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SOME MAJOR IMPACTS OF THE NATIONAL SPACE PROGRAM

Final Report of Pilot Study

Prepared for:

I.P. HALPERN
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
WASHINGTON, D.C.

September 1968

STANFORD
RESEARCH
INSTITUTE

SRI

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SOME MAJOR IMPACTS OF THE NATIONAL SPACE PROGRAM

Vol VII

Final Report of Pilot Study

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FOREWORD

This is the final report describing a brief pilot study entitled "Some Major Impacts of the National Space Program."

Within this investigation, many candidate impacts were first screened and those that appeared (a) minor or (b) not likely to yield to sufficient study within the short time available were eliminated. The remaining impacts were subjected to a complete review of related prior investigations and to further study at SRI, and each impact topic was separately described in a series of informal reports.*

The results of this study are the first concrete assays within a welter of conflicting, incomplete, exaggerated, and frequently unsupported information. Stanford Research Institute considers its objective study an important task and is looking forward to extending the scope of this study in the future by application of the background, methodologies, and initial results obtained to date.

John G. Meitner
Project Manager

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* The titles are: 1. "Identification of New Occupations," 2. "Impacts Upon Aviation and Aeronautics," 3. "The Impact of the Space Program Upon Science--1. Astronomy," 4. "Impacts of New Materials Technology," 5. "Economic Impacts," and 6. "Impacts Upon Health, Biology, and Medicine."

CONTENTS

SUMMARY

Summary of Study Background

Summary of Study Results

SUMMARY OF STUDY BACKGROUND

Our national space program is now entering its second decade, and it appears pertinent to subject some of its major impacts upon the nation to an impartial analysis.

There is little doubt that the primary objective of our space program--the exploration of space and the early installation of earth-oriented orbital application programs--have been spectacularly successful. Contrarywise, much division of opinion exists in regard to the value of undertaking this effort altogether, of its impacts and returns to the American public, and similarly, as to the value of committing future resources to the continuation of our space program--particularly in the light of grave pressures upon our resources at home and abroad.

Much debate and discussion along these lines has been heard in support of the space program and its benefits to the public, as well as in opposition. Unfortunately, much enthusiasm in the former quarters has led to unsupported claims by those who favor the program, and similarly, many opinions of concern were exaggerated to bring about a substantial reduction of our national space program, or perhaps its total discontinuation. Although the truth may not necessarily be somewhere between these extremes, it is obviously important to study in considerable detail the evidence supporting the continuation or the discontinuation of this substantial national program.

Controversy exists, however, even in support of this proposition: on the one hand, it is claimed that many such studies have already been conducted, on the other hand it is claimed that such prior work is not conclusive; middle-of-the-roaders have also suggested that it may not even be possible to study impacts quantitatively, to define them simply, or to measure them.

In the light of this background, Stanford Research Institute has undertaken a pilot study particularly oriented toward the resolution of the problem of definability and measurability of some impacts of the national space program, while simultaneously pursuing the goal of establishing <u>some</u> of these impacts--both positive and negative--if they could indeed be defined and measured in the first place. Some guidelines and circumstances that directed as well as constrained the study include the following:

1. In many of its elements, the study was to be a review of prior work, and it attempted to sort and reconcile results of such prior work, check the documentation, or, dismiss unsubstantiated claims.

2. Any material subjected to analysis in the course of the study was thus based on substantive evidence and appropriate references and bibliographies document each of the SRI study topics. (See Bibliography)

3. New impact selection criteria and measurement criteria were to be established as an ultimate objective if possible; some of these criteria had already been established in prior work by Stanford Research Institute.*

4. The modest amount of funds and time available to pursue the study necessitated a somewhat arbitrary selection of some impact areas among the many topics available for study.

5. It was one of the purposes of the study to provide for NASA management some visibility of the impacts--both, positive and negative--that the space program has made upon the nation, so that they could include this information in their future planning.

In the initial phase of this investigation, the senior members of the crossdisciplinary study team accordingly reviewed several potential study areas, and, in the light of some of the constraints discussed above, they selected five study topics for further investigation. These are:

- Some Impacts Upon Aviation and Aeronautics
- Some Impacts Upon Science ≠
- Some Impacts Upon New Materials Technology
- Some Economic Impacts
- Some Impacts Upon Public Health, Medicine, and Biological Research

In addition, another area was subjected to initial examination for later study:

- New (Space-Derived) Occupations

Some of these topics tended to yield pertinent and quantitative information immediately, while other topics could not be reduced to simple conclusions during the available study period. All study topics were separately described in informal reports (see FOREWORD), and the present report summarizes these. Accordingly, this report provides first, a broad summary of the

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* The Benefits of the National Space Program and Their Appreciation and Understanding by the American Public; Volume I: Study Report, Volume II: Literature Review. Stanford Research Institute, Menlo Park, California, March 1968.

≠ Exemplified by Astronomy

major study results, and subsequently provides more detailed summaries, conclusions, and recommendations of the individual study topics; references to each of these are collected in a master bibliography in the appendix of the present report.

SUMMARY OF STUDY RESULTS

1. In the light of considerable expenditure over a period of 10 years in the novel area of space exploration, the question of new occupations is obvious. While we only expended a few days in addressing ourselves to this particular problem we found (1) some preliminary results significant in their own right and (2) a series of interesting background items that strongly confuse the identification of new occupations; accordingly we also feel strongly about the importance of continuing that particular study topic. Results in line with point (1) above indicate that some new occupations --under the particular ground rules of the study these must be (a) specifically related to the space program and (b) clearly and officially identified by job title--do exist; these range from Space Vehicle Test Mechanics to Spacecraft Managers, through Life Support Research Managers to Space Systems Assemblers and so forth. In line with point (2) above, we are struck by the sparsity of such new occupations, particularly in the light of the fact that a force of several hundred thousand workers supports the space program; our tentative conclusion indicates that many more new occupations do indeed exist but are not specifically so identified. Instead, we find that the workers in these new occupations are titled within very general categories--e.g., Mechanical Engineer, Welder, Test Support Mechanic.

