CHAPTER VI

CHAPTER VI

O R G A N I Z A T I O N   A N D   M A N A G E M E N T*

The NASA organization and management approaches were based on the requirements of the National Aeronautics and Space Act of 1958 and certain principles and concepts of management that were established, extended, and refined by the NASA Administrators in accordance with the statutory requirements.

The National Aeronautics and Space Act of 1958 was enacted during the administration of Dwight D. Eisenhower under the leadership of the Senate Special Committee on Space and Astronautics under the chairmanship of the majority leader, Senator Lyndon B. Johnson, and the House Select Committee on Astronautics and Space Exploration under the chairmanship of the majority leader, Congressman John W. McCormack.

The Act establishing NASA specified that:

> the Administration shall be headed by an Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate. Under the supervision and direction of the President, the Administrator shall be responsible for the exercise of all powers and the discharge of all duties of the Administration, and shall have authority and control over all personnel and activities thereof.

The only other Presidential appointee specified in the Act is the Deputy Administrator who "shall perform such duties and exercise such powers as the Administrator may prescribe. The Deputy Administrator shall act for, and exercise the powers of, the Administrator during his absence or disability."

It is therefore the responsibility of the single administrator, and within his authority, to define the organization

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*This chapter was prepared by Charles F. Bingman.

and management principles, policies, and practices to be followed in carrying out the activities of the Agency. The foresight of the authors of the Act is indicated by the success that has been achieved under the system it established and by the continued validity of the Act over the last decade as the basis for defining and implementing programs, plans, and activities related to the major aeronautical and space responsibilities of NASA.

The Administrator clearly had executive authority to make the major agency decisions himself. However, when he came to NASA in 1961, James E. Webb immediately made clear that Dr. Dryden would remain as Deputy and that Dr. Seamans would remain as Associate Administrator, with the support needed to implement his organizational position as "General Manager of Operations." As Mr. Webb pointed out in his Foreword to Rosholt's "An Administrative History of NASA"[1],

> the three of us decided together that the basis of our relationship should be an understanding that we would hammer out the hard decisions together and that each would undertake those segments of responsibility for which he was best qualified. In effect, we formed an informal partnership within which all major policies and programs became our joint responsibility, but with the execution of each policy and program undertaken by just one of us. This meant that everyone in and out of the agency knew all three of us would be involved in all major decisions; that with policy established, the orders for its execution could be issued by any of us; and that, while NASA had an Administrator as a single point of final decision, to the fullest extent possible we would act together.

This arrangement continued through a time of much change, including a major reorganization in 1963, up to the time of Dr. Dryden's death in 1965.

The November 1963 reorganization made major changes in the assignment of program and administrative responsibilities to the offices in NASA Headquarters, and the relationships between Headquarters and the Field Centers. The most fundamental change was the addition of responsibilities for institutional center management to the existing program responsibilities assigned to the Headquarters Program Office with which the Center was primarily concerned.[2] In the organizational pattern that had been in effect since 1961, the Centers had reported to the NASA Associate Administrator and were responsible to him for meeting the needs of the Program Offices.[3] In 1963 the increased authority and responsibility of the Headquarters Program Directors was recognized by changing their titles to Associate Administrator for Manned Space Flight, Associate Administrator for Advanced Research and Technology, and Associate Administrator for Space Science and Applications.

These changes came after the period from 1961-1963 when James E. Webb, the new Administrator, Dr. Dryden, the Deputy Administrator, and Dr. Seamans, the Associate Administrator, had established an organizational structure which permitted them to

> participate directly (without an intervening layer of management) to ensure a continuing evaluation of the performance and growth potential of senior personnel . . . We wanted enough time, in a fluid state, to make a more permanent match of the men with the work assignment.[4]

Strengthening the program Associate Administrators was an important move to give these men latitude for decision making and control over the essential resources needed to carry out the programs of NASA for which they were responsible. At the same time however, Webb, Dryden and Seamans sought to emphasize the need for a balanced organization and management system which recognized all the needs of the agency and not just its principal programs. Essential intelligence had to flow to the Administrator so that progress could be evaluated and problems resolved. There was a clear commitment to the Congress to keep it informed of program and operating status. There was an equally important responsibility to appraise program activity so that resources could be shifted to break bottlenecks or take advantage of emerging opportunities. There also was a need for management to have the means for gauging the effectiveness of the total management job being done throughout the agency, and identifying the need for change and accommodation. Flexibility was required and rapid and perceptive feedback was a critical element in knowing when that flexibility should be exercised.

The 1963 reorganization thus brought to fruition an innovative form of organization and management relationships which transcended more traditional concepts of line/staff organization, and strove for a functional management system which would balance and round out the authorities incorporatedin the line structure. Functional managers in such areas as procurement, personnel, resources control, and other administrative specialties were to play a stronger role than simply furnishing "staff advice" to the line official; they were charged with the broader responsibility of observing and evaluating the manner in which their functions were being performed throughout NASA and seeing to it that functional needs were met in a way which accomplished institutional as well as program objectives and which were consistent with policy and sound practice. In effect, decisions were not adequate if they failed to take into account the functional and administrative requirements of the agency as defined by law, regulation, management policy, or the dictates of sound management principles. Functional managers were expected to define these requirements, and line managers were expected to give the requirements full consideration in shaping their own decisions at every level in the organization. Usually this meant that functional managers had two bosses, since they had to be supportive of line officials who had difficult jobs to accomplish, and yet had to assure agency management that every decision was based on a balanced judgement which reflected administrative needs and constraints as well.

As Mr. Webb has stated it,

> Functional management, as we perceive it, is a means of optimizing administrative specialization, while, at the same time, retaining the essential ingredients of traditional line management concepts. It is an effort to cope with the persistent problems we have in modern complex organizations of solving the dilemma between hierarchy and specialization. [5]

The functional manager's job thus has these characteristics: he is to support substantive programs, and help them to succeed; he is also a "countervailing power" to assure the balance of administrative considerations within the management system; he is a separate line of communication and advice to top management and contributes to the formulation of overall decision making; he is an advocate of excellence in the performance of his functions throughout the organization. The functional management group contributes that vital balance which is necessary to make the total management system effective and self-policing.

PROGRAM IMPLEMENTATION BY GOVERNMENT-INDUSTRY-UNIVERSITY TEAM

Under the statutory requirement that U. S. space activities be so conducted as to make "the most effective utilization of the scientific and engineering resources of the United States" and that NASA "arrange for participation by the scientific community in planning scientific measurements and observations" and "provide the widest practicable and appropriate dissemination of information concerning its activities and the results thereof," NASA has, from the start, developed and used a combined government-industry-university basis upon which to build its aeronautics and space programs. The concept was established during the first five years of NASA's existence and it is fundamental to NASA's operations.

As NASA began to move forward into the implementation of the new programs that had been proposed by President Kennedy in 1961 on the advice of Vice President Johnson, the magnitude and complexity of the civilian space program became apparent. The collaborative team of government, industry, and universities which NASA had set out to assemble was seen as a necessary way to carry out the space program. The agency's program, therefore, was to be conducted not by NASA alone. Its accomplishment was to depend on a complex of resources, successfully drawing together organizations and capabilities of all segments of the National economy, and integrating them into an effective operational system.

New ideas and methods had to be developed for this enormous management task. NASA, as the responsible government agency, was to emerge, perhaps more extensively than any other government agency, as a technical management organization with strong in-house technical competence charged with decision making, direction, and program evaluation responsibilities of an interrelated network of industrial contractors, university scientific investigators, and other government agencies.

In Mr. Webb's words,

> We have sought on the one hand, to minimize the disruptive effects of what has necessarily been a vast undertaking, and, on the other hand, to so conduct our operations as to strengthen in every way feasible the positive values of our society and its institutions.

We rejected a proposal by one large industrial firm to do the entire lunar landing job single handed, as well as a similar proposal by a leading university to operate a laboratory that could do all the scientific research.

We decided as a matter of deliberate policy to place principal reliance on the American industrial establishment and the American university system as a whole. We decided to focus our governmental efforts principally on developing the needed in-house competence to make responsible decisions, and on <u>organizing</u> and <u>managing</u>. A measure of what we had in mind is the fact that ninety percent of every dollar that has come to NASA has moved outside the Agency. Our purpose was to spread the difficult problems over the largest number of able minds in the belief that this would produce the best answers. We recognized that to be effective in this approach NASA had to have very strong scientific and technical in-house capabilities.

THE NASA IN-HOUSE CAPABILITY

Let us now examine how the required resources were drawn together by NASA. We will consider first the in-house NASA laboratory capabilities which have been carefully and deliberately built up to provide a national resource applying its talents to advancing the technology of aeronautical and space systems so as to provide scientific understanding of the Earth and its atmosphere, of the solar system, and of man and other life forms.

By way of summarizing its in-house capability, it should be pointed out that NASA now has eleven research and space flight centers; and counting the various unique installations that are associated with these centers, NASA has nineteen installations plus twenty-seven tracking stations. NASA owns a total of 143,000 acres of land and utilizes, through leasing and other arrangements, an additional 194,000 acres. The total capital investment at these in-house installations is over four billion dollars. About 32,000 civil service employees as well as other thousands of contractor and university employees are now involved in operating or supporting these installations. These employees cover the span of disciplines from mechanics, technicians, and clerks, to Ph.D's in the science, engineering, and management disciplines.

The strength of NASA is essentially the strength of its field centers, and perhaps the most significant accomplishment of NASA's first decade will prove to be the manner in which the NACA base of capability was enlarged and expanded, with new centers of excellence in technology added to those which already existed. The creation of effective new organizations is always difficult; the creation of new laboratories for research and development is particularly costly and time-consuming, and a "critical mass" of self-sustaining accomplishment is not always achieved. NASA was concerned that its great new development projects had to be handled in a way which did not hamper or destroy the research capability which already existed.

The development and growth of NASA's laboratory competence in research and advanced technological development and in flight operations was accomplished in several ways. When NASA was established, the research capabilities of the National Advisory Committee for Aeronautics -- the Langley, Lewis, Ames Research Centers and the Wallops and Flight Research Stations -- were brought in to serve as the nucleus for NASA's aeronautical and space research and development. Each of these research centers was assigned limited flight mission development projects as a means of using its capabilities to assist NASA in handling its large growth in flight activity and also to keep so involved in real flight problems that research activities would be realistically directed toward advancing the country's capability in aeronautics and space. Among the flight development activities that were placed in these research centers are, for example, the responsibility for directing the development of the Centaur rocket at the Lewis Research Center, the Pioneer solar probes at the Ames Research Center, the Biosatellite projects aimed at determining the effects of the space environment on life forms at the Ames Research Center, and the Lunar Orbiter project directed by the Langley Research Center. The need for an in-house capability for research in advanced electronics was recognized later with the establishment of the Electronics Research Center in Cambridge, Massachusetts.

In addition to the research responsibilities assigned to the National Aeronautics and Space Administration, the National Aeronautics and Space Act assigned to NASA a development and space flight operations responsibility that required a scientific and engineering development capability beyond that available in NACA. As a result of authorities specified in the National Aeronautics and Space Act of 1958,[6] the Vanguard team of the Naval Research Laboratory was transferred to NASA and formed the nucleus for NASA's Goddard Space Flight Center in Greenbelt, Maryland; and the Jet Propulsion Laboratory operated for the Army by the California Institute of Technology was transferred to NASA. In 1960, the Development Operations Division of the Army Ballistic Missile Agency was transferred to NASA to form the basis for the Marshall Space Flight Center in Huntsville, Alabama. In addition, a cadre of personnel of the Langley Research Center were assigned to the Space Task Group to initiate this country's first manned space flight activities in Project Mercury.

In 1961, when the national commitment was established to develop a space flight capability sufficient to land man on the Moon in this decade, the Space Task Group became the core of the Manned Spacecraft Center in Houston and was assigned responsibility for all manned spacecraft, including Gemini and Apollo which will land men on the surface of the Moon, and for the flight operations of these systems. The Kennedy Space Center in Florida was an outgrowth of the Launch Operations Directorate of the Marshall Space Flight Center, and was established as NASA's major launch operations facility for all types of programs.

These centers are referred to as NASA's "development" centers because of the nature of their mission responsibilities. Although their emphasis is on the development and conduct of space missions, some research and advanced technological development is conducted at these Centers as a means of anticipating the best means for carrying out and planning our future programs and, in the process, to maintain the technical competence of the personnel assigned. Therefore, NASA's in-house competence was established in two principal ways -- by bringing into NASA existing laboratories and adjusting and expanding their capabilities to meet the needs of the aerospace program, and by establishing new laboratories based on an existing nucleus of a strong and competent group already performing work in the required areas.

Serious attention was given to the need for and the establishment of the new facilities required to carry out the agency's program. Dr. Seamans outlined NASA's policy regarding the acquisition or construction of facilities at NASA installations in testimony before the Senate Committee on Aeronautical and Space Sciences:[7]

> Research facilities, fabrication plants, and testing sites for space hardware are expensive to design and construct. In the past, the government has often undertaken to supply contractors with the necessary, specially built facilities at sites adjacent to or on the contractor's own plants . . . .
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> However, it has been NASA's policy to explore other possibilities whenever a gap in facility capability presents itself. Instead of building facilities which can be fully utilized only if a particular contractor were to continue indefinitely on NASA work, NASA has attempted wherever feasible, to provide government-owned land to serve all user agencies and contractors regardless of which way later developments eventually move. The government's possession of central facilities operated under its direct supervision will achieve substantial economies through avoidance of duplicating expensive facilities. In addition, this approach avoids giving any one contractor an unfair competitive advantage.

The expansion of NASA's facility base could not be allowed to overburden its existing installations. Therefore, entirely new locations had to be selected, and adequate resources provided to create new centers of excellence of a quality comparable to those the agency already possessed. Formal site selection procedures were established which provided for carefully considered criteria for site evaluation which would be approved by the Administrator before any sites were investigated. A team of experts was used in each major site evaluation, and individual cities were encouraged to make presentations which highlighted their advantages and their interest in the program. Final selections were made by the Administrator, based on the complete evaluation of the expert teams and other significant policy and operational considerations.

Role of the Army Corps of Engineers

No description of the growth and activation of NASA's facilities would be complete without a discussion of the important role played by the U. S. Army Corps of Engineers in the design and construction of these facilities. The Corps acted as the manager of most of NASA's major construction projects during the past decade. The basic interagency agreement under which the

Corps performed these functions in support of NASA programs was established in April, 1960. This decision on NASA's part to rely on the Corps was consistent with the requirements of the National Aeronautics and Space Act and with NASA's determination to rely on existing competence rather than building its own capability to perform all required functions.

Recognizing the magnitude of the facility construction activity that was required to carry out its programs, NASA management was faced with the fact that there was only a limited capability within NASA to devote the necessary attention to its major construction projects while also planning, managing, directing, and, in certain cases, conducting the research and development activities necessary to carry out its programs.[8] Although it would have been possible to build up an in-house construction management organization, this would have meant a diversion of manpower resources which could be more productively utilized in other areas.

The Corps of Engineers already possessed the competence for the management of large scale construction. The Corps had a nation-wide field organization, broken into regional and local offices, which could undertake the work of the NASA installations. The Corps also had an existing structure of construction management policies, procedures, standards, and inspection techniques, and was familiar with the labor and industry groups that would have to be involved in the NASA construction program. In addition, as Dr. Seamans pointed out before the House Committee on Science and Astronautics in testimony dealing with a NASA authorization for fiscal year 1964:

> The particular places where we are using the Corps are those that would have involved large buildups inside NASA in order to take the responsibility. We felt it advisable in those cases to use the Corps because they have the flexibility to work with us during this buildup of these major facilities and then to draw back when this effort is completed.[9]

Facilities for Manned Space Flight

The major segments of NASA's total complex of necessary buildings, laboratories and test facilities had been defined by FY 1963, and funds had been appropriated by the Congress in fiscal years 1961 and 1962 for their construction and activation. In FY 1963 the main requirements for manned space flight were outlined: $635 million for the acquisition of land on Merritt Island at Cape Kennedy for the construction of NASA's own major launch facilities, and in rural Mississippi, near New Orleans, for the construction of the facilities for ground static tests of the large Saturn launch vehicle systems being developed under the direction of the Marshall Space Flight Center. With these two new facilities, the basic manned space flight facility capability was and is as follows:

1. Marshall Space Flight Center (MSFC) where the design, development, and test of Saturn IB and Saturn V launch vehicle systems has been managed. The Huntsville, Alabama, location itself has launch vehicle component test stands, but the main static test capability, especially for the Saturn V first stage, is at the Mississippi Test Facility(MTF). Production of Saturn I, IB and V first stages is carried out at the Michoud plant in New Orleans, Louisiana, managed by MSFC. Finally, a special computer facility at Slidell, Louisiana, located midway between MTF and Michoud, was activated in the spring of 1963.

2. Manned Spacecraft Center (MSC) where, in addition to normal office and shop facilities, the Mission Control Center was being constructed to control flight missions for all manned space flight programs beginning with Gemini and including Apollo. Two major vacuum chamber facilities for the development test of large manned spacecraft systems were planned and are now being used at MSC. In addition, the Houston site contains such other research/test facilities as astronaut flight simulators, a man-rated centrifuge, a lunar landing simulator and, more recently, the Lunar Receiving Laboratory for the processing and analysis of samples of material brought back from the surface of the moon. On a site adjacent to the U.S. Army White Sands Missile Range, and designated the NASA White Sands Test Facility, MSC manages the static testing of its on-board spacecraft propulsion systems.

