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AN ANALYTICAL STUDY OF THE INTERACTION OF TECHNOLOGICAL AND ADMINISTRATIVE DECISION-MAKING IN THE DEFINING OF MARS PROJECT VIKING

A dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy
in
Administrative and Engineering Systems

by

James Francis McNulty

<u>Doctoral Committee</u>:

Professor Gardner M. Ketchum, Chairman
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June 1974

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VITA

James F. McNulty was graduated from Union College with the degree of Bachelor of Science in Civil Engineering in 1944. Following a short tenure as a stress analyst for Glenn L. Martin Company and two years of service in the armed forces, he has been a career engineer with NACA/NASA.

For fifteen years, he was engaged in civil engineering of large scale research facilities--their design and construction. He was awarded a Master of Applied Mechanics from the University of Virginia in 1954. He was a recognized authority in foundation engineering and served as a consultant to Architect and Engineer companies on the design of many large projects in Virginia including the Chesapeake Bay Bridge.

In 1962, he switched his field to aerospace engineering where he was involved in the planning of interplanetary missions. His current position is assistant branch head of Aeronautical Systems Engineering Branch where he is engaged in the planning of future aircraft such as a hydrogen fueled transport. He is a member of technical societies, the author of numerous technical papers in the fields of civil engineering and in aerospace engineering, and a registered professional civil engineer.

He, his wife, and daughter (a junior at Northwestern University) reside at Yorktown, Virginia where they enjoy fishing and pleasant living on the shores of the Chesapeake Bay.

ABSTRACT

AN ANALYTICAL STUDY OF THE INTERACTION OF TECHNOLOGICAL AND ADMINISTRATIVE DECISION-MAKING IN THE DEFINING OF MARS PROJECT VIKING

James Francis McNulty

An engineering and administrative systems study is made of the definition of NASA's 1975 Mars landing project. The work performed at NASA's Langley Research Center in the years 1964-1969 from initial probe studies to lander hardware commitment is described. The focus is on the technical staff, its contributions and its interactions with Langley management, Washington NASA Headquarters, and other NASA Centers. The workings of the technical-administrative systems are analyzed by utilization of formal system concepts. An appendix documenting the technology base developed in this period is included.

The main body of the work, the Narrative, follows the progress of the program through (1) the Voyager years where Langley's roles were first that of consultant to the Jet Propulsion Laboratory on entry problems and then manager of the Voyager entry system and (2) the Viking years where Langley undertook the total project responsibility. The Narrative starts by describing Langley's operations in the pre-Mars years--working environment, management policies, sketches of pertinent personalities, contributions to Apollo--to furnish the necessary background for an understanding of the technical-administrative interplay

during the Mars studies. The Mars years, viewed from the vantage point of a member of the technical staff, traces the definition of the mission and the administrative responsibilities as influenced by the technological challenges, Langley Research Center's and NASA Headquarter's interests, and forces external to NASA such as Congress and the scientific community. Two principal contributions of the technical staff--the defining of entry and landing mission mode, and the total system definition of launch vehicle, spacecraft, and lander--are presented in technical depth to delineate the engineering systems methodology developed. The Analysis portion examines the workings of the technical staff, of the technical staff-Langley administration operation, and the technical staff-Langley-NASA interactions. Formal concepts proposed by physical and behavioral scientists are utilized to analyze (1) the means by which a researcher makes a major contribution, (2) the performance of the technical staff, (3) the operation of Langley's management system, and (4) the efficacy of NASA project decisions. Similarities are noted in the methods utilized at Langley in contributing to the Apollo and Viking projects. Conclusions are drawn on the basis of the Analysis regarding why and how Langley Research Center's staff was able to make major contributions to project hardware definition although the Center's primary function is research.

PREFACE

The NASA, starting in the late 1950's and carrying through the 1960's, faced and mastered many complex challenges of large size projects such as Mercury, Gemini, Surveyor, Lunar Orbiter and Apollo. The size and complexity of these challenges necessitated NASA to utilize its technological capability together with administrative procedures in a new way which is now commonly termed "aerospace technology." Because of the success of the space program, considerable attention has been given to the "aerospace technology" and transferring its methodology to attacking problems in the civil sector, i.e. mass transportation, pollution, urban problems, etc. The success has also attracted attention in the management area and investigations have been made to study and document the management techniques used to allow their exploitation in other fields. These studies were carried out by schools or authorities in management and, for the most part, have concentrated on the management decision making and have treated the technical aspects only incidentally. For this reason, it is felt that there is a gap in the literature--that of presenting the technical and managerial problems of a large scale project from the point of view of the engineering or technical staff level.

In an effort to broaden the base of project management studies, this dissertation (using the NASA Mars lander program as the case in point) will focus on the technical aspects--both definition and execution--with the role of management viewed as (a) supportive of the technical staff (b) expansive or constrictive regarding technical options and (c) directive toward technical approach. It is conceded that the work presented herein will tend to be biased in favor of the importance of the technical staff's contribution; however, it is felt that a description and analysis of the entire systems operation from the vantage point of one intimately associated with the technical details is a singular approach worthy of consideration. The objectives of this dissertation will be:

1. To present the technical problems and their solutions by the technical staff in sufficient detail to demonstrate the derivation of the essential technological base for mission definition.

2. To detail how the technological base impacts on administrative decision making and, vice versa, how administrative decisions impacts on the technological base.

3. To apply basic formal administration and engineering system concepts to the technical staff's actions and to the technical staff-administrative interactions so as to form a conceptual framework for explanation and analysis of the system's operation.

The focus of this study will be the Langley Research Center—its technical and administrative staffs. The dissertation will detail Langley Research Center's efforts in support of a scientific investigation of Mars; in particular, how Langley entered into studies of the problem, how Langley organized and carried out its assignments, and its participative role in defining a national project. It will concern itself with such topics as concept formulation and technical approach; the definition and solution of critical problem areas; team organization and cohension; Langley interfaces with other NASA Centers, Headquarters, and industry; decision making at all levels; and the evolution of an acceptable program through the many perturbations in direction from Headquarters and Congress.

This evolution of the program and Langley's participation will be tracked through its following phases:

The Saturn 1B/Centaur "Voyager" Phase (1964-1965)

During this phase, Langley's responsibility was primarily that of a consultant on the entry problem and technology development. The Jet Propulsion Laboratory was responsible for all mission hardware for a 1971 launch. This modest mission was terminated by NASA and replaced by the large scale...

The Saturn V "Voyager" Phase (1966-1967)

Langley assumed responsibility for the entry system hardware. The overall mission was to be managed by NASA Headquarters. The scheduled launch data of 1971 slipped to 1973 because of Congressional funding priorities and later was cancelled by Congress in its entirety for the same reason.

The Titan/Centaur "Viking" Phase (1968-1969)

Langley assumed responsibility for the enitre mission management and hardware. Funding problems necessitated a revision in launch date from 1973 to the presented scheduled 1975.

The writer was continuously involved in Mars studies from their inception at Langley in 1964 until a firm contract was awarded to

Martin Marietta in 1969 to carry out the Mars landing. My roles were such that they afforded me a microscopic view of work and decisions at the technical level and a macroscopic view of the administrative decision making at the highest NASA levels. At the time when Mars studies were initiated at Langley, I was made responsible for systems integration (a role which continued throughout the entire period) which required me to understand all technologies and their interfaces. This role, incidentally, made me a focal point for the effort and furnished me with an overall view of all the technologies and their meshing, technically and administratively. In addition to this project responsibility, I, as a first-line supervisor in my Division (Engineering) was directly responsible for supervising the structural design, subsystem integration, and system analysis portions of the work. As a result, I became acquainted with and worked closely with technology specialists in various disciplines throughout NASA and industry.

Other roles assigned to me during this period which increased my appreciation of the many facets of the problems were:

(1) Secretary of Langley's Planetary Missions Technology Steering Committee which was responsible for making recommendations to top Center management.

(2) Member of NASA intercenter Mariner Mars 1971 Probe Working Group.

(3) Author of technical work statements for industry-wide contract competition.

(4) Member of NASA evaluation boards for contractor selection.

(5) Technical Representative of the Contracting Officer on Mars studies - responsible for approving contractor performance.

The dissertation will be divided into three parts: Narrative, Analysis, and Appendix. Part I, the Narrative, will have a straight expository, historical base relating the key technological advances and key decision points within the human technical staff-administrative interactions so that the reader can obtain a broad appreciation of all aspects of the project's development; the narrative will be divided into chapters, each describing, normally, a year's effort. Part II, the Analysis, will analyze how the technical and administrative system worked by examining the systems and decisions within the framework of formal concepts and theories. Part III, the Appendix, will contain, mainly, the documentation of the development of the pervasive technology base.

Thus, in effect, this work will reflect an inside view from the technical staff level of how an approximate billion dollar project reached fruition through many technological challenges and administrative course redirections. It is believed that the presented material represents a significant addition to the literature on project management in that its approach is fundamentally that of the influence of the engineering input on administrative decision making and program definition.

The dissertation is the result of a cooperative endeavor of Union College and Langley Research Center. Both institutions have given me full encouragement throughout the four year period for academic course work, research, and dissertation preparation. In particular, appreciation is owed to my immediate supervisor at Langley Research Center, Mr. Ken Bush, and to my co-advisors at Union College, Dr. Gardner Ketchum and Dr. Robert Sharlet; without their unstinting support and aid, this dissertation could not have been written.

Finally, this dissertation is dedicated with love to my wife for her understanding and positive attitude which sustained me throughout.

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THE NARRATIVE

CHAPTER I

INTRODUCTION--THE PRE-MARS YEARS

Langley Operation 1915 - 1964

Before proceeding into the mainstream of the Mars studies, it is essential to define the "sentiments"[1] (ideas, beliefs, or feelings about the work and others involved in it) of the organization and of the people in it because these sentiments influence the course of Langley management and its technical staff. To explain these sentiments, it is necessary to look at the organization in its prior NASA days and to trace its progress and its driving forces until we reach the initiation of the Mars studies.

In 1915, Congress created a Government organization to be known as the National Advisory Committee for Aeronautics (NACA) with the charter "to supervise and direct the scientific study of the problems of flight, with a view to their practical solution," and also to "direct and conduct research and experiments in aeronautics." The act specified that NACA be governed by a committee appointed by the President and that it report directly to the President. Twenty-eight years later Dr. Karl T. Compton of MIT, in a 1943 address to British scientists described the NACA as "... unique among our Federal scientific agencies, in that its controlling body is a Committee which

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[1] Lawrence, Paul R. and Seiler, John A., Organizational Behavior and Administration, (Homewood, Illinois, Richard D. Irwin, Inc. and the Dorsey Press, 1965) pp. 154-161.

serves without salary and has been composed of men of such high character and distinction as to render it completely free from political influence."[2]

One of the first decisions of the committee was that a well equipped laboratory was essential to its work. A tract of land near Hampton, Virginia fronting on Back River, an estuary of Chesapeake Bay, was purchased in 1916 and the property was named "Langley Field." An office building and wind tunnel were constructed shortly thereafter and formally opened in dedication exercises in June 1920. This was the seed from which several NACA Centers originated in the following decades and which, in turn, served as the nucleus for NASA in 1958.

The early years, prior to NACA expansion in preparation for the oncoming World War II, were a period of slow but steady growth. Facilities and a competent staff were gradually built up. Key men, leaders in research, were carefully selected and put in jobs where their ability would find its opportunity. By 1930, Langley was the recognized leader in aeronautical research world-wide. In 1936, Langley had grown to a staff of 370 with 10 wind tunnels and war clouds were gathering. The years between 1939 and 1946 were years of comparatively rapid growth. From 1939 to 1941, two new laboratories

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[2] Gray, George W., Frontiers of Flight, (New York, Alfred A. Knopf, 1948) p. 11.

(Ames at Moffet Field, California and Lewis at Cleveland, Ohio) were authorized and Langley was expanded. With the attack on Pearl Harbor, the United States' aeronautical position was in a crisis condition; daring proposals for the development of military aircraft were being made by the Army and Navy. Complex problems were being referred to NACA for solution. Additional men and facilities were required; a large construction program and a recruitment program were undertaken. During this period, NACA temporarily put aside basic research and concentrated on studies of military aircraft; at one time, there were 78 different types of aircraft under investigation. In addition, NACA was requested to investigate guided missiles and Langley acquired a tract of land, Wallops Island, on the Atlantic side of the Virginia Eastern Shore as a test site. A missile launch site was constructed on Wallops Island and a new type of research came under Langley's cognizance. At the war's end, NACA's resources could be tabulated as follows:

(1) A staff of 6,804, approximately 50% professional, -- 3,253 at Langley, 844 at Ames, 2,572 at Lewis, and 135 at the Washington Office.

(2) Laboratory installations represented an outlay of $85,000,000 in three centers as against $12,000,000 in one center in 1939.

It is also worth noting that the NACA effort during the war years was primarily an "in-house" effort; NACA sponsored research, mostly to universities, totalled only $1,500,000 from 1940 to 1946.

I returned to Langley from military service in 1946 after having previously worked for several months at Langley as a Civil Engineer during the construction expansion following graduation from Union College in 1944. NACA's table of organization at this time is shown in Figure I-1. I was reassigned to the Construction Engineering Section of the Engineering Services Division as a structural engineer to assist in the design and construction supervision of new facilities. The section consisted of approximately 50 engineers and designers divided into three groups--mechanical, structural, and architectural--and was responsible for a construction budget of five to ten million dollars per year; again, all design work was done in-house as were the contracting and construction inspection.