2. In line with the continuing theme of the advanced technology effort sustained by NASA, a portion is directed toward aviation and aeronautics; this effort has been eminently successful through the years.

Our study indicates that this fact is not positively presented to the general public, nor appropriately or completely presented to the technical community.

On the other hand we find that direct economic benefits have resulted from the aeronautics-directed advanced technology effort, particularly in the area of variable sweep wings, subsonic jet transports, and high thrust engines. Contrarywise, we find that some of the past excellence in establishing advanced projects is now lagging; the V/STOL work is late and the leadership in space vehicles is similarly slipping from NASA. Because direct benefits from this work are accruing to military as well as civilian aviation, this effort may require augmentation. The study also indicates that the anticipated expansion in civilian aeronautics may permit an application of past and present advanced technology efforts to the expansion of the economy of depressed areas, by locating the future manufacturing facilities there. Similarly, the expectations of economic benefits from the advanced technology work leading to the SST application are also high.

3. In reviewing several economic and social impacts of the space effort, our study examined the topic of science via the example of astronomy. In this

major areas in which the US South has lagged behind other areas of the country.

6. Our pilot study attempted to assess some of the derived benefits in the medical and public health area. We find that one such direct item is the first and only extensive collection of performance data on healthy adults. We similarly find the initial introduction of new R&D techniques in medical fields (ranging from diagnostic instruments to sterilization techniques) and associated with other fallout, and perhaps new management techniques that have provided these and other improvements in the public health spectrum. Among individual equipment transfer items that deserve mention we find a particularly impressive improvement in X-ray diagnostics (resulting from the application of a technique designed for the enhancement of remotely relayed lunar pictures), special equipment for handicapped persons (wheelless wheelchairs, glance-directed switches, etc.) and widening applications of remote monitoring of hospital patients.

7. Associated with these and other findings in the six study topics abstracted above, our study also included initial findings for the identification, documentation, and measurement of some of these impacts that are more quantitative than previously possible, and by application of these methods, perhaps developing a tool toward the deliberate enhancement of the positive impacts of the space program upon the nation.

Noting once more that the study reported here is a pilot experiment, we feel encouraged about these study methods which will facilitate future studies of this type, as well as about the initial results abstracted above. Future study seems indicated to remove increasingly this important subject from the realm of opinion and move it into the dispassionate area of information, and thus to provide an important guide for the decision-makers of this country in regard to the future of our nation's space effort.

DISCUSSION

Identification of New Occupations

Impacts Upon Aviation and Aeronautics

Astronomy as an Example of Scientific Impacts

Impacts of New Materials Technology

Economic Impacts

Medical, Biological and Public Health Impacts

I. IDENTIFICATION OF NEW OCCUPATIONS

INTRODUCTION

The objective of this study phase was to define that economic impact of the space program which accrues to the nation in terms of new occupations; the more immediate objective of the pilot study reported here was therefore, to identify these.

In order to arrive hopefully at comprehensive identification schemes for the space effort-generated occupations, several methods were defined; some of these methods were examined and validated--mostly in the Los Angeles area.

SUMMARY

On the basis of this preliminary pilot experimentation, a) several candidate search methods were thus refined and established, b) others (not yet fully tested) were additionally conceived, c) a study plan was formulated on the basis of (a) and (b), and d) some 18 new professional and blue collar occupations--formally established by job titles--wholly derived from the space program were already identified; these range from Assistant Spacecraft Manager, through Life Support Research Scientist, to Space Documentation Requirements Analyst and Space Structures Assembler.

In the light of our initial experience, the search methods selected for further study are likely to yield additionally a number of new occupations that exist solely as a result of the US space effort; these search methods take into account basic problems encountered in the pilot survey--mostly the inconsistencies and the accidental or deliberate lack of descriptiveness in job titles, the confusion in existing skill indices, the recurring revisions of occupational titles within the aerospace industries, the formal (non-descriptive) and the informal (descriptive) lists of job titles employed simultaneously by the same organization, and the usual overlap between missile- and space-applied occupations. We believe that the search methods designed by SRI will be successful in identifying and perhaps obviating some of these problems. Further study of this type is necessary, because we are surprised to find how many professionals and blue collar workers exclusively engaged in space work (in NASA and industry installations alike) have titles that go back to the beginning of the aircraft age. There is, obviously, a need to accelerate the adoption of new and space-related job designations and in order to accomplish this--while identifying those job categories already up-dated--further study is required, to make appropriate recommendations for action.

In the light of our early returns we are reassured that many widely varying occupations already have been created as a result of the space effort; in the light of other impacts studied, we also feel that the suggested collection and documentation of new occupations would spell out a rather consequential impact. On that basis we strongly recommend the continuation of the study discussed here.

CONCLUSIONS AND RECOMMENDATIONS

- New occupations solely due to the space program exist and have been established in industry and government alike--both in formal and informal inventories of job titles.

- More than a dozen of these occupations were readily found on the basis of a brief search described in this report. These are well defined--e.g. life support research scientist, space labs supervisor, etc.

- Five search methods for identifying these new occupations on a national basis were established and some were already tested.

- Identification of these new occupations in extension of the very small pilot search reported here can be confidently expected through further search and on the basis of search methods already established; SRI recommends that such study by continued.*

- Problems in identifying and establishing these occupations exist throughout the aerospace industry and the corresponding government organizations.

- These problems currently occupy personnel departments and government agencies alike.

- New rosters are being prepared by some of these organizations, and problems exist in their preparation.

- A uniform resistance to updating job titles in NASA and aerospace industry organizations is quite apparent--we are overwhelmed with the almost complete absence of descriptive space-related job titles in such organizations <u>wholly</u> committed to space work as JPL or in space divisions of aerospace companies.

- Intermediate sidestepping of these problems by some of these organizations include employment of non-descriptive job titles, establishment of qualifying job criteria, job descriptions, skill indices, and use of different job titles involving the same position for formal and informal purposes.

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* Cooperation of outside organization required for further search was requested by SRI and the necessary assurances were already received.

