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SPACE DIVISION LAUNCH SYSTEMS BRANCH

MANAGEMENT PROBLEMS FACED IN MAKING FUTURE MANNED SPACE EXPLORATION DECISIONS

by

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ABSTRACT

This paper presents in synoptic form, an analysis of the management problems being faced in making future manned spaceflight decisions. It is an attempt to view the manned space program in total perspective - its relationship to other scientific research, other national programs, the role of Congress, the President's role, industry's role, and then show their relative influence and impact on decision making for the Post-Apollo period.

I. INTRODUCTION

America's space program again stands at another crossroad, that of what to do after Apollo. This paper is a synoptic survey of the major post-Apollo programs in an attempt to view these programs in their total perspective, and identify the major management problems being faced. There are three broad directions in which the nation can direct the next manned space efforts. They are Earth-orbit, Lunar exploration, and man-to-the-planets. Many missions and national space programs studies relative to post-Apollo have been conducted by NASA, industry, and the scientific community, including the alternates of Earth-orbit emphasis, Lunar emphasis, planetary emphasis, and the so-called balanced programs. The management problems for these programs fall into four major categories; 1) technological, 2) economic, 3) political, and 4) overall management.

The category of technological problems is rather self-evident. They are those problems that are purely technical or program in nature. Can we do it? What are the various means of mechanization? What is the final configuration? What are the tools for controlling and managing the technical aspects of a program?

The economic aspects of space exploration are as they relate to the rest of the nation's economy. Can the country afford these programs in the time period being considered?

The political aspects are those dealing with the basic and fundamental problems that both Congress and any administration have in making decisions as to the acceptability and desirability of supporting space research. Congress and the administration are the elected representatives of the people who eventually pay for these programs, and it is their responsibility to be sure that the people's tax money is used effectively and wisely.

The management problems include all three of the above and anything else that might be pertinent.

To establish adequate perspective, first the Apollo decisions are reviewed, then the current Apollo Applications, and finally man-to-the-planets. Discussions on large Earth-orbiting stations and extended Lunar exploration are not analyzed as separate subjects, but sufficient pertinent points and features of these programs are brought out in the Apollo Applications discussions to provide a framework for analysis.

An analysis framework of the various space programs and their management problems was constructed. Each notation in the framework is presented in a highly abbreviated form, and in reality is a separate major subject of discussion in itself. The conclusions drawn from this framework are the results of a one-man study. The primary data source for arriving at these conclusions include NASA and Administration Advisory Committee Reports, Congressional hearings on space activities for the past six years, and other open literature government and non-government sources.[1]

To set the stage for reviewing the history of Apollo, one should briefly review the more significant milestones in the development of the modern rocket. The bar chart (Figure 1) illustrates the breadth and depth of the industrial base available to the late President Kennedy at the time of his decision to commit the nation to Apollo. The events are briefly discussed below.[2]

On March 16, 1926, Dr. Robert H. Goddard's historic launching of the world's first liquid fueled rocket represents the first major milestone in liquid-propellant rockets. This was followed in the 1936-1953 time period by the work of the Guggenheim Aeronautical Laboratory (GALCIT) of the California Institute of Technology in considering rocket

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[1] A listing of the referenced documents is furnished in the Bibliography.

[2] The source data for this section were derived primarily from the following documents which contain a much more detailed discussion of these events and notations to the original source documentation: Rosholt, Robert L., An Administrative History of NASA, 1958-1963, NASA SP-4101 (Washington: U.S. Government Printing Office, 1966); Swenson, Jr., Loyd S., Grimwood, James M., and Alexander, Charles C., This New Ocean: A History of Project Mecury, NASA SP-4201 (Washington: U.S. Government Printing Office, 1966).

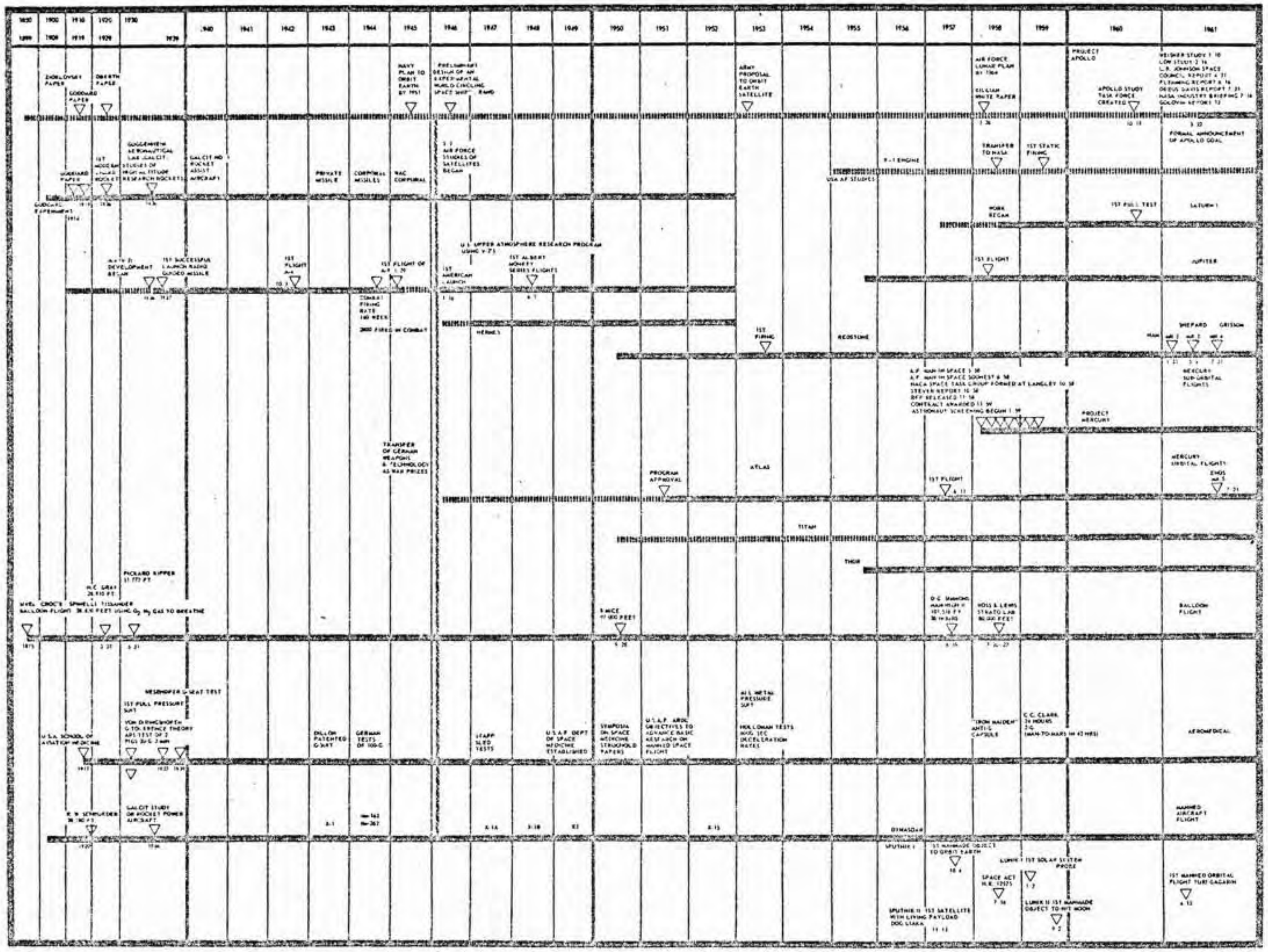

Figure 1: HISTORICAL MILESTONES RELATED TO MANNED SPACE FLIGHT

propellant aircraft and atmospheric research products.[3] This work led to the Private and Corporal series of rockets which were mated with captured V-2 rockets after World War II to conduct upper-atmospheric research.

In 1936, work began in Germany on the A-4 (V-2) rocket; the first major effort to make an operational, liquid-fueled, rocket-propelled, guided missile. The first successful flight of the V-2 was on October 3, 1942, at Peenemunde. On January 24, 1945, the Germans flew the A-9 rocket, a winged prototype ICBM. By the end of World War II, Germany was able to make this weapon operational and to successfully launch approximately 2,800 of them at targets in England and on the continent. The launch rate peaked out at 180 per week. This work represents a development period of six years with a prior intensive technology effort of three years preceded by a basic multi-continent, multi-national investigation and feasibility period of roughly 30 years. Thus, it took approximately four decades to evolve an operational new mechanism from basic liquid-rocket technology application research studies.

With the end of World War II, Operation Paperclip gathered over 130 German and Austrian scientists and their families as well as a host of data, together with 300 freight carloads of V-2 components, and transported them to the United States.[4] A great deal of this material went to White Sands, New Mexico, and the staff was dispersed to the Army, Navy, Air Force, and the Department of Commerce. The first captured V-2 was fired at White Sands on January 16, 1946, symbolizing the integration of the German efforts into the United States' work. The Hermes rocket represented the integration of the two technologies (German/American), while the Redstone represented America's scaling up and wringing out of the inherent shortcomings of the V-2, which were bypassed in the haste to make an operational wartime weapon. The

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[3] Emme, Eugene M., and Maliva, Frank J., The History of Rocket Technology (Detroit: Wayne State University Press, 1964), pp. 47-66.

[4] Akens, David S., Historical Origins of the George C. Marshall Space Flight Center, MSFC Historical Monograph No. 11, Huntsville, 1960, p. 27.

Atlas, Jupiter, and Thor rockets are further scale-ups and variations. Thus, the better than 20 years work conducted in Germany was effectively translated by the United States to operational "second generation" ballistic missiles of much greater range in approximately ten years.

The liquid-fueled rockets developed for military applications form the foundation of the launch vehicles presently utilized by NASA, including the preliminary efforts leading to the Saturn V. The basis for the design of the Saturn V centered on the F-1 engine for the S-IC first stage. This engine was originated as an Air Force study about 1955 and was transferred to NASA in 1958. Full development of this engine began in January of 1959 and the engine was first fired in May 1963. The Saturn I vehicle was originated by the Army, essentially as a cluster of Redstone rockets around a Jupiter core. The use of liquid hydrogen as a propellant fuel for upper stages also has its roots deep in military technology.

The technology for manned flight slowly evolved from the first use of stored oxygen/nitrogen by the ill-fated flight of three Englishmen in a balloon in 1875.[5] Serious work on man's ability to exist and work in upper atmosphere began with the establishment of a U.S. Army School of Aviation Medicine during World War I.[6] Work on manned flight concentrated on features applicable primarily to aircraft type flight. These efforts provided a fine technology capable of working out the problems associated with a manned rocket flight and space flight. Without this broad understanding of manned aircraft flight, manned rocket-borne space flight would have been slowed greatly.

In 1957, Sputnik I set the stage for manned space flight. It proved the ability to orbit man-made objects about the Earth. Sputnik II in the same year demonstrated that living organisms of complex nature (the dog Laika) could exist in space for extended period ("Albert" monkey ballistic flights were conducted using V-2s in the late 1940s). These successes were followed by the first manned orbital flight on April 12,

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[5]Gillies, J. A., (ed.), A Textbook of Aviation Physiology (London: Pergamon Press, 1965), p. 3.

[6]Link, Mae Mills, Space Medicine in Project Mercury, NASA SP-4003 (Washington: U.S. Government Printing Office), p. 11.

1961, of Soviet Cosmonaut Yuri Gagorin in Vostok I. On February 20, 1962, John Glenn became the first American to orbit the Earth.

In little more than six decades (1898 to 1961), modern rocketry has progressed from an abstract, little publicized, discussion on the rate of burning of fuel through highly complex mechanisms by which man could travel and exist in the new ocean of outer space. Man's learning to survive in the upper world began almost a quarter-century earlier.