The management philosophy at that time is worthy of examination. The center was, for all practical purposes, an independent operating entity controlled by first generation aeronautical researchers with the individual researcher furnishing the basic input into the programs which Langley would carry out. Promotions were slow, salaries were low, and emphasis was placed on worthwhile research. Facilities were excellent and constantly upgraded. Status within the profession was high. Challenges were great--frontiers in transonic and supersonic flight were under investigation. As mentioned previously, NACA was an independent agency reporting to the executive branch. Its yearly budget was in the order of $200,000,000 and usually passed Congress without controversy--presumably because the budget was not sufficiently large to attract undue attention and because the

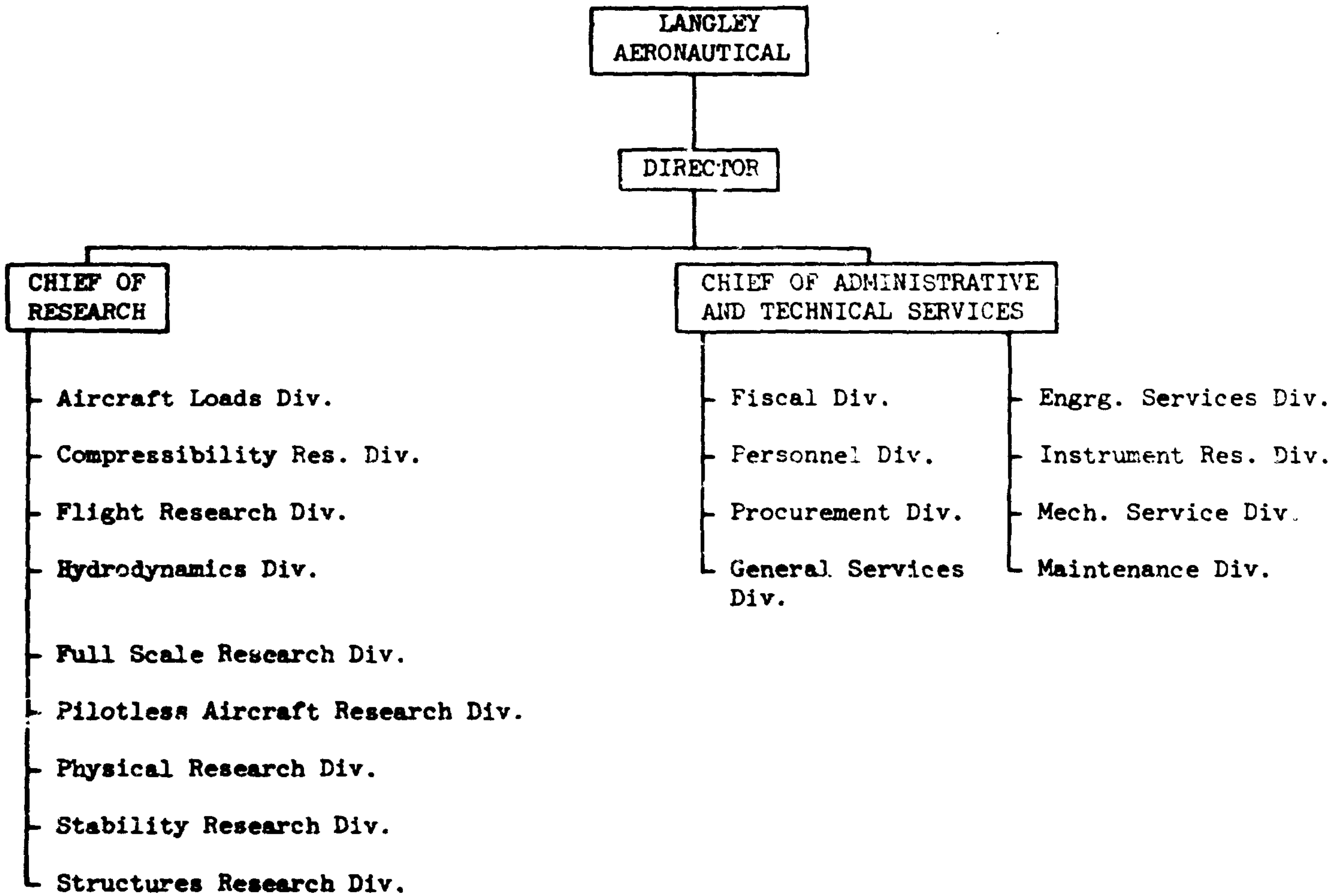

Figure I-1.--Langley organization in 1946.

reputation of the agency was good. The Washington office was small and served the centers rather than vice versa. The funds were funnelled to the centers and utilized where the centers themselves deemed appropriate. The younger engineers, recruited into the center during the war years, were socialized into the system by the senior engineers and, in the most part, remained loyal to, and did not question, the system. The engineer who did not fit the system quickly left on his own accord (turnover was extremely small). All in all, it was an efficient, paternal organization, somewhat remote and "ivory-towerish," manned by two distinct groups--the few senior engineers from the 1920's and early 1930's and the many young engineers hired in the late 1930's and early 1940's.

From the end of World War to "Sputnik" in 1957, NACA operated in a near "status quo" mode as outlined above. Promising engineering graduates were hired annually to replace engineers leaving the agency so that by 1957 a few of the engineers hired during the 1939-1946 expansion period had moved into positions of middle management although their primary responsibility remained technical rather than administrative; administrative work remained minimal and the center operated more or less on its own policies. There were minor organization changes in this period and the Pilotless Aircraft Research Division, charged with research responsibility on guided missiles, increased somewhat in size and importance relative to the rest of the organization.

The flight of Sputnik might have shocked the United States but its effect on NACA could only be termed revolutionary. Funds poured into NACA to push space science--a field in which only a tiny minority were working. Young engineers obtained funds to develop launch vehicles and spacecraft for all types of space study--atmospheric physics, thermal heating, communications, etc The organizational system reacted well; the senior staff remained in control; it co-opted the new discipline and gave the younger engineers the freedom to investigate the new technology including studies of how to put a man in orbit. On July 29, 1958, President Eisenhower signed the National Aeronautics and Space Administration Act and on October 1, 1958, the National Aeronautics and Space Administration was formed with NACA as the nucleus

President Eisenhower approved "Project Mercury" which committed NASA to put a man in earth orbit. The Langley group working on the project was separated administratively from Langley and given the name of Space Task Group (STG) with Dr. Gilruth as head. Astronauts were selected and assigned to STG. STG, with mission responsibility, expanded and Langley took over the job of developing the technology to support the mission. Many of the ambitious and adventuresome aeronautical engineers transferred from Langley to STG during this period. As Project Mercury was too large for STG to handle by itself, many elements were "subcontracted" to various NASA Centers. For example, the building of the worldwide communications network was delegated to Langley. It was at this time that I was introduced to the Aerospace world. I was made project engineer for constructing sites at Bermuda and in the Canary Islands. Another group of Langley facility design engineers were pressed into service of conducting ground and flight tests of preliminary Mercury hardware. In this manner, the Engineering Services Division in which I worked was split about in half--half supporting flight projects and half working on ground facility design.

This arrangement continued throughout the years 1958 to 1961--the carrying out of Project Mercury, the development work on Project Gemini, and the commitment in 1961 for Project Apollo at which time STG became the Manned Spacecraft Center (MSC) with permanent facilities in Houston, Texas. As MSC built up in 1962 and 1963, there was less need for "subcontracting" to other Centers so that while Langley was still heavily involved in developing Apollo technology, personnel were being "freed-up" to work on research problems in much the same manner, and under the same management, as in pre-NASA days. A major change, however, had occurred in the type of research problem to be investigated. Space research had become an equal partner with aeronautical research; this was recognized even at the engineering level where the Engineering Services Division was reorganized into two divisions--the Flight Vehicles and Systems Division--FVSD--(for space projects) and the Research Models and Facilities Division (for ground-based projects).

The "sentiments" at Langley in 1964 at the initiation of Mars studies could then be summarized as:

(1) Top management was research oriented, conservative, and protective of their independence from Washington Headquarters.

(2) Middle management had much the same sentiments and was research task discipline oriented. A sprinkling of middle managers, however, had enjoyed the challenge and experiences associated with working with contractors on large aerospace projects and were interested in broader systems problems.

(3) The engineers themselves were a more sophisticated group than ten years previously, and the availability of funds for space research furnished the engineers with fluidity to transfer within Langley, with more freedom in job selection and execution, and with more opportunity to display their talents.

A table of organization for LRC at this period of time is given in Figure I-2. In general, the organization was designed to work in the following manner:

(1) Ground research carried out within the line Research Divisions (Groups 1-3) with aid of the Research Models and Facility Division to design research apparatus and of the shops in the Mechanical Service Division to build same. Output would be a Technical Note publishing the research results with wide circulation in the field of the particular discipline.

(2) Space research usually implied an actual flight test. In this case, the individual researcher requiring a flight test would, through his Division, obtain the services of a Research Program Manager from the Applied Materials and Physics Division under the

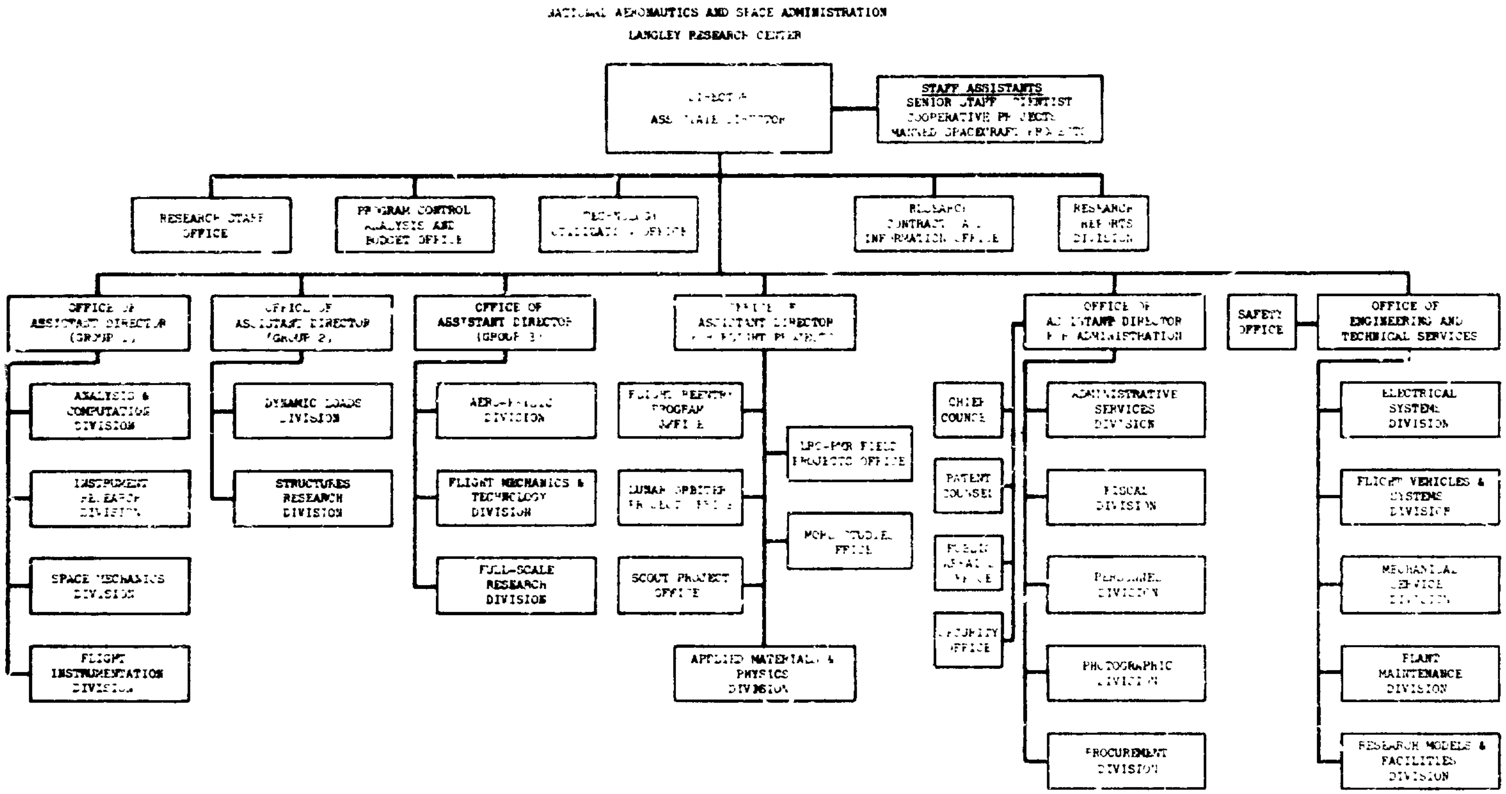

Figure I-2.- Langley organization in 1965.

Office for Flight Projects. This manager would interface with and coordinate the researcher, Washington Headquarters (for funding), and the Office of Engineering and Technical Services (OETS). OETS, through a technical project engineer (TPE) in FVSD and the line organizations, would be responsible for carrying out the technical aspects of the project. The duties of a TPE are outlined in a memorandum from the Deputy Chief (OETS) which is included as Appendix I-A.

(3) Large flight projects, approximately ten million dollars or more, were managed out of a special project office set up for that particular purpose. The line organizations (such as FVSD) would assign men to the project for the length of the project. One such project was the Lunar Orbiter Project which was assigned the responsibility of a precursor mission to Project Apollo for photographic mapping of the moon and determining the landing sites. Approximately 100 engineers were assigned to this project office.

Individual Researcher - Langley Management - Headquarters Operation

As indicated previously, the Langley management philosophy at the beginning of the Mars studies was primarily one of "bottom up" generation of research programs with maximum independence of the individual researcher. By "bottom up" it is meant that the ideas or programs are conceived at the technical level and are transmitted to the Langley management for implementing approval -- funds, manpower, etc. An overall systems concept of this procedure is indicated on figure 1-3. For the vast majority of Langley programs, the Washington Headquarters loop is not activated. If the researcher's request is well defined to be within Langley's charter, the line organization reviews the request and evaluates its worthiness. If supported, the researcher performs his work, has it reviewed by the line organization and/or special technical committees, and outputs his product whether it be a technical data report or a piece of hardware.