3. Kennedy Space Center (KSC), which includes shops, assembly buildings, and launch facilities on the older Cape Canaveral site of the Air Force Eastern Test Range, plus a new complex of NASA facilities on Merritt Island nearby. The Merritt Island Launch Area (MILA) houses the offices, laboratories, and shops to serve both manned and unmanned launch operations. It is the location for the facilities required for the Apollo-Saturn V

space vehicle combination to be used in the manned lunar landing program.

This complex of facilities, located at government installations, is intended to serve as a national resource for space flight activities. In addition to these facilities are the Sacramento, California, test facility of the McDonnell-Douglas Aircraft Corp. for the static testing of the Saturn S-IV-B stage; the Santa Suzana, California, test complex of the North American-Rockwell Corp. for the test of S-II and rocket engines; the large static test stands at Edwards AFB for the F-1 engines being manufactured by Rocketdyne Division of North American-Rockwell; and others.[10]

The years 1962 through 1965 witnessed a massive effort within the manned space flight program to design, develop, construct and activate the facilities required, particularly for the Apollo Program, The following table shows the facility funding in millions of dollars at NASA's manned space flight field installations during this period:

	FY 62	FY 63	FY 64	FY 65
MSFC	30.03	40.61	28.24	12.30
MTF	23.36	76.25	103.38	58.51
Michoud	10.12	28.55	7.58	6.45
KSC	115.83	333.19	275.37	88.52
MSC	73.10	24.52	34.08	19.79

During these years, the expenditure for construction of facilities at the manned space flight field installations constituted from 63% (1963) to 82% (1965) of the total of all construction funds spent at all NASA field centers.

At Kennedy Space Center alone, an investment of almost a billion dollars has been made by NASA for the unique facilities required for the assembly, checkout, test, and launch of the Saturn-Apollo space vehicle system. These facilities include the Vehicle Assembly Building, the Crawler Transporter, Launch Complex 39, and the Launch Operations Control Center.[11]

The design and construction of assembly and launch facilities had to accommodate to the specific requirements of booster and spacecraft. Therefore, facilities design and construction could not be firmed up until booster and spacecraft specifications and needs were known. Furthermore, any changes to booster or spacecraft might have a secondary impact on the test and checkout facilities at KSC. Consequently, Kennedy management had to monitor the progress of other hardware than its own.

Also, the manufacturers of sophisticated R&D hardware are not able to identify and resolve all technical problems before shipment for launch. KSC had to be prepared to make final corrections of discrepancies and, if necessary, to replace components or subsystems on flight hardware after it arrived at the Cape.

These requirements necessitated the development of a rapidly-functioning system of configuration management and flow of hardware-related information capable of following flight hardware through its various tests and checks, so that each succeeding group could take responsibility for it with full knowledge of what remained to be done to prepare it for use. KSC always has been the end of this line. The last steps of preparation must be taken there and must be right. Automatic checkout equipment was developed to assist in this process and all KSC facilities were built with this responsibility in mind.

Most of the major facilities of the manned flight program became operational by the end of FY 1966. MSC occupied its principal buildings in February 1964, and began controlling Gemini flights in the Mission Control Center in June of 1965. The Mississippi Test Facility began the conduct of static test firings in early 1966. KSC's new Headquarters on MILA was occupied in April 1965, and the first launch of a Saturn IB from Launch Complex 37 occurred in February of 1966. And then, after several months of pre-launch preparation in the Vehicle Assembly Building, the first and successful launch of a Saturn V took place from Launch Complex 39 on November 9, 1967.

Science and Engineering Research Facilities

NASA expenditures for facilities for the manned space flight program have quite naturally attracted major attention in

NASA, in Congress and by the general public. However, in development centers such as GSFC and JPL, requirements for development, test and operations facilities were also developed and met. And, over the past decade, many of the facilities specifically funded and built in NASA's programs of science, applications, and advanced research and technology have contributed significantly to developing or upgrading the nation's overall basic research capability.

The importance of adequate basic research facilities was emphasized by Dr. Raymond L. Bisplinghoff in testimony before the House Committee on Science and Astronautics in defense of NASA's FY 1965 authorization:

> The technical program I have described is critically dependent upon the existence of research facilities which represent one of the Nation's strongest resources in its bid for pre-eminence in aeronautics and space. The very existence of advanced research facilities such as high speed wind tunnels or environmental chambers has spelled the difference between success and failure in projects in the past. Interestingly, many of our new facilities must themselves be evolved through research since they usually have little or no precedent . . . .
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> One of the fundamental premises of NASA's program of advanced research and technology is that of performing as much ground research and development as possible before undertaking flight experiments. A continuous upgrading of our research facilities is mandatory if we are to maintain the effectiveness of our research and development programs.[12]

A fundamental requirement of NASA's research facilities was to provide simulation of the full range of environmental conditions to which aeronautical and space vehicles would be exposed. Experience has illustrated that the timely construction of research facilities which permit the simulation of flight environment on the ground have reduced costly flight programs and saved valuable time. Hence, wind tunnels, environmental chambers, centrifuges, flight simulators were indispensible tools in research programs in such areas as propulsion, aerodynamics, materials, structures, controls, guidance and life support. Facilities were needed to simulate the effects of space in order to examine and solve operating problems of these systems, and also to provide an understanding of the physical phenomena underlying this operation.

The decision to create NASA's newest field center -- the Electronics Research Center (ERC) in Cambridge, Massachusetts -- brought into focus basic issues of how best to meet a defined research need. In his letter to Congressman George P. Miller, Chairman of the House Committee on Science and Aeronautics, Mr. Webb described the problem and the solution (the establishment of ERC) proposed in the President's FY 1964 budget request as follows:[13]

> During the first few years of NASA's existence, the Agency relied heavily on existing electronics technology and electronics research being conducted in industry and in universities for the aeronautics and missile fields. Electronics research and development within the Agency has been conducted on a decentralized basis, primarily as an adjunct to the major booster, spacecraft, or ground-support system developments. As a consequence, most of the NASA centers developed a limited electronics research competence closely related to those specific technical areas and development missions comprising their primary missions.
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> By 1961, a number of top NASA space scientists and engineers began to recognize the need for additional electronics research and advanced development. The accumulated flight experience was beginning to show the significant differences between the atmospheric and the space environments for electronics components and systems. The magnitude and importance of the problem is reflected in the fact that electronics components account for over 40 percent of the cost of our boosters, over 70 percent of the cost of our spacecraft, and over 90 percent of the cost of the resources going to tracking and data acquisition. It was becoming clear that the existing technical base was not adequate to the growing electronics requirements.
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> Following discussions with members of the NASA staff and others about this problem, I took a number of steps to correct this deficiency. A separate office

of electronics and control was created with the Office of Advanced Research and Technology during the NASA Headquarters reorganization of November 1961. This office, under the leadership of Dr. Albert J. Kelley, was asked to study in detail NASA's present resources and capabilities in electronics research, the long-range needs of the overall space program in this field, and to recommend a plan to meet these needs.

Dr. Kelley's group found that, although NASA was involved deeply in developmental projects covering almost all segments of the electronics field, NASA's in-house research efforts were diffused and comprised a relatively small cumulative effort. Our program for contractual research in electronics was handicapped by NASA's lack of a group of able scientific and engineering personnel, concentrating on electronics and associated physics research, and relating such contracted research effectively to the overall space program. Early in the fall of 1962, Dr. Kelley reported that NASA's long-range requirements for in-house competence required a substantial increase in electronic research efforts, and strongly recommended the establishment of a new research center. This matter was carefully reviewed by Dr. Bisplinghoff, the Director of the Office of Advanced Research and Technology, Dr. Seamans, Dr. Dryden, and myself. We were unanimous in our judgment that the best interest of NASA, and of the Nation, would be served by the establishment of a new electronics laboratory to fulfill the requirements of the Nation's aeronautics and space program.

Before reaching this judgment, consideration was given to several ways of creating an in-house electronics research capability. One was to increase the present electronics research capability at several NASA research centers. A second was to create a major electronics subcenter at an existing NASA center. The third was to create a new electronics research laboratory. Although the estimated costs in personnel and facilities for these three approaches is similar in magnitude, our judgment was based on other factors. The first course of action was not adopted, primarily because the total program would remain diffused and electronics research would not permit the creation of an essential "critical mass" or concentration of electronics capability which is needed to perform the many advanced efforts in electronics research and technology facing NASA and the Nation. We rejected the concept of a satellite or appendix to an existing NASA laboratory, because we were concerned that the addition of a satellite facility would adversely affect both the quality of performance in the ongoing effort of any center charged with this additional responsibility as well as of the electronics research we urgently need.

The basic purpose of the laboratory is to provide this Agency with the in-house competence it requires to properly plan, conduct, direct, and supervise a major segment of electronics research and advanced development in our aeronautical and space program. As much as possible of this will be under contract or grant to universities or industries capable of performing the work required. Existing NASA centers will continue to carry out some electronics research, and will conduct those developments necessary for their primary missions. These centers will draw heavily on the proposed center for electronics technology, components, subsystems, and prototype systems, required for their projects . . . .

With regard to the selection of a site for the proposed new research center, there were several basic criteria that had to be satisfied. A community having adequate utilities, services, communications, and transportation facilities was, of course, basic. In addition, it would be very desirable to be assured of adequate housing and the related family welfare, education, and recreation facilities, as well as adequate land in a reasonably convenient location not in conflict with local metropolitan planning. However, in addition to these considerations, there were two overriding criteria which carried the greatest weight in the selection. The first of these was to have the research center located in close proximity to institutions, of graduate and postgraduate scientific and engineering education, which are already deeply immersed in the forefront of the electronics basic research and technology over a broad range. The second was to be located in an area where the industrial community has allied technical interests and are research oriented.

Although there were several locations in the East, the Midwest, and the Far West, which could be favorably considered to a greater or lesser extent, the Greater Boston area was superior to any other in offering major advantages relating to these essential requirements.

The ERC facilities are now being constructed.

Tracking and Data Acquisition Facilities

When NASA was established in 1958, it acquired the Department of Defense's Minitrack network and the Jet Propulsion Laboratory's Deep Space Network. With the beginning of the manned space program, NASA began to assemble a special network to handle unique demands imposed by Mercury and its follow-on programs. Substantial network growth was required as a result of the decisions made to expand space activity in 1961. Chief among these was the beginning of the Apollo manned lunar program which required even more complex and extensive tracking facilities.[14] The simultaneous addition to NASA of new applications satellites as well as more scientific satellites and probes also contributed greatly to the need for network growth. From these distinct requirements have developed three tracking and data acquisition networks: The STADAN, the deep space, and the manned space networks. The Satellite Tracking and Data Acquisition Net (STADAN) satisfied the need for simultaneously gathering large amounts of real time information from many satellites. To the original IGY minitrack net have been added new tracking stations in the higher latitudes to provide coverage of satellites in polar orbits.* Also, STADAN now includes data acquisition facilities equipped with multi-frequency high-gain antennas capable of supporting applications satellite missions (such as communications and meteorology) which "require a wide variety of orbits, wide variations in instrumentation accuracy, and great variations in the amount of data that must be acquired from individual satellites."[15]

(1) By 1968, the STADAN network included 18 fixed tracking

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*See related discussion of STADAN in Chapter IV.

stations around the world and two transportable stations in Australia. These stations operated twenty-four hours a day in support of unmanned scientific satellite programs. Overall control was exercised by the Spacecraft Operations Facility at the Goddard Space Flight Center. In addition to the NASA stations, STADAN included the optical camera network managed by the Smithsonian Astrophysical Observatory.

(2) The Deep Space Network (DSN) was operated by the Jet Propulsion Laboratory and exercises tracking, data acquisition, and command functions over satellites at interplanetary distances. This network provided support to such programs as Mariner and Ranger through facilities at the Jet Propulsion Laboratory and the tracking stations in Spain, Australia, and California.

(3) The Manned Space Flight Network (MSFN) included 19 land based tracking stations plus an interconnected network of instrument ships and aircraft provided and managed by the Department of Defense. The MSFN is managed and directed at the Goddard Space Flight Center; the Mission Control Center, however, was located at the Manned Spacecraft Center.*

MANPOWER AND PERSONNEL MANAGEMENT

In addition to the expansion, development, and modification of NASA's facility base to accomplish its programs, NASA had to assure that it had a complement of people properly trained to carry out its work. Dr. Seamans expressed the importance of properly trained people in his Goddard lecture of March 15, 1966:

> . . . machines are designed, built, tested, and operated by men, and it is men who, at the bench or at the desk, are responsible for the new product of (technical) advance. That new product is knowledge, which, when directed and integrated and focused through the lens of man's mind, becomes power. What kind of men, working to what ends and under what conditions, have brought us so rapidly to the present from a recent past that already looks a century old?

The influx of new people from diverse organizations presented both a problem and a challenge to NASA management. The

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*See Chapter III.

problem was obviously to attract a large number of highly qualified and experienced personnel who would be able to operate effectively with a minimum of organizational or policy guidance. The challenge was to utilize fully the valuable skills of all personnel being brought into the Agency and to see to it that the best experience, procedures and policies, wherever they emerged, were adopted for the operational benefit of the entire NASA organization.

The difficult task of recruiting manpower resources to meet the needs of new field centers was matched by the equally important personnel challenge of fusing those thousands of new employees into a unified work force operating in the context of effective personnel policies and assuring the proper kinds of career opportunities in an Agency that was new and unprecedented.

The utmost in flexibility was demanded of individual employees during the early years. Many NACA employees were called upon to "retread" themselves in order to keep up with the changing character of research needs or to move into jobs where NASA urgently needed their experience and competence. Engineers who had been doing research on the structures or operating characteristics of aircraft often found themselves with the new problems of vehicles intended to fly in outer space. Men who had been working on theoretical research problems found themselves coping in the fast paced world of project management.

In many organizational elements, each having its own difficult technical and program problems, it was necessary for months and even years to deal with a continuing influx of new employees each of whom had to be guided and assimilated into the organization. The early, massive transfers, first from the NACA nucleus, then from other agencies, companies, or universities, forced many persons to tear up their roots and relocate themselves in order to serve the needs of the new programs. Thus, almost every employee faced the challenge of new organizational patterns, new working relationships, new bosses, and new subordinates.

NASA enjoyed the advantage of special authority in the Space Act of 1958, to employ a stipulated number of highly qualified scientific, technical, and administrative personnel in "excepted" positions without regard to the normal constraints of Federal personnel regulations. In addition, NASA has been permitted to employ a limited number of retired military personnel in a way which allowed them to work full-time and still retain their full retirement pay. Both of these flexiblities made available important reservoirs of talent and experience which might not otherwise have been available.

Looking back from the perspective of a little history on those early days of rapid manpower growth in NASA, it seems remarkable how smoothly and efficiently the build-up proceeded. Certainly the challenge of the space program had much to do with attracting the high quality of job applicants, many of whom did adapt to the new environment and became, and have remained, effective participants in NASA programs.

Fiscal Years 1963 through 1967 continued to show a manpower build-up in civil service employees to a peak of 33,726 but at a slower rate than during the Agency's first four years.

Table VI-1* showing civil service manpower on board at the end of each fiscal year, also indicates that selective cutbacks in civil service manpower had begun by fiscal year 1967, as a result of budget reductions made by the Congress. In fact, reductions meant that the build-ups still required in certain parts of the manned space flight program and the Electronics Research Center only could be satisfied if they were balanced by reductions at the other centers. The Johnson Administration had consistently stressed the importance of limiting the total federal employment.

NASA's response to this policy is indicated in Mr. Webb's letter to the Bureau of the Budget in September, 1965:

> At the request of the President, in January 1964, I reported on my personal examination of NASA personnel requirements. At that time, NASA program needs totalled 39,000 for the end of FY 1965. The level finally approved was 33,800. We accepted that ceiling and pledged not to request relief from the serious burden that it imposed in execution of the space program. We have kept that ceiling pledge. We have been, and are increasingly concerned about this limit on needed employment because our major programs are proceeding from the planning stage to

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*See Volume II, Appendix B-VI-1.

hardware development and flight test, and because this limit on personnel both in numbers and capabilities places us in a worsening situation in our hard work to insure hardware reliability and flight success. Nevertheless, recognizing the President's determination to resist levels of government employment, we undertook again, in our 1966 budget estimates, to carry out our mission within the set limitations.[16]

As Table VI-1* in Appendix B indicates, the FY 1967 employment was the peak of NASA civil service employment. Beyond that point, manpower reductions followed the phasing-down of some programs and the reduced budgets for program and administrative operations which were enacted by the Congress.

In the broadest sense the NASA total manpower resource always has been regarded as a much broader basis than just the civil service population, since NASA's whole program approach has been built on the concept that its aerospace research and space exploration program would have to be accomplished by utilizing the resources of industry, the universities and other government agencies.

Obviously, the great bulk of detailed design, fabrication, test and operation of space major hardware systems was going to be accomplished by those major industrial organizations which already had the manufacturing capabilities for that kind of activity. Most of the scientific experimenters engaged in the NASA flight programs have continued to be in the universities, and important parts of the total NASA program have been carried out by other federal agencies. Selected R&D management-skilled military officers, for example, also were detailed to NASA for duty tours, particularly for manned space flight responsibilities.