II. REPRISE OF THE APOLLO DECISION

a. TECHNOLOGICAL PROBLEMS

There were no serious technological problems that the United States scientific and engineering community considered unsolvable. In fact, the program had a prior extensive feasibility study phase, and the ballistic missile developments of the early and mid-50's in the United States established the industrial base for producing Apollo. This industrial base for the launch vehicle consisted of designing and developing ballistic missiles, including the elements of re-entry techniques, navigation systems, launch and range systems, and liquid-fueled rocket engines. An Air Force study was completed, and development was begun on a liquid-fueled rocket engine capable of producing a million and a half pounds of thrust. This engine was kept at a technology level with no assigned mission. High-altitude flight equipment was available through the Man-high and Strato-lab programs as well as the 'X' series of aircraft.

A launch vehicle capable of producing roughly a million and a half pounds of thrust, the Saturn I, was being developed by the Army, and had been tested on a captive test stand. This launch vehicle had an exceptionally short development period (2-1/2 years), resulting from the fact that its primary elements, the Jupiter and Redstone rockets, had been previously developed. With some further extrapolation of this launch vehicle, it was initially considered feasible to send men to the moon and return by way of Earth-orbit rendezvous. Other launch vehicles considered were clusters of Titans and Atlases. The Nova vehicle, and the C-5 were at that time considered the most advanced launch vehicle concepts. The major element of these vehicles under serious development was the F-1 engine. The choice of launch vehicle centered in the mission mode (Figure 2).[7]

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[7]This chart was constructed from the various configurations contained in the early Marshall Space Flight Center history (MHM) documents. These vehicles are really classes of configurations and should not be considered as the total family studied before the final Apollo configuration was chosen. The author was not able to locate any data on the Saturn A or C-4 configurations.

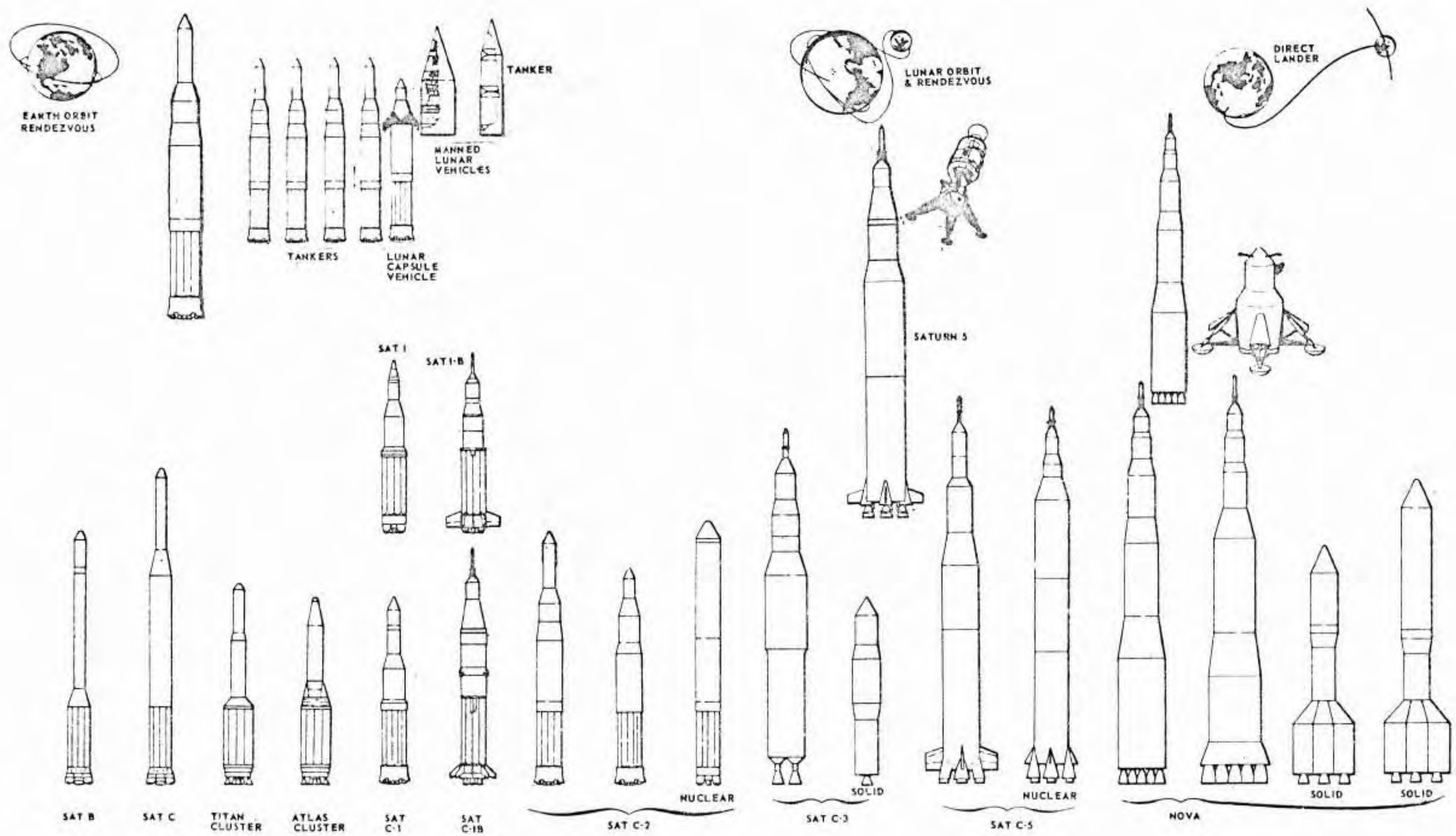

Figure 2: APOLLO LUNAR MISSION VEHICLE EVOLUTION

The launch vehicle and spacecraft problems were not one of, "Could it be done at all?", but rather, "What was the most efficient and effective means to accomplish the task?".

The most critical technical problems requiring solution centered about man himself. Could man exist in space? Could he perform effectively in space? Could he exist safely in space long enough to go to the moon and back? Would he have any adverse after-effects? Could he survive the re-entry? Answers to these questions could be obtained through the Mercury and Gemini programs. The Man-high and Strato-lab flights contributed to the confidence that man could survive in space.

The Mercury program was intended to demonstrate the ability of man to exist in space for a short time, exist in the zero-gravity environment, prove out the capability of the basic life-support system, and survive re-entry. Gemini was designed to prove man's ability to exist in space long enough to survive the Apollo mission (14 days), and to prove out the vital techniques of rendezvous and docking.[8]

These efforts were paralleled by the supporting technologies, including instrumented unmanned missions to the moon to prove out the navigation and communications techniques, and provide the supplemental data needed to design the landing gear. Close-up photos obtainable from an automated Lunar-orbiter were needed to select the final landing site. The Pegasus program provided data on the amount of micrometeroid activities. Other programs provided data as to the radiation profile.

In summary, the pre-Apollo decision had a very sound technological base of 1) an existing launch vehicle (the Saturn I) well on hand; 2) fundamental work well advanced in designing larger and more sophisticated launch vehicles; 3) basically sound communications, guidance, navigation technology, and re-entry technology; and 4) a reasonable knowledge of man's ability to survive in a closed-cycle environment and a conservative plan for extending that capability to survive in space through projects Mercury and Gemini.

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[8]The original intent of Mercury was not directed to supporting a manned Lunar landing program whereas Gemini was.

b. ECONOMIC ASPECTS

In the five-year period, 1956-1961, the NACA-NASA budget rose by a factor of 10 (about 71 million to 740 million dollars) or a hundredth percent of GNP to a little more than one-tenth percent of GNP, while in this same time period the GNP rose close to 100 billion dollars. The general economy had just passed through a minor recession, and while the economy was rising, defense expenditures as a percentage of GNP, were on the downturn. The long range projection for GNP growth was a trillion-dollars economy by 1970. Thus, an Apollo program whose projected total costs ranged from twenty to forty billion dollars was considered to be well within the country's ability to afford.

c. POLITICAL CLIMATE

In 1961, the primary political climate centered around the desires of the new Kennedy Administration to focus the nation's attention on a totally new image. The Apollo Mission appeared the ideal answer. First, it drew attention away from national vexation over Soviet accomplishments we could not readily match, because of technical limitation during the first Kennedy administration. It also set a goal of putting a man on the moon in this decade. This was far more ambitious than any project ever undertaken in the history of man. Thus, Apollo provided the means by which the Soviet physical accomplishments could be counter-balanced in the world's arena of national image. While Apollo might not be able to surpass the Soviet's for a long time, the intentions and scope of accomplishments could be sufficiently significant to prevent the subject from becoming a major political issue. Also, President Kennedy, in his May 25th, 1961, message to Congress, had said that we had the technology well in hand (Figure 1), all that was needed was the decision to use it.[9]

Establishment of the Apollo goal provided the Kennedy administration greater flexibility in the world's political balance of power. A second benefit was the "open space knowledge" feature which allowed everyone to participate in our space program by being able to observe our successes and failures and having access to the scientific and engineering data gathered. Third, the United States could effectively advance

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[9] Rosholt, op. cit., p. 192.

many technologies of peaceful intent that also had possible military applications. Fourth, the space agency could serve as an excellent economic pump primer, wherein the economy could be stimulated without building war machines, thus in essence creating a new national economic tool. Fifth, the products developed for space would have no direct competition in industry. Sixth, the technology created could produce many new spin-off industries. Seventh, the space centers could be put almost anywhere in the country and become long-term regional development tools.

d. MANAGEMENT PROBLEMS

The top management problem was to build a management system capable of creating and effectively managing a single large and sophisticated nationwide team in a few years, to maintain control of this team, to achieve the program objective, and to build the facilities to perform the work. To roughly illustrate this problem, a simplified Apollo program phasing chart is shown in Figure 3. This shows the major program elements being accomplished in parallel almost from the start. The dollar value of each of these major program elements is measured in billions of dollars. Superimposed onto this main-stream effort of vehicle design and manufacture was the parallel program to design and build the facilities to manufacture the products, and a third-level program to select and train the operating personnel. On top of all this was development of a new management system to control all of these activities. Next was the task of selection and training of the astronauts themselves.

To accomplish these tasks on schedule, required the very rapid build-up of a team of over 300,000 scientists, engineers, craftsmen, and supporting personnel and to assign tasks on the basis of minimum specifications under conditions of major revisions. The overall Apollo management problem was, and still is, the delivery of safe and effective products on schedule with a minimum of waste.