- We feel that it is high time to recognize the 10-year old space program in the very organizations that operate it, and to replace obsolete and general job titles by descriptive terms, specifically relating to the space task at hand.

- There are problems that delay attainment of this goal and appropriate recommendations must be based on further study, e.g. time-trends and additional identification of the new occupations.

II. IMPACTS UPON AVIATION AND AERONAUTICS

INTRODUCTION

The NASA Aeronautics Program work is categorized into three areas:

Step 1 - Advanced Research

Exploration of new ideas not yet related to aircraft.

Aerodynamics
Propulsion
Structures
Operating Environment
System Dynamics

Step 2 - Applied Technology

Study of ideas from disciplines combined to give a new aircraft type.

Aerodynamics
Propulsion
Structures
Operating Environment
System Dynamics

Step 3 - Developmental Technology

Support of other groups in choice of specific vehicles and solution of detail problems.

Aerodynamics
Propulsion
Structures
Operating Environment
System Dynamics
Mission (from DOD, FAA, etc.)

Step 1, advanced research, consists of exploration of new ideas, not related to specific aircraft, in aerodynamics, propulsion, structures, operating environment, and system dynamics and forms the basis for step 2. The applied technology step consists of the study of new vehicle concepts resulting from the integration of new developments in advanced research. NASA does not develop these vehicles but the definition resulting from this research phase has proved helpful in indicating to the industry, to Congress and to the public where NASA aeronautics research is leading the country in terms of new aircraft. Step 3, developmental technology, is a supporting activity to the agency responsible for specifying an aircraft mission and developing the aircraft to meet it. This activity absorbs a substantial percentage of the NASA aeronautics effort. The table entitled, "NASA Developmental Technology Support for Governmental Agencies (CY 1965)" shows the percentage of NASA aeronautics research activity and professional manpower which has been devoted to answering requests for assistance from military and civil agencies and the industry.

NASA DEVELOPMENTAL TECHNOLOGY SUPPORT
FOR GOVERNMENTAL AGENCIES (CY 1965)

	Facility Hours	% of Total	Analysis, Consulting Man-Years	% of Total
NASA total available	69,000	100	374	100
Total NASA support supplied to DOD and other agencies	29,392	42.5	86	23
NASA support of DOD (13 aircraft, 13 missiles, 6 miscellaneous projects)	17,883	25.9	58.2	15.6
NASA support of other agencies (FAA, NSF, etc.) (Proposal evaluations, accident and safety of flight investigations	11,509	16.6	27.8	7.4

Source: NASA

SUMMARY

Highlights of the NASA aeronautical research program as presented by NASA and as presented to the public through the trade and news press were reviewed.

We find that while the research and development effort is eminently successful and current as shown by the technical quality and competitive position of U.S. aeronautical equipment the NASA effort is never presented in a positive light when the message is directed at the general public, nor is it complete when directed toward the technically oriented community.

Since the NASA developmental aeronautical activity is not separated from operational vehicles by more than a few years, direct economic benefits which pay for all of the NASA aeronautical research can be pointed out. Also, since the technology is not far in advance of its application, the new jobs resulting from improvements can be identified; opportunity exists to train the surplus labor (hard core unemployed) for the jobs. These and other benefits are described.

On the other hand, there are indications that the lead in aeronautical research NASA once had is gone; in fact, some valuable breakthroughs are late. It is also indicated that the advanced programs are important in maintaining research lead.

Advanced Research

The advanced research step occurred in the time period from 1945 to 1959 and consisted of work with models in the wind tunnels, flight of several research aircraft, development of a new variable sweep wing concept, and studies of aircraft configuration in which the concept was utilized.

Applied Technology

The applied technology step always overlaps the research step. In this instance it consisted of the time period from 1958 to 1960 and involved work in aircraft configuration and performance studies using the new variable sweep wing concept.

Developmental Technology

The third, or developmental technology step involved NASA support of other agencies for the F-111 and the SST during the time period from 1959 to the present. The supporting activity included (1) briefings of the staff using the technology and extending it for a specific aircraft mission; (2) assistance to the procurement agency in reviewing industry proposals; and (3) actual testing of a succession of aircraft models in various wind tunnels to evaluate all flight regimes, with variation in armament stowage and delivery, radar antenna location and size, etc.

At the beginning of the supporting activity (developmental technology), NASA is most expert in the technology and in the ability of the experimental method (facilities) to provide information on which to base vehicle design decisions. In the supporting phase, the technology is transferred to the user; in return, NASA obtains perspective on operational aspects of the particular aircraft mission. When the supporting phase is ending, the data are obtained, permitting correlation of wind tunnel and flight performance measurements. The supporting activity is the basis for improvement of the overall capability of the NASA staff and facilities. This activity provides guidance and background for additional basic research or applied technology as the aircraft is developed or improved after it is in operation. Continuing research and development activity performed by the manufacturer, by the user, and by the government (for the people) is usually a natural demand of aircraft operation based on advanced technology, particularly when it is successful. Two of the many possible examples will be given:

1. Operational success of the subsonic jet transport has caused it to be used for purposes and in quantities far greater than forecast. This

increase in the operational use brought attention to the noise. More efficient, higher thrust engines (fan) were developed because the demonstrated demand justified the development cost. The fan engines are quieter at the exhaust, but the inlet noise is more noticeable. So, R&D proceeds; it solves some problems but makes others; and alternative solutions are sought.

2. New, higher thrust engines made it possible to use higher cruise speeds if the critical speed of the airplane could be increased. The critical speed is the speed at which some portions of flow over the airplane become supersonic and cause a rapid drag rise. This need, and perspective based on earlier work led to a new concept of airfoil design for high subsonic (transonic, supercritical) aircraft.

Confirmation of NASA's Aeronautical Research Policy

The importance of all three steps in the aeronautical research cycle is indicated by the statement of Dr. John S. Foster, Director, Defense Research and Engineering, before hearings of the Senate Committee on Aeronautical and Space Sciences considering NASA FY 1969 authorizations: "...Every military aircraft the Defense Department buys evolves in part from basic and applied research conducted in the facilities of NASA. Industry depends on NASA to extend the aeronautical art and, through systematic research, to provide design data which can be used with confidence in developing new aircraft."