The Washington Headquarters loop is activated (by Headquarters directives to the Center) if (1) the dollar value of a particular planned contract is over one million dollars or (2) the program is one that would impact overall NASA planning (such as any interplanetary study). In these cases, Headquarters must approve the planned program before the Center can proceed. In isolated cases, Washington Headquarters could initiate programs by furnishing the original input to the Center. Two such programs were the Lunar Orbiter and the development of the worldwide communications network for Project

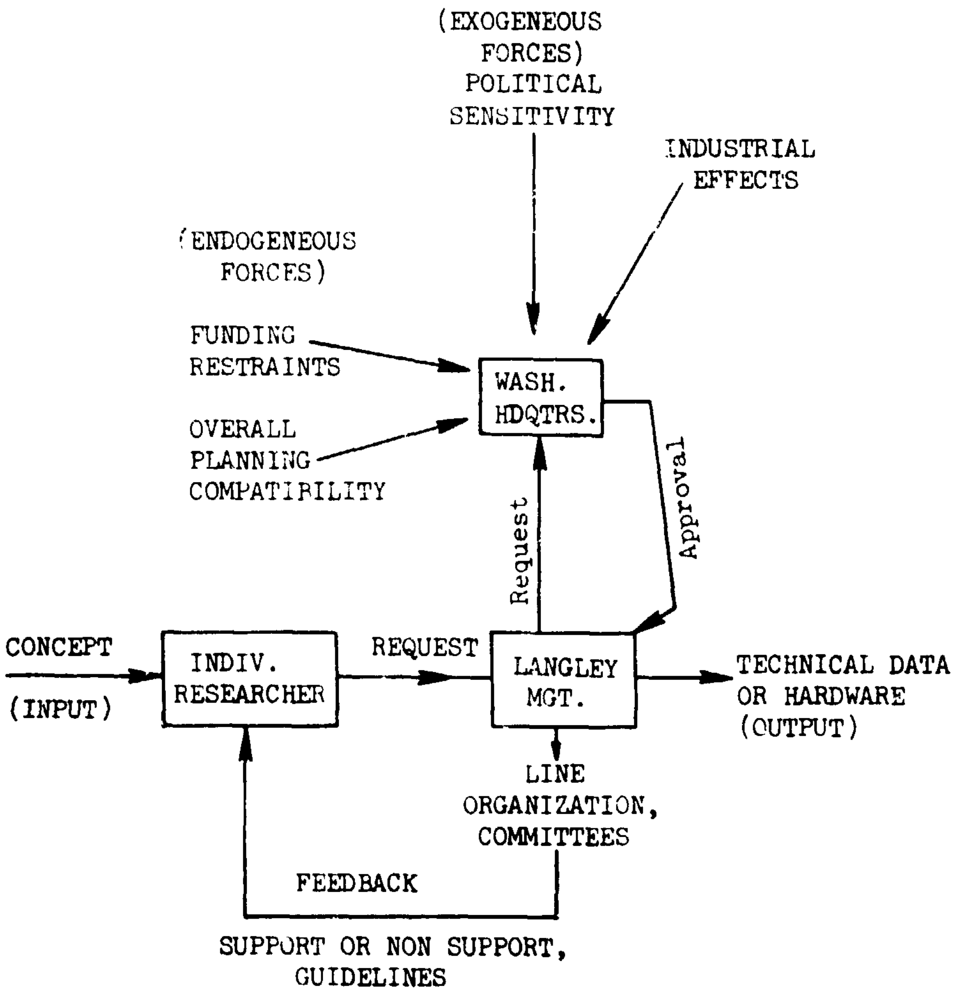

Figure I-3.--Normal Langley operating mode.

Mercury; in both instances, the original responsible Center was unable to carry out the programs because of a commitment overload. The systems mode is this instance is illustrated in figure I-4. Briefly, this mode consists of a negotiating cycle between Headquarters and LRC management to obtain agreement or contract as to end item and resources. At which time, the responsibility is given to a project office reporting directly to top LRC management to carry out the program. Mr. Erasmus H. Kloman, Senior Research Associate, National Academy of Public Administration who researched the management methods on Lunar Orbiter says in this regard "Senior management at NASA Headquarters debated at length whether an agency center rather than JPL should be assigned responsibility for management of a lunar project and the development of the specialized competence required. Recognizing that some duplication might be necessary and desirable, Headquarters authorized Langley Research Center to investigate the feasibility of its undertaking a possible assignment from NASA of a major flight project of the scope of Lunar Orbiter. Langley management deliberated carefully and concluded that it would be able to handle such a mission. The Center was very receptive to the challenge of its first spaceflight project. The positive attitude and enthusiasm of top management were contagious and infected the Lunar Orbiter project staffs. Some of Langley's top talents sought assignment on the project, considering it a career plus. The Lunar Orbiter at both Langley and the Boeing Co. [the contractor] were tightly knit cohesive units. They [Langley] accepted the assignment

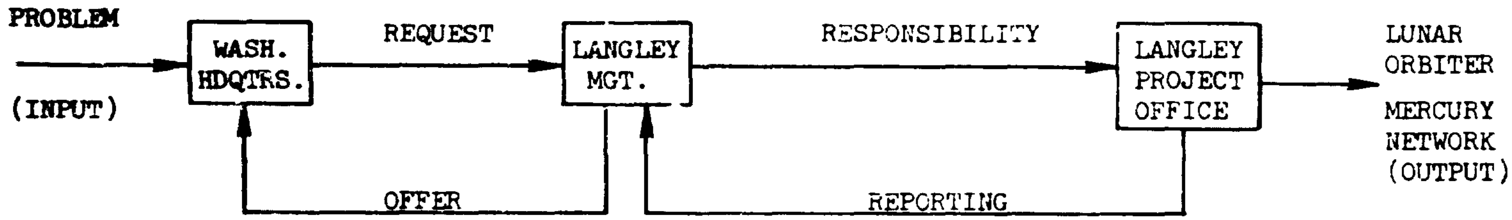

Figure I-4.--Lunar Orbiter/Mercury Network operating mode.

with full commitment and a determination to make it succeed. The Langley management placed great store in its reputation for fulfilling every mission it set out to accomplish. In reporting to Washington Headquarters, Langley made no effort to hold back information concerning problems that arose. Washington Headquarters reciprocated with full cooperation and support. For all of these reasons, the institutional environment surrounding Lunar Orbiter was favorable to teamwork."[3] Much the same is appropriate relative to the Mercury network; the quote above is included to demonstrate the operation of the systems mode of figure 1-4.

To illustrate further the operation of the individual researcher - Langley management - NASA headquarters system mode in figure 1-3 in programs of large national impact (similar to the Mars landing program), Langley's role in Project Mercury and Project Apollo will be examined.

Immediately after the Soviet Union orbited Sputnik, a Langley researcher, Max Faget, initiated studies in his work unit on the problem of orbiting a man in space -- this was premature even to the United States concentrating on orbiting a "ball" in space. Since his work was engaged in rocket performance and propulsion, no extraordinary procedural changes were necessary to allow him to research the problem; no large contractual funds were required as the work

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[3]NASA SP-4901, Unmanned Space Project Management. Surveyor and Lunar Orbiter, Kloman, p. 11, 19.

was carried quietly in-house. Further, this was prior to the establishment of the NASA and the NACA centers operated as nearly independent entities. After the establishment of the NASA and the national approval of Project Mercury (Faget's Concept), Faget's work unit formed the nucleus of the Manned Spacecraft Center and Faget's LRC Division Chief, Dr. Gilruth, was named Director of MSC which carried out Projects Mercury, Gemini, and Apollo.

After Apollo was approved as a national program, committees formed from individuals from the various NASA centers debated at length over the best method to carry out the lunar landing. Marshall Space Flight Center, through Director Van Braun, and Manned Spacecraft Center, through Director Gilruth and Mr. Faget, took official positions while Langley took no official position but allowed an individual researcher, Dr. John Houbolt, to attend the committee meetings and present his concept as an individual. MSFC favored an Earth Orbit Rendezvous (EOR) wherein two Saturn rockets, one carrying extra fuel and the other carrying the spacecraft would be launched into Earth orbit where they would rendezvous and, with the extra fuel, the spacecraft would be launched to the moon. MSC favored a direct ascent method from Earth which would require the development of a monster rocket. Houbolt's concept was the Lunar Orbit Rendezvous where the spacecraft would be launched to moon orbit by a Saturn and a smaller craft (the LEM) would ferry between the moon's surface and the spacecraft. Houbolt's concept was ridiculed in these committee meetings but he kept trying and pushing his approach. When NASA administrator James Webb announced that EOR appeared the best method and direct ascent the second best (not even mentioning LOR); Houbolt despaired of committee action and, bypassing the committees, appealed directly to NASA Associate Administrator Robert Seamans. In his letter requesting serious consideration of his concept, he stated, "Somewhat as a voice in the wilderness, I have been appalled at the thinking of individuals and committees -- Give us the go-ahead and we will put men on the moon in very short order -- and we don't need any Houston empire to do it."[4] Seamans requested a review from his deputies who reported favorably. In time, both Faget and Von Braun swung behind the LOR concept which became the mission mode for Project Apollo. Houbolt was later awarded NASA's Exceptional Scientific Achievement Award for "his foresight and perserverance" in advocating the LOR.

In this section, I have shown the persistence of the Langley management operational mode or system to adapt when acted upon by either endogenous inputs (normal research, concepts for orbiting a man in space and for the Apollo mission mode) or exogenous inputs (Mercury tracking station or Lunar Orbiter).

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[4] Life, "How an Idea Nobody Wanted Grew up to be the LEM," Vol. 66, No. 10, March 14, 1969.

Langley in 1964

Langley Research Center had at this time approximately 4000 employees operating in the following manner. The Director, Associate Director, Assistant Directors, and their staffs occupied Headquarters Building, Bldg. 1219, a two story brick office building; the power center was commonly known as the "second floor of 1219." The Center itself was spread over an "East Area" and a "West Area" divided by Langley Air Force Base runways. Its physical appearance is not unlike an Ivy League college campus--well kept lawns with various buildings well separated from each other. In general, each Division would be housed in its own building(s) and would consist of 100-200 employees. The Division Chief, a respected researcher in his field, would be responsible for the operation of his Division and was extremely powerful in determining many aspects of working conditions--type work, assignments of personnel, promotions, and management philosophy. The Divisions were further organized into Branches and Sections to facilitate the division of work. As "1219" generally followed the recommendations from the Division Chiefs, the Division Chief position was one of strength representing a respected authority and his staff.

The individual researcher usually looked to his Division Chief for support of his programs and for his own advancement. As the individual researcher and his Division Chief shared a mutual aim of the advancement of science and that the work was on the frontiers of knowledge, the line between ordinary science and extraordinary science was not a discernible one. In fact, the emphasis was on the development of new breakthroughs such as John Stack's (a national aeronautical authority) concept of slotted throat in a wind tunnel test section that proved planes could fly "faster than sound." Thus, the individual researcher was given to pursuing the truth regardless of past experience or "established" methods.

The engineering portion of the organization operated somewhat differently although again the Division Chief represented the focal point of its strength. The "job" of the individual engineer was to support research--in the eyes of some researchers, engineering was a secondary function. Although not working primarily to advance science, the engineer required innovative thinking and ingenuity to transfer the researcher's advanced concepts into hardware. In addition, the engineer, through construction and space projects, represented the Center's capability in the integration of disciplines and experience in managing contractors. Thus, the Division Chief had credentials for advising the Center Director on project policies as well as on the importance of the engineering functions. By use of the technical project engineer concept, the Division Chief had the capability of assigning an experienced chief engineer to any multi-disciplined program to work on a near co-equal basis with the lead researcher. While the engineer lacked some of the freedom of the researcher to define his own programs, he still could, in some degree, follow his inclinations as to whether to be a specialist in a specific area (i.e. structures) or to be a coordinator (technical project engineer).

Headquarters Organization in 1964

NASA Headquarters is located in a new multi-tiered, modern office building in Washington, D. C. The complement of about 1500 personnel is organized as shown in fig. I-5. Reporting to the Administrator's office are three main technical offices--the Office of Manned Space Flight (OMSF), the Office of Space Science and Applications (OSSA), and Office of Advanced Research and Technology (OART). OMSF is responsible for all manned flights (Mercury, Apollo, Shuttle, etc.) and has three dedicated Centers supporting its programs--the Marshall Space Flight Center (MSFC) at Huntsville, Alabama; the Manned Spacecraft Center (MSC) at Houston, Texas; and the Kennedy Space Center (KSC) at Cape Canerval, Florida. OSSA is dedicated to unmanned scientific space flights and has line responsibility over the Goddard Space Flight Center (GSFC) at Greenbelt, Maryland; the contractor operated Jet Propulsion Laboratory (JPL) at Pasadena, California; and the Wallops Station launch site in Virginia. OART is responsible for carrying out advanced research programs through its four supporting Centers--Ames Research Center (ARC) at Moffett Field, California; Flight Research Center (FRC) at Edwards, California; Langley Research Center (LRC) at Hampton, Virginia; and Lewis Research Center (LeRC) at Cleveland, Ohio.

While the charter dividing responsibilities appears sufficiently clear, it must be noted that OART supports OSSA and OSMF programs by developing the needed technology and this has funding implications

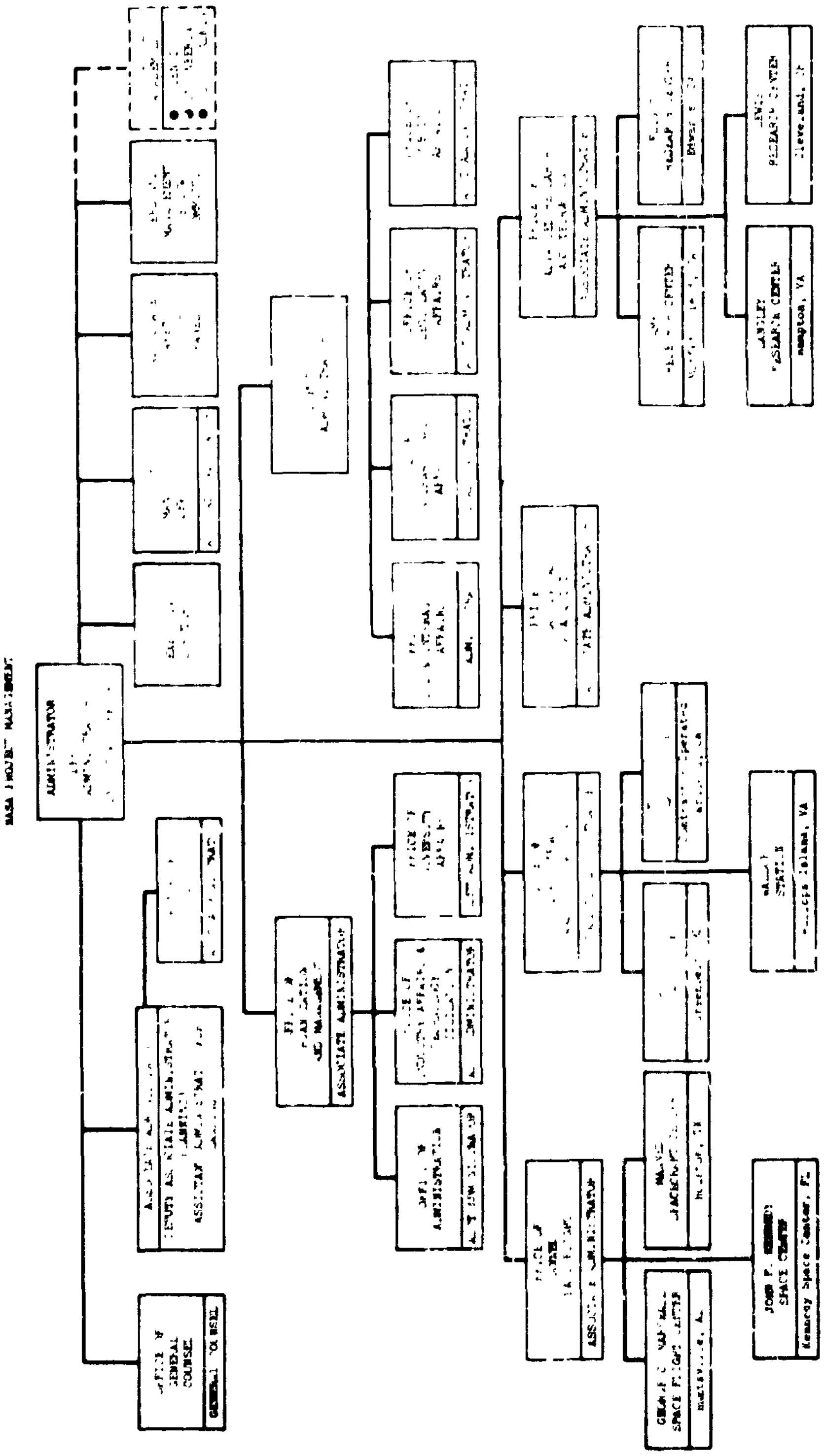

Figure I.5.--NASA organization chart.

on each Office's funding and, thus, the Centers' operations. Further, OART (Langley) has taken over an entire OSSA project (Lunar Orbiter) which supports Apollo (OSMF). Thus, program responsibility among offices and Centers are often obtained after lengthy negotiations among officials occupying powerful positions (Center Directors and Office Administrators). In addition, there is likely to be competition among the Centers for "lead" Center responsibility if a proposed program is compatible with the Center's activities.

