withdrawn from the program. In total, the 886 3-year traineeships awarded in 1962 and 1963 will have provided partial support to about 1,075 students who earned doctorates.

Results of the program.- As of May 1, 1968, complete data had been received on 1,054 participating students who had earned Ph.D. degrees in the program. The discipline of their training and initial career choices are shown in table 23. Almost 60 percent are still in the university community as teachers, researchers, or postdoctoral students. About a third went into industry. Other data indicate that about 1 percent were employed by NASA. Considering that more than a thousand doctorates have already been produced and that more than 3,400 students are still occupying traineeships, the SUP training program is achieving its objective of substantially increasing the supply of engineers and scientists at the doctorate level in space-related disciplines. It will probably meet the specific objective of 1,000 Ph.D.'s per year by the end of 1970, although the drastic curtailment of the program now makes the figure meaningless.

An objective of the SUP training program was to accelerate the production of Ph.D. degrees by shortening the time required to earn the degree. While it was realized that few students could earn a doctorate in 3 years, it was hoped that 3 years of unencumbered support would reduce the total time required. Students do not believe this has happened except in the obvious situation where teaching or outside jobs would otherwise be required. They view the uncertainties of research and dependence on the major professor as outweighing the influence of the method of support. They generally felt that research assistants, who did their research and course work in parallel, would earn degrees as rapidly as trainees who did course work and research in series. Faculty members also usually failed to see any shortening in time required to earn a degree except in the obvious cases.

TABLE 23.- Ph.D. DEGREES EARNED BY NASA TRAINEES

[Through May 1, 1968]

Discipline	Initial career choice					Total	Percent of grand total
	University	Postdoctoral	Government	Military	Industry		
Physical Sciences	254	97	43	14	132	540	51
Engineering	124	21	21	17	191	374	36
Life Sciences	54	30	2	5	4	95	9
Behavioral Sciences	20	7	1	2	6	36	3
Other	5	0	1	1	2	9	1
Total	457	155	68	39	335	1,054	
Percent of grand total	43	15	6	4	32		

Faculty members at one school felt that engineering doctorates had been accelerated, though they had no quantitative evidence. However, a recent study by William Scott* has indicated that some acceleration may actually have

*Scott, William E.: Federal Support to Graduate Students: A Comparison of NASA Traineeships with Research Assistantships. S. M. Thesis, Sloan School of Management, Massachusetts Institute of Technology, 1968.

occurred. He compared two groups of 164 Ph.D. recipients, one of former NASA trainees and the other of former research assistants on NASA-sponsored research. His data show that a trainee, on the average, spent 1 year less in graduate school - 4.7 years versus 5.6 years - than did a research assistant. Also, the total elapsed time from bachelor's degree to doctorate was less by a year and a half - 5.3 years versus 6.9 years - for the trainee group. These figures are not conclusive, however, since graduate schools usually award their traineeships and fellowships to the very best students, who would be expected to finish degree requirements in the shortest time. However, the data also show that such crude measures of productivity as publications, patents, and inventions indicate no significant differences between the two groups by the time they begin their professional careers.

The Scott study found some other interesting relations between former trainees and former research assistants. In both his groups, the majority (almost two-thirds) indicated that financial aid was the only benefit from their NASA support. However, significantly more of the trainees (29 percent versus 10 percent) responded that NASA support also shortened the time required to obtain their doctorate. More research assistants than trainees (16 percent versus 3 percent) felt that the support itself contributed to their education; to them, association with an exciting national program was of value. Fifty-one percent of the former research assistants, compared with 42 percent of the former trainees, are still working on space-related problems. Scott's data also show that 62 percent of the research assistants and 57 percent of the trainees are now working on Government-sponsored programs. Within these totals, only 20 percent and 5 percent, respectively, are working solely on space-related problems. Many of the former students in both groups are working on defense, health, education, and welfare programs as well. Thus, NASA's training and research efforts are contributing to the solution of a broad range of national problems.

Students holding traineeships were found to be almost completely isolated from NASA. They were intellectually aware that their support came from the space program but had developed no ties or identification with NASA. One result of this was found in the Scott study. His data showed that the research assistant had a greater interest in working for NASA and was more apt to continue working on space-related problems after graduation than the trainee.

University attitudes.- A variety of views of the NASA traineeships were found in universities. Attitudes varied from school to school and depended on how the grant was administered. Administrators uniformly liked the traineeships because of their flexibility. They felt that trainees opened new areas of research by seeking out faculty advisers who had no project research obligations. Faculty, especially those engaged in project research, sometimes objected to traineeships and felt that the student's research and progress could be better controlled if the same funds were used for research assistantships. Students generally liked the freedom of the traineeships and felt they contributed to their departments by opening up new research areas and working with newer faculty members who had no outside research support.

Students seldom apply specificially for a NASA traineeship; they usually apply to their department for support and the university awards its NASA traineeships along with NSF, NDEA, or whatever other fellowships and traineeships are available. Students generally believed they would have been in graduate school regardless of the availability of NASA traineeships and were confident of their ability to compete successfully for research or teaching assistantships had there been no traineeships. (Research and teaching assistantships were viewed as being less desirable, in that order, even though the students were predominantly preparing themselves for university careers.) They also felt they would not have accepted a traineeship with a payback requirement had any other alternative been available.

Effect on universities.- The impact of the SUP training program on a university depends on its size and state of development. Impact is small in the established schools. For example, NASA's 65 traineeships at Cornell go unnoticed among 1,500 graduate students receiving Federal support. Similarly, at Michigan, NASA traineeship funds are less than 2 percent of available Federal fellowship funds. At the larger schools, the university-allowance funds attached to the grant also tend to lose their identity and become general institutional support. Traineeships are relatively more important at the less well-established universities where they provide a significant increase in total student support funds and attract superior students. These universities are also more conscientious in using university allowance funds to strengthen graduate programs. Since training grants were made to 152 institutions, much of the support has gone to schools in the latter category and has strengthened and broadened the base of graduate education.

Sustaining University Research Program

As mentioned previously, the SUP research program has invested about $50 million in multidisciplinary research grants to 50 universities. The common thread in the program was NASA's insistence that the research proposal come from the university as an institution, rather than an individual or department, and that the proposed research have multidisciplinary aspects to bring researchers from different disciplines together to work on space-related problems. These requirements were based on premises that space-related and other complex problems facing the country were often of such broad scope that they could be effectively attacked only by multidisciplinary research teams representing many departments within the university and that universities had the capability to organize and manage such research.

Within these broad guidelines, the grants had multiple objectives and tended to be individualistic since emphasis was tailored to the school involved. In less well developed universities, emphasis tended to be on "seeding" research to build new capability. In established schools, emphasis tended to be on supplementing and reinforcing existing research - to attract established researchers to aeronautics and space problems, to support new concepts, and to provide a cushion of assured support to smooth out the fluctuations in project research. In all the grants, the university as an institution was involved in planning, managing, and assessing the research.