CONCLUSIONS AND RECOMMENDATIONS

- NASA's aeronautical research programs are directed toward solution of today's problems and tomorrow's technology needs. Historically, the direction has been effective and it is based on tradition established by many years of work experience in the research/industry interface.

- The variable sweep wing technology which was pioneered by NASA in 1945 is now being applied to military and commercial aircraft. This technology was available in advance of the need.

- NASA's activity in support of aircraft development programs of other agencies is generally beneficial; it constitutes the first direct step in technology transfer and utilization, and guides future work at NASA.

- Cost savings resulting from maintaining a sustaining research and technology activity are significant; and savings are passed on to the taxpayer.

- NASA's role in general aviation research and technology development is current and responsive to need. The work is appropriate, considering the economic and social importance of the light aircraft for personal and business use.

The forecast increase in production of general aviation equipment provides opportunity for new plant location in economically depressed areas. We recommend that NASA take maximal advantage of the opportunities for implementation of social programs resulting from expansion in the manufacture of vehicles and equipment for the general aviation market. (See Future Study Program).

- V/STOL technology is late. The research and technology tasks must cover a wide range of concepts; testing must cover a variety of flight regimes from hover to high-speed flight, including controllability and human factors.

- The sound suppression program which is part of NASA's continuing work on the subsonic jet transport is of critical importance to the community; the findings are important to transportation system planning.

- The transonic wing breakthrough announced by NASA and Lockheed will have an important bearing on the economy of subsonic jet transport aircraft operation.

Aeronautical technology advances have resulted in the development of the C-5 cargo aircraft. The technology permits forecast of an even more capable cargo carrier and a realizable step into a peaceful airman's world.

- NASA's support of the SST program is extensive. The demands made upon aeronautical technology influence NASA's advanced research programs.

- NASA is developing research skills and doing research work in several areas associated with hypersonic cruise aircraft. We are led to the conclusion, however, that this effort will not be emphasized.

- We have observed that the transonic wing breakthrough was late relative to its availability for application to the C-5 cargo aircraft.

- We conclude that aeronautical technology will continue to fall behind need if advanced programs are not pursued.

- Because of its success, NASA's role in aeronautics and aviation should be strengthened and expanded to keep pace with the increasing use of aeronautical vehicles.

- The quality and tone of the press coverage does not present NASA in a manner consistent with the activity.

II. ASTRONOMY AS AN EXAMPLE OF SCIENTIFIC IMPACTS

INTRODUCTION

One of the great positive impacts of the U.S. space program is upon science. This appears to be a two-way phenomenon. On the one hand, the exploitation and exploration of space has made great demands on all fields of science, so as to provide the fundamental information required to embark into space. This great flurry of pointed scientific inquiry has, of course, also resulted in many new scientific discoveries that are not related to space exploration. On the other hand, once space exploration was under way, a great number of new scientific facts were discovered in space, and new theories ranging from the origin of life to the magnetic field of the Earth were thus established:

- There is no single endeavor or phenomenon that has increased the discovery of scientific facts and theories as much as the advent of space exploration, and in the near future those new discoveries will exceed all total prior scientific knowledge.

SUMMARY

Results of this study phase (1) describe in some detail the great impact of space exploration upon science by exemplification of one discipline--astronomy--and (2) indicate the impacts of astronomy upon our culture, again as an example of the impact of science upon the nation, and by conjunction of (1) and (2), the impact of the space program upon an important aspect of our society.

- The impacts of astronomy upon human culture from the dawn of recorded history to this very day are indeed astonishing:

- The beginning of civilization--man's adoption of agriculture--was based upon astronomical findings.

- Man's discoveries of his earth--ranging from geography to navigation throughout the ages--are also largely due to the findings of the astronomers.

- Many discoveries of major consequences to mankind--ranging from the discovery of infrared to telescopy and from instrumentation and optics to fundamental physics--are also accomplishments of astronomy; even to this day, many of the world's great mathematicians were originally astronomers.

- Astronomy has given rise to our modern-day philosophy and placed man appropriately within his universe.

- The tremendous sweep of science and much of a sparking of the young, their search for knowledge, and their appreciation of factual

observations are similarly due to the findings and exhibits of astronomers.

In relating astronomy to man's culture, it is important to do justice, in turn, to the great progress that astronomy owes to the advent of space exploration. Some of the past achievements (P)* and some of the likely accomplishments to be made in the future (F)* by space-based astronomy include the following:

- The chief advantages of space-based observation are of course the absence of refraction, the elimination of systematic observation errors, and the resulting capability for the determination of surface detail of masses in celestial bodies (P).

- In addition to these astrometric advantages, a great deal of the physical properties of the galaxies and their chemical composition was determined by orbital observations through spectroscopy (P) and future studies in the infrared region will bring valuable information regarding protostars. Similarly, standardization of magnitude systems will be accomplished through orbital photometry (F).

- Orbital astronomy has permitted the determination of thermal emissions from planets (P) and will in the future permit the determination of such paramount items as maps of the Milky Way, the background of stellar evolutions (cocoons), and perhaps a test of the steady state theory of the universe (F).

- Within our solar system, orbiting probes have led to the discovery of X-ray and ultraviolet emission from the sun, determination of planetary atmospheres, and much detail about the physical parameters of Venus (P). In the future, masses and densities of other planets, effects of solar winds, composition of atmospheres, and nature of magnetic fields of trans-Martian planets will similarly be based upon orbiting probes (F).

- One of the greatest scientific findings of the near future will be the determination of life or protolife in the solar systems, and the consequent clues to the origin of life on Earth (F).

- The discovery of X-ray and gamma-ray sources with extra-atmospheric probes has already permitted the determination of physical processes and new astronomical events (P). Based on (presumably manned) probes in the future, X-ray and gamma-ray astronomy will probably permit the determination of cosmic ray origin and perhaps test the continuous creation theory (F).