The Administrator is, of course, appointed by the President. The heads of the various offices are drawn by the Administrator from various sources--NASA, industry, or the academia; they are liable to be leading scientists, researchers, college presidents, or industrial managers. In brief, the socialization of Headquarters into a common mold is much less than for a Center like Langley.

Human Factors

The course of any program is, to a large extent, dependent on the people involved--their personal characteristics, expertise, experience, and work methods. Sketches of some of the key people in the Mars program are given below to furnish additional insight for understanding the narrative material (descriptions given are those existing at initiation of Langley's Mars studies):

Langley:

Dr. Floyd Thompson - Director

A thin, distinguished six footer in his mid sixties. Grey haired with a trimmed mustache. Low key, relaxed. Formerly, Chief of Research at Langley. Forty years with NACA/NASA. Folklore--runs Center quietly and efficiently from inputs received informally at his table in the Cafeteria and in corridor encounters in 1219.

Charles Donlan - Deputy Director

A cigar smoker, short and aggressive, about fifty. A NACA researcher up through the ranks. A believer that expertise resides at the Centers and not at Headquarters. Blunt, ambitious, and responsible.

Dr. Leonard Roberts--Branch Head, Dynamic Loads Division

Born and educated in England. PhD. in Mathematics. Came to Langley from M.I.T. Short, early thirties, personable, outgoing. Interested in applied research. Concise, excellent speaker. Ambitious, political.

Edwin Kilgore--Chief, Flight Vehicles and Systems Division

Champion tennis player, early forties, wiry. Excellent engineer. NACA/NASA career. Flair for management and instilling loyalty. Switched to aerospace at first opportunity. Ambitious, personable, political.

Roger Anderson--Assistant Chief, Structures Research Division

Tall, ex-athlete, early forties. NACA/NASA career. Recognized as a leader of structures research. Interested in applications and new concepts. Heads committees, ambitious, political.

James Martin--Assistant Head, Viking Project Office

Large man, mid forties. New hire from Republic. Management oriented. Aggressive, capable, hard working. Direct and convincing. Totally dedicated to project success. Interested in results.

David Stone--Head, Project Fire Office

A career researcher with NACA/NASA. Believer in the "Langley system." Capable supervisor, considerate of his men. Independent, technically competent, blunt--not a worrier. Mid forties.

Washington Headquarters:

Edgar Cortright--Deputy Director, OSSA

Brilliant, distinguished man in early forties interested in the nation's problems. Convincing speaker for NASA and technology to the public and Congressional committees. Dedicated to public service. Hard working, ambitious, political. From NACA/Lewis to NASA Headquarters. Technically distinguished.

<u>JPL</u>:

Dr. William Pickering--Director

A distinguished scientist, authority in space science. In early fifties, quiet, low key. Good speaker, academically inclined. Relies on staff for engineering of space projects. Administrator.

Langley's Administrative Mode

As can be deduced from the foregoing, Dr. Thompson's administration was characterized by full support to his staff. Very little direction was given by 1219 on research matters; Dr. Thompson and Mr. Donlan concentrated on those problems requiring interfacing with Headquarters. Primary consideration was given to Langley and not NASA with the firm conviction that there was no conflict; i.e., what's good for Langley is good for NASA.

An example of how Dr. Thompson entered into a space project (Lunar Orbiter) problem is indicative of his philosophy. This story again may be folklore but it rings true to those familiar with his management techniques. Apprised that Lunar Orbiter was having a slight overrun in costs, he telephoned an executive at Boeing and expressed his concern. The executive immediately offered to come to Langley and discuss the matter. Boeing gathered all the cost data and prepared a presentation. The executive and his staff arrived at Langley and were greeted by Dr. Thompson who took them on an extended tour of Langley while Dr. Thompson pointed out the various facilities and described the on-going research work. At lunch, Dr. Thompson remarked to the effect that he was an old man trying to run Langley and that he would appreciate anything Boeing could do to hold down costs on Lunar Orbiter. Word has it that the Boeing people left immediately after lunch--no presentation or opening of brief cases--with the conviction that they had to help "that fine old gentleman."

CHAPTER II

THE BEGINNING - 1964

Summary

The first year of Langley's participation in Mars studies was an active year with emphasis on a small group's efforts to obtain a technology base. A five man multi-disciplined group undertook, more or less on its own initiative, to examine the aerodynamic and structural problems associated with vehicles entering the Mars atmosphere. In order to define the problems, the group found it necessary to set up a "straw man" concept. Because this concept appeared to have mission application, NASA management approved a contractual effort to study the concept in depth. The same group then dedicated its efforts to the preparation of the necessary procurement documents defining the individual tasks and overall scope of the contract.

Initiation of Studies

Early in 1964, Dr. Leonard Roberts, a Branch Head in the Dynamic Loads Division (DLD), became interested in the technology problems associated with a vehicle entering the Martian environment. Langley Research Center, by virtue of its extended research in the behavior of bodies in the Earth's atmosphere, was recognized as the lead NASA center in entry vehicle design considering both aerodynamic and heat loads. At Dr. Roberts' request, an informal group of high-level center scientific personnel was formed; this group consisted of:

Dr. Leonard Roberts - DLD

Mr. William Mace - Flight Instrumentation Division (FID)

Mr. Roger Anderson - Structures Research Division (SRD)

Mr. Edwin Kilgore - OETS

Mr. Kilgore assigned me the engineering task of assisting these researchers by acting as a systems coordinator and performing the duties of the technical project engineer. This assignment was, for practical purposes, my introduction to Aerospace Technology and I was to be supervised by my Branch Head, Mr. C. T. Brown. It should be noted at this point that although not a large commitment was made by Langley management at this time, the action to allow the researchers to embark into a new technology was consistent with management's past actions with respect to Faget and Houbolt.

The first meetings of the group (Roberts, Mace, Anderson, McNulty and Brown) were directed to the question of how best could

Langley contribute its talents to the investigation of Mars. It was felt by all members that the investigation of the planets and Mars, in particular, would be a major NASA role after Apollo. Thus, it was necessary for Langley to become cognizant of this area of study in order to guide the necessary research in the ensuing years. The group was starting from near zero in knowledge pertaining to Mars and interplanetary missions. Since Langley's entree into this field was its expertise in entry aerodynamics, it was decided to concentrate on a baseline entry vehicle and payload; the question of how to deliver it to Mars was considered second order at this time and, besides, this could well be some other Center's responsibility. However, by emphasizing a baseline entry system, the Roberts team was taking the first step into mission studies and away from research investigations in specific disciplines. The members were asked to initiate work in their respective divisions under the following broad responsibilities:

Roberts - Science and management

Anderson - Structures and thermal protection

Mace - Electronics

McNulty - Systems and mission analysis

As the group was small, the problems large, and all members approximately equals in responsibility, there was no need or time for formal memoranda and documentation. Telephone calls, bull sessions, and cryptic notes were the recognized means of communicating and exchanging thoughts and information.

Within a few weeks, the following basic data had been gleaned from many sources in the technical literature as well as from telephone calls to contacts in other centers and in industry:

1. Mars' period around the sun is approximately twice that of Earth's; thus, launch windows occur every two years which allow for feasible communication paths of approximately 160×10^6 KM or less. Mars' diameter is 4210 miles. Mars' gravity if 12.3 feet/sec^2. Mars' pressure at surface is estimated to be very thin (10 to 40 mb; 1000 mb = 1 Earth's atmosphere).

2. Jet propulsion Laboratory (JPL) was the implementing arm for NASA interplanetary unmanned scientific projects. JPL is a research and development laboratory of the California Institute of Technology and had been affiliated with NASA since 1959, unlike NASA field Centers, JPL was under contract to NASA.

3. JPL had carried out a successful Mariner Mars flyby mission. JPL had demonstrated capability in electronics and interplanetary mission analysis.

4. Atlas Agena launch vehicle can deliver about 800 pounds payload to Mars, Thor-Delta about 400 pounds (actual payload weight dependent upon launch year).

5. JPL was planning to let a study contract in the near future for Advanced Mariner Missions involving a landed package on Mars. Atlas-Centaur was to be the launch vehicle and could inject about 1500 pounds into a Mars trajectory.

6. Ames and Goddard Centers had study efforts underway concerning probes in the Martian atmosphere to obtain scientific data regarding the atmosphere. The probes would be small in nature and rely on statistically reconstructing the atmosphere from indirect measurements.

7. Headquarters was looking to the future beyond Mariner-type missions to a large interplanetary program for the planets. Study contracts for Voyager (1969-1975) had been awarded to AVCO Corporation and General Electric Company to consider payloads in the range of 6000-7000 pounds (Saturn V Launch Vehicle).

8. Entry velocity into the Martian atmosphere for an entry vehicle would be in the range of 20,000 feet per second for a direct Mars impact trajectory.

9. There existed a Headquarters Science Directive that specified that any vehicle entering the Mars atmosphere be sterilized so as to prevent contaminating Mars with Earth micro-organisms.

Initial Concept Definition and Approval

Based on the foregoing, the group decided to concentrate its efforts on (1) an entry vehicle about 8-feet in diameter (to fit within the Mariner shroud) and about 300 pounds in weight (this appeared to be a reasonable weight and would be compatible with Atlas-Centaur launch vehicle using a Mariner spacecraft as a bus to deliver the probe to the planet,),and (2) a payload consisting of instruments to make direct measurements of the Martian atmosphere while descending on a parachute deployed from the heat shield after the entry heat pulse. A preliminary design effort was initiated to iterate science instruments and the required subsystems until a reasonable concept was identified. It took approximately two months for this effort to converge with about 20 men of various disciplines working on the problem in scattered locations; my office was the hub because the actual designs were integrated on the drafting boards as well as the weights tabulated. There was no problem in obtaining production--people were motivated by the concept of a Mars probe and realized that they may be getting in on the "ground floor" of something big. No sophisticated analyses were made, designs were broad brush, and most work was done on scratch paper. All work was very preliminary to get a feel of practicability; a lot of work and concepts were turned out, analyzed, modified, or discarded in that time period.

Two problems which arose during this period and which required much discussion, trading-off, and judgment were (1) a descent television experiment and (2) the heat shield design.

The fundamental instruments necessary to make direct measurements of the atmosphere were readily identified. Their weights (as well as the weights of their supporting subsystems--power and communications) could be estimated with a reasonable degree of accuracy. These instruments were:

Temperature: Platinum Resistance Thermometer

Density: X-ray Backscatter and Accelerometer

Pressure: Pressure Transducer

Composition: Mass Spectrometer

Altitude: Radar Altimeter

Descent T.V. was believed to be a worthwhile experiment and, in addition, rather a glamorous one. However, weight allowances could not tolerate the experiment without deleting some of direct measuring instruments and, thus, relying on indirect analytical derivations. After examining many trades and much discussion, it was agreed, reluctantly, to omit a descent T.V. experiment. We expected, should the proposed probe become an actual flight program, that the question would arise again.

The other problem, that of the heat shield, was again one of weight. Since the entry vehicle would experience aerodynamic forces on entering the Martian atmosphere causing deceleration loads and heat pulse, it would be necessary to protect the payload with a heat shield through this period. While we had but a rough idea of what these loads would be, it became obvious that we couldn't build a heat shield of the required size with state-of-the-art technology within the weight restraint. Fortunately, there appeared a way out of this problem; researchers under Roger Anderson in the Structures Research Division were, at that time, working on a new configurational concept--a "tension shell" hat-like configuration designed to take pressure loads in membrane tension. This configuration had promise of being much more efficient than a cone or Apollo-shaped heat shield because of the absence of bending stresses.

In addition, researchers under William Mace in the Flight Instrumentation Division had become interested in the sterilization problem and had started a group of several engineers working on procedures and studying the effects of the elevated sterilization temperature (135° for 24 hours).

Thus, we had a concept to present to Langley management for consideration. The mission outline is shown on Figure II-1; the rationale for its consideration rested on the following main points:

1. The scientific instruments would make direct measurements of the atmoshpere.

2. Langley has expertise in parachutes and heat shields.

3. Langley has interest in sterilization.

4. The mission hardware requirements could serve as a focus for LRC research and technology development for several years.