NASA also has relied heavily on support contractors in its field installations to provide support to some facets of the Agency's program activities or to meet general support requirements.

Basic to the decision to use support contractors was a key management requirement or policy that NASA would not relinquish to a contractor any function necessary to protect the government's interests. NASA personnel would continue to exercise

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*See Vol. II, Appendix B-VI-1.

full managerial control over all facets of a program including those which were performed under contract. This has meant that NASA retains in its own ranks sufficient managerial and technical competence to define government program and technical objectives, direct and monitor program accomplishments, control the expenditure of government funds and effectively integrate the constituent parts of its total program. The NASA civil service work force therefore has served as the central managerial team, coordinating a total manpower complex drawn from varied sources, and assuring that goals were reached through the effective interaction of many separate organizational entities.

Out of the assembling of facilities and manpower described above has emerged a new group of National laboratories, built on the NACA base of research oriented centers, but augmented by the development centers created to manage NASA's large scale flight programs. These installations represent the enduring institutional base which makes possible much of NASA's flexibility of operation. These centers form the reservoir of scientific and technical talent which does basic and applied research across a broad spectrum of technology. This reservoir is also the source of skilled technical management personnel to form the cadre for development flight projects as they are approved. The centers carry the main operational burden of these programs including technical management and the supervision of industrial contracts, relationships with university scientific investigators, and technical and administrative support for project activities. This operational base has proved capable of rapid buildup of new programs, but is now demonstrating the equally critical ability to phase down activity as specific programs reach their zenith and begin the down curve leading to completion.

The significance of this ability to survive phase-down cannot be underestimated. In his Diebold Lecture at Harvard, Mr. Webb recognized the public's concern over the creation of new public entities for every new public problem. In its broadest sense this means that:

> We must develop and systematize methods whereby we can combine, dismantle, and recombine elements of existing establishments in and outside of government to get big and increasingly complex jobs done. We must learn how to marshall and focus the great resources available in our established organizations and institutions to shifting points of main impact. No one thing, it seems to me, is as important in gaining acceptance for the use of large and complex endeavors

to get big and special jobs done as the demonstration of a capacity for the orderly phasing down of activities if the early momentum cannot continue.

CONTRACTING WITH INDUSTRY

To indicate the importance of the private sector's contribution to NASA's programs, it should be pointed out that the total manpower involved in NASA's aerospace activities reached a peak of about 420,000 people in FY 1966 of which about 34,000 were civil service employees working in NASA. That total manpower now has dropped to almost 200,000 as a result of the combined effects of the normal reduction in manpower as facility construction and hardware production are completed and the reduced program budget levels that have not permitted taking on new flight projects. The ability of industry and NASA to adjust its total effort downward by this magnitude is indicative of the management attention that was applied in planning the proper phasing of these activities.

NASA's ability to manage the space program was contingent upon its ability to work effectively with American industry. There was really no other alternative to carrying out the aeronautics and space program, since even in the total spectrum of industrial capability there were few companies which seemed capable of undertaking the necessary complex development, fabrication and operations tasks. In its dealings with industry, NASA sought better solutions to three important and interrelated types of problem:

1. <u>Broadening the Industrial Base</u>.

Industry was faced with the same essential problem facing NASA-how to respond urgently to the new space challenge in bringing the best facilities and management to bear. Individual companies in activities such as aircraft, missiles, electronics, and instrumentation had to make individual corporate decisions to compete for the new business which the space program would generate. NASA for its part had to let industry know what its program needs were. This was done not only through contract statements of work, but also through numerous industry conferences, bidders conferences, continuous discussions with leaders throughout industry, and detailed guidance on how NASA contracting was to be managed. Of critical importance were a large number of decisions by NASA centering around the way in which procurements were to be "packaged." There was concern, for example, over whether NASA contracts would disrupt industry patterns and whether there were to be real opportunities even for smaller companies.

In many cases, it was not possible to develop precise definitions of the hardware and operational requirements of the emerging programs. This fact impacted the type of contract which could be employed. The fixed price contract was used where possible, but the inherent risks and uncertainties of research and development were in many cases such that the more flexible "cost plus" forms of contract were necessary. NASA pushed early and hard for incentive contracts, not only to achieve cost savings over fixed fee arrangements, but also to make clear in the incentive equation the fact that we would demand, and pay extra, for high performance and reliability.

These and other important policy issues had to be faced time and time again as NASA moved urgently to convert its program concept into practical operating contracts. Industry was expected to work out the complex arrangements of prime and subcontractors and parts suppliers, but NASA was more than a "silent partner" in building up this basic capability. Substantial help was offered through government research and test facilities available to any contractor, and through NASA's own technical and management staff who frequently possessed critical knowledge and experience needed to handle the special techniques, materials, and new types of equipment which characterize the space program.

2. <u>Contractor Selection</u>.

The new field of space research and exploration had many attractions for industry. The work was exciting and there would be much prestige for those companies which could engage successfully in the program. There were new profits to be made and new product lines to be added. Of considerable importance also was the opportunity to get in on the ground floor in the evolution of new and important technologies. NASA management anticipated and encouraged vigorous competition for each new contract as the program developed. There was also a recognition that the R&D nature of these contracts made it difficult to define requirements with sufficient precision so that the traditional "low bid" could be the sole criterion for selection. It was important that NASA be able to judge a company's technical skill, manufacturing competence, and managerial capability to meet costs and schedule targets with successful performance of systems. It was also recognized that individual corporate capabilities would change rapidly over time, and that NASA's program needs would probably also change in character as we gained experience.

It was important, therefore, that a technique be found which would insure any industrial company a fair opportunity to compete for NASA contracts and have its capability properly and accurately evaluated. Such a system was found in the source evaluation process which Mr. Webb has described as follows:

> . . . Dr. Dryden, Dr. Seamans, and I determined that we would personally examine, in detail, the results of the work of all source evaluation boards on competitively negotiated contracts that amounted to 5 million dollars or more. We expected these boards to appear before us personally in a formal setting and make a full and complete presentation of (1) the method chosen to break down for evaluation the contractor proposals, (2) the results achieved in the application of this method, and (3) the judgement of the board on each of the categories of the breakdown. The effect of this systematic approach to a continuous emphasis on the judgement factor has been that for five years, on innumerable occasions and for extended periods, the three senior officials of NASA have sat side by side and personally examined in detail, and tested by question and answer, the quality of the individual and collective contributions of these boards to major decisions affecting the area where ninety percent of our resources are expended. We thus formed our own personal judgements, based on a great deal of personal involvement, as to the validity of board findings. We deeply immersed ourselves on a daily basis in very complete analyses of the main factors, within NASA and at the plants of our contractors, on which our projects depend for success, and the views, approaches, and analytical judgement of our senior personnel. In this process we were able to observe and evaluate how rapidly the organization and its contractors were developing their capabilities, and how effective our effort to get nine-tenths of NASA's work done by contractors was proving. We believe this constant and visible personal contact among NASA's three senior officials and the other responsible personnel involved in the hard problems and decisions in procurement provided a great deal of stimulation, motivation, and innovation throughout the organization.

The fact that the three senior officers of the agency would take the time to conduct what amounted to a thorough hearing and question-and-answer period on each contractor selection action enabled all levels of management, in Headquarters and in our Centers, to get their questions out on the table before all three of us for debate and clarification. Another important result was that when the presentation to the three of us was over, everyone involved had a clear understanding of the elements basic to a proper decision and everyone in NASA concerned with the matter was aware of this. The burden then passed to Dryden, Seamans, and me to make the final decision, and the personnel of the boards were in position to form their own judgements as to whether the three of us did in fact arrive at the best decision as indicated by the facts and analysis. Further, an important element of a NASA-wide and pervasive self-policing system was thereby established. This has had an important effect on maintaining high standards throughout the agency.

3. Evaluation of Performance.

The great bulk of contracts let with industry by NASA have been research and development in nature. This means that they are susceptible during their period of performance to an element of uncertainty and change as we moved down the learning curve of experience and technical understanding. This circumstance has complicated the process of evaluation of contractor performance which is a vital part of the exercise of the government's responsibility. Since the work of each contractor had to fit into a broader pattern of operations for a total program, it was necessary for the government to assure itself that the contractor could perform as required and would be able to deliver the product for which he was responsible, on time, and within the performance standards required of it. Performance always was regarded as a major evaluation factor. It was also necessary that we assure ourselves that these products would be delivered within cost limitations, and that the government received a fair value for each dollar spent.

In the agency's earlier days the cost-plus-fixed-fee form of contract was the predominant mode, in recognition of the high order of uncertainty which was inherent in the entirely new undertakings we were attempting. NASA management understood, however, that the cost-plus contract ultimately was not in the best interests of either the government or the contractor. We needed to move as rapidly as possible to incentive forms of contracting which could offer adequate economic incentives to those companies capable of sharpening the quality of their performance in the R&D environment. Both NASA and industry learned rapidly through experience to identify those areas where incentives could replace the earlier cost-plus arrangement, and by the end of 1968 NASA had achieved a position where 52 percent of its procurement dollars were being spent under incentive contracts. The older concern within industry over the unknown risks inherent in R&D contracting has been replaced by increasing confidence in the ability of the government/industry team to operate under incentive arrangements which produce ultimate economies for the government and yield attractive profits to companies willing to accept this kind of challenge.

UNIVERSITY RELATIONSHIPS

Just as NASA had to find ways to do business with the industrial sector, it also was faced with the challenge of finding propers ways of involving the universities in the space program. There was a continuing concern that the Federal government had a strong responsibility not only to avoid arrangements with universities which might be harmful to their ways of working, but also to take active steps to assist universities to improve the quality and quantity of basic research and graduate education in the United States. These issues were of great concern to NASA management. The participation of university scientists, engineers, and other researchers and scholars was conceived as a critical element of NASA's overall strategy for the involvement of existing institutions as the means for accomplishing the vast buildup of capability which was foreseen. While industry's main motivation was profit, it was harder to determine how to put the case to universities as to how they could participate in the space program and benefit from it. In fact, the agency was faced with a fundamental issue of how NASA could involve universities without hurting them in some way, or diverting them from their necessary overall role.

There was a fear that NASA, with its existing new charter and expanding program, was simply going to become a formidable new competitor for the highly qualified scientific and engineering talent in the university environment.

NASA's fundamental decision was twofold. First, it would choose to rely on the university community as its primary scientific resource and it would do so in a way which permitted these skills to remain on the campus. No effort would be made to bring all needed scientific talent into NASA field centers. Instead, university scientists would be encouraged to become principal investigators in the development of scientific experiments to be flown in space, working from the base of their own university laboratory and involving their associates and graduate students where possible. These experiments would be integrated by NASA into its scientific flights, but the data obtained from these missions would be returned to the university investigator for evaluation and publication of research results. After an appropiate period the basic data would be fully disseminated so other scientists could participate in its analysis.

For those scientists and engineers who would not or could not involve themselves to that extent, a broad range of university grant relationships was established for the conduct of individual or small group research efforts. These grants were expected to fall within a fairly flexible definition of NASA's research needs, but were largely the product of the individual research interests of university faculty.

Finally, NASA established a number of scientific and technical advisory committees as mechanisms through which the external scientific and engineering community could examine the total spectrum of NASA's scientific programs, and give their advice and counsel effectively to top management.

The second aspect of NASA's fundamental policy for university relationships was with respect to the universities themselves. Means were to be found to aid and strengthen universities through their participation in space-related activities. It was recognized that space research and exploration was going to offer exciting and fruitful arenas of new scientific investigation and that university scholars would be deeply involved in these experiences. This involvement would follow the natural process of intellectual ferment from which would flow gross contributions to scientific and technical knowledge and understanding. This process inevitably would benefit individual scholars and disciplines, but its impact on universities _as institutions_ seemed neither as clear nor as direct. It was the intention of Webb, Dryden, and Seamans to build up university research, teaching, and the quality and quantity of both graduate and post-graduate education and to deal with each university as an institution rather than solely through individual faculty members. In a letter to Clark Kerr, President of the University of California, Webb stated:

> The major policy decision Hugh Dryden, Homer Newell and I have made (with respect to universities) is that we are going to try in every way possible to work within the universities and within a pattern which permits the administrative leadership of the university to develop the resources on an interdisciplinary basis and to have our own (NASA's) requirements met through this general advance rather than through sharply defined and specific area activity. [18]

To back up this intention, NASA instituted three forms of university relationships:

1. _The Project Research Program_. This is a form of the well-established system of Federal agency support

to a principal investigator in a university working on a problem or several closely related problems dealing with some concept or phenomenon of concern to NASA in conducting the aeronautics and space program. It includes supporting research and technology in disciplines such as engineering and the 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. The acquisition of specialized facilities has been supported, including surplus NASA equipment. Post-doctoral study and a significant amount of involvement of graduate students has been supported under these grants.

2. The Sustaining University Program (SUP). In a truly innovative way, the Sustaining University Program has sought to provide the kind of open-ended support to the university as a whole which Mr. Webb envisioned. As described by one evaluator,

> The SUP as it was planned in 1961 and launched in 1962, had three main parts. To increase the National stock of specialized manpower, NASA began making grants to universities to finance three-year graduate traineeships in space science and technology. To encourage innovation and communication among scientific fields relevant to space research and provide modest amounts of scientific support money that the universities themselves could use flexibly to offset the rigidities of the project system, NASA made institutional grants for what were called -- multidisciplinary research. And, to relieve critical shortages of laboratory space at a few selected universities heavily committed to space research, NASA offered to make relatively large grants for construction of space science facilities. [19,20]

Since its inception, 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 made 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. These grants are made to an institution rather than to one or more principal investigators, and permit the university to make its own judgment as to individual proposals and the allocation of resources.[21]

3. Personnel Programs. A related and less formal group of activities center around the interchange between the universities and NASA for education, consultation, and exchange of knowledge. Employee training programs have taken advantage of the educational services of universities to upgrade and update staff experience and qualifications. Programs for coop students, summer institutes, faculty fellowship programs, post-doctoral study, adjunct teaching by NASA employees, and other types of programs have been arranged. These activities have involved a significant number of people and considerable mutual impact.

Above and beyond the consequences of these programs, however, there was the hope that universities would benefit in yet another way. The Sustaining University Program had, at its heart, the concept that the academic disciplines within the university could be brought together to work in a multidisciplinary team to attack research problems which were themselves multifaceted in character and would not yield to narrow, single discipline research. This approach was counter to the traditional concept of increasing scholarly specialization within a discipline, but it seemed more truly representative of "real world" situations at a time when universities were being increasingly challenged to come to grips with the society which surrounds them. In effect, NASA was urging university faculty and administrations not only to use their participation in the space program to strengthen their institutions, but also to regard the grant as a mechanism which might help to move the institution in directions of ultimate great benefit to society as a whole. Memoranda of Understanding with universities spoke of the need to help in the process of transferring new knowledge gained in the space program to other segments of the economy. As stated in one such Memorandum:

> . . . the university will undertake, in an energetic and organized manner, to create a broadly based multidisciplinary team to explore mechanisms whereby the progress and research results achieved in space science and technology may be fed into the industries and segments of the economy with which the university normally has close relations.

But contained within the bounds of this concept was the further, deeper thought that, by means of the NASA relationship, individual universities could build the kind of understanding and ability to associate individual faculty members in multidisciplinary activities which would help them serve industry, their local communities, and society in general in ways which are more effective than before.

CONTINUING ADJUSTMENTS IN ORGANIZATION AND MANAGEMENT

The Reorganization of 1965

With the death of Dr. Hugh L. Dryden, who had been the NASA Deputy Administrator from the time of NASA's establishment, President Johnson appointed Dr. Robert C. Seamans, Jr., as Deputy Administrator. In part to adjust to the new situation that was created by Dr. Dryden's death, and also to carry out certain changes that appeared to be necessary as a result of operations during the period of 1963-1965, a revised organizational structure in NASA Headquarters was established in December, 1965.[22] The major element of this reorganization was the establishment of the Office of the Administrator. Within this office, the operating pattern was based on:

> . . delegations of authority and responsibility to the Deputy Administrator to enable him to serve on a day-to-day basis as general manager of the agency and to serve as Acting Administrator in the absence of the Administrator. . . . These delegations to the Deputy Administrator will be complete, and it is expected that he will, on a day-to-day basis, take final action on most matters, except where there are legal or special requirements that necessitate personal action by the Administrator.

Under this arrangement, Dr. Seamans served as both the Deputy Administrator and the Associate Administrator.

To emphasize the responsibilities involved, Mr. Webb's memo to the "Heads of All Headquarters Offices and Directors of Field Centers," (December 29, 1965)[23] stated:

> As Administrator, it will be my purpose to rely fully and completely on Dr. Seamans as general manager to conduct the affairs of the

Agency in conformance with both agency and governmental requirements and in accord with the broader context within which we must operate. He will keep me fully informed, as I will him. On policy and actions having more than ordinary implications, we will, whenever possible, consult together before either takes action. The Associate Administrators in charge of Program Offices, both individually and collectively, will be encouraged to prepare for and to undertake more of the NASA-wide responsibilities of general management under the direction of the Deputy Administrator... . There will be continued emphasis on the development of workable patterns of strong NASA-wide functional coordination and supervision of those elements of policy and administration which can be fully effective only if an acceptable degree of NASA-wide coherence and consistency is achieved. All functional staff offices will report to the Deputy Administrator. Together, they will constitute a single central functional staff serving the Office of the Administrator and also serving the Associate Administrators in charge of program offices to the fullest extent possible.