A typical SUP research grant provides funds for an annual level-of-effort. Universities have usually chosen to manage the grant with a committee of administrators and senior faculty. Progress reports and renewal proposals are

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reviewed by NASA personnel. However, the university committee determines the final allocation of funds to individual projects within the level-of-effort.

Joint SUP-project grants.- In some cases, SUP research grants were used as a convenient administrative mechanism to consolidate several small project grants along with multidisciplinary research. The additional funds for project research were provided by program offices. NASA managers reasoned that institutions would then assume some responsibility for administering the smaller grants and use SUP research funds that came through the same instrument to assist projects over uneven funding periods. This has not happened. As soon as the funds reach the university, the projects receive their original portion of the allocated funds and are then treated as any other project grant.

New capability.- SUP research funds have created new capability for research and education in universities. One example is the Department of Astronomy at UCLA. The SUP-R grant supplied a 24-inch optical telescope and auxiliary instrumentation that made possible the development of a program in observational astronomy that is training both graduate and undergraduate students. These funds were also used to develop and staff an optical shop that the department felt was necessary for the program. SUP research funds also initiated research that has since found support from program offices. More recently, NASA funds were used to recruit a new faculty member to initiate a program in radioastronomy.

The University of Florida provides several examples of strengthened or new capability. A physics and astronomy program which started late in a very competitive field has grown fast and developed significant potential. The faculty's rate of publication has tripled since a NASA SUP-R and an NSF science development grant were received. The University's young Aerospace Engineering Department has been largely sustained by the NASA SUP research grant, which provided equipment and graduate student support for its initial research program. A new capability that has stemmed directly from NASA-sponsored research in the department has resulted in an NIH grant to develop air-pollution sensors. A slightly different aspect of the application of SUP research funds was illustrated at Florida by the support of a psychologist's research on sleep. This support allowed the researcher to establish the relevance of his research after rebuffs by NASA personnel. He has since obtained project support. In this instance, university administration recognized the value of a particular project that NASA personnel had overlooked. Overall, the SUP-R grant at Florida has supported students who earned 21 master's and 17 Ph.D. degrees. The research resulted in 107 publications and 40 talks during a 4-year period.

The University of Arizona provides even more examples of new and strengthened capability. Its Lunar and Planetary Laboratory is a center of excellence making major contributions to space science. The Laboratory's support has come primarily through project research but has been substantially augmented from SUP research funds. SUP research funds have also contributed to an optical-science capability that has led to the Nation's second doctorate program in the discipline. The University credits NASA support with helping to build the strength needed to attract a new $5.25 million 5-year Air Force grant as well as outside financing for a new optical science building.

Another example of strengthened capability is hybrid computer research in the electrical engineering department at Arizona. Much of the equipment developed is now used for classroom instruction. The quality of the research has led to additional support from program offices. At least one NASA employee is in the department on graduate-study leave.

Overall, the SUP research grant at the University of Arizona has supported 38 graduate students, of whom eight have earned master's degrees and two have earned doctorates in 2 years. There have been 25 publications over the same time span.

One measure of new research capability is the degree of success in attracting project support. UCLA reports that research started under its grant has generated more than twice the original SUP investment in grants from NASA program offices and centers, the Air Force Office of Scientific Research, Office of Naval Research, National Science Foundation, Atomic Energy Commission, National Institutes of Health, and other groups. More than 30 percent of all projects (33 of 106) have acquired such support. The University of Florida shows only three of 45 projects continued with other funding, but there is an indication that additional new projects with outside funding began as spin-offs from SUP research. The University of Arizona reports that nine of the 39 projects (or almost a quarter) in their SUP research program obtained support from the Office of Naval Research, National Science Foundation, and NASA project offices.

Multidisciplinary research.- The grants have not been successful in stimulating multidisciplinary research involving engineers and physical, life, behavioral, and social scientists. Some narrower multidisciplinary research is supported, however, which involves engineers and life scientists or engineers and physical scientists; e.g., the Space Biology Laboratory and the Institute of Geophysics and Planetary Physics at UCLA. It is difficult to argue that they are the result of SUP-R support, since the research groups are older than NASA. In addition, their multidisciplinary aspects are not appreciably different from those of such groups as the High Altitude Engineering Laboratory at Michigan or the Center for Radiophysics and Space Research at Cornell, which have had only project support. As a matter of fact, the UCLA examples also have appreciable project support. The teams seem to have evolved naturally from joint interests in a problem area. The plausibility of such an occurrence is enhanced by the observation of a NASA program manager: he said that he had had no difficulty whatsoever in starting multidisciplinary research; all he needed was a multidisciplinary problem to challenge the researchers.

Universities have not seriously attempted to stimulate broad multidisciplinary research with the grants. The funds are expended on individual projects in specific disciplines. The projects are in multiple disciplines but with few connections between any of them.

Social scientists have had very little involvement in the SUP research. Almost none appear to have participated in the multidisciplinary teams although the desirability of their involvement in SUP research has been repeatedly communicated to grant administrators. A few have conducted individual projects that did not interact with other research. For example, a professor of architecture and urban planning at UCLA applied space-developed technology to an urban-simulation problem (discussed in detail in a subsequent section). Most social scientists have been reluctant to even try to develop a space-related project; a management scientist had to be recruited by the Space Science Committee at the University of Florida to look at technology-transfer processes. Space scientists tend to mirror the views of the social scientists; they cannot imagine why NASA is interested in involving social scientists.

Administration of research.- Administration of SUP research by universities has been conservative, with few attempts at innovation. Some schools, such as the University of Florida, which called in an outside panel to review its procedures, have worked very hard at the task. Other schools have tended to divide the funds and then allow individuals to administer their own portion. Dynamic or charismatic committee members tend to have disproportionate influence in allocation of the funds. Generally, university administrators have not used the SUP research grant to direct research, although the opportunity was present.

The space science committees have varied in effectiveness. They have been useful as an interdepartmental meeting ground. The committees are a first step toward multidisciplinary interactions. They also give the aeronautics and space program a visibility and focus in their universities, which is missing in universities without a SUP-R grant, such as Michigan and Cornell, where vice presidents for research coordinate all research.

Administrators praised step funding very highly. There is some evidence that it had permitted advanced planning with greater confidence, especially when budgets were declining. Investigators being supported by a step-funded SUP research grant were less affected since their individual projects were usually funded on a year-to-year basis by university administrators.

Isolation of investigators.- Many of the researchers active in the SUP program are isolated from NASA and its problems. Accident and chance seem to govern contacts with NASA scientists and engineers interested in similar problems. One physicist reported that he had never received feedback from NASA on his research and so had no idea how the agency benefited from his work. This results from the way the grants are administered. The NASA grant monitor communicates with the space science committee of the university but no researcher-to-researcher contact is provided. Investigators on project system research, who are in direct contact with a NASA technical monitor, consistently report that interactions with NASA personnel lead to better and more useful research as well as increased motivation for them and their students. Similar benefits could result from closer agency contact with SUP researchers.

