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MAJOR FACTORS

IN

AEROSPACE PLANNING

AND

DECISION-MAKING

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FOREWORD

The following report is an analysis of some of the significant factors considered by industrial and government aerospace executives in their long-range planning and decision-making activities.

It is one of a series of studies on management concepts, functions and processes, and is based on: 1) an analysis of selected books, documents and reports; 2) discussions with responsible and knowledgeable individuals in the federal government, in research institutes and in private industry; and 3) prior studies conducted by the author while serving in staff and management capacities in the aerospace industry.*

The report evolved in several phases. During the initial stages a preliminary survey of the planning process within a selected group of aerospace companies, government agencies and not-for-profit institutes was conducted. For each of the organizations surveyed, data was obtained through interviews and correspondence on the following topics:

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* While much of the data for this report were obtained from personal interviews and a literature search, the basic concept and the research approach employed evolved from the following studies in which the writer participated as author and co-author respectively:

The National Space Program: Some Considerations for Aerospace Management, The Systems Development Corporation, Santa Monica, California, September 1963, and

Hilltop 1970: An Analysis of the Key Factors Influencing National Policy and the Future of the Martin Company in the 1960's, The Martin Company, Denver, Colorado, 1957.

1) general characteristics of the company, agency or institute; 2) the evolution of long-range planning within the specific organization surveyed; 3) management's role in decision-making and planning; and 4) the organization's planning process, including the basic assumptions, the factors considered and the data base. To supplement the organizational survey a comprehensive literature search was conducted and a detailed bibliography prepared.

The initial survey indicated that while each company, agency or institute that was interviewed followed certain common principles, the structure and utilization of planning within each organization, as well as the relevant assumptions, varied from company to company and problem to problem. This led to the subsequent conclusion that there was no universally acceptable planning format suitable for all companies and all situations. In addition, the literature search revealed that a number of worthwhile books and articles had been prepared on the basic principles of planning, including detailed case histories of the techniques employed by specific companies.* Consequently, it was not necessary to prepare another "cookbook" on long-range planning--including a collection of specific company "recipes." Such an effort would only duplicate the work of other individuals and organizations.

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* See Bibliography; 12, 35, 36.

Therefore, on the basis of the initial research, coupled with a desire to produce a unique and informative document, it was decided for the final report to prepare an analysis of the key economic, technical and socio-political factors considered by aerospace managers in their long-range planning and decision-making functions, stressing not only the significance of these factors but more importantly their interrelationships and utility.

With this kind of emphasis attention would be focused on the interdisciplinary or "systems" aspects of the space-age planning process, and some insight into the challenges and problems facing aerospace executives would thus be provided.

The study was supported by the National Aeronautics and Space Administration under General Grant No. NsG-727. Much of the data employed in the study has been provided by numerous individuals and organizations to which the author is deeply indebted. However, the opinions expressed and the conclusions reached are the author's and do not necessarily represent the opinions or policies of the Program of Policy Studies, The George Washington University, or the sponsoring agency.

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INTRODUCTION

Since the launching of the first Sputnik in October, 1957, the space program has become one of the major generators of economic and technological growth and development in the United States, and has had a significant effect on our international prestige, as well as on the political and social character of the nation. Evidence of this can be found in the rapid growth of technologically-based industries; in the economic and social impact of new space activities on selected cities and towns; in the growing status and power of the engineer and scientist both in industry and in the federal government; and the geometric increase in public and private expenditures for space-oriented R & D. Furthermore, the space effort has become a major issue in political campaigns and activities, and its scope and magnitude are influencing man's view of himself in a rapidly shrinking world.

This dynamic increase in space activities has brought with it new and challenging management problems which have been met in part by the creation of special organizations such as Bellcomm, The Aerospace Corporation, Comsat and NASA, and has accelerated the development of new management techniques such as PERT/Cost, program budgeting, systems engineering, and long-range planning. Partially as a consequence of these analytical, organizational and procedural innovations a managerial and technological revolution has taken place in those private organizations and federal agencies directly involved in the space program. This revolution has created both problems and opportunities for executives and managers who must plan for and decide upon the future growth and development of their respective organizations. These challenges and opportunities are attributable, in part, to the complex and evolutionary nature of the U. S. space effort. The technology is dynamic and expanding in all directions; future space missions and requirements are difficult to define; the facility and manpower requirements change very rapidly; and the level and distribution of federal expenditures for future space missions and technology are difficult to predict. Additional complexities are introduced into an aerospace executive's decision-making and planning process by Soviet space activities, U. S. foreign policy developments, as well as national defense and domestic political considerations; which all influence the magnitude and direction of the national space effort.

In such a dynamic and complex environment, it is necessary for the aerospace manager to have access to concise and timely information on a broad spectrum of subjects, ranging from the impact of national policy on the space budget, on one hand, to the status of the human economic and facility resources of the company or government agency he represents, on the other.

The space-age executive must also have some understanding of the objectives of the national space program, including their relationship to space missions and operational requirements. He must also be aware of the significant technological developments and their effect on space systems management and organization, as well as on the distribution and evolution of the space budget. Even events that are not directly related to the space program, such as the war in Vietnam, must also be considered by an aerospace executive before he makes the necessary decisions, initiate planning activities, or commits his organization's financial, manpower and facility resources.

While the data an aerospace executive must evaluate are numerous, complex and varied,discussion of <u>all</u> of the factors considered by aerospace management is beyond the scope of this study. Therefore, an attempt has been made to isolate those major factors that are <u>common</u> to the long-range planning and decision-making activities of <u>most</u> aerospace executives, in both government and private industry, these include: 1) national space policies and objectives; 2) space missions and requirements; 3) the space environment; 4) scientific and technical developments; 5) aerospace management and organization; 6) manpower and facility resources; 7) Soviet space developments; 8) business competition; and 9) Federal space expenditures. (Figure 1).

As previously noted the significance of any one or group of planning factors varies from organization to organization and problem to problem.

AEROSPACE PLANNING FACTORS

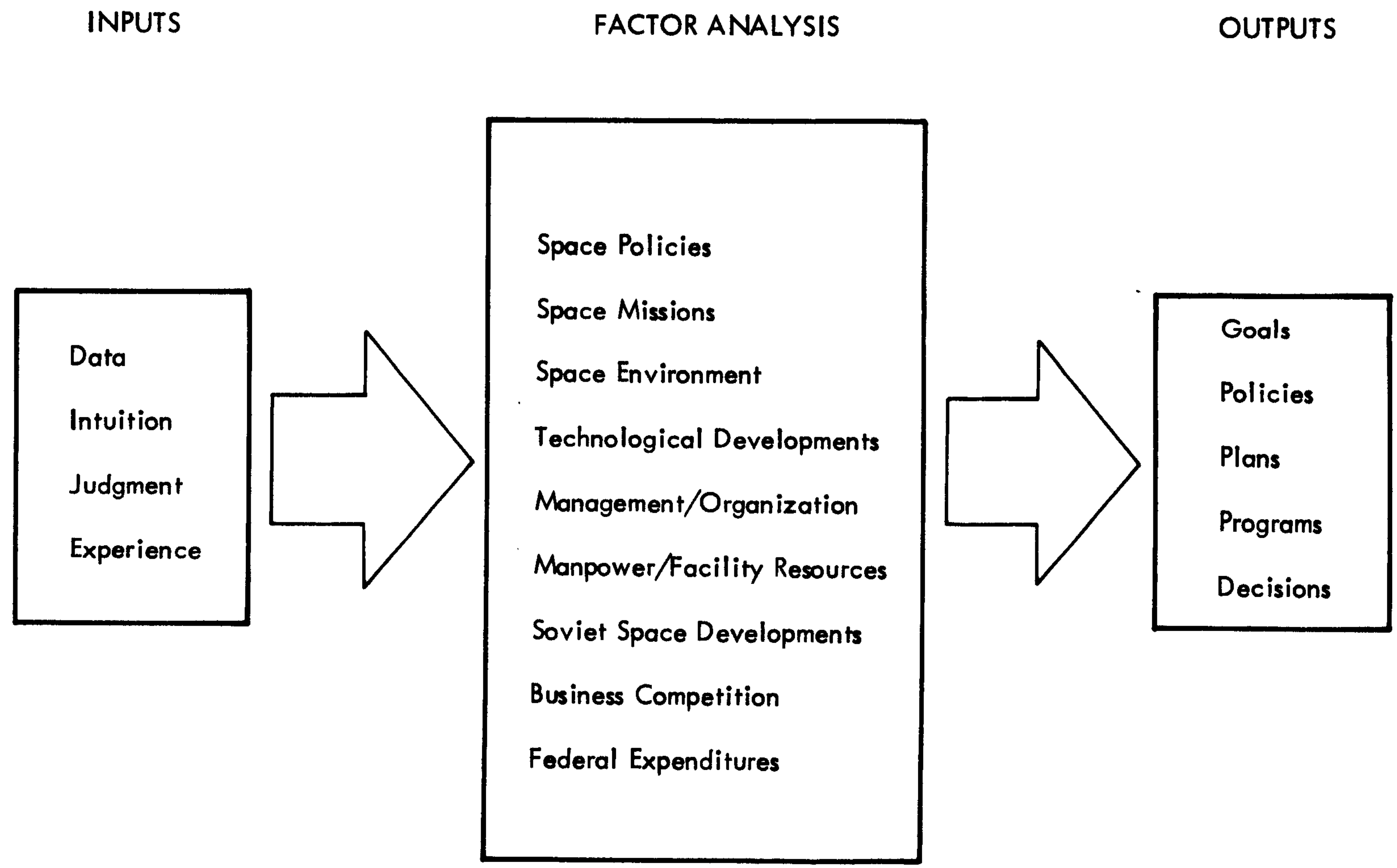

Figure 1

But in the planning and decision-making process these differences are essentially of degree rather than of substance. For example, both industrial and government aerospace executives must take national space goals and objectives into consideration in their planning and decision making activities. The government aerospace executive is directly involved in shaping as well as implementing national policy, whereas his industrial counterpart is concerned more with supporting space policies through hardware developments. However, the industrial executive or his company shape policy indirectly through consultation with government officials or by developing technologies which may ultimately bring about changes in national space plans and programs.

NATIONAL SPACE POLICIES AND OBJECTIVES

While the relative influence of private industry and the federal government on space policy may be debated, it is important to stress that both industrial and government aerospace executives in their planning or decision-making must consider U. S. space policies and objectives since they are the basis for allocating the manpower, dollar and technological resources committed to space, and provide the basic management guidelines for structuring the overall national program as well as defining the scope and direction of specific projects.

For example, one can directly relate an official space policy, namely, that space activities, "should be devoted to peaceful purposes for the benefit of all mankind," to NASA's Space Science and Applications Program; to a specific budgetary appropriation; to a specific project, the TIROS satellite; and finally to RCA, the company that designed and developed the TIROS.

Moreover, the policy "feedback" from this project, i.e., "for the benefit of all mankind," can be shown in the form of photographic data which have been gathered by TIROS and utilized in a direct and practical way to support, on a global scale, such human activities as weather forecasting, agriculture and transportation.

U. S. space policies, as with national policy as a whole, are generated primarily by Congress, the Executive Branch of the federal government and private institutions (see Fig. 2). More specifically, space policy is formulated in the public sector by the Space Committees of the U. S. House and the Senate; the Executive Office of the President, i.e., the Office of Science and Technology, the Bureau of the Budget and the National Space Council, and such Federal agencies as NASA and DOD. In the private sector, national space policy is influenced by industry, the universities and research institutes, and by private associations and individuals with vested interests of one kind or another.

However, regardless of the organizational involvements or interests, policy formulation, whether it relates to space or to other national activities, is comprised of three basic functions: planning, decision-making, and implementation. Moreover, these functions, must be carried out in a reasonably structured and rational environment if clear policy formulation and subsequent action are to take place, in either the government or private industry.

In the federal government the policy functions of planning, decision-making and implementation, carried out in the context of the space programs of NASA, DOD, the Weather Bureau and National Science Foundation, involve considerations of a complex spectrum of political, social, economic and technical factors ranging from the impact of a particular government contract on a city or region, to the nature of the Martian atmosphere. In some cases these factors are evaluated intuitively by the policy-makers;

SPACE POLICY MATRIX

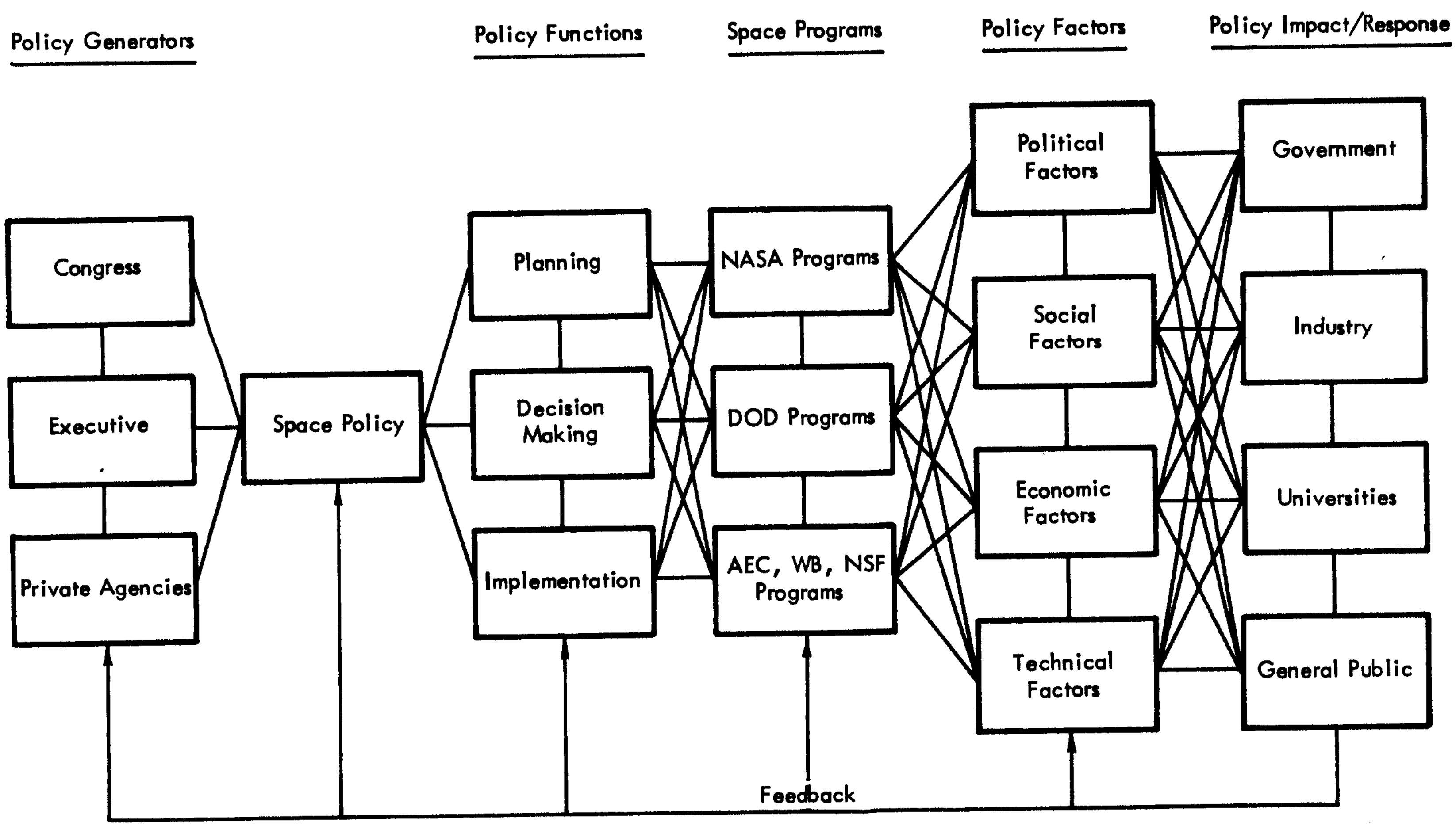

Figure 2

in other cases, a particular factor or relevant problem may be analyzed in great depth and the findings submitted in report form. These in-depth studies may involve forecasts of the space technology state-of-the-art extending ten to fifteen years into the future, or analyses of the long-term economic impact of the space budget on private industry. In any case, whether these policy factors are evaluated intuitively or analyzed in depth, they are - in essentially normal, non-crisis situations - individually and collectively considered by the appropriate organizations and individuals, such as the National Space Council, Congress and NASA Management, before the final policy statement is issued, the national objectives defined, and subsequent action taken.

These space policy actions, the analyses and the management decisions can have an impact on all levels of our society including the government, private industry, the academic community and the general public. Whether each of the relevant communities or institutions feel the effects at the same time or in the same manner often depends upon the particular policy statement or action. For example, the late President Kennedy's policy statement in May 1961 on "Urgent National Needs", and the resulting national commitment to land a U. S. astronaut on the moon, had wide-ranging impacts on our society, that is still being felt today.* On the other hand,

* Government Operations in Space, Thirteenth Report by the Committee on Government Operations, Washington, D. C., June 4, 1965, p. 2.

the decision to proceed with the MOL program in August 1965 had impacts that were felt primarily by the government and private industry, and had little or no impact on the academic community or the general public. Whereas, the policy decision to initiate discussions with the Soviet Union on cooperative space efforts had an even narrower impact on the various public and private institutions in the sense that the effect was felt primarily at the level of the federal government.

Finally, the various organizations involved in space policy formulation, as well as the related plans, programs, decisions and actions, are all tied together by a feedback mechanism that operates in both direct and subtle ways. Nevertheless, feedback occurs at all levels and at all steps in the policy formulation process. As a consequence policy is never static but is changed, updated and revised, as time and events as well as technological advances and institutional requirements dictate.

Consequently, the dynamics of policy formulation create situations wherein the relationship between national space policies and objectives, the space programs, the resource allocations and the relevant organizations is not clear. Confusion about these relationships can also occur when planners and decision-makers fail to carefully examine or misinterpret our space policies. However, in some cases the misinterpretation is a result of the vague wording of official space policy statements. In some instances, the statements' real or imagined vagueness is heightened by the debate about our space program that exists from time to time in high political and scientific circles.* As noted in a Congressional report on "Government Operations in Space,"** the discussion is focused on the rationale of and policies behind the national space effort, wherein questions of the following types are raised: "Is it wise to devote so large a portion of our national resources and energies to putting a man on the moon when pressing economic and social needs go unfulfilled? Are there derivative benefits through industrial and military applications, and to what extent do these justify the heavy investment in the civilian space program?

"Has the multi-billion dollar lunar landing program distorted the civilian space organization and caused a wide departure from the scientific space mission charged to NASA?

"Are we concentrating too much on civilian space and neglecting military space with future risk to the national security?

"Why is it necessary to have two lines of government endeavor in space?

"If civilian and military agencies both must be involved, how can overlap and duplication be eliminated or avoided?"

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* Scientists Testimony on Space Goals, Hearings before the Senate Committee on Aeronautical and Space Sciences, Washington, D. C., June 1963.

** Govt. Operations in Space, pp. 1-2.

While the Congressional report notes that several of these questions "are mooted by time and circumstance," their existence and nature, coupled with the fact that the same questions are asked repeatedly (and not always by the same individuals) gives rise to the feeling that certain of our space policies and objectives are vague or are misinterpreted by many responsible people in our society, including planners and decision-makers in government and industry.

The first definitive statement of U. S. space policies was made in the National Aeronautics and Space Act of 1958; namely, "that activities in space should be devoted to peaceful purposes for the benefits of all mankind"....and "that the general welfare and security of the United States require that adequate provisions be made for aeronautical and space activities." These "aeronautical and space activities," in turn are to be conducted so as to contribute materially to one or more of the following goals: *

- The expansion of human knowledge of phenomena in the atmosphere and space;
- The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;
- The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

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* Summary Report, Future Programs Task Group, A report by the National Aeronautics and Space Administration to the President, printed for the House Committee on Science and Astronautics, Washington, D. C., April 1965, p.2.

- The establishment of long-range studies of the potential benefits to be gained from the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;
- The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;
- The making available to agencies directly concerned with national defense of discoveries that have military value of significance, and the furnishing by such agencies, to the civilian agency established to direct and control non-military aeronautical and space activities, of information as to discoveries which have value or significance to that agency;
- Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and
- The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities and equipment.

To support these policies and objectives, Congress has authorized a twenty-fold increase in the total federal space budget, from $348 million in 1958 to more than $7 billion in 1966; the National Aeronautics and Space Agency has been created; and a wide variety of costly and complex programs such as Gemini, Apollo, and MOL have been initiated. Furthermore, twenty thousand individual companies as well as hundreds of colleges and universities have committed significant percentages of their scientific and industrial resources to meet our national goals in space.

Since the Space Act was passed, the original policies and objectives of the space program have been modified, as time and events required. As previously noted, one of the most significant changes was suggested by the late President Kennedy on May 25, 1961, in a speech before Congress on "Urgent National Needs." Mr. Kennedy stated: "It is time for this nation to take a clearly leading role in space achievement which in many ways may hold the key to our future on earth," adding "I believe that this nation should commit itself to achieving the goal before this decade is out, of landing a man on the moon and returning him safely to earth."*

For example, on the day following his speech to Congress, President Kennedy submitted requests for an additional $549 million for the National Aeronautics and Space Administration including an increase in appropriations

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* Urgent National Needs, A Special Message to Congress by President Kennedy, published by the Department of State, Washington, D. C., May 25, 1961.

for manned space flight activities from $104 million to $234 million. In addition, the funds for the large launch vehicles associated with the man-in-space program were increased from $224 to $273 million.

In the weeks and months that followed, our national space plans were revised, new organizations and facilities within NASA, such as the office of Manned Space Flight and the Manned Spacecraft Center were created, supplementary man-in-space programs such as Gemini and the Saturn V, were initiated, the initial goal to land a U. S. astronaut on the moon was re-evaluated, and the date for the lunar landing was changed from the post-1970 to pre-1970 time period. Even the selection of the technique for landing men on the moon was influenced by the new objective and the associated time schedule.*

As a consequence of the late President's action, dynamic changes also took place in private industry; the American Telephone and Telegraph Company and General Electric established new corporate organizations (e.g., Bellcomm) to provide NASA with systems analysis and integration support in meeting the new goals of the man-in-space program. Furthermore, industrial executives and planners in aerospace companies throughout the United States revised their corporate goals and objectives and refocused

*"Report on Space Programs," Bulletin of the Atomic Scientists, Vol. 19 (1963), pp. 22.

the human, material and financial resources of their respective companies in the direction of the new U. S. goal to land men on the moon before 1970.

A more recent shift in our national space policy, namely, the decision, in August 1965, to go ahead with the development of the Manned Orbital Laboratory, has had its effect, not only on the structure and scope of the national space effort, but on the plans and decisions of aerospace managers in both government and industry. For example, the decision on MOL, according to a recent Congressional report, would represent a sizeable new commitment in space. * The report also found that the development and launching of the first series of MOL vehicles would cost at least a billion dollars, noting further that references have been made to bigger and more complex space stations which would increase this initial estimate to five to ten billion dollars.

The present and future scope of the MOL program has raised a number of policy questions which have yet to be fully and adequately answered, namely: Is it necessary to develop a manned orbital laboratory to validate military missions in space? And: can a manned space station be utilized by both NASA and DOD? The answer to the first question was partially answered when Secretary of Defense McNamara announced that the Manned Orbital

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* Govt. Operations in Space, p. 9

Laboratory would be developed, adding, that it was necessary to put men in space for an extended period and to conduct certain experiments to determine the military value of a manned space station. * This was a departure from earlier DOD policy statements that there was no clearly defined military role for men in space.

The second policy question relative to the MOL: Can a manned space station be utilized by both NASA and DOD? can be answered affirmatively, even though some experiments will have special military implications. Most of them, however, will produce scientific, technical and operational data which are not specifically military or non-military, but can be of value to both DOD and NASA.

As a consequence of this somewhat paradoxical situation, coupled with the estimated heavy cost of this new program, some concern and confusion have been generated, particularly about DOD's and NASA's plans and proposals for future manned space stations. This has prompted some Congressional and industrial spokesmen to suggest a merger of space station requirements in a single national program that would serve both NASA and the Department of Defense. In addition, the fact that both NASA and DOD have sponsored extensive studies by private industry to determine each agencies specific and separate needs adds further to the confusion and debate

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* Ibid p. 9.

over the policy implications and the relative roles of NASA and DOD in the development of a manned space station. This, in turn, gives rise to additional questions from industrial and Congressional circles, namely: Can a single space station program fulfill both NASA's and DOD's requirements? Which agency's requirements are paramount? Who should manage and fund the program? What design should be chosen?

In the minds of many planners and decision-makers these questions have not been resolved by the MOL decision. In fact it is still difficult for some members of Congress and industry to determine which agency, DOD or NASA will develop and manage the first fully operational space station. As an illustration, some industrial executives still base their plans and related developmental efforts on the possibility that NASA will eventually manage the first manned space station; others bet on DOD; still other executives try to maintain a flexible planning approach, hoping that whichever agency, or combination of agencies, manages the program, their company will benefit. Again, each executive bases his plans and decisions on his interpretation of the facts and an evaluation of what he belives our national space policies and objectives to be.

In addition to our own technological developments, such as MOL, the development of a military version of the Kosmos or Voskhod spacecraft by the Soviet Union might force the United States to alter the essentially peaceful policies and objectives of our space program as well as the scope of individual projects. For example, the existence of a Soviet military capability in space would probably result in a counter development by the United States with consequent shifts in the budgetary, management and technological structure of the current space program. Or, if positive evidence was received that the Soviet Union was going to land men on the moon before 1969 there is a distinct possibility that the present national objectives--to carry out a manned lunar landing before 1970--would have to be re-evaluated and the related schedules, technology and budgets modified. These changes, in turn, would have a significant effect on the strategy, plans and resource requirements of most of the current aerospace organizations, particularly those involved in the Apollo program.

As previously noted, developments that are not directly related to space and space technology can also affect our space policies and objectives. One such example is the establishment by President Johnson in August, 1965, of a "new" federal Planning-Programming-Budgeting System. This system will have significant and far-reaching impacts on the management of the federal government, particularly on the federal policy and decision-making process, on the relationship between the Legislative and Executive branches of government and on the responsibilities and prerogatives of the various federal agencies including NASA. For example, not only will the total NASA program be structured on the basis of the PPB System, but within the Bureau of the Budget, the overall NASA program will be compared in terms of its cost and effectiveness with defense, transportation and urban housing programs and budgets. As a consequence, this new management system will, in turn, affect NASA's decision-making and planning activities as well as those of private industry; in particular those companies that deal directly with the agency. Moreover, the Planning-Programming-Budgeting System will be employed to evaluate the post-Apollo space goals including the manned space station, the lunar base and manned planetary exploration.

Therefore, with the introduction of the PPB System into the federal decision-making process, it is not only essential for government and industrial managers to examine and analyze the space program and related policies as a separate unit, but to compare such programs and policies with other national goals in such areas as transportation, health, education and welfare.