In addition, Mr. Webb's memorandum defined the functions of the Secretariat, headed by the Executive Secretary, as assuring effective communications throughout NASA, for assuring that proper coordination has been provided and policy accurately reflected in matters coming to the Office of the Administrator, for expediting and scheduling the flow of work in the Office of the Administrator, and for providing central reference and office services in the Office of the Administrator.

In closing his memorandum, Mr. Webb said:

...I hope we will all recognize that while some features of the new pattern are experimental in their application to NASA, the steps we are taking are all based on successful experience in the management of large organizations. Dr. Seamans and I believe that one of our greatest challenges is to be as inventive and as willing to search out new and better practices in management as we are in our scientific and engineering work.

Organizational Changes from 1967 to Present

On January 6, 1967, steps were initiated to continue to strengthen NASA's organizational structure. A special task force on organization was appointed under the leadership of Harold B. Finger, Manager, AEC-NASA Space Nuclear Propulsion Office. In announcing Mr. Finger's appointment to this temporary assignment as Special Assistant to the Administrator, Mr. Webb stated:

> It has been NASA policy to bring into the study of future problems, both of program and of administration... executives who have successfully managed major projects. The joint AEC-NASA Space Nuclear Propulsion program, under Mr. Finger's direction, has been an outstanding success, and this additional assignment will enable NASA to benefit from the concepts and procedures required to successfully operate this very important joint AEC-NASA office.[24]

The Apollo 204 fire at the Kennedy Space Center on January 27, 1967 occurred three weeks later. The report of the Apollo 204 Review Board,* and the internal evaluations by NASA officials led to the initiation of a number of measures to improve both technical and management operations.

These measures were aimed at preventing future problems by assuring that the self-policing features of NASA's organization and those elements of the total management system which were supposed to give "advanced warning" of potential problems were functioning effectively and were providing the required visibility to all levels of NASA management.

A significant move in this direction was the establishment, in March of 1967, of an Office of Organization and Management which brought together a number of separate offices dealing with all facets of the ways in which NASA carried out its business. Experience since the earlier organization change of 1963 had indicated that the decentralization of technical decision-making combined with the delegation of program direction had not provided the kind of management visibility and functional supervision

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*The Complete documentation in the investigation of the Apollo 204 Review Board has been impounded for ten years. While NASA spokesmen were frank in discussing the tragedy, as was the Review Board Report on this disaster, the future historian will one day be interested in examining all the documents.

which agency management wanted. The Office of Organization and Management brought into being a more integrated structure of functional and administrative offices designed to make possible a stronger focus for administrative management and assurance of necessary balance to overall management decision making. In a description of the management character of NASA, Mr. Webb assessed the role of the Associate Administrator for Organization and Management by stating that he:

> . . . works closely with the Administrator to emphasize that, in NASA as an R & D organization subject to tendencies to relegate administration to a secondary position, all senior officials must accept responsibility for developing improved means for judging the administrative performance of subordinate officials; develops criteria for selection upward of R & D personnel who also demonstrate administrative competence and a broadening base of multi-disciplinary competence and the transfer to non-administrative specialties of those who cannot grow in both program and administrative areas.*

The Associate Administrator for Organization and Management thus was given responsibility for the development and implementation of major mechanisms for agency review and approval of management actions and resources. He is expected to see to it that the decisions reached through these processes represent the best balance of judgment of line management needs and functional administrative needs; that agency policies and practices are adhered to; and the requirements and positions of external entities such as the Congress, GAO, Bureau of the Budget and the Civil Service Commission are understood and recognized. While this is a "checks and balances" concept, the emphasis is placed on complete and well rounded management decisions, now and for the future.[25]

In a further move of this same type, the Office of Assistant Administrator for Special Contracts Negotiation and Review was set up in the Office of Organization and Management to give special attention to certain procurement actions and contracts designated by the Administrator as being of such significance that they should come under the continuing review and cognizance of one of NASA's senior officials.

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*See Footnote #25

Seamans' Departure Precipitates Further Changes

In September, 1967 Deputy Administrator Seamans let it be known that after more than seven years with NASA, he was planning to leave at the end of the year. His decision hastened the evolution of further measures underway to strengthen Headquarters management -- but now with the added impetus of the need to prepare for Dr. Seamans' departure.

A revised set of top management relationships would have to be created which would continue to push toward the initial goals of strengthening Headquarters management, but which also would take up the workload and responsibilities that had been Dr. Seamans'. It was also necessary to make these organizational arrangements in such a way that the Administrator would not be constrained in terms of the responsibilities to be given to a new Deputy Administrator whenever he came on board.

Newell Moved Up to Associate Administrator

Dr. Homer E. Newell, then Associate Administrator for Space Science and Applications, was elevated to the revised position of Associate Administrator. In this new role, Dr. Newell was given the opportunity to study the pace and direction of the space program and its organization in the light of projected future circumstances. He organized a central planning system which brought together agency capabilities and ideas to define promising program alternatives. This new planning system involved agency-wide participation and is still subject to further changes based on experience. This system organized steering, coordinating, and working groups led by senior line managers and scientists with representation from Headquarters program and functional offices and the field centers, to develop planning options on a disciplined basis. These options were then "synthesized" into overall agency program alternatives for top management consideration. Thus, this system developed: (a) plans, programs, and funding data for consideration by NASA management for internal planning purposes; and, (b) data and information required for NASA's annual submissions to the Bureau of the Budget, including Program Memoranda and special analytical studies. The participation of the top field center and program management in this process helped to assure the availability of the best-qualified technical people from the line organizational elements for participation in the several working groups doing the detailed planning.

An effort to draw NASA's senior officials still closer together was the establishment of the Management Council including the senior officials in NASA Headquarters. The Management Council met weekly under the direction of Associate Administrator Newell to consider various policy matters and also to discuss emerging program and operating problems and the best ways to bring agency-wide capability to bear on their solution.[26]

Basic Procedures Strengthened and Simplified

As a corollary to these organizational changes it was also necessary to redefine basic management procedures dealing with how programs were defined and funded, and to redefine how these processes were brought to top management for decision. This need for change was taken as an opportunity to strengthen and simplify these processes and recast them into a simple, unified framework of documentation and accounting which would form the basis for directing, coordinating, and controlling much of NASA's activities.

In order to expedite the process of policy definition and dissemination, an office of Assistant Administrator for Management Development was created to take the lead in developing Agency policies, procedures, responsibilities, and authorities with some real initiative and vigor. Admiral Charles E. Weakley USN (Ret.) was appointed to this post, and advises the Administrator on the full range of management activities.

Administrator Webb issued Management Instructions that required that each operating budget line item be linked and supported by one or more Project Approval Document (PAD's). The PAD was formally made the basic document for authorizing the technical scope of work, and for approving the annual plan for use of the agency resources (funds, manpower, facilities) to achieve the directly associated work and related schedules which had been previously controlled in separate documents. The PAD also defines objectives, technical scope, major procurement and other management arrangements, and relationships to other NASA and external activities. As such, it represented a single basic device for authorization and control of agency programs and resources and the framework of feedback of information on status, progress and problems. Program management reviews and other management supervisory techniques can be keyed to reports of progress and problems under each of these PAD's rather than through a separate reporting system.

Another means for defining clear responsibilities and improved visibility and feedback in NASA's management system was provided by the establishment and use of the NASA Management Delegation. It is the means for delegation by the Administrator and, where redelegation is permitted, by the senior officials with powers and authority for specific actions. An important feature of these delegations is the built-in requirement for feedback.

Certain External Relationships Centralized Under Associate Deputy Administrator

One area of activity which was growing increasingly significant was that of relationships with other agencies of the government. Relationships with the Department of Defense always had been extremely important to NASA but in many areas the development of space technology was creating the potential for important new relationships with the Department of Commerce, the Federal Aviation Agency, the Department of Agriculture, and the Department of Interior, plus projected new international cooperative agreements.

In December of 1967, those Headquarters offices dealing primarily with external relationships were brought together under Mr. Willis Shapley, the Associate Deputy Administrator, In addition to offices responsible for international affairs, legislative affairs, and public affairs, the Headquarters office previously dealing with DOD relationships was expanded to monitor relationships with other Federal agencies. The clustering of these offices integrated under a single executive has allowed NASA to focus its own initiative in informing other agencies of the potential of NASA's new technology and seeking their cooperation and support in the evaluation of new programs of mutual concern.

Paine Named as Seamans' Successor

Dr. Robert C. Seamans left NASA on January 6, 1968. On January 31, 1968,* Dr. Thomas O. Paine of Santa Barbara, California, was appointed as Deputy Administrator by the President.

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*See biography in Vol. II, Appendix A-IV.

Webb Retires--Paine Appointed Acting Administrator

After 25 years of distinguished public service, including almost eight years as the Administrator of NASA, Webb retired from the full-time government service effective on October 7, 1968. At the White House news conference announcing Webb's retirement, it was also announced that President Johnson had appointed the Deputy Administrator, Thomas O. Paine, as Acting Administrator.[27] "Dr. Paine," said Webb at the time of the announcement, "is one of the outstanding men in this country, both in science, in technology, engineering and in management. . . . He is qualified to do the job without a doubt."

Very shortly after his retirement, Mr. Webb was sworn in as a NASA consultant by Dr. Paine.

A TIME OF TRANSITION

Congressional and public reaction to the space program in 1967-68 appeared markedly different from that of earlier years. Further, the competition of other national priorities -- notably the Vietnam war and the growing urban crisis -- created a changed attitude in terms of priorities given NASA space programs.

The Administrator spoke for all of NASA top management when, in an address in Denver, Colorado, on July 15, 1968, he expressed his view of NASA's altered position in the light of competing national priorities:

> The totality of the problems our nation faces reaches far beyond NASA. As responsible government officials, we in NASA accept the result of our nation's decision-making processes. We must now direct our leadership and our managerial abilities toward the successful run-out of the programs approved in past years and now nearing completion. We must at the same time adjust our organization, programs, contracts, university grants, and facilities to meet the reductions that have been decided on, and in the process, do all we can to lay a sound foundation for the future.'[28]

NASA quietly celebrated its tenth anniversary on October 1, 1968. After a decade of perhaps unparalleled accomplishment, NASA faced an uncertain future -- one in which it is impossible to forecast what pressures and conditions will exist and how they might impact NASA's emerging roles and mission. Mr. Webb pointed out in his Diebold lecture that: "These are uncertain and unusual times, not only for the aeronautics and space program but for almost every other important national and regional activity."[29]

NASA's organization and management during its period of achievement in the Johnson Administration has demonstrated on many occasions the ability to adapt to whatever goals and responsibilities the Congress and the Administration has assigned priorities. One of the hallmarks of the Johnson Administration has been the freedom which the President afforded to Mr. Webb to manage the agency according to his own best judgment, on the belief that this kind of relationship would produce the most effective response to the rapidly evolving management problems which had to be faced.

During the year of 1968, NASA had attempted to create the kind of organization and top management structure capable of guiding the Agency through a period of transition marked by a decline in the level of program activity and in the scale of operations of the NASA field installations, industry, and the universities. Perhaps one of the most important consequences of NASA's first decade of achievement has been the build-up and extension of NASA strength across a broad spectrum of scientific and technical capabilities, and the availability of those capabilities as a national resource.

> . . . The U.S. can now count on a facilities base in the NASA complex valued at over four billion dollars and a know-how in industry and a competence in science that can be put to work again when the time comes. We now have a management competence in large scale space development that can restore these assets to operational status with a high degree of efficiency.[30]

James E. Webb stated in the second of his McKinsey Foundation lectures:

> I believe that our accomplishments in space . . . have laid a foundation on which we can usher in a new era of advances. I believe this primarily because among those accomplishments has been a fundamental improvement in man's ability to do research and to use knowlege. These include the new ways in which large-scale organized efforts are managed; the encouragement of multi-disciplinary effort. . . . The new techniques and tools for the conduct of research, and the manner in which these are applied to the solution of age-old scientific, social, and technical problems.[31]

Just as the aeronautical capability of the NACA represented a foundation upon which the new concepts of space research and exploration could be built in NASA, so also the NASA experience and capability of this past decade can be regarded as a foundation from which future national goals and objectives can be served. Such is the potential NASA management offers. Indeed the basic challenge of aeronautical and space science and technology, and their application to national purpose and human welfare is not ended in 1968.

Notes to Chapter VI

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2. CF. "Adapting NASA's Organization and Management to Future Challenges," Office of Administration, Staff Paper, October 1963.

3. "Reappraising NASA's Organizational Structure to Achieve the Objectives of an Accelerated Program," John D. Young, Asst. Administrator for Administration, Staff Paper, June 1951.

4. James E. Webb, Forward to Robert Rosholt, An Administrative History of NASA, 1958-63 (NASA SP-4101) 1966.

5. Banquet Address, "Administration and the Conquest of Space," Mr. James E. Webb, at the National Conference of the American Society for Public Administration, Detroit, Michigan, April 13, 1962. Available as a NASA News Release.

6. National Aeronautics and Space Act of 1958, Title III Section 302.

7. U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, NASA Authorization for Fiscal Year 1964, Hearing, Part 2, p. 1001.

8. Testimony by Ralph Ulmer, Facilities Coordinator Director, NASA, before the House Subcommittee on Space Sciences and Advanced Research and Technology, 1964 NASA Authorization, Hearings, (Washington, D.C.: GPO, 1963), Part 3(b), p. 2637.

9. Testimony by Dr. Robert C. Seamans, op. cit., footnote 27, Part 3(a), p. 2050. See E. M. Emme, "The Decision to Use the Army Engineers for Management of New Construction," (Draft NASA Historical Note No. 57), April 1966.

10. For more information on these facilities see Statement of Dr. George E. Mueller, Associate Administrator for Manned Space Flight, NASA, before the Subcommittee on Manned Space Flight of the House Committee on Science and Astronautics, 1965 NASA Authorization, Hearings (Washington, D.C.: 1964) Part 2, pp. 453-469.

11. A comprehensive history of the concept, design, construction and activation of these facilities is being prepared at KSC as part of the NASA Historical Program. The U.S. Corps of Army Engineers also has an approved historical project to document their support of the NASA program.

12. Statement by Dr. Raymond L. Bisplinghoff, Associate Administrator for Advanced Research and Technology, NASA, before the House Committee on Science and Astronautics, H.R., 1965 NASA Authorization, Hearings, (Washington, D.C.: GPO, 1964) Part 1, p. 309.

13. Senate Committee on Aeronautical and Space Sciences, NASA Authorization for Fiscal Year 1964, Hearings, Part2, pp. 955-957.

14. A detailed explanation of Apollo tracking and data requirements may be found in the Statement of Mr. Buckley before the House Committee on Science and Astronautics, 1965 NASA Authorization, Hearings, (Washington, D.C.: GPO, 1964, Part 1, pp. 335-342.

15. *Ibid.*, p. 328.

16. James E. Webb to Director, Bureau of the Budget, letter asking for additional manpower, September 1965.

17. James E. Webb, John Diebold Lecture on Technological Change and Management, Harvard University Graduate School of Business Administration "NASA as an Adaptive Organization", September 30, 1968, Boston Mass.

18. Letter, James E. Webb to Clark Kerr, President, University of California, December 6, 1961.

19. The NASA Memoranda of Understanding, Laurin L. Henry, Inter-University Case Study Program, Inc., Syracuse, New York, June, 1967. p. 4-5.

20. Launching NASA's Sustaining University Program, W. Henry Lambright, Inter-University Case Study Program, Inc., Syracuse, New York, November, 1967.

21. See A Study of NASA University Programs, NASA SP-185, prepared by The Task Force to Assess NASA University Programs, 1968.

22. James E. Webb, Memorandum for Heads of all Headquarters Offices and Directors of Field Centers, Subject: "The Office of the Administrator." Dated December 29, 1965.

23. James E. Webb, Memorandum for Heads of all Headquarters Offices and Director of Field Centers, Subject: "The Office of the Administrator," Dated December 29, 1965.

24. NASA Announcement of Key Personnel Change: "Harold B. Finger, Assistant to the Administrator," January 6, 1967.

25. NASA Management Issuance 1130.1, Subject: "Roles and Responsibilities -- The Associate Administrator for Organization and Management."

26. NASA Management Instruction "Administrator's Management Council" (NMI 1152.29A) May 3, 1968.

27. White House Press Briefing, September 16, 1968.

28. James E. Webb, "Space Projections from the Rocky Mountain Region," address before American Astronautical Society Symposium, Denver, Colo., July 15, 1968.

29. James E. Webb, John Diebold Lecture on Technological Change and Management, Harvard University Graduate School of Business Administration "NASA as an Adaptive Organization", September 30, 1968, Boston, Mass.

30. James E. Webb, "Space Projections from the Rocky Mountain Region," address before American Astronautical Society Symposium, Denver, Colo., July 15, 1968.

31. James E. Webb, " Goal Setting and Feedback in Large Scale Endeavors," Graduate School of Business, Columbia University, New York, N.Y., May 9, 1968. Lecture in McKinsey Foundation Lecture Series: Reflections on Government Service. It is understood that these lectures are to be published.