The initial management problems included; 1) selecting many prime vehicle contractors in a very short period, 2) defining the scope of work required of these people in terms of levels of effort, 3) keeping the second and third tier contractors informed of the progress on vehicle design, 4) determining the points in time when sufficient confidence has been achieved in the design to authorize building of vehicles and facilities,

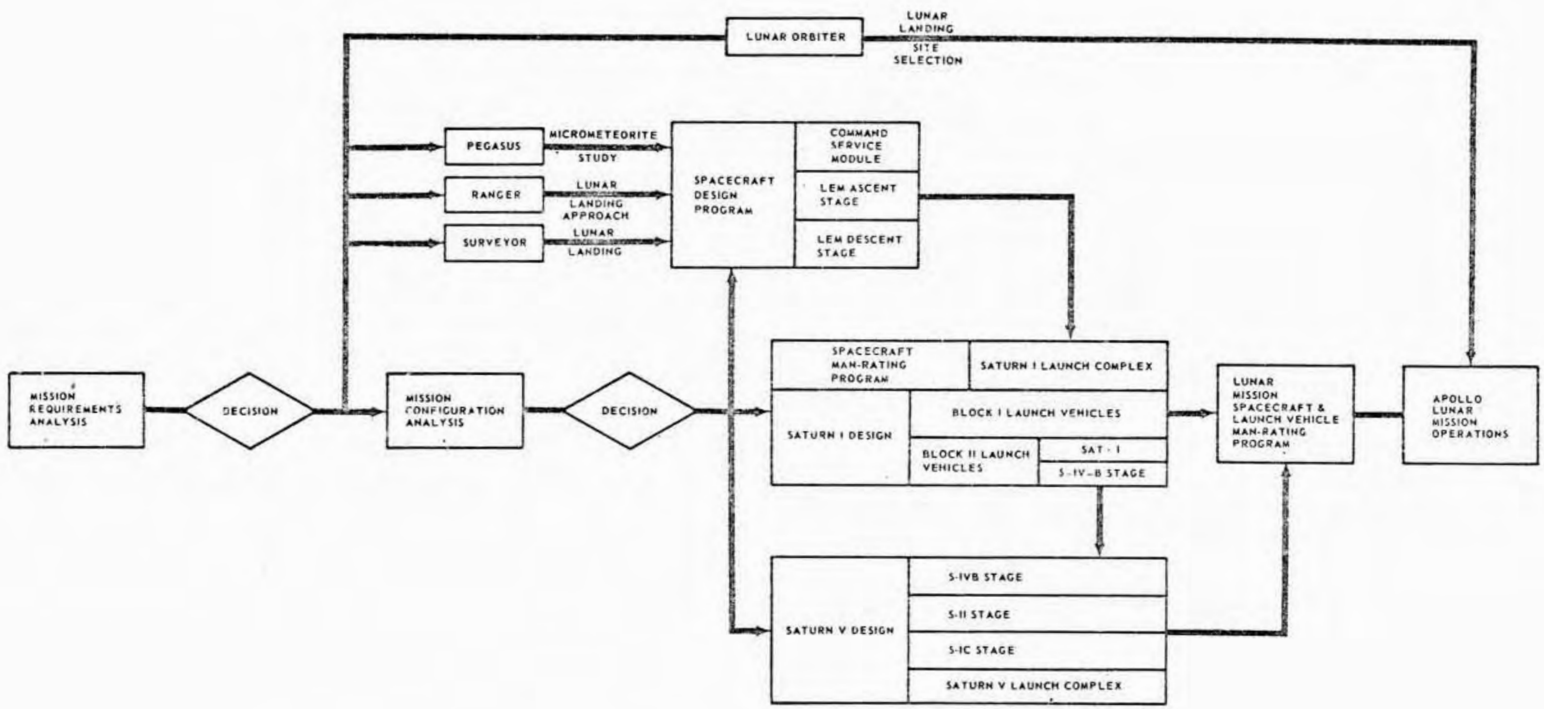

Figure 3: SIMPLIFIED APOLLO PHASING CHART

5) evaluating the long-term and short-term impacts of delays, 6) seeking alternatives when impasses arose, 7) assuring that all contractors were oriented to the proper direction, 8) establishing management communications channels, 9) defining technical training requirements, 10) implementing technical training programs, 11) establishing and implementing adequate fiscal controls, 12) starting new government centers, 13) implementing the space program into existing centers which were being integrated into the space organization, etc.

With Apollo currently entering the man-rating stage, the great bulk of the facilities have been built, all hardware contracts (less changes and certain spares) have been let, the Saturn I program launches have been completed with 100 percent success, the Saturn IB vehicles are being readied for launch and man-rated Apollo spacecraft will be put into Earth-orbit. The Saturn V stages are being assembled for flight testing in 1967. The program is now entering the phase which is the true test of effective program management, that of mission success. The quality of the design, planning, and management will be reflected in the number and scope of problems uncovered during the integration phase. As the vehicles are assembled, and the system is man-rated for the Lunar Mission, there will be inevitable stepped-up pace of operations and redirection of men and equipment, which is characteristic of program evolution from development to operation.

III. THE CURRENT APOLLO "X"/APOLLO EXTENSION SYSTEM/APOLLO APPLICATIONS DECISION

a. GENERAL

The Apollo Applications Program has been identified as a four-year space-exploration effort to be conducted in the 1968-1972 time period, with a good probability that the program will be continued beyond 1972. The program is presently considered as being the transition phase to new and greater efforts, such as a long-term Earth-orbit space station and extended Lunar exploration. The time span is parallel with and beyond Apollo such that it, in effect, provides a buffer of launch vehicles and spacecraft in case serious problems develop in Apollo. Also, the early success of Apollo has the opposite and more positive effect of releasing additional vehicles for the applications on the operational phase. (This feature alone makes it a very sound contribution to the manned space exploration program.) The program will utilize the same launch vehicles and spacecraft as Apollo. One of the prime program guidelines is that all vehicles scheduled for flight before the first successful Apollo Lunar landing must be readily convertible back to the basic Apollo configuration.

The intent of the program is inherent in its current name, that of applications or the operational use of this new capability to explore space. Its features are a three-man crew, the ability to escape the Earth's gravitational attraction, the ability to perform extended maneuvers in Earth orbits such as polar and synchronous orbit, to stay in Earth-orbit from 45 to 90 days without resupply.

The manned Apollo Applications missions include a variety of Earth-orbiters, Lunar-orbiters, and Lunar landings. With respect to Lunar exploration, the parallel can be drawn that Apollo Applications is to Apollo, what Gemini was to Mercury, in that with Apollo we only prove that man can reach the moon, but Apollo Applications marks the true beginning of Lunar exploration. There are a variety of mission plans and schedules in existence. Each NASA center probably has at least two versions as to what the mission profiles should be. More than likely all the Apollo and Apollo Applications contractors also have their own plans. This represents a healthy though sometimes exasperating situation. From all these efforts should evolve a program that does make maximum use of this new tool for scientific and advanced engineering investigations.

Some flight plans call for the operational ability to launch twelve Apollo-class space vehicles a year (six Saturn IB, six Saturn V) which would result in approximately 52 missions in 1967-1971 time period (inclusive of the Apollo missions). Implementing one of these plans would result in accumulating up to 20 man-years of flight time in space. (Based upon a three-man crew per mission, an average of 45 days in space per mission and 52 missions.)

The broad program impact areas are illustrated in Figure 4. The launch vehicles will have little or no significant changes beyone those normal to improve an operational system. The spacecraft will be impacted by modification to accept all the experiments and a two-step modification of mission duration capability. A major change will be in extending the life support system. The present Apollo life and operations systems are open ended, that is, all the supplies are stored and used once. The applications system can probably be partially closed-loop or have a basic power source which regenerates waste; that is, closed-loop life support in terms of oxygen and water supply, but open ended in terms of food.

The experiments are in three major categories; 1) those oriented toward expanding man's fundamental knowledge of the world around us and the universe, 2) those designed to learn more about practical applications of this new space technology, and 3) those experiments designed to solve engineering problems to further manned space flight. As current plans stand, they should go a long way towards assurance that this nation will establish and maintain preeminence in space.

b. ECONOMIC ASPECTS

As Apollo draws to completion, the level of expenditures are expected to drop off rapidly. The funds required to build and install the operating facilities, as well as the design and development of the Saturn Apollo vehicle, are on the downturn. There are no new billion-dollar-class design requirements, and no new major facilities additions are required. In view of the fact that the Apollo Applications Program is the operating phase, the level of expenditure must be expected to be

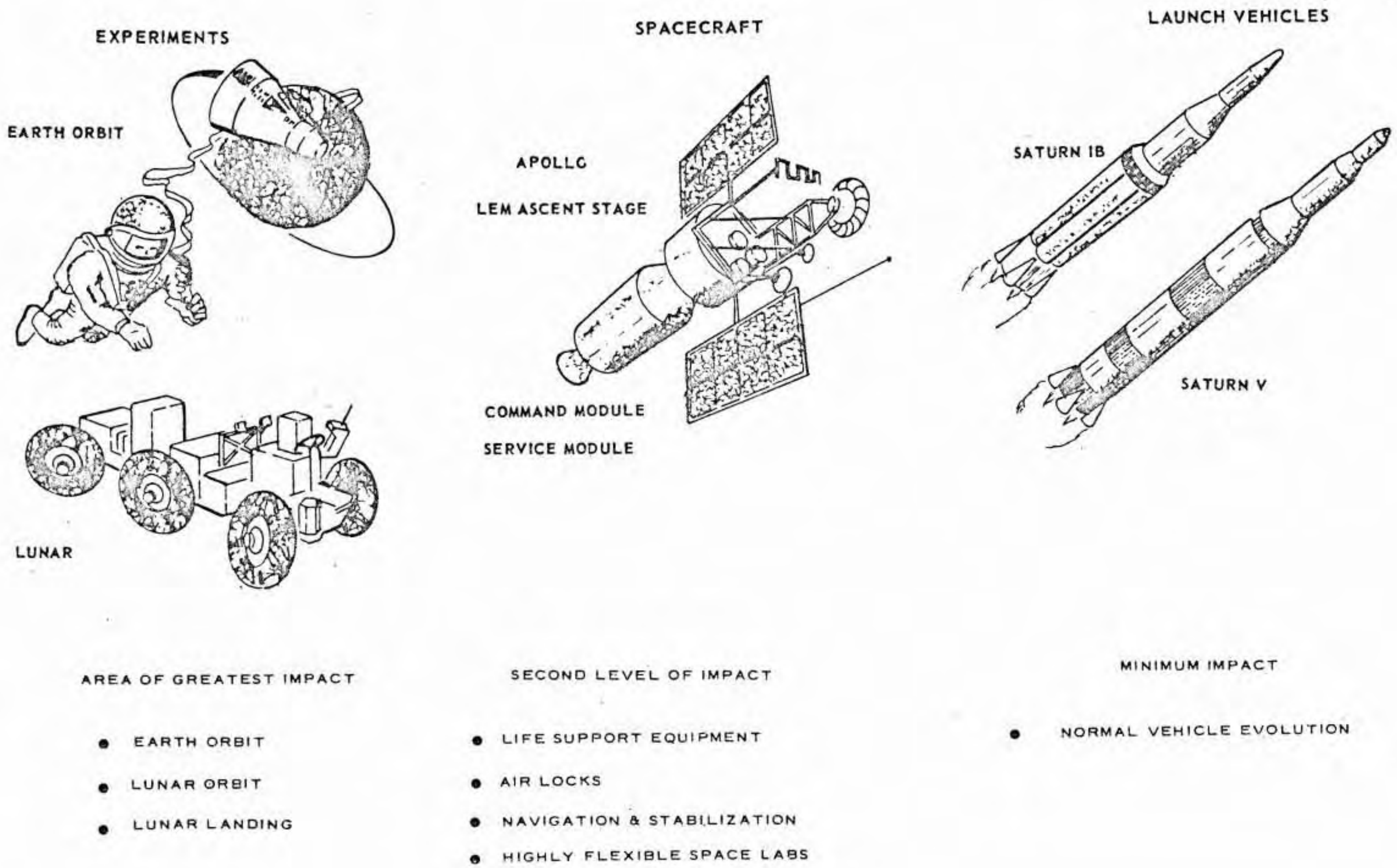

Figure 4: APOLLO APPLICATIONS IMPACTS

substantially less than that of development. Total budgets for the physical hardware to conduct the experiments are relatively modest. The major cost items are the launch vehicles, spacecraft, operation of the launch facilities, and the mission control center. The annual funding baseline for Apollo Applications is simple to compute. It consists of the sum of the cost of launch vehicles plus spacecraft plus operations, times the number of missions per year. To this figure we can add the costs of experiments and their management. Thus, a post-Apollo dip in NASA manned space flight funding requirements is normal. This dip can only be eliminated by launching more vehicles into space or starting new programs.

Maintenance of the current level of expenditure by increasing the number of vehicles launched into space is not readily justifiable since the best level of effort for conducting manned Lunar exploration can only be determined after the first landing is a fact. The only currently essential elements for Lunar exploration are advancement in the technology for extended life support, surface transportation, and certain long-lead-time experiments. Commitments to hardware programs may be desirable from the standpoint of continued growth in Lunar exploration, but because of the many unknowns the more prudent program is to keep as many options available as possible at the risk of producing a "pseudo gap."

c. POLITICAL PROBLEMS

The key political problem is best illustrated by the name changing game for this program which has started with Apollo "X," then Apollo Extension System, and the current Apollo Applications. This name game is a by-product of whether the present administration feels the need for identity to new space goals or not. This dilemma has been reflected in public statements of key NASA officials. Evidently the decision is going in favor of not projecting this as a new space program but as it really is, a continuation of manned space exploration.