Another development that will have an increasingly important effect on space goals and objectives is the growing application of aerospace systems management and analysis techniques to non-aerospace problems. These techniques have been effectively applied by the State of California, which recently asked systems engineers, employed by California's defense and space industry, to study four major problems affecting the state; namely: 1) transportation, 2) pollution, 3) data collection, and 4) crime. These studies have been completed and the results and recommendations are being successfully applied. The significance of these studies and the need to apply aerospace management techniques to other non-space problems has been voiced by a number of high government and industrial officials. This, in turn, indicates a growing concern and desire to apply space management techniques and technology to other national problems. If this were to take place on a gradually increasing scale, a significant modification of our space policies and objectives could take place, particularly if a growing percentage of the human and material resources now devoted to space research were applied to other national activities.

Another factor that has affected our space goals and objectives is the war in Vietnam. While current national commitments and projects such as Apollo will not be greatly affected, there is no question that the Vietnamese war has had a delaying effect on decisions relative to future post-Apollo goals and programs. How seriously this will affect the future space effort cannot be determined at this time since it is dependent, to a major degree, on the future scope of the war and the level of U. S. defense and political commitments.

On the other hand, improvements in the Vietnam situation as well as in the international climate, as a whole, could also lead to a redefinition of our national space policies and objectives. For example, if a reduction in cold war tension were to take place, it is possible that the present agreement between the Soviet Union and the U. S., to cooperate in the coordinated launchings of weather and geomagnetic satellites, might be expanded to include a joint effort by the U. S., and the USSR to construct a lunar base or carry out an international expedition to Mars. If such arrangements were to become national goals, our current space program schedules, project priorities and budgets would be significantly modified and, consequently, so would the plans and objectives of the aerospace industry.

Therefore, it is essential for aerospace management to consider national space policies and objectives in terms of: 1) their historical context; 2) the factors that influence their modification and evolution; and 3) their effect on such things as federal expenditures, technological developments and industrial growth.

SPACE MISSIONS AND OPERATIONAL REQUIREMENTS

Space missions and operational requirements are specific statements of how our national space policies and objectives will be met. As such, they are the basis for overall program planning and affect, in a direct way, system design, costs and project resource allocations.

However, it is often difficult for aerospace managers to correlate national space policies and objectives with specific missions and requirements because space policies are usually stated in very abstract terms, e.g., "the preservation of the role of the United States as leader in aeronautical and space science...," while the space missions and requirements are defined in terms of specific programs, functions, or needs, e.g., manned space flight, space defense, or planetary exploration.

In addition to being a reflection of national policy, space missions and requirements are dependent on three basic factors: 1) specific national objectives; 2) the needs and responsibilities of the using agency; and 3) the interaction between a specific technology and its operational environment.

This relationship between national objectives, agency responsibilities, technology and the environment, and their collective influence on specific missions and operational requirements was most clearly defined in the period between 1900 and 1950, when the needs of a growing economy coupled to advances in technology made it possible, for the first time in history, for large military and civilian transport systems to simultaneously evolve and function in three distinct environments: land, sea, and air. For example, modern, highly mobile ground armies and transportation networks came into being in the period between 1915 and 1940 when specific national defense or civil needs were coupled to specific technologies, i.e., the gasoline or diesel engine, and the wheel and gear, and the stressed steel shell which resulted in the development of locomotives, automobiles, trucks, and armored tanks. To a marked degree the design, operational requirements and missions of these vehicles and their supporting rail and road networks were influenced by the terrain, i.e., environment, over which they were built or operated.

During the same period, modern sea-based transportation systems and naval weapons evolved when military and civil missions and requirements, and specific technologies (steam generators and steel hulls) were employed in a particular environment (the sea). As a consequence, naval forces and maritime transportation, with their unique missions increased in importance as contributors to the economic health and military power of this and other western nations. For the most part, the design and operational distinctions between the missions, operational requirements, and technological characteristics of a sea-based system as compared with those of a land-based system, were obvious during this period.*

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* In some unique cases (i.e., amphibious vehicles), land and sea operations and their related technologies are combined into one system.

The evolution of highly mechanized ground and sea-based systems, designed for specific military or civil functions or requirements, was closely paralleled in the first fifty years of the twentieth century by the development of aircraft which carried out their own unique missions in a specific environment: the atmosphere. However, air transportation and aerial warfare did not become of prime significance until World War II when reciprocating and jet engines were coupled to the all-metal airframe. Following the war, the importance of aircraft technology to the national security and economy of this country was highlighted by the creation of a separate Air Force in 1947, and the growth of commercial airlines, which expanded and began to compete with the railroad and maritime transportation systems.

In each of the above cases the marriage of a specific national requirement and a specific technology to a particular environment influenced the development of separate air, sea, and ground systems and their related doctrines, missions and operational capabilities.

These basically different systems had one common characteristic, however; they all operated on or very near the surface of the earth, in an essentially flat, two dimensional environment, with geographic and technological limitations on their mission, range, and operating time.

These operational limitations were overcome to a significant degree during the 1950's when rocket and space technology became a significant factor in man's activities. Now he could operate away from the surface of the earth, in a vastly larger, three dimensional environment where there were few restrictions on the time, velocity or range of operations. However, because man has a natural tendency to evaluate and apply new technological developments within a framework of current and past experience, space technology applications were considered by many as only a supplement to existing terrestrial activities. This was particularly evident in the military hierarchy where individual service interests and operational methods, as well as organizational rivalries, led to the creation of separate and competing Army, Navy, and Air Force space programs in the late 1950's. One of the arguments employed at that time to justify this duplication of effort was that space activities were just natural extensions of existing Army, Navy and Air Force operations.

While there is some basis for this argument, particularly in the case of orbital missions--where a more direct application of space technology to man's activities on earth can take place--it ignores or minimizes the possibility that space and space technology--including the missions and operational requirements--are in many ways unique and distinct from most terrestrial activities.

At the present time space missions and the related operational requirements are defined almost entirely on the basis of separate agency responsibilities and needs, rather than on overall national requirements. While there is a total national space program in concept, at the organizational and operational levels there are two semi-autonomous programs with NASA responsible for the larger scientific, developmental and exploratory effort and DOD, i.e., the Air Force, responsible for the military space effort. While the structure and orientation of the space program is partially an outgrowth of past policies and decisions made in response to Sputnik I, the duality of the program is based primarily on operational considerations with duplication and program overlap minimized through a series of NASA-DOD coordinating boards, panels and committees.

Under this arrangement NASA and DOD initiate and manage their individual space programs to meet specific agency missions and requirements. Where these missions and requirements are distinctly different, as would be the case in comparing NASA's planetary exploration and DOD's space defense missions, separate program management, missions and operational requirements prevail. However, when both agencies have a similar mission and operational requirement, such as Manned Space Flight, the management/mission/requirement distinctions are vague and tend to overlap. In such situations special coordinating arrangements must be established. (See "Space Program Management and Organization," pp. 91-92).

Under the present arrangement NASA and DOD have structured their programs and missions as follows:

NASA

MANNED SPACE FLIGHT

SPACE SCIENCE AND APPLICATIONS

ADVANCED RESEARCH AND TECHNOLOGY

TRACKING AND DATA ACQUISITION

DOD

MANNED SPACE FLIGHT

COMMUNICATIONS

NAVIGATION

SPACEBORNE DETECTION

SPACE DEFENSE

VEHICLE AND ENGINEERING DEVELOPMENT

SUPPORTING RESEARCH AND DEVELOPMENT

SPACE GROUND SUPPORT

GENERAL SUPPORT

The above program categories are structured primarily on the basis of separate agency missions and responsibilities. However, a close examination of the general program or functional categories listed under each agency, indicates that there are more program and mission similarities between NASA and DOD than is apparent at first glance. For example, both NASA and DOD have manned space flight missions and programs. NASA's Space Science and Applications Program includes many separate projects that are essentially analogous to a series of individual DOD space activities carried out in the areas of Communications, Navigation and Space-borne Detection. NASA's Advanced Research and Technology Program and missions are functionally similar to the combined DOD categories of Vehicle and Engineering Development, and Supporting Research and Development; whereas, NASA's Tracking and Data Acquisition programs and missions are somewhat akin to a combination of DOD's Space Ground Support and General Support categories.

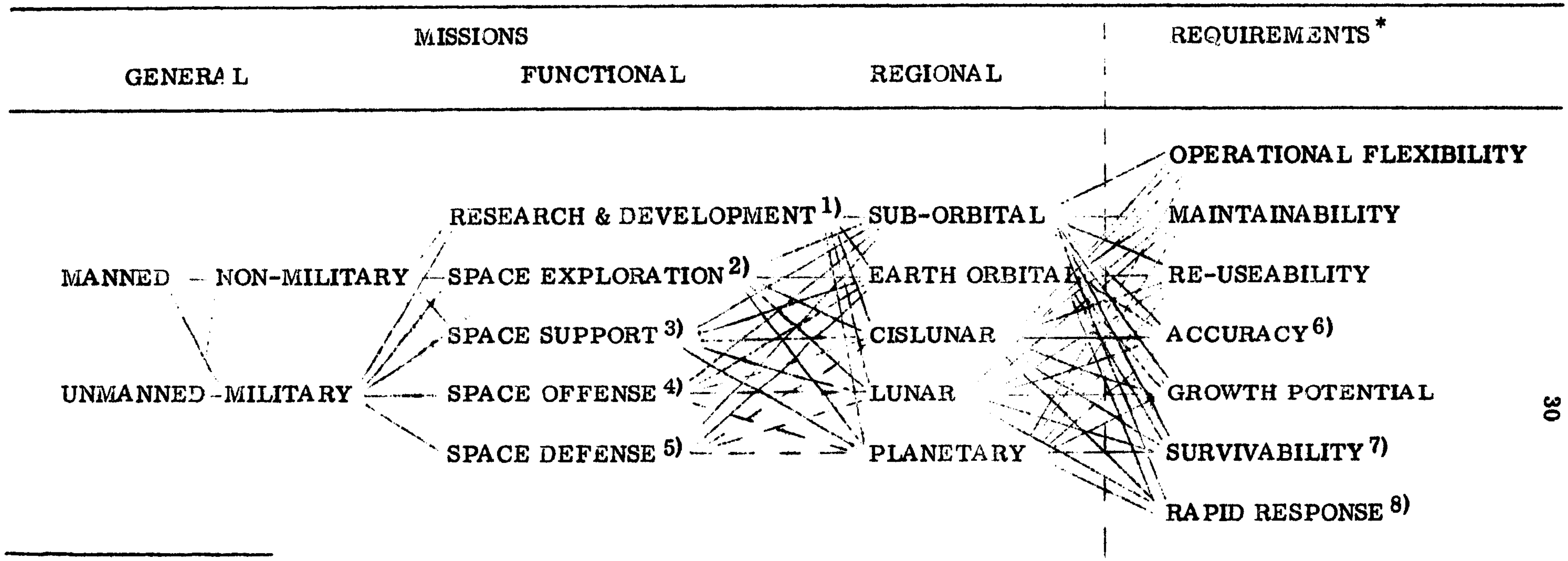
Nevertheless, in spite of these functional program and mission similarities, the belief that this country has two distinctly separate space efforts, carried on by two separate federal agencies still persists.

In some cases planners and decision-makers, particularly in industry, have operated on the basis of separate civil and military space programs. In other cases, industrial managers and their planning staffs have considered the DOD and NASA programs an complementary elements of a single national space effort and have structured and implemented their plans accordingly.

One approach employed by space-age planners to define space missions in terms of national rather than separate agency needs is to subdivide the missions into general, functional, and regional categories (see Fig. 3). The general category is comprised of manned, unmanned, military and non-military missions. The general mission category can then be subdivided into functional missions, including: 1) research and development, which involves the testing and improvement of hardware and the perfection

FIGURE 3

SPACE SYSTEMS MISSIONS/REQUIREMENTS



1) Hardware development.
2) Data collection.
3) Military/non-military reconnaissance; launching, tracking and recovery; logistic support.
4) Counterforce/countervalue attacks against earth, lunar or space-based targets.
5) Active/passive defense against earth, lunar or space-based weapons.
6) Spacecraft guidance and/or weapon delivery.
7) System survivability via active/passive defense and/or system design.
8) Military/non-military requirement for system survival and/or precise launch window timing.

____ ____ Possible missions.

* Differences between military and non-military requirements are a matter of degree rather than of substance.

of operational techniques; 2) space exploration, i.e., missions related to the expansion of the space "frontier" and the collection and interpretation of new data; and 3) space support, which encompasses a variety of missions including: military/non-military reconnaissance; launching, tracking, and recovery operations; and space logistics, i.e., maintenance, re-supply and cargo transport.

It is significant that the current U. S. space activities as redefined under the first three functional missions, i.e., research and development, space exploration and space support, including the related spacecraft systems, are presently the joint responsibility of DOD and NASA. On the other hand, there are two additional functional space missions which are entirely military. These are: space offense, which would include counter-force and counter-value attacks against earth, lunar, or space-based targets; and space defense, including active and/or passive defense against earth, lunar, or space-based weapons.

Another basis for classifying space missions is to define them regionally, i.e., missions that are carried out in a specific area of space having unique physical and operational characteristics. For example, suborbital missions typified by the earlier Mercury-Redstone flights would involve ballistic or semi-ballistic flights extending from the surface of the earth out to a distance of 100 miles. Earth orbital missions, as flown in the Mercury, Gemini, and

MOL spacecraft would include single, multiple, or sustained orbit flights carried out in a region lying between 100 and 20,000 miles from the earth's surface. Cislunar missions, involving such vehicles as the Lunik III, which took the first pictures of the far side of the moon, would be conducted in a zone lying between the earth orbital and the lunar orbital regions; whereas lunar missions would be carried out directly on the moon's surface by spacecraft such as the Lunar Excursion Module (LEM) and Luna 9. Finally, the planetary missions would be those involving spacecraft such as the Mariner or Voyager, launched on inter-planetary trajectories into a region extending tens-to- hundreds of millions of miles beyond the earth, to the planets of our solar system.

Aerospace planners recognize that regional space missions have been and will continue to be carried out by military, as well as non-military spacecraft. However, the non-military space program--which has moved ahead of military space activities (in terms of hardware development and time schedules) in the exploration of earth orbital space--will continue to maintain this lead in the exploration of cislunar, lunar, and planetary space. This forward thrust by the non-military space effort into the outer limits of space cannot be paralleled by a military space program if for no other reason than it becomes increasingly difficult (in spite of any existing technological capabilities) to establish military missions and requirements as the zone of operation shifts away from the earth orbital, to the lunar and planetary regions.

To support the various military and non-military missions, space systems have to meet certain basic operational requirements which aerospace planners, in turn, must take into consideration (see Fig. 3). These requirements include reliability, which may have a certain range of acceptable values depending on the complexity of the spacecraft and the mission to be performed. For example, an unmanned vehicle designed for a single earth orbit would not necessarily have to have as high a degree of reliability as an unmanned vehicle launched on a trajectory to Mars where the spacecraft's operational life is measured in months rather than hours. On the other hand, a manned spacecraft launched into a single earth orbit may have to have a higher order of reliability for crew survival, than an unmanned communication satellite designed for a synchronous earth orbit.

Another basic space systems requirement is operational flexibility. Defined as the degree to which a given space system can operate in a variety of mission modes, operational flexibility is essentially a function of the space system's design (particularly its weight and volume) and the requirements of the using agency. For example, the Apollo spacecraft has a high degree of operational flexibility in the sense that it will be used for earth orbital, cislunar and lunar landing missions and has a broad range of other potential applications; whereas Mercury, designed specifically to launch the first U. S. astronaut into orbit, had very little operational flexibility.

Another space systems operational requirement is maintainability. A function of system's complexity, reliability and operational mode, it is measured by, the level of skills required, the number and complexity of maintenance procedures and the degree of component and sub-system's accessibility existing in a given spacecraft. A high order of maintainability is a particularly important requirement for military space systems and has a direct bearing on the operating costs of all types of space vehicles; a factor that must be considered by aerospace planners and systems designers.

Re-useability, another requirement, is defined as the capability of a space vehicle to be launched more than once in a given mission mode. It is a function of the vehicle's design, its mission and the requirements of the using agency, and can be measured in terms of the cost (in dollars) per pound of spacecraft launched into orbit. To date spacecraft and booster systems that have a high degree of re-useability have not been put into operation, but are under design and development for future space operations, particularly where repetitive launchings may be required. One such vehicle is the Scramjet, an air-breathing system, which in some configurations could be designed to repeatedly launch a large number of payloads and return, after each launching, to its home base. This vehicle would have a high degree of re-useability as compared with a Saturn booster which can only be used once.

Another space systems operational requirement is accuracy, defined as the ability of the total system (launch vehicle and spacecraft) to operate within an acceptable range of geometric error, or to arrive at a given point in space with the required velocity and orientation. In the case of an offensive or defensive space weapon, the CEP and/or kill potential delivered against a fixed or moving target is an additional parameter employed to measure the spacecraft's accuracy requirement.

Growth Potential, i.e., the capability of a given space system to evolve into a more advanced design is also a basic operational requirement which must be considered by space planners and designers. It is a function of the spacecraft's design and mission, as well as the operational needs of the using agency. For example, the Saturn and Titan boosters as well as Apollo are space systems with a relatively high growth potential; whereas Vanguard, Atlas, and Mercury were systems with a low growth potential. In another sense high growth potential allows flexible and long-term (thus lower cost) use of a space system. A spacecraft with low growth potential inhibits its flexibility and long-term use.

Survivability is another basic space system requirement. In a non-military environment this is defined as the ability of the spacecraft and the crew to survive in the face of a hostile, but natural threat, e.g., collision with a meteorite, or intense solar radiation. In a military environment, systems survivability is considered more in terms of a man-made threat (i.e., offensive weapons). In a military environment systems survivability is attained through dispersal, hardening, defensive armaments, mobility and/or maneuverability.

In addition, there are military and non-military space systems which have a requirement for rapid reaction. This is a function of the system's mission mode, reliability and complexity. In a non-military environment, a requirement for rapid reaction would exist in a simultaneous spacecraft launching, such as Gemini 6 and 7, where orbital rendezvous is the object, and where the time and launching window criteria are limited. In a military environment, a quick reaction capability may be required to destroy an enemy satellite, to permit a friendly space system to survive a surprise attack, or assure crew survivability during attack.

THE SPACE ENVIRONMENT

The importance of the space environment to aerospace planning and decision-making has increased significantly since January 31, 1958 when the first American satellite, Explorer I, was placed into orbit. Since that date the space program has slowly gathered momentum and passed a number of primary milestones, including the series of Mercury and Gemini spacecraft launchings. These flights marked the beginning of an exploratory program that will take man and machines further and further into an essentially unknown environment which extends from the earth's atmosphere to the surface of the moon and beyond, to planets of our solar system.

The space environment not only has a direct effect on spacecraft design and operation but consequently on program costs, lead times and launching schedules, as well as man's functions and survival. Therefore, an understanding of these various effects of the space environment is an important input to any "space age" planning or decision-making activity. For example, in deciding on the level of funding for a specific space project, an aerospace manager might have to ask and obtain answers to such questions as the following: What is the correlation between the physical nature of the space environment and the development costs of this proposed project? To what extent will space environment affect its launching schedule, and therefore, the U. S. - USSR "space race"? What are some of the design problems associated with long-time distance flights to the planets of our solar system? What kinds of facilities and funds will be required to simulate the space environment? In what ways will the lunar environment hamper man's functions? Enhance his functions?

The space environment has been described as a radiation continuum, containing thinly dispersed gaseous material and spiced with sharp meteoric pepper.* More specifically, it is characterized by solar and cosmic radiation which can damage or kill unprotected organisms, temperature extremes, weightlessness, meteorites, and gravitational forces which differ greatly from those experienced on earth. In space, distances between points range from a few hundreds to millions of miles, and spacecraft flight times, as compared with those of aircraft operating in the terrestrial atmosphere, are measured in terms of days, weeks, or months, rather than hours. All of these factors, individually and in combination have an effect on the planning and the design, as well as on the operation, cost of and reliability of booster, electronic and spacecraft systems.

The physical nature of the space environment is not uniform; it differs significantly from place to place (see Fig. 4). Its basic characteristics are altered by the sun and the planets as well as by the magnetic forces which

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* Howard S. Seifeit (ed.), Space Technology (New York: John Wiley & Sons, Inc., 1959).

THE SPACE ENVIRONMENT

SPACE GAS: H+ + $\bar{E}$
10 TO 2 X 10^4 PARTICLES/IN^3

SOLAR FLARE CORPUSCULAR RADIATION: 0.1 TO 1 BEV AT 10^3 TO 10^4 PRIMARY PROTONS/IN^3/SEC.

GALACTIC COSMIC RADIATION:
1-10^9 BEV/NUCLEAR; 85% PROTONS, 14% α PARTICLES, INTERACTS WITH ATMOSPHERE TO FORM MANY NEW PARTICLES PLUS PHOTONS.

SOLAR WIND:
50 EV TO 20 KEV AT ~ 10^4 TO 10^6/ $IN.^3$

TOTAL SOLAR FLUX:
130 WATTS/$FT.^2$

RADIATION TEMPERATURE SINK OF SPACE ≈ 7^oR

OUTER REGION--SUBJECT TO CHANGES BY FACTORS OF 10 TO 100 IN A FEW DAYS. OUTER BOUNDARY NORMALLY AT GEOCENTRIC DISTANCE OF 11 EARTH RADII (R⊕) MEASURED IN ELECTRONS ≥ 50 KEV, ALTHOUGH CAN BE "PRESSED IN" TO ≈ 8 R⊕. COUNTING RATES SUBJECT TO SHARPER PEAKS IN HIGH ENERGY REGION OF SPECTRUM WITH MAXIMUM AROUND 3.1 R⊕.

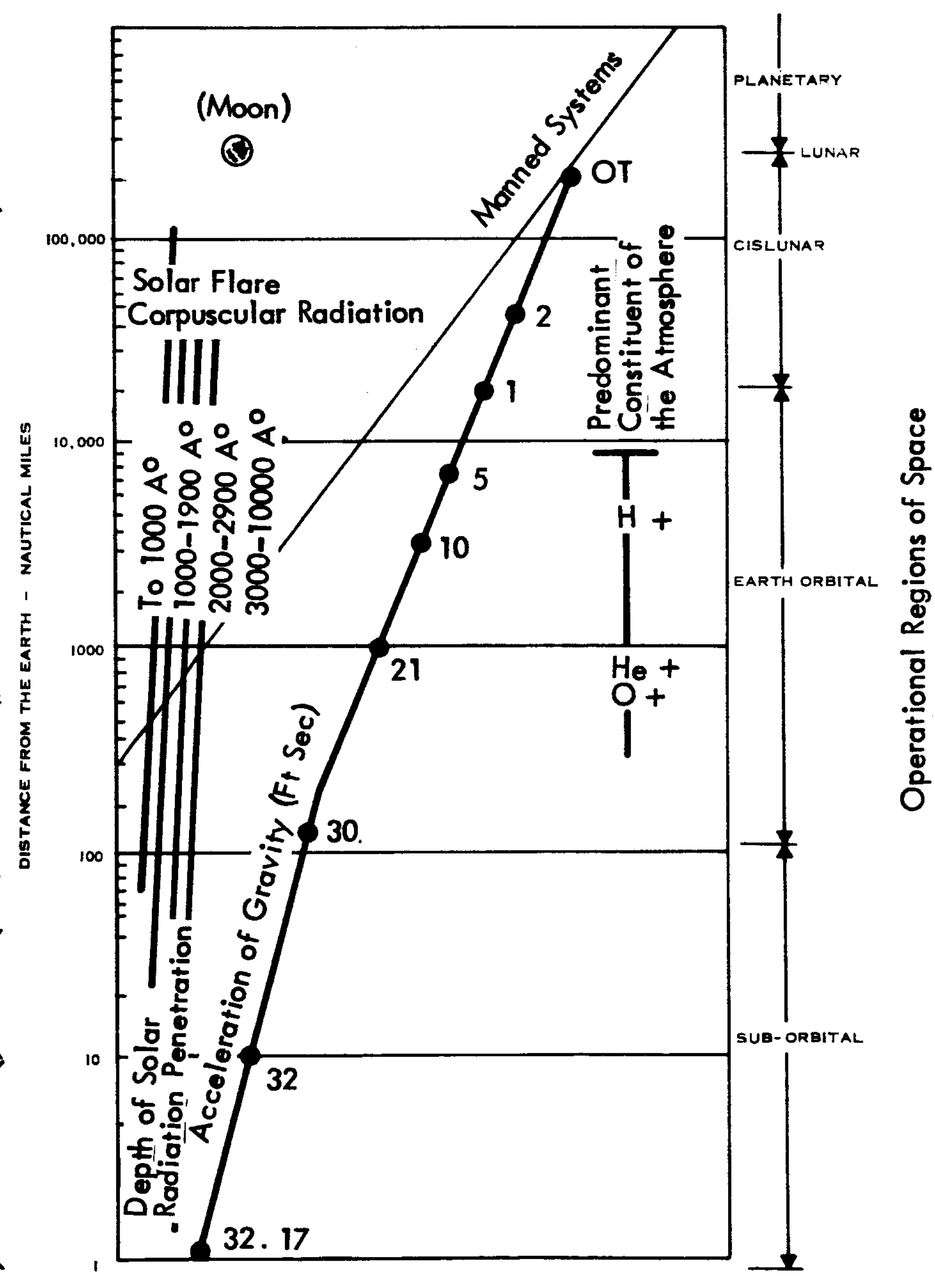
VAN ALLEN RADIATION BELTS:
INNER REGION—WHILE RELATIVELY QUIESCENT, OBSERVED TO CHANGE IN INTENSITY BY FACTOR OF TWO OR THREE IN SIXTEEN MONTHS, ASSOCIATED WITH MAJOR GEOMAGNETIC AND/OR SOLAR PROTON EVENTS OF IMPULSIVE CHARACTER.

ATMOSPHERIC IONIZATION
~10^2 TO 6 X 10^7 PARTICLES/IN^3

FREE MOLECULAR MOTION:
THERMODYNAMIC, RAM AIR, ACOUSTIC PROPAGATION, AND AERODYNAMIC EFFECTS BECOME NEGLIGIBLE.

OZONE LAYER (O_3) UP TO ≈ 12 PPM

TROPHOSPHERE ENVIRONMENTS:
HIGH & LOW TEMPERATURE
DYNAMIC PRESSURE
HUMIDITY, SAND, DUST
SHOCK, VIBRATION, ACOUSTICS
ACCELERATION



SOURCE: AEROSPACE TECHNICAL FORECAST 1962-1972
AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA
WASHINGTON, D.C., 1962

Figure 4

emanate from these bodies. For example, the earth's magnetic field strongly influences the influx of solar and cosmic rays and the formation of the radiation belts which are composed primarily of high energy electrons and protons.

These belts are one of the most significant factors affecting spacecraft operation and crew survival. Within the radiation belts the radiation intensity increases by factor of several thousand between 300 and 1,000 miles, where it may reach as much as ten roentgens per hour--enough to deliver an average lethal dose in two days to an unshielded human being. * However, current data indicates that the radiation intensity falls off rapidly at a distance of roughly 20,000 miles above the earth. Consequently, it would be dangerous for a manned spacecraft to stay within the region of high-density radiation for an extended period of time, but for most missions (particularly those involving earth escape) a short period of time in the region of high intensity, or spacecraft exit or reentry at the polar regions where the earth's radiation is at a minimum, may be all that is required. Some shielding may be necessary, however, to protect the crew, on extended earth-orbital missions, but the overall spacecraft weight could be held down to a minimum, through the use of radiation shielding based on sandwich structures comprised of thin layers of lead, aluminum and/or plastic.