CHAPTER VII

CHAPTER VII

THE IMPACT OF NASA ON SOCIETY*

Before men spoke of a Space Age, they had talked of an Air Age and an Atomic Age. The Air Age dawned at Kitty Hawk in 1903 so gently that mankind was slow to perceive its omens. The explosion at Alamagordo in 1945 and the flight of Sputnik I in 1957 were more alarming jolts to conventional foresight. Both of these events produced numerous reverberations that were entwined in the years reviewed in this preliminary history of NASA.[1]

Both tapping nuclear energy and delving into outer space opened vistas that commentators promptly likened to those first seen five centuries earlier by the navigators of distant seas and the explorers of the New World. Dr. Arthur Compton referred to "the Italian navigator" in the first report of the first operation of the first atomic pile. A generation later the vertical frontier that the U.S.S.R. first dramatically penetrated reminded men even more strongly of the horizontal frontier that had faded into history. The Western world's "winning card" had long been its people's "technological precocity."[2] Both this and their hopes were challenged by the breakthrough into space.

The atomic and the space ventures of the United States differed, nevertheless, in significant ways. One was achieved secretly, the other openly. The Manhattan Project was a development effort, based on a scientific discovery, to help win a war. Its success gave the United States a kind of international preeminence that the Russian satellite suddenly seemed to have jeopardized. NASA was the nation's somewhat uncertain response to the Sputnik's challenge. Its assignment was to undertake a research program, based on technological possibilities, to regain America's prestige. The author of the legislation creating this civilian agency declared after becoming President of the United States that the nation had "no purpose in space whatever except peace."[3]

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*This chapter was written by Volta Torrey.

A Maze of Effects

This new agency was asked to find out new things for all men's benefit -- and the impact of its extension of human horizons was more difficult to appraise quickly than the effects of an atomic bomb. The might of the latter could be measured with devices sensitive to its light, heat, radiation, and blast.[4] At Alamagordo, Enrico Fermi dropped pieces of paper to see how far the blast from the first nuclear explosion would carry them from where he was standing.[5] No one knew any such simple mechanistic way to measure the might of an enlargement of human knowledge and skills, even though it could soon govern many men's occupations, influence their educational systems, affect their economies, and become a factor in interactions between nations.

"My reading of the history of science and technology," said a president of the American Institute of Aeronautics and Astronautics, "has led me to believe that there are many examples where technology triggered vast areas of accomplishments in their wake, extending over periods of time measured in decades. Unfortunately the most significant byproducts in the longer term are the most difficult to define in contemporary times. The really profound influences may require decades to assert their importance."[6]

The frontier opened by spacecraft was so much vaster than the one opened by aircraft that its impact on men's lives could be forecast only by recalling the consequences of earlier historic developments, none of which was wholly analogous. Many of the papers that will be cited in this chapter were hastily conceived attempts to predict NASA's impact. Some day they may seem as feeble as Dr. Fermi's "straws in the wind" at Alamagordo. When this account was written, few of the straws had come to a stop, and no one could say how much farther, or which way, the rest of them might be carried.* It was only possible to foresee the most immediate impacts of space exploration on science, education, the economy, men's aspirations, and international affairs.

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*On September 30, 1968, after Congressional support of the space program had waned, NASA Administrator James E. Webb said at the Harvard Business School: "The U. S. is accepting for a long time, perhaps for the indefinite future, both the advantage of expenditure reduction and the disadvantages of a second-rate position in space. In aeronautical research and development the situation is not the same, but still is a cause for concern."

Satellite Uses in 1963

On November 22, 1963, a television program was transmitted across the Pacific Ocean for the first time via the Relay I satellite. President Kennedy's recorded greetings to viewers in Japan had to be omitted because of his death a few hours earlier.[7] The largest gathering of foreign statesmen ever in Washington attended the state funeral four days later, and it was seen on television screens not only in Japan but also in Europe and the U.S.S.R.[8] Never before had so many people so far apart been able to witness historic events simultaneously as they did then and throughout the administration of Lyndon B. Johnson.*

President Kennedy had intended to say on the day of his death that there was no longer any fear that a Communist lead in space would become the basis of military superiority.[9] To honor him, his successor determined on November 28 that "Station No. 1 of the Atlantic Missile Range and the NASA Launch Operations Center in Florida" should be known thereafter as the John F. Kennedy Space Center.[10]

The American landing on the Moon proposed as one of NASA's goals was still distant in 1963, but those who persisted in viewing the new agency as the nation's entry in a sporting contest with the U.S.S.R. had begun to find the parameters of the score progressively perplexing. Mariner IV had passed within 22,000 miles of Venus in 1961, and Project Mercury, the United States' first effort in manned space flight, had been completed in 1963.[11] By then, too, the TIROS meteorological satellites had been developed, Syncom II had demonstrated the feasibility of synchronous-orbit communication satellites, and a score of geophysical satellites had begun the investigation of cislunar space.

"In the new Age of Space which brings us together," Mr. Johnson had written shortly before he became President, "we are destined to go a long way further."[12]

In Half a Decade

Within the next five years the whole world was photographed from hundreds, then from thousands, of miles away.[13] The pictures

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*The Communications Satellite Corporation (Comsat) began developing a global communication system soon after it was incorporated in 1963.

taken on the ten manned Gemini flights gave men a new over-view of their continents and seas, revealing broad features of their planet that had never been seen before in such perspective. As test pilots the astronauts had often soared high into the atmosphere; even so, they found the Earth's beauty "overwhelming" when they first saw it from space.[14] Their color photographs were both stunning and convincing evidence of the future potential of synoptic observations to geologists, oceanographers, and virtually all other scientists concerned with men's environment. Almost simultaneously, more communications and meteorological satellites became operational. These and other orbiting probes yielded more new data about the Earth and the solar system than explorers had been able to gather in any previous decade.

The Rangers, the Surveyors, and the Lunar Orbiters familiarized even the children watching television with features of the Moon's surface. Instruments made by men dug into the lunar soil and analyzed samples chemically for the cosmologists debating the origins of that natural satellite of the Earth. Mariner IV, by showing that Mars was cratered like the Moon, demonstrated how much more future generations could learn about other planets. Then, late in 1968, an Orbiting Astronomical Observatory began to enlarge scientists' information, too, about stars so distant that they were barely visible to the naked eye of a person below the Earth's atmosphere.

To do such things, NASA had to mobilize the nation's varied resources without the forcing motivation of war. Its successful management of mammoth, complex undertakings in space encouraged many men to believe that a new kind of geohygiene was also feasible. Why, they wondered, were we not doing greater things in greater ways to use the Earth's resources efficiently, reduce poverty, and improve cities? Some observers even saw genuine hope for peace "in the technical union of mankind by the conquest of space."[15] It seemed at times, indeed, as if the gift that Robert Burns had prayed for, that we could "see oursels as ithers see us," was being granted at last to human beings.

A TRIPLE IMPACT ON SCIENCE*

By historical analogy the space program's impact on science was easier to predict than its other consequences.

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*See Chapter IV.

Advances in technology had enabled Galileo Galilei to discover that the Moon had mountains and valleys.[16] Time and again instrumentation that extended men's sensory systems had led to surprising discoveries. Dr. Victor Weisskopf, the director general of the European Organization for Nuclear Research in the early 1960's, often likened the body of men's knowledge to an island in a sea of ignorance.[17] The more it was enlarged, the longer its shores became. Space was virgin territory, and NASA's impact was threefold:

It opened tremendous new areas for research.

It armed experimenters with new tools.

And it sped the flow of nourishment between the roots and the youngest branches of science.

Dr. Philip A. Abelson, the editor of Science, pointed out several significant trends that had become highly important by 1968.[18] One was the increased speed with which scientists were "mining out" newly opened fields for research. "The picture of the opportunities for research," he commented, "would be very somber if it were not for another major trend that has been manifest in the last 10 years -- namely, the development of new equipment and instrumentation." NASA's spacecraft were an important addition to the scientific community's arsenal. They not only carried aloft both old and new varieties of instruments but also demonstrated the potentialities of newly available devices on the ground. The third trend that Dr. Abelson emphasized was toward the greater use of computers in science. These electronic aids were essential to the launching, guidance and utilization of spacecraft because they "could do many things that humans cannot do," and NASA's necessities in both space and aeronautics accelerated improvements in computer hardware and software.[19]

Many items in the scientists' tool kits had to be miniaturized, automated and made highly reliable for use on spacecraft. Multi-spectral imaging devices, magnetic tape recording and telemetering apparatus, and both familiar and newly developed instruments for chemical analysis were modified and sharpened.[20] Remote sensors of physical phenomena of nearly every variety were used in space science and applications, and the improvement of such tools made it feasible for researchers to "mine out" new areas of scientific interest more swiftly than in any previous age.

To store, organize, and make the immense quantities of data yielded by space probes accessible to scientists, NASA established a National Space Flight Data Center at the Goddard Space Flight Center. There computer technology and new mathematical model techniques helped scientists and engineers interpret and relate findings regarding the dynamics of the Earth and its environs.[21]

Men on foot were the principal sources of knowledge of the Earth's lands until the twentieth century. Aerial photography greatly increased scholars' knowledge of the planet. Then space photography increased the ease with which changes in its surface could be monitored.[22] The advantages of space photography included the large areas that could be encompassed in a single picture, the speed of coverage, the speed of repetition, and the worldwide coverage possible from single vantage points.[23] Data that scientists formerly acquired so slowly that it was mainly of only theoretical value could be collected swiftly enough at last to be of immediate practical value both to theoreticians and to those striving to apply scientific information to mankind's problems.

Where Disciplines Met

In pre-Sputnik days, the noted mathematician Norbert Wiener likened the state of science to "what occurred when the Oregon country was being invaded simultaneously by the United States settlers, the British, the Mexicans, and the Russians."[24] Special fields of science were blossoming profusely in all directions and intruding on each other without being integrated. The result of several different nationalities' simultaneous appearance in Oregon was an "inextricable tangle of exploration, nomenclature and laws." Progress in science was producing similar proliferation of unrelated information. Hence, Professor Wiener suggested, the most fertile areas for gaining more scientific insights might be in the gaps left as a result of the isolation of science's many custodians.

The opening of the giant telescope on Mount Palomar in the 1940's, and the use of radar antennas as radio "ears" in the 1950's, deepened millions of men's interest in astronomy, "the oldest of the sciences and the parent of the mechanical arts."[25] Then, in the 1960's, space science began to free the students of the sky from "crawling coop'd" within the Earth's atmosphere. First only a few, then many, of the mansions of science felt the impact of NASA's findings.

Some scientists had come to think of themselves as participants in esoteric research rather than in exploration to enlighten all men. Some resisted the sudden pressure to work hand in hand with battle-hardened engineers and administrators. But Professor Hunter Dupree reminded researchers that the necessity of adapting experiments to delivery systems was not really new. Such scientific insights as Darwin's, he recalled, were gained "within the tradition of exploring and surveying expeditions."[26]

The solar system was the most colossal natural "laboratory" ever opened. Satellites carried experimenters' probes into its vast, previously untouchable fields to test theories, to obtain the data needed to refine old ideas, and to provide the detailed information needed to formulate new concepts. Beyond the atmosphere the experimenters could examine the particles that triggered avalanches of cosmic rays, study great belts of trapped radiation, and trace long tongues of plasma swept about by the solar wind.[27] The Rangers, in effect, gave astronomers a thousand times more powerful a telescope with which to study the Moon, and the Surveyors increased the resolution of pictures of the lunar surface another thousand times.[28] Simultaneously ways were devised to place sensors of radiation from distant stars and galaxies on new platforms beyond the atmosphere.

Within the solar system one of the fundamental units of measurement, the astronomical unit, was refined by several orders of magnitude.[29] Lunar Orbiters photographed the Moon from all sides and made a better atlas of the Moon feasible than formerly had been produced of the Earth. Surveyors took close-up portraits of four sites considered for men to land on first, and a fifth region of especial scientific interest. Those pictures and other data obtained regarding the Moon at the same time strengthened the belief that this "slag heap in the sky" was really a Rosetta stone in which much of the history of the solar system might be decipherable.[30]

The geoscientists were the first great beneficiaries from all this activity. For them, the opportunities created were comparable to those opened for the physicists earlier in the century by the discovery of means to explore the fields and particles within the nuclei of atoms. Astronomy, physics, and the geosciences were swiftly drawn together in the study of sun-interplanetary-Earth relationships.

From the new laboratory beyond the clouds the Earth's shape was determined more accurately and its cartographers corrected their maps. In addition to distant factors affecting the flow of energy from the Sun to the Earth, the meteorologists discovered curls in cloud formations that they had not observed from the ground.[31] Geologists obtained pictures of spectacular features of land masses that could not be viewed in toto otherwise. Oceanographers found that sea currents, boundaries, and temperatures could be recorded daily in areas that men seldom visited. Biologists simultaneously began to learn more about the interfaces between living creatures and their surroundings.

From telescopes on Earth men had seen both similarities and differences between their planet and other planets. The Mariner satellites revealed intriguing properties of both Venus and Mars about which there had been much uncertainty. By learning more about those sister planets, Dr. Gordon J. F. MacDonald of the Institute for Defense Analyses pointed out, men might come to understand better the processes taking place deep in the Earth's interior.[32] Discoveries regarding them might help explain such devastating phenomena as earthquakes.

Although space often was called a hostile environment, Professor C. Stark Draper of the Massachusetts Institute of Technology insisted that it was really a friendly frontier.[33] Many things, he observed, were easier to do out there than inside the Earth's cocoon of air. Compared to the vacuum accessible in space, the vacuums attainable in even the finest man-made laboratories were picayune. In space, scientists could study weightlessness and other conditions difficult to simulate. Both animate and inanimate materials could be tested readily in strange environments henceforth.

One of the most surprising gaps that NASA's work revealed was in what men knew about themselves. Although the sick had been studied intensely, researchers had relatively little detailed knowledge of the characteristics and responses of superbly healthy persons. Men healthy enough to be astronauts had not been examined closely under such a great range of conditions as was deemed necessary for manned space flight. The wide range of "normal responses" recorded under the stresses of simulated and actual space flights, particularly the heart rate, modified the physicians' understanding of what "normal" really meant.[34]

The interfaces between human beings and their machines was another subject of NASA-supported research that brought workers in disparate fields together. Men at the cutting edge of progress in psychology and the social sciences found themselves being aided by and aiding mechanical engineers in the study of training devices and teaching machines. These devices, in fact, began to assume such importance that the production of new educational and training aids became of considerable interest on Wall Street.

Space was a "no-man's land" when the United States' and other countries' specialists were enlisted to help explore it. For the pioneers in X-ray, ultraviolet, and radio astronomy, it opened new doors. For the much more numerous experimenters in other branches of science, it was a challenge to correlate their skills and knowledge. To get things done in space, NASA had no choice but to turn nearly everywhere in the scientific and engineering worlds for help. This brought about new working relationships, not only between universities, industries, and government agencies, but also between scholars who had scarcely nodded to each other previously in the long corridors of research institutions. The space agency's helpers soon learned how much more could be accomplished by working together than by working apart. New hybrid fields of study as well as new devices resulted from men's involvement in space science and its applications.

Bringing specialists in scientific disciplines out of their cloisters into the hurlyburly of exploration and the glare of publicity in which NASA labored, of course, often schocked academicians. It helped nevertheless to change the attitude of artists, theologians, and other non-scientists toward science.[35] How cordial the climate of world opinion was becoming for science was suggested, perhaps, when the Vatican announced in 1968 that the Roman Catholic Church would reconsider its attitude toward Galileo.[36]

A CATALYST FOR EDUCATION

Dr. Hugh Dryden, Deputy Administrator of NASA from 1958 until his death in 1965, said on several occasions that perhaps the greatest influence of the space program was "its arousal of popular interest in science and in inspiring young people to study science and engineering."[37] In the 1950's educational reformers such as the Physical Science Study Committee at the Massachusetts Institute of Technology had begun attempts to update the teaching of science in the lower schools. The space program gave more impetus to their campaigns.*

In the United States, the Russians' beeping Sputniks started "a hue and cry against public education and the administrative establishment that manages it, and the colleges that staff it, such as had never been heard before."[38] New physics, new chemistry, and new mathematics courses that bewildered many youngsters' parents were developed and introduced throughout the country. There had never been a comparable revolution in the curricula of the public schools, or as enthusiastic efforts as ensued to keep teachers abreast of new knowledge and methods.[39]

"Scientific literacy in general and scientific competence in particular" were the twin goals of many of these reforms.[40] The belief spread that science should be as much an accepted part of the basic curriculum as reading, writing, and arithmetic, and some educators recommended that children's introduction to it begin in the kindergarten. Both in the lower schools and in the universities, the nation's activities in space increased students' motivation to understand science and its uses.

A Scientifically Literate Citizenry

In response to the teachers' needs, a growing mass of good supplementary resource books and teaching materials appeared. So, too, did educational television programs about science. A survey of elementary schools published by the U.S. Office of Education in 1965 showed, nevertheless, that classroom teachers in grades one to five were still struggling along without the help of elementary science specialists in more than 80 per cent of the schools, and in grades six to eight in more than 70 per cent of them. Only about eight per cent of all public elementary schools considered their science supplies and equipment plentiful, and only 45 per cent regarded them as adequate.[41] A similar survey of junior high schools disclosed that reference materials from outside the classroom were still not readily available in four-fifths of them, audio-visual material was still meager, and some schools were still using textbooks 14 or more years old.[42]

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*The United States' response to Sputnik I, a high school student said when interviewed on WGBH-TV in Boston in 1957, was "to kick the teachers into orbit."