5. The probe itself could be considered an experiment to supplement Mariner flights.

6. The probe mission could obtain the necessary data to guide design of Voyager landers.

Dr. Roberts decided the next logical step would be to have an experienced aerospace contractor study the concept in depth under

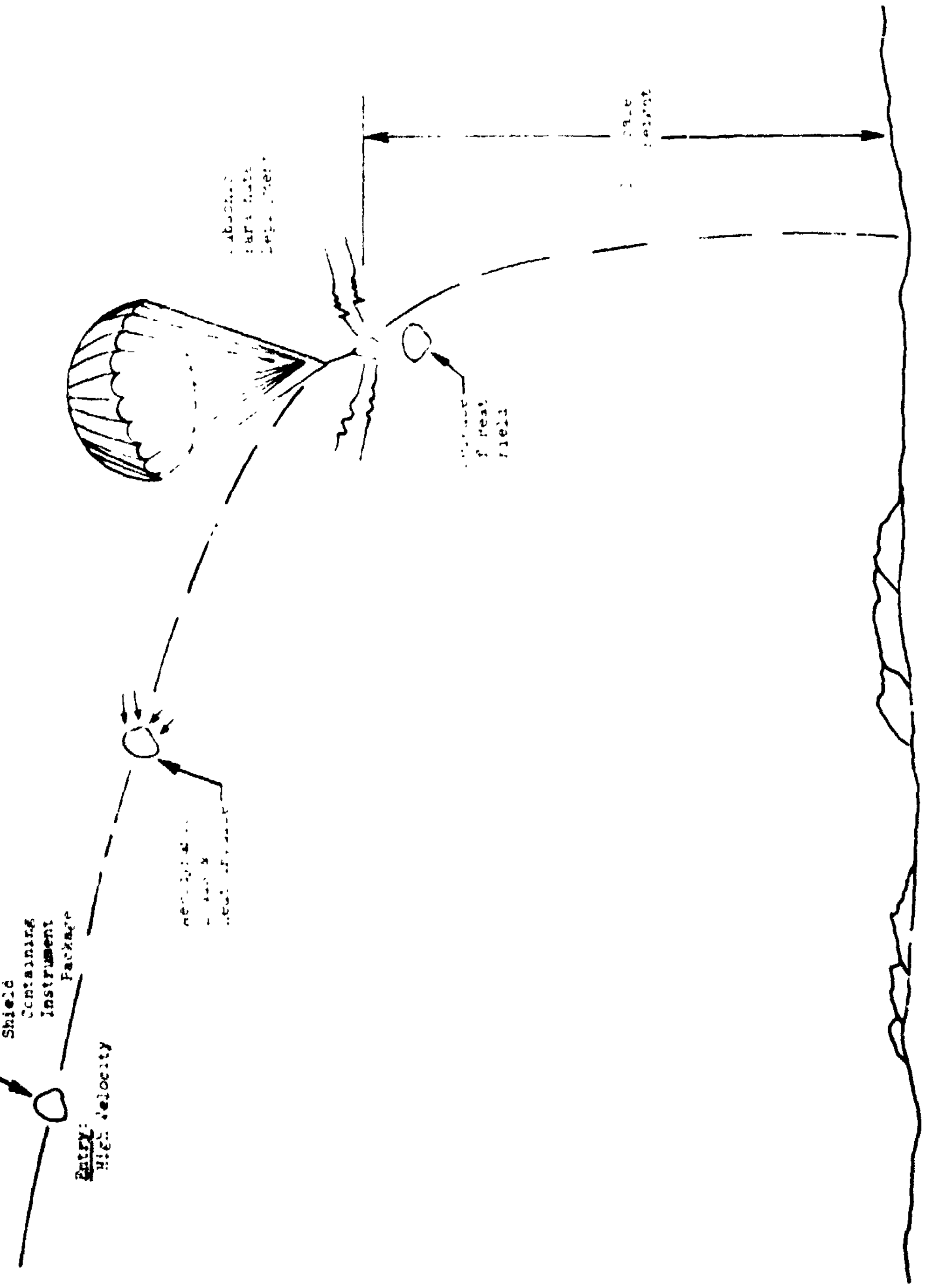

Figure II-1.—Mission mode concept.

Langley direction; he talked of a $500,000 contract. I felt that he was optimisitic about obtaining funding of that order. Dr. Robert perservered, however, and, by virtue of his aggressive championship of the concept obtained the support of Langley management and Headquarters. This commitment was a key decision with far reaching consequences for Langley and NASA since $500,000 was sizeable enough to put Langley in the mainstream of interplanetary studies for the first time. Further, the driving force had been Dr. Roberts and his technical staff acting on their own initiative.

I was assigned to consult specialists in all disciplines and to write up an inclusive work statement which would serve as the basis for the contractor proposals. Headquarters allocated $500,000 for the contractual study. $250,000 each was supplied the Office of Advanced Research and Technology (OART) and the Office of Space Sciences Applications (OSSA) as it was felt that study results would be applicable to both research and mission applications. Headquarters' decision approving Langley's entree into the interplanetary missions studies which, heretofore, had been a JPL monopoly was based on the consideration that missions to Mars (or other planets) appeared to be the next logical program after Apollo and it was well to consider broadening NASA's base beyond JPL which was not a NASA Center, had been subjected to Congressional criticism for its management of the Surveyor program[1], and was too small to handle a large Apollo-like

[1] NASA SP-4901, Unmanned Space Project Management, Surveyor and Lunar Orbiter, Kloman, p. 11.

program by itself.

A model of technical-administrative path leading to Mars probe commitment is given in fig. II-2.

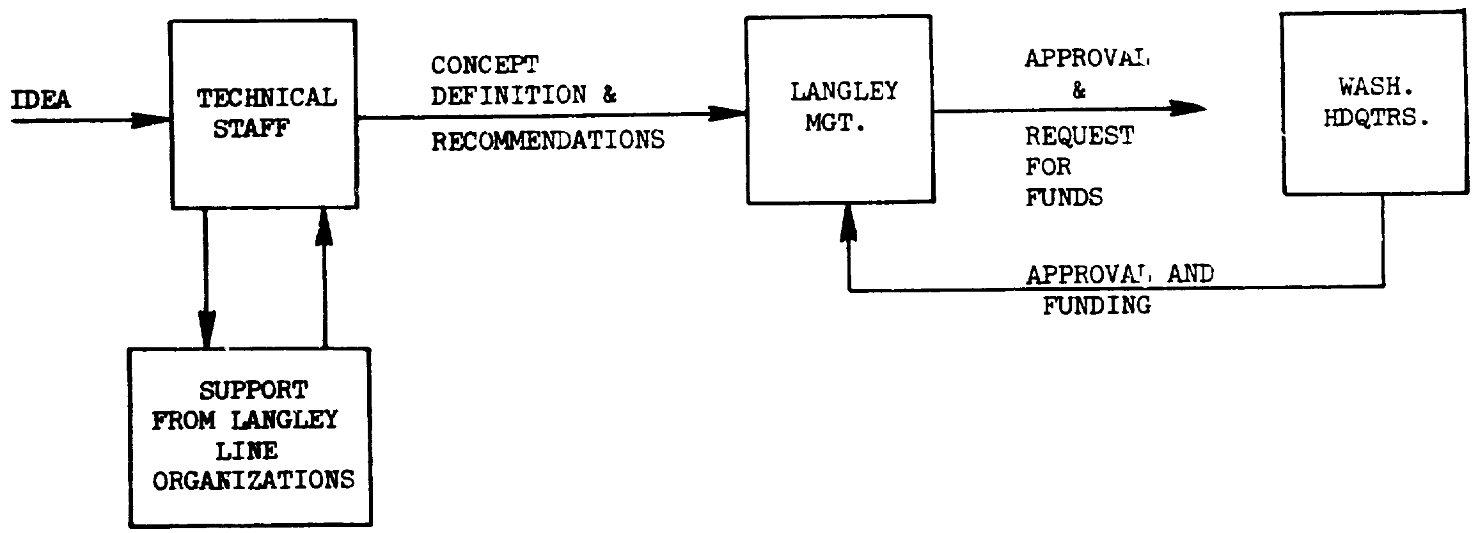

Figure II-2.--Model of the technical/administrative interactions leading to funding for a Mars probe study.

Preparing the Request for Proposal

Between July, when the go-ahead was given, and December, when the Request for Proposal (RFP) was released for bids, most of the Roberts team effort was centered on defining the tasks that the contractor would perform. Defining these tasks was a complex undertaking for two reasons: (1) we were lacking in expertise--it was out first experience with interplanetary missions and we did not have the grasp of the technological details, and (2) soon after go-ahead, Washington Headquarters directed that a lander be included in the mission and we had not examined a lander in any manner. The addition of a lander was influenced by a desire to increase the potential mission's appeal to the public and to Congress and by a possible need to match any Soviet competition. It is to be noted that the lander was only included, at this stage, as a study item; thus it could be included or not included in any mission as circumstances (technical or political) warranted at a later date. The adding of the lander enthused us for the following reasons:

1. The mission was greatly enlarged giving the study prime NASA importance and national recognition.

2. It gave us an entree in a new technology (lander) that was previously the domain of JPL.

3. It justified changing launch vehicles--going to the Saturn 1B/Centaur with much greater capability; thus, easing any weight bind we might have had in trying to build the 8 ft. probe for 300 pounds.

In short, it was a new and bigger project--and it was our responsibility.

Preparation of the work statement entailed problems other than technical ones. It was necessary to determine overall work statement objectives as well as defining individual tasks in detail. Leaving the technical problems aside for the time being, the following work statement approach was agreed upon after numerous meetings. It was decided to consider more than one launch opportunity. In fact, we agreed to think in terms of launches in 1971, 1973, and 1975, each larger in scope insofar as the landed package would be concerned. 1971 was taken as our baseline mission with emphasis on the entry experiments but including a minimum landed package. The landed package would consist of a crush-up ball with accelerometers to measure deceleration impact (surface hardness) upon landing together with a minimum of instrumentation to determine atmospheric density and other parameters which might influence the design of future more sophisticated landers. The 1973, 1975 missions were to be primarily lander missions with the landed package increasing in weight and complexity through 73 to 75 to the maximum payload capability that could be launched by the Saturn 1B/Centaur. A commonality concept of subsystems was to be utilized to the maximum extent practicable. The heat shield would perhaps be common for all three missions and more heavily loaded in the last two. This would mean that the heat shield would be over-designed for the 71 and 73 missions in order to save the development costs associated with three different heat shields. The second objective to be agreed upon was that the contractor should consider the development of a complete probe lander system (heat shield plus all subsystems) rather than concentrating on technology items per se. The contractor would be responsible for defining a complete development plan for the probe lander including the following items:

1. Manufacturing plan
2. Sterilization plan
3. Test program plan
4. Flight qualification plan
5. Facilities plan
6. Cost

It should be noted that while Langley was still not involved in the entire mission planning from launch to landing, it was very interested in the entire systems phase of probe lander separation from the spacecraft to landing. There were several reasons for the decision to use this systems approach. They are:

1. It was felt that a system study of the entire probe lander system would be the only way to determine the interfaces between the various technologies and to determine exactly what was required from each of the technologies.

2. The probe lander would be an integral unit which could be developed by Langley and supplied to any Center responsible for carrying out a Mars mission.

3. Because of Langley's interest in sterilization and in flight

qualification programs in the Earth's atmosphere, the study would generate data allowing Langley to proceed with plans in these areas as well as determining what ground facilities would be necessary to support a Mars mission.

An output from the contract would be a complete preliminary design of the 1971 probe lander defining all components and their weights--for example, a complete design of the heat shield. This complete system design then could be used as a basis for further final fabrication drawings and detailed drawings of all parts if a decision was made to go forward with this concept.

To serve as a base for discussion of the technical problems involved in the work statement, our preliminary concept of the mission is shown in Figure II-3. This concept assumes that the probe lander would be separated from the spacecraft several days prior to Mars encounter by a mechanical spring system which would be designed to give the necessary velocity increment to put the probe lander on a Mars encounter trajectory. The probe lander would be aerodynamically stable so that once it entered the Mars atmosphere it would align itself to the air stream at zero angle of attack and, thus, take the reentry and heat loads in an axial direction. It was further assumed that the probe lander could be designed so that its drag would furnish sufficient braking to decelerate the probe lander to a velocity of less than Mach 1 at approximately one-half scale height above the Mars surface (a scale height is equal to the altitude necessary to change the density by one order of magnitude). At this altitude,

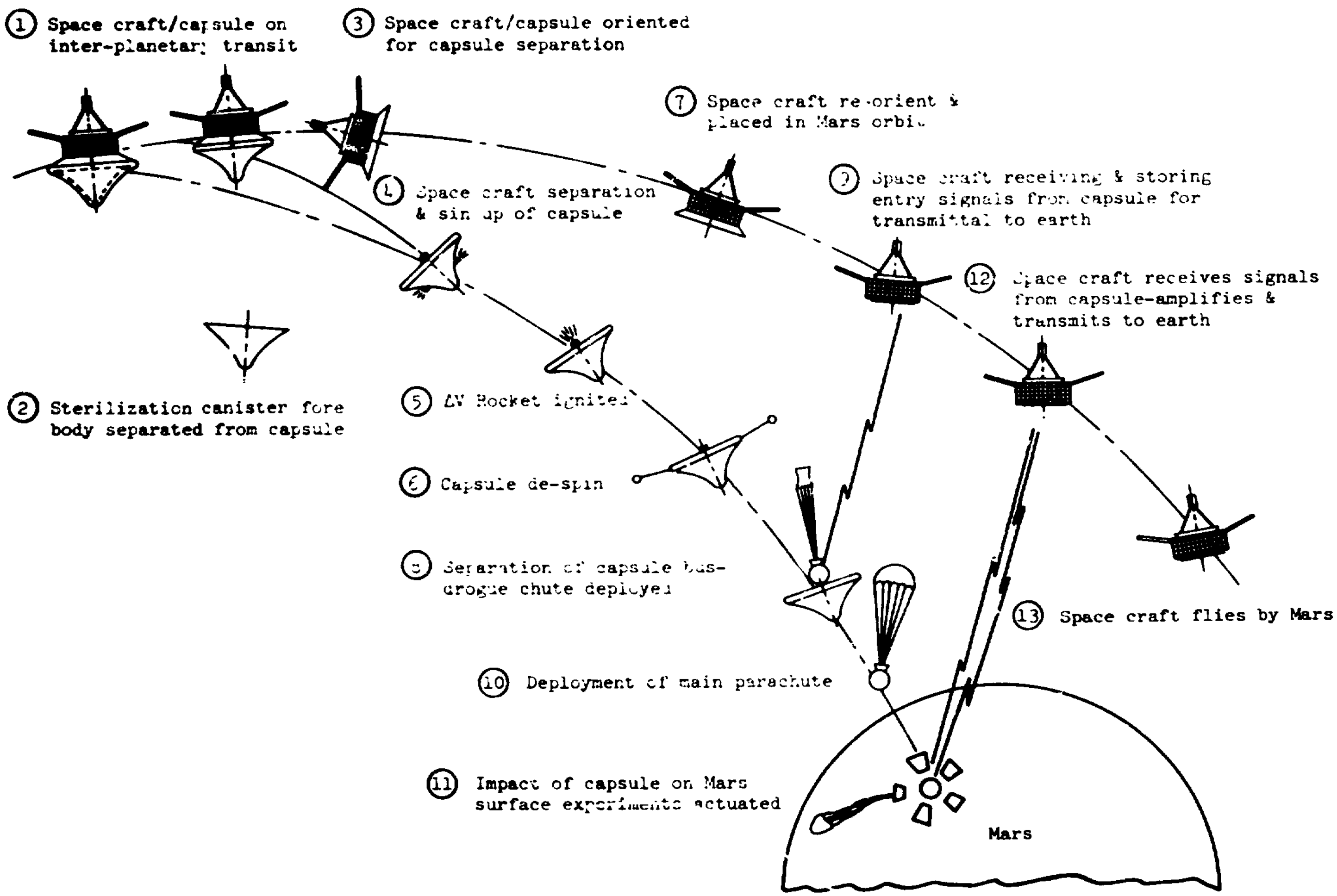

Figure II-3.- Mars probe sequence of events.

a parachute would be deployed which would lower the instrument package (pulled from the heat shield) to the surface of Mars impacting the surface of Mars at a velocity of approximately 100 feet per second. The spacecraft on its Mars flyby path would serve as a relay station for communications from the probe lander back to earth. Using the spacecraft in this manner would minimize the amount of power and the complexity of instrumentation required on the probe lander.