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* Space Handbook, Report of the House Committee on Astronautics and Space Exploration, Washington, D. C., February 24, 1959, p. 16.

The sun also influences the radiation levels in the space environment. It is most intense after solar flares which discharge clouds of almost pure protons into space. When these particles reach the vicinity of the earth, they not only produce abrupt changes in the intensity of the natural radiation trapped in the belts around the earth but also communications blackouts and auroral displays. If an astronaut got caught in a cloud of these particles, no reasonable amount of shielding could protect him. If the big flares were anticipated, long-range flights would have to be cancelled. Solar flares could also affect our ability to land men on the moon, and thereby interrupt our time schedule for getting to the lunar surface. In addition, high energy particles associated with solar flares are a hazard to spacecraft operating in earth orbits greater than 50 degrees inclination and altitudes above 10,000 miles. *

Man and his machines will also be affected by the meteoroids and meteoric materials that exist in the space environment. Meteoroids are believed to originate from cometary tails and the asteroid belt and their intensity varies from a light and random influx to brief intense showers. ** Based on data gathered by unmanned satellites, it is estimated that roughly 2,000 tons of this "spatial debris" enter the earth's atmosphere each day;

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* Space Planners Guide (Washington: United States Air Force, Air Force Systems Command, 1965), p.II-10.

** Aerospace Technical Forecast, 1962-1972 (Washington: Aerospace Industries Association of America, 1962), p. 12.

however, most of the meteoric particles are too small to be hazardous to man and equipment in space, even though they reach velocities of 7 to 45 miles per second. Consequently, the probability of penetration of the spacecraft's thin skin is low. However, for spacecraft operating for extended periods of time in the space environment, the erosive, sand blasting effects of these particles could affect the performance and realiability of the spacecraft, as well as the emotional stress levels of the crew.

Along with the dangers of radiation and meteoric penetration, the spacecraft and its crew will be affected by the weightlessness that exists in the space environment. As outlined in the USAF Space Planners Guide, the problems of weightlessness can be divided into two classes: operational and medical. * The operational problems result from the effects of weightlessness on such space crew tasks as eating, washing, and the use of tools and instruments. By comparison, the medical effects of weightlessness are more severe and if prolonged can result in a degeneration of the crew members' skeletal, cardiovascular and muscular system, to a point where permanent physical damage may result. As a consequence knowledge about these effects on the crew is essential to the planning and design of adequate training facilities, simulators, and crew compartments, and particularly, the planning of long-duration manned missions to the planets.

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* Space Planners Guide, p. II-17.

In addition to the danger of radiation and meteoric penetration, as well as the effects of weightlessness, the spacecraft structures, the equipment and the crew will be affected by wide temperature variations on both short and long duration flights into space. During reentry, for example, spacecraft will be subjected to temperatures ranging from 1,000° to 6,000° Farenheit, and on extended flights into space the spacecraft will experience wide temperature extremes over its entire surface, depending on its distance from and relative orientation to the sun. Fox example, a spacecraft operating in the vicinity of Venus will receive about 50 times more heat per square inch of surface than it would if it were operating in the vicinity of Jupiter. * Consequently, a vehicle equipped for a trip to Venus is not (from a structural and temperature control viewpoint) necessarily suited for a trip to Jupiter. Temperature will be a critical planning factor in those operations and equipment design areas involving crew exit from the spacecraft for extended periods of time. For example, special space suits, which take the extreme temperature conditions in space into consideration, will be required. However, in space the heat flux through the space suit will depend on so many factors that special suits may have to be designed for special missions. **

* "The Medical Aspects of Space Flight," in Seifert, op. cit., p. 28-08.

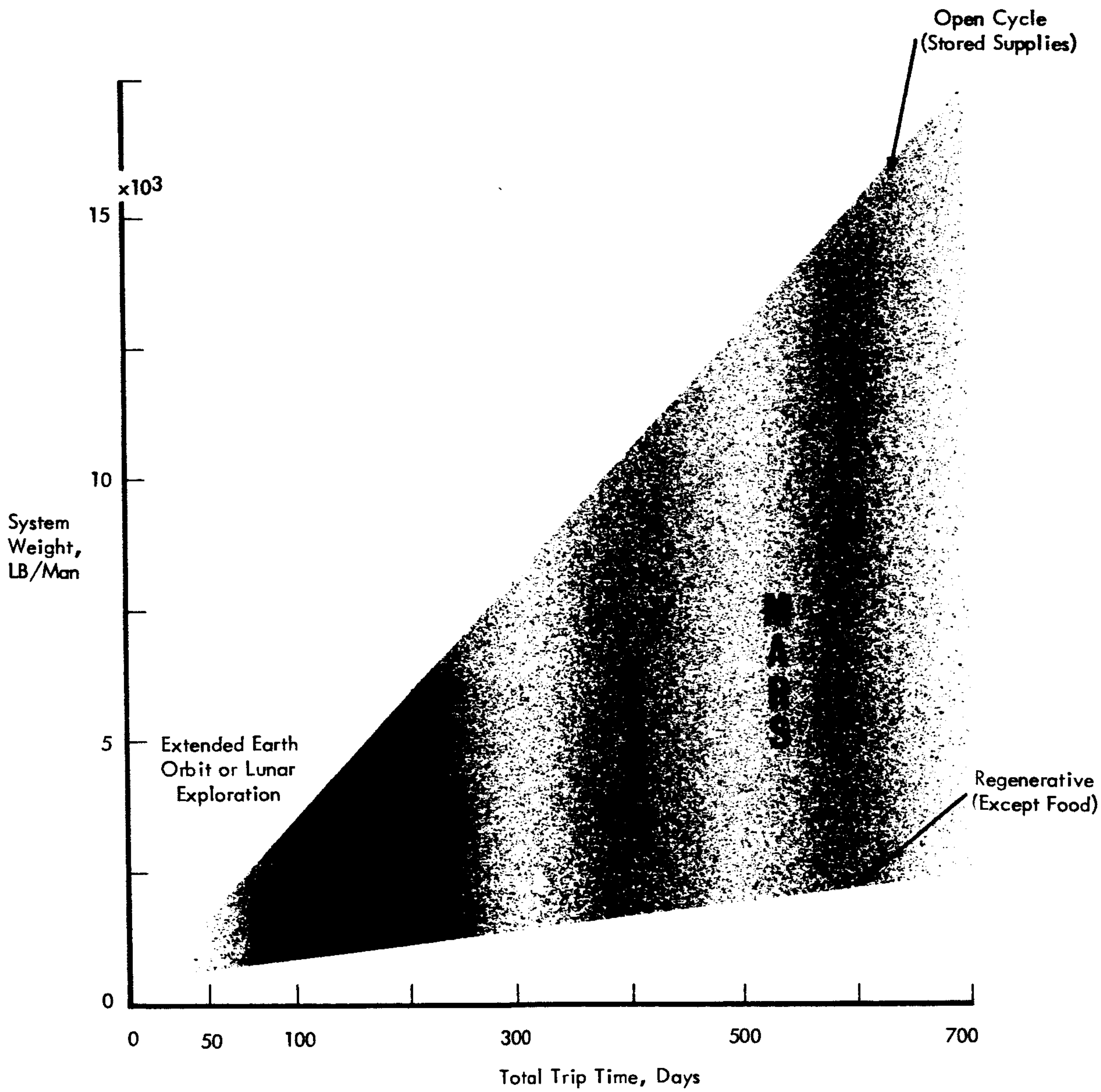
** Space Planners Guide, p. II-18.

As more extended missions in space are carried out, the problem of equipment reliability, weight and volume, as well as man's survival in a closed ecological environment become significant in the planning and design of space systems (Fig. 5). This will be particularly true where flight, or on-station times in excess of two weeks are experienced. Not only does equipment reliability become a critical factor on extended flights into the space environment, but where manned systems are involved there must be equipment on board for partial or total recovery of water, food and oxygen, as well as for decontamination of the air supply.

Consequently, it is important in any "space age" planning and decision-making activity to consider the effects of the space environment on such things as spacecraft launching and flight-time schedules (as affected by solar flares and celestial mechanics), on system costs (as affected by radiation shielding, temperature control and flight-time requirements), and on the survival of man himself (as affected by long and dangerous voyages into planetary and deep cosmic space.

45

LIFE SUPPORT SYSTEMS WEIGHT



Source: NASA

Figure 5

TECHNOLOGICAL DEVELOPMENTS

Of the many factors considered by aerospace executives in their planning and decision-making functions, technology is one of the most--if not the most--significant. Not only do technological considerations shape and motivate the executive's decision-making process, but they affect the very character of the organization he directs and controls: its organizational structure; its competitive position; its financial status; and its future growth and survival.

The impact of technological developments, however, extends beyond the realm of specific companies and organizations. In fact, technology has affected virtually every facet of society; its institutions, its people, and its political, economic and social fabric. This interaction between society and technology and its specific impact on the public and private decision-making process was vividly demonstrated by the events that followed the launching of Sputnik I by the Soviet Union. Excluding the initial public reactions ranging from skepticism to alarm, Sputnik ultimately caused the United States to re-examine its strengths and weaknesses, particularly in the areas of missile and space technology, as well as public and private education. As a consequence, decisions with far-reaching implications were made within the various branches of the Federal government. Large sums of money, initally in the several hundreds of millions and later several billions of dollars, were appropriated and spent to meet the challenge of the Sputnik; new organizations such as NASA were created; certain industries modified their management, engineering and production structures to support the space effort; and large numbers of American citizens with the necessary administrative, scientific and technical skills began to move to areas where the new space facilities were being built. *

In addition, technology became a big factor in international prestige. For example, the underdeveloped as well as the mature nations began to see the conflict between the United States and Russia in the new light, in the sense that the Soviet Sputniks gave positive, as well as "between the lines" indications of Russian military and technical power vis-a-vis the United States which had never been demonstrated so dramatically before. Space and space technology very quickly became internationalized and its terminology accepted as part of a new international language.

However, "space technology" is a term with many meanings. To define the term in a context that is relevant to the aerospace planning and decision-making process it is necessary to consider space technology as consisting of two distinct but related categories: modular technology and systems technology (see Fig 6). Modular technology includes rocket propulsion (chemical, nuclear, electric); auxiliary power (solar, chemical, nuclear); electronics (data processing, radar, communications, command and control, telemetry); space medicine (human factors, environmental

* See, "Space Age Boom is Bringing Revolution to the Southwest," New York Times, August 25, 1963, p. 56.

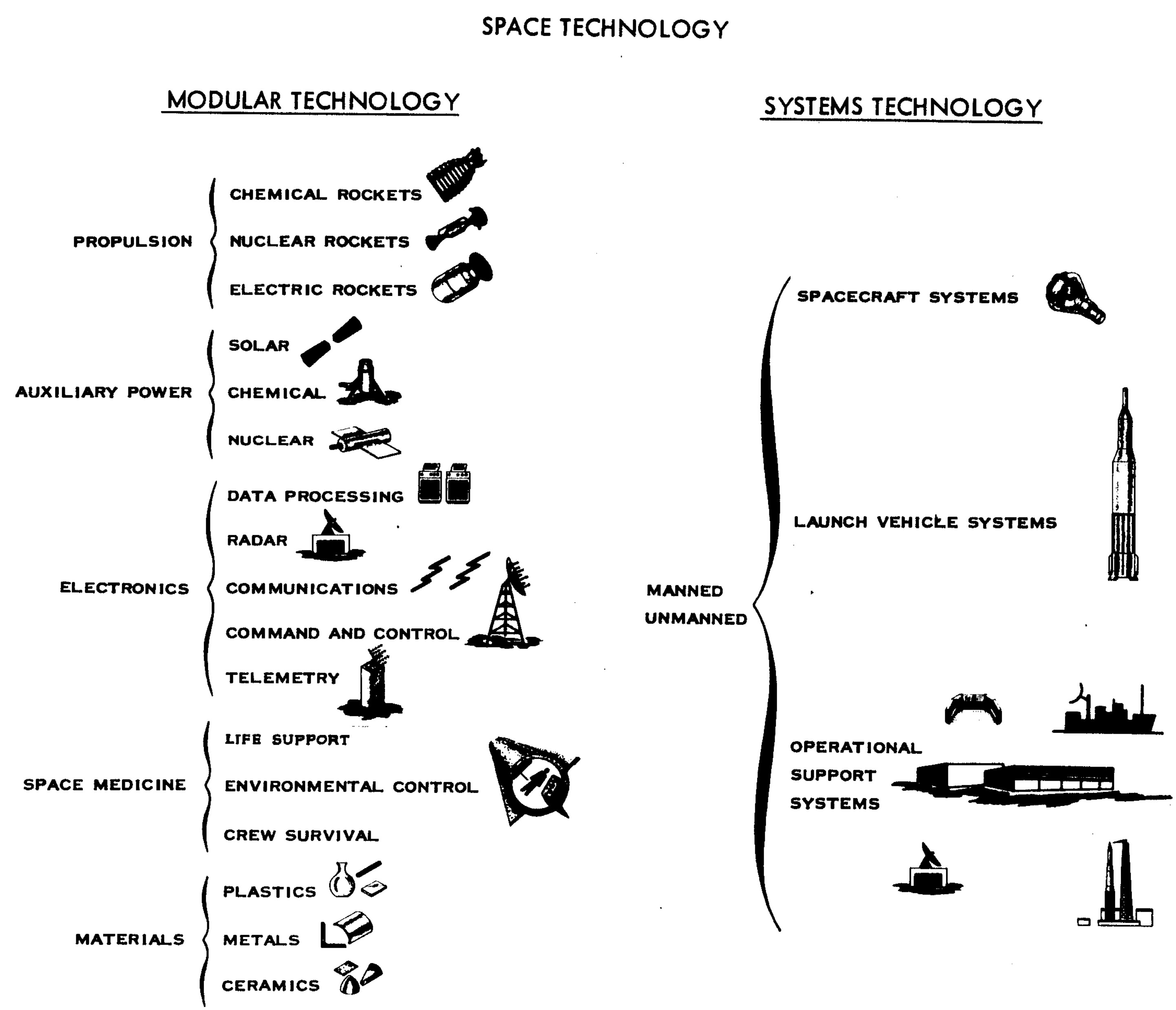

SPACE TECHNOLOGY
MODULAR TECHNOLOGY
PROPULSION
CHEMICAL ROCKETS
NUCLEAR ROCKETS
ELECTRIC ROCKETS
AUXILIARY POWER
SOLAR
CHEMICAL
NUCLEAR
ELECTRONICS
DATA PROCESSING
RADAR
COMMUNICATIONS
COMMAND AND CONTROL
TELEMETRY
SPACE MEDICINE
LIFE SUPPORT
ENVIRONMENTAL CONTROL
CREW SURVIVAL
MATERIALS
PLASTICS
METALS
CERAMICS
SYSTEMS TECHNOLOGY
MANNED
UNMANNED
SPACECRAFT SYSTEMS
LAUNCH VEHICLE SYSTEMS
OPERATIONAL
SUPPORT
SYSTEMS

Figure 6

control, crew survival); and materials (plastics, metals, ceramics). Systems technology--a composite of several modular technologies--includes spacecraft systems (e.g., Apollo); launch vehicle systems (e.g., Saturn); and operational support systems (e.g., the Manned Spacecraft Center).

Modular Technology

To maintain our pre-eminence in space and aeronautics and to lay a basic foundation for planning and decision-making relative to future objectives and programs in space it has been necessary for the federal government and private industry to initiate and support a broad and varied R & D program in modular technology, which, in turn, provides an aerospace planner and decision-maker with a variety of technical options to plan for and meet new and emerging space requirements. As stated by former NASA official, Dr. Raymond L. Bisplinghoff:

> The existence of several technical options is fundamental to sound planning of national objectives. Because of the immense social, economic, scientific, political and military implications of space missions, policy planners will demand in the future that they be given options in the selection of new missions. *

One of the most significant efforts in modular technology involves the development by the federal government and private industry of a wide range of roc

* 1966 NASA Authorization, Hearings before the House Committee on Science and Astronautics, Part 4, Washington, D. C., March 1965, p. 295.

propulsion capabilities. These public and private R & D activities, carried on over the last twenty years have led to the development of rocket engines such as the North American H-1 with a thrust of 150,000 to 188,000 pounds, which was used to power the Atlas booster that placed the first U. S. astronaut in orbit. Eight of the H-1 engines providing a total of 1.5 million pounds of thrust are used for the first stage of the Saturn I booster, and an uprated version of the H-1 with a single-chamber thrust of 200,000 pounds will, in an eight-chambered cluster, provide a total of 1.6 million pounds of thrust to the first stage of the more advanced Saturn IB. However, the H-1 will eventually be replaced--as a first stage engine--by the more powerful F-1 which will produce 1.5 million pounds of thrust in a single chamber. A cluster of five F-1's, delivering a total thrust of 7.5 million pounds, will power the first stage of SaturnV, a booster capable of placing more than 250,000 pounds into low earth orbit and 90,000 pounds on the moon.

Also under development is the J-2, an oxygen/hydrogen fueled engine with a thrust of 200,000 pounds. This rocket in clustered configurations will power the upper stages of the Saturn IB and Saturn V. In addition, developmental research is continuing, at minimum funding levels, on even higher thrust liquid and solid fueled engines than those presently in operation or under development.

In addition to the chemically fueled engines, nuclear powered rockets such as NERVA are under development. This engine could be employed in the upper stages for advanced Saturn V configurations for high-payload earth-orbit, lunar or Mars missions. Also in the developmental research stage are air breathing and nuclear-electric systems which will provide auxiliary and/or primary propulsion modules for advanced spacecraft.

As previously noted, the significance of these developments in rocket propulsion to management planning and decision-making is sometimes overlooked. Yet it was the lead established by the Soviet Union in rocket engine and booster technology which enabled the Soviets to launch the first satellite, to place the first man in orbit, to take the first photographs of the far side of the moon, and to carry out a simultaneous launching of two Vostok capsules in August 1962. These accomplishments have added to their techno-military stature and have steadily enhanced their international prestige.

For example, the development of a family of higher thrust and more efficient rocket engines permits a nation to launch increasingly larger payloads into space. This is not only a prime factor in the race for space supremacy, but a large payload also provides a high degree of operational flexibility. For example, a 1000-pound spacecraft, designed for earth orbital missions, is restricted in weight, volume and kinds of equipment it can carry and, consequently, the missions it can perform. On the other hand, a 100,000-pound orbital spacecraft has a high degree of operational flexibility, inasmuch as it can carry a wider variety of scientific and/or military equipments. This not only tends to reduce the number of boosters and individual spacecraft required to meet a specific objective (such as landing men on the moon or assembling a manned space station) but permits a reduction in launching costs as well. *

Another significant area of modular technology receiving increased attention from aerospace management is that involving auxiliary power packages, inasmuch as all space vehicles regardless of their size or mission, require auxiliary power for communications, data processing and sensing. Moreover any life-support system is critically dependent upon a reliable source of electric power.

There are three principal types of auxiliary power systems: chemical, solar and nuclear. Their selection and use depends upon the required power level and the electrical energy requirements for a given mission. **

To date, the major electrical power source for both manned and unmanned spacecraft has been fuel cells, batteries and solar cells. As space missions become more complex, higher power levels than those presently available will be required. These requirements in all likelihood will be met by nuclear-electric systems.

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* H. H. Koelle, "Missiles and Space Systems--1962," Astronautics, Vol. 7 (1962), 29.

** NASA Authorization for Fiscal Year 1964, Senate Committee on Aeronautical and Space Sciences, Washington, D. C., p. 361.

As the space program evolves, auxiliary power packages ranging in output from hundreds of kilowatts to many megawatts will be required. Representative applications of such power levels include manned space platforms, manned interplanetary spacecraft, communications satellites and unmanned planetary probes. These applications can generally be divided into on-board power requirements for communications, life support, and data acquisition and transmission, as well as to provide the power for electric propulsion. The estimated requirements for on-board power is on the order of 30 to 40 kilowatts, whereas the electric power requirement for a large electric rocket system, to propel a manned interplanetary spacecraft, may be on the order of 20 to 30 megawatts.

At the present time there are a number of developmental programs under way which will eventually provide the electric power and propulsion requirements for advanced spacecraft. Among these are the joint NASA-AEC, SNAP-8 program and NASA's thermionic conversion system research project.

Along with rocket propulsion and auxiliary power generators, other modular technologies associated with the space program will advance and their impact on the aerospace planning process will be felt. For example, the field of space electronics--specifically computers, radar, and communications--will continue, as in the past, to grow and expand at a rapid rate. Complex electronic equipment carried aboard spacecraft will have to be reduced in size, weight and power requirements, while improvements of several orders of magnitude in reliability, operating life and data rates will have to be obtained; particularly as man begins flights to the distant planets. For example, the Ranger VII spacecraft using existing communication facilities was able to transmit more than 4000 good quality pictures over the 250,000 miles from the moon to the earth. However, at planetary distances of tens or hundreds of millions of miles the information transmitting capacity of the communications link decreases drastically. According to NASA calculations, if all other factors remain constant, the capacity of a radio communication link decreases as the square of the transmission distance. This means that the Mars-to-Earth data transmission capacity of the present facilities is on the order of 1/1,000,000 of their moon-to-Earth capacity. Consequently, if the Ranger VII spacecraft had been flown to Mars, only a small fragment of one picture could have been transmitted to the earth in the time interval of approach. *

In addition, ground-based communications, tracking, and command and control equipments, which can operate for extended periods of time over ranges of hundreds of thousands and millions of miles, will continue to be developed and improved. This requirement to communicate over millions of miles with distant spacecraft or manned outposts on the planets will be matched by a requirement to communicate with intelligent beings

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* Summary Report, Future Programs Task Group, A report by the National Aeronautics and Space Administration to the President, Washington, D. C., April 1965, p.79.

living beyond the range of our solar system. If such communication were possible, its ultimate effect on our society could be profound. To meet these growing electronic requirements both DOD and NASA are supporting a significant number of electronic research projects. NASA, in particular, through its new multi-million-dollar Electronic Research Center in Cambridge, Massachusetts, will conduct both basic and developmental research on a wide range of electronic systems, subsystems and components for space applications.

The significance of this growing research effort in space electronics to aerospace planners and decision-makers is highlighted by the fact that the percentage of electronic hardware for space, purchased by the federal government has been increasing as evidenced by the fact that in 1960, 25 percent of every dollar spent in space technology was for electronics, whereas in 1965, 30 percent of every "space dollar" was spent on electronics.

As manned space flight becomes more commonplace, there will be an increased emphasis on bio-medical technology, particularly as extended lunar and planetary explorations are planned and later carried out. Of singular importance will be the development of escape and survival techniques and equipment, as well as research into the bio-medical, and psychological problems associated with man's survival in a hostile, cramped, non-terrestrial environment, for days, weeks, and months at a time.

Two bio-medical areas of primary interest for future planning purposes involve research into the effects of weightlessness on the cardiovascular and musculoskeletal systems. In addition there will be a need to develop technologies and experiments to test the effect of the space environment on the genetic effects of micro-organisms, as well as the physiological responses of animals to weightlessness. There will also be a need for further research and development of life support technology which will, for the long duration missions, make up significant percentages of the weight and volume of the spacecraft, since it provides all the things needed for men to endure the hostile environment of space, i.e., food, water, air, climate control, protective clothing and waste removal (see Fig. 5). However, developing such equipment is difficult because it is not only complex, but it must be lightweight, reliable, and fit into a small space.

The successful evolution of the space program also depends on advances in the critical area of materials technology. At the present time, the lack of proper materials is a major difficulty in the development of advanced, high-performance space systems. Currently available materials are unable to withstand all of the temperature, pressure, radiation, corrosion and the stress conditions existing in space. However, through materials research, particularly in the development and use of plastics, ceramics and refractory metals, further improvements are expected.

Eventually, by-products of these new materials will be employed in non-space activities--such as home construction--where they may compete with or displace existing materials and markets. On the other hand, space materials, reconstituted in the form of consumer products and medical equipment, can add to our comfort, convenience and health. *

Systems Technology

For the purpose of this report the space systems technology developments of interest to planners and decision-makers will be sub-divided into: 1) spacecraft systems; 2) launch systems, and; 3) operational support systems with each category including, where appropriate, both NASA and DOD programs, as well as manned and unmanned vehicles.

At the present time there are two manned and twelve unmanned spacecraft systems managed by NASA, and several types of classified DOD spacecraft managed by DOD, that are in operational use or are under development at the present time. These include such unmanned vehicles as TIROS, Ranger, Mariner and VELA, as well as the manned systems, Gemini and Apollo. This diversified family of spacecraft has supplied data on space phenomena in an area extending out from the surface of the earth

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* See NASA News Release No. 63-197, Report on Commercial Use of Space Technology, Washington, D. C., August 31, 1963.

to planets of Mars and Venus; has collected information or provided operational support in such areas as weather forecasting, communications and navigation; or has been utilized to obtain operational experience in manned orbital flight, rendezvous and bio-medical effects.

Up to the present time these manned and unmanned spacecraft have been launched by a family of first-generation launch vehicle systems including Atlas, Thor, Scout and Titan II with thrusts ranging from 90,000 to 430,000 pounds and orbital payload capabilities of 250 to 8,000 pounds.

The preflight testing, launching, controlling and recovery (where required) of these first-generation spacecraft and launch vehicles is carried out by a large and complex network of operational and logistic support systems ranging in size and importance from the Kennedy and Vandenberg Space Flight Centers, through the Manned Spacecraft Center at Houston, to the network of manned and unmanned mission tracking stations located throughout the world.

In the 1966 to 1970 time period, developments in all areas of systems technology will continue. For example, some of the existing manned and unmanned spacecraft such as Ranger and Gemini will be phased out and replaced by more advanced spacecraft such as Surveyor and Apollo. However, throughout 1966-1970 most of the existing unmanned spacecraft such as TIROS, Explorer, the Observatory Series (OAO, OGO, OSO) and Mariner will continue to be improved upon and utilized to a greater degree than is presently the case. In addition, between 1966 and 1970, spacecraft such as Voyager, Apollo and the MOL, as well as new communication and bio-satellites will emerge from development into full operational status.

Dynamic improvements in launch vehicle systems will also take place in the 1966-1970 time period. Such systems as Atlas and Titan II will be phased out to be replaced by a varied and flexible family of vehicles, including, the Saturn I and Titan III with thrusts of 1.5 million pounds to 2.5 million pounds and earth-orbit payloads of 25,000 to 30,000 pounds. Later in the 1966-1970 time period the Saturn IB and Saturn V launch vehicles will reach operational status. Saturn IB has a thrust of 1.6 million pounds and an earth-orbit payload of 35,000 pounds; the Saturn V, which will carry the first U. S. astronauts to the moon, will have a first-stage thrust of 7.5 million pounds and a low earth-orbit payload of more than 250,000 pounds.