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* P = past; F = future

- Other cosmological determination accessible with future extraterrestrial observations will determine the fitness of several cosmological models and determine the open or closed nature of the universe and exact nature of red-shifts (F).

The relation between the past and future accomplishments of space astronomy concerning these and other items is concisely described in the body of this report. The last chapter deals with the relation of these and other findings to mankind, or the role of astronomy in society.

IV. IMPACTS OF NEW MATERIALS TECHNOLOGY

INTRODUCTION

The overall purpose of this study phase was to examine the contributions of NASA to selected areas of materials technology and their impact upon the economy of the nation as a whole. Quantitative as well as qualitative measures were to be obtained so that an estimate could be had of the proportion of the NASA effort in relation to the total national effort in the same areas.

The determination of the technical contributions of NASA both as to amount and degree was accomplished with the design and utilization of a specific literature search technique. The procedure included the use of a console/computer arrangement, which had access to a linear file of citations of reports including those abstracted in STAR (Scientific and Technical Aerospace Reports) of NASA. This made it possible to obtain a listing of the accession numbers of all entries in STAR for each of 33 selected materials technology areas over the period 1962 to 1967. The quantitative measure that was selected for this study was the proportion of NASA vs all contributions of literature entries in STAR for each one of these materials areas. Eight out of the 33 materials technology areas had a significant percentage of NASA reports referenced in STAR and were studied in greater detail. The survey covered the significant technical contributions and the ensuing and potential applications to sectors of the economy outside the space program. The source material included the NASA-sponsored reports that were sorted out from the computer listings, other materials literature, and discussions with experts in the various fields. Evaluation of the eight areas indicated that each had an impact on sectors of the economy outside of the space program itself. The nature of the impact together with a listing of items transferred to other sectors of the economy are summarized in the table entitled, "Impact of NASA-Sponsored Work" for each of the eight materials areas.

SUMMARY

Even though the scope of the present study was limited, sufficient data and information were generated to show that the contributions by NASA in the materials technology areas were not only significant in proportion to the total national effort but also that the impacts on the national economy as a whole were considerable and varied. This variety is shown in the table entitled, "Materials Impacts in Major Sectors of Nation's Economy", which depicts to which four major sectors of the nation's economy--power generation, communications, transportation, health care--each of the eight materials technology areas has contributed significant innovations or improvements.

Further extension and refinement of the techniques developed here could be applied readily to a larger sampling of the materials technology

IMPACT OF NASA-SPONSORED WORK

Materials Areas Selected	Impact by NASA*	Transfer to Other Sectors of Economy
Electroforming	+	• Stress-free components • Improved nickel-cadmium batteries • Tooling and dies • Solar concentrators • Complex parts • Artificial limbs
Fuel cell	++	• Deep ocean technology • Silver-zinc batteries • Dry tape battery • Electric automobiles • Life support system
Nickel-cadmium battery Silver-cadmium battery Silver-zinc battery	+++	• Economical, compact hearing-aid batteries • Electric automobile • Battery systems of improved reliability and energy density • Deep submergence vehicles and submarines • Life cycle testing
Refractory alloy	+++	• Power generation systems • High temperature, ductile alloys • Oxidation resistant coatings • Plasma spraying • Welding techniques • Jet turbine engines
Solar cell		• Weather prediction (satellite) • Communication (satellite) • Remote area power generation • Emergency telephone systems • Improvement in solar cell systems for all uses • Establishment of standards
Stress-corrosion of titanium alloys	+++	• Supersonic aircraft • Rapid, reliable, low cost stress-corrosion cracking test procedure • Helicopters • Deep submergence vehicles • Desalination plants • Chemical processing industry • Medical implants

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* +++ Heavy impact
++ Moderate impact
+ Light impact

areas. In this way, the considerable nature of NASA's contributions to materials technology and the transfer of this knowledge to benefit the nation as a whole in many sectors are clearly indicated. It is recommended that consideration be given to extending the work that was initiated in this study so that the full measure of the NASA contribution can be identified and recognized.

MATERIALS IMPACTS IN MAJOR SECTORS OF NATION'S ECONOMY

Materials Areas	Power Generation	Communication	Transportation	Health Care
Electroforming	X	X	X	X
Fuel Cell	X	X	X	
Nickel-cadmium battery	X	X	X	X
Silver-cadmium battery	X	X		
Silver-zinc battery	X	X	X	
Refractory alloy	X		X	
Solar cell	X	X		
Stress-corrosion of titanium alloys	X		X	X

CONCLUSIONS

- NASA is a heavy contributor in the materials technology areas encompassing battery systems (nickel-cadmium, silver-cadmium, and silver-zinc), refractory alloys, and stress-corrosion of titanium alloys. The impact of each of these areas was concentrated mostly in similar applications outside of the space program. These included improvements in reliability and higher energy density for battery systems in everyday use; application to power generation systems for refractory alloys; and applications of titanium alloys to the SST program, deep submergence vehicles, and chemical processing plants.

- NASA is a moderate contributor to the area of fuel cells, where the potential applications outside the space program were somewhat broader--smog-free electric automobiles, life support systems, and deep ocean technology.

- NASA is a heavy contributor to the solar cell program, but the applications in this case were more exclusive with fewer direct applications outside of space. However, some of the space applications--mainly weather and communication satellites--have indirect benefits such as improved weather prediction and better radio and TV transmission and reception.

- NASA has also made a contribution to electroforming, where the applications were more diffuse--covering such items as improved batteries, tooling and dies, solar concentrators, and production of complex parts.

- NASA has contributed significantly to the knowledge in different areas of materials technology. Thee have included breakthroughs in processing techniques such as electroforming and pioneering of new materials such as new refractory alloys.

- The impact of NASA work in materials technology has been considerable. Many of the new materials developments by NASA have been applied to other sectors of the nation's economy than the space program. These include the major economic sectors such as power generation, transportation, communications, and health care.