The work statement was divided into technology areas where the contractors' tasks were defined. In the first technical area, that of Mission Profile and Analyses (an area where we had a dearth of information), the contractor was made completely responsible for defining the mission profiles for the spacecraft and for the probe lander from separation to the end of communications. However, we had the foresight to ask the contractor to look into some additional items because we had no knowledge of the impact trajectories or of the associated loads. The items which we asked the contractor to consider were the influence of (a) terminal guidance on the probe lander and (b) probe lander separation from the spacecraft after the spacecraft-probe lander combination was in orbit. As will be seen later, the additional requirement of asking the contractor to look into separation after orbit took on major importance.

The second item, that of Structures (including the design of the probe lander heat shield), was exercised thoroughly as this was an area of Langley expertise. Since the Saturn 1B/Centaur removed the weight problem as a major restraint, the contractor was asked to study three different configurations for heat shield application; these three configurations were the tension shell, the Apollo-shape, and a large blunted cone. The contractor was required to make detailed stress analyses and to trade-off the pros and cons of these three shapes based on their aerodynamic drag efficiency, their overall weight requirements, and their system packaging capability. In doing this, he was required to define the critical aerodynamic loads and heating inputs (both convective and radiative) for all ranges of proposed trajectories and atmospheres.

The third technology area was Science Instrumentations and Communications. The scientific measurements to be made were delineated in the work statement as well as candidate instruments to make those measurements for the 1971 probe lander. The contractor was responsible for specifying the communications equipment aboard the probe lander to condition the science data and transmit the data to either the bus for transfer to Earth or to Earth directly. In the case where the spacecraft was used as a transfer link, the contractor was further responsible for delineating the equipment on the spacecraft in order to effect this transfer. The contractor was also required to determine the power requirements from imputs from the science and the communication equipment.

The fourth technology area was Aerodynamics. Again, as with the structural design, this area was exercised thoroughly because of Langley's experience. Although it was assumed that the probe lander would be designed to be aerodynamically stable, there was considerable uneasiness amongst aerodynamicists concerning the dynamic behavior of the probe prior to achieving stability. One concern was that before entering Mars' atmosphere the probe lander may tumble and be in a random mode. Such behavior would possibly negate any communications link during this period and would require, at a minimum, special unknown design procedures. For this reason, the contractor was required to look into the possible need to provide a method for spinning the probe lander after separation from the spacecraft to assure that it would not tumble. Should these spinup conditions be necessary, it might be further necessary to despin the probe lander after entry to allow it to go to its natural stable attitude. A second problem which concerned he aerodynamicists was the motions of the probe lander during entry. Assuming a random angle of attack entry condition, the question became one of how soon would the motions damp out before obtaining stable flight. Further, would there still be a large angle of attack on the probe lander when it penetrated sufficiently far in the atmosphere to have aerodynamic loads or heating inputs? If so, how did this effect the structural design of the probe lander shell? It was our hope at this time that, even should a design angle-of-attack at entry be achieved (through spinup or other means) which would be satisfactory for a nominal case, we could further obtain at least a partial successful mission for a random entry condition (if, for example, the spinup mechanism failed). For the above reasons, the contractor was asked to define the motions of the probe lander "during entry for design and possible off-design conditions." As one can imagine, that simple sentence requires the contractor to perform innumerable analyses and designs.

The last technology area concerns the parachute. Here again the problem was one of dynamics--defining the motions of the parachute to assure that it was in stable flight during the science measuring period. The contractor was required to determine the size of the parachute and the weight of the system in order to meet the final requirements of landing the instrument package at 100 ft/sec and providing sufficient dwell time in the atmosphere to make the science measurements. Since the data available on Mars indicated there might be wind gusts in the atmosphere, the contractor was further asked to study the system motions while penetrating 50 ft/sec gusts of 10 second duration and to damp these motions, if required, in a manner so that system operation was compatible with the science requirements. Again, to cover an unknown exigency, we inserted an additional requirement that the contractor evaluate the influence of adding a supersonic parachute to the entire probe lander system to be deployed at a maximum Mach number of 2.5. The purpose of this supersonic parachute would be to add to the drag of the probe lander in order to assure that the subsonic parachute could be deployed at an elevation of one-half scale height above the surface of Mars.

For informational purposes, it may be noted that 14 drafts of the work statement were prepared in the converging process of obtaining a consensus before the final work statement was approved by the Source

Evaluation Board and was released for bids. With reference to the aforementioned Source Evaluation Board (SEB), a few words on its makeup and objectives are in order. "In the NASA, formal Source Evaluation Board are established for competitively negotiated research and development procurements when (1) The estimated cost of the contract will exceed one million dollars or (2) The estimated cost of the contract itself will not exceed one million but possible follow-on work for later phases of the same project will."[2]

Source Evaluation Boards have four primary functions: to approve the RFP, to assess the technical and business qualifications of prospective sources, to evaluate proposals received from these sources, and to report their finding to the person who is responsible for selecting the source of award. The members on our Source Evaluation Board were selected by the Director of the Langley Research Center. The SEB was composed of several high-level personnel from the Center and two representatives from Headquarters; the Chairman named was Edwin C. Kilgore, Division Chief of Flight Vehicles and Systems Division, Langley Research Center. Because of the size and complexity of the procurement, it was necessary to supplement the Source Evaluation Board itself with subsidiary technical and business committees and subcommittees for analysis and research purposes. The Source Evaluation Board is also responsible for approving the evaluation criteria which the committees serving the board will use in

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[2]NASA Procurement Management Seminar pgs. 31-34.

grading the proposals. Thus, in this context, the RFP must include, in addition to the technical work statement, a statement as to the broad guidelines on which the proposals will be evaluated. Again, the same group which prepared the work statement was involved in developing the evaluation criteria and submitting its recommendations to the Source Evaluation Board for approval.

To fulfill this requirement, we asked that the contractor submit his overall technical approach with substantiating data analysis for the following five technical areas:

1. Overall System Concept and Integration
2. Subsystem Concepts and Associated Analyses
3. Qualification Program
4. Sterilization
5. Technical Management and Plans

In addition to the Technical Management Proposal, the bidders were required to submit a Business Management Proposal which included the following: (1) past performance and experience (2) the relation of projected work load capacity, and (3) their management structure. With the approval of the Source Evaluation Board, the subsequent release of the RFP represented the completion of Langley's first year's efforts on Mars mission studies. The following items are included in the Appendix for Chapter II: (II-A) Statement of Work, (II-B) Instructions for Technical and Business Management Proposals, (II-C) LRC Announcement designating the Source Evaluation Board, (II-D) Langley Announcement establishing SEB Committees. The commitment by Langley to set up a Source Evaluation Board and its committees was not a minor one. As can be seen from the Appendix, it represents breaking about 40 senior staff members away from their line responsibilities for at least a month's effort. A model of the technical/administrative interactions utilized to request contractor proposals on a Mars probe lander study is given in fig. II-4.

At the end of the first year, Langley had a small technical staff under Dr. Robert's direction, a nucleus for the future effort, that was beginning to understand the problems and were well placed for the next phase. Washington Headquarters was giving Langley more responsibility. The Langley administration was giving full support but was not getting directly involved for project participation.

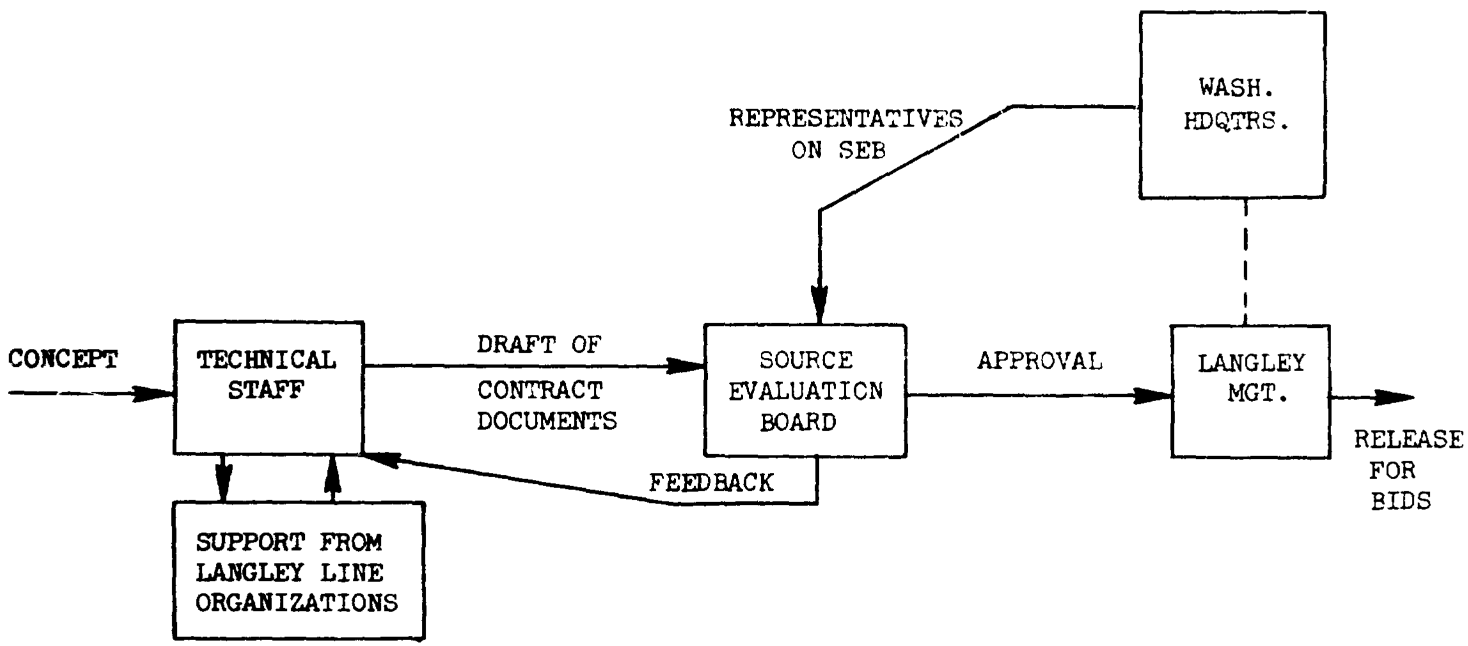


Figure II-4.--Model of the technical/administrative interactions to request contractor bids on a Mars Probe Lander study.

Synopsis

A synopsis of the first year's effort could be tabulated as indicated below:

1. Formation of a high-level group to study problems associated with Mars entry. Action initiated and managed by Dr. Roberts, a middle-manager in position responsibility.

2. Identification of Langley's role as one of the entry vehicle technology as applied to obtaining direct science atmospheric measurements utilizing a parachute descent to assure sufficient dwell time.

3. The preliminary definition of a hardware concept which was compatible with item 2 above.

4. The approval by management of the concept with the authority to pursue the concept further through contractual means--allocation of five hundred thousand dollars.

5. The increased interest of Washington Headquarters in the procurement by directing inclusion of a lander into the mission and thus causing the procurement to become one of major significance.

6. The preparation of the request for proposals
   a. The contract approach--systems (rather than research) oriented.
   b. Delineation of technical tasks.
   c. Development of evaluation criteria.

7. Approval by the Source Evaluation Board and the release of the Request for Proposals.

CHAPTER III

DEVELOPMENT OF A NATIONAL PROGRAM - 1965

Summary

The second year could be divided into two distinct phases. For the first half of the year, Langley continued on its more or less independent path with minimum interfacing with NASA Headquarters, other NASA Centers, and industry. In this period, Langley concentrated on increasing its technology base by means of in-house studies and on selecting a contractor for the probe/lander contract. In contrast, the second half of the year was devoted to initiating a Langley role in Voyager and integrating Langley's effort into a national NASA effort. This required both formalizing the effort at Langley so that Center management could keep current and respond as well as defining lines of communication with JPL and Headquarters.

Langley In-House Studies

With the release of the RFP for bids, a slack time became available to strengthen Langley's technology base by continuing the in-house studies which were dropped when Roberts' technical staff switched its efforts to the preparation of the contract procurement documents. In my role as systems integrator and mission analyst, I started two teams in my division, Flight Vehicles and Systems Division (FVSD), to work--one team on the engineering design of a tension shell heat shield and another on mission analysis (trajectories, launch vehicle requirements, and Mars entry loads and heating).

Starting the work on heat shield design presented no problem--an experienced structural design engineer together with a designer was made available and assigned the task. The mission analysis problem was another story--I had no one with any expertise to call upon as well as having none myself. I advised Mr. Kilgore, my line Division Chief, of this fact and recommended that our Division should build a technology base in this area. I further requested a team of four promising young, ambitious engineers (who I had hand picked) to tackle this problem. Mr. Kilgore concurred and for two months, I worked closely with these engineers to develop an appreciation and understanding of the parameters and their fit in the definition and design of the probe/lander and sub-systems.

In a similar manner, other team members started in-house studies in their areas of responsibility. In addition, other line research organizations, sensing the future direction of our efforts, began to orient their long range research objectives toward a Mars mission objective. However, the main forcing function of our group's in-house studies was to prepare ourselves for the task of technically monitoring the probe/lander contract work once it was initiated.