As the number and variety of manned and unmanned spacecraft launchings increases in the 1966-1970 time period, and the primary effort of the U. S. space program focuses on the manned lunar landing, the operational support and logistics systems, such as the Manned Spacecraft Center will be concurrently expanded and improved upon. For example, Apollo ground support requirement studies have indicated that the present manned spaceflight tracking network will have to be augmented through the addition of two transportable stations as well as additional S-band equipment with

30-foot antennas. In addition, the planned extension of tracking coverage for Apollo to the lunar surface has necessitated further improvements in the existing operational ground stations as well as in the tracking ships and aircraft. This will result in a significant increase in operational support capabilities over that required for Gemini. *

In addition to the Apollo operational support networks, expansion has and will continue to be necessary in the deep space network during 1966-1970. This improved capability will include real-time, simultaneous handling of Pioneer, Surveyor, and the proposed Lunar Orbiter over communication distances ranging from 250,000 to 150 million miles. This has resulted in a need to increase command and control capabilities as well as system sensitivity. In addition, three new 210-foot diameter and two new 85-foot diameter antenna stations are under construction or planned to provide tracking support for lunar and planetary missions.

While expansion of existing ground, sea and air-based tracking stations, additional command-control and data processing units, as well as large-diameter antennas and data link requirements will be required to meet the requirements of the manned and unmanned space missions in the 1966-1970 time period, it will not be necessary to construct operational,

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* 1966 NASA Authorization, Hearings before the House Committee on Science and Astronautics, Part 1, Washington, D. C., February-April 1965, pp. 191-193.

support and logistics facilities similar to the Manned Spacecraft Center at Houston or the Merritt Island launch complex at Cape Kennedy. However, expansion within these facilities will take place during 1966-1970. However, one additional and large launching and control facility is under consideration at the present time. This new operational support facility, to be developed for the MOL program, will probably be located south of the present Western Test Range in California. *

Up to 1970, the scope and characteristics of the manned and unmanned programs in the areas of spacecraft systems, launch vehicle systems and operational support and logistics systems are essentially structured and the funds committed. Except for the effect of such critical developments as a Soviet lunar landing before 1969, most of the program and funding changes that take place between now and 1970 will be relatively minor.

Beyond 1970, the specific goals and funding decisions relative to the national space program have yet to be made. However, based upon studies and proposals for post-1970 space goals and considering the broad and flexible base of hardware systems and operational capabilities that have been built up since 1958, it appears that the following post-1970 developments are possible.

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* Manned Orbiting Laboratory, Hearings before the Senate Committee on Aeronautical and Space Sciences, Washington, D. C., February 1966.

For example, in the area of manned spacecraft systems for the post-1970 time period, the following types have been proposed: A large manned space station based on the combined technology and operational experience of the Gemini, Apollo and MOL. Launched into low-earth or high-synchronous orbit, the space station could have a number of missions, including, weather observation, communications and navigation as well as oceanographic, natural resources and bio-medical research. It could also serve as a training and logistics support station for orbital assembly, lunar and planetary missions. The modules for the space station will probably be developed from Apollo and MOL hardware, with a supporting earth-to-orbit ferry system based on Gemini, Apollo or a new lifting vehicle developed from the current M-2 or HL-10 configurations.

It is also possible, to maximize cost/effectiveness, that the space station and the first manned planetary spacecraft will be developed from common modules with the space station configuration serving as a realistic training base for the later manned planetary mission. In addition, other spacecraft may be developed in the post-1970 time period; these could include a direct earth-to-lunar surface logistics vehicle and a temporary station on the lunar surface, both based on Apollo-LEM hardware.

It is also possible that the late post-1970 time period will see the development of a manned planetary vehicle for the exploration of Mars.

Because of the mission requirements in terms of propulsion, time, velocity, fuel, and life support equipment, this vehicle could be a radically new design which, unlike other post-1970 manned systems, will incorporate a minimum of Apollo hardware. In addition to the basic vehicle, the manned Mars mission will require the development of advanced nuclear propulsion modules, life support systems and long-life auxiliary power packages.

The post-1970 period could also see the development of a winged hypersonic vehicle that would be neither aircraft nor spacecraft, but a combination of both. This system would travel at speeds of Mach 6-8 and have global ranges in and on the outer limits of the earth's atmosphere. Variations of this design could be used as a reuseable first-stage booster or an orbital transport for advanced manned missions. Since this vehicle could be employed for a variety of non-military and military missions, in both the earth's atmosphere and in space, it would have a good cost/effectiveness ratio,based on considerations of economics, mission versatility and operational flexibility.

In the unmanned spacecraft area, the emphasis in the post-1970 period will continue to be on improving existing capabilities, or developing new capabilities, where necessary, in the areas of application satellites, i.e., communications (particularly synchronous TV satellites) navigation and weather observation; as well as exploratory vehicles such as the OAO, OGO, OSO series and the Pioneer, Explorer, Mariner and Voyager series. As with manned space flight, these vehicles will be used to the maximum with new hardware developed only where mission requirements cannot be met with existing capabilities, as may be the case for fly-by missions to the distant planets, e.g., Jupiter, or the asteroid belt.

In the manned, military spacecraft area the emphasis in the post-1970 period should be on improving and developing the MOL system into a larger and fully operational military space station with multi-mission capability. It is also possible that a manned spacecraft based upon current hypersonic lifting vehicle research (e.g., Scramjet) may be developed in the post-1970 period, for military missions in space.

The unmanned spacecraft requirements for military space missions in the post-1970 period will be met by synchronous communications satellites, navigation and meteorological satellites for military forces, as well as early warning, reconnaissance and anti-satellite systems. However, it is possible that some, if not all of these missions and functions could be incorporated into a larger version of the MOL in the 1970's; consequently, a need for specialized unmanned military space systems could be substantially reduced or eliminated.

It should be emphasized, however, that specific and more detailed definitions of military spacecraft requirements beyond this level cannot be made. This has been noted by Dr. Harold Brown, Secretary of the Air Force. In a statement before a Senate Committee in 1965, Dr. Brown said:

> I know that you appreciate the difficulty in precisely forecasting a "real world" of the 1975-85 era upon which to base any firm space system planning factors. We recognize that not all the space system concepts we are studying today are, as yet, technically feasible as well as economically or operationally sensible. We continue to weigh potential threats in an attempt to determine the spectrum of potential future military needs. I like to refer to this continuing effort as the definition of a set of building blocks for future military capability with a two-pronged emphasis--operational effectiveness and economic realism. *

As for the post-1970 launch vehicle systems (for both manned and unmanned missions) they will probably be off-the-shelf versions of Saturn IB, Tital III and Saturn V, employed to launch both DOD and NASA spacecraft into low, and high synchronous earth and lunar orbits, as well as to the surface of the moon, to the planets, and into deep space. Later in the post-1970 time period (1975-1980) advanced versions of Saturn IB and V with high energy or nuclear upper stages will be required for high payload earth orbital, lunar and planetary flights. In addition, a reuseable launch system, which could evolve from current hypersonic vehicle research, may be required for more advanced earth orbit, ferry and space rescue missions, as well as a radically new planetary fly-by landing vehicle

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* National Space Goals for Post-Apollo Period, Hearings before the Senate Committee on Aeronautical and Space Sciences, Washington, D. C., August 1965, p. 314.

which could be used to carry manned expeditions to Mars and Venus. * This system, with an earth-orbit weight of several million pounds would most likely be assembled in earth orbit with the individual spacecraft modules launched into the assembly area by an advanced Saturn V.

When the launch vehicle development program reaches a point where a single booster can place 500,000 pounds into orbit, the requirement for large chemical booster systems will taper off. From that point on orbital payload requirements in excess of 500,000 pounds will probably be met by multiple launchings and assembly in orbit.

DOD requirements for launch vehicles in the post-1970 time period will probably be met by advanced versions of the Titan III-C, a system with sufficient growth potential to provide the capability for delivering 30,000 to 50,000 pound payloads, both manned and unmanned, into space throughout the 1970's. Any additional payload requirements for advanced military missions could be met by multiple launchings and assembly in earth orbit, or by the use of larger higher-thrust, solid fuel strap-on rockets, such as the 156 inch solid engine now under development. It is also possible that DOD may require a reusable booster for post-1970 manned and unmanned missions. This vehicle, possibly based on Scramjet developments, could be used where repetitive launchings of military spacecraft are necessary.

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* NASA Authorization for Fiscal Year 1967, Hearings before Senate Committee on Aeronautical and Space Sciences, Washington, D. C., February-March 1966, p. 259.

In the post-1970 time period, if the planned evolution of manned and unmanned spacecraft and launch vehicles takes place, and new programs such as the large manned space station, the lunar base and manned planetary exploration, as well as an advanced MOL are initiated, significant expansion and orders-of-magnitude improvements in the existing, operational and logistic support system area will have to take place. In addition, new operational support systems may have to be developed to meet the advanced mission requirements.

For example expansion of the launch and test facilities at the Eastern and Western Test Ranges may be required, or an entirely new launch facility may have to be built on one of the mid-pacific islands, particularly if nuclear powered launch vehicles or upper stages are developed. In addition, the existing facilities at the Manned Spaceflight Center at Houston will have to be expanded in size and capability particularly in the areas of command and control, data handling and display capabilities to support extensive lunar and planetary operations. To support the large manned space station, the lunar base and the manned Mars expedition, significant increases in the command-control, data handling and sensitivity capabilities of the current deep space and manned spaceflight network will also be required. In fact a merger of the current manned tracking and deep space networks into a single system in the post-1970 time period is possible.

To handle the increased spacecraft traffic of the post-1970's in terms of launch, control and recovery operations, additional capabilities will be required at the Eastern and Western Test Ranges, as well as in the tracking and recovery stations around the world, particularly as launches and recoveries of both manned and unmanned vehicles increase and become more numerous and repetitive. The conduct of space rescue logistics supply and crew replacement operations between earth and a manned space station or earth and a lunar base will also impose additional requirements on existing ground-based support facilities.

The post-1970-1980 time period will probably see the development of large-scale operational support and logistics facilities in space or on the lunar surface. These new and unique facilities could serve as supplementary launch, tracking, recovery and re-entry stations; as space repair and rescue facilities; or as stage areas for major planetary and lunar operations. As such, these space-base facilities would perform some of the tasks currently carried out at the present earth-based launching, recovery and control centers.

THE NATIONAL SPACE BUDGET

Another significant factor to consider in any aerospace planning activity is the annual federal space budget; including the total appropriation, the specific amounts allocated to N ASA and to DOD, and the expenditures for individual programs. In addition, to being the prime economic indicator of this country's commitment to space exploration the national space budget is a positive indicator of the relative "political" strength of those agencies that have presented their program and dollar requirements to the Legislative and Executive branches of government.

In a total sense, however, the federal appropriations for space technology are a reflection of: 1) U. S. national policies and objectives; 2) the Soviet techno-military threat; and 3) specific military and/or scientific requirements. In addition to these factors, the national space budget is molded by decisions and actions taken in Congress, the Executive Branch, the government agencies, the scientific community and private industry.

Once enacted, the space budget can affect the organizational structure of the relevant federal agencies as well as the relationships between the federal government and private industry. For example, the increasing amounts of money spent on space since 1957 have been a factor, along with the nation's reaction to Soviet space accomplishments, in the growth of new agencies such as NASA, as well as in the de-emphasis or assimilation of others such as NACA (National Advisory Committee for Aeronautics) and ABMA (Army Ballistics Missile Agency). In addition, the fact that non-military space programs have received higher percentages of the national budget than their military counterparts, has had both direct and indirect effects upon the organizational relationship between NASA, DOD and the Air Force. Moreover, between 1957 and 1963 the trend in government spending, from aircraft to missiles, and then to space systems, has also changed the basic character of the aerospace industry, as well as the management, personnel skills, and product mix of specific corporations.

One such company whose growth and current organizational structure is, in part, due to variations in federal aerospace spending since 1957 is the Martin Corporation. For example, in the period between 1956 and 1960, the company de-emphasized its aircraft engineering and production operations at Baltimore and built new missile and space system facilities in Denver, Colorado, and Orlando, Florida, to keep pace with actual and anticipated changes in federal spending. Later, Martin modified its organization, its management and engineering staffs, as well as its operational policies in response to increased federal spending for space technology--by merging with the American-Marietta Company and setting up a separate division to provide centralized management of the company's space programs. *

* For more details on the organization of, and the planning within the Martin-Marietta Corporation, see "Corporate Horizon," <u>Wall Street Journal</u>, October 10, 1961.

Another prime example of a company that modified its orgainzation and product line in response to federal space expenditures is North American Aviation Incorporated. Their rapid transition from a prime manufacturer of military aircraft in 1957 to the top space systems contractor in the early 1960's is evidence of this.

In addition to its effect on government-industrial organizations and relationships, a decision to increase or decrease total federal space budgets, or specific portions thereof, affects the planning, the direction, and, in some cases, the very survivability of specific space projects and programs. For example, on May 25, 1961, when the late President Kennedy established a national goal to place men on the moon before 1970, the fiscal and legislative machinery of the U. S. government was set in motion, a supplemental appropriation of $549 million was added to our space effort, and a re-examination of NASA's man-in-space program was initiated. Subsequently, the time schedules, budget priorities, and the management of such projects as Gemini, Apollo, and Saturn were significantly modified. *

Later, on December 10, 1963, the DOD decision to cancel the multi-million dollar Dynasoar project and the related funds, not only had a direct economic effect on the prime contractor, Boeing, but on several hundred associated companies. Subsequently, a new DOD project, the Manned

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* Some of the program changes initiated after President Kennedy's speech of May 25, 1961, are detailed in 1962 NASA Authorization, Hearings before the House Committee on Science and Astronautics, Part 3, July 1961, pp. 1036-1060.

Orbital Laboratory (MOL), was initiated and additional emphasis placed on an accelerated Gemini project; but different funds, organizations and companies, than those associated with Dynasoar, were now involved.

An examination of the history of the federal space budget illustrates its significance in terms of total dollars appropriated. For example, in 1957-- the first years of the space age--only $179 million was appropriated for all space programs. In 1958, following the launching of the Soviet Sputniks, the total national space budget was increased to $348 million; in 1960 it exceeded $1 billion; and by 1962, the total federal appropriations for space had risen to approximately $3.3 billion, whereas Congress approved a total of $5.5 billion for various federal space programs in 1963. Since 1963, the national space budget has risen to its present level of $7 billion. (Fig. 7).

It is significant that of the total amounts appropriated for space in the 1958 through 1966 time period, NASA's share increased from $117 million or 34 per cent of the total federal space budget, to approximately $5.2 billion or 74 per cent of the FSB. In the same time period, the DOD portion of the federal space budget also increased from approximately $206 million to $1.7 billion. However, on a percentage-of-total basis, the DOD space appropriations decreased during the 1958-1966 time period from 60 to 24 per cent of the FSB. *

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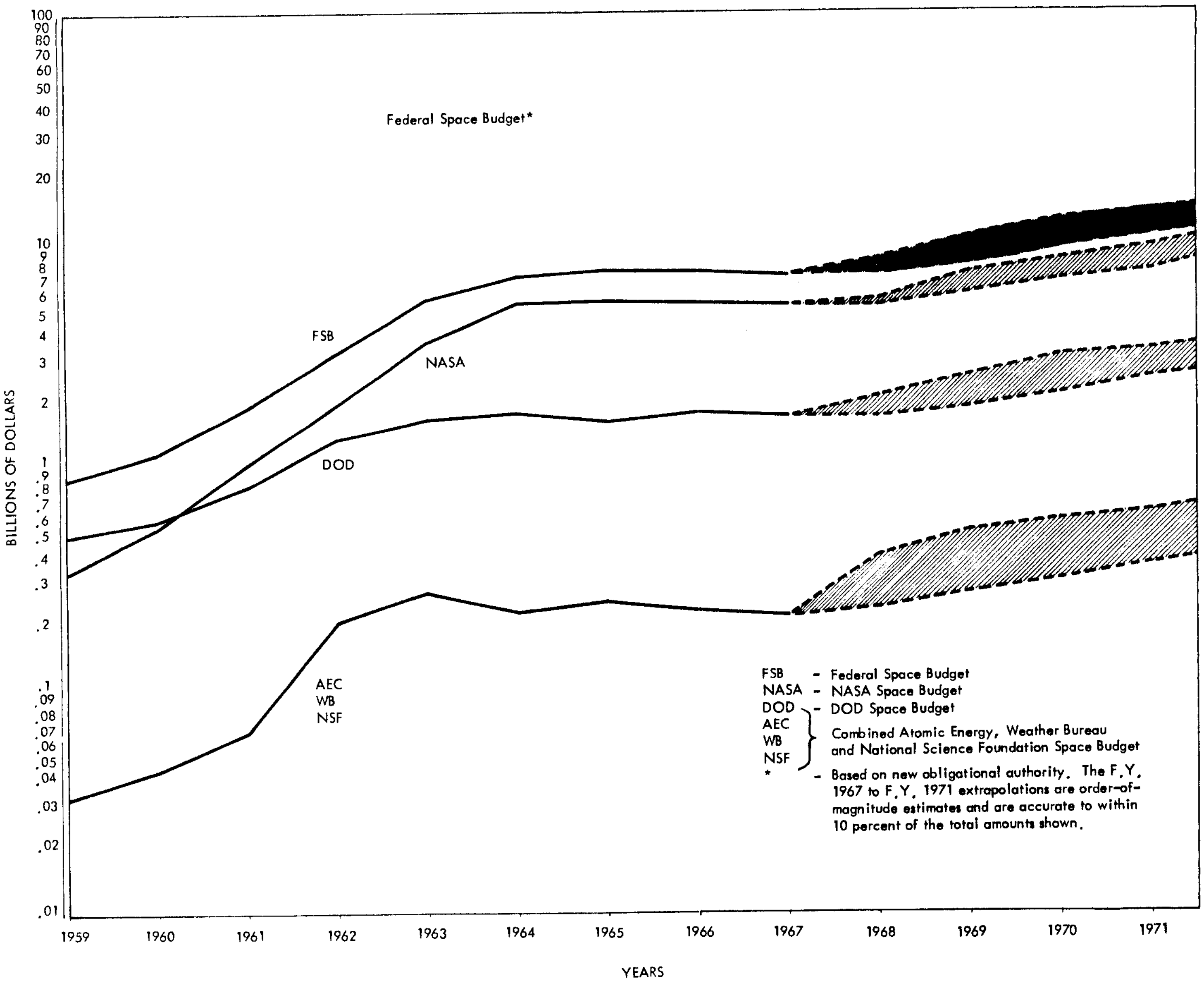
* See NASA Authorizations for Fiscal Years 1960 through 1967 Eight Reports to the Senate Committee on Aeronautical and Space Sciences, Washington D.C.



Federal Space Budget*
FSB
NASA
DOD
AEC
WB
NSF
BILLIONS OF DOLLARS
100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2 1 .9 .8 .7 .6 .5 .4 .3 .2 .1 .09 .08 .07 .06 .05 .04 .03 .02 .01
1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971
YEARS
FSB - Federal Space Budget
NASA - NASA Space Budget
DOD - DOD Space Budget
AEC, WB, NSF - Combined Atomic Energy, Weather Bureau and National Science Foundation Space Budget
* - Based on new obligational authority. The F.Y. 1967 to F.Y. 1971 extrapolations are order-of-magnitude estimates and are accurate to within 10 percent of the total amounts shown.

Figure 7

As for future budgetary levels it is possible that a variety of factors, including domestic issues, a further escalation of the war in Vietnam, or a shift in federal spending to other national problem areas such as transportation and water pollution will keep the national space budget at a $7-billion level or even reduce it somewhat. Other factors of interest to aerospace planners and decision-makers may tend to keep the space budget for 1967-1970 at current levels. Some of these factors are directly related to the inherent operational and technical characteristics of the space program itself. For example, the 1957-1965 period was characterized by a race to catch up with or match the Soviet Union in space accomplishments. Consequently, boosters, spacecraft and launch facilities had to be built, government agencies had to be created or consolidated, new industrial enterprises developed, test and support facilities expanded or constructed, and thousands of scientists, engineers and technicians recruited, transferred and moved from one locality to another. As a consequence the federal expenditures for space between 1957 and the present rose at a geometric rate.

However, there are strong indications that the period of rapid and concurrent building of a varied technological and operational base is leveling off and the space program is entering a period where the requirement will be for reliable and repetitive launchings of existing boosters and spacecraft, and the maximum use of current launch, control and recovery facilities as well as on-the-shelf hardware that can now be used for a multiplicity of purposes rather than a single, one shot purpose. As a consequence, the period between now and 1970 may be characterized by a more efficient and less costly use of space resources.

In addition, federal space budgets could remain at current levels through 1970 as a result of a continuation and possible further escalation of the Vietnamese war, a factor that space-age managers in government and industry will have to take into consideration in their planning activities. If the war continues and the U. S. commitment increases significantly, federal space spending will very likely remain at the current $7 billion level, or may even be reduced. There are indications, for example, that the MOL program funding and schedule have been affected by the war in Vietnam.

Finally, federal space budgets may hold at current levels owing to increased government spending on other critical national problems such as transportation and water pollution. These budgetary actions may be promoted not only by the critical nature of these "new" problems, but as a result of the widespread use of the new federal Planning-Programming-Budgeting System, which will be employed as a decision-making device by the President to compare the space program requirements and budget with such things as the national transportation, education, housing and defense requirements. With such across the board comparisons of major national programs, it is possible that money and effort intended for space research will go elsewhere.

However, there are a number of developments which could take place between 1966 and 1970 which could result in an increase in the total annual space budgets, above the current $7 billion level. * For example, it is very possible that a continuing series of Soviet space "spectaculars", such as a manned cislunar flight, the construction of a space station in earth orbit or a lunar landing (all of which are technologically possible before 1970), could result in demands to step up and/or supplement the current space programs and thus lead to further increases in annual space appropriations above the $7 billion level. This would certainly occur if Congress approved one or more of the proposed post-Apollo programs, i.e., the lunar base, the manned space station or manned planetary exploration.

While it is possible that the rising cost of the Vietnamese war as well as the need to solve other pressing domestic problems may cause shifts in federal spending away from space research, it is equally possible that the war effort may level off or peace negotiations could be initiated before 1970; consequently, some of the public and private resources currently supporting the war effort would be available for additional space research.

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* For a discussion of federal space expenditures and some of the factors that do or could influence federal space expenditures, see Leavitt, William, "Speaking of Space," Air Force and Space Digest, April 1966.

Moreover, while increased federal spending in other domestic problem areas such as transportation, urban planning and water polution will place between 1966 and 1970, there appears to be no critical economic reasons (assuming continued growth of the GNP) that current space budget levels could not be increased. (See Figs. 7 and 8).

Other factors which could push the federal appropriations for space above $7 billion in the post-1965 time period are the technical and economic unknowns in our own space program. For example, there has been a tendency in this country to underestimate the final costs of missile and space programs, particularly when the increased costs are a result of new technological developments or management difficulties that often emerge downstream in any complex project. To illustrate, the initial estimate of the cost of the Vanguard project was $20 to $30 million; however, before it was complete, Vanguard cost over $100 million. Another example of cost over-runs is found in Project Mercury. The cost of this program was originally estimated at $200 million; the final cost was over $400 million. Also, there is evidence that technical and management difficulties in the Centaur and Gemini programs have resulted in higher-than-anticipated program costs. * Some of these increased expenditures result from management problems or changes in program priorities and schedules, while other

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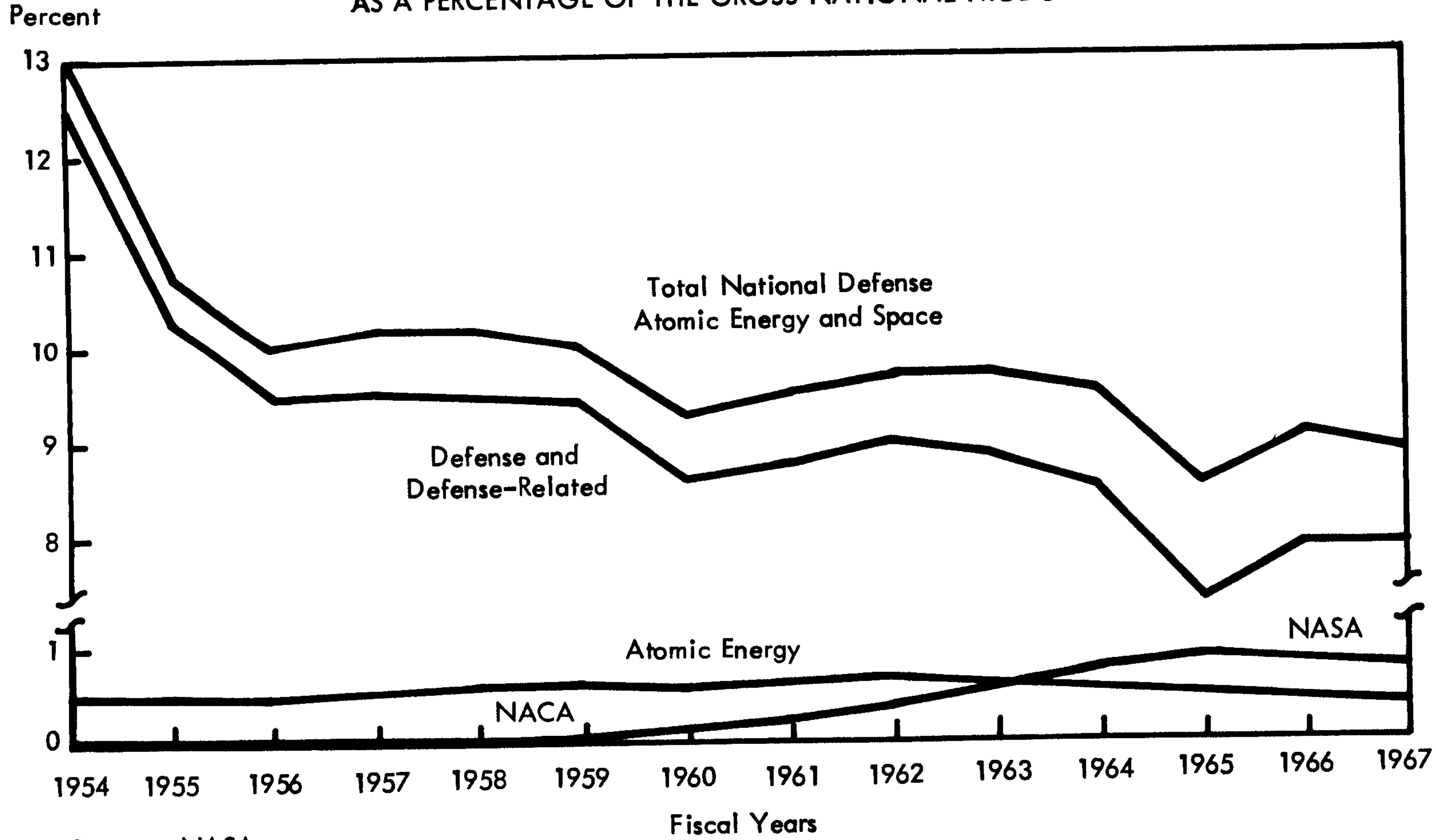
* See Centaur Launch Vehicle Development Program, House Committee on Science and Astronautics, July 1962, p. 11.

FEDERAL EXPENDITURES
DEFENSE, ATOMIC ENERGY, AND SPACE
AS A PERCENTAGE OF THE GROSS NATIONAL PRODUCT



Source: NASA

Figure 8

increased costs are a result of our attempts to quickly match Soviet space accomplishments, or unforseen, but costly technical modifications downstream in a given program.