The Facilities Grant Program

The Sustaining University facilities program has obligated about $43 million to 32 universities for 35 research facilities containing 1,446,000 square feet of laboratory space. The locations of the facilities are shown in table 24. Twenty-seven facilities were in use and two others were more than 90 percent complete in May of 1968.

TABLE 24.- UNIVERSITY RESEARCH FACILITIES FINANCED BY SUSTAINING UNIVERSITY PROGRAM

University	Topic	Cost (millions of dollars)
University of Arizona	Space science	1.200
University of California at Berkeley	Space science	1.990
University of California at Los Angeles	Space science	2.000
Case Western Reserve University	Space science[a]	2.226
University of Chicago	Space science	1.749
University of Colorado	Space science	.792
Cornell University	Space science	1.350
University of Denver	Space science	.900
University of Florida	Space science[a]	1.190
Georgia Institute of Technology	Space science and technology	1.000
Harvard University	Biomedicine	.151
University of Illinois	Space science	1.125
University of Iowa	Space science	.535
University of Kansas	Space technology[a]	1.800
University of Maryland	Space science	1.500
Massachusetts Institute of Technology	Space science	3.000
University of Michigan	Space science and technology	1.436
University of Minnesota	Physics	.542
	Space science[a]	2.500
New York University	Aerospace science	.582
University of Pittsburgh	Space science	1.497
Polytechnic Institute of Brooklyn	Aerospace science	.632
Princeton University	Propulsion science	.625
Purdue University	Propulsion science	.829
Rensselaer Polytechnic Institute	Materials science	1.500
Rice University	Space science	1.600
University of Rochester	Space science[a]	1.000
University of Southern California	Human centrifuge	.160
Stanford University	Exobiology	.535
	Space technology[a]	2.080
Texas A and M University	Space science	1.000
University of Washington	Aerospace science[a]	1.500
Washington University	Space science	.600
University of Wisconsin	Theoretical chemistry	.365
	Space science and technology[a]	1.694

[a]Not completed as of May 1968.

Nature of the grants.- NASA awarded a dollar amount up to the full cost of the laboratory space or building with each grant. The building could contain only laboratory and office space for research activities; no classroom space was provided. Funds for furnishings and equipment were not provided either. In all of the facilities grants NASA determined that it was in the national interest to invest the title to the building in the university.

An important consideration in the award of a research facilities grant was an agreement between NASA and the university that culminated in the signing of a Memorandum of Understanding by the Administrator of NASA and the principal executive officer of the university. While wording of these Memorandums varied slightly in each case, two points stood out.

First, the university agreed to seek better ways for utilizing space-related research in solving other problems of the elements of society with which it normally deals; that is, it agreed to study the technology-transfer process. The Memorandums do not require that anything specific be done, but rather that research on the problem itself be undertaken in an energetic and organized fashion.

The second point called for the university to make use of its total competence - in social science, the arts, and commerce, as well as in physical and life sciences and engineering - in space-related research. This was a call for the broadest kind of multidisciplinary research involving specialists from multiple disciplines working on common problems. Again, the requirement was only that this be attempted in an energetic and organized manner. The building resulting from the facilities grant was to be the symbol and focus of these activities.

Implied in the Memorandums of Understanding are other goals of the Sustaining University Program. These include developing a concern for real-world or societal problems; developing capability to respond as an institution to major national problems; increasing the awareness of universities of their service role, in addition to their education and research roles; and encouraging universities to strengthen their ties with industry and their local and regional communities.

Achievements of the program.- The SUP facilities program has achieved its immediate objective of providing working space for universities heavily engaged in scientific and technical activities vital to the aeronautics and space program. The facilities are used to house multidisciplinary activities, usually in the form of a space-related institute, center, or laboratory representing several departments. Of the five facilities visited, two were dominated by such a group, two others were shared by more than one group, and only one did not house an institute, center, or laboratory. The dominant disciplines housed in the facilities were engineering and physical sciences. Only one facility had life sciences represented but four had behavioral scientists (psychologists) involved to a limited extent. There was no other social science involvement.

Graduate student involvement in the research appeared to be less than it could have been in two of the five facilities visited. The research being conducted in all facilities (one of the five was incomplete, but its designated occupants were active researchers) appears to be of high quality and of significance to the aeronautics and space program. The effectiveness of the research had probably been improved by consolidation and by availability of adequate working space.

The Memorandums of Understanding.- The SUP facilities program has been ineffective in achieving the goals expressed in the Memorandums of Understanding. There is little evidence of an "energetic and organized" attempt to implement the concepts of the Memorandums. Multidisciplinary research of the scope contemplated cannot be said to have resulted from the Memorandums. Except for isolated studies, university concern with technology-transfer processes cannot be attributed to the Memorandums.

Administrators within universities have two views of the Memorandums of Understanding. The first view is that they ask for things which universities do routinely and do not call for new and different action. One university indicated more than 200 research groups under its organizational structure that work on a multitude of problems - many of a multidisciplinary nature - and pointed out that they exist regardless of the Memorandum. In the area of technology transfer, the argument runs that trained people are the best transfer mechanism known, and training people has always been the first concern of universities. The other view of the Memorandums is that they call for tasks of such difficulty, requiring the expenditure of such great resources, that attempting to respond is futile. This is the usual reaction to suggestions that the Memorandums call for action on technology-transfer problems. It is plain that the leverage of the Memorandums was totally inadequate to elicit a response from universities.

The faculty members are generally unaware of the existence of the Memorandums. This indicates that administrators have not tried to use them to stimulate multidisciplinary research, to increase concern for technology-transfer processes, or to induce change of any sort within their universities.

One of the universities visited by the Task Force had been visited 2 years previously by a NASA committee charged with determining response to the Memorandums of Understanding. Nothing was being done by the university to implement the Memorandum at the time of the earlier visit and nothing had happened since. The university did not receive any feedback from the committee.

The failure of the universities to respond to the explicit agreements of the Memorandums - technology transfer and multidisciplinary research - suggests that the SUP goals, which they contained implicitly, were not achieved. Thus, the SUP facilities program cannot claim to have developed concern for societal problems, capability for institutional response, awareness of a service role, or strengthened ties with industry and the local and regional community.

The major criticism that must be made of the universities' response to the Memorandums of Understanding is that they did not try. They clearly committed themselves to make an "energetic and organized" effort to implement the Memorandums, and then did not make it.

Since each Memorandum was associated with a facilities grant and all funds were obligated by NASA at the time of the award, the symbol of the agreement, the building, was not a major factor in the university's operations for about 2 years after the award. NASA's leverage with such relatively intangible aspects of the grant as the Memorandum ceased once the award was made. Similarly, the Memorandum lost its utility to administrators for influence with faculty once the grant was delivered. It would appear that a Memorandum of Understanding could be used more effectively to induce change if it were associated with a SUP research grant (or some other mechanism) which has a renewal feature and thereby retains its leverage, first, for NASA, and second, for university administrators.