The Educational Programs Division of NASA did not advocate new space science courses. Instead, it set out to help teachers, textbook writers, and administrators improve, and insert space concepts, in courses already being taught. It strove to meet their urgent needs in relating space to biology, chemistry, industrial arts, mathematics, and related subjects. It did this by providing additional curriculum resources for the schools, services to teachers and young people, publications, audio-visual materials, and a touring space science lecture and demonstration called the Spacemobile.

"Unfolding developments of the space program," this division's director told a United Nations conference in 1968,

> provide a well-informed and skillful teacher many opportunities to lead pupils into the exhilarating and satisfying experience of critical thinking. The student can be led to sense and define problems for study; to state the hypotheses on these problems; to gather, sort, and weigh evidence available to him; to learn to distinguish assumptions from facts, and to arrive at conclusions. The teacher can present techniques and skills used by NASA scientists in interpreting data and in stating their findings on the basis of testing evidence.[43]

The Massachusetts Department of Education prepared an Aerospace Curriculum Resources Guide in cooperation with NASA that suggested helpful topics and learning activities for teachers (from the kindergarten to the twelfth grade) to use to reinforce instruction in nearly every subject being taught.[44] "The toys of our children, the ambitions of young men and women, the fortunes of industrialists, the careers of military officers, the pronouncements of high church officials -- all have reflected the influence of the beginning steps in space exploration," Dr. Dryden could report proudly in 1965.[45]

The National Science Teachers Association and NASA jointly sponsored Youth Science Congresses in 1963, 1965, and 1967. The agency also assisted the Boy Scouts of America, the National Association of Rocketry, the Junior Engineering and Technical Society, and other such organizations. At the same time special workshops were arranged for pre- and in-service teachers to help them take advantage of the intense curiosity of young people about space. In 1967, 15,000 persons attended 233 such summer workshops.[46]

Informational and educational publications issued by NASA for the general reader -- bearing titles such as "Report from Mars," "Space Jobs," and "Medical Benefits from Space Research" -- were widely disseminated. A series of "NASA FACTS" posters appeared on school bulletin boards, in libraries and in classrooms, to answer students' questions about weightlessness, spacecraft tracking, telemetry, and other developments. Films and filmstrips were produced to describe NASA space exploration programs, to share the beauty of the Earth as photographed by the astronauts with elementary school students, and to show them how the Moon would look to the first men to reach it.

The Spacemobile program developed in 1961 was a further substantial aid to schools striving to meet the challenge of the Space Age. The trucks driven by carefully selected lecturer-demonstrators toured the country with models of launch vehicles, spacecraft, and other visual displays that fascinated both kindergarten children and sophisticated alumni of Ivy League postgraduate schools. In 1967 the Spacemobiles gave 11,488 demonstrations to audiences that totalled 2,733,140 persons.

Augmented Higher Education

In the colleges and universities, "the academic revolution" with which a major study of them dealt in the 1960's had begun years before NASA existed.[47] It had brought men who were pillars of professionalism to power, especially in the graduate schools. Higher education in the United States had never before enjoyed such great prestige, and gaining admission to a noted school became more challenging as more young men and women sought it.

Engineering education was becoming more strongly polarized around science. Practicing engineers found in the early 1960's that the rapid advances in science since they were graduated a decade or so earlier were making their professional training obsolete. Ways were needed both to enlarge opportunities for advanced study and to provide realistic exercises in the professional schools that would inculcate the knowledge and skills necessary for actual practice. These needs coincided with NASA's needs.*

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*"When President Kennedy and Vice President Johnson set our sights on broader goals in aeronautics and space," Administrator James E. Webb recalled at the dedication of the Coordinate Science Laboratory Building at the University of Illinois in 1967, "some of us at NASA became concerned that not enough basic research was being undertaken to lay the groundwork for the kind of space flight

The laboratories at such centers of excellence as the California Institute of Technology and the Massachusetts Institute of Technology became deeply involved in work for NASA that did not normally fall within the purview of universities. The former operated the Jet Propulsion Laboratory, which was responsible for some of NASA's most advanced spacecraft, and the M.I.T. Instrumentation Laboratory designed the Apollo guidance and navigation system. More such facilities and talents were clearly needed to exploit discoveries in space.

Many university faculties represented a broader range of disciplines than could be found elsewhere, and were trustworthy sources of both specialized information and needed guidance. Hence NASA strove both to utilize and to strengthen the nation's universities. In the first instance the agency's program offices and centers did this by project-oriented research grants and contracts. Then a panel of experts from universities, industry, and government recommended that NASA also make sustaining university grants for special training, research, and facilities. This, too, was done. By 1968 NASA had invested about $572,000,000 (in addition to its Cal Tech and M.I.T. investments) in work at universities throughout the country. Of this sum, $379,000,000 was in project-oriented grants and research contracts, and $193,000,000 in the Sustaining University Program.[48]

In 1967 about 1400 research projects in astronomy, engineering, and other disciplines including the environmental, behavioral, and life sciences in 200 colleges and universities were being supported by NASA, and about half of the published scientific results of NASA's flight projects was based on work that had originated in the academic community.

The Sustaining University Program provided: (1) training grants to support an accumulated total of about 5400 predoctoral students studying space-related sciences and technology since the program began, (2) facilities grants for the construction of space science research laboratories on 32 university campuses, and (3) multidisciplinary research grants to 50 universities to develop their academic and research strengths by pursuing space-related

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experiments that would be available in the years ahead, which seemed to offer the greatest value. At the same time we were concerned that the universities were not producing enough trained, qualified men and women in the various scientific fields."

studies. By the summer of 1968, 25 research laboratories accommodating 3000 scientists, engineers, and graduates, had been completed under this program, and about 1100 students had received their Ph.D. degrees under the training grants.

In addition, nearly 1000 graduate students and about 500 faculty members were being supported under the multidisciplinary research grants.[49] This help encouraged academicians to strive to relate their universities' structure, attitudes, and activities more closely to a changing world's requirements. The development of a few university teams, working together across the lines of traditional disciplines, and combining the best efforts of technology, social science, and management capability, might write "a new chapter in problem-solving in this country," NASA's Associate Administrator Homer E. Newell pointed out.[50]

A task force assigned to review NASA's impact on the universities found that by 1968 it had contributed greatly to the creation of new centers of excellence.[51] Many of the schools, nevertheless, had been slow to grasp opportunities for innovations that this support made possible.* NASA's use of a systems approach to its missions brought to attention the country's need for more engineers trained in reconciling the many conflicting requirements of scores of subsystems and relating them to the operation of a whole system. In both industry and government the need rose for individuals with a broad understanding of management and public administration, as well as science and technology. Hence NASA proposed in 1968 to increase the emphasis on these topics in its sustaining university program.[48]

"We are at a time of challenge when universities must seek to develop broad ranging minds capable of new and original thinking about all factors that underlie the human and social problems of today," Administrator Webb observed.

> The kind of brainpower that can guide and control spacecraft to fly within 25,000 miles of the planet Venus should certainly be able to apply much of the same kind

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*In general, the task force found, universities had perceived grants from NASA as a means of strengthening themselves in the conventional and traditional ways. Multi-disciplinary attacks on great problems had been stimulated, but few social scientists had been drawn into them yet.

of innovative thinking to many problems here on earth, such as air and water pollution, disease, hunger,housing, transportation, and crime control. We have developed a pattern in the National Aeronautics and Space Administration that has given success in developing three generations, and in some cases four generations, of spacecraft in less than a decade. This may offer some promise with respect to approaches to other complex problems.[52]

THE FIRST ECONOMIC EFFECTS

Mid-twentieth century economists continued to credit economic growth primarily to the inputs of labor and capital, but increasingly recognized the importance of the quality of those inputs.[53] All of NASA's funds were spent on Earth and nine-tenths of them went to the private sector of the American economy. Hence they had some of the usual "multiplier" effects of large government expenditures on the regions in which they were spent. These funds, however, also had the further effect of enhancing the knowledge and the skills of labor and industry.

The immediate impact of the space program was similar in some respects to what would have happened if a decision had been made to create a gigantic new defense system with comparable alacrity. Because of the variety of things and skills that were needed, a broad cross section of the country's industry was directly affected.

Some communities felt the lifting power of the investments in space work almost overnight. More towns and cities benefitted as the nation's reservoirs of technology grew and additional entrepreneurs learned to tap the abundance of new technology. Much of NASA's research and development work was as applicable to peacetime challenges as to military crises.* By widening the scope of engineering, the agency enlarged and prolonged the dividends from the initial investment.

"I think," said one of the University of California's Nobel laureates, Dr. Willard Libby, "the space program will come out to be one of the best bargains the American people ever made -- both for its practical value in technological developments and for its contributions to pure knowledge through science."[54]

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*See discussion of "Technology Transfer" which follows.

Revitalized Communities

At the peak period between 1963 and 1968, NASA had fewer than 36,000 employees "on board" in its laboratories, headquarters, and field facilities.[55] They were mostly at 18 locations in the United States and tracking stations around the world. But the agency was served by some 20,000 contractors, dispersed across the nation, who employed 400,000 men and women full time. By and large the money went to areas in which the required design and production facilities already existed. Some of these plants had been built to meet military requirements, particularly for the large missile programs, which had similar needs for high technology aerospace and electronic work.[56]

The installations that were readily available, however, were not adequate for the space program. Many had to be altered and extended. At one time, 40,000 men were employed in construction work for NASA. This not only contributed to employment generally, but also spurred the industrial development of some areas, particularly in a "fertile crescent" across the Southern states.[57]

In Huntsville, Ala., Science Magazine found a "neatly capsuled case study" of the impact of the Space Age on a cotton town in which "many of the mills had fallen on hard times, and their spindles were idle."[58] Thanks largely to the presence of the Redstone Arsenal, the population had more than quadrupled between 1950 and 1960. NASA's investment of more than a billion dollars a year to develop the Saturn family of rockets, managed from there, stimulated much further growth and industrial development of the area. Huntsville, the Science reporter found, "tried gamely, and with considerable success, to create the conditions necessary for the growth of a well-diversified community."

The whole tone of life changed. About 350 wives of scientists and engineers taught in the public schools, which were greatly improved at the same time that they were enlarged. A Huntsville branch of the University of Alabama expanded and housed what came to be the largest graduate engineering school in the South. Large national firms placed facilities in a 3,000-acre Research Park established in 1962 by the Huntsville Industrial Expansion Committee.

To assemble the units built elsewhere into first and second stages of Saturn rockets, NASA used a very large plant built during World War II 15 miles from New Orleans to produce cargo planes.[59] It had been idle for several years. But 11,000 people were employed there by October 31, 1964, which brought about "a very substantial beneficial effect on the level of employment in the area."[60]

The New Orleans Chamber of Commerce estimated that the decision to assemble the Saturn rocket stages in the Michoud plant added $71,000,000 a year to the personal income in the area, increased retail sales by $33,000,000, and created some 16,000 new jobs.[61] "Less evident, but in the long run probably of even greater significance," The New York Times reported,

> is the impact that the Michoud plant is having upon the social and educational pattern in the area . . . . In every way possible, including recruiting advertisements in local Negro newspapers, the space agency and its contractors have tried to proclaim to the community that they are 'equal opportunity' employers . . . . Within the plant, the integration has been achieved with far less difficulty than expected by Boeing officials.

In Hancock County, Mississippi, about 35 miles from New Orleans, 13,500 acres of land that was formerly largely cow pasture became the Mississippi Test Facility for NASA.[62] "With the beginning of construction on the Mississippi Test Facilities in 1963," a historian wrote at the time,

> the federal government has undertaken a task somewhat parallel to the role of the Illinois Central in Mississippi in the nineteenth century. The proportions of NASA's involvement, however, are grander. . . . Plans include the improvement of 15 miles of river channels for purposes of transporting bulky equipment and fuels that cannot be transported by rail. Total construction costs have been estimated at $111,000,000.[63]

From the New Orleans area, the Saturns were taken to Cape Kennedy for assembly of the stages into the full-sized Saturn Boosters and for launching. Empty stretches of sandy beach there became "varied and booming communities." The population of the region, which had risen 235,100 between 1930 and 1954, rose by 401,700 in the next decade. Retail sales soared and investigators found the economic growth of the area "phenomenal."[64]

Construction of the Manned Spacecraft Center at Clear Lake, Texas, to manage the development and flight of the Gemini and Apollo Spacecraft was also beneficial to the Gulf Coast economy. In addition to the direct dollar contribution to the Houston area's prosperity, "this had the far more important result of sparking a broad advance in the industrial interests of the community," which until then had been "overdependent on petroleum and natural gas."[64] Three-fourths of the professional personnel of this center came from other areas, and 124 national companies "opened new offices to maintain liaison with the Center."[65]

The geographical distribution of the nation's industrial resources might have been affected likewise by equivalent expenditures for military purposes. Such expenditures also had often given birth to advances in the industrial arts. Work done primarily for military objectives, however, cannot always be carried out as openly as that which was done in NASA's research centers and production facilities. This added force to the new technology's impact on the state of peacetime arts.

Technology Transfer

For spacecraft, the aircraft industry and its contractors had to develop new materials, devices, techniques, and skills.* These, of course, often could be used to improve aircraft, too, and much of this technology was readily adaptable to a multitude of other tasks. Many innovations need only minor modification to be helpful on the Earth's surface as well as above it. Others catalyzed serendipitous reactions in researchers and inventors in formerly remote fields, even though not directly applicable to the problems that they faced. NASA strove to increase this kind of round-about but often portentous impact on the whole nation's economy by exploring new means of transferring technology from one region to another and from one industry to another.

A paint perfected to protect spacecraft was soon being sold for other uses.[66] An ionization gage built for use on satellites also appeared on the market quickly.[67] An electromagnetic hammer that made its debut in a NASA field facility was tried out promptly by shipbuilders and automakers.[68] And ground was being broken in 1968 for a large new California plant to make drainage and irrigation pipes the way that rocket casings had been made successfully.[69]

A National Commission on Technology, Automation and Economic Progress, authorized by Congress in 1964, found widespread agreement

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*See Chapter V.

that the knowledge resulting from public investments in research and development constituted a major, rapidly increasing, and insufficiently exploited national resource. This commission also found, however, that traditional means of transferring technology were not wholly adequate, and recommended that "complementary mechanisms be devised to aid in the channeling, transfer, and utilization of new technologies from sector to sector, industry to industry, region to region, discipline to discipline, market orientation to market orientation."[70]

An advocate of such steps, Dr. Richard L. Lesher, NASA Assistant Administrator for Technology Utilization, pointed out that: "The history of technology is replete with examples of applications lagging as much as 150 years, and the lag is even greater for second order applications. While the time period of the lag may be growing shorter, most economists agree that it is still on the order of 13 to 20 years on the average."[71]

The Office of Technology Utilization that NASA established undertook to hasten the impact of the agency's findings. It strove to encourage the exploitation of new technical resources through experimental or "pilot model" projects for accelerating the flow of data over the numerous social obstacles. It collected reports of aerospace-related research and developments from all parts of the world, both to aid the industries directly serving NASA and to make those reports readily available for other constructive uses. In 1968 this collection contained nearly half a million documents and 6000 more were being added to it monthly. To save space and reduce the cost of distributing these documents, nearly all of them were microfilmed. To make particular ones easy to locate, they were abstracted and indexed in such a way that a computer could find them for a particular user. A new kind of thesaurus was published in 1967 to guide indexers and users of this kind of technical library.[72]

To assure that items having commercial potentialities were reported, and announced promptly in appropriate ways, Technology Utilization Officers were appointed at NASA field installations. They both searched for such items in-house and monitored a special clause that required contractors serving NASA to report innovations that could be put to additional benign uses.

In 1964 the agency began issuing one- or two-page bulletins called Tech Briefs, which concisely described innovations, explained the basic concepts and principles, and directed readers to sources of more detailed information.[73] By 1968 the Cumulative

Index of Tech Briefs listed nearly 3000 such announcements of innovations in electrical work, mechanical devices, materials, computer programs, the physical sciences, and the life sciences.[74] In addition to these bulletins, special reports and comprehensive surveys of NASA contributions to such arts as solid lubrication, non-destructive testing, and high-velocity metalworking were published. Abstracts of about 50 such publications were listed in *NASA Publications Currently Available, Fall 1968*, issued by the Scientific and Technical Information Division. These publications helped both students and practicing engineers and technicians keep abreast of developments helpful to them.

Experimental Dissemination Aids

Research on the entire process of understanding, accepting and employing technical change, a report to the U.S. House of Representatives by the National Academy of Sciences stated in 1967, was clearly needed "as a consequence of the growing volume and diversity of technology, and the potential and exciting demands for its fruitful use."[75] In this research, NASA pioneered by helping to sponsor experimental Regional Dissemination Centers and Biomedical Application Teams.