Voyager and Probe/Lander Contract Evaluation

In the Spring of 1965, NASA Headquarters made the decision to follow the JPL Mariner Mars 1969 mission with a "Voyager" Mars mission in 1971 (launch windows to Mars occur at two year intervals). "Voyager", at this time, was a nebulous term to denote a lander mission to the planets (Mars and Venus). A series of Voyager missions was envisioned similar to the Mariner Flyby missions and would be precursors to any manned planet mission. JPL was instructed to proceed with contract definition studies of the spacecraft to ferry a lander to Mars. The lander definition was not to be included. The omission of the lander from the Voyager Study was significant; our group concluded that Headquarters must be looking to Langley and its Probe/Lander contract for definition of the Voyager landers. As far as we knew, however, there had been no commitment from Dr. Thompson, Langley's director, to Headquarters for Voyager support--in fact, Dr. Thompson had stayed very much in the background throughout and had not displayed any personal interest in Mars studies.

The month of March was spent in evaluating the contractor's proposals for the Probe/Lander study. The aforementioned committees took over a floor of the nearby Chamberlin Hotel and graded the proposals received from AVCO, General Electric, Grumman, Hughes, Northrup and Space General. While these deliberations are confidential, it can be reported that the competition was keen with companies, as expected, showing varied strengths in the technologies required. While the committees were evaluating the proposals, members of the

Source Evaluating Board (SEB) were visiting the six companies to inspect their facilities as a guide to their competence to perform the work. In addition to the committee evaluations and plant visits, a oral presentation was held at Langley on March 23 by all companies in secret to the SEB and committee members. The purpose of the presentation was, of course, to aid in the decision making process. The companies were given the opportunity to present their philosophy, technical approach, and to expand on their proposal wherever they felt they might have left loose ends or to emphasize the points they deemed important. They were also questioned by Langley personnel on points which were not clear in the proposal.

The committees reported their finding to SEB on March 30. The report consisted of a complete written record of the evaluation plus an oral summary from each chairman; I presented the findings of the Overall Concepts and Integration panel. The SEB now had complete information to start their deliberations with the objective of making a recommendation to the Center Director regarding award of the Probe/Lander contract.

Results of FVSD In-House Studies

In late spring, the FVSD's in-house studies on the tension shell and in mission analysis had progressed far enough to have some preliminary results. In a manner similar to the normal method that FVSD carries out a hardware assignment, FVSD undertook to "engineer" the Mars probe lander with the variety of disciplines within the Division. As a result, FVSD was building a team capability within the division under my designations on Roberts staff as integrator, design chief, and mission analyst. There was no conflict between the groups because the groups were working different problems and FVSD's date fed directly to Roberts and his staff. Both Kilgore, FVSD Division Chief, and Roberts were pleased with the arrangement and it was most effective. The FVSD team at this time consisted of about eight engineers-four in design and four in mission analysis.

The results of FVSD's findings are presented in the following sections:

Tension Shell

The problem of the tension shell is shown in Figure III-1. The concept is that the shell is configured to the shape a membrane would assume with symmetrical loading under Newtonian theory. My structural engineer reported two problem areas:

(1) The base ring would be heavy as a large moment of inertia would be required to prevent buckling.

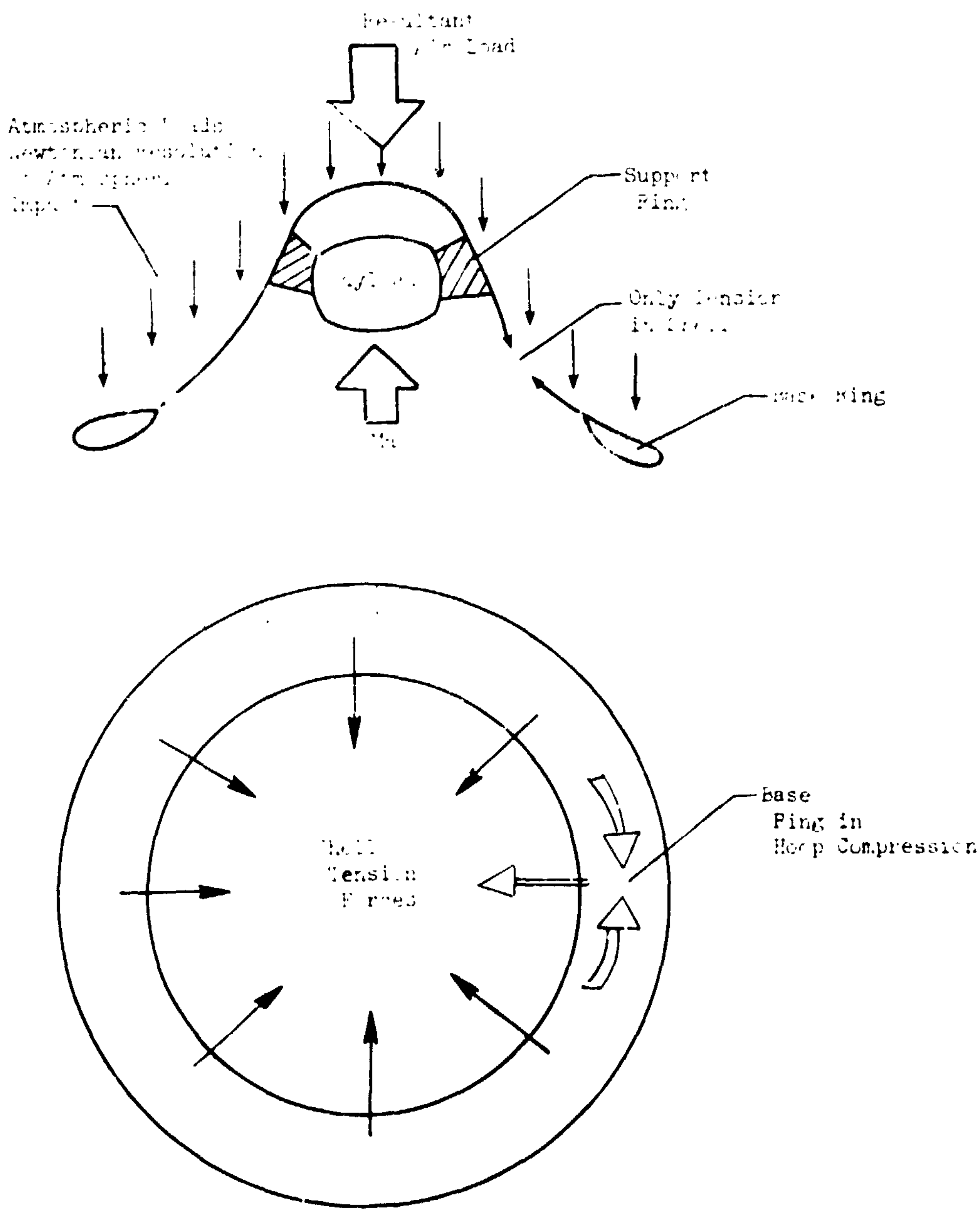


Figure III-1.--Theoretical tension shell loading.

(2) Engineering design procedures were not available for defining shell stresses under unsymmetrical loading as would be anticipated with an angle of attack during entry. Further, texts such as Formulas for Stress and Strain (Roark) or Theory of Plates and Shells (Timoshenko) were not directly applicable to the problem; the shell would probably have to be designed to resist some bending, and the development of an analytical solution would represent advancing the state of the art.

Mission Analyses

Few experiences have been as rewarding or as enjoyable as the first couple of months work in this field. Starting from scratch and working, by and large, without guidance, we defined a simple methodology--not anywhere near a complete understanding of the technology but an understanding sufficient to make complex trade-offs in a short time and to identify critical parameters--a working knowledge sufficient for all near term purposes. It was a stimulating experience and a surprise to us that a group of five people could progress to such a depth in a new technology in so short a time. The secret was, I think, that we were interested in the application and not the methodology for itself. When mission analyst specialists tried to explain refinements or optimizations, we turned a deaf ear and ran; when texts got complicated, we skipped pages and looked for a formula we could use for our purpose. Beyond this was the constant cross feed among five persons aimed at understanding the problem; in effect, we taught each other.

First, let us look at the final results--what we could do. We could:

(1) Size a launch vehicle and fuel for a mission to Mars for any size payload (spacecraft and probe/lander) for the following phases--launch, earth orbit, and to place payload in interplanetary orbit.

(2) Size spacecraft for interplanetary cruise, course corrections, and orbit maneuver at planet if desired.

(3) Size propulsion requirements on probe/lander for entry.

(4) Determine entry trajectories--velocities, altitudes, loads, flight path angles.

Now, let us look at how we got there.

(1) Literature search uncovered data such as given in Figure III-2[1]; similar data is contained for launch windows in 1973 and 1975. Concentrating on the parametric data given for departure velocity (V_D) and approach velocity (V_A), we obtained a wealth of data sufficient to study launch payloads and Mars entry loads and trajectories.

[1] Voyager Design Studies, Volume 3: Systems Analysis, AVCO Corporation, October 1963, pg. 80.

Planet	Type	Date	Time of Flight (days)	Departure Velocity (km/sec)	Approach Velocity (km/sec)	Injected Weight (lb)	Burnout Weight			Propellant Weight (lb)
							All Lander (lb)	All Orbiter (lb)	Orbiter with 2000 pound Lander (lb)	
MARS	I	4/24/71	188	3.4806	3.5868	6721	6721	6089	2165	2556
			190	3.4832	3.5184	6717	6086	3270	2195	2522
			192	3.4893	3.4556	6710	6079	3310	2221	2489
			194	3.4991	3.3984	6698	6069	3344	2242	2456
			196	3.5129	3.3469	6682	6054	3372	2258	2424
			198	3.5313	3.3014	6660	6034	3392	2268	2392
			200	3.5547	3.2620		6010	3405	2272	2361
			202*	3.5839	3.2291	6598	5978	3410	2269	2329
			204	3.6200	3.2030	6555	5939	3406	2259	2296
			206	3.664[illegible]	3.1846	6501	5890	3390	2239	2262
			208	3.7190	3.1748	6435	5830	3362	2209	2226
		5/10/71	198	2.9212	2.9163	7343	6653	4034	2821	2522
			200	2.9217	2.8938	7343	6653	4051	2833	2510
			202	2.9231	2.8749	7341	6651	4064	2842	2499
			204	2.9255	2.8594	7339	6649	4075	2849	2490
			206	2.9288	2.8471	7336	6647	4082	2854	2482
			208	2.9329	2.8380	7332	6643	4087	2857	2476
			210*	2.9379	2.8319	7327	6638	4089	2857	2470
			212	2.9437	2.8286	7321	6633	4088	2855	2466
			214	2.9503	2.8279	7314	6627	4085	2852	2462
		5/24/71	204	2.8142	2.8222	7448	6748	4164	2929	2518
			206*	2.8100	2.8235	7502	6797	4193	2959	2543
			208	2.8088	2.8274	7503	6798	4190	2958	2545
			210	2.8083	2.8336	7503	6798	4186	2954	2549

Continued

Planet	Type	Date	Time of Flight (days)	Departure Velocity (km/sec)	Approach Velocity (km/sec)	Injected Weight (lb)	Burnout Weight: All Lander (lb)	Burnout Weight: All Orbiter (lb)	Burnout Weight: Orbiter with 2000 pound Lander (lb)	Propellant Weight (lb)
		6/9/71	192	3.1254	2.8836	7133	6463	3942	2722	2411
			194	3.1122	2.8851	7147	6475	3949	2729	2418
			196	3.1015	2.8887	7159	6486	3953	2734	2425
			198	3.0914	2.8943	7169	6495	3955	2737	2432
			200*	3.0818	2.9019	7179	6505	3955	2739	2441
			202	3.0728	2.9114	7189	6513	3953	2739	2450
			204	3.0644	2.9225	7198	6521	3949	2738	2460
			206	3.0568	2.9354	7206	6528	3944	2736	2470

*Time of flight corresponding to the minimum to the sum of departure and arrival velocities.

Figure III-2.--Trajectory Parameters.

The departure velocity squared is usually termed C_3 and is a measure of launch vehicle energy (E), and payload (P). Rationale:

E (for a given launch vehicle) = constant

$E \sim mV^2 \sim PV_D^2 = \text{constant}$

the smaller the V_D, the greater the payload--so minimize V_D.

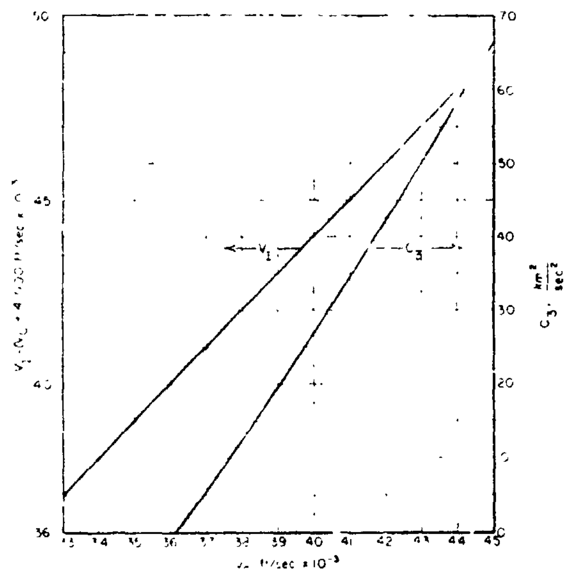
(In layman terms--when the planets are favorably aligned, it takes less departure velocity to deliver a given payload).

Checking down the departures velocity column in Figure III-2, for example, we find that the minimum velocity of 2 8 km/sec occurs on 5/24/71 and represents a $C_3 = 2.8^2 = 7.85$. We can then proceed to a launch chart, such as given in Figure III-3 [2], which designates payload as a function of C_3. This completes the discussion regarding the launch phase.