Congress should find the applications program quite palatable because the funds will tend to be dispersed more evenly over the country. Many organizations not currently participating in the space program, or participating at a modest level, will be able to increase their efforts. University participation will increase. Most existing equipment suppliers will have follow-on production orders as well as a modest level of engineering changes. Therefore, it would seem that there are no serious political problems in securing approval and funds for Apollo Applications. There is one weakness, however. It stems from the diffusion of efforts which generally produce only mild political support and interest.

d. TECHNOLOGICAL PROBLEMS

Assembling the equipment and conducting the operations of integrating the various experiments into effective mission packages will prove to be quite difficult. Program plans are a sound base for operations, but as the experimental hardware evolves, the actual mission assignments can be expected to change sometimes radically due to schedule slippages and changes in priority assignments as a result of evaluations of experiments conducted in previous missions.

Another serious problem will be that of astronaut training, since with man-in-the-loop the experiment conductor will have to be a trained observer with rather extraordinary multi-disciplinary capability. Effective dissemination of the data and its subsequent utilization will not be easy.

e. MANAGEMENT PROBLEMS

Some of the management problems are reflected in the shift of emphasis from basic launch vehicle and spacecraft development to an operational program. This will result in a surplus of launch vehicle development capability and a shortage in the capability to manage highly sophisticated and complex scientific experiments. The major management problem faced is what to do with the launch vehicle development team and facilities. This valuable national asset is on the downslope and once dissipated, will be very expensive and difficult to rebuild.

In building up Apollo Applications, there is the problem of expansion of the scientific management team. The current management problems are that of selection of the best possible experiments and finding sufficient valid experiments to justify the number of missions planned. Part of the experiment management problem includes controlling the processing, dissemination, analysis, and drawing of useful information from the experiments. NASA's current method for data utilization may well prove to be inadequate for the much greater volume of data to be acquired in Apollo Applications.

An extremely difficult management problem to be solved is that of industry-originated experiment suggestions. To date, NASA has not been able to effectively draw out experiment suggestions from industry. While the current major Apollo contractors will naturally contribute to these efforts as much as practicable, it is the very resourceful and dynamic middle-size companies who have not responded as well as they could. The major stumbling block is the prudent business manager's rightful reluctance to just give away free an experiment suggestion without at least some measure of proprietary protection. No provision has been made to pay the experiment suggestor for his idea in terms of a firm commitment for the hardware contract. Also, there is virtually no need for a hardware reorder, since the experiments are one time in nature. The only valid management reason for participation is if there is a direct commercial output or there is a business slack period and managers feel the need to retain their engineering force intact. Therefore, it can be expected that they will pursue this class of business in a rather sporadic manner.

In line with this thought is the condition where the experiment conductor is not the experiment suggestor, and for some reason or other the suggestor does not have the technical staff to conduct the experiment, or he did not put in the low bid for the hardware. Clarification is needed as to what are NASA's liabilities both ethically and legally. The minimum that is needed is some public awards program on experiment suggestions to inspire submissions and to recognize individuals.

IV. MAN-TO-THE-PLANETS DECISION

a. GENERAL

A number of studies have been conducted by NASA, industry, and the scientific community in general as to what would be the most profitable next major space goal. The most studied mission has been the Manned Mars Mission for which various mission profiles have been constructed, the technological problems identified, the scientific contributions considered, and cost/time projections constructed. The Mariner IV flight has reopened the discussions as to where man could and should go next - Mars, Venus, or the Asteroids. Manned travel to Jupiter and the other planets is only achievable in the next century, or at the best in the 1990's.

The decision as to which planet to visit first is much more complex than the moon decision because so little is known about the planets. More elaborate study of Mars and Venus has only been possible in this century, and our best Earth-bound telescopes do not provide us with adequate data to seriously design a manned vehicle. The Voyager unmanned planetary explorer, in addition to its primary mission, could provide the additional information required to design a manned spacecraft and aid in establishing the mission priority (Mars or Venus).

b. TECHNOLOGICAL

The technological decisions to be made in evolving the manned planetary exploration vehicle are far more difficult than those made for Apollo because far less is known about the planets than the Earth's moon from the standpoint of designing a spacecraft to accomplish the mission. A rough rule-of-thumb for measuring level of technical difficulty is through comparison of the investment dollars required. The Apollo program is at the $20 billion level of effort. Up to $100 billion has been estimated for the manned planetary program. This indicates that the technical decisions are roughly five-times tougher to resolve. Although there are many technological problems in such an effort, only one of the key pacing items will be very lightly touched upon here; that of the engine for interplanetary propulsion together with its total propulsion stage.

The choices of engine types are chemical, nuclear, and electric. Chemical propulsion is based upon the extension of currently proven and man-rated technology, and could be used in fly-by missions for both Mars and Venus. But extrapolation of this capability to a manned lander mission results in a rather high risk primarily in terms of the launch windows available, mission duration, and growth potential.

Since 1955, over a half-billion dollars have been invested in solid-core nuclear-engine research programs such as KIWI, ROVER, NERVA, and Phoebus. The current program status is that the NERVA engine is being readied for extensive developmental testing. More advanced nuclear propulsion types such as gaseous-core engines are in the concept study phases, and would require at least five years to catch up with the NERVA.

Electric propulsion has been progressing at a rather rapid pace, but based on the 25 years it took from beginning development of the V-2 until the Shepard flight for chemical propulsion, electric propulsion will not be a serious contender for manned space exploration until later (banning some presently unforeseen technological break-through).

The most popular concept for the interplanetary propulsion vehicle is a basic orbital-launch stage consisting of the engine and its associated fuel tank. A series of stages are assembled in Earth-orbit and the number of stages in a cluster is a function of the missions propulsion requirements. This clustering of stages concept is common to both the nuclear and chemically propelled vehicles. (This concept is similar to the original mission mode seriously considered for Apollo, Figure 2).

Due to its higher efficiency, the nuclear propulsion system has greater flexibility in that the best launch windows appear in 1984, 1986, and 1988. The best chemical system launch window is 1986. Current and future launch windows and mission mode analyses may produce better and more flexible launch options; however, at that plans must still be targeted for the best launch windows and have the other windows as alternatives. Thus, there is a calendar-fixed set of mission requirements if the Mars mission is to be accomplished in this century. The only alternative is to conduct extensive research to create totally new and more powerful propulsion systems which could allow window independence.

When these total program requirements are projected backwards to what is currently being done and what must be done soon, it is found that the nuclear engine is being developed but serious effort for the total stage is not being undertaken. To land on Mars in the 1980's, the time for decision to committing the nation to the development may well come before the primary Apollo mission is accomplished. The NERVA nuclear engine is the prime contender as the propulsion system since it is the only engine currently under significant development.

c. ECONOMIC ASPECTS

The costs of developing a manned interplanetary travel vehicle and conducting the missions have been estimated to range from $40 billion to in excess of $100 billion. The costs necessary to develop a manned planetary exploration vehicle by today's budgetary standards are prohibitively astronomical. However, to be realistic; one must look at the projected growth of the nation's GNP, and then determine the country's ability to afford the program in the next two decades. A currently accepted economic projection of GNP growth is an average annual growth rate of five percent (Figure 5). If the costs of the man-to-the-planets program are superimposed upon this projection, the scale correlation is rather interesting. First, the funding requirements roughly parallels the growth of the GNP. If we assume that the National Budget will follow the GNP in the same scale and NASA will attempt to keep its relative position in percentage of National Budget as opposed to some absolute dollar value, the conclusion is that this program's cost does not represent an abnormal strain on the nation's economy. Also, it could be postulated that to achieve the growth of GNP at this rate may require a space program of this magnitude.

Accepting the premise that the country can afford this venture, the next step is to determine what major budget items would appear as competitors. Perhaps "Competitive Programs" is better illustrated by rephrasing the term as "National Goals." There are two major categories of national goals, essential and required. The essential goals are a continuation of national security, general welfare, and ship-of-state. During the 1950's, the Eisenhower administration set 15 additional national goals (acquired), including that the United States seek to establish positions of world leadership and world community responsibility.

FEDERAL ADMINISTRATIVE BUDGET EXPENDITURES
NATIONAL DEFENSE, ATOMIC ENERGY AND SPACE
COMPARED WITH GROSS NATIONAL PRODUCT (IN BILLIONS OF DOLLARS)

FISCAL YEAR	DEFENSE & DEFENSE RELATED		ATOMIC ENERGY		NACA-NASA		TOTAL	GROSS NATIONAL PRODUCT	PERCENTAGE
1954	45.09	12.5%	1.895	0.52%	0.090	0.02%	47.1	362.1	13.0%
1955	38.84	10.3%	1.857	0.49%	0.074	0.01%	40.8	378.6	10.8%
1956	39.07	9.6%	1.651	0.40%	0.071	0.01%	40.6	409.4	10.0%
1957	41.38	9.6%	1.990	0.46%	0.076	0.01%	43.4	431.3	10.1%
1958	41.77	9.5%	2.268	0.51%	0.089	0.02%	44.3	440.3	10.1%
1959	43.94	9.4%	2.541	0.54%	0.145	0.03%	46.6	469.1	10.0%
1960	43.07	8.7%	2.623	0.52%	0.401	0.08%	46.1	495.2	9.3%
1961	44.78	8.8%	2.713	0.53%	0.744	0.14%	48.2	506.5	9.5%
1962	48.30	9.0%	2.806	0.51%	1.257	0.23%	52.4	542.1	9.7%
1963	50.00	8.7%	2.758	0.48%	2.552	0.44%	55.3	572.4	9.7%
1964	51.42	8.4%	2.765	0.45%	4.171	0.68%	58.4	609.6	9.6%
1965	47.54	7.3%	2.625	0.40%	5.093	0.78%	55.3	648.7	8.5%
*1966	54.27	7.8%	2.390	0.34%	5.600	0.80%	62.26	700.0	8.89%
*1967	58.24	7.8%	2.300	0.30%	5.300	0.70%	65.84	750	6.78%

*ESTIMATES SOURCES: REPORT OF THE COMMITTEE ON THE ECONOMIC IMPACT OF DEFENSE AND DISARMAMENT, JULY 1965 THE BUDGET OF THE UNITED STATES, 1967