- The literature search method devised for and used in this preliminary survey has proven to be a valuable technique in locating and separating items pertinent to specific areas of materials technology.

V ECONOMIC IMPACTS

INTRODUCTION

Recent studies have begun to show conclusive evidence of a dramatic relationship between advancing technology and economic growth. Although such a relationship seems intuitively obvious, the proof has been, and still is, considerably elusive. No clear, definitive, quantitative theory yet exists in the economic literature, although much attention has been paid to the subject in the past 10 years.

Since NASA is exclusively a research and development agency of the government, it is important that the relationship between R&D and economic growth be understood. This report discusses some aspects of the relationship and indicates some of the required ingredients for economic growth. These are, for example, a more productive work force, gained largely through education; a continuous building up of the store of knowledge; greater utilization of knowledge by entrepreneurs; and a high rate of utilization of human capital, first by virtue of low unemployment in all occupational categories and second by a continual development and utilization of higher skills.

To find out how NASA contributes to these various elements, this study examined to some extent the role of the Agency in extending the quality of environment at its centers and production and test areas in the South. It was found that by contributing to improvements in local educational systems, NASA had effectively modified the direction of growth taking place in a number of locations. It is clear that this is more noticeable in small cities, towns, or counties than in large metropolitan areas. On the other hand, in a particular kind of environment, such as Houston, growth in both quantity and quality is also apparent if the immediate vicinity of a center is examined separately. Furthermore, the same elements that have been detected before with regard to scientific complexes in other cities, such as growth of graduate and higher education facilities, are noticeable in connection with NASA centers and other facilities in the South. In each of the areas--with the possible exception of New Orleans, where it may not be possible to detect such changes--NASA has contributed to those elements that constitute the ingredients for economic growth. It has upgraded the skills of the labor force, upgraded the level of education available to local inhabitants, decreased unemployment, and built up the store of knowledge by virtue of its scientific mission.

SUMMARY

In summary, we find that:

1. NASA activities have had a positive and consequential influence on the localities in the South in which it has established

research and development centers and production, testing, and launch facilities.

2. These influences have gone beyond those associated merely with the channeling of government funds into an area, primarily because of the research and development nature of the work.

3. R&D is different from other transfers of government funds because it requires more highly paid, highly educated workers who demand more in the way of quality of environment. This in turn affects the quality of education, for example, available to new residents of the community as well as to old ones, resulting in greater levels of achievement by all.

4. NASA and NASA-contractor personnel have contributed to this upgrading of the environment in each community in a variety of ways, from running for and being elected to local political offices to providing pressure through neighborhood and community organizations and volunteer, charitable, and religious groups. Furthermore, it was found that, in many cases, a substantial portion of the teaching staff in local grade and high schools was made up of wives of engineers and scientists on NASA projects.' These women are generally well educated, often from a more cosmopolitan environment than that found in many of the NASA locations in the South, and thus able to bring to school children a broader experience and a greater appreciation for education than they would have otherwise.

5. NASA's influence is also felt because of radical changes in per capita income that it brings about. Recent scholarly studies have indicated that the South must upgrade the productivity of its workers to achieve a position of economic (and social) health and well-being equivalent to that of the rest of the United States. Per capita income is the most reliable measure available to judge such progress, and this indicator has been affected greatly by NASA presence.

6. In certain cases, NASA has been a catalyst in stimulating other developments, particularly in New Orleans. In this case, the local economy was in a slump before the advent of space activities in the area. Uniform agreement was found among local business leaders, Chamber of Commerce officials, and others that the NASA presence was a critical influence in enlightening the community to new and progressive business opportunities.

7. The influence of NASA on education in the South is pertinent, above and beyond that mentioned above. In insisting on good educational facilities for their sons and daughters (and for themselves through college extension and graduate programs), NASA and NASA-contractor employees have laid the groundwork for a higher quality educational environment for all of the people in the communities where they reside. The South particularly needs such influences to enhance its own development.

VI. MEDICAL, BIOLOGICAL AND PUBLIC HEALTH IMPACTS

INTRODUCTION

The purpose of this study phase is to analyze the impact of the total American space program on public health, medicine and biological research. The background information was obtained through in-depth interviews with scientists and officials responsible for various bioastronautics programs in aerospace companies, government agencies (including headquarters groups and laboratories), universities and hospitals. Scientists and physicians outside of the space program who are benefiting from space technology transfer, or who are potential beneficiaries were also contacted. Geographic coverage was restricted to the state of California and the Washington, D. C., area including nearby communities in Maryland and Virginia. While this is not a complete coverage of all the organizations engaged in applicable space activities, the organizations which supplied useful data represent approximately half of the nation's ongoing space biomedicine and they can be considered as a representative sample. Also many of the interviewees had recently come from other organizations in geographic areas not included in the study. Consequently, the data collected represents a sufficiently broad sample of total space R&D experience to permit the conclusions reached in this report.

The interviews were conducted during a time when space research budgets had already been seriously curtailed and face the prospect of even greater budget cuts in the next fiscal year. It should be mentioned that there was a prevailing feeling of deep pessimism among most of the people contacted and that this attitude of mind may have unconsciously influenced their evaluation of the present and near-term impact of the space program in the biomedical field. In many cases the budget restrictions in NIH and other agencies not responsible for astronautics resulted in funding cutbacks for programs which would have included technology transfer items. At the present time it is harder to obtain funds for some of the promising technology options than it was two or three years ago. The uncertain pattern of funding in the next fiscal year means that technology transfer will continue to be adversely affected by the overall cuts in the nation's R&D and public health programs.

Many concerned officials have been disappointed because many of the most promising items of technology transfer have taken a very long time to reach a practical clinical application following the testing and equipment modification phases. A representative sample of these systems is found in the table entitled, "Matrix Showing a Representative List of Space Systems Useful in Medicine and Biological Research."