Potential for achieving long-range goals.- While response to Memorandums of Understanding is disappointing, activities were found in universities that indicate progress toward the objectives of the Memorandums. These activities are only beginning to stir, and their relationship to the Memorandums of Understanding is not clear. However, they indicate that the long-range goals of the Sustaining University Program may ultimately be achieved, as a few examples will illustrate.

Concern with acceleration of technology transfer is evident in some universities. Two of the institutions visited had research projects on technology transfer within their Business Administration Schools. These projects do not represent the broad multidisciplinary approach anticipated, but they are a beginning. The University of Michigan established an Industrial Development Division which participates in the Michigan State Technical Services Program and focuses on academic-industrial interactions. The Division is currently concerned with applying space satellite technology to locate schools of fish, applying electronics to the fishing industry, diagnosing human illnesses, and applying space sensors to pollution problems. The same university is conducting a short course to train Latin Americans in techniques of technology transfer. It also has a Center for Research on Utilization of Scientific Knowledge which is devising programs to update medical doctors as its initial project. A young professor at the University of Arizona reported that he spent up to a month each year in a NASA center because he wanted to see his research results applied to real problems.

Multidisciplinary research is also taking place in some institutions. It is not as broad in scope as envisioned by the Memorandums, but engineers and physical scientists or life and behavioral scientists can be found conducting joint research. Michigan has about 20 groups concerned with interdisciplinary research or societal problems. A project research grant has also led to a flight-simulation center at Michigan involving three departments - psychology, electrical engineering, and aerospace engineering. UCLA's Brain Research Institute has staff members from 14 academic departments, while the staff of its Institute of Geophysics and Planetary Physics comes from five departments. Cornell's Center for Radiophysics and Space Research has a multidisciplinary team of physicists, astronomers, and engineers. Such multidisciplinary activities seem to have evolved in the schools with well-established graduate education and research programs regardless of NASA support. Universities that have not yet reached a position of strength in research seem to be concentrating on development along more traditional academic lines without innovating with multidisciplinary research groups.

One outstanding example of research on a multidisciplinary societal problem was found. The project was started at UCLA with $10,000 from the SUP research grant to transfer NASA-developed computer graphics technology to a cityscape simulation in the Department of Architecture and Urban Planning. The university is now seeking support for a multidisciplinary Urban Laboratory, which has developed from the project. The concept is for a tool that simulates the urban environment. It will utilize models, gaming techniques, and computers to simulate the dynamics of social, economic, and physical processes. It will also utilize sciences and technologies such as cinematographic simulation, hologram visualization, systems analysis, stochastic models, engineering, government, education, law, medicine, architecture, business administration, and the social, life, and physical sciences.

Though years of development will be required, such a tool would be extremely valuable to engineers, social scientists, urban planners, managers, and politicians. University administration has organized to support the activity by appointing a Vice Chancellor as coordinator, appointing a steering committee consisting of Deans and an Assistant Chancellor, and creating a planning committee from industry, local government, and senior faculty from several departments. Faculty members from engineering, business administration, and architecture and urban planning are reported to be very enthusiastic about the project. Social scientists are less enthusiastic but are participating because of the potential of this important development.

It is not possible to say that the Urban Laboratory is a result of the Memorandum of Understanding. However, the university is engaging in multidisciplinary research of the broadest scope, transferring space-related technology, demonstrating its concern with major societal problems, developing working relationships with industry and the local community, and attempting to serve its community. It has also found a way to respond as an institution.

CHAPTER V

PERSONNEL DEVELOPMENT PROGRAMS

NASA has a variety of programs that involve the movement of personnel through the government-university interface. The programs have many purposes: research, education, consultation, and transfer of technology. The report will now focus upon the most significant of the personnel interchanges.

Employee Graduate Training

The Government Employees Training Act of 1958 has allowed NASA to develop programs to improve and update employee capabilities. The graduate education provided to NASA employees is also widely regarded as vital for successful recruitment of technical personnel. Graduate training programs generally pay all fees for employees in training. Graduate-study leave is available for either part-time attendance at local universities or full-time study at distant universities. Some employees work for graduate degrees while others take not-for-credit courses. Since the amount of graduate-study leave available to any one employee is fixed, most employees working for degrees arrange to conduct thesis research on the job. The magnitude of NASA's program is shown in table 25.

Most of the advanced degrees were earned at universities in the proximity of field centers but there is some geographic dispersion. For example, employees

TABLE 25.- GRADUATE STUDY BY NASA EMPLOYEES[a]

Fiscal year	Participation		Universities granting degrees		Degrees earned	
	Universities	Employees	M.S.	Ph.D.	M.S.	Ph.D.
1964	67	2,325	24	7	80	9
1965	79	2,764	25	12	75	16
1966	84	2,687	31	13	110	21
1967	102		42	20	131	35

[a]Source: NASA Annual Training Reports for Fiscal Years 1964-1967.

from Langley Research Center earned graduate degrees from 14 universities in seven states and the District of Columbia during a recent year. NASA employees were found to be studying in two of the five universities visited, although all were relatively remote from centers; they were in aeronomy at the University of Michigan and hybrid computers at the University of Arizona.

A survey of employees who had earned graduate degrees in the program was conducted at the Marshall Space Flight Center. The degrees earned were predominantly in engineering and physical sciences. About five out of six degree earners had entered the program on their own initiative (as opposed to management's initiative) and almost three out of four had done so within the first 2 years of their employment. About 70 percent earned their graduate degrees through a combination of evening classes and full-time resident study.

Effect on NASA.- The significant return to NASA from employee training programs is, of course, better trained employees. They are more competent to perform their previous jobs or able to undertake new assignments. There is also an indication that the agency is able to recruit more highly qualified personnel because of the availability of graduate training opportunities.

In the survey mentioned above, employees overwhelmingly reported a positive return to NASA from their graduate training. Some of their reasons were: more effective performance of duties, a higher level of competence, better quality reports, awareness of changing technology, and stimulation of university research on problems of interest to NASA.

Effect on universities.- There are significant indirect effects of employee graduate training programs in universities located near NASA centers. The most apparent result is that new courses and programs are created and their introduction in the universities is accelerated to meet the needs of NASA. The University of Houston has established a graduate program in public administration and will build a graduate studies center at Clear Lake, near the Manned Spacecraft Center, which will be open to area residents as well as MSC employees. Kennedy Space Center and Florida State University have instituted a Master of Science in Management program, which is open to the entire aerospace community. The Marshall Space Flight Center has supported development of master's level graduate programs in mathematics, physics, and five areas of engineering at the University of Alabama in Huntsville. It has also influenced Georgia Institute of Technology to develop systems engineering courses at the doctorate level.