"Discoveries of great magnitude, those that lead to the creation of whole new industries, for example, generally have sufficient inherent force to bring about their own exploitation," said George J. Howick, Director of the Technology Utilization Division. "But the incremental advances that singly seem of minor importance, but in combination underpin our industrial might, are less easily brought to the attention of the many who can benefit from them."[76]

To help industry relate the bits and pieces of new knowledge not widely publicized, NASA found that the Regional Dissemination Centers were highly useful. No two of the centers established with the space agency's help were exactly alike, but each one was based at a university or a not-for-profit research institute, and staffed with professional personnel experienced in using a computer to search for and retrieve technical information. The number of paying clients served by these Regional Centers grew from 29 the first year to several hundred in the fifth year, Dr. Lesher reported in June 1968,[77] and each center was expected "to meet the market test by becoming self-supporting."*

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*Two of the host universities were pledged to continue disseminating information from NASA without further support from the agency.

Another kind of center was established at the University of Georgia to make computer programs developed by NASA available to other computer users throughout the nation. In its first year, this center sold more than 1000 programs for fees determined by the cost of reproducing and distributing them. Producing those programs had cost sums ranging up to $100,000, but they had served their initial purpose and the average cost for a copy for another use was less than $100. Thus further use of computers was encouraged by reducing the cost of software for them.

Other government agencies as well as private concerns found NASA's experience and its constantly growing technological resources helpful in their activities. The Atomic Energy Commission began a similar program to aid in the transfer of technical information in cooperation with NASA. The Office of Technology Utilization also cooperated with the Small Business Administration, the Office of Technical Services of the Department of Commerce, the Office of Law Enforcement Assistance of the Department of Justice, and the Social Rehabilitation Agency of the Department of Health, Education and Welfare.[78]

Perhaps the most novel of NASA's experiments in facilitating technology transfer was the formation of Biomedical Applications Teams. These teams were formed at three independent research institutes in 1967 to identify and define medical needs, and then to mine the NASA mountain of new information and data for ore that could be helpful in meeting those needs.

The potentialities of such work already had been demonstrated dramatically by then: A technique developed to enhance the clarity of pictures televised from spacecraft had been found applicable to the improvement of X-ray photos for physicians. A walking machine devised for use on the Moon had been converted into a walking chair for crippled children. And work done by NASA and AEC to improve manipulator arms that were remotely controlled seemed likely to prove helpful to makers of artificial limbs for human beings.[79]

"The continuing, visible technical accomplishments of the space program may be modifying attitudes toward technological innovation among those who previously have been hostile or neutral to innovation," Sumner Myers, director of the National Planning Association's Research and Development Utilization Project, commented. "To the extent that this is so, the very existence of the space program as a model of technological achievement may finally prove more important to the economy than either the multiplier effect of its investment or the 'spillover' of its technology."[80]

Before 1963 orbiting satellites contributed only in relatively minor ways to the world's economy, but from then on both these new vehicles and the engines that put them in orbit affected it increasingly. "We have learned the precision control of very large concentrations of power," NASA's administrator told the Investment Bankers Association in 1967.

> We have developed advanced guidance systems and sensors than can perform many earthly tasks more reliably and more precisely than they have ever been done before . . . . We have a present basis of knowledge for new fuels, new combustion processes, new pumps and turbines, valves, and nozzles that make possible new supersonic and hypersonic propulsion systems that will operate inside or outside the atmosphere . . . . This research . . . is certain to pay dividends, many of which we cannot foresee or predict, and some of which will be revolutionary.[81]

AN IMPACT ON ECONOMIC ASPIRATIONS

The "technology gap" between the United States and European countries -- and the great chasm between them and younger nations -- worried far-sighted men increasingly during NASA's first decade. The space program was but one of many factors in the rapid advances in the industrial arts in America. It was a factor, however, that could have beneficial consequences for men everywhere because:

> It demonstrated the feasibility of managing major programs to meet complex, colossal challenges.
>
> Spacecraft could help monitor the Earth's resources.
>
> And the new vehicles fascinated the people of all nations.

"The American challenge," a French journalist wrote in a book that became a best-seller in Europe in 1968, "is not basically industrial or financial. It is, above all, a challenge to our intellectual creativity and our ability to turn ideas into practice."[82] Thus the "technology gap" was increasingly viewed more realistically as a "management gap."

Americans had managed huge businesses before NASA was born. They had succeeded, too, in great military campaigns. But there were no adequate precedents for NASA's global assignments. Its tasks demanded unusual performance in an unusual type of government organization. The agency's importance as a prototype for future large-scale undertakings, consequently, could dwarf in time both the effects of its expenditures and those of the new technology it developed during the years reviewed here.

A Challenge to Management

Aviation was the seedbed from which that technology came, and benefitted directly from its growth, but spacecraft were more complicated systems of structural, mechanical, chemical, and electrical devices than were needed in aircraft. The requirements for precision and reliability greatly exceeded those that engineers and manufacturers were accustomed to meeting. The new vehicles had to be both constructed and flown by complex systems of men and machines, contractors and subcontractors, with a multitude of different capabilities.[83]

Many space flights had multi-objectives. Often they overlapped. Ranking those objectives was difficult -- yet plans had to be made long before the flights, costs had to be estimated, allowances made for unforeseeable problems, and the work of a variety of organizations in all parts of the country had to be coordinated. There were all of the usual constraints on an industrial enterprise -- plus those imposed by the necessity of doing new things in new ways in a new environment about which too little was known at the outset.

Difficult decisions were called for quickly -- almost instantly, once that a flight had begun -- and many of them had to be based on vast quantities of data and information that varied greatly in both its adequacy and its reliability.

To succeed, NASA required "the kind of flexible organizational and administrative framework within which the procedures used and the responsibilities, even of quite senior officials, could be readjusted without embarrassment or great difficulty."[84] First-class performance was needed at every level of the organization, in all phases of administration as well as in the numerous special disciplines that were involved.*

"Complex large-scale undertakings cannot be handled ad hoc or haphazardly," NASA's administrator told his audience at Columbia University's Graduate School of Business in 1968.

> The costs are too great, the stakes are too high, and the consequences of failure too dangerous . . . . An ability to use large-scale endeavors when needed is certainly one of the great requirements of our times. To learn how to use them well is a continuing challenge. The essence comes down to extending good management -- sound, effective, and complete management -- into a new and extremely complex dimension.[86]

Community Improvement

Men's aspirations soared like their spacecraft as "the systems approach" that NASA chose became more widely known. The Department of Defense had familiarized the aerospace companies with it. Their production lines, however, could not meet the unprecedented specifications for spacecraft. The industry consequently became more highly research oriented. In California especially, leaders in it also began bringing their new skills and systems approach to bear on urgent regional and urban challenges -- having to do with schools, crime detection, health services, and other necessities of modern life.[87]

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*The agency drew heavily on such techniques as operations research and cost-effectiveness analysis that the Department of Defense had used to develop weapons systems. It also enlarged this kit of tools with new ones, such as the Goddard Research Engineering Management Exercises (called GREMEX) to train its executives in the kind of decision-making that was required, and a new system of making Forecasts and Appraisals for Management Evaluation (called FAME).[85]

"A recent systems analysis of one American city," Gen. Bernard A. Shriever told a conference sponsored by two aerospace companies and a university, "revealed that it had 130 subsystems, including water, sewerage, transportation, education, law enforcement, housing, recreation, industry, and so on. If one is concerned with the rehabilitation of that city, he must consider how each of those subsystems interacts with the other subsystems."[88]

Impressed by NASA's achievements with a systems approach to space mysteries, the Department of Housing and Urban Development advocated a similar attack on the complex, inter-related ailments of great cities participating in its Demonstration Cities Program.[89] The new approach was taken also in formulating plans for High Speed Ground Transportation (HSGT) in the Northeast Corridor in a study undertaken by the Massachusetts Institute of Technology's faculty for the Department of Commerce. M. I. T. students also applied this technique later to a study of trash collection in Boston.[90]

Industrial leaders as well as government officials and college faculties saw new opportunities in the approach. A General Electric Company official, for instance, told an Urban America, Inc., conference:

> From past experience in production and distribution of power, in attaining far-reaching objectives in aerospace and weaponry, it is convincingly evident that a systems approach to complex problems is time conserving, economical, and effective. Rapidly advancing computer technology is helping to solve complex problems . . . at a feasible cost in both time and money. If we can only establish and define the end results we seek in a city environment, or putting it another way -- create performance specifications -- then a kind of reverse Critical Path can be mapped out which identifies necessary input and the desired sequences of application required to reach the end objectives. Therefore, if we can identify what constitutes a better community and know what values to end up with, it should be possible to create the kind of city people would really like to have, and at costs that they can afford to pay.[91]

Cities, despite their growth and the shocking turmoil in them, were but one of mankind's grave problems in the 1960's. The human race was managing its whole environment rather badly and consuming the Earth's resources faster than ever, a subcommittee on Science, Research and Development reported to the Committee on Science and Astronautics of the U. S. House of Representatives.[92] Together, the managerial concepts and the orbiting satellites developed by NASA suggested that pollution could be monitored, and natural resources better conserved, for the whole world, by using spacecraft as sources of additional information and data.

Resource Monitoring

"Our unearthly satellites," the director of the Langley Research Center, Edgar M. Cortright, predicted, "will help us solve a host of earthly problems."[93]

The use of working satellites in international communications and weather observations began quickly to facilitate navigation of the seas and direction of traffic on the airways. Imaging sensors aboard the growing variety of satellites showed synoptic coverage of the lithosphere and hydrosphere as well as the atmosphere was possible. This cracked a "plausibility barrier" against the use of satellites for workaday purposes.[94] The color photographs taken by the Gemini astronauts further shattered that barrier, for these were not the product of inhuman devices that only specialists understood, but snapshots taken by men, with hand-held cameras, of familiar seas and lands.[95] They further demonstrated "that certain phenomena related to the Earth can be understood only when viewed from a great distance."[96]

Until satellites began to photograph the clouds everywhere every day, most of the Earth's weather had gone unobserved. To meteorologists examining the pictures transmitted from high above the clouds, Nature seemed to be drawing her own weather map for them. The meteorological satellites followed storms on all sides of the Earth -- from their births until their deaths -- and quickly began to make warnings possible that saved lives and property.

Although multi-million dollar command and data acquisition centers were used on the ground to receive the pictures from the satellites at first, this limitation on their availability was soon removed. By 1968 a ground station to receive a picture transmitted automatically from a satellite passing overhead could be bought for about $5000 or built from surplus parts for as little as $500.[97] This made it possible for a local weather bureau, commercial organization, TV station, or school -- even in a nation with meager means -- to receive views instantly, directly, and inexpensively, of the cloud formations in its vicinity.

If pictures from a NASA-developed satellite had not been available, two Mexican cities (Gomes Palacios and Torreon) might have been flooded in the fall of 1968 to save a dam that was being built above them. Heavy rains had threatened to sweep the dam away, and authorities considered opening it and flooding the cities to save the dam. Pictures from ESSA VI, however, indicated that the rains would soon end. The dam was kept closed, withstood the pressure, and both the cities and the water above it were saved.[98]

Professor Oskar Morgenstern, the noted Princeton economist, was among those who pointed out that orbiting satellites opened an area "for truly significant economic studies."[99] A report by the World Meteorological Organization estimated that by 1975 further improvements in weather forcasts made possible by the use of satellites could allow direction of the time of planting on a world-wide basis with such reliability that $15 billion now lost annually might be saved.[100] "And this would be only one use of better weather forecasting," Professor Morgenstern emphasized. "And weather prediction is only one welcome product of space exploration."

To writers such as Stuart Chase it was "sobering to remember that only about 12 per cent of the Earth is fit for human habitation."[101] Since Biblical times men had gambled on food production and fought for control of the Earth's fertile areas without really knowing their extent or their capabilities. The United States already had found it worth while to collect statistics on more than 50 crops. The use of data fed to computers from satellites regarding day-to-day conditions could readily be envisioned. This might so improve the predictions of harvests that the effects of poor crops on one continent could be offset by earlier plantings on another continent.

The same satellites that served mankind in this way could simultaneously alert people everywhere to storms, floods, and forest fires. Nor were losses to deluges and flames the only catastrophes that Space Age technology held out the promise of minimizing. A study sponsored by NASA led directly to experimental use of a laser system to detect slight movements in the Earth's crust for the students of earthquakes,[102] and geological phenomena seemed likely to become less puzzling as scientists learned more about other planets as well as about the Earth. Satellites aloft in the 1960's demonstrated that they could indicate snow coverage, trace the movement of ice, and record the rise and fall of reservoirs with the sensors already available.

Forests still covered 10 billion acres of the Earth's surface despite men's tendency for centuries to regard them the way that frontiersmen had once regarded herds of buffalo. Forest products constituted one of the four largest complexes in the American economy, but even the United States did not have a reliable map of the distribution of its woodlands. Color photography from satellites showed that the type of trees, the rate of growth, and their health, could be ascertained at the same time that forests were mapped from space. Migrations of insects could be traced by the changes in the color of the foliage in inaccessible woods.

In the first two-thirds of the twentieth century, men's use of the Earth's raw materials was believed to have exceeded the quantity consumed in all the previous centuries of their existence.[103] The increasing population's demands made better inventories of the reserves imperative. Extrapolations such as those that indicated the United States would double its consumption of minerals by the 1990's began to appear increasingly ominous in the 1960's.

In the photos brought back by the Gemini astronauts for geologists, features of the Earth's surface that miners and drillers had found were often indicative of mineral and oil accumulations could be recognized. From localized studies, scientists had learned that warping, folding, and uplifting of the crust were signs of great activity within the Earth, that cracks and faults often provided channels for ore-depositing fluids, and that certain geologic features controlled the formation and movement of oil beneath the surface. Overlapping photos taken from the Gemini spacecraft revealed such features on a scale that made them easier to recognize than they are when a searcher is confined to the surface.

Prospectors and biologists had learned, too, that plants could guide them to concealed mineral deposits. Workers in a hybrid field of science called biogeochemistry wrote in 1968 that "a new concept of moving from wide surveillance of the Earth's surface to the pinpointing of mineral-rich areas" was becoming applicable.[104] It involved the use of orbiting satellites and multi-spectral imagery to identify the areas, by the vegetation, in which to apply such tools of mineral exploration as soil sampling and chemical analysis.

The seas cover twice as much of the Earth's surface as the continents, but many of their hidden riches remained unknown until oceanographers began detailed exploration of the oceans in the nineteenth and twentieth centuries. Exploitation of the oceans' resources was still hampered in the 1960's, however, by great voids in men's knowledge of the water's boundaries, currents, temperatures, and depths. In Gemini photographs, oceanographers could see how erosion was changing shorelines, note signs of temperature variations, and trace patterns in the waves. Even in some of the shallower, most familiar areas, they found that the actual contour of the bottom did not correspond with their most recent maps of it.

Orbiting satellites equipped with sophisticated remote-sensing apparatus, it became obvious, could serve the oceanographers in much the same way that they were serving the meteorologists. Communication satellites could relay reports from ships and buoys to aid in the interpretation of data transmitted from the sensors in space.

Systems to realize these great and varied benefits became feasible at the very time that men's activities began to pollute the water, the air, and the land, to a menacing extent. Many bathing beaches were no longer safe, many cities were choked with smog, and woodlands in relatively undeveloped nations still were being despoiled. Hence the new instrumentation for monitoring and helping to manage the environment that NASA showed could be developed came to seem less like a scientific luxury and more like a necessity for human survival. A day might come when men would seem to have soared into space in the very nick of time.

"Commercial applications of space flight increase the productivity of the economy now," the director of the Goddard Institute for Space Studies, Robert Jastrow, wrote in the summer of 1968, "and applications in pure science plant seeds for increases in future years. The increased productivity generates the tax dollars necessary to meet urgent social needs. Far from sapping our economic strength, the space program, along with electronics, computers, and other advanced technologies, generates new wealth. Yet, the returns to date are only a small fraction of the gains which can be realized.

"The satellites of the 1960's are primitive machines, whose economic and scientific value shrinks into insignificance against the returns from spacecraft now on the drawing boards and awaiting funding.

"This is the promise of space: a dollars-and-cents return in increased productivity in the United States, so great that the question is not, can we afford a space program but, can we afford to be without one?"[105]

AN IMPACT ON INTERNATIONAL RELATIONS

The competition between the United States and the Soviet Union in outer space was somewhat reminiscent of the race between European powers centuries earlier for sovereignty in America. Both nations sought status for their ways of life and both hoped for commercial gains as well as knowledge. The competition, however, began differently: The first satellites went into orbit as national contributions to the International Geophysical Year (IGY) program of the International Council of Scientific Unions.

Thirty-five national bodies and 10 scientific unions were members of an International Committee for Space Research (COSPAR) formed in 1958 to continue and expand the IGY pattern of cooperation.[106] Although it bound no governments, it set standards for reporting research results, sponsored World Data Centers, and promoted such activities as synoptic launchings of rocket experiments. The International Aeronautical Federation, which also represented groups within nations rather than governments, provided an additional forum for engineers engaged in space ventures.

American scientists had proudly considered themselves members of an international fraternity for many years. So did Rotarians and other groups, but few of them had such strong old school ties with their occupational brethren abroad as those of the scientists. Many of them had studied abroad, and many foreign scientists had studied in the United States. Few world-wide groups felt it necessary to correspond as regularly, or meet as frequently, as they did, and many participants in such activities hoped like the theologian, Reinhold Niebuhr, that space science could become a thread of common understanding and culture to bind nations together.[107]

"The frontier of space is a frontier that we believe all mankind can and should explore together for peaceful purposes," said President Johnson, "and I have enunciated that doctrine in all the forums in which I have been allowed to trespass."[108]

Partnerships in Space

NASA's activities touched all continents. The agency sprang no surprises on other countries. From countdown to splashdown, its major ventures were visible to the whole world, and setbacks were as well known to observers in other countries as to the American people.