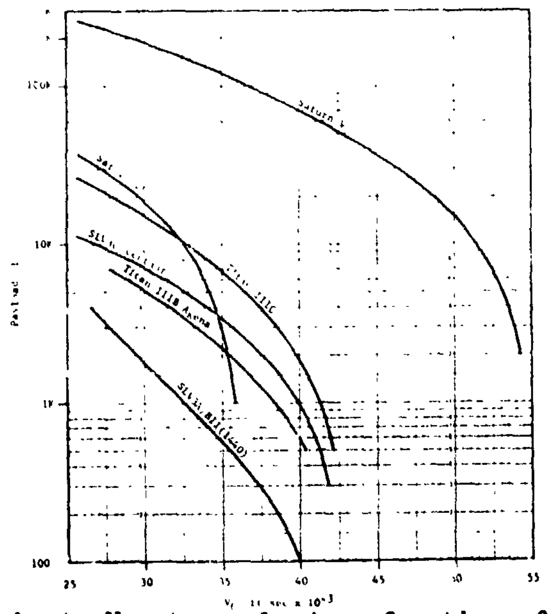
The Mars approach problem was also examined. The approach velocities designated are the velocities as the spacecraft approaches Mars when the gravity of Mars becomes the prime factor in determining the subsequent trajectory. By using simple formulae [3], the velocity at any aim point (entry or orbit maneuver) near Mars can be calculated. Since we must eventually land on the planet, this approach velocity must eventually be decelerated to zero. Thus, it is logical that we keep the approach velocity as low as possible to minimize the work we must do. In summary, tools were in hand to determine the entry velocity of the vehicle at atmospheric entry conditions--assumed to be

2 Launch Vehicle Estimating Factors, NASA, January, 1970.

3 Voyage Design Studies, Volume 3: Systems Analysis AVCO Corporation, October, 1963, p. 70.



(a) Conversion chart, C_3 to V_c



(b) Conversion chart, V_C to payload as function of launch vehicle.

Figure III-3.--Launch vehicle performance.

800,000 feet above Mars. (For simplicity and because the refinements are not essential to first cut analyses, I have omitted mention of other parameters such as launch azimuth restraints, communication links to Earth, landing site on Mars, Sun position relative to the vehicle, length of launch window, etc.)

(2) To obtain required data on the entry, a simple particle ballistic Earth entry program was modified. By working with a programmer in Langley's Computer Division, the atmospheric and planet characteristics [4] reflecting the current scientific estimates for Mars were substituted for the Earth's values. Such niceties as six degrees of freedom programs and entries relative to the atmosphere's rotation were ignored. From this simple program, parametric studies could be readily carried out; we could call in to the programmer the values of the parameters-entry velocity, entry angle into the atmosphere, and ballistic number (a measure of the weight-drag characteristics)--and get the print-out in the same day which would describe everything we wanted to know about velocities and loads. From this work, we identified the critical parameters and could understand the trade-off problem--this allowed us to carry out complete mission analyses with confidence. It is interesting to note how this very important assistance was obtained. Two of my young engineers made discreet inquiries to determine who could help us. They then made an appointment with the specific programmer (female),

4 NASA TN-D2525, NASA Engineering Models of the Mars Atmosphere for Entry Vehicle Design, Levin, G. M.; Evans, D. E.; and Stevens, V., November 1964.

explained they were in trouble with their assignment, were ignorant of the technology, and requested any help they could get. The cooperation and assistance obtained was invaluable and no formal interdivision arrangements were ever made.

Preliminary Langley - JPL - Headquarters Activities

With the increased interest in a Mars mission as indicated by Langley's Probe/Lander effort, JPL's spacecraft effort, and Headquarters' desire to define a mission, the Langley management began to take steps to identify Langley's mission role (if any) and its internal research and technology direction. Since Voyager was an OSSA program, the definition of Langley's fit in the program was a complex problem involving OART, OSSA, and Langley.

At the request of Mr. Kilgore, Mr. Brown and I were closely associated with Dr. Roberts in the preparation of two documents early in May. The first document was an internal memorandum defining, as best we could, the options available (together with their justification from a technology viewpoint and the resources required for each option responsibility) to OART in its participation in the Voyager Program. This memorandum OART's Role in the Voyager Program is contained in Appendix III-A, and a summary chart is included herewith as Figure III-4. Briefly, it outlines three options all with overall JPL management and responsibility for launch vehicle and spacecraft systems. Under Option I, Langley would be responsible for the entire entry vehicle ("capsule bus") development including science. Option II is the same except the science integration function would be performed by JPL. Option III gives mission hardware responsibility to JPL with Langley furnishing technology suppor .

The second paper was for a presentation at Washington Headquarters by Dr. Roberts on May 11 to OSSA and OART management. This presentation was entitled Voyager Research and Technology Programs and was

	I	II	III
TOTAL SYSTEM INTEGRATION	JPL	JPL	JPL
S/C Bus	JPL	JPL	JPL
S/C Experiment Integration	JPL	JPL	JPL
S/C Experiments	From Experimenters		
Capsule Bus Development	LRC	LRC	JPL
Capsule Bus Definition Program	LRC	LRC	LRC
Earth Atmosphere Flight Program	LRC	LRC	LRC
Capsule Experiment Integration	LRC	JPL	JPL
Atmospheric Measurements Exper.	LRC	LRC	LRC
Other Experiments	From Experimenters		
LRC MANPOWER	120	80	50

Figure III-4.--Alternate Langley roles in Voyager program.

devoted to "educating" Headquarters on Langley's capabilities in both general applicable technology areas and in Voyager mission understanding specifically. The objective of this presentation was to supplement the previous memorandum (Appendix II-A) by illustrating Langley's expertise and its relation to Voyager requirements and schedule. An overall technology schedule program plan (Figure III-5) was included which illustrated the technology development fit with Voyager scheduling but no recommendation or mention was made concerning any Langley direct role in the mission hardware program. Langley management was obviously sitting tight at this time and awaiting future developments before committing to a position or setting up any formal mission office. All Langley personnel working the "mission oriented" problem were still carrying out their line functions; there was no Langley Voyager Office as there was at JPL.

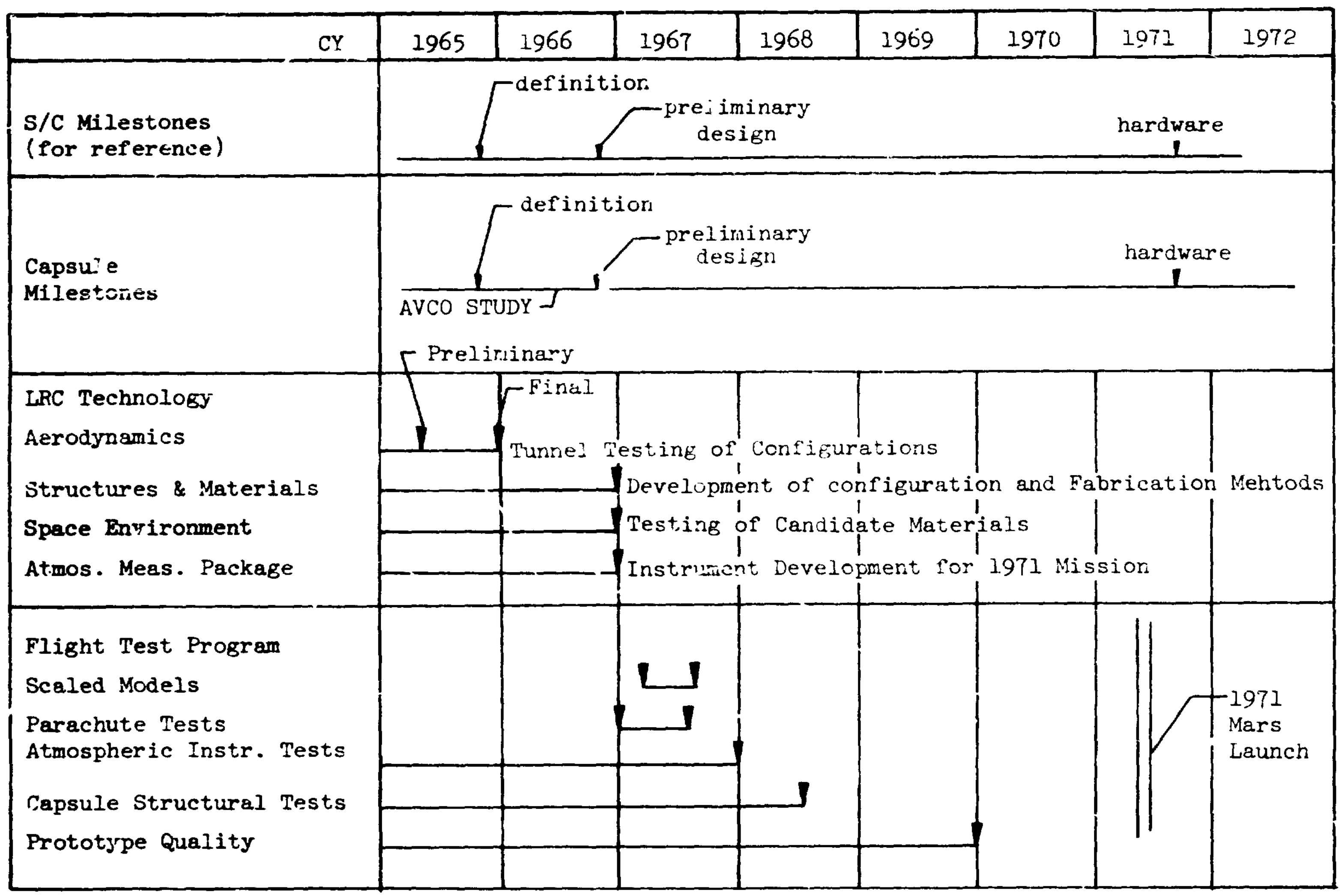


Figure III-5.--Voyager capsule technology program.

Voyager Planning at Headquarters, June 1965

At this time, NASA Headquarters had initiated project and definition of Voyager with plans to fund the start of hardware fabrication, test, and operations in 1966. The first operational mission was scheduled for 1971 with a Saturn 1B/Centaur launch vehicle. There was enthusiasm for Voyager within the scientific community; the Space Science Board of the National Academy of Sciences recommended that unmanned exploration of Mars and the search for extra-terrestial life be the primary objective of post-Apollo space program. There was clamor among biologists for ambitious missions including the landing of a large Automated Biological Laboratory (ABL); a minority viewpoint was for a more gradual, evolutionary approach starting with small, simple payloads. Donald Hearth, OSSA Voyager Program Manager, stated that Voyager "extends a major challenge and great opportunity to the scientific community and the aerospace industry. Neither the technical difficulties nor the potential rewards of the program are underestimated." [5]

For all intents and purposes, Voyager appeared to be an established program on firm ground with support from NASA and the scientific community.

5 Donald P. Hearth, "Voyager", Astronautics and Aeronautics, May 1965.

Langley's Response to Voyager Impetus

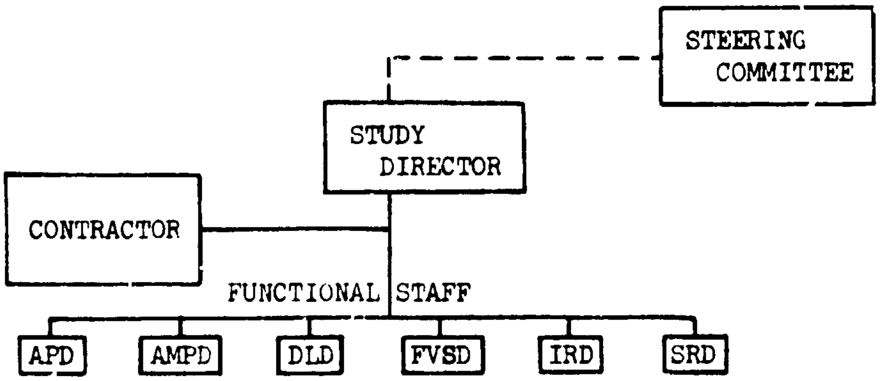
Because of the aforementioned events (Voyager's importance and Langley's Probe/Lander input), Langley administration recognized the need to organize its efforts in a manner compatible with the overall requirements of NASA. Its first step was the creation of a Planetary Mission Technology Steering Committee (PMTSC) reporting to the Director and chaired by Dr. Roberts. The membership consisted of eight senior Center engineers in the various divisions and included the basic core of personnel who worked the earlier Mars missions studies; I was appointed Secretary for the committee. Through this mechanism (both formal meeting minutes and discussions with the chairman), the Director was kept informed of all developments regarding Langley/ Voyager interactions and could participate as he saw fit. Two of the specified functions of the committee were to (1) guide and review the progress of contract studies and (2) evaluate results of studies and recommend future actions. (The memorandum establishing the PMSTC and its functions is included as Appendix III-B.) Through this mechanism of a PMTSC, the Langley management could get the Langley staff involved to a degree while still not perturbing the research line organizations or creating a project office to centralize the work.

With the award of the Probe/Lander contract to AVCO, Wilmington, Massachusetts, the stage was set for the acceleration of Langley's efforts to include directing of Probe/Lander work and coordinating

Voyager participation with JPL and Headquarters. The PMTSC addressed itself to the problem and undertook three major responsibilities at the behest of Mr. Charles Donlan, Associate Director, who met with the committee and gave it broad operating guidelines. Mr. Donlan stated that "the Voyager Program is moving fast and LRC should participate because it is primarily an exercise in reentry technology. The present AVCO study is being used as a focal point--for preliminary definition."[6] He asked the PMTSC to (1) guide AVCO's study, (2) work up an Langley research program to support Voyager, and (3) prepare a draft of working agreement with JPL to define mutual responsibilities.

The PMTSC set up the organization shown on Figure III-6 to guide the study; as indicated therein, I was responsible for system integration, mechanical design, environmental control, qualification program, and mission analysis. Subcommittees in the various research disciplines were appointed to outline and cost research programs necessary to support Voyager. Thirdly, a draft of a "Recommended LRC Position in the Voyager Program" was prepared for the Director for his use in negotiations with JPL. A copy of the draft is included as Appendix III-C and is based on LRC's position being one of "strong technical support in the area of entry technology." In essence, it committed LRC to carry out the necessary aerodynamic wind tunnel testing, entry vehicle structural research, and plan and conduct a supporting flight test program in the Earth's atmosphere--total Voyager mainline hardware was "assumed" to be the responsibility of JPL.

[6] Minutes of the fourth meeting of Planetary Missions Technology Steering Committee, August 9, 1965.



Study Director

Leonard Roberts, DLD	Technical direction of Study Technical direction of Functional Staff

Functional Staff

1. R. A. Jones, APD	Aerodynamic Configuration Aerodynamic Heating
2. E. M. Sullivan, LMPD	Propulsion Decelerators Flight Test Program
3. P. J. Bobbitt, DLD	Entry Dynamics Entry Loads
4. J. F. McNulty, FVSD	System Integration Mechanical Design Environmental Control Qualification Program Mission Analysis
5. S. T. Peterson, IRD	Communication System Instrumentation Tracking Sterilization
6. L. D. Guy, SRD	Structural Analysis Thermal protection Impact Structure Structural