Langley Research Center has been stimulating graduate education in Virginia schools since 1948 in order to meet its education requirements. The first such activity was a master's program in engineering at the University of Virginia. The first degrees were awarded in 1951 to 17 students, all Langley employees. This has grown to become a strong self-supporting graduate program with only a small percentage of Langley employees. In 1953, Langley developed a graduate work-study program with Virginia Polytechnic Institute. Ninety percent of the graduate enrollment in aeronautical engineering for the first 12 years were Langley employees, who also received most of the master's degrees and the first three Ph.D. degrees awarded. VPI now operates this program without dependence on Langley employee enrollment. A similar pattern was followed when a physics program at the College of William and Mary was begun at the master's level in 1960. A doctorate program in physics started in 1964 and a Langley employee received William and Mary's first Ph.D. degree in physics in 1967.

In all these cases, new university programs were developed to meet specific needs of NASA centers and initially served mostly NASA employees. The programs have grown, become strong, and now serve the entire community. It seems certain that NASA's influence helped start these programs much sooner than would otherwise have happened. This kind of impact has occurred only in schools near NASA centers that can provide a large supply of talented students demanding graduate education; similar impacts have not occurred in universities remote from centers, which receive only a handful of NASA employees for graduate study.

Effect on the community.- Employees who have earned graduate degrees in the program feel that their training has led to greater personal interest in civic affairs and caused them to assume a more prominent role. They feel they are more influential in church or other community activities. They also often become part-time instructors in local universities and junior colleges.

Short Courses and Seminars

Short courses and seminars cover a variety of noncredit employee training activities, which sometimes are conducted by universities. They vary in duration from a few hours to a few weeks and cover scientific, technological, managerial, or administrative subjects. Their intent is to familiarize employees with the current state of the art, develop competence in new areas, and provide refresher training. Almost 30,000 NASA employees participated in such training activities during fiscal year 1967. The extent of the activities at one center is shown in table 26.

A large part of the university involvement in these programs is through 1- and 2-week short courses in specialized technical subjects. Two of the

TABLE 26.- MARSHALL SPACE FLIGHT CENTER SEMINARS AND SHORT COURSES

Fiscal year	No. of courses	No. of courses conducted by universities	Total fees and tuition	University tuition	Total employee enrollment	University enrollment
1964	293	98	$ 221,091	$ 79,289	7,303	459
1965	315	119	275,800	75,650	7,815	439
1966	383	79	272,499	85,669	6,691	519
1967	423	151	338,633	124,119	6,541	576
Total	1,414	447	$1,008,023	$364,727	28,350	1,993

universities visited, UCLA and Michigan, have a major commitment to such programs and view them as mechanisms for accelerating the flow of technology from universities to users. NASA is making significant efforts, by committing people and money, to be receptive to their offerings.

To evaluate the returns from such programs, a Marshall Center survey was conducted of supervisors of employees who had attended four short courses and of the attendees at one of the courses. As would be expected, they consider that the principal return to NASA is the employees' acquisition of job-related knowledge that improves work performance. Since many of the short courses are taught at or near NASA centers, educational opportunities are also made available to personnel of other government agencies and industry. For example, Langley initiative resulted in a 2-week acoustics technology course at the Virginia Associated Research Center (VARC) in which engineers from the Army, Navy, and shipbuilding industry participated on at least a part-time basis.

Cooperative Work-Study Program

NASA participates in cooperative work-study arrangements with about 60 colleges and universities. Students alternate academic study with work experience at nine NASA field installations. More than 95 percent of the students are in science or engineering; the rest are in administrative areas of study. Both undergraduate and graduate students participate in the program, but it is largely an undergraduate program. Center objectives for participating are, first, to provide a source for recruiting qualified professional personnel and, second, to obtain the services of preprofessional-level personnel. The extent of the program is shown in table 27. More than 50 percent of the graduates have been employed by NASA, indicating that the program has been a successful recruiting tool.

The program was examined further by sending questionnaires to current and former co-op students at the Marshall Space Flight Center, the center with the largest co-op program in NASA (287 students from 20 universities in 12 states during 1967). The student responses showed that financial considerations were

TABLE 27.- COOPERATIVE WORK-STUDY PARTICIPANTS

Fiscal year	Number employed	Number graduating	Number accepting permanent NASA employment	Dropouts
1964	1,046	48	30	207
1965	1,018	101	52	179
1966	1,115	98	62	214
1967	840	124	62	169

the major factor in their decision to enroll as co-ops. However, their desire for practical work experience was only slightly less important. They felt that they were given responsible positions as co-ops and that Marshall provided a good future for a co-op graduate. Their attitudes were overwhelmingly in support of aeronautics and space goals. They have been good advocates for NASA on their campuses.

In one sense, co-op programs are a form of undergraduate scholarship. Auburn University illustrates this point. Auburn ranks eighteenth in co-op student enrollment among 86 United States institutions engaged in cooperative education. It has 500 students eligible for employment. NASA, during fiscal year 1966, had about one-fifth (113) of these on its rolls at the Kennedy, Langley, and Marshall centers. Total earnings of Auburn's co-op students was about $920,000 that year, and it is estimated that half of this returned to the University and local community for tuition and living expenses of the type usually covered by scholarships. Since one-fifth of the students worked for NASA, the agency is estimated to have contributed the equivalent of $92,000 in undergraduate scholarships to this one school. Since Auburn's formal undergraduate scholarship program was only $120,000, the impact of the co-op program is obvious.

Cooperative work-study programs contribute materially and qualitatively to the education of many individuals. The financial support available in this manner keeps some students in school who would drop out otherwise and they are better professionals upon graduation because of their work experience. It was also the opinion of those responding to the survey that they were making valuable contributions to NASA during their student work periods.

NASA-ASEE Summer Faculty Fellowship Program

This program, established with the assistance of the American Society for Engineering Education, is designed to expose young faculty members to the latest developments in science and technology, to encourage them to attack real-world aeronautics and space problems, and to strengthen ties between NASA personnel and university faculty. The program is administered cooperatively between NASA centers and nearby universities. The faculty fellows spend 10 weeks during the summer at a NASA center or nearby university working on problems of mutual interest. The fellows have the opportunity to attend seminars and lectures. Two separate approaches have evolved: research programs wherein the fellow works on individual projects with a center colleague, and systems engineering programs wherein the fellow works as a team member on a design project. The participation in this program is shown in table 28.

NASA managers were found to be enthusiastic about this program. In many instances, faculty participants had been able to make solid contributions to their technical and scientific problems. Interactions between the fellows and NASA staff had been excellent and had often led to continuing contacts. For example, in the space power and electric propulsion program discussed in Chapter III, four former fellows were found to be engaged in research supported by a NASA grant.