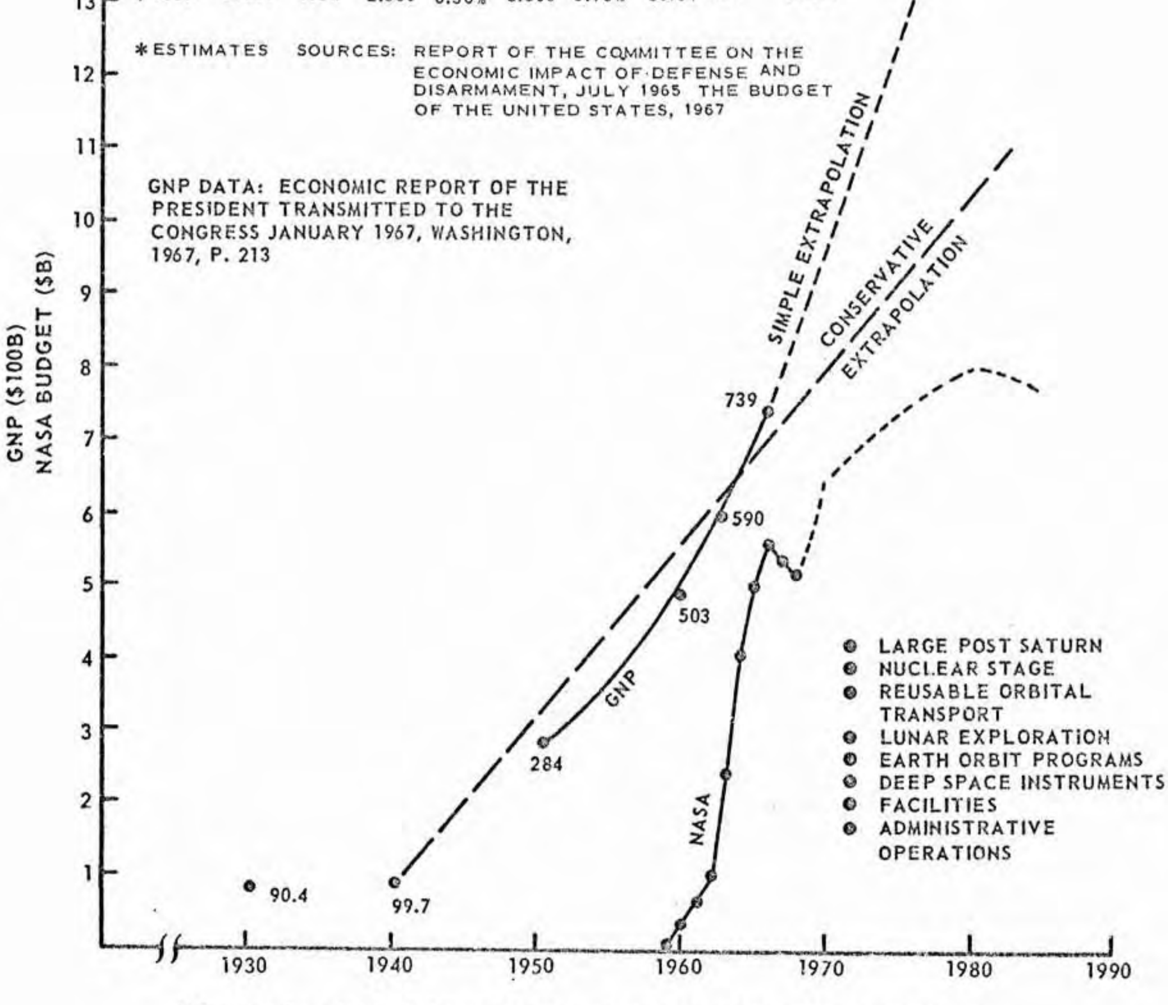

Figure 5: COMPARISON OF GNP WITH NASA BUDGET INCLUDING MAN-TO-THE-PLANETS

The Kennedy administration added to these the man-on-the-moon-by-1970 project, education, Peace Corps, and Alliance for Progress. The Johnson administration has an overall theme of The Great Society with its war on poverty, improved civil rights, and new programs in the process of formulation, including air pollution and water conservation. Thus, we have what has been called a contest of national goals or, expressed in more parochial terms, competition for position in the national budget.

The competitive programs were not studied in any great depth, but only identified as to their costs, time span, and goals, and then evaluated as to their impact upon the space program. Some of the leaders in terms of dollars-volume required are the North American Water and Power Alliance, the total scientific community, urban renewal, transportation, and the very heavy stand-by, the Department of Defense. A brief resume of these programs are included in the Appendix for your convenience.

The water and transportation programs will probably be approved because they are more essential to the nation's growth and general welfare. Both of them will also have active industrial participation and financial investment.

Open literature projections of the nation's defense requirements for the 1970's and 1980's are necessarily broad-brush and vague. The costs of nuclear war defense will be much higher because of the increased threat of more nations having nuclear weapons. Major weapons such as next generation strategic missiles, the hypersonic aircraft, naval weapons, and several Army weapons will all be multi-billion dollar programs. Since W orld War II, the long-term military budget has had step upratings associated with open combat or serious crises. The DOD budget will remain the biggest single budget item during the 1970's.

The total scientific community requirements budget will unfortunately remain a buffer item due to the diversity of its programs. It provides easy access to shifting to next year's budgets, and lacks the ability to generate a strong backing for any single effort.

d. POLITICAL

PRESIDENT - The Office of the President is different from the other two branches of our government in that the responsibility is focused on one person, and all operations are performed and decisions are made in the name of the President.

From a practical political-truism point of view, any administration's attitude towards any project can be divided into five basic categories; 1) those programs inherited from previous administrations, 2) those programs initiated and completed in the current four-year administrative cycle, 3) those which continue into the next four-year administration, 4) those that continue at least eight years beyond this current administration, and finally 5) those programs designed to be permanent activities.

The present administration inherited the Space Administration and its Apollo goal from two previous administrations. President Johnson has no other space mandate beyond Apollo. However, he does have Public Law 85-568 to enforce, which calls for achieving and maintaining the nation's preeminent role in space. In making decisions that will not bring forth political fruit for almost two decades, the President has the big political option of taking credit in history for setting the goal and setting the machinery into operation or not. (He is keenly aware that setting the goal too early might seriously jeopardize its eventual success by some future interim administration in the next decade that will reap no political fruit from the program's accomplishment.) Beyond this option he has a much broader latitude of options ranging from stopping all efforts on manned planetary exploration to full support just short of the final announcement of a new goal. It is politically prudent to keep these options open until the most propitious moment.

As a matter of status report, the current level of administrative support is to endorse the technology developments necessary to conduct a broad range of missions. Thus, the technology lead-times for manned interplanetary travel are at cross-purposes with good administrative political practice.

CONGRESS - Congress has the responsibility to review and pass upon all funds spent by the government. Inherent in this responsibility is the need for a balanced national program each year (also true of the President). A particularly vexing problem has been that of determining what research is required to be government supported; what levels, where, how long, how much does it cost, and uppermost, what are the returns to the people? For the most part, congressmen do not have the backgrounds most suited to judge the merits on one scientific program over another. They are also honest enough to be the first ones to admit it. So to more effectively judge the value of the scientific budget context, the National Academy of Sciences (NAS) was contracted by Congress in December of 1963 to produce a comprehensive study and evolve useful guidelines by which an overall national science policy could be formulated. The objective was to ensure adequate attention to America's contribution to science. With these policy guidelines, Congress then could conduct a more effective and comprehensive line-by-line review of the budget, and be better able to judge for themselves what should or should not be passed. Some 15 of the nation's top scientists contributed essays to this study. A condensation of this report to the suggested management policy guidelines is tabularized in Figure 6. This report suggests that it is better to support little sciences as a level-of-effort with management and distribution of funds being carried as specific line items in the budget for closer congressional review.

The current budget submission practices of NASA are in general agreement to the NAS suggested guidelines. NASA develops problems with both the Bureau of Budget and Congress with those items which are obviously mission-oriented research studies, but to which there are no clearly defined or authorized missions. In this category fall the large solid boosters, and the space-propulsion vehicles, the nuclear-power generators, and the deep-space communications studies. Questions regularly asked in congressional hearings include; do we have a mission or not, and if not, why are we doing this research? If NASA has a mission in mind, why not tell Congress, since they are the ones who represent the people and make the final decision as to whether NASA will or will not do this work by virtue of fiscal approval control? These activities could very well be handled in terms of level of effort rather than line items. The big problem is the high vulnerability of level of effort items too harsh, and arbitrary cuts which make it almost impossible to invest in long-term programs.

BIG SCIENCE	LITTLE SCIENCE
SOME PROJECTS CLEARLY MISSION ORIENTED	PROJECTS HIGHLY INDIVIDUALISTIC
REQUIRES THOROUGH INVESTIGATION AS TO NEED TO ATTAIN GOALS	PERFORMANCE VARIES
COSTS ARE LARGE	COSTS ARE RELATIVELY LOW
COSTS CONCENTRATED IN ENGINEERING EFFORTS	COSTS CONCENTRATED IN SCIENTIFIC EFFORTS
FISCALLY OPEN-ENDED	TOTAL BUDGET CAN BE ARRIVED AT AS A LEVEL OF EFFORT
EACH BIG PROJECT REQUIRES SPECIAL JUDGEMENT AND ACTION	CAN BE MANAGED BY TECHNICAL PANELS
SIZE SO GREAT THAT DECISIONS HAVE TO BE MADE AT THE HIGHEST LEVELS OF GOVERNMENT	
MUCH MORE CENTRALIZED PLANNING AND DELIBERATION	
STRONGEST POSSIBLE INTERPLAY BETWEEN SCIENTIFIC AND POLITICAL COMMUNITIES	

Figure 6: BASIC SCIENCES CHARACTERISTICS

e. MANAGEMENT PROBLEMS

The technical management problems center about the accuracy with which engineering managers predict advanced-on-technology and hardware lead-time requirements on a scale never before attempted. The major milestones of a man-to-the-planets program are shown in Figure 7. To these one can add research and development lead-time requirements. When one starts to select the hardware for the mission, the temptation is very strong to choose systems which are currently on hand, or those clearly feasible, but in 10 years time will be obsolete. This is the standard problem so well recognized by the military. Guidelines used by the military in selecting a technology freeze point to make a weapons system operational are somewhat applicable to space exploration, but not necessarily so. A good example is the prime criteria for a military aircraft (performance and flexibility) versus that of a commercial aircraft (safety, comfort, economy). As design commitment and development progresses, criticism will mount, and suggestions will begin to wait and include the most modern systems. Also, freezing on today's technology limits the growth capability.

The first big questions for management are; when to freeze on a mission, and how long to wait before freezing on a particular technology. It is plausible that within the next decade, a new propulsion technique not known or considered practical today can achieve the mission in a fraction of the costs and time currently projected. However, concrete plans cannot be based upon such wishful thinking. The techniques for determining the level of effort required for systems study and criteria for selection of the design freeze points used in the current Apollo program will require a complete reassessment and new standards. Most certainly, the time required to arrive at critical decisions will be extended considerably as well as the data input requirements and other criteria. The level of training required of the people making these decisions will be very high. Therefore, NASA's educational support program will probably need expansion.

NASA is currently faced with seven major questions; 1) how to eliminate the slip in funding requirements which occurs in the Apollo Applications period; 2) when is the opportune time to start developing the manned planetary vehicle; 3) should we attempt the manned planetary landing missions using the chemical propulsion technology, the nuclear technology, or electric technology; 4) can man survive and perform

YEAR			
(1961)		– FIRST CLOSEUP MEASUREMENTS OF VENUS	INSTRUMENTED PROGRAM TO ESTABLISH – MISSION PRIORITY – DETAIL DATA FOR MANNED SPACECRAFT DESIGN
(1965)	MARINER IV	– FIRST CLOSEUP PICTURES OF MARS	
(1971)	VOYAGER	– EARLIEST POSSIBLE MARS ORBITER	
(1973)		– FIRST REALISTIC MARS LANDER	
1970	BEGIN TESTING OF NUCLEAR PROPULSION STAGE		
1973	CONDUCT FIRST ORBITAL TESTING OF NUCLEAR PROPULSION STAGE		
1975	MAN-RATE NUCLEAR STAGE IN LUNAR LOGISTICS MISSIONS		
1978	CONDUCT FIRST ORBITAL TESTING OF PLANETARY SPACECRAFT		
1979	CONDUCT PRACTICE LANDINGS ON MOON (LOGISTICS MISSIONS TO MOON)		
1980	TEST NUCLEAR STAGE CLUSTER IN EARTH-ORBIT AND PUT LARGE LOGISTIC PAYLOADS ON MOON		
1980	SPACECRAFT OPERATIONAL CAPABILITY DEMONSTRATION IN EARTH-ORBIT AND LUNAR LANDINGS		
1982	ASSEMBLE FINAL VEHICLES IN EARTH-ORBIT TEST IN LUNAR TRANSFER RETURN TO EARTH FOR FINAL CHECKOUT IF CONFIDENCE IS HIGH ENOUGH TO CONDUCT VENUS ORBITER/LANDER MISSION		
1984	CONDUCT FIRST MANNED MARS LANDER MISSION		
1986	CONDUCT SECOND MANNED MARS LANDER MISSION		

Figure 7: POTENTIAL MAN-TO-THE-PLANETS MILESTONES

effectively for years in space; 5) which planet should take the top mission priority, Mars or Venus; 6) when should we build a large Earth-orbiting space station; and 7) what is the best rate and extent of Lunar exploration.