SUMMARY

It should be emphasized that the medical profession has been historically very conservative in the adoption of new techniques and

MATRIX SHOWING A REPRESENTATIVE LIST OF SPACE SYSTEMS

USEFUL in MEDICINE and BIOLOGICAL RESEARCH

	Early Transfer	Delayed Transfer	Bioastronautics Systems	Nonlife Science Space Technology	Serendipity or Item from Unfunded Proposal
Automated Blood Pressure Cuff		•	•		
Wheelless Wheelchair		•		•	•
Spray-on Electrodes	•		•		
Gas Powered Cryoknife		•			•
Computer Image Enhancement	•			•	
Graphite Implants	•			•	•
EEG Helmet		•	•		
Marsupial Biopack		•	•		•
EKG Biotelemetry	•		•		
Laminar Airflow-Sterilization		•	•		

technology. It has been frequently observed that there has been a 10 to 15 year lapse of time before items of advanced technology are fully employed in clinics, hospitals and biomedical laboratories. One important impact of the space program has been a practical reduction in this time lag since all the items that have been successfully adopted have at least beaten the historic time lag. Furthermore the space program has clearly demonstrated that it is possible to achieve very significant state-of-the-art advances in a very short period of time when sufficient talent, funds, priorities and management direction is provided to allow the early realization of specific goals.

CLINICAL DATA - THE HEALTHY ADULT

The astronaut and astronaut substitute working in various space laboratories are normal healthy adults who must function in a completely alien environment in order to understand what the physical and mental capabilities of man in space would be, a large number of studies have been conducted to uncover physiological data that had not been thoroughly investigated in historic biological research primarily concerned with various pathological processes. In order to walk effectively in a space suit on the moon, scientists first have to know more about the mechanics of walking here on earth. The chemical composition of saliva and tears was determined for the first time. Sensory deprivation, exotic gas atmosphere compositions, humidity, pressure, circadian rhythms and work cycles have been but a few of the many physiological parameters where complete or relatively complete information is now available as a space dividend.

The clinical data on the healthy adult are presently scattered in many reports and study summaries in government agencies and organizations who have gathered this data, and it is not readily available to the research physician or scientist who may not be familiar with the space program or the organizations which have been responsible for conducting these investigations during the past ten years. Consequently access to these data is severely restricted and in many cases it does not appear in reference tables in recent medical books prepared by scientists operating outside the space community. One strong recommendation is that a monograph or monograph series be prepared to bring all these pertinent data together and also adequately reference the more detailed coverage of the physiological parameters that appear in the specific reports that provide information obtained through diverse bioastronautics grants and contracts. Several scientists have suggested that a symposium, or similar meeting, which would bring together and give attention to data obtained on the healthy adult, might be something that should be seriously considered for a NASA support in association with other government agencies supporting biomedical R&D.

ITEMS OF EQUIPMENT TRANSFER

The transfer of the systems and subsystems developed as the result of space research to meet the needs of terrestrial biological research and medicine has been slower than originally expected. The most serious time gap exists between the initial clinical testing phase and the subsequent manufacture and distribution of the system to those sectors of the biomedical community where actual requirements are to be found. Understanding and analyzing the machanics of this barrier may be the most important contribution of this report. In many cases we are considering relatively expensive systems which require separate funding by a government agency or outside organization in order to complete the transfer. For instance, an automated blood pressure cuff was developed by Garrett for the Mercury and Gemini programs. This system was clinically tested in 1961 and could have been installed in a hospital intensive care center at that time. First actual installation took place in an intensive care center at the National Institutes of Health in 1968. The system is not likely to save a life in the same dramatic manner as less expensive items such as EKG monitors which were among the first automated devices installed in care centers. Garrett was fully occupied during the intervening years and had no internal pressure to attempt to diversify through this transfer option. The traditional conservatism of the medical community was also an important factor.

The most rapid equipment transfer has been made to other user requirements when the development for hardware modifications is conducted by the same organization that engaged in the original bioastronautics program. For instance, Garrett developed a biomedical recording system under NASA contract to evaluate physiological behavior of man under actual flight conditions in our manned space programs. This system was quickly transferred to Air Force requirements to monitor the effects of stress on pilots in Vietnam during actual combat operations. In almost every case where a transfer can be made to a military requirement, it has been quickly made because the organizationsengaged in space research are almost always cognizant of Air Force, Army and Navy requirements. The accounting, manufacturing and customer relations patterns are not barriers in transferring space systems to other government agency requirements.

R&D CAPABILITY TRANSFER

The space program has caused interdisciplinarian teams of scientists to be brought together to successfully achieve diverse goals, many of which are only partly related to the life sciences. Frequently it is the availability of these teams that permits a life science program to be successfully undertaken that would not have been possible without the space program. For instance, SIM One is a revolutionary application of aerospace technology to medical education. It is a computer-controlled, life-like mannequin developed at AeroJet General's Von Karman Center to accurately simulate human response in training anaesthesiologists. The basic concept of SIM One is an extension of simulation theory originally developed in AeroJet's space power systems, rocket engine systems, and space satellite systems. Here the research team (rather than the hardware) was transferred to produce a completely new educational technology. The SIM One program is a representative sample of the potential employment of the methodology of space R&D in providing completely new solutions to various problems areas.

RESEARCH TECHNIQUES

Almost all of our space R&D has required completely new instrumentation and methodological approaches, and this has been particularly true of bioastronautics programs. Research techniques developed for space requirements have been most readily transferred within the same organizations that non-space biomedical research is conducted. In some cases the transfer has been made by an individual going from a bioastronautics group into a new affiliation where he carries the new techniques with him. In many cases we are considering components and subsystems such as better skin electrodes for EKG and EEG measurements.

There has been widespread employment of computer programming techniques, including mathematical models of various physiological processes. The availability of third generation computers may be considered as one of the indirect transfer benefits of the space program. This refined computational capability permits complex two-and three-dimensional matrices to be programmed in order to determine complex interrelationships between very large numbers of environmental and physiological parameters.

The digital computer processing of optical and electron microscope images promises a quantum improvement in new areas of research emphasis, particularly molecular biology. This technique coupled with new electron microscopes of near theoretical resolution, which are now being developed, may permit a direct "readout" of the structure of many organic molecules.