TABLE 28.- PARTICIPATION IN NASA-ASEE SUMMER

FACULTY FELLOWSHIP PROGRAM

Year	Research program		Systems engineering program	
	Centers	Fellows	Centers	Fellows
1964	3	45		
1965	6	120		
1966	7	166	1	15
1967	7	249	3	70
1968	9	254	3	70

A survey of 35 former fellows who had participated in the Lewis Research Center-Case Western Reserve University program resulted in 28 replies, from which the following indirect but continuing returns from the program could be identified:

- 4 new graduate programs directly influenced
- 10 new courses in 9 universities
- 25 major additions or changes to graduate and undergraduate courses in 19 universities
- 31 active research projects at 19 universities on problems either continuing or stemming directly from the summer fellowship program
- 9 new grants or contracts at 6 universities
- At least 6 Ph.D. dissertations from the new research
- 7 major additions or changes to student laboratories
- 2 textbook contributions

In addition, a variety of other influences ranging from special lectures and seminars to a timely illustration in a lecture were reported. All these examples illustrate the very extensive influence that even a modest program can exert.

Case study at North Carolina State University.- A significant education and research development at North Carolina State University is a growing center of excellence in acoustics within the Department of Mechanical Engineering. The growth of this capability in a discipline concerned with the societal problems of "noise pollution" had its genesis in the NASA-ASEE summer faculty program. Dr. Franklin D. Hart, the man behind the program, accepted an NASA-ASEE fellowship at Langley Research Center in 1965 after completing his Ph.D. in mathematics and mechanical engineering. The summer at Langley revealed to Hart the broadness and potential of acoustics research and he became keenly aware of the need for engineers trained in the field.

After a second summer at Langley in 1966, Hart and a colleague, Dr. Larry Royster, who had recently finished a dissertation on vibrations, combined their efforts to begin a program of graduate and undergraduate acoustics courses at NC State. The curriculum in acoustics now offered by the Departments of Mechanical Engineering and Mechanics now contains 11 courses (31 semester hours), including courses in vibration and noise control, architectural acoustics, acoustic radiation, mechanical transients and machine vibrations, random vibrations, nonlinear vibrations, and applications of ultrasonics. Students are interested. At present, 15 M.S. and Ph.D. candidates at NC State have selected acoustics as their major field of study. Students and faculty have participated in ONR-sponsored acoustics research as well as continuing their efforts on a small ($25,000 a year) NASA grant from Langley.

Hart and Royster have been encouraged by the support of industry for graduate students. The E. W. Bliss Company of Swarthmore, Pennsylvania, has given the university an industrial fellowship for a student interested in vibration and sound research. The first recipient of this fellowship is applying technology developed during research on the NASA grant to industrial-machinery noise control.

Hart has made arrangements to send one of his master's candidates to the Institute of Sound and Vibration Research at the University of Southampton, England - one of the most prestigious institutes of its kind for doctoral study. The university had earlier sent Hart to England to study the curriculum and operations of the Institute. The Institute has granted Hart's student a $3,600 stipend, which by English standards is excellent support.

Acoustics research is multidisciplinary by its very nature. Since acoustics involves the hearing mechanism in addition to structural vibration, physiologists and psychologists are needed to determine the parameters of human response. Although there is a tendency for each discipline to see the problem from its own peculiar viewpoint, Hart has deliberately involved several disciplines in his research and more or less forced each researcher to involve himself in the total problem. The result has been that psychologists are now rubbing elbows with mechanical engineers and electrical engineers. A second small grant has been received from NASA for research on human-factor aspects of noise. Hart and his department head, Dr. R. W. Truitt, also have plans for broader cooperation with the medical staff at the University of North Carolina.

Meanwhile, Hart has been arranging for his students to spend time at Langley for exposure to vital research problems. Langley also intends to send two employees on graduate study leave to NC State for further academic training in acoustics in 1969.

Dr. Hart has organized the Raleigh Chapter of the Acoustical Society of America. Already one of the largest locals in the country, it serves as a forum and focus of communication between universities, local industry, and the business world. One result has been to acquaint local industry, such as textiles, with the hazards of unwanted noise.

The State Legislature has approved $650,000 for increase of facilities in mechanical and aerospace engineering at the University. A significant part of the new facility will be devoted to expansion of the present vibration and sound laboratories. The expansion and development of research capability in acoustics at NC State is an integral part of the evolution of a systems engineering curriculum, which has the support of local industry and the State legislature.

North Carolina State University is developing a capability for vital research on a societal problem. It is too soon to guess what implications this new resource will have for industry, government, and society generally, but it should help solve a few of the many problems that concern society. It is developing largely because a young professor was exposed to the need within a NASA center and was then encouraged, and moderately supported, to continue his work at his university.

Case study at Louisiana State University.- Dr. R. W. Pike, a chemical engineer at Louisiana State University who was formerly with the petroleum industry, spent the summer of 1965 as an NASA-ASEE Fellow in Langley Research Center's Entry Structures Branch. He became interested in ablation processes of entry-vehicle heat shields and familiarized himself with the state of the art through Langley's research program. Shortly thereafter, he was awarded a project grant titled "Energy Transfer in the Char-Zone During Ablation" for research closely related to Langley's in-house program. Dr. Pike welcomed an opportunity to focus his efforts on the exact areas needed to supplement Langley's efforts. He spent a month at Langley during each of the following three summers in order to infuse his results into the Langley program and keep abreast of Langley developments and interests. He has since developed contacts at the Manned Spacecraft Center and Ames Research Center and is contributing to communications and coordination of the total NASA program.

Langley managers are enthusiastic about the contributions the research has made in less than 3 years. The principal technical result has been a practical method for treating chemical kinetics within ablating materials. Seven university reports and three conference papers are indicative of productive research. The closeness that has been maintained with Langley has also led to significant impact on the in-house program of research to develop improved heat-shield materials.

The university contributed several thousand dollars for refurbishment of laboratory space to house the research. The grant has equipped the laboratory, which will be useful for other university research after the present work is completed.

Dr. Pike's teaching has been influenced to a considerable extent; his graduate course in fluid mechanics has been extensively revised and he uses examples from the research to illustrate the state of the art. He has brought chemical engineering expertise from the petroleum industry to the research, and through his students and professional associations he is now transferring space-related technology back to the chemical industry.

Two graduate students are being supported by this research in their doctoral programs. Dr. Pike brings them to Langley for annual reviews so that they may have an opportunity to report their own results and be exposed to the Langley program. They have been able to attend technical meetings and have presented three conference papers. They are developing professional status prior to receiving their doctorates. Dr. Pike feels that their educational experience is greatly enriched by exposure and close contact with real problems. Both students are preparing for university careers.

NASA-NRC Resident Research Associateship Program

Engineers and scientists who hold a Ph.D. degree or equivalent may spend a year or more in residence at NASA centers through the NASA-NRC Postdoctoral Resident Research Associateship Program. The National Research Council administers the program under contract to NASA. It establishes the policies, screens and selects applicants using panels of judges from the National Academy of Sciences and the National Academy of Engineering, and monitors the interaction between the associates and NASA centers. The NASA centers assign a scientific adviser to each associate and provide computer and laboratory services for his research. The extent of the associate's involvement with ongoing programs of NASA varies with the center, the associates, and their advisers. Associates are usually young researchers with recently acquired doctorates, although some senior postdoctoral associates are included in the program.