All of the evidence we have to date indicates that similar factors will probably continue to increase the federal space budget above present levels throughout the 1966-1970 time period; in spite of strong efforts by NASA, DOD and industry to keep such costs from rising.

Finally, another development which could lead to increased federal spending for space is the appearance of a distinct military space threat. This would lead to supplementary expenditures for a series of manned military vehicles based on Gemini, MOL and/or Apollo, which in turn would lead to new requirements and increased expenditures for ground installations, including command and control systems. *

Therefore, on the basis of evolving and currently unforeseen program requirements, coupled with the effect of the Soviet space developments and/or military threats, it is possible that the total federal space budget could rise from the current $7 billion plateau to as much as $13 billion by 1970. This budgetary increase is certain to occur if we get firm evidence that the Russians are going to beat us to the moon.

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*See Missiles and Rockets, Vol. II (1962), p. 32 for statement on aerospace command and control requirements by General Charles H. Terhune, former Commander, Air Force Electronic Systems Division, AFSC.

SPACE MANPOWER AND FACILITY RESOURCES

Manpower and facilities, coupled to the available monies, are the primary resources employed to carry out the national space program, and consequently are an important consideration in any space-age planning and decision-making activity. As was noted previously, the current U. S. space effort employs close to 500 thousand people * and involves ten major government agencies, approximately 100 large corporations, several thousand medium and small companies, and roughly 200 universities and non-profit institutes.

In many ways the manpower and facilities employed in the space effort are unique in the sense that in their impact on our national life, as well as in their skills and design they are unlike those found in the automobile, steel and chemical industries. Some of the unique characteristics of the manpower utilized in the space program, were noted in a book prepared by the editors of Fortune Magazine. They stated:

> The space effort is the first para-military effort in history not accompanied by a demand for heavy hardware and mass-produced materials. Its great demand, instead, is for professional people and it may relatively soon employ up to a million. Since more and more money will go into manpower, particularly engineers and other technical specialists, the

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* Estimate includes industrial, government, and university personnel.

coordinating their space planning, budgeting and program management activities. On the whole, these working arrangements, which have slowly and painfully evolved, have reduced much of the duplication and overlap between our military and non-military space activities and have improved the overall management and organization of our national space program since it was first initiated in 1958.

At the onset of the space age, the United States did not have an organized space program. Up to that time the federal government had been supporting a number of independent research projects with little or no inter-project coordination or management control.

After Sputnik I, the U. S. space program began to gather momentum and the need for closer coordination and administrative control became more apparent. In an attempt to meet this requirement, the Advanced Research Projects Agency (ARPA) was established within the Department of Defense and given the prime responsibility for managing the various U. S. space programs, as well as the development of advanced weapons. * This was the first and only time that the national space effort was administered by a single agency. By the end of 1957, however, the U. S. reaction to

* Department of Defense News Release, No. 109-58, DOD, Office of Public Information, Washington, D. C., February 7, 1958.

Sputnik I had reached the crisis level and there were demands made and proposals put forth to restructure the nation's space effort to meet the Soviet challenge. Consequently, on October 1, 1958, another and major reorganization took place; the responsibility for the peaceful, non-military aspects of our space program was officially given to the National Aeronautics and Space Administration, and such projects as Mercury, Vanguard, meteorological and communication satellites, and lunar probes--including some of the related funds and personnel--were gradually transferred from ARPA to the new agency. However, ARPA, in concert with the Air Force, Navy and Army, continued to manage military reconnaissance, navigation and communication satellite projects.

Since ARPA and NASA were relatively new agencies, and because they were trying to manage a dynamic and complex technology, it was not possible for either agency to clearly delineate its responsibilities, missions, and program requirements--or to define areas for cooperation and coordination. As a consequence, inter-agency conflicts arose over program management, budgets, missions, and technical requirements. *

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* For a more detailed discussion of the organizational problems in the space program, see: <u>Government Organization for Space Activities</u>, Senate Committee on Aeronautical and Space Sciences, Washington, D. C., August 25, 1959, and <u>Organization and Management of Missile Programs</u>, Report of the House Committee on Government Operations, Washington, D. C., September 2, 1959.

On September 18, 1959, the Department of Defense carried out another reorganization of its space program; ARPA continued to be responsible for missile defense and other special research projects, but its prime role in space was downgraded. For example, ARPA turned over responsibility for certain military satellites to the Air Force; Project Transit went to the Navy; and Project Notus, i.e., Advent, became the Army's responsibility. * Rather than improving inter-agency coordination, a further deterioration in space program management and control resulted as each agency attempted to establish its own space effort. This situation continued until January 1961, when, after several months of study, the Ad Hoc Committee on Space, a group appointed by then President-elect Kennedy and headed by Dr. Jerome Wiesner, found that under the current management concept, "each of the military services has begun to create its own independent space program. This presents the problem of overlapping programs and duplication of the work of NASA." Therefore, the Wiesner Committee recommended that the President should: "establish a single responsibility within the military establishments for managing the military portion of the space program". **

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* The military communications satellite program is currently a Defense Communication Agency responsibility, with Army, Navy and Air Force participation.

** Defense Space Interests, Hearings before the House Committee on Science and Astronautics, Washington, D. C., March 1961, p. 19 & 23.

This report was followed on March 6, 1961, by a DOD directive from Defense Secretary McNamara which stated:

> Each of the military services is authorized to conduct preliminary research to develop new ways of using space technology to perform its assigned function within the limitations to be fixed by the Director of Defense Research and Engineering. When these studies result in proposals for research and development projects, the military services will submit the proposals for research and development to the Director of Defense Research and Engineering who will recommend to the Secretary those proposals which he believes should be developed. Upon approval of the project by the Secretary of Defense, the management of further research and development of the project will become the responsibility of the Department of the Air Force, unless in the opinion of the Secretary or Deputy Secretary of Defense, unusual circumstances justify assignment of the particular project to another Service. *

To a degree, the McNamara directive enhanced the status and responsibility of the Air Force, as DOD's "space agent"; however, the overall decision-making responsibility, and budgetary control for military space programs, remained with the Department of Defense. Moreover, the directive triggered a series of executive actions, organizational re-alignments, and program changes which brought the National Aeronautics and Space Administration and the Department of Defense into very close agreement on national space policy, and led to improvements in both NASA and DOD planning, budgeting and staffing, and in overall management of the separate, as well as joint U. S. space efforts.

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* Department of Defense News Release, No. 196-61, DOD, Office of Public Affairs, Washington, D. C., March 8, 1961.

The next major reorganization of the national space program occurred in the summer and fall of 1961, after the flight of Yuri Gagarin in Vostok I and following President Kennedy's speech to Congress on Urgent National Needs. This time, most of the reorganizational activity centered on the National Aeronautics and Space Administration.* In the main, this involved the creation, within NASA, of an Office of Manned Space Flight, the establishment of a Manned Spacecraft Center at Houston, Texas, and a centralization of the lunar landing program under a single director. In turn, these organizational changes within NASA had immediate and long-term impacts on both government and industrial managers, in particular, on the decisions they had to make to bring their respective organizations into phase with the new NASA program structure.

In addition to the changes in NASA's organizational structure, the National Aeronautics and Space Council, Presidential advisory group, and the Aeronautics and Astronautics Coordinating Board** established joint NASA-DOD guidelines for the development and utilization of launch vehicles, spacecraft, ground instrumentation and facilities, as well as the conduct of research in specialized technological areas. Later, DOD and NASA agreed to exchange and coordinate their five year plans for budget, technology and scheduling concurrence, and adopted a common PERT/Cost program.

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* See Figure 9 for pre-1961 NASA organization.

** See Systems Development and Management, Part 5, Hearings before the House Committee on Government Operations, Washington, D.C., August 1962, p. 1926-1949.

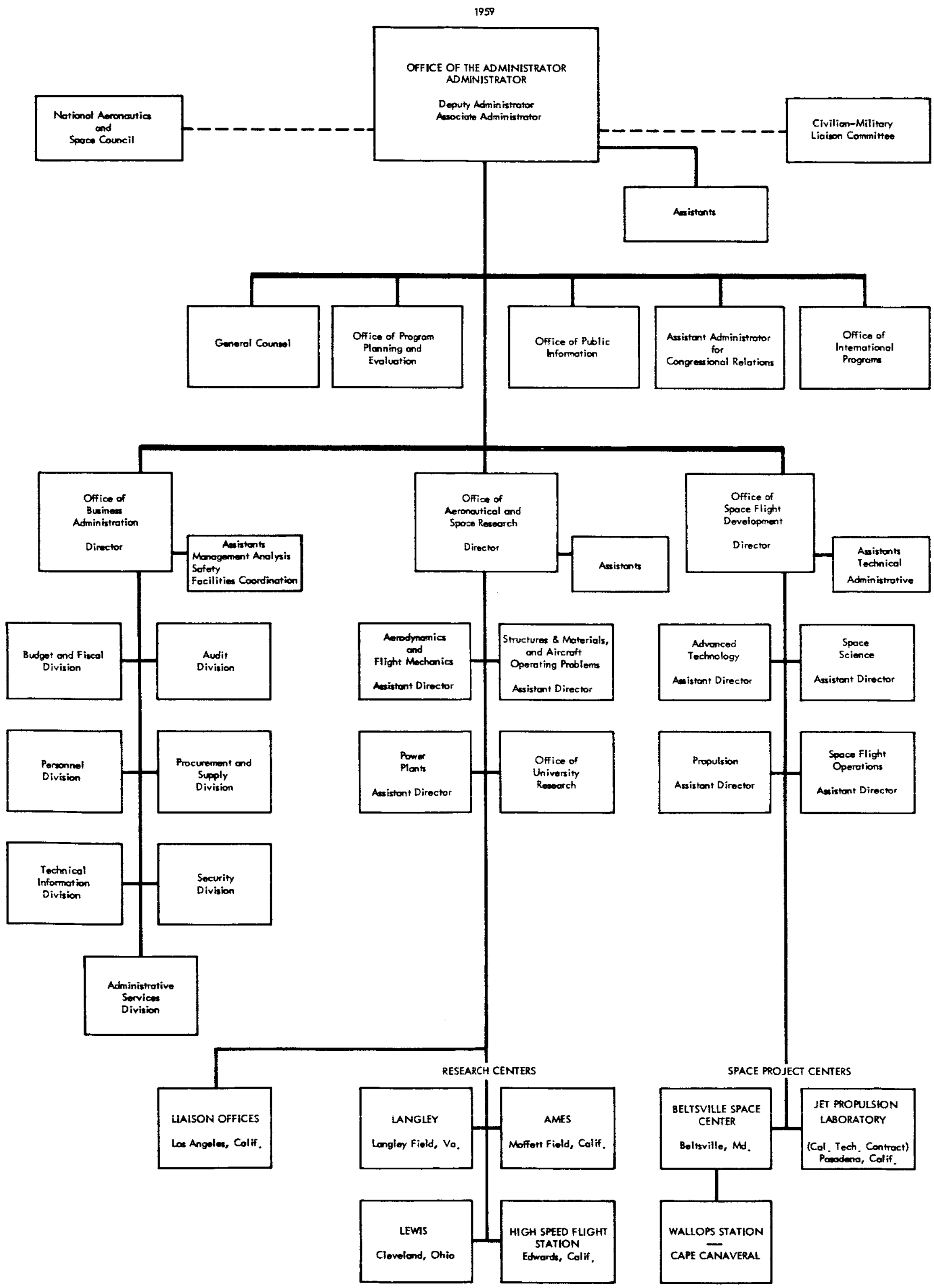
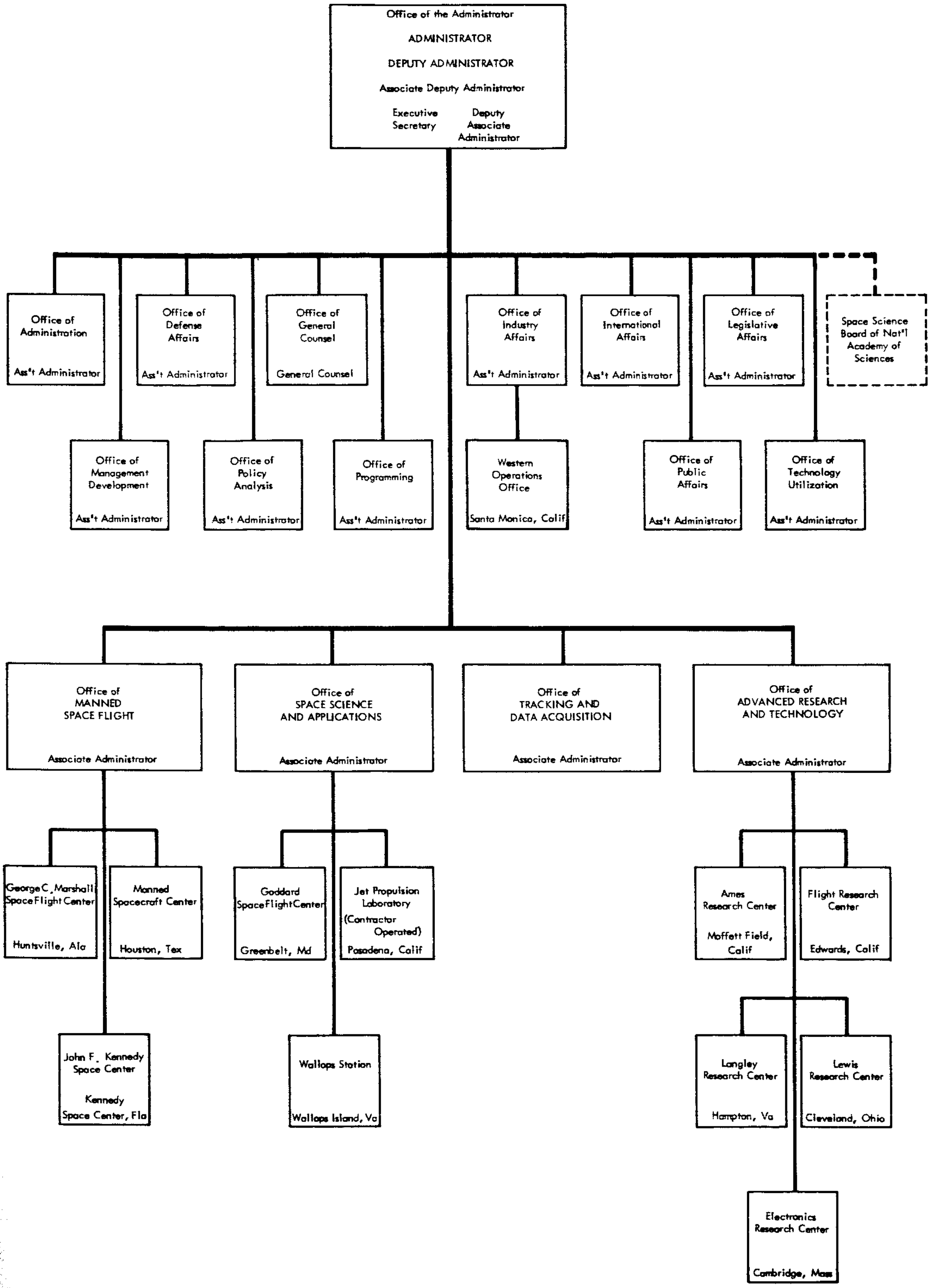

1959
OFFICE OF THE ADMINISTRATOR
ADMINISTRATOR
Deputy Administrator
Associate Administrator
National Aeronautics and Space Council
Civilian-Military Liaison Committee
Assistants
General Counsel
Office of Program Planning and Evaluation
Office of Public Information
Assistant Administrator for Congressional Relations
Office of International Programs
Office of Business Administration
Director
Assistants
Management Analysis
Safety
Facilities Coordination
Office of Aeronautical and Space Research
Director
Assistants
Office of Space Flight Development
Director
Assistants
Technical
Administrative
Budget and Fiscal Division
Audit Division
Personnel Division
Procurement and Supply Division
Technical Information Division
Security Division
Administrative Services Division
Aerodynamics and Flight Mechanics
Assistant Director
Structures & Materials, and Aircraft Operating Problems
Assistant Director
Power Plants
Assistant Director
Office of University Research
Advanced Technology
Assistant Director
Space Science
Assistant Director
Propulsion
Assistant Director
Space Flight Operations
Assistant Director
RESEARCH CENTERS
SPACE PROJECT CENTERS
LIAISON OFFICES
Los Angeles, Calif.
LANGLEY
Langley Field, Va.
AMES
Moffett Field, Calif.
LEWIS
Cleveland, Ohio
HIGH SPEED FLIGHT STATION
Edwards, Calif.
BELTSVILLE SPACE CENTER
Beltsville, Md.
JET PROPULSION LABORATORY
(Cal. Tech. Contract)
Pasadena, Calif.
WALLOPS STATION
CAPE CANAVERAL

Figure 9

9 0

1966


Office of the Administrator
ADMINISTRATOR
DEPUTY ADMINISTRATOR
Associate Deputy Administrator
Executive Secretary
Deputy Associate Administrator
Office of Administration
Ass't Administrator
Office of Defense Affairs
Ass't Administrator
Office of General Counsel
General Counsel
Office of Industry Affairs
Ass't Administrator
Office of International Affairs
Ass't Administrator
Office of Legislative Affairs
Ass't Administrator
Space Science Board of Nat'l Academy of Sciences
Office of Management Development
Ass't Administrator
Office of Policy Analysis
Ass't Administrator
Office of Programming
Ass't Administrator
Western Operations Office
Santa Monica, Calif
Office of Public Affairs
Ass't Administrator
Office of Technology Utilization
Ass't Administrator
Office of MANNED SPACE FLIGHT
Associate Administrator
Office of SPACE SCIENCE AND APPLICATIONS
Associate Administrator
Office of TRACKING AND DATA ACQUISITION
Associate Administrator
Office of ADVANCED RESEARCH AND TECHNOLOGY
Associate Administrator
George C. Marshall Space Flight Center
Huntsville, Ala
Manned Spacecraft Center
Houston, Tex
John F. Kennedy Space Center
Kennedy Space Center, Fla
Goddard Space Flight Center
Greenbelt, Md
Jet Propulsion Laboratory (Contractor Operated)
Pasadena, Calif
Wallops Station
Wallops Island, Va
Ames Research Center
Moffett Field, Calif
Flight Research Center
Edwards, Calif
Langley Research Center
Hampton, Va
Lewis Research Center
Cleveland, Ohio
Electronics Research Center
Cambridge, Mass

To further consolidate and strengthen the nation's space effort, NASA and the Department of Defense, operating through DOD's agent, the Air Force System Command, established in May and June 1962, a management group at NASA Headquarters to coordinate the manned space flight program. A few months later, on November 22, 1962, NASA announced the appointment of Admiral Walter F. Boone (Retired) to the newly created post of Deputy Associate Administrator for Defense Affairs. NASA said Boone's job would be to strengthen the flow of technical and management information between NASA and the Department of Defense.

Late in 1963, NASA went through another major reorganization. As described in a report by the House Committee on Government Operations, this involved the program offices' returning to the status of line agencies, with the different field centers and installations reporting directly to them instead of to top management. * At the same time the program office directors were elevated to Associate Administrators. Reporting to the Associate Administrator for Manned Space Flight were the Marshall Space Flight Center at Huntsville, Alabama; the Manned Spacecraft Center at Houston, Texas; and the Launch Operations Center in Florida. The Office of Space Sciences and the Office of Applications were merged into one, and reporting to the new Associate Administrator for Space Science and Applications were the

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* Govt. Operations in Space, p. 75.

Goddard Space Flight Center in Maryland, the Pacific Launch Operations Office in California, the Wallops Station in Virginia, and the Jet Propulsion Laboratory in California. Advanced research and technology also was placed in the charge of an Associate Administrator, supervising the old NACA research centers of Ames, Langley, Lewis, and Edwards.

This re-alignment of the various centers responded to a growing emphasis on specific project management. For example, under the new arrangement the Marshall Center would concentrate primarily on the development of the Saturn family of launch vehicles, whereas the Manned Spacecraft Center in Houston would concentrate on capsule development and astronaut training for the Gemini and Apollo programs. The Goddard Center, however, would not only engage in applications development, but also manage the work directed by the separate Office of Tracking and Data Acquisition. Nevertheless, while some overlap still existed between centers and center activities, the new arrangement "contributed to the unification of resources and activities needed to achieve success on particular projects."

These organizational changes did not diminish the authority of NASA's top management: in fact, under the 1963 reorganization, the overall management staffing at NASA headquarters was strengthened, specifically in the administrative areas of programming, budgeting, policy planning, liaison, and contracting.

As with Nasa, the Department of Defense had similar management problems that came to the surface in 1962-1963. In DOD's case, however, the issues involved not only project management but the question of the military's role in space. Furthermore, the high costs and management difficulties involved in developing new technologies, as well as the problem of costly duplication between NASA and DOD space projects were also involved.

As noted in a recent Congressional Report, "The competition with NASA had become a bedeviling problem for the Defense Department by 1963, particularly where the area of manned space was involved. It was over the question of the military role of man in space that the (Defense) Secretary and the Air Force were sharply divided. Faced with the probable cancellation of Dynasoar, the Air Force was seriously concerned that there would be no such role. The concern was heightened by the equally dim prospects for future manned bombers now that the B-70 project had been cut back and the Skybolt cancelled in late 1962. Moreover, reliance on missiles also reduced the manned role, and in the area of ballistic missiles, development was coming to a close.

"This concern of the Air Force was not restricted to doctrinal abstractions about the role of military man in space nor to the problem of a diminishing workload and resource base. Air Force planners seriously considered that manned space flight held out important military promise, not only to counter Soviet developments and potentially hostile spacecrafts, but also to enhance certain existing military missions, such as reconnaissance, intelligence, command and control, electronics countermeasures, detection, and bombardment. The job of bombardment had been withdrawn from the mission of Dynasoar. Questioning the feasibility of an orbital or other space bombardment system as compared with missiles and desirous of avoiding an arms race in space, the Administration announced that the United States did not intend to orbit weapons of mass destruction in space. Later statements of the same kind by the Soviets finally resulted in a mutual policy position, given international recognition in the United Nations." *

"The Air Force, however, was unwilling to rely completely on NASA. Recognizing that NASA's efforts would contribute to needed basic technology, the Air Force still did not believe that certain techniques of systems would be developed by NASA. Consequently, the Air Force submitted a number of manned space projects to the top review levels of the Department throughout 1962 and 1963. All of these plans, manned orbital development system (MODS), Blue Gemini and the like, were returned to the Air Force for more analysis and definition. Defense officials sympathized with Air Force concern but under the prevailing policies of restraint in space work, cost-effectiveness, and precise program and requirements definition, the specific proposals did

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* United Nations General Assembly Resolution 1884 (SVIII), Oct. 17, 1963.

not survive." * At this point in time, the Department of Defense began to look to NASA for manned space efforts and both agencies initiated cooperative agreements for the management of specific space programs.

For example, on January 21, 1963, NASA and DOD signed an agreement to jointly participate in NASA's Gemini project, and a Gemini Program Planning Board was formed. This action gave official recognition to the decision to rely on Gemini rendezvous and docking experiments for satellite inspection applications, rather than proceeding with development of DOD's Saint project.

DOD's reliance on NASA for manned space flight operations and experience continued until December 10, 1963, when Secretary of Defense McNamara, after announcing that Dynasoar would be cancelled, stated that a new manned orbiting laboratory (MOL) program would be initiated and managed by the Air Force. With this announcement the Defense Secretary appeared to be emphasizing two points: 1) that DOD would no longer rely entirely on NASA for manned space flight experience and applications, and 2) that, contrary to previous DOD policy, there appeared to be a valid requirement for manned military operations in space. Furthermore, the MOL decision appeared to be counter to previous NASA-DOD agreements on manned space flight, and duplicated NASA plans for manned space stations.

* Govt. Operations in Space, pp. 80-81.

The apparent overlap of DOD and NASA space station plans and programs created new demands for coordination from Congress which were met, to a degree, by a joint NASA-DOD agreement to exchange information relative to MOL and other manned space flight experiments. However, NASA went ahead with its own plans to study the requirements for a manned space station based on Apollo hardware. However, to minimize future conflicts and duplication between NASA and DOD manned space flight activities, and the MOL and Apollo space station programs in particular, the Joint Manned Space Flight Committee was established in January 1966. It is the purpose of this committee to review the total manned space flight effort of both agencies including NASA's Gemini and Apollo programs and DOD's Manned Orbiting Laboratory. *

In spite of some conflict and overlap, as illustrated by the MOL and Apollo space station programs, it appears that NASA and the Department of Defense will continue to view U. S. policies and objectives through the same pair of glasses. This will be reflected in a strengthening of the close working relationships between the two agencies; their utilization of interagency planning and study groups--such as the Aeronautics and Astronautics Coordinating Board, the Gemini Joint Planning Board and the Joint Manned Space Flight Committee--to resolve organizational, technical and

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* NASA Authorization for Fiscal Year 1967, p. 51.

budgetary conflicts; and their joint management of, or cooperation on, certain projects, such as the X-15, Gemini, MOL and Apollo. Furthermore, while a merger of NASA and DOD space activities under a new supra-agency is possible, the probability of such a move will be low, as long as U. S. policy emphasizes the peaceful exploration of space. However, if the Soviet Union were to develop and orbit a series of offensive and/or defensive space weapons, which could be clearly identified as such, the probability of a NASA-DOD merger under a new national space agency, would be very high. However, in the future it is possible that DOD and NASA will plan for and obtain funds from the same program package, as is indicated by the initiation of the new federal Planning-Programming-Budgeting System.* While this may bring NASA and DOD into even closer cooperation, nevertheless, the essence of separate military and non-military space organizations will probably be retained.

As for future cooperation on the project management level, DOD and NASA--following the precedent set by such programs as the X-15, Mercury and Gemini--will probably cooperate on the development of the large manned space station as well as the hypersonic research aircraft, a vehicle with the capability to take off from a conventional airfield, go into orbit, re-enter and land like an aircraft. Another project of major size and importance,

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* See, Bulletin No. 66-3, Executive Office of the President, Bureau of the Budget, October 12, 1965.

which in all probability, will be jointly managed by NASA and DOD, is the construction of a lunar base; since both agencies have funded lunar basing studies in the past. For example, NASA initiated a study contract with the Army Corps of Engineers to define the requirements for a lunar base development program in 1963, and since 1957 the Air Force has funded a series of studies aimed at defining, in great detail, the requirements for constructing scientific and military facilities on the lunar surface.

Owing to the size and complexity of the lunar project, the resources required, and the multimission capabilities inherent in a lunar base, a closely coordinated management effort by DOD and NASA may be required. Or, it may be necessary to establish a new and autonomous agency to manage the project.

While NASA and DOD will continue to jointly administer and coordinate their efforts on certain common purpose programs, there are missions, requirements and programs that exist now, or will exist in the future, within each agency's area of responsibility, which will remain the separate responsibility of that particular agency. Consequently, there will be no specific need to enter into joint management relationships. This is particularly true where either NASA or DOD have a clear-cut mission requirement which is not directly associated with, or does not overlap a mission requirement of the other organization.