Bioastronautics research techniques have been employed in the development of experimental artificial hearts under Dr. Willem Kolf at the Cleveland Clinic. Body cooling procedures refined as a result of NASA's reduced metabolism program have been used in hypothermia research. Automated monitoring of equipment is a space research technique that has been widely adopted.

TECHNOLOGY TRANSFER BARRIERS

Where sizable expenses are not involved, systems and subsystems developed throughout the space program will go through the initial clinical testing phase of technology transfer in a comparatively short period of time. Here we are usually dealing with a single prototype which may have been modified for the non-space applications. The organizations that produced the prototype as a rule do not have a manufacturing and marketing capability required to supply these systems in large numbers for hospitals, clinics, and laboratories. Consequently, there is a serious time gap between the initial clinical or other testing phase and the availability of the system as a manufactured item.

The hospital or university scientist frequently is interested in solving his own equipment needs and regards a prototype system as a philanthropic gift from an affluent company which the scientist may also regard as a "merchant of death" because of defense contracts. The need for a transfer from the testing phase to profitable product line is frequently not recognized by the scientist, contributing to the barrier.

In almost every case where there has been a successful transfer in a relatively short time period, a "champion" has served as the transfer catalyst. The champion may be an influential official or principal scientist whose influence permits the essential steps in the transfer activity to be conducted on a bootlegged or sub rosa basis.

A thorough analysis of the role of the champion in successful transfer should be undertaken. Converting his role from an unofficial to an authorized function might be one of the best ways to speed technology transfer in all advanced military and space fields. Here we are partly considering the psychology and motivational dynamics of the transfer process itself.

RECOMMENDATIONS AND CONCLUSIONS

Writing from a vantage point of 1968, one can state that space biomedicine has had a gratifying transfer impact in the state-of-the-art of laboratory instrumentation and research techniques for terrestrial life science R&D. Many specific items of technology have been successful in the initial clinical or other testing phase, and can be expected to be widely distributed in the future.

The NASA Tech Briefs provide an adequate description of biomedical systems with a transfer potential. Unfortunately many scientists outside of the space and military fields are either not aware of this quick identification service or the Tech Briefs that would be of greatest interest simply do not reach them. It must be recognized that these are extremely busy, over-committed professionals and some means should be devised to directly contact them about technology transfer items of potential value in their programs, rather than expecting them to go through the presently established identification system. It is naive to assume that the potential user will take the initiative in the identification phase of the transfer process.

The principal question regarding the future impact of technology transfer from bioastronautics depends on the possibility of adopting new procedures. The transfer to other life science research requirements can become more effective by a system of monitoring prospective user needs. One solution might be to prepare a programmed "interest profile" of various biomedical professions and specialities, and then devise a system by which Tech Briefs are automatically sent to the scientists who are most likely to use the space systems in their research.

More effective future transfer of bioastronautics systems to widespread clinical medical practice will largely depend on the funding available to accelerate such transfer. It is naive to assume that the simple identification of such transfer options will permit their early adoption, especially where relatively expensive systems are involved.

The severe R&D budget cuts caused by fiscal pressures, primarily stemming from the Vietnamese conflict, may be eased if a negotiated settlement is reached in 1969. Federal R&D funding is likely to resume its historic growth pattern, providing new opportunities for the clinical utilization of space technology.

The solution to optimized clinical transfer was invented by the Phoenicians--MONEY! Stated conventionally, specific funds must be allotted in grants and contracts to complete all the transfer steps where comparatively expensive systems are involved. The desirability of such transfer programs are evaluated in Section VII of this report. Close cooperation between NASA, NIH and other agencies, probably facilitated in part through joint committees, would be necessary.

Many of the potential transfer items in bioastronautics are extremely expensive by the standards of organizations, such as hospitals, who are potential users. Frequently the cost of an automated device will be an order of magnitude over the system it replaces. The fact that the time saved by highly skilled professionals will make the automated device quite economic, is frequently not accepted by biomedical specialists until the system has been in operation for a year or more. Consequently, some means of funding the clinical proof-of-principal phase is likely to have a significant impact in reducing the overall lag in the widespread adoption of space biotechnology.

The possibility of establishing a new agency to fund critical phases of the transfer of bioastronautics technology is a possibility that deserves attention. Such an organization could identify the potentially useful systems while they were still being developed prior to their use in an operational space system.

After ten years, some definite conclusions can be reached concerning the space biomedical technology transfer process. The 10 to 15 year time gap in applying advanced technology to clinical requirements has been broken, but there is still a long delay in transferring operational technology and research techniques. Systems developed for space requirements are extremely expensive by conventional biomedical standards (clinical or research). The expense factor frequently creates a psychological barrier in potential users which is difficult to overcome.

There is a fundamental need for direct or indirect funding support to accomplish the initial transfer steps. Frequently a "champion" will use his influence to allow the steps to be conducted on a bootlegged or sub rosa basis. The champion may also assist in obtaining grants or funds from agencies not engaged in space programs for additional equipment modification, etc.

The clinical proof-of-principal testing is frequently conducted with the original space hardware. There is a serious time gap between this first step and the commercial availability of the system. Most aerospace organizations do not have a commercial manufacturing and marketing capability for such systems.

The effectiveness of space life science transfer is particularly sensitive to overall funding trends in government supported R&D. When space budgets are declining, essential personnel are frequently lost, and there is less money for programs outside of major requirements. When federal biomedical funds are not growing, new programs essential for transfer must compete with established programs, and frequently budgets are completely committed. These considerations were very much in evidence and frequently mentioned by interviewees, during the study.

Assuming the space program resumes its historic growth pattern in the post-Vietnamese conflict time period, there could be a great increase in items with transfer potential. A Voyager Mars mission, with a fully automated biological lab containing several different bacterial identification systems, would have great clinical potential. The initial bioastronautics R&D required for manned planetary exploration, as a confirmed national goal, would provide a cornucopia of transferable technology far in excess of the comparatively modest requirements of the Apollo program.

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