NASA has invested about $11.4 million in the program since its initiation at Goddard Space Flight Center. More than 300 researchers with an average tenure of 1.3 years have been involved. The number of participants in recent years is shown in figure 3. The program has grown rapidly; almost 200 postdoctoral associates were involved in research in 1968 at any given time.

The international character of the program and the extent of participation by various NASA centers are shown in table 29. Since 1962, more than 60 percent of the participants have come from 28 foreign countries. The largest numbers came from India (30), United Kingdom (27), Germany (21), and Japan (20). Three of every four associates were in residence at either the Goddard Space Flight Center (including the Goddard Institute for Space Studies) or Ames Research Center.

The program is highly regarded by NASA managers who have contact with associates. The participants are viewed as being extremely competent and as making substantial contributions to science and NASA programs. They also are seen as a source of ideas and stimulation for the permanent NASA staff. The United States' associates, and to some extent those from other countries, often continue their contacts with the NASA staff after returning to their home universities.

Although predominately an international program, there has been impact on U.S. universities. More than a hundred individuals have been given the opportunity for postdoctoral study. An excellent example of the opportunities afforded by the program is the continuing relationship developed between the Department of Aeronautics and Astronautics at Stanford University and NASA's Ames Research Center. Dr. Max Anliker, associate head of the department, spent a year as a senior resident research associate at Ames and initiated research in the life-science area that Ames has continued to sponsor. After completing his tenure, Dr. Anliker built a multidisciplinary research program around the bioscience problems of manned space flight and the application of engineering to medical monitoring. His group includes 12 Ph.D. candidates, 11 in engineering and one in physiology, who have guest-worker privileges at the Ames Research Center and are in close contact with the research in progress there. At least two Ph.D. degrees have already been earned by his students. He reports that both students and faculty are stimulated by the close contact with real problems at Ames. Thus, the interaction stemming from the associateship program has strengthened and broadened NASA research, created a multidisciplinary university research group with capability for attacking some of the nation's health problems, enriched the curricula of the university in a new area, and is producing highly skilled scientists.

TABLE 29.- PARTICIPANTS IN THE NASA-NRC RESIDENT RESEARCH ASSOCIATESHIP PROGRAM SINCE 1962

NASA installation	Country of residence		Number of countries
	United States	Other	
Ames Research Center	37	31	15
Electronics Research Center	2	5	5
Goddard Institute for Space Studies	19	27	15
Goddard Space Flight Center	34	76	19
Jet Propulsion Laboratory	9	9	6
Langley Research Center	6	16	9
Marshall Space Flight Center	3	15	6
Manned Spacecraft Center	6	0	0
Total	116	179	[a]28

[a]Column does not sum to total because of duplications.

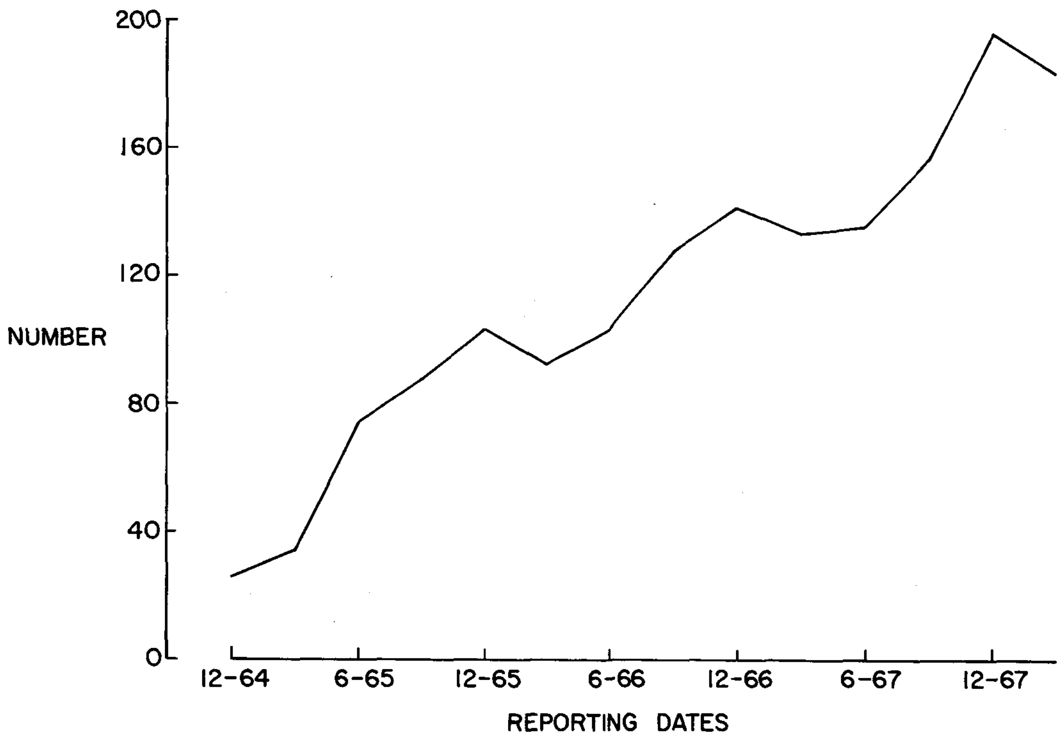

Figure 3.- Number of NASA-NRC resident research associates on tenure since 1964.

CHAPTER VI

FURTHER ISSUES OF NASA UNIVERSITY PROGRAMS

A number of issues not covered in previous chapters arose during the study. No pretense is made that the following covers such issues exhaustively or that all the significant issues have been examined. However, the discussion in this chapter may shed light on future university programs.

Balance Within Universities

A criticism often leveled at the project system of research is that it leads to unbalanced development both within the total university community and within a single university. Under the project system, principal investigators and departments that have capability tend to attract support that develops further capability. The rich get richer while the poor stay poor. NASA's Sustaining University Program has aimed at alleviating this problem by building a broader base of competence throughout the university community. This it has generally done; NASA support has assisted some universities in increasing their total level of competence to the point of successful competition for project research, especially in the physical science and engineering disciplines. NASA support obviously has not displaced high-ranking institutions from positions of strength but the gap between such schools and some less widely known institutions has been narrowed.

NASA's Sustaining University Program has also contributed to balanced development of the various engineering and physical science disciplines within many universities. At its worst, SUP research was administered by the universities as project support which tended to overdevelop one or two already well-established specialties. At its best, it was distributed so as to develop a uniform competence across space-related departments. SUP research funds have tended to flow to areas not being supported by project money. As competence developed and other support was received, the SUP research funds have tended to flow into new areas.