For example, DOD is solely responsible for the military reconnaissance and the space defense missions. The Department of Defense will also be directly involved where there are other specific military missions to perform in space, e.g., early warning, or where there is a need for quick reaction, positive and secure control, and high systems survivability. On the other hand, any space system such as Mariner, Voyager and the Orbiting Astronamical Observatory (OAO) designed to meet a specific non-military mission, e.g., lunar or planetary exploration, solar research, etc., will be managed and developed entirely by NASA.

In summary, it can be stated that the management and organizational changes that have taken place in DOD and NASA relative to the national space program have had both positive and negative effects on the management planning and decision-making process in government and industry. These management changes and their impact were more frequent and pronounced in the period between 1957 and 1963 when this country was essentially reacting to a Soviet challenge and at the same time attempting to manage a costly and explosive technology, where the missions, requirements and agency responsibilities were not clearly defined. This situation was reflected in the management decisions and actions within the aerospace industry which frequently went off on many unpromising tangents during the early days of the space program, in an attempt to develop and/or produce space system concepts and hardware to meet ill defined missions and requirements. However, since 1963, the management and organizational aspects of the national space program have been refined and improved upon to the extent that the management responsibilities of NASA and DOD are more specifically outlined; space missions and requirements more clearly stated; cooperative arrangements for the management of joint space projects have been defined and utilized; and aerospace planners and decision makers in both industry and government have the financial, and experience base to manage existing or plan for new projects. While new organizational and management structures may be needed as the space program continues, these changes will not be as dramatic or as frequent as in the past when a firm mission, requirements, data and experience base did not exist.

SPACE MANPOWER AND FACILITY RESOURCES

Manpower and facilities, coupled to the available monies, are the primary resources employed to carry out the national space program, and consequently are an important consideration in any space-age planning and decision-making activity. As was noted previously, the current U. S. space effort employs close to 500 thousand people * and involves ten major government agencies, approximately 100 large corporations, several thousand medium and small companies, and roughly 200 universities and non-profit institutes.

In many ways the manpower and facilities employed in the space effort are unique in the sense that in their impact on our national life, as well as in their skills and design they are unlike those found in the automobile, steel and chemical industries. Some of the unique characteristics of the manpower utilized in the space program, were noted in a book prepared by the editors of Fortune Magazine. ** They stated:

> The space effort is the first para-military effort in history not accompanied by a demand for heavy hardware and mass-produced materials. Its great demand, instead, is for professional people and it may relatively soon employ up to a million. Since more and more money will go into manpower, particularly engineers and other technical specialists, the

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* Estimate includes industrial, government, and university personnel.

** "The Space Industry", by the editors of Fortune Magazine, Prentice-Hall, Inc., New Jersey, 1962, p. 90.

> well-worn questions of whether the U.S. is producing enough professionals is no longer academic. By 1970, thanks in large part to the space venture, the U. S. will need more than two million scientists and engineers, or about double the number employed in 1959. *

The effect of larger numbers of scientific and technical personnel entering the space program is shown in the organizational structure of certain space related industries, where the research and development staff outnumbers the production staff. Moreover, there are industrial and government organizations, such as NASA, Bellcomm and Comsat, where the entire work force is employed in space research.

The growing numbers of scientists and technicians going into the aerospace industry is also one of the factors ** responsible for upsetting the industry's traditional four-to-one ratio of production to non-production workers. For example, in 1954, hourly production workers comprised 72 percent of the aerospace industry's work force. By 1959, only 50 per cent were production workers. At the present time, aerospace production workers represent roughly 40 per cent of the industry total, whereas predictions indicate it will decrease to approximately 30 percent by 1970. ***

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* The Space Industry, by the editors of Fortune Magazine (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1962), p. 90.

** The other factors are: increased automation and the shift in the aerospace industry away from mass production to limited production.

*** Aerospace Facts and Figures 1962, (Washington: Aerospace Industries Association of America 1962), p. 61-66.

While the demand for production workers goes down, the space age requirements for new scientific and technical skills will go up, particularly in the fields of astrophysics, astronomy, bio-medicine, materials engineering and chemistry.

These manpower trends are largely borne out by Figure 10, which shows the changing situation in a typical aerospace company. Another indication of the changing manpower situation is the changes in the diversification of college degrees in the aerospace industry. For example, in 1943, the degrees of professional employees at North American Aviation Inc., a major aerospace company, were concentrated in the following fields:

Mechanical Engineering

Chemical Engineering

Aeronautical Engineering

Civil Engineering

Physics

Metallurgy

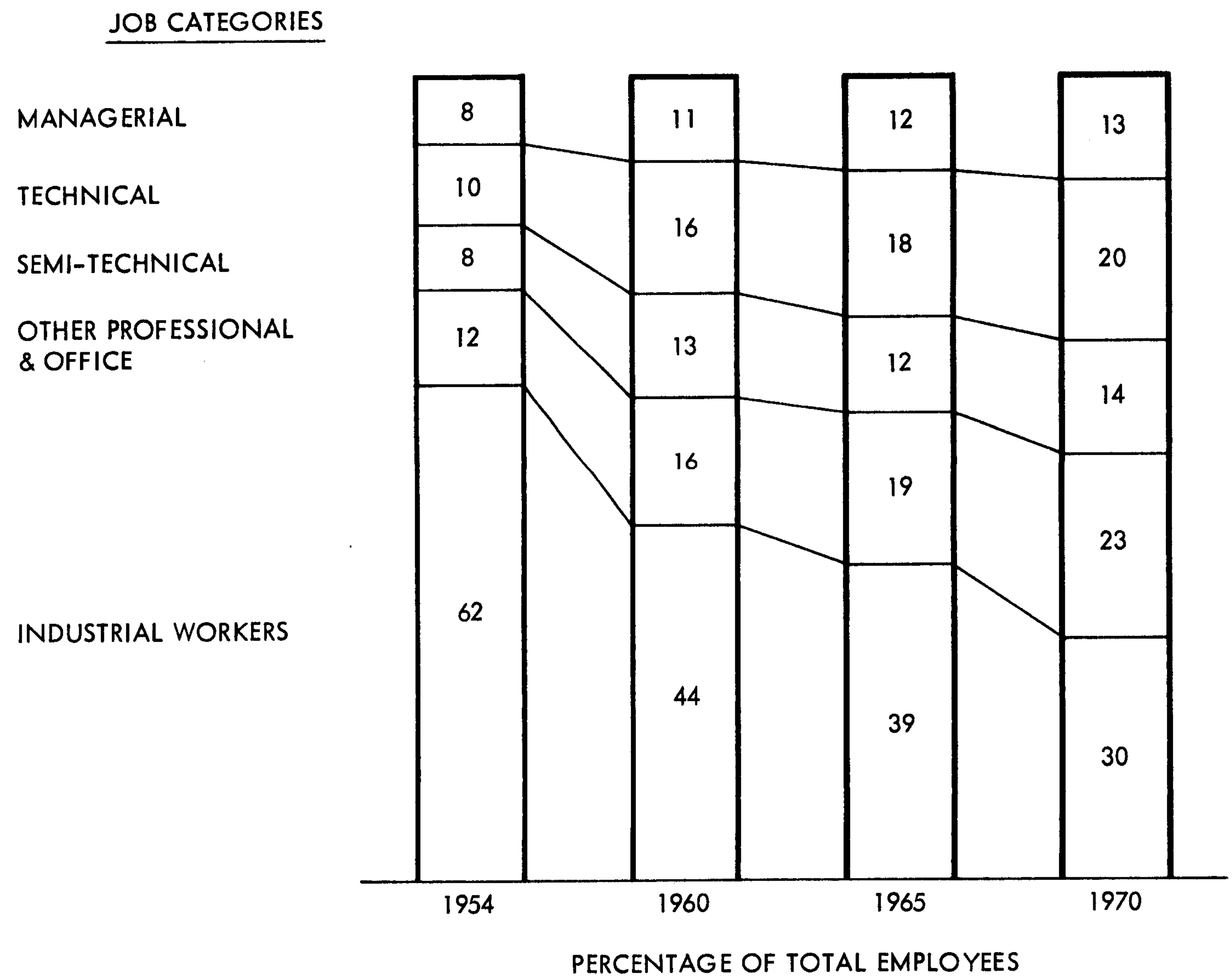
JOB CATEGORIES
MANAGERIAL
TECHNICAL
SEMI-TECHNICAL
OTHER PROFESSIONAL & OFFICE
INDUSTRIAL WORKERS
8
10
8
12
62
11
16
13
16
44
12
18
12
19
39
13
20
14
23
30
1954
1960
1965
1970
PERCENTAGE OF TOTAL EMPLOYEES

Figure 10

However, by 1963, the typical degrees covered more than <u>175 different disciplines including:</u>

Actuarial Science	Metallurgy
Anthropology	Mining Engineering
Architecture	Nuclear Physics
Astronomy	Nuclear Engineering
Astrophysics	Optics
Bacteriology	Osteopathy
Banking	Phosphate Science
Biochemistry	Photogrammetry
Ceramics	Physical Chemistry
Electronics	Pomology
Cytology	Psychology
Gemology	Sociology
Geophysics	Tool Engineering
Library Science	Traffic Management
Marine Engineering	Zoology
Medicine	Meteorology
Microbiology	

Even a cursory examination of the 1943 and 1963 list of disciplines at North American indicates the dynamic changes that have taken place in the manpower levels and skills as well as the facilities requirements of the aerospace industry in a twenty-year period. Moreover, it is an indication of the many challenges facing the aerospace planner and decision-maker, who must not only acquire training and utilize this highly diversified group of specialists, but must have some understanding of the evolutionary trends in space research that made the acquisition of these specialists necessary in the first place. (see Fig. 11)

Since the demand for these highly skilled and diversified personnel will exceed the supply, the requirement will be partially met by retaining and increasing the workloads of currently employed engineers and scientists.

In addition to their effect on the structure and skill ratios of line and production organizations, an increasing number of scientists and engineers entering space industry are being placed in management, advisory, or decision-making positions--or are being asked to assist or advise on major policy decisions of the U.S. government. For example, it was the space program, coupled to the rising importance of the scientist and engineer, which resulted in the creation, under President Eisenhower, of the Office of Special Assistant to the President for Science and Technology, and the appointment of Dr. James Killian to the new post. The activity was

FIGURE 11

DISTRIBUTION OF EMPLOYMENT OF SCIENTISTS AND ENGINEERS
IN THE AEROSPACE INDUSTRY BY PRODUCT GROUP IN THE UNITED STATES *

September 1965 - June 1966

Product Group	September 1965 Employment (000)	September 1965 Percent of U. S.	December 1965 Employment (000)	December 1965 Percent of U. S.	March 1966 Employment (000)	March 1966 Percent of U. S.	June 1966 Employment (000)	June 1966 Percent of U. S.
Aircraft	93	46	96	47	100	48	104	48
Missiles & Space.......	98	49	97	48	98	47	99	47
Non-Aerospace	10	5	10	5	12	5	12	5
TOTAL	201	100	203	100	210	100	215	100

* Based on data provided by the *Aerospace Industries Association*, Economic Data Branch.

continued in the Kennedy administration through the appointment of Dr. Jerome Wiesner, and in the Johnson administration with the appointment of Dr. Donald Hornig.

In addition, special groups made up of noted scientists and engineers--some not necessarily associated with the space program--advise Congress, the military services and NASA, as well as large industrial organizations. * While many of these groups were initiated prior to the advent of the space age, nevertheless, they increased in number and importance after Sputnik I.

The entrance of scientists and engineers into management decision-making and policy positions in government and industry has raised questions about the role of the scientist and engineer as a policy maker, advisor and decision-maker; namely: Is the scientist capable of operating effectively in areas where political, economic and social, not scientific considerations are paramount? To what extent and in what ways are scientific advisors employed in reaching national policy decisions?

While it is not possible to find quick and simple answers to these and related questions, the growing numbers of scientists and engineers entering the space industry, their rising importance in government and industry, coupled with the lessening demand for production workers, are as significant a facet of space program management as are launch

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* Examples of such scientific and advisory groups are the Air Force's Scientific Advisory Board, The Panel of Science and Technology of the House Committee on Science and Astronautics; and in industry, the Technical Advisory Board of the Aerojet-General Corporation.

vehicles, spacecraft and dollars. For these reasons, these human resources, their diversity, utilization and growth should be considered as a significant input to any planning exercise directly associated with the national space program.

A recent development in the basic character of the space program emphasizes this point. For example, a significant percentage of the 400,000 to 500,000 people employed in space research have been working on the design, development and testing of the current family of launch vehicles and spacecraft, such as the Saturn, Titan, and Apollo. These systems are now, or soon will be, operational and while some of the engineers and technicans working on these programs will continue to be employed throughout the program's life cycle, a certain percentage of them will face unemployment or will be given tasks not consistent with their skills; particularly, as the initial development phase of these projects is completed. Consequently, as the design, engineering, development and preliminary test phases of the current space projects, such as Gemini are completed, it will be necessary, unless these professional skills are to be lost or diverted, for the top policy makers and planners to make the necessary decisions to undertake some of the proposed second or third generation space programs.

This "decision gap" and the associated manpower problems were highlighted by NASA Administrator James Webb and Associate Administrator

Dr. George Mueller in testimony on post-Apollo goals before the Senate Committee on Aeronautical and Space Sciences. * In their testimony, both Mr. Webb and Dr. Mueller cited the impact and problems associated with space program planning and decision-making on the 400,000 space workers employed on NASA programs. In his testimony Mr. Webb stated:

> I think these very highly qualified engineers and scientists in American industry are going to be pretty deeply concerned that the very success of their efforts cause them to be looking for new jobs in other fields before we are ready to move forward with the next step. Certainly, I think all of those in industry and in the government would be very much encouraged if we could make the decision to utilize, as the chairman has indicated, the present equipment, and to extend its life, and to provide these scientists and engineers with continued work in this field. All of this equipment can be upgraded for more advanced work and for work we need to do. But it must be upgraded by these people because the work is very specialized. Unfortunately, however, this comes at a time when we have other very large national requirements on the budget. So we have a national problem here. We do not assert the space need as against all other needs, but nevertheless we must state this need to the President and I believe to you.

To a degree, the total numbers of personnel employed, as well as the changing manpower and skill ratios of the space age are directly related to the changes that have been taking place in aerospace facilities and equipment requirements. These, in turn, have been affected by the

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* National Space Goals for the Post-Apollo Period; Hearings before the Senate Committee on Aeronautical and Space Sciences, Washington, D. C., August 1965, pp. 17-22.

evolution of technology, national policy and federal expenditures over the past twenty years. The present aerospace industry, for example, is essentially an outgrowth of the aircraft and electronic industries which grew during World War II. During that period the requirements of military strategy, the limitations in technology and the emphasis on non-nuclear weaponry created demands for hundreds of thoudands of aircraft and electronic components which could only be met by traditional mass production methods, with its emphasis on large plants and tens of thousands of workers.

After World War II and the Korean War, nuclear weaponry, high performance jet aircraft and ballistic missiles, as well as the "new look" in military strategy changed the character of the aircraft and electronics industry. Large numbers of aircraft and missiles were no longer required. Consequently, mass production facilities and machine tools were not needed. Moreover, the aircraft, missile, and electronics systems of the nuclear age were not only built in fewer numbers but were considerably more complex. This led to a reduced demand for large numbers of production workers on one hand, but an increased demand for skilled technicians, engineers, and scientists on the other. Furthermore, while the complex aircraft, missiles and spacecraft of the 1955-1960 time period needed less production floor space than was required in World War II, their complexity and operational characteristics created demands for sophisticated research and test facilities that were unheard of in the 1940's. * Consequently, the aerospace industry and the federal government were faced with a somewhat paradoxical problem, namely, what to do with the surplus mass production facilities, machine tools and workers inherited from World War II, and yet build the new and unique facilities and obtain the skilled craftsmen required to develop, produce and test the high performance jet aircraft, missiles and space vehicles of the 1960's. In some cases, companies were caught in the unusual position of reducing their facilities and labor force in one geographic area, while constructing a new plant and recruiting employees in another section of the country.

The problem of how to dispose of, or reduce, the excess production facilities and machine tools inherited from World War II and the Korean War period still plagues the federal government and the aerospace industry. In some cases, the remedy has been modification, consolidation, or sale of excess facilities, or scrapping of obsolete tools and equipment. This, along with the construction of new space age facilities (in most cases away from the area of the home plant) has created economic, social, and political problems near the home plant, as well as in the area where the new facility is located.

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* For a detailed analysis of the changes that have taken place in the aircraft industry, see M. J. Peck and F. M. Scherer, The Weapons Acquisition Process, Harvard University, Boston, Massachusetts, 1962.

The facility and equipment problems generated by the space age are still evolving. Launch vehicles and spacecraft increased so rapidly in performance, size and complexity in the past five years that plants and tools become obsolescent more rapidly. Moreover, the trend away from extensive to selective hardware production in the aerospace industry continues. These factors, plus the emphasis on research and development will generate requirements for new and costly research laboratories and design facilities. For example, much of the present emphasis is on developing those facilities and devices which will provide realistic conditions for studying radiation effects, vibration, acceleration, intense light, pressure and temperature. In addition, there will be requirements for testing human reactions and man-machine systems under various accelerations and decelerations, as well as high-speed particle accelerators, adapted to simulate radiation effects, and devices to simulate weightlessness. Again, North American Aviation, Inc., serves as a case in point. In 1947, North American Aviation had only 82,000 square feet of floor space devoted to research and development activities.* This included the following types of laboratories:

Chemistry	Metallurgical	Fuel
Structures	Materials	Production Development
Electrical	Engine run-up	Aerophysics

* Based on data appearing in the following paper: Harber, Bernard D., "How do Changing Demands for Manpower and Technical Production Affect the Economy of Industry and the Community?", Conference on Space, Science and Urban Life, Dunsmuir House, Oakland, California, March 1963.

By 1963, not only had the number of square feet devoted to research and development at North American Aviation increased from 80,000 to 1,629,930, but the types of laboratories included the following:

Thermoelectrical	Material Research	Electronic
Thermonic	Process Development	Computing
Instrument Calibration	Production Development	Simulation
Physiology and Ecology	Vibration and Shock	Space Science
Gas Dynamics	Propulsion	Life Science
Astronomical	Aerothermal	Acoustic
Nucleonics	Thermodynamics	

All of these changes in the manpower, skills, and facilities requirements generated by the space age have not only added to the overall complexities of the space program, but have encouraged aerospace managers in government and industry to give additional and thoughtful consideration to such questions as: What are some of the future manpower trends in the aerospace industry, in terms of total numbers, ratios of production to non-production workers, and skills distribution? How have scientists and engineers specifically affected the aerospace industry's organization and management structure? How has technology, national policy and military strategy influenced the trend away from mass production to limited production of complex systems?

SOVIET SPACE DEVELOPMENTS

One of the most significant factors affecting aerospace decision making and planning is the space accomplishments of the Soviet Union. For example, their demonstrated ability to achieve space "firsts" (i.e., the first earth satellite, the first man in orbit, and the first to soft land instruments on the moon) is not only a direct challenge to our technical and managerial competence, but to our international prestige; whereas, the military implications of their space program pose a threat to our national security and defense posture.

In addition to challenging our prestige and security as a nation, the Soviet space program directly or indirectly influences: 1) national policy, as formulated by the President, Congress, and the heads of government agencies; 2) the amount and distribution of the annual federal space budget; 3) the decisions made by aerospace management in both Government and industry; 4) the priority, scheduling and planning of the various DOD and NASA programs; and 5) the direction and scope of American technological developments.

To illustrate: In 1958, Congress increased federal appropriations for space over twofold--from $347 million to $759 million; a new government agency, the National Aeronautics and Space Administration was created; and a 10-year plan for the peaceful exploration of space was submitted and approved--all in response to the challenge of the Soviet Sputnik.

It is significant that unmanned space flight programs were given a dominant place in this plan as well as in the associated budget allocations. For example, in the NASA budget for Fiscal Year 1959, only $58 million was appropriated for manned programs; whereas $128 million was set aside for unmanned spacecraft and related launch vehicle developments.

While it is reasonably certain that the initial space budgets, the space-policy decisions made within the Executive and Legislative branches of government, as well as the configuration of our first long-range space plan with its emphasis on unmanned systems, were to some degree related to the technological state of the art, there are indications that pre-1961 space policies were also based on: 1) the assumption by U. S. policy makers that the Russians were concentrating most of their effort on unmanned space flight, and 2) the belief within the Executive branch of the federal government that there was relatively little to be gained in terms of scientific, military, or national prestige, by extending manned space flight programs beyond the then indefinite Project Mercury.

On April 12, 1961, another event took place which again focused attention on the relationship between Soviet space activities and our own space policies. On that date, the Soviet Union launched the Vostok I with Cosmonaut Yuri Gagarin aboard. This time, the reaction within the Executive and Legislative branches of our federal government was more rapid, direct, and realistic than had been the case after Sputnik I. One of the first positive steps was taken by the late President Kennedy on May 25, 1961, one month after the Gagarin flight. In a special message to Congress on Urgent National Needs, the President stated:

> It is time for this nation to take a clearly leading role in space achievement which in many ways may hold the key to our future on earth....I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth....
>
> Let it be clear that I am asking Congress and the country to accept a firm commitment to a new course of action--a course which will last for many years and carry very heavy costs. *

The following day, the President submitted requests for an additional $549 million for the National Aeronautics and Space Administration, including an increase in appropriations for manned spaceflight from $104 million to $234 million. In addition, the funds for Saturn, the high-thrust booster system associated with the man-in-space program, were increased from $224 million to $273 million. Thus, the national space program shifted dramatically and rapidly from a "business as usual" basis to a faster pace, with the emphasis now on manned rather than unmanned flight.

Gagarin's flight and the subsequent message from the President not only brought about changes in the pace and expenditure levels of the space program, but resulted in the creation of new organizations and facilities within

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* Urgent National Needs, A Special Message to Congress by President Kennedy, published by the Department of State, Washington, D. C., May 25, 1961

NASA, e.g., the Office of Manned Space Flight and the Manned Spacecraft Center. In addition, such man-in-space programs as Gemini, and the Saturn V were initiated, and existing NASA plans and schedules were revised. For example, in an effort to match Russian progress, the initial plan to land a U. S. astronaut on the moon was re-evaluated and the date for the lunar landing was changed from the post-1970 to pre-1970 time period. Even the selection of the technique for landing men on the moon was made with an eye to the new time schedule.* Furthermore, to meet the objectives of the revised man-in-space program, General Electric and the American Telephone and Telegraph Company were asked to form new organizations (e.g., Bellcomm) to provide NASA with systems analysis and integration support for the man-in-space and lunar landing programs.

Following the Gagarin flight the Soviet Union throughout the 1961-1964 period continued to launch both manned and unmanned aircraft of the Vostok and Kosmos series as well as unmanned lunar and planetary spacecraft. These launchings indicated a significant step-up in the number and variety of Soviet spacecraft and an increase in the overall pace of the Soviet space program. The overall impact of this accelerated Soviet activity on our own space program is difficult to determine other than the fact that between April 1961 and 1965, the U. S. space budget increased from $1.8 billion

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* "Report on Space Programs", Bulletin of the Atomic Scientists, Chicago, Illinois, May 1963, p. 22.

to $6.9 billion and the number of spacecraft launched by the United States increased significantly. How much of this was a result of prior planning and how much a reaction to Soviet accomplishments is difficult to determine (see Fig. 10).

However, one Soviet spectacular that may have had a direct and significant impact on our own program was the twin launchings of Vostok's III and IV on August 11 and 12, 1962, respectively. These two vehicles came very close to rendezvous without docking. One specific indication of the possible impact of this Soviet spectacular on our own program was the change in the Gemini flight schedule. Before the twin Vostok flights, the first unmanned flight by Gemini was scheduled in late 1963 or early 1964. After the simultaneous Vostok III and IV launchings the first unmanned flight was rescheduled for mid-1963 and the first manned flight in late 1964. * However, subsequent program delays forced another change in the Gemini schedule so that the first unmanned flight took place on April 8, 1964, and the first manned flight on March 23, 1965.

Another reaction to the twin Vostok flights came from the late President Kennedy on August 13, 1962. On that date in a nationally televised address, he commented that the U. S. was behind the U.S.S.R. in space exploration

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* Posture on the National Space Program, Report of the House Committee on Science and Astronautics, Washington, D. C., May 1963, p. 6.

FIGURE 12

SUMMARY COMPARISON OF U. S.—SOVIET SPACE FLIGHTS

UNITED STATES

	LAUNCH VEHICLES		SPACECRAFT		
	Expended	Successful	Orbited	Escaped	Failed
1957	1	0	0	0	1
1958	17	5	5	0	12
1959	20	10	9	1	11
1960	29	16	16	1	14
1961	41	29	35	0	14
1962	59	52	54	4	13
1963	46	38	60	0	11
1964	64	57	69	4	8
1965	70	63	94	3	8
1966*	20	19	24	0	1
TOTAL:	367	289	366	13	93

SOVIET UNION

	LAUNCH VEHICLES		SPACECRAFT		
	Expended	Successful	Orbited	Escaped	Failed
1957	2+U	2	2	0	U
1958	1+U	1	1	0	U
1959	3+U	3	(1)	3(2)	U
1960	5+U	3	3	0	4+U
1961	6+U	6	6	1	1+U
1962	20+U	20	20	1	5+U
1963	17+U	17	17	1	1+U
1964	30+U	30	36	2	1+U
1965	48+U	48	66	7	2+U
1966*	16+U	16	17	2	1+U
TOTAL:	148+U	146	168	17	15+U

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* Complete through May 3, 1966.

U Unknowns

The above data, updated through May 3, 1966, was obtained from a paper prepared by Dr. Charles S. Sheldon, Member of the Professional Staff of the National Aeronautics and Space Council. See, Porter, Richard W., and Sheldon, Charles S., "A Comparison of the United States and Soviet Space Programs," Paper No. 10, Program of Policy Studies, The George Washington University, Washington, D. C., June 1965.

and that it would "be behind for a period in the future....We are making a major effort now, and this country will be heard from in space as well as in other areas in the coming months and years."

The next Soviet spectacular to have an effect on the U. S. space program was the flight of Cosmonauts Leonov and Belyayev in Voskhod II on March 18, 1965. During this mission Cosmonaut Leonov took the first "walk" in space. The direct impact of this accomplishment was felt in the Gemini program which was accelerated significantly in the following months.* For example, prior to Leonov's "walk" the first exit of a U. S. astronaut from Gemini was scheduled <u>after</u> the GT-IV and GT-V flights.** Under the new accelerated schedule the first walk in space by a U. S. astronaut occurred on June 3, 1965.

It would be an over-generalization to state that all changes in our space program between 1957 and the present were no more than reactions to Soviet efforts; however, there is enough evidence to indicate that Russian space accomplishments have and will continue to influence the magnitude, direction, funding and organization of our space effort as well as the related decision-making and planning.

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* <u>United States Aeronautics and Space Activities</u>, Report to the Congress from the President of the United States, January 31, 1966, p. 9.

** <u>1966 NASA Authorization</u>, Hearings before the House Committee on Science and Astronautics, Part 2, Washington, D. C., March 1965, p. 44.