Congress ordered that this civilian program be so conducted as to nourish other nations' cooperation, and the criteria developed by Deputy Administrator Dryden for their participation were simply: (1) Scientific validity and mutual interest, (2) open conduct with scientific results freely available to scientists everywhere, and (3) significant contributions and independent funding by each participant.

From the outset, NASA sought the cooperation of the Soviet Union as well as other nations, but Soviet scientists "echoed the refrain that no progress would be made toward cooperation between the United States and the Soviet Union until complete and total disarmament had been achieved."[109] Other nations, fortunately, were more receptive to opportunities to share in NASA's work, and by 1968 the agency and scientists of 83 countries had cooperated in various ways.

Britain and Canada were the United States' first partners in space. The British National Committee for Space Research designed, prepared, and funded the instumentation for Ariel 1.[110] It did the engineering too, for the second and third Ariels that were launched in 1964 and 1967. The Canadian Telecommunications Establishment designed, engineered, and financed the Alouette satellites that NASA placed in orbit in 1962 and 1965, and Canada also agreed to provide three more satellites.

The United States launched a French satellite in 1965, and cooperation between the two countries blossomed despite stresses in other aspects of Franco-American relations. The French Center for Space Research and NASA planned a joint effort in 1969 to establish an experimental satellite-balloon system to gather meteorological data on a global scale. The first Italian-built and instrumented satellite, San Marco, was launched from NASA's Wallops Island facilities by an Italian crew that was trained there. The Italians later launched a similar satellite from a platform in the Indian Ocean. A third San Marco was to be launched in 1969 or 1970, and a German scientific satellite in late 1969. By July 1, 1968, nine satellites had been launched in NASA cooperative international projects.

Space was so costly a frontier to examine that 10 European nations pooled their scientific interest in it in a European Space Research Organization (ESRO), which made its tracking and data acquisition stations compatible with those of the American agency. A European Launcher Development Organization (ELDO) was formed, too. NASA, however, launched the first satellite that ESRO designed and built.

"ESRO alone has the potential for engaging the very considerable technological and economic strength of Europe in a significant, if selective, program," Arnold W. Frutkin, NASA Assistant Administrator for International Affairs, declared in the keynote address to an international astronautics conference in 1967. "To the extent that such a program is generated in Europe, the possibilities for rationalizing its relationship with the United States grow."[111] In December, 1968, a satellite launched from Cape Kennedy for ESRO bore experiments that had been prepared in laboratories in Britain, Belgium, France, Italy, and West Germany.[112]

Foreign scientists also were invited to propose experiments to be carried aloft with those of American researchers on NASA's satellites. Eleven such experiments were carried thus between 1958 and mid-1968, and more were selected for future flights. Virtually all categories of the American spacecraft were open to other countries' experimenters, and the specialists invited to analyze lunar surface materials to be brought back by the Apollo astronauts included outstanding men from eight countries.

Small rocket sounding projects were less expensive than orbiting satellites and 19 nations joined NASA in such activities.* These joint projects enabled the participating countries to develop and to contribute their citizens' talents as well as to share the benefits of space research. Some of them also served as nuclei for further international efforts. Bilateral work with India, for example, produced an equatorial sounding rocket range that interested other members of the United Nations. NASA's ionospheric studies with Norway led to collaborative efforts among all three of the Scandinavian countries. In Argentina, the site of a small rocket project, Chamical, became a training center for representatives of Latin American countries, and Argentina and Brazil signed a memorandum of understanding in 1964 that provided a framework for their future cooperation in space.

The willingness of many nations to cooperate with the United States was especially helpful in acquiring data from satellites. Twenty-three ground stations made coordinated observations of a NASA satellite that flew in 1964 (the fixed-frequency topside sounder), and, by July 1968, 102 stations in 37 countries were working with signals sent earthward by NASA satellites, thus helping to maximize the returns from those vehicles. Meteorologists in more than 40 countries were equipped to receive the cloud cover photographs transmitted automatically from U. S. weather satellites.

Stations around the world helped to track and assure the safety of American astronauts. Canada and the United Kingdom bore substantial portions of the cost of operating stations in their areas, and Australia contributed to the cost of station operations there.[113] The American astronauts crossed Australia more often in the dark of night than in daylight, and the people of Perth kept their lights burning for them. Like a candle in a window, this symbolized the good will that the antithesis of secrecy regarding the American flights evoked.

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*More than 400 small sounding rockets had been launched from all quadrants of the globe at this writing.

Exchanges with the U. S. S. R.

Throughout the administration of Lyndon B. Johnson, NASA continued the efforts begun under his predecessor to find ways to collaborate with the U.S.S.R. When Chairman Krushchev of the U.S.S.R. had congratulated President Kennedy on John Glenn's flight in 1962, he had observed that it would be very beneficial if the two countries pooled their scientific, technical, and material efforts "to master the universe." President Kennedy had promptly replied with concrete proposals and declared he hoped that "at a very early date our representatives may meet to discuss our ideas and yours in a spirit of practical cooperation."*

Talks between Dr. Hugh L. Dryden of NASA and Soviet Academician Anatoly A. Blagonravov led to bilateral agreements in 1962 and 1965 for the two foremost nations in space to work together in meteorology, communications, and magnetic field mapping, and to undertake a joint review of space biology and medicine. A "cold line" was opened over which an exchange of meteorological satellite data began in 1966 but this was only
a first step toward coordination of efforts in space meteorology. 114
Radio signals were transmitted to the U.S.S.R. via an American satellite with the help of the United Kingdom's Jodrell Bank Observatory, but no signals were received from the U.S.S.R. in that experiment. The exchange of magnetic field data fell behind schedule, and a U.S. - U.S.S.R. editorial board had not completed the projected joint review of space biology and medicine yet in 1968.

In 1964 NASA proposed an exchange of visits by American and Soviet teams to deep space tracking and data acquisition facilities, but the Soviets replied the following summer that such visits were not then possible. In 1965 NASA's administrator invited the Soviet Academy of Sciences to send a high-level representative to the launching of Gemini VI, but the invitation was not accepted. Twice, NASA also proposed communications tests via a Soviet satellite, but none were arranged.

President Frederick Seitz of the National Academy of Sciences joined Administrator Webb in efforts to open a fruitful dialogue with the Russians regarding space work. So, too, did Ambassador Arthur Goldberg, who told the United Nations General

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*See Chapter I.

Assembly that, if the U.S.S.R. desired tracking coverage of its satellites from U.S. territory, his government would discuss the technical and other requirements "with a view to reaching some mutually beneficial agreement." But all such friendly gestures seemed to be futile.

"We again renew these offers today," President Johnson declared in the fall of 1967. "The hard business of foreign relations requires a certain optimism."[115]

The United Nations' Role

Space exploration added no crises to those with which the United Nations had to grapple in the 1960's, and its specialized agencies assisted efforts to extend the benefits. The International Telecommunications Union, for example, allocated frequencies and established international regulations for the use of radio in space communications and research, and the World Meteorological Organization undertook a study of a world weather system that would include satellites.

The United Nations' main concern was that space be used peacefully. This, of course, was also America's objective. The General Assembly asked all states to inform the Secretary-General of the objects it launched into orbit or beyond -- and this resulted in the establishment of a United Nations public registry. To provide for exchange of information, to study measures for the promotion of international cooperation, and to report on problems that might arise, the United Nations set up a Committee on Peaceful Uses of Outer Space. This committee formed two subcommittees, both of which aided in moving toward international amity in space.

Recommendations of the Scientific and Technical Subcommittee led to publication of biennial reports on national and international activities in space and on training opportunities. This subcommittee also was instrumental in bringing about the United Nations' sponsorship of an equatorial rocket launching site in southern India that had been established as part of NASA-India cooperative projects. France and the Soviet Union joined the United States in lending equipment for this facility, at Thumba, which was open for use by any member of the United Nations.[116]

The Legal Subcommittee produced a treaty prohibiting the placing of weapons of mass destruction in orbit, limiting the use of the Moon and other celestial bodies to peaceful purposes, and laying down basic ground rules for peaceful cooperation.[117] "I greet this treaty," President Johnson declared when it came into force. "I see it as a hopeful sign that mankind is learning, however, slowly, that wars are not inevitable, that national rivalry is not a permanent barrier to international understanding, and that a world of hostility and hate need not be the abiding condition of mankind."[118]

Another treaty followed this one, dealing more specifically with the rescue of astronauts and the return of space objects.[119] This was signed by the U.S., the U.S.S.R. and 41 other nations.

"The old antagonisms which we call the cold war must fade," the President declared in 1968,[120] and these treaties were among the developments he cited at Glassboro, on Independence Day that year, as evidence that progress was being made.[121]

When the United Nations Conference on Exploration and Peaceful Uses of Outer Space opened in Vienna on August 14, 1968, a message from the Vatican made the point that space benefits should be available to developing nations as well as to the leaders in space exploration. This became a notable theme of that conference. The East, however, was still the East despite the West's hopes: Premier Kosygin, in a message to that conference, announced that his "and other Socialist countries" planned an Intersputnik communications system to compete with Intelsat, the system that the United States had repeatedly invited the Soviet Union to join.[122]

THE IMPACT ON THE FUTURE

In 1840 former President John Quincy Adams warned fellow members of the House of Representatives that the Russians were building "the most complete establishment for astronomical observations on the face of the Earth."[123] Congress was indifferent then. The future of the fast-growing frontier beyond the Alleghenies preoccupied its attention, and legislators tended to agree with the ancient Persian astronomer who had allegedly written of the sky, "Lift not your hands to It for help." The settlers approaching the Pacific thought that they needed railroads and other hardware more urgently than they needed astronomy.

That geographic frontier molded the nation's character, but it was gone and the Atomic Age had altered the American people's attitude toward pure science when space beckoned in the 1950's. Intercontinental missiles had begun to replace manned bombers. A military base on the Moon would be many times farther from a foe on Earth than a base in Antarctica, but the Sputniks made the importance of technological leadership plain for everyone to see. NASA was the United States' means of showing other nations that its people had no intention of surrendering the prestige that their fathers had earned.

Its impact on the planning and the resources of the Department of Defense was unconcealable. The wind tunnels and other new facilities that the civilian aeronautical and space agency required were useful also to the Army, Navy, and Air Force. Much of its research was applicable to military systems, and the Air Force drew heavily on the technology and hardware developed for the Gemini flights in formulating its plans for a Manned Orbiting Laboratory to determine the usefulness of a military man in space.[124] But paradoxically, NASA, while helping to arm the nation, came also to be viewed as a possible aid to deescalation of the arms race.*

Space exploration cried for the humanitarianism of sportsmanship. "Maybe one of these days," Vice President Hubert H. Humphrey suggested, "we will get civilized enough on this Earth to have our contests, not on the battlefield, but rather in the field of adventure in space and the exploration of the universe. It might very well be that space offers us the chance for peace."[125]

Few Americans other than the science fiction addicts had given much thought to space travel until the 1960's, but nearly everyone became interested then. The Reader's Guide to Periodical Literature gave an inkling -- as crude perhaps as Enrico Fermi's bits of paper at Alamagordo -- to the magnitude of the ferment that orbiting satellites started. The mere

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*"Our hope," said Dr. Charles S. Sheldon of the National Aeronautics and Space Council staff when interviewed on TV January 20, 1965, "is space can become a substitute for war by diverting man's restless energies into a supreme challenge of a constructive nature." (NASA SP-4006, p. 27).

titles of magazine articles pertaining to space that the guide listed between March 1963 and June 1968 filled 822 column inches; the titles of articles regarding atomic developments ran for 368 column inches, and those of articles about agriculture took up only 167 inches.[126]

Some Americans still asked, like Dr. Abraham J. Heschel, a noted professor of ethics: "Of what value will it be to land a man on the wilderness of the Moon if we neglect the needs of millions of men on Earth?"[127] Others questioned whether those needs could be met any better without a space program, and argued that the skills and the resources that were being acquired could help the world meet humanity's other needs more effectively. Then, as the astronauts went their way, many persons came to share the feeling of Louis J. Halle, a specialist in international law, who wrote in The New Republic: "Our position is simply that of the intelligent creatures confined in the ocean deeps. Now, however, that we are beginning to escape from our native confines, there is no telling what light we may find in the larger universe to dissipate the darkness of our minds."[128]

Eminent theologians welcomed this enlightenment. Father Francis J. Heyden, S. J., for example, wrote that "through science man's future in space can be as bright and high as the stars," and the Rt. Rev. James A. Pike of the Episcopal Diocese of California declared: "Space exploration can be a source of inspiration. The wonders of the universe that it is revealing can magnify our vision of God."[127]

The thrust of NASA's work was on the vector which Americans chose in the presidential elections of 1964 and 1968. As the nation moved forward, nevertheless, many persons felt uneasy. "A curious automatism, human in origin but not human in action seemed to be taking over," the poet, Archibald MacLeish wrote.

> We were proud . . . of our technological achievements, but we were aware also from the beginning that these achievements were not altogether ours or, more precisely, not altogether ours to direct, to control -- that the processes had somehow taken over leaving the purpose to shift for itself so that we, the ostensible managers of the process, were merely its beneficiaries.[129]

The sociologists said that technology could only open doors for people, but a house with many new doors differs from what it was before. Whether those doors seem alarming or inviting, the behavior of people in such a house may change. "New technology also means a high probability of change in individual and social values, because it alters the conditions of choice," the director of the Harvard University Program on Technology and Science wrote in 1968.[130] Space technology gave the American people a fresh taste for new, high adventures. Its successes prompted many individuals and groups to demand that social goals within the nation that previously had been considered unattainable be reached almost overnight.

The subtle reactions to the exploration of space within men's minds and hearts became increasingly evident. But there were no equivalents of Geiger counters with which to measure the impact of NASA's work on the teaching and practice of the humanities -- even though this might have been more sweeping than the effects noted on the teaching and practice of science, on the world's economy, and on international relations.

Some signs of the Space Age were visible in the "astro architecture" brought about quickly by new materials and computer-aided design techniques such as NASA helped to spawn.[131] Commercial concerns advertised their involvement with space ventures. The impact on art and literature, nevertheless, was difficult to distinguish from that of other momentous events, for a more highly educated and affluent generation turned out also to be an impatient and turbulent generation.

Governments, universities, and industries were the driving forces in the Air Age. The communication channels between them were improved to meet the requirements of space exploration, and society could clearly put those channels to more uses. But how humanely would new skills be used to rebuild cities? How effectively would they be employed to alleviate poverty? Did the mixture of rivalry and collaboration between nations in space bring nuclear disarmament closer? Neither the savants nor their computers had adequate inputs in the 1960's to divine the auguries of space to all men's satisfaction.

Certainly the space program demonstrated anew the genius of the innovators, long ago, of the past and future tenses in the languages that people spoke. Certainly, too, it would require the labor and the artistry of a William H. Prescott* to

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*Space exploration, although nonviolent, was as dramatically studded with surprises as The Conquest of Mexico and The Conquest of Peru that he portrayed long afterwards.

recapture the rapture that millions felt as they saw Gemini astronauts being plucked from capsules in the sea, and scanned details for the first time of the worn countenance of the "man" they had envisioned in the Moon when they were children.

As the great audience awaited its first close-up peeks at Mars, some hoped to see Schiaparelli's canals or a clear sign of life on that planet. Those hopes were dashed. Yet many continued to contend that "we are not alone" because of the improbability that life would have evolved on only one minor planet in a minor subsystem of a single galactic subsystem of the detectable universe. Others shared the suspicion of President Johnson, a man born close to an earlier frontier, who said: "It may be -- it may just be that life as we know it with its humanity is more unique than many have thought, and we should remember this."[132]

Historians had begun to take "a systems approach" to their tasks before the aerospace industry popularized the phase. They had advanced from being mere chroniclers of events in courts, camps, and monasteries to become the biographers of society in all its departments. Nevertheless, when the great western wilderness had the greatest influence on the development of American democracy, its impact was less clear to the frontiersmen and their contemporary historians than it became a few decades later to Frederick Jackson Turner. "Behind institutions, behind constitutional forms and modifications," he wrote,

> lie the vital forces that call these organs into life and shape them to meet changing conditions. The peculiarity of American institutions is in the fact that they have been compelled to adapt themselves to the changes of an expanding people -- to the changes involved in crossing a continent, in winning a wilderness, and in developing at each area of this progress out of the primitive economic and political conditions of the frontier into the complexity of city life.[133]

Walter Prescott Webb, a later historian, questioned whether men ever could find again such a rewarding frontier as the New World had been to Western civilization. Even he, however, conceded that "the most plausible claims are made in the name of science and technology."[134] Interplanetary space was not only the largest but also the strangest frontier men ever entered, and the impact of their invasion of it on their society and welfare may be much more vivid to historians who can view it from afar than it was to the many eye-witnesses.

On a visit to the Manned Spacecraft Center at Houston, in March 1968, President Johnson said that, of all the legislation which he had helped to bring about, he thought he took the most pride in having written and introduced the bill that made NASA possible. "I am certain," he declared,

> that as future generations look back on our incredible decade they will be unanimous in their belief that the treasure that we have dedicated to sending men to explore the stars was the most significant and important investment ever made by any people. [135]

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