NASA support has contributed to the imbalance of support of social sciences and the humanities relative to physical sciences and engineering. Although the agency has encouraged universities to involve more social scientists in their space-related research, the response has been meager. In many cases, universities have not shifted internal resources to the social sciences and humanities to compensate for the imbalance. There appears to be no great concern in many quarters about the problem. However, the social sciences have not been retarded in their growth by NASA support, but their rate of growth has been less than that of physical sciences and engineering.

Values of Support by a Mission-Oriented Agency

Universities like multiple sources of Federal support. If a single agency were providing all the support, they argue, then a single individual or a small "in-group" could have an unhealthy influence over progress in a particular discipline. If universities were denied support by mission-oriented agencies, two consequences are predictable. First, the traditional role of university professors in generating new knowledge, writing textbooks, and graduate education would decline in disciplines closely associated with missions of the "big science" agencies. Second, many active researchers in the mission-related disciplines would be forced to leave universities and associate themselves with government-sponsored laboratories. The effect would be to lose indirect educational returns and technology-transfer aspects now expected of advanced research and development.

Mission requirements often accelerate the development of areas of science or technology that would otherwise be stagnant. An example frequently cited is the revival of interest in planetary astronomy generated by NASA's mission. Astronomers concentrated on stellar astronomy for decades until NASA's scientific program and mission requirements rekindled curiosity about the planets. Similarly, NASA's mission requirements stimulated research on biomedical sensors and opened new areas of research in space biology.

There is a considerable body of opinion within universities that sponsorship of research by NASA has great value in itself. This is especially true in the engineering and applied science areas. University researchers welcome opportunities to work closely with NASA in-house programs. They report that research is of higher quality, students are more highly motivated, and impact on teaching and professional status is more significant when research is related to "real" problems. They feel that NASA support also gives them access to NASA facilities for research. Concern about violations of academic freedom or undue interference is rare, possibly because work tied so closely to NASA's program tends to influence NASA as much as the researcher.

Some highly respected scientists believe that NASA support is no different from NSF support. They feel that NASA project research requirements are of such a basic nature that NASA support is analogous to generalized science support.

Postdoctoral Research

Postdoctoral research appointments have become a fact of life in many disciplines. Well established in the physical and life sciences, they are becoming a requirement in the engineering disciplines. A post-Ph.D. appointment is particularly appealing to those preparing for careers in university teaching and research. New faculty positions in the prestigious universities are beginning to require postdoctoral preparation.

Since inadequate postdoctoral fellowship support is available, postdoctoral research is largely financed by project research. NASA university programs have supported a considerable amount of postdoctoral study in the physical sciences.

Satellite flight experimentation affords rich opportunities for postdoctoral research. As space-science support has helped raise the level of competence, additional universities have desired to participate in space-related research at a level of sophistication beyond that of most predoctoral students. Thus, NASA has helped increase both the level of postdoctoral research and the number of postdoctoral research positions in universities. The overall result is that university scientists have been trained to a higher level of competence. In return, the Nation's aeronautics and space programs have benefited by having participants with higher level skills.

Federal Contract Research Centers

In the early stages of the space program, NASA management rejected the approach of involving the scientific community through the establishment of federal contract research centers, as was the practice of the Atomic Energy Commission. Rather than establish a few national centers of excellence with which space scientists could affiliate, NASA has taken the diversified, pluralistic approach of bringing the space program to the campus and thereby has given many more universities the opportunity to participate in the space program. NASA believed its approach would allow it to achieve its objectives while simultaneously strengthening the research base for graduate education throughout the Nation and training more and better students. It was also expected that technology developed in the space program would be more rapidly disseminated and utilized by the rest of the nation if the effort were diversified.

The decision to involve the total community has generally met with approval by universities. University scientists familiar with both approaches feel that space-science research has been more dynamic in concept and achievements than it would have been with contract centers. In the present era of shrinking budgets, space-science research groups that have been created within universities also represent capability that may be diverted to new areas of national concern with less dislocation than would occur under the contract center approach. Regardless of the availability of space-science support, the universities will retain a competence for graduate education that would not have existed under the other approach. Therefore, based on the involvement of university scientists in the aeronautics and space program, the increased capability for graduate education which NASA has stimulated, and the graduate students who have been financially supported and involved in NASA research, it appears that the decision against federal contract research centers was in the best interests of the agency and the country.

Organizational Structure

The difference between the organizational structure of NASA and that of most universities often interferes with communications. For example, NASA has no "Assistant Administrator for Electrical Engineering" and universities do not have a "Dean of Manned Space Flight." Some previous studies of NASA university programs have recommended that NASA alter its structure to more closely resemble discipline-oriented university departments in order to simplify communications for the university researcher. Since NASA is organized to achieve its mission objectives, such recommendations are hardly practicable. Similarly, universities, which are designed basically for educational purposes, have been criticized for failure to adapt adequately to be responsive to research and service needs. However, matrix-type organizations are developing within many universities, apparently in order to be more responsive to these needs. These are the centers, institutes, and laboratories found in most large universities that bring together faculty and graduate students from several academic departments. The common bond among the staff is research on related problems. Although, as discussed earlier, some organizations of this type are weak in their educational functions, such weakness does not seem to be endemic to the approach itself.

By definition, space science includes several disciplines. This has forced universities engaged in space-science research to work across departmental lines. As a result, a few new academic departments called space sciences have been created. These departments are too new to allow conclusions about their viability. A more typical university response has been to establish one or more of the matrix-type organizations. These have not been drastic innovations, but simply adaptations. NASA university programs and the interest in space sciences generally have accelerated experimentation with and evolution of university organizational structures even though innovations such as broad multidisciplinary research teams have not been as significant as was desired.

Evolution in Organization for Education and Research

The evolution in university organizational structure discussed above apparently results partially from the complexity of modern research and the increasing role of research in a university's activities. The counterpart to the changing university is the changing role of education in the NASA centers. Education is still a minor function of the centers and is still related to their requirements for recruiting, upgrading, and updating personnel. However, it has resulted in some elaborate graduate training programs for employees in which staff members teach graduate-level courses and employees conduct thesis research as part of their NASA responsibilities. Other centers arrange for research in residence by nonemployee graduate students, with NASA staff providing part of their supervision. It is also quite common for staff members to hold adjunct professorships at nearby universities.

The functions of individuals within NASA centers and individuals in university research organizations are becoming more alike. For example, a young NASA scientist or engineer doing in-house thesis research is functioning similarly to a university graduate student who is a research assistant. The duties of a university professor, who may teach one course, supervise graduate students, and conduct research, differ only in emphasis and degree from those of a NASA scientist who teaches in an adjacent university and supervises thesis research in addition to his personal research. Partial support for all four individuals in this example probably comes from the Federal Government.

The ultimate evolution of government research centers and university research institutes into one organization is only speculative. However, there seems to be a trend for their organizational structures to reflect the inseparability of research and education. One result of a closer alinement of government research centers and university research institutes would be a simplification of communication between the groups. Is it possible that they might ultimately merge into centers with the dual functions of research and education in the area of broad societal problems?

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