To understand these relationships it is necessary to examine the Soviet space effort in some detail. However, in contrast to the United States, the U.S.S.R. publishes very little specific data about their current or future space effort , particularly the launching dates, the booster characteristics, or the precise objectives to be attained. However, a survey of Soviet space developments indicates that while secrecy conceals the specifics, the Soviet Union has not concealed the larger goals and expectations of their space program. * This fact has been noted by Dr. F. J. Krieger, a Soviet space specialist at the RAND Corporation. He reported that, "The Soviet scientists (and political leaders) not only have clearly specified their goals well in advance, but have consistently attained them with apparent ease ."**

To illustrate, on March 14, 1961, one month before Gagarin's flight, former Soviet Premier Khrushchev declared, "The time is not far off when the first (Soviet) spaceship with a man on board will soar into space." Later at the 22nd Congress of the Communist Party on October 17, 1961, Khrushchev said, "In the immediate future the Soviet Union will orbit a team of cosmonauts, soft land a vehicle on the moon, place a satellite in orbit around the moon, and finally attempt to orbit the planets of Mars and Venus." The concurrent

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* Soviet Space Programs, Staff Report, Senate Committee on Aeronautical and Space Sciences, Washington, D. C., May 31, 1962, pp. 71-72.

** F. J. Krieger, "Soviet Space Experiments and Astronautics," Aerospace Engineering, Vol. 20 (1961), 35.

launchings of Vostoks III and IV in August 1962, the continuing series of Venus and Mars probes, and the more recent soft lunar landing by Luna 9 and lunar orbiting missions by Luna 10, affirm Khrushchev's earlier predictions.

Other indications of future Soviet space goals were obtained at a press conference on August 11, 1961, on the occasion of cosmonaut Titov's orbital flight, when Academician L. I. Sedov, one of the top Soviet space scientists said, "Our scientists and designers are working according to a broad plan. They are working on the further development of orbital flights; they are working on flights to the closest planets." At the same conference, Academician M. Keldysh stated, "The flight of Soviet spaceship satellites shows that the time is approaching when men will be able to penetrate far into space and realize age-old dreams of flights to the Moon, Mars, and Venus, and even more remote regions of the universe. *

After Yuri Gagarin's orbital flight on April 1961, a series of more specific future space objectives was described by Professor N. A. Varvarov, who declared, "This (Gagarin's flight) will be followed by the construction of flying laboratories with crews of several men, the launching of satellites to Mars and Venus, and the landing of a rocket with scientific instruments on

* Soviet Space Programs, p. 89.

t he Moon. After having orbited the Moon and returned to Earth, rockets with crews will be launched to land on the moon and return to Earth. All of these tasks have been thoroughly thought out and can be implemented in the coming years." *

On March 12, 1964, Cosmonaut Titov was quoted on Moscow radio as favoring the establishment of an orbital launch facility as a way to interplanetary travel. He said the moon would be the first target and orbital flights of up to 14 days would not surprise anyone. With regard to the moon: "I am convinced that we will witness such flights....I do not know who will make the flight. At least we have such hopes, and there is a basis to presume that we will get a flight to the moon."

More recently, on April 6, 1966, Cosmonaut Lenov, speaking in Budapest, said that the Soviet Union will land a man on the moon during the current five-year plan (1965-1970). Later, on April 10, 1966, Cosmonaut Titov predicted that "builders and assemblers will soon appear in space" and even build small towns on the moon. "They will exit into space and put together various parts of space stations, assemble spaceships and stations on the moon and various structures." Adding, "That the moon would eventually become a giant space center where spaceships will be built for flights into the universe." *

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* Soviet Space Programs, p. 85.

** New York Times, April 11, 1966, p. 37.

These previous and current statements outlining future Soviet goals cannot be considered as just so much propaganda. While it is true that a propaganda element is introduced into their space programs (as it is in all Soviet activities), an analysis of past Soviet accomplishments indicates that there is very close correlation between the predictions of their key officials and scientists, and subsequent space vehicle launchings. Consequently, there is no reason to assume that they will fail to attain their stated future goals. In fact, when their predicted space objectives are evaluated against a background of past Soviet achievements and compared with analogous U. S. space plans and technological developments, a reasonably logical outline of future Soviet space capabilities can be postulated, and their possible impact on the U. S. space effort determined (see Fig.13).

Current Activities

The simultaneous launchings of Vostoks III and IV in August 1962 as well as Polet I on November 1, 1963, and Polet II on April 12, 1964, indicate that the U.S.S.R. is continuing its efforts to achieve a manned rendezvous in earth orbit. * While earlier Vostok launchings appeared to indicate that a successful Soviet rendezvous would take place before the

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* See, Military Procurement Authorization - 1964, Hearings before the Senate Committee on Armed Services, Washington, D. C., February and March 1963, p. 922, Testimony of General Curtis LeMay.

SOVIET SPACE DEVELOPMENTS
(Actual-Possible)

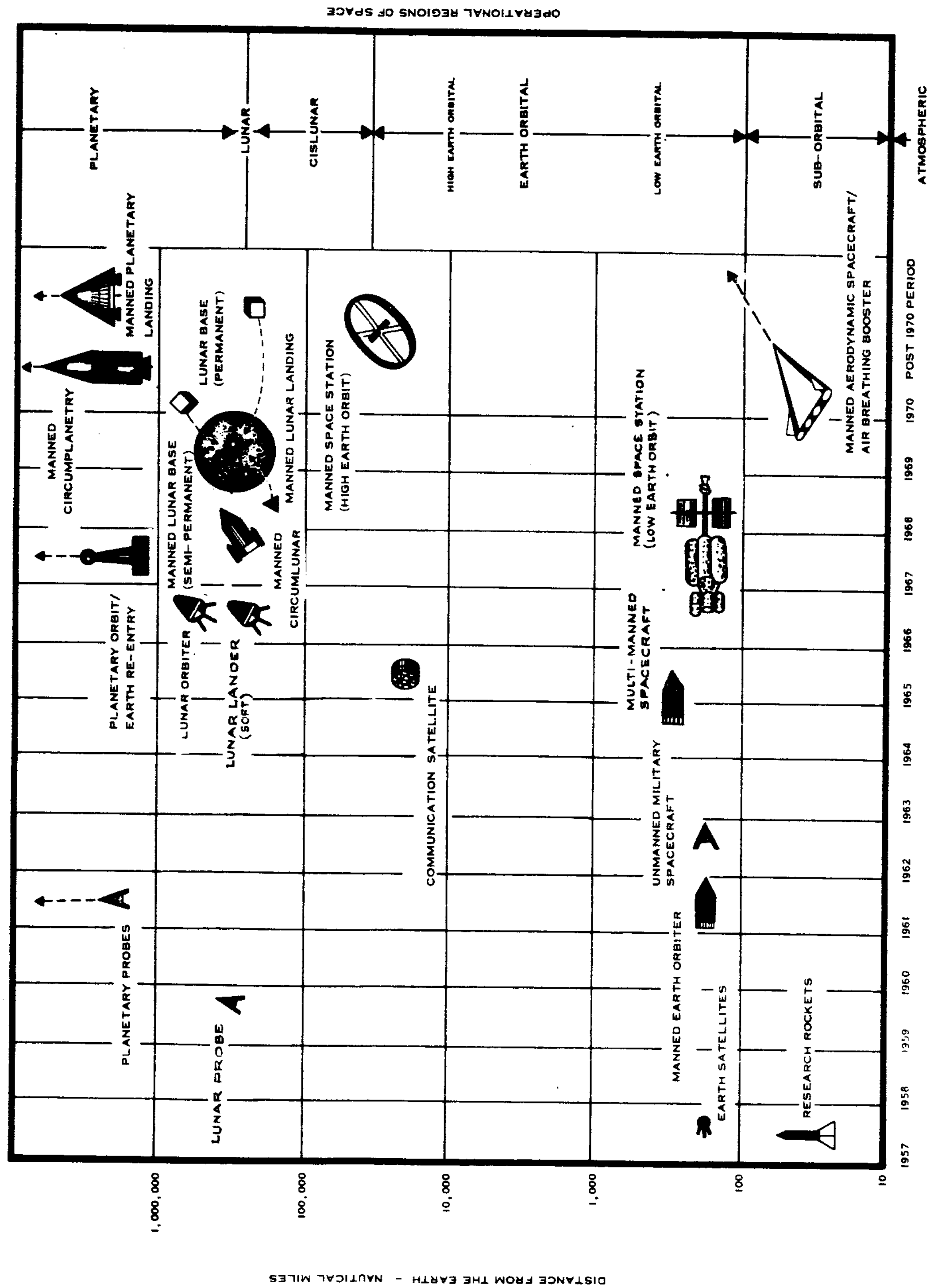

Figure 13

end of 1965, the goal has not been attained. However, it is possible the Soviet Union decided that such a rendezvous will not take place until they are able to launch in series their newer and heavier 27,000 pound Proton spacecraft, an event that could take place in 1966.

While this would not have been the case had a Soviet rendezvous occurred in 1965, U. S. reaction to such an event in late 1966 will be considerably minimized owing to the successful rendezvous of Gemini 6 and Gemini 7 on December 15, 1965. Nevertheless, a successful rendezvous in orbit by the U.S.S.R. in 1966 could possibly reduce some of the growing criticism of the U. S. space effort, encourage the proponents of a more energetic military space program, and possibly lead to an increase in federal expenditures for space technology for fiscal year 1968, particularly for Apollo applications and the MOL program. This reaction would very likely take place if the Soviet rendezvous involved larger boosters, the assembly in orbit of several 27,000 pound Proton spacecraft, and greater numbers of men than the prior U. S. effort.

If the Russians carry out an orbital rendezvous in 1966, with a series of Proton spacecraft, they could develop enough experience in complex, assembly-in-orbit operations to begin constructing the first multi-manned space station by the end of 1966 or the beginning of 1967. A number of Russian scientists have indicated that such development is part of the Soviet space plan.

Among these is G. G. Kuznetsov, a physics professor who stated that it would be possible "in the not distant future to create a big, permanent, artificial earth sputnik which will serve as a hugh scientific laboratory to conduct research into various types of cosmic radiation and study the effect of space flight on the human organism." He further stated that, "Eventually this sputnik will serve as a unique kind of transit station for human flights to the moon and other planets of the solar system." *

In addition to the uses suggested by Professor Kuznetsov, a Soviet space station based on Proton modules could have a number of military and non-military uses, owing to its inherently large interior dimensions and payload capabilities. It could serve as an astronomical observatory, a space communications, navigation or television station, and an orbital offense/defense weapons system; or it could be utilized by the U.S.S.R. as an operational support facility, e.g., a staging base for a manned lunar landing, or a space command-control station to augment their existing ground-based, launching, tracking, and recovery network.

Based on the estimated payload capabilities of the new Soviet booster, the manned space station could be comprised of a series of individual Proton modules, each weighing approximately 30,000 pounds. With modules of

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* Aviation Week, February 15, 1960, p. 31.

this size, plus orbital rendezvous and assembly techniques, the U.S.S.R. could construct permanent space stations with gross weights ranging from 60,000 to 100,000 pounds. *

The effect of such a development on the U. S. space effort cannot be determined specifically, but there is no question that if the Soviet Union were to assemble a large-multi-manned space station in earth orbit before 1967, our somewhat indefinite post-Apollo programs would crystallize and a more vigorous effort would be initiated in both the Apollo Applications and MOL programs, including the design of new configurations of Gemini and/or Apollo for orbital re-supply and transfer. However, it has been estimated that the cost of accelerating the DOD and NASA space station projects would increase the U. S. space budget by as much as $1 billion to $5 billion. **

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* This may be a conservative estimate inasmuch as on September 7, 1963, Moscow Radio announced that the Soviet Union was on the verge of carrying out a rendezvous of two space ships in orbit, adding, that such a rendezvous is necessary for the construction of large space stations weighing <u>several hundred tons.</u>

** <u>National Space Goals for Post-Apollo Period</u>, p. 73.

In addition to expanding operations in the earth orbital region, * conservative extrapolations of Soviet space technology indicate that the Russians should be capable of launching heavier and more complex vehicles into cislunar and lunar space between now and the end of 1967. These spacecraft could include additional and heavier unmanned lunar orbiters similar to Luna 10, designed to provide detailed photographs of the surface of the moon, and soft lunar landers such as Luna 9 which would carry an unmanned mobile laboratory to the moon's surface. However, one of the most significant Soviet accomplishments of the 1966-1967 time period could be the launching of a multi-manned spacecraft on a circumlunar flight. This objective was cited by G. I. Pokrovsky, a leading Soviet space scientist as an example of "projected priority work." **

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* Other than vertical rocket launchings of instrumented scientific payloads carried out between 1950 and 1962, plus some educated speculation, there is not enough data to make a forecast of future Soviet operations in the sub-orbital region of space. For example, there is no detailed information to indicate that the Russians have been testing an X-15 spacecraft, or have conducted sub-orbital flights similar to those which involved astronauts Shephard and Grissom in the Mercury-Redstone vehicles. For a discussion of the possible development of an X-20 (Dynasoar) or Scramjet type vehicles within the USSR, see Department of Defense Appropriations for 1962, Part 4, Congressional Committee on Appropriations, Washington, D. C., April 20, 1961, p. 27; Comprehensive Analysis of Soviet Space Programs, Commerce Department, Air Information Division, Washington, D. C., May 22, 1961, pp. 12-30; and Aviation Week, January 28, 1962, p. 38.

** Soviet Space Programs, p. 89.

The circumlunar spacecraft could be assembled in space from Voskhod and/or Proton modules launched individually into earth orbit, or the vehicle could be a single Voskhod unit launched from the earth on a circumlunar trajectory by their new 2.5 to 3.0 million pound booster. What specific effect this accomplishment would have on the U. S. space program is difficult to determine; however, NASA might, as a consequence, decide to utilize a modified Gemini capsule and a Saturn I booster, to carry out a similar circumlunar flight, or the mission could be bypassed entirely and additional emphasis placed on a speed-up of the Apollo lunar landing effort.

While most of the "spectacular" Soviet space activity in the 1966-1967 time period should take place in the earth orbital, cislunar and lunar regions, the Russians should continue throughout 1966-1967, to launch unmanned probes toward Mars and Venus in an attempt to broaden their technological and operational base, and to challenge the planetary exploration program of the United States.

1967-1970 Time Period

Between 1967 and 1970, the Soviet Union should have acquired enough "on the shelf" and reliable spacecraft and launch vehicles as well as the related operational experience to have a number of possible mission options. As noted by Mr. James Webb, NASA Administrator, "The Russians will not be limited by booster capability for anything that they choose to try to accomplish in space; that they have built into their systems sufficient options for payloads so that they can select those that are to their greatest advantage; and, that they have the booster capability to put those payloads where they want to put them." *

However, while the Soviet Union will have a wide spectrum of space options to choose from between 1967 and 1970, the most significant Soviet space development may not take place in earth orbital, cislunar or planetary space, or even in the area of possible military applications, but in what they accomplish on the moon's surface. For example, before 1969, the Soviet Union should have the man-rated boosters, the associated technology, and the operational experience to land a manned spacecraft on the moon. This mission has been cited by leading Soviet scientists, cosmonauts and politicians as one of their priority goals. ** If they carry out a lunar landing before 1969, the USSR could win the moon race by at least one year, unless the pace of the Apollo program can be increased significantly.

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* NASA Authorization for Fiscal Year 1967, p. 47.

** In October 1963, former Premier Khrushchev was reported to have said that the Russians were not going to the moon. This statement later turned out to be a misinterpretation of his remarks.

There are indications that the Soviet Union will employ earth orbit rendezvous rather than a lunar orbit mode, to land men on the moon. * In the earth orbit mode the Russians could utilize an improved version of the Vostok or Voskhod spacecraft as building blocks with earth orbit-to-moon propulsion and landing modules attached. ** To launch the lunar spacecraft modules the new Proton booster with high-energy upper stages could be used. The development, by 1968-1969, of a lunar lander based on Vostok, Voskhod or Proton, an advanced version of the Proton booster, and multiple launching and orbital assembly techniques are within the estimated technological capabilities of the Soviet Union.

There is no doubt that if the Soviet Union were to carry out a lunar landing before the United States it would have a significant effect on our international prestige as well as the structure of our own space program. For example, there is a distinct possibility that a Soviet manned lunar landing in the 1969 time period would result in a critical examination of our entire program. This could lead, in turn, to a decision to initiate either a massive

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* Washington Star, January 26, 1963. It is quite possible that the USSR will maintain its time-rocket-thrust lead over the United States, well into the 1966-1970 time period; consequently, their technique for landing a man on the moon may not be subject to the time and payload constraints that influenced the selection of lunar orbit rendezvous, i.e., the U.S. method for a manned lunar landing.

** For a discussion of the Vostok and some of its potentialities, see J. S. Butz, "What Are The Lessons of the Vostok", Air Force and Space Digest, March 1962, p. 36.

crash effort aimed at closing the "lunar gap," or to leap-frog the moon program and aim for the first manned landing on Mars. If a Mars, rather than a lunar landing was established as a U. S. objective, higher priorities would have to be placed on developing a manned space station as a planetary training and flight simulator; on a nuclear version of the Saturn V; and on an enlarged bio-medical research effort; while the current high priority lunar programs as well as many of the unmanned satellite programs would have to be reoriented.

Post 1970 Time Period

Following a series of manned and unmanned lunar landings, the USSR should be capable of establishing a permanent manned base on the moon in the post-1970 time period. The initial facility would probably be an austere station, somewhat similar to the one set up under Operation Deep Freeze in the Antarctic, with the prime emphasis on determining if man can survive in the lunar environment for an extended period of time.

To construct and support the lunar base the Soviet Union <u>may</u> have to develop an advanced Nova-type booster with a gross weight in the 6 million to 8 million pound class and a thrust of 15 million to 20 million pounds, and/or nuclear upper stages. Such developments will permit order of magnitude improvements in their current booster payload-to-gross weight ratios, and as a consequence, the Soviets should be able, in the mid or late 1970's to place individual payloads of 500,000 to 1,000,000 pounds or more, into low earth orbits, or send cargo vehicles weighing 200,000 to 400,000 pounds to the vicinity of the moon. *

Furthermore, with boosters and payloads of this capacity, the Soviet Union could launch and assemble in orbit the various modules required for a manned planetary spacecraft. Based upon a survey of analogous U. S. developments, the manned planetary spacecraft could be assembled from basic nuclear powered stages each weighing 200,000 to 250,000 pounds, with the crew and mission support modules attached. ** The total weight of this spacecraft in earth orbit would vary with the specific mission, i.e., planetary fly-by or landing, and the launch year. For a range of planetary missions and launch years the weight-in-orbit of the manned planetary spacecraft would vary from 1 to 5 million pounds. However, the time when the Soviet Union would launch the first manned planetary spacecraft is dependent upon such things as national intentions, available resources, technological developments and the launch year or window. Assuming the USSR decides that a

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* For a discussion on Soviet nuclear rocket developments see Donald J. Richie, Soviet Rocket Propulsion, paper presented at the Fifth Symposium on Ballistic Missile and Space Technology, Los Angeles, California, August 1960. For an evaulation of U. S. nuclear rocket capabilities see Project Rover, Hearings before the House Committee on Science and Astronautics, 87th Congress, Washington, D. C., February 27-28 and March 1, 6, and 7, 1961; and Aerospace Engineering, May 1961, p. 14.

** NASA Authorization for Fiscal Year 1967, pp. 565-569.

manned planetary mission is desirable and their technological pace is essentially similar to our own, it is possible that the initial Soviet manned planetary missions could take place in the late 1970's or early 1980's.

In addition to the development of radically new propulsion and spacecraft systems, there is some evidence that the Soviet Union is working on a recoverable, air-breathing booster which would probably be available in the post-1970 time period. The possibility that such a vehicle is under development within the USSR has been mentioned in a report published on May 22, 1961,* as well as in statements made by Artem Mikoyan, a leading Soviet aircraft designer. **

As described in the reports, the air-breathing booster has a winged configuration, propelled by a combination of turbojets and ramjet engines, and is employed to launch upper stage rockets and spacecraft. After staging, the air-breathing booster returns, under the control of a pilot, and lands like a conventional aircraft. Analogous systems are under "building block" development in the United States; the most promising being the Scramjet, a supersonic, combustion ramjet powered vehicle which is designed to fly from subsonic to orbital speeds. *** The chief advantages of such a vehicle are:

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* Comprehensive Analysis of Soviet Space Program, Commerce Department, Air Information Division, Washington, D. C., May 22, 1961, pp. 12-30.

** Aviation Week, January 28, 1963, p. 38.

*** Scramjet Flight Test Program, the Marquardt Corporation, Van Nuys, California, September 1965.

re-usability, thus reduced operational costs, and the ability to deliver a given payload into orbit at a minimum cost per pound; plus a capability for taking off and landing like a conventional aircraft.

In addition to its use as an air-breathing booster, this versatile system could be utilized as an orbital patrol vehicle, as a logistic support system for an orbital space station, or as a hypersonic transport aircraft. In this latter role it would be a strong competitor to the supersonic transport currently under development in the West. If a hypersonic transport vehicle were developed and flown by the Soviet Union several years before the U. S. or West Europe could develop such a vehicle, it would not only mean serious economic competition, but it would be a major blow to U. S. technological competence and prestige.

It should be re-emphasized at this point that any of the current and future Soviet space developments could evolve into military systems when and if a requirement arises. This is to be expected inasmuch as the USSR has never differentiated between scientific and military research and development, and Soviet leaders by their past actions and statements have frequently stressed the military significance of their technological achievements. This fact was highlighted by Soviet Academician L. I. Sedov, a leading Soviet space scientist, who stated, "there is one large team in Russia that handles all space projects. The same key men are in charge of guidance, tracking, and other segments for each of the projects. It is a very large team and it can well take care of several projects in parallel. We have no distinction between military and civilian projects." * And in 1958, Soviet Major General Pokrovskii, a member of the Soviet space agency, said "the development of technology has led to artificial earth satellites which, together with their scientific value, also have military significance. From them it is possible to observe the opponent's territory and to throw atomic bombs on that territory." ** Moreover, when the Soviet Union resumed nuclear testing in 1961, former Premier Khrushchev said that the heavy-thrust boosters which powered Gagarin and Titov into orbit could also deliver 50 to 100 megaton warheads to any point on earth. The estimated thrust of their boosters, the physical size of the Vostok, Voskhod and Proton capsules, and the possibility that in their underground test series the Soviets have greatly improved their warhead weight to yield ratios, adds an element of realism to Khrushchev's earlier statement.

Further evidence that the Soviet Union does not draw a line between military and non-military space projects is revealed in the organization of the Interdepartmental Commission of Interplanetary Communications within the USSR Academy of Sciences.*** While most of the members, such as

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* Congressional Record, Washington, D. C., August 1, 1963, p.13103.

** McMillan, Brockway, "The Military Role in Space," Astronautics, American Rocket Society, October 1962, p. 18.

*** Reported to have been changed to the Commission on Exploration and Use of Outer Space. See Astronautics, November 1962, p. 178.

P. I. Kapitsa and L. I. Sedov, are senior scientists connected with institutes of higher learning, a number of them are directly associated with the military. Academician A. A. Blagonoravov, for example, is a Lieutenant General of artillery and is a specialist in automatic weapons. G. I. Pokrovskii, a nuclear weapons and missile expert, is a Major Gen: ral of the Soviet Army's technical services. V. F. Bolkhovitinov is a professor at the Military Air Academy. Colonel Y. A. Pobedonostev is a professor of aero-dynamics at Moscow State University where he specializes in gas dynamics, and has worked on launch facility and rocket engine design.

A more direct indication of Soviet interest in military space applications appeared in a recent book entitled "Soviet Military Strategy" and edited by Soviet Marshal V. S. Sokolovsky. In a section of the book devoted to the use of space for military purposes, the authors stated:

> Soviet military strategy acknowledges the need to study the use of space and space vehicles to reinforce the defense of the socialist countries. The need to ensure the security of our Motherland, the interests of the whole socialist commonwealth, and the desirability of preserving peace on earth demand this (a Soviet military study of space). It would be a mistake to allow the imperialist camp to gain any superiority in this area. The imperialists must be opposed with more effective weapons and methods of using space for defense. Only in this was can they be forced to refrain from the use of space for a destructive devastating war. *

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* Sokolovsky (ed.), Soviet Military Strategy, trans. H. S. Dinerstein et al. (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963), p. 427.

American spokesmen have also indicated that they believe the Soviet space program has a distinct military orientation. For example, General Le May, in testimony before the House Armed Services Committee stated that is was his personal belief that "the Russian space program is entirely military," and F. J. Krieger, specialist in Soviet technology of the RAND Corporation, indicated that the Soviet aerospace program is part of the total Soviet military effort. Moreover, there is some evidence to indicate that some of the Kosmos spacecraft may be military reconnaisance satellites.

Nevertheless, and in spite of belligerent statements and past actions, the Soviet Union has yet to place a military system in space that is a direct and open threat to the United States--at least one that can be identified as such.

Yet, of all the possible future Soviet space activities, the one which would have the greatest effect on the composition and evolution of the U. S. space program is the development of a military space capability by the USSR particularly if it is an offensive system, or is designed to restrict in any way the U.S. access to the space environment. There is no question that the USSR has the basic building blocks for developing military space systems and will deploy them, if the need arises. When their systems will be deployed and what specific form they will take is difficult to predict. *

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* See Donald A. Brennan, "Arms and Arms Control in Outer Space," Outer Space, ed. the American Assembly, Columbia University (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1962), pp. 123-149.

This is the dilemma facing those who advocate a heavier build-up in our military space program. They understand and can focus attention on the potentially threatening nature of the Soviet space program but they cannot point, conclusively, to a specific and direct Soviet threat from space and consequently, cannot present strong arguments for additional development and increased expenditures for a military space program in the United States.

Nevertheless, this does not minimize the fact that the series of technological achievements, beginning with Sputnik I, as well as the close ties that exist between Russia's scientific and military community, gives positive evidence of a well-planned space program with a dual objective in mind: 1) to establish the scientific primacy of the USSR; and 2) to develop a technical and military capability to control the realm of space.

BUSINESS COMPETITION

Business competition is another major factor affecting the planning and decision-making functions of aerospace executives. As a rule, industrial executives are more concerned about inter-company competition--namely that which occurs when company A and company B compete for contract X--than their government counterparts. Nevertheless, aerospace managers in both government and industry take the competitive aspects of the industry into consideration in their planning and decision-making functions. The executive in private industry, for example, must realistically appraise the strengths and weaknesses of his competitors before he can establish realistic objectives, initiate planning activities and define his organization's short and long-term strategy, in a manner that will strengthen his company's long-term competitive position. In addition to comparing his company's overall capabilities vis-a-vis the competition, an aerospace executive needs to watch for expected changes in competitive business relationships, e.g., multi-company associations, diversification moves, within the industry, as well as anticipated developments of a financial or technological nature. By anticipating such actions or developments, a company is able to stay one jump ahead of its competitors.

Knowledge about a competitor's strengths and weaknesses as well as possible competitive actions, which may alter the aerospace business environment, comes from a variety of sources, including company intelligence and market research. Trade publications such as Aviation Week, and management and planning service reports from organizations such as the Stanford Research Institute and Arthur D. Little, Inc., provide a good deal of information, both about the technical research activities of competitors and about financial, organizational, or diversification moves that competitors are, or may be, contemplating. Other excellent sources of data on competitors are found in the testimony given by government and industry officials before the Space Committees of the U. S. House and Senate.