Of all the areas of scientific exploration available to man, the exploration of space stands most unique with the ease of being identifiable to goal setting and the ease by which achievement of these goals can be recognized.[10] Up until the mid-1950's, man was essentially Earth-bound. He is now capable of getting to orbit, and by the end of this decade will have the vehicles capable of taking him to the moon and back. We also now have the capability to send instruments out of the solar system. The next step is for man to go beyond the moon. These goals are easy to identify.

A question worth pursuing is association of space exploration with such clearly defined goals and the resultant problems of identifying the next goal possible even before the current targets are a fact. Unfortunately for the scientist in his pursuit of extending the frontiers of knowledge where answers are almost never really black or white, the programs of space exploration will most probably always have an identity with clearly identified goals. The general public tends to look at the space goals in black or white terms. One answer may be that the Space Agency and the nation need a sound declaration of national policy establishing a series of major national goals of exploration that will stand for the balance of the century. A well founded and well stated set of goals could go a long way toward assuring the country's preeminent position in space by setting the pace for the rest of the world to follow. Once established, these goals would serve as the basis for scientists to plan their careers, and the people and Congress to measure accomplishments. The United States alone has the ability to support programs of this magnitude. This country stands to gain much more by clearly stating to our people and to the world what we will try to accomplish in space and when.

The major technological problems are; 1) decision as to what type of propulsion system will be used, 2) whether or not man can exist and function effectively for extended time periods in space. The secondary problems are storage of propellants, orbital rendezvous, assembly of vehicles in space, navigation, communications, and electric power to operate all the systems.

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[10]See Appendix A, Par. II.

Perhaps the most severe problem to solve is an emotional one — man's fear of the unknown. Because space is a new environment and so little is known about its effects upon man, there is a tendency to magnify all parameters beyond reason. This can result in an overly conservative approach. By the end of this decade, sufficient data on man-in-space should be available to realistically assess this problem, which is the first and most important step in arriving at a satisfactory solution.

V. ANALYSIS

By assembling the classes of features and problems of the various possible major space programs into a matrix, a number of similarities and differences are apparent. This matrix is shown in Figure 8. From this, one can easily see that the man-to-the-planets program is by far the boldest, and most similar to Apollo. It is the only mission requiring new major launch vehicles and space propulsion vehicle programs. Both Apollo Applications and building of large earth-orbiting space stations do not require new propulsion vehicles, and a great deal of Lunar exploration can be effectively accomplished with rather modest improvements to the Saturn V. The Saturn V, or an uprated Saturn IB or Titan III (with appropriate strap-ons and upper stages), could be utilized for unmanned Lunar logistics. Uprating the Saturn V would make it economical to achieve extended Lunar logsitics. Uprating the Saturn V would make it possible to achieve extended Lunar stay-time, as well as a buildup of a Lunar base for conducting continuous modest level exploration of the moon. The scope of Lunar exploration plans will necessarily remain at a modest level until 1970, when man first lands there and the information brought back is assessed by the scientific community. The Apollo missions are too short to accomplish much beyond proving the ability to get to the moon and back. The Apollo Applications missions will mark the beginning of the era of true Lunar exploration, but again will be quite limited.

LESA class bases will require the buildup of a dependable Lunar logistics program; improvements in the launch capability of the Saturn V to ensure a precise launch schedule development of a Lunar colony shelter complex, life support systems, electric power generators, surface and/or flying vehicles, and the scientific instruments for use in studies of the Cosmos as well as the Lurain. Assurance of reasonable dependable launch schedules will be an outgrowth of the Apollo and Apollo Applications programs. However, any serious continued effort will require a precise launch schedule. Improvements to the Saturn V and the Saturn IB can be obtained at rather modest costs. Uprating the Saturn V to its maximum capability and/or the use of large strap-ons (either solid or liquid) are required to make a large permanent Lunar base economically feasible.

CHARACTERISTICS	APOLLO	APOLLO APPLICATIONS	EARTH-ORBIT STATIONS	MOON BASES	MAN-TO-THE-PLANETS
TECHNOLOGICAL	• NO UNSURMOUNTABLE TECHNICAL PROBLEMS • BUILD: SATURN I SATURN IB SATURN V APOLLO SPACECRAFT • DEVELOPS THE CAPABILITY TO ESCAPE FROM THE EARTH	• NO UNSURMOUNTABLE TECHNICAL PROBLEMS • NO NEW LAUNCH VEHICLES (SAT IB & SAT V) • EXTENDS LIFE SUPPORT • EXPLORE MOON • CONDUCT SPACE EXPERIMENTS • LEARN ABOUT SPACE	• NO UNSURMOUNTABLE TECHNICAL PROBLEMS • USES TITAN IIIC/SATURN IB SATURN V • EXTENDS LIFE SUPPORT • CONDUCT SPACE EXPERIMENTS • LEARN ABOUT SPACE • BUILD LARGE COMPLEX IN SPACE • BUILD RESCUE VEHICLE	• NO UNSURMOUNTABLE TECHNICAL PROBLEMS • IMPROVEMENTS TO SATURN IB AND SATURN V • EXTENDS LIFE SUPPORT • BUILD MAN'S FIRST STATIONS ON ANOTHER PLANET • EXPLORE THE MOON	• NO UNSURMOUNTABLE TECHNICAL PROBLEMS • PLANET YET TO BE CHOSEN • BUILD SATURN V MAX, OR POST SATURN • BUILD SPACE PROPULSION MODULE • BUILD SPACECRAFT • BUILD QUARANTINE STATION • BUILD ORBITAL LAUNCH STATION • BUILD REUSABLE ORBITAL SHIP • DEVELOP ABILITY TO GO TO PLANETS
ECONOMIC	• COUNTRY CAN AFFORD THE PROGRAM • GOOD SPURT TO ECONOMY • CREATES NEW INDUSTRY • PRODUCTS NON COMPETITIVE WITH EXISTING MARKETS • NO ORGANIZED OPPOSITION	• OPERATIONAL PHASE OF APOLLO • CAN BE FUNDED BELOW APOLLO LEVEL OF EFFORT • COMPETITION WITH WAR IN VIETNAM	• CAN BE FUNDED BELOW APOLLO LEVEL OF EFFORT	• RATE OF EXPENDITURES A FUNCTION OF MAN'S INTEREST IN MOON • HIGH LAUNCH RATE OF EXISTING SATURN V WITHOUT IMPROVEMENTS RESULTS IN EXCESSIVE COSTS	• COUNTRY CAN AFFORD PROGRAM • GOOD SPURT TO ECONOMY • EXPANDS SPACE INDUSTRY • COUNTRY HAS PLANS FOR OTHER PROGRAMS IN SAME PRICE CLASS
MANAGEMENT	• PROGRAM SCOPE HAS NO EQUAL EXCEPT WAR • REQUIRED NEW APPROACH TO MANAGEMENT BY GOVERNMENT • COVERED 10-YEAR DEVELOPMENT PERIOD	• CONTINUES EXISTING BASIC ORGANIZATION • NATURE OF WORK SHIFTS IN EMPHASIS FROM VEHICLE DEVELOPMENT TO OPERATIONS • 2-5 YEARS LEAD TIME REQUIRED FOR EQUIPMENT • BREAKS UP U.S. LAUNCH VEHICLE DEVELOPMENT TEAM	• REDUCES EXISTING BASIC ORGANIZATION • REQUIRES DEVELOPMENT SIMILAR TO SATURN I PROGRAM (PRIMARILY ADAPTATION OF EXISTING DESIGNS) • 4-6 YEARS LEAD TIME	• CONTINUES EXISTING BASIC ORGANIZATION • MODEST LAUNCH VEHICLE DEVELOPMENT • CONTROL OF OPERATIONS ON THE MOON • 4-6 YEARS LEAD TIME	• MAJOR GROWTH IN ORGANIZATION • PLANET PRIORITY TO BE CHOSEN TECHNICAL DECISIONS REQUIRE EXTENSIVE STUDY • 15-YEAR DEVELOPMENT PERIOD
POLITICAL	• INTERNATIONAL ASPECTS GOOD • ECONOMIC CLIMATE GOOD • CREATED MAJOR NEW OUTLETS FOR POLITICAL PATRONAGE • CONTRIBUTED TO THE ADMINISTRATION'S IMAGE	• COMPETITION WITH WAR IN VIETNAM • MISSIONS CAN BE SCALED TO FIT BUDGET • CAUSES SHIFT OF PEOPLE ALLOWS GREATER DISTRIBUTION OF POLITICAL PATRONAGE • NO SIGNIFICANT INDUSTRIAL BEYOND EXISTING CONTRACTORS • EARTH ORBIT MISSIONS HAVE DIRECT BENEFIT TO MANKIND	• RESULTS REALIZABLE WITHIN A TWO ADMINISTRATION PERIOD • RESULTS WILL BE VISIBLE IN THE SKY • NO MAJOR POLITICAL PATRONAGE GAIN • CAN CONTRIBUTE TO ADMINISTRATION'S IMAGE • WILL RECEIVE SIGNIFICANT INDUSTRIAL SUPPORT • CAN BE DELETED OR CHANGED IN ADMINISTRATION • DIRECT SUPPORT TO A NUMBER OF MANS SERIOUS PROBLEMS	• RESULTS REALIZABLE WITHIN A TWO ADMINISTRATION PERIOD • NO MAJOR POLITICAL INTEREST • CAN CONTRIBUTE TO ADMINISTRATION'S IMAGE • WILL RECEIVE SIGNIFICANT INDUSTRIAL SUPPORT • CAN BE DELAYED OR REDUCED BY CHANGE IN ADMINISTRATION	• RUSSIA CANNOT AFFORD • ECONOMIC CLIMATE PROJECTED TO BE GOOD • ALLOWS MAJOR SHIFT IN POLITICAL PATRONAGE • WILL RECEIVE MAJOR INDUSTRIAL SUPPORT • WILL BE STRONG CONTRIBUTOR TO ADMINISTRATION'S IMAGE • RESULTS WILL BE WELL BEYOND EXPECTED POLITICAL INFLUENCE PERIOD

Figure 8: MANNED SPACE FLIGHT PROGRAM ANALYSIS NETWORK (FEATURES OR PROBLEMS)

With respect to venturing to the planets, there are no unsurmountable technological problems; difficult yes, but no areas have been publicly identified as requiring a major fundamental scientific breakthrough. Rather, the true scientific breakthrough takes the form of creating the capability for man to travel to and explore the planets. A significant amount of the basic ground work required to prove the practicability of building the manned-planetary spacecraft is currently being carried out. NASA has funded studies as to the practicability of recovering the S-IC stage to achieve a significant cost saving. There are 156-inch and 260-inch solid boosters being built which might possibly be used as strap-ons to the S-IC stage in a manner suitable to the Titan-IIIC. The Saturn V vehicle could also be uprated significantly without the use of solid strap-ons, or a combination of both the solid or liquid strap-ons with improvements to the Saturn V to achieve all the Earth-launch requirements for at least the next 20 years and possibly the balance of this century.

Chemical-rocket space propulsion systems are readily available. Existing Apollo stages could be modified to serve as space-propulsion modules. However, from a mission's reliability point of view, travel to the planets using chemical rockets would be difficult if not unnecessarily hazardous. The nuclear rocket shows promise of being the primary means of space propulsion within the next 10 to 20 years. Electric propulsion may require at least another decade of work before it can become a serious contender for manned planetary propulsion.

Viewing the space exploration programs as to their political importance and impacts, the program having the greatest interest is man-to-the-planets. The political advantages are undeniable. Like Apollo, it has the most to contribute to an administration's image, and there is a whole family of major new facilities and centers required.

Our only serious contender for space leadership is the USSR, and the Soviets probably cannot afford to embark on this mission. During the 1970's the impact of the two world wars will be greatest in terms of population growth rate which has a direct bearing upon the Soviet's GNP growth rate. This physical fact compounded with another decade of socialistic economy will result in a Soviet GNP growth rate that cannot realistically tolerate a program of this scope. Also, the Soviet social pressures in the next decade will most probably become greater. As a result, the United States will be able to totally out-class the Soviets in space by starting the man-to-the-planets program. If the Soviets elect to accomplish a man-to-the-planets program within this century, it will be at the expense of many other much needed programs.