Another source of knowledge about anticipated competitve actions comes from an understanding of major trends affecting the industry. The planner or decision-maker may recognize that new government markets, e.g., transportation,urban development, are going to develop rapidly, and by data collection, analysis and personal contacts is able to anticipate competitive developments with a high degree of accuracy.

In addition to anticipating changes in competitive relationships and markets, a company executive must also make assumptions regarding developments of a technical nature within the aerospace industry. To do this, it is necessary for the aerospace executive to understand the way in which development in one area, say space guidance systems, is frequently dependent upon progress in supporting or related areas, such as propulsion. In addition, he must also have a "feel" for the business potential inherent in new and emerging technologies. A skillful planner, after completing a study of technological trends, might also help the competitive position of the company greatly by going one step further and encouraging company management to spend relatively small amounts of money on exploratory research in an area that appears, in the trend analysis, to be very promising.

While the aerospace industry is highly competitive, it is not competitive in the same sense that General Motors and the Ford Motor Company are competitive. These differences are mainly a function of the aerospace industry's unique characteristics and position in the American economy. For example, the aerospace industry, unlike the more traditional commercial companies, designs and produces hardware primarily for national defense and space exploration. Consequently, with the federal government as its principal customer, the industry is at one and the same time a private industrial concern and a prime instrument of national policy. In addition, the industry is the largest single employer in this country and is second only to the automobile industry in dollar volume of sales. However, unlike the automobile industry, over 80 per cent of the products and services of the aerospace industry are sold annually to the United States government.

Also, unlike its commercial associates, the aerospace industry is heavily oriented to research and development activities, as evidenced by the fact, that as the nation's principal reservoir of high-priced talent, it employs one-fifth of the nation's scientists and engineers. This has given the industry a unique capability to solve the most complex technological problems. However, because it has this problem-solving capability, the aerospace industry has had to develop an extraordinary degree of flexibility, take greater than normal risks, and reach out beyond the leading edge of technology to a greater extent than consumer-oriented industries. Moreover, the aerospace industry has had to adjust rapidly to quantum changes in a variety of directions in order to survive, particularly, as the pace of technology has accelerated, as the military and technological capabilities of the Soviet Union have increased and as national policies have changed to meet these challenges.

The aerospace industry also has a unique relationship with the federal government which commercial industries do not have. This relationship has both negative and positive effects on the industries' business environment in the sense that the government provides substantial funding to the aerospace industry to develop and produce the most complex hardware ever developed. This has a tendency to reduce <u>some</u> of the related financial risks. However, since the American taxpayer is the source of the funding and national issues are frequently involved, the federal government intrudes upon the affairs of the aerospace industry to a greater extent than in commercial industry.

The fact that the federal government is both a prime source of funds, and a purchaser of the products of the aerospace industry leads many to believe that the industry, with a guaranteed income and one steady customer, is non-competitive. While there is some substance to this belief, the facts indicate that pre-contractual competition between specific companies comprising the aerospace industry is keen* with no guarantees from the U. S. government that a specific company's contract funding level will be maintained year after year. This is illustrated by Figure 14 ab. It indicates the changes that took place in the contractual position of the twenty-five top NASA contractors between Fiscal Years 1961 and 1965. With the exception of North American Aviation, Incorporated, and the Bendix Corporation, the contractual status of twenty-three of the twenty-five companies in the F. Y. 1961 list changed by F. Y. 1965. Six of the twenty-three companies on the F. Y. 1961 list improved their contract status between F. Y. 1961 and 1965, whereas eight companies slipped to lower positions. However, nine of the top twenty-five companies for F. Y. 1961 did not appear on the F. Y. 1965 list, again indicating the competitve nature of an industry that has been referred to in some areas as a "kept" or "guaranteed income" industry.

On the other side of the competitive coin is the federal government and the agency managers. They are also concerned about business competition, but for different reasons than their industrial counterparts. For example, the industrial executive's concern about his company's competitive status is directly related to the organization's ability to survive, in a

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* The competition between Boeing and General Dynamics for the TFX (F-111) contract is a case in point.

FIGURE 14a

TOP TWENTY-FIVE NASA CONTRACTORS LISTED ACCORDING TO NET VALUE OF DIRECT AWARDS

FISCAL YEAR 1961

Contractor	Thousands of Dollars	Per Cent of Total Awards to Business
Total	$423,294	100
1. North American Aviation Inc.	75,009	18
2. McDonnell Aircraft Corporation	41,843	10
3. Douglas Aircraft Company	30,698	7
4. Western Electric Company	26,609	6
5. Space Technology Laboratories	13,098	3
6. Chrysler Corporation	12,922	3
7. Grumman Aircraft Engineering Corporation	11,168	3
8. The Hayes Corporation	10,278	2
9. General Electric Company	9,197	2
10. Chance Vought Corporation	8,773	2
11. Radio Corporation of America	8,580	2
12. Brown Engineering Company, Inc.	6,680	2
13. Bendix Corporation	6,481	2
14. Aerojet General Corporation	6,286	1
15. Lockheed Aircraft Corporation	3,335	1
16. Honeywell, Inc.	2,730	1
17. Norair Engineering Corporation	2,512	1
18. General Dynamics Corporation	2,135	1
19. Flexonics Corporation	2,128	1
20. Ball Brothers Research Corporation	2,025	*
21. United Engineering & Construction, Inc.	2,000	*
22. Collins Radio Company	1,994	*
23. Arthur Venneri Company	1,969	*
24. Carl N. Swenson Company	1,835	*
25. Ampex Corporation	1,685	*
Other	131,324	30

* Less than one-half of one per cent.

business sense. The government executive, on the other hand, encourages business competition between company A and company B, in the hope that such competition will result in a better product or service for a better price. However, the government is also concerned when the competition reaches a point where the public welfare or the development of a specific program is jeopardized; or when the loss of the competition for a given contract by company A results in unemployment, loss of business, and public criticism in the region, state, and city where company A is located.

Both NASA and DOD encourage the aerospace industry to be competitive in a number of ways; one being the use of the incentive contract and the other through the mechanics of the source-selection board.*

The level and type of competition expected in the aerospace industry was defined by NASA officials in testimony before Congress. They stated that:

> The competitive base for awarding contracts is broadened to include scientific and technical capabilities, management competence as well as target costs. Our experience with cost-type contracting reveals that companies that ranked highest in scientific, technical and managerial capabilities are usually the ones qualified to direct the contract most efficiently in terms of time, quality and reliability, and therefore, at the lowest overall cost to the government.**

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* The percentage of competitive awards to industry has been increasing. In 1962, 55 per cent of NASA procurements, or $565 million, was placed through the competitive processes; by the end of 1964, this percentage had increased to 60 per cent, or $2.1 billion. During the first six months of FY 1966, 68 per cent of NASA procurement was competitive. Moreover, NASA and DOD policy to procure competitively to the maximum extent possible will receive continuous emphasis. See, <u>1966 NASA Authorization</u>, Hearings before the House Committee on Science and Astronautics, Washington, D. C., February and April 1965, pp. 272-273.

** <u>Ibid.</u> p. 273.

FIGURE 14b

TOP TWENTY-FIVE NASA CONTRACTORS LISTED ACCORDING TO NET VALUE OF DIRECT AWARDS

FISCAL YEAR 1965

1961 Rank		Contractor	Thousands of Dollars	Per Cent of Total Awards to Business
		Total	$4,141,434	100.00
1	1.	North American Aviation, Inc.	1,099,448	26.55
-	2.	Boeing Company	305,988	7.39
7	3.	Grumman Aircraft Engineering Corporation	267,226	6.45
3	4.	Douglas Aircraft Company, Inc.	251,668	6.08
9	5.	General Electric Company	181,472	4.38
2	6.	McDonnell Aircraft Corporation	166,670	4.02
-	7.	International Business Machines Corporation	128,312	3.10
14	8.	Aerojet-General Corporation	123,186	2.97
18	9.	General Dynamics Corporation	111,148	2.68
11	10.	Radio Corporation of America	106,552	2.57
6	11.	Chrysler Corporation	85,986	2.08
-	12.	General Motors Corporation	72,531	1.75
13	13.	Bendix Corporation	66,100	1.60
5	14.	Space Technology Laboratories	50,533	1.22
-	15.	United Aircraft Corporation	43,330	1.05
-	16.	Sperry Rand Corporation	39,401	.95
15	17.	Lockheed Aircraft Corporation	35,796	.86
22	18.	Collins Radio Company	31,532	.76
12	19.	Brown Engineering Company, Inc.	30,850	.74
--	20.	Philco Corporation	30,029	.73
8	21.	Hayes Corporation	28,496	.69
16	22.	Honeywell, Incorporated	27,068	.65
--	23.	Hughes Aircraft Company	26,457	.64
--	24.	Catalytic Construction Company	25,296	.61
--	25.	Trans World Airlines, Inc.	20,862	.50

As previously noted, the federal government also encourages competition in the aerospace industry through the mechanics of the source selection board and related processes. ; For example, in selecting contractors to develop and produce specific hardware, the government evaluates in detail the competing companies' defense or space systems proposals in terms of system design, productibility, maintainability, operational effectiveness, costs, lead time, contractor capability and past performance. It is obvious that companies submitting bids on a given space or weapons system must not only be able to show "across-the-board" competence in each of the above areas, but to increase the probability of winning the contract, must be able to convince the government source selection board that their particular design, its production, maintenance, cost, lead time, and operational characteristics, as well as the overall management capabilities and performance of their company is superior, and therefore, more competitive.

A statement from the Defense Industries Advisory Council (DIAC) of the Department of Defense highlights the role of DOD's source selection process in stimulating intercompany competition as follows:

> The source selection procedure should encourage the proper kind of competition for the attainment and demonstration of the proper objectives. A marketplace must be created and maintained in which this competition can take place. That marketplace must provide rewards for risk taking on the part of industrial concerns--including investments in facilities, the commitment of financial resources, and the commitment of competent people and teams toward objectives which properly serve government requirements. *

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* TFX Contract Investigation, Hearings before the Senate Committee on Government Operations, Part 5, Washington, D. C., May-June 1963, p. 1523.

The competitive nature of the aerospace industry, its relationship with the government and its unique position in the national economy was more than adequately summarized by Karl G. Harr, Jr., President of the Aerospace Industries Association, who stated that the aerospace industry is:

> ...a highly competitive industry and daily growing more so. It must operate in a goldfish bowl under the closest scrutiny of the public, the Congress, the executive agencies of the federal government and the press. It must not only work at the forefront of scientific and technological knowledge, it must advance those frontiers in order to survive. It plays for unique stakes in that its product underpins not only the safety of our traveling public but also our national security and our national prestige. *

All of this must be done by an industry which has a severly limited capability to influence or even predict the scope or needs of its principal market. The industry must also operate within a framework of government controls and in an environment of uncertainty arising from the fact that the true nature of its unique relationship with the government has not been fully determined. Moreover, the industry, because of its highly competitive and technological nature, must invest well over half of its earnings into new equipment, facilities and research, even though its rate of profit is approximately one-half the national industry average.

Finally, when a commercial firm goes into the marketplace to sell its products in competition with other companies, it places its reputation

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* Karl G. Harr, Jr., "The Aerospace Industry Today and Tomorrow," Speech before the Economic Club of Detroit, Aerospace Industries Association, Washington, D. C. (n.d.)

and the interests of its stockholders on the line, knowing that the price of bad judgment or a poor product may be reduced sales or even bankruptcy. However, when an aerospace company enters into competition for a contract the reputation that it ultimately lays on the line is not only its own but often that of the United States. In this sense the stockholders that an aerospace company represents are not only the company's but the American people, and rather than bankruptcy, the price of failure may range from a drop in international prestige to national disaster.

CONCLUSIONS

- The dynamic increase in space activities since 1957 has brought with it new and challenging management problems which have been met in part by the creation of special organizations such as Bellcomm, The Aerospace Corporation, Comsat and NASA, and has accelerated the development of new management techniques such as PERT/Cost, program budgeting, systems engineering, and long-range planning. Partially as a consequence of these analytical, organizational and procedural innovations a managerial revolution has taken place in those private organizations and federal agencies directly involved in the space program.

- The management functions of planning and decision-making as carried out by aerospace executives in the government and private industry, involve considerations of a complex spectrum of political, social, economic and technical factors including: National space goals and objectives, technological developments, and Soviet space capabilities. In some cases these and other relevant factors are evaluated intuitively by aerospace management, in other cases, a particular factor or problem may be analyzed in great depth and the findings submitted to the decision-maker in report form.

- Developments that are not directly related to space and space technology can also affect national space policies and objectives. One such example is the establishment by President Johnson in August 1965, of a "new" planning-programming-budgeting system within the federal government. This system will have significant and far-reaching impacts on the management of the federal government, particularly on the policy and decision-making process, on the relationship between the Legislative and Executive branches of government and on the responsibilities and prerogatives of the various federal agencies including NASA.

- Another factor that has affected national space goals and objectives is the war in Vietnam. While current national commitments and projects such as Apollo will not be greatly affected, there is no question that the Vietnamese war has had a delaying effect on decisions relative to post-Apollo goals and programs. How serious this effect will be cannot be determined at this time since it is dependent, to a major degree, on the future scope of the war and the level of U.S. defense and international commitments.

- If a reduction in cold war tension were to take place, it is possible that the present agreement between the Soviet Union and the United States, to cooperate in the coordinated launchings of weather and geomagnetic satellites, might be expanded to include a joint effort by the U.S. and the USSR to construct a lunar base, or carry out an international expedition to Mars. If such agreements were to become national goals, current space program schedules, project priorities and budgets would be significantly modified and, consequently, so would the plans and objectives of the aerospace industry.

- At the present time space missions and the related operational requirements are defined almost entirely on the basis of individual NASA and DOD responsibilities and needs, rather than on the basis of overall national requirements. For example, while there is a total national space program in concept, as well as at the organizational and operational levels, there are two semi-autonomous programs with NASA responsible for the larger scientific, developmental and exploratory effort and DOD, i.e., the Air Force, responsible for the military space effort. While the current structure and orientation of the space program is partially an outgrowth of past policies and decisions made in response to Sputnik I, the duality of the program is based primarily on separate civil and military needs with duplication and program overlap minimized through a series of NASA - DOD coordinating boards, panels and committees.

- In some cases planners and decision-makers, particularly in private industry, have operated on the basis of separate civil and military space programs. In other cases industrial managers and their planning staffs have considered the DOD and NASA programs as complementary elements of a single national space effort and have structured and implemented their plans accordingly.

- Aerospace planners recognize that space missions have been and will continue to be carried out by military, as well as non-military spacecraft. However, the civil space program--which has moved ahead of military space activities (in terms of hardware development and time schedules) in the exploration of earth orbital space--will continue to maintain this lead in the exploration of cislunar, lunar, and planetary space. This forward thrust by the civil space effort into the outer limits of space cannot be paralleled by a military space program if for no other reason than it becomes increasingly difficult (in spite of any existing technological capabilities) to establish military missions and requirements as the zone of operation shifts away from the earth orbital to the lunar and planetary regions.

- The space environment not only has a direct effect on spacecraft design and operation but, consequently, on program costs, lead times and launching schedules, as well as man's function and survival. Therefore, an understanding of these various effects of the space environment is an important input to any space age planning or decision-making activity.

- Of the many factors considered by aerospace executivies in their planning and decision-making functions, technology is one of the most--if not the most--significant. Not only do technological considerations shape and motivate the executive's decision-making process, but they affect the very character of the organization he directs and controls: Its organizational structure, its competitive position, its financial status, and its future growth and survival.

- As manned space flight becomes more commonplace, there will be an increased emphasis on bio-medical technology, particularly as extended lunar and planetary explorations are planned and later carried out. Of singular importance will be the development of escape and survival techniques and equipment, as well as research into the bio-medical, and psychological problems associated with man's survival in a hostile, cramped, non-terrestrial environment, for days, weeks, and months at a time.

- To maximize cost/effectiveness, it is possible that the space station and the first manned planetary spacecraft will be developed from common modules with the space station configuration serving as a realistic training base for the later manned planetary mission.

- When launch vehicle capabilities reach a point where a single booster can place 500,000 pounds into orbit, the requirement for increasingly larger chemical booster systems will taper off. From that point on orbital payload requirements in excess of 500,000 pounds will probably be met by multiple launchings and assembly in orbit.

- In the post-1970 time period, if the planned evolution of manned and unmanned spacecraft and launch vehicles takes place, and new programs such as the large manned space station, the lunar base and manned planetary exploration as well as an advanced MOL are initiated, significant expansion and orders-of-magnitude improvements in the existing earth-based operational and logistic support systems will have to take place. In the post-1970-1980 time period the development of large-scale operational support and logistics facilities in space or on the lunar surface will take place. These new and unique facilities could serve as supplementary launch, tracking, recovery and re-entry stations; as space repair and rescue facilities; or as staging areas for major planetary and lunar operations. As such, these space-based support facilities would supplement some of the tasks currently carried out at the present earth-based launching, recovery and control centers.

- The federal appropriations and expenditures for space technology are a reflection of: 1) U.S. national policies and objectives; 2) the Soviet techno-military threat; and 3) specific military and/or scientific requirements. In addition to these factors, the national space budget is molded by decisions and actions taken in Congress, the Executive Branch, the government agencies, the scientific community and private industry.

- A decision to increase or decrease total federal space budgets, or specific portions thereof, affects the planning, the direction, and in some cases, the very survivability of specific space projects and programs. For example, on May 25, 1961, when

President Kennedy established a national goal to place men on the moon before 1970, the fiscal and legislative machinery of the U.S. government was set in motion, a supplemental appropriation of $549 million was added to our space effort, and a re-examination of NASA's man-in-space program was initiated. Subsequently, the time schedules, budget priorities, and the management of such projects as Gemini, Apollo, and Saturn were significantly modified.

- Of the total amounts appropriated for space in the 1958 through 1966 time period, NASA's share increased from $117 million or 34 per cent of the total federal space budget, to approximately $5.2 billion or 74 per cent of the FSB. In the same time period, the DOD portion of the federal space budget also increased from approximately $206 million to $1.7 billion. However, on a percentage-of-total basis, the DOD space appropriations decreased during the 1958-1966 time period from 60 to 24 per cent of the FSB.

- Federal space budgets could remain at current levels through 1970 as a result of a continuation and possible further escalation of the Vietnamese war, a factor that space-age managers in government and industry will have to take into consideration in their planning activities.

- There are a number of developments which could take place between 1966 and 1970 which could result in an increase in the total annual space budgets, above the current $7 billion level. For example, it is very possible that a continuing series of Soviet space "spectaculars", such as a manned cislunar flight, the construction of a space station in earth orbit or a lunar landing (all of which are technologically possible before 1970), could result in demands to step up and/or supplement the current space programs and thus lead to further increases in annual space appropriations above the $7 billion level. This would certainly occur if Congress approved one or more of the proposed post-Apollo programs, i.e., the lunar base, the manned space station or manned planetary exploration.

- On the basis of evolving and currently unforeseen program requirements, coupled with the effect of the Soviet space developments and/or military threats, it is possible that the total federal space budget could rise from the current $7 billion-plateau to as much as $13 million by 1971. This budgetary increase is certain to occur if we get firm evidence that the Russians are going to beat us to the moon and have initiated a manned Mars exploration program.

- In spite of some conflict and overlap, as illustrated by the MOL and Apollo space station programs, it appears that NASA and the Department of Defense will continue to view U.S. policies and objectives through the same pair of glasses. This will be reflected in a strengthening of the close working relationships between the two agencies; their utilization of interagency planning and study groups--such as the Aeronautics and Astronautics Coordinating Board, the Gemini Joint Planning Board and the Joint Manned Space Flight Committee--to resolve organizational, technical and budgetary conflicts; and their joint management of, or cooperation on, certain projects, such as the X-15, Gemini, MOL and Apollo.

- Following the precedent set by such programs as the X-15, Mercury and Gemini, DOD and NASA will probably cooperate on the development of the large manned space station as well as the hypersonic research aircraft, a vehicle with the capability to take off from a conventional airfield, go into orbit, re-enter and land like an aircraft. Another project of major size and importance, which in all probability, will be jointly managed by NASA and DOD, is the construction of a lunar base.

- Owing to the size and complexity of the lunar project, the resources required, and the multimission capabilities inherent in a lunar base, a closely coordinated management effort by DOD and NASA may be required. Or, it may be necessary to establish a new and autonomous Comsat type agency to manage the project.

- The growing numbers of scientists and technicians going into the aerospace industry is also one of the factors responsible for upsetting the industry's traditional four-to-one ratio of production to non-production workers. For example, in 1954, hourly production workers comprised 72 per cent of the aerospace industry's work force. By 1959, only 50 per cent were production workers. At the present time, aerospace production workers represent roughly 40 per cent of the industry total, whereas predictions indicate it will decrease to approximately 30 per cent by 1970.

- After World War II and the Korean War, nuclear weaponry, high performance jet aircraft and ballistic missiles, as well as the "new look" in military strategy changed the character of the aircraft and electronics industry. Large numbers of aircraft and missiles were no longer required. Consequently, mass production facilities and machine tools were not needed. Moreover, the aircraft, missile, and electronics systems of the nuclear age were not only built in fewer numbers, but were considerably more complex. This led to a reduced demand for large numbers of production workers on one hand, but an increased demand for skilled technicians, engineers, and scientists on the other.

- The problem of how to dispose of, or reduce, the excess production facilities and machine tools inherited from World War II and the Korean War period still plagues the federal government and the aerospace industry. In some cases, the remedy has been modification, consolidation, or sale of excess facilities, or scrapping of obsolete tools and equipment. This, along with the construction of new space age facilities (in most cases away from the area of the home plant) has created economic, social, and political problems near the home plant, as well as in the area where the new facility is located.

- One of the most significant factors affecting aerospace decision-making and planning is the space accomplishments of the Soviet Union. For example, their demonstrated ability to achieve space "firsts" (i.e., the first earth satellite, the first man in orbit, and the first to soft land instruments on the moon) is not only a direct challenge to our technical and managerial competence, but to our international prestige; whereas, the military implications of their space program pose a threat to our national security and defense posture.

- The Soviet space program directly or indirectly influences: 1) national policy, as formulated by the President, Congress, and the heads of government agencies; 2) the amount and distribution of the annual federal space budget; 3) the decisions made by aerospace management in both government and industry; 4) the priority, scheduling and planning of the various DOD and NASA programs; and 5) the direction and scope of American technological developments.

- It would be an over-generalization to state that all changes in our space program between 1957 and the present were no more than reactions to Soviet efforts; however, there is enough evidence to indicate that Russian space accomplishments have and will continue to influence the magnitude, direction, funding and organization of our space effort as well as the related decision-making and planning.

- While the Soviet Union will have a wide spectrum of space options to choose from between now and 1970, the most significant Soviet space development may not take place in earth orbital, cislunar or planetary space, or even in the area of possible military applications, but in what they accomplish on the moon's surface. For example, before 1969, the Soviet Union should have the man-rated boosters, the associated technology, and the operational experience to land a manned spacecraft on the moon. This mission has been cited by leading Soviet scientists, cosmonauts and politicians as one of their priority goals. If they carry out a lunar landing before 1969, the USSR could win the moon race by at least one year, unless the pace of the Apollo program can be increased significantly.

- There are indications that the Soviet Union will employ earth orbit rendezvous rather than a lunar orbit mode to land men on the moon. In the earth orbit mode the Russians could utilize an improved version of the Vostok or Voskhod spacecraft as building blocks with earth orbit-to-moon propulsion and landing modules attached. To launch the lunar spacecraft modules the new Proton booster with high energy upper stages could be used. The development, by 1968-1969, of a lunar lander based on Vostok, Voskhod or Proton, an advanced version of the Proton booster, and multiple launching and orbital assembly techniques are well within the estimated technological capabilities of the Soviet Union.

- It should be emphasized that any of the current and future Soviet space developments could evolve into military systems when and if a requirement arises. This is to be expected inasmuch as the USSR has never differentiated between scientific and military research and development, and Soviet leaders by their past actions and statements have frequently stressed the military significance of their technological achievements.

- Of all the possible future Soviet space activities, the one which would have the greatest effect on the composition and evolution of the U.S. space program is the development of a military space capability by the USSR: particularly if it is an offensive weapon. There is no question that the USSR has the basic building blocks for developing military space systems and will deploy them, if the need arises. When their systems will be deployed and what specific form they will take is difficult to predict.

- The series of technological achievements, beginning with Sputnik I, as well as the close ties that exist between Russia's scientific and military community, gives positive evidence of a well-planned space program with a dual objective in mind: 1) to establish the scientific primacy of the USSR; and 2) to develop a technical and military capability to control the realm of space.

- While the aerospace industry is highly competitive, it is not competitive in the same sense that General Motors and the Ford Motor Company are competitive. These differences are mainly a function of the aerospace industry's unique characteristics and position in the American economy. For example, the aerospace industry, unlike the more traditional commercial companies, designs and produces hardware primarily for national defense and space exploration. Consequently, with the federal government as its principal customer, the industry is at one and the same time a private industrial concern and a prime instrument of national policy.

- Since the aerospace industry employs one-fifth of the nation's scientists and engineers it has developed a unique capability to solve the most complex technological problems. However, because it has this problem-solving capability, the aerospace industry has had to function with an extraordinary degree of flexibility, take greater than normal risks, and reach out beyond the leading edge of technology to a greater extent than consumer-oriented industries. Moreover, the aerospace industry has had to adjust rapidly to quantum changes in a variety of directions in order to survive, particularly, as the pace of technology has accelerated, as the military and technological capabilities of the Soviet Union have increased, and as national policies have changed to meet these challenges.

- Both NASA and DOD encourage the aerospace industry to be competitive in a number of ways; one being the use of the incentive contract and the other through the mechanics of the source-selection board.

RECOMMENDATIONS

Based upon the research conducted during the preparation of this report it is recommended that the following topics be considered for further study:

- The space policy implications of a pre-1969 Soviet manned lunar landing. A post-1969 Soviet manned lunar landing.
- Cost/effectiveness criteria for selecting post-Apollo goals.
- Policy alternatives relative to U.S.-Soviet cooperation and/or conflict in space.
- The application of aerospace planning and decision-making techniques to other regional and national problems.
- Major space technology trends for 1970-1985.
- The impact of a Soviet military breakthrough in space.
- The role of private industry in space policy formulation.
- The policy implications of a joint U.S.-Soviet lunar base program and/or joint U.S.-Soviet Mars expedition.
- Possible Soviet space goals for 1970-1980.
- The application of space systems management techniques to the development of urban transportation systems.
- Similarities and differences between military and civil space missions, operational requirements and technology.
- The application of space management techniques and technology to oceanographic research.

- The impact of the war in Vietnam on space program planning and decision-making.

- The national requirements for, and utility of, a hypersonic aerospace vehicle.

- Technical and operational alternatives to large-payload, post-Saturn booster systems.

- The impact of the new planning-programming and budgeting system on the federal decision-making process.

- The economic and social impact of an expanded space program. The impact of a reduced or minimum effort space program.

- Competitive practices in the aerospace industry: Selected case histories.

- The manned space station and the manned Mars spacecraft: A composite system or two separate systems.

- Space policy formulation: Its process, evolution and structure.

- The growth potential of the MOL Program.

- A comparative analysis of U.S. space goals and other national objectives.

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