Inherent in Apollo Applications is a broadening of the current distribution of NASA funds to many smaller contractors throughout the country as well as continued follow-on funding to most existing contractors. Politically, this feature of the program has more weaknesses than strengths. The primary weakness is that it will result in a major cutback of the launch vehicle and propulsion development team. The second weakness is that greater diffusion of the contracts results in general mild support by Congress but no new strong backing.

The large orbiting space station and the Lunar base will cause major competitions among the contractors. Both programs have greater advantages over Apollo Applications because they are bolder and more imaginative. The large Earth-orbiting space station has a very significant political feature, that of easy visibility by all the peoples of the Earth. This political feature should not be overlooked. Less developed people view space exploration as a symbol of political, economic, and technical strength, and an Earth-orbiting spaceship that can be clearly seen with the naked eye both day and night will provide tremendous political leverage for the nation who does it first. It may well be that this feature will shift the priority from the scientifically desirable Lunar exploration program to the establishment of a large space station. It should be noted that many of the elements required for development of a space station are also directly applicable to Lunar exploration and man-to-the-planets.

As to the management aspects; again, the only program offering major challenge and growth is man-to-the-planets. The other three represent shifts of effort among the existing NASA centers. The economic aspects fall into the same category. The key economic question ties in with the probability of a major war after Vietnam or the Vietnam war breaking out into a general war with China. The current conservative approach of Apollo Applications is a direct outgrowth of the Vietnam conflict. The FY 1967 and 1968 NASA budgets illustrate President Johnson's continued support of Apollo, and his keeping Apollo Applications going as well as the total National Budget will allow but not allowing it to develop to the point that space planners feel they should be. If he (President Johnson) can succeed in a quick Vietnam settlement this year, then Apollo Applications could be accelerated to take up any post-Vietnam economic-technological dip. Our goals would not change but the timetable will be a function of scope and duration of war. Meeting the 1980's Mars launch windows would probably be missed if we entered into a major war. A Venus-orbiter in the late 1980's would probably be the best alternative. However, in any case abandonment of peaceful space exploration would be a serious national error.

CONCLUSIONS

At the risk of over-simplification, the following broad conclusions have been drawn:

TECHNOLOGICAL - If we can conclude that the large earth-orbiting space station and Lunar exploration represent operational outgrowths of Apollo and Apollo Applications, then the primary technological management question becomes, "Do we have sufficient scientific and engineering knowledge to recommend that the nation commit itself to the man-to-the-planets program?" The first subquestion is mission-mode choice in terms of transit time and stay-time. This is directly associated with the second equally important question of determining the scientific gains. It should be remembered that advancement of scientific knowledge of the universe is the true goal of space exploration and development of a vehicle systems represents the means by which we can arrive at these goals.

ECONOMIC - The primary economic problem is more emotional than real. This results from the very strong general tendency of both scientists and managers to measure tomorrow's economy by yesterday's standards. Future cost profiles are all too often viewed as being abnormally high. Ginzberg[11] points out that the growth in our recent economy (since 1930) has been caused largely by Federal expenditures and is what could be termed as "artificial." Berger[12] defines America as a Nation with a social conscience that will do what they (the people, sic the Government) feel is "necessary and right." If we accept the premise that the Government has a responsibility to assure a total

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[11] Ginzberg, E., "The Passing of the Economy That Never Was," Columbia Journal of World Business, Vol. 1, No. 3 (Summer 1966), pp. 133-138.

[12] Berger, B. M., Planning for a Nation of Cities, ed. S. B. Warner, Jr. (Cambridge: MIT Press, 1966), 157. "Americans have a propensity for finding social problems. By then defining them as real and hence setting ameliorative forces into action, we affirm our humanitarian heritage — America is a country dedicated to the propositions that no evils are ineradicable, no problems insoluble, no recalcitrance beyond conciliation, that no ending need be unhappy; we are a most un-Greek democracy."

national economy that meets all the peoples needs, then the management question becomes one of deciding the means for mechanization (goals).

The defense motivation has been the primary source of Government expenditures for the past three decades and is by nature noncompetitive with the commercial section of the economy. Space exploration is similar to defense in that it is both non-competitive and also provides technological support to the remainder of the economy. Thus, the National Space Program has a definite role in the total economy which should be better exploited and utilized rather than maligned.

POLITICAL - The primary political problem stems from the conflict of the practical politics rule-of-thumb relating to goal setting (that of not setting an administrative goal beyond 10 years) and the best Mars launch windows which are beyond this time period. The answer to this problem may be the development of a National Consensus of Goals for the remainder of the century.

The next most important political point is that of deciding that space exploration is a valid effort on its own merit and a continued strong effort leading toward manned interplanetary travel does not require international competition as a justification.

MANAGEMENT - This is the standard management problem, that of setting the direction of effort, setting the pace, setting the standards of performance, controlling the operation, and keeping everyone working in the same direction. Managing the man-to-the-planets program with a goal some 20 years off will require a very high degree of management perseverence, single-mindness and dedication.

APPENDIX A

I. COMPETITIVE PROGRAMS

a. NORTH AMERICAL WATER AND POWER ALLIANCE (NAWPA)[13]

In the concept study phase is a continent-spanning, water development program that would take more than 30 years to complete, and cost about $150 billion. This plan is under study by a special Senate Subcommittee on Western Water Development headed by Senator Frank E. Moss (D) Utah.

The concept shown in Figure A-1 will divert water from the Fraser, Yukon, Peace, Alhabasa, and other rivers, and redistribute it to the water-scarce areas of Canada, Western United States, and Northern Mexico. It is estimated this will be an annual redistribution of 180 million acre-feet of water, and a generation of millions of killowatts of electric power.

The objective is to assure an adequate water supply for 75 million people of the three countries for the next 100 years. George A. Morre, president of the First National City Bank of New York, feels that although there are immense administrative, legal, and financial problems to be solved, none are insurmountable.

Industry definitely wants an active role in the program so it will not be totally financed by the United States Government.

b. TOTAL SCIENTIFIC COMMUNITY[14]

A national budget item that can be expected to increase substantially is funding the total scientific community. This includes the life

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[13] Cray, D. W., O'Toole, E. T., "Water is a Multibillion-Dollar Business," New York Times, September 12, 1965.

[14] Basic Research and National Goals, A Report to the Committee on Science and Astronautics, U.S. House of Representatives by the National Academy of Sciences, Washington, 1965.

Figure A-1: NORTH AMERICAN WATER AND POWER ALLIANCE (NAWPA) sciences, the biomedical sciences, the applied physical sciences, the behavioral sciences, and the Earth sciences. The nation's leading scientists in these areas look for major increases in their budgets. Their projected work for the next decade offers great promise of many benefits for economic and sociological worth, as well as advancement of the knowledge of mankind.

Programs currently being funded at a $20,000 per year level will, due to the necessary complexity of investigation, require funding at the million dollar level. The chief causes of increasing funding level are the needs for more expensive instruments and the need for computers to process the data. For example, what could be done with one man and a $500 microscope in the past now requires a half-million-dollar electron microscope supported by a million-dollar computer and a staff of 15 people. Thus, the total scientific programs on the 1970's can easily reach the multi-billion dollar level.

c. DEFENSE

The nation has always been faced with the problem of effective defense with reasonable costs. A reasonable level of support for one generation may not be adequate for the next. The major change in armed forces expenditures since before World War II, has resulted in a peacetime shift from 3 percent of the national budget to almost 50 percent. Each year the Bureau of Budget and the administration have the serious problem of trimming off desirable defense programs and yet maintaining the security of the country. That expenditure will probably be higher in the next decade. To predict that the nature of man will change in the next decade is rather naive, since man's warlike nature has not changed since prehistoric time. The requirements for defense expenditures will increase significantly by the end of the decade. In fact, the current FY '68 projections of $70 billion are an increase of $25 billion over that of the FY '65 budget ($47.5 billion). Budgets on the level of $80 to $100 billion per year could easily be the norm in the next decade.

In the 1966 DOD briefings to industry, the armed forces five-year forecast cited six major nuclear war functional systems. They are the new manned bomber, the strategic missile force, the anti-bomber defense, the new manned interceptor, the Nike-X anti-missile system, and the civil defense system. These programs added up to $46.3 billion to be spent in the next five years on new systems.

The most significant nuclear war budget item is the Nike-X system, which is currently costing over one-half billion dollars per year for research and development. Due to its major budget and military strategy, the administration would like to maintain Nike-X at the technology level, but never going to operational status. Like the man-to-the-planets decision, once the decision is made to make Nike-X operational, the program will require a significant portion of the national budget for many years. However, there are several significant differences. The most important being that all our people can never be fully protected no matter how much money we spend on nuclear defense. Therefore, the program has a sliding scale of cost effectiveness, allowing variables in levels of expenditures nonexistent in the man-to-the-planets program. Also, the Nike-X system is designed primarily for an all-out war against a major power. How effective it can be in a world with 15 to 20 nuclear powers is a question to ponder (the Nth country threat problem).

Conventional or limited war will be fought by the general purpose forces using all weapons other than nuclear. New techniques and systems will evolve around improving readiness, mobility, and operational effectiveness. The current Vietnam conflict is typical of the areas that the communists wish to confront us with; one in which we presently cannot effectively utilize our economic capabilities except at a great loss in efficiency. Military tactics and conventional weapons are due for some major revisions.

The current DOD policy on space is to; 1) use space when it is clearly the most effective way to carry out the mission, 2) support the national space program in developing technology, and 3) to provide technological insurance against possible military surprise in space. The military space missions are currently support in nature rather than weapons systems as such. The MOL program is a means by which DOD hopes to define man's military role in space and provide that necessary insurance. Current discussions center around cost effectiveness wherein the Air Force's goal is to reduce costs down to $100-per-pound of payload in orbit, or less. Rather than some large, permanent, manned-space-stations, or space battleship, it is reasonable to believe the Air Force will evolve a number of smaller reusable vehicles that could achieve orbit at will. Such a program would cost about $20-30 billion. Military applications of the moon would easily cost $30 billion and more, depending upon the scope of operations.

d. TRANSPORTATION AND URBAN RENEWAL

The current interstate highway program represents a $40 billion expenditure. This can be expected to be followed by several other programs of equal or greater magnitude, such as the Washington-to-Boston high-speed railway, with eventual extensions to Detroit and Chicago. These programs can be expected to be concurrent with the man-to-the-planets program. Whereas, they are needed efforts and most certainly will be carried out, the primary problem is that of government take-over of industries and services normally supplied by nongovernment organizations. In the past, the United States has encouraged private industries to develop transportation, as with the land grants to the railroads during the last century.

The current urbal renewal government practices are expected to continue. The level of effort will probably increase in the next decade, but not to the point where it will become a serious competitor for the man-in-space funds.

II. THE SETTING OF GOALS

The following discussion is a simplified chronological abstract of the more significant public data relating to the process of generating our next major goals and missions in space exploration.

On the 30th of January 1964, President Johnson wrote to James Webb requesting that the Space Agency conduct a review of our National Space Objectives in terms of what we have learned from our space efforts and what are the most important concepts of missions needed for scientific purposes and advances in technology. He also asked for estimates of time and funds required to complete programs already approved and underway.

On May 20, 1964, Webb responded to President Johnson with the recommendations for future explorations outlined in Figure A-2. These are presented only as possible missions. These new programs are in the major categories of Earth-orbital operations as well as Lunar, interplanetary, and universe exploration.

On the 16th of February, 1965, Mr. Webb recommended to President Johnson the Voyager program (instrumented landed probes to Mars in 1969 and 1971). He cited as a basis for this action the recommendations of the National Academy of Sciences (letter Oct. 30th, 1964 from Frederick Seitz, president of NAS). These NAS recommendations are tabularized in Figure A-3, and show manned planetary exploration (Mars) by 1985 as the most recommended program. The Voyager represents the first significant milestone in manned planetary exploration.

Mr. Webb also put together a 50-man task force which spent the better part of a year to conduct a review and evaluation of the currently funded NASA programs as a capability for growth and extension determining the next step or intermediate space missions, identifying long-range missions which deserve serious attention, and identifying technology levels related to mission objectives. The major milestones are tabularized in Figure A-4. The task forces conclusions were; 1) "continued space exploration will be an evolutionary process in which the next step is based largely on what was learned from the experience of preceeding research and flight missions", 2) the pace will depend upon many factors such as budget, manpower, resources, and changing national needs for

EARTH ORBIT	UNMANNED	ORBITING SOLAR OBSERVATORIES	ORBITING ASTRONOMICAL OBSERVATORIES	RECOVERABLE BIOLOGICAL SATELLITES	METEOROLOGICAL SATELLITES	COMMUNICATIONS	NAVIGATION		
	MANNED	2 WEEKS – 2 MEN (GEMINI)	30 DAYS – 2 MEN (AF GEMINI/MOL)	90 DAYS – 2 MEN (AES) LOGISTICS	1–3 YEARS LOGISTICS • TO STUDY FEASIBILITY OF MANNED PLANETARY MISSIONS • TO DEVELOP OPERATIONAL CAPABILITIES • QUALIFY LUNAR & PLANETARY SYSTEMS • SPACE LAB	SEMI-PERMANENT 24 MEN • SUPPORT PLANETARY MISSIONS • SPACE LAB	SYNCHRONOUS LABS • EARTH OBSERVATIONS		
LUNAR	UNMANNED	RANGER PROBES	LUNAR ORBITER	SURVEYOR SOFT LANDING					
	MANNED	APOLLO	AES 2 WEEKS LANDER SHELTER ROVER (10 STUDIES)	SEMI-PERMANENT LUNAR STATIONS (6 STUDIES)	PERMANENT BASE (PRELIMINARY STUDY)				
INTERPLANETARY	UNMANNED	SOLAR PROBES	MARINER FLY-BY	MARS–VENUS ORBITER LANDER	AUTOMATED BIOLOGICAL LABS.	JUPITER FLY-BY	MERCURY FLY-BY	ASTEROIDS FLY-BY	COMET FLY-THRU
	MANNED	MARS – VENUS FLY-BY		MARS LANDING / VENUS ORBITER					
		(6 STUDIES IN PROCESS)							
UNIVERSE	UNMANNED								
LAUNCH VEHICLES	MAN-RATED	ATLAS	TITAN III	SATURN IB	SATURN V				
	INSTRUMENTS								

Figure A-2: FUTURE SPACE PROGRAMS (AS OUTLINED TO PRESIDENT JOHNSON BY JAMES WEBB, MAY 1964)

NATIONAL ACADEMY OF SCIENCES
SPACE SCIENCES BOARD
NATIONAL GOALS IN SPACE 1971–1985

.... "THAT SCIENTIFIC EXPLORATION OF THE MOON AND PLANETS SHOULD BE CLEARLY STATED AS THE ULTIMATE OBJECTIVE OF THE UNITED STATES SPACE PROGRAM FOR THE FORESEEABLE FUTURE."

1961 BOARD RECOMMENDATION TO GOVT.

PRIORITY	MISSION	VEHICLE	TIME PHASING
(1C) TOP PRIORITY EXPLORATION OF PLANETS WITH MARS AS PRIMARY GOAL	1. TO DISCOVER EXTRATERRESTRIAL LIFE 2. PHYSICAL & GEOLOGICAL EXPLORATIONS EXPLORATIONS: - BIOLOGICAL - PHYSICAL - CHEMICAL - GEOPHYSICAL		
(1B) HIGHEST IMMEDIATE PRIORITY	FIRST STEPS – UNMANNED VEHICLES - BIOMEDICAL RESEARCH - BIOENGINEERING (AUTOMATED INSTRUMENTS) EXPLORE MARTIAN ENVIRONMENT - PROBES - MARS LANDERS - ORBITERS	SATURN V	
(1) MOST RECOMMENDED PROGRAM	MANNED MARS LANDING EXPLORATION		
(2) ALTERNATES (RECOMMENDED AS PARALLEL BUT LOWER PRIORITY)	EXTENSIVE LUNAR EXPLORATION - LUNAR BASE CONSTRUCTION - MAJOR MANNED ORBITAL SPACE STATION - SPACE LABORATORY PROGRAMS		
	KNOWLEDGE OF THE EARTH - EARTH UPPER-ATMOSPHERE RESEARCH - COMMUNICATIONS - METROLOGY - GEODESSY	SMALL INEXPENSIVE ROCKETS	1970–1990
	KNOWLEDGE OF OUR SOLAR SYSTEM - PHYSICS AND CHEMISTRY OF SPACE - KNOWLEDGE OF THE SUN - SOLAR CORONA PROBES - MERCURY PROBES - JUPITER PROBES		
	FUNDAMENTAL ASTROPHYSICAL RESEARCH IN THE NATURE OF MATTER AND ENERGY - LARGE ORBITING OBSERVATORIES - ASTRONOMY - OPTICAL - RADIO - X-RAY - GAMMA-RAY		

OTHER PERTINENT COMMENTS –
BOARD CONSIDERED THREE BASIC QUESTIONS:
1. WHAT PROGRAM WILL PRODUCE THE MOST SIGNIFICANT RESULTS IN THE NEXT DECADE OR SO?
2. HOW CAN THE NATION MOST INTELLIGENTLY BUILD UPCN APOLLO? ANSWER – GAIN SCIENTIFIC KNOWLEDGE USING SATURN V FOR PLANETARY GOALS.
3. HOW CAN AN UNINTERRUPTED FLOW OF MEANINGFUL RESULTS BE INSURED OVER THE NEXT 20 YEARS?
SATURN V PROVIDES THE CAPABILITY TO PRODUCE UNMANNED SPACE PROBES FOR PLANETARY SOLAR SYSTEM AND ASTRO-PHYSICAL RESEARCH.

REFERENCES: NATIONAL ACADEMY OF SCIENCES LETTER TO J. E. WEBB FROM F. SEITZ 10/30/64
STATEMENT OF SPACE SCIENCES BOARD – ON NATIONAL GOALS IN SPACE 1971–1985 10/28/64

Figure A-3: NATIONAL ACADEMY OF SCIENCES SPACE SCIENCES BOARD NATIONAL GOALS IN SPACE 1971-1985

PRESENT PROGRAMS (APPROVED)

- GEMINI
- APPOLLO
  - 1-TO-2-WEEKS EARTH ORBITAL FLIGHTS
  - MANEUVER
  - RENDEZVOUS
  - DOCKING
  - LUNAR ORBIT
  - LUNAR LANDING

- VEHICLES

TITAN III
SATURN IB
SATURN V

EXTENSION PROGRAMS (GROWTH & APPLICATIONS)

- APOLLO EXTENSION SYSTEM

1-TO-2-MONTHS EARTH ORBITAL
◇ POLAR
◇ SYNCHRONOUS
◇ ELLIPTICAL
FOR SCIENTIFIC & TECHNICAL EXPERIMENTS

- RENDEZVOUS
- REPAIR
- RESCUE
- INSPECTION OF SATELLITES
- EXTENDED LUNAR STAY-TIME
- EXTENSIVE LUNAR MAPPING
- UNMANNED PLANETARY EXPLORATION

- VEHICLES

NO NEW LAUNCH VEHICLE
CAPABILITY TO LAUNCH ANNUALLY
◇ 6 SAT IB OR SAT IB/CENTAUR
◇ 6 SAT V

ADVANCED PROGRAMS (REQUIRES MAJOR NEW DEVELOPMENTS)

- SPACE STATIONS
- LUNAR ROVING VEHICLE
- LUNAR BASE
- MANNED PLANETARY EXPLORATION

- VEHICLES

POST-SATURN LAUNCH VEHICLE
LIFTING RE-ENTRY VEHICLE

SOURCE: FUTURE PROGRAMS TASK GROUP SUMMARY REPORT - 1965

Figure A-4: MAJOR MILESTONES RELATED TO MANNED PROGRAMS

EARTH	– ATMOSPHERE, IONOSPHERE, MAGNETOSPHERE
MOON	– PROPERTIES, SITE SELECTION
VENUS/MARS	– PROPERTIES, POSSIBLE LIFE
SUN	– PHYSICS, EFFECTS
STARS AND GALAXIES	– ASTRONOMY, COSMOLOGY
BASK	– TO ACQUIRE FUNDAMENTAL KNOWLEDGE OF THE SPACE ENVIRONMENT AND OF THOSE PHENOMENA WHICH CAN BE BEST STUDIED FROM SPACE CRAFT
VEHICLES	– SCOUT, THOR, ATLAS, ATLAS/CENTAUR, TITAN, SATURN I, SATURN IB, SATURN V

Figure A-5: UNMANNED SPACE SCIENCE OBJECTIVES the future, 3) no single area of space development appears to require an overriding emphasis or crash effort, and 4) a balanced program will not impose unreasonably large demands upon the nations resources, and such a program will lead to a preeminent role in aeronautics and space.

The task force report was presented to Congress on the second of April, 1965. Congressional response was immediate and vehement. The Senate Committee on Science and Astronautics found the report to be obsolete and lacking in information required to make an informed decision of what our post-Apollo space program should be. The specific criticisms were; 1) alternatives were presented but no criteria for selection were given, 2) no cost information is given, 3) no indication of resources required, 4) no indication of when decisions should be made, 5) only a brief mention of military considerations, and 6) there is practically no discussion of foreign programs and their effects on our plans. The committee asked for a list of alternatives, what is recommended and why, and instructed NASA to make specific project recommendations no later than the FY '67 budget request. The report was considered below the expectations projected to Congress in the FY '66 budget hearings.

The Congressional hearings are informative to a certain degree on identifying the next major goals. By a study of the hearings we can extrapolate a priority of space exploration to be as follows:

a. Mars is the next major goal past 1970;
b. Lunar program is subordinate to Mars;
c. Continued program of instrumented space probes;
d. Continued manned Earth-orbital operations.

There is, however, a considerable reluctance on the part of NASA's chiefs to speak publicly about these goals. The degree of conservatism appears to have a direct relationship to the status of the Apollo program. This is perhaps a combination of good politics not to upstage the chief executive and a mixture of rightful timidity and conservatism on the key question of man's ability to survive prolonged exposure to outer space.

The next major goal is the manned Mars mission, with the first alternate being Venus. The Voyager program is designed to provide the technical data necessary to make the final missions decision. NASA and industry (independently and NASA funded) have spent significant sums on identifying the problems involved in reaching the planets. The mission most studied is manned Mars landing and Venus-orbiter. The most often considered Earth-launch vehicles are the Saturn V (which has been uprated to its maximum capacility) or the large post-Saturn. This vehicle is used to put into Earth-orbit a sufficient number of space propulsion modules to propel manned spacecraft to the target planet and back to Earth. The most studied space propulsion schemes are the chemical stage and the nuclear stage. The chemical stage is by far the most conservative approach since it is based upon well proven launch vehicle technology. However, it does put a severe limit on growth capability for exploration in the last two decades of the century. Nuclear propulsion has had considerable study and testing, but is yet to be proven and man-rated. Under serious consideration is a manned Mars (chemical or nuclear) fly-by mission in 1978 and a manned Mars (nuclear) landing mission in 1984.

The spacecraft technologies which require advancement are the basic structure itself, electric power (nuclear power generated for up to two years in space), communications, navigation, sterilization, life support systems, reliability of the total spacecraft for a two-year period, and man's ability to survive and function in space for an extended period.

The technologists are staggered by the engineering problems, and have made many carefully thought out projections as to what is possible in the next 15 to 20 years. The breakthrough requirements have been defined, and some funds are currently being spent on developing practical solutions. The ability to navigate to Mars has been demonstrated by the Mariner IV. The Voyager missions represent the first step in uprating the mission profiles to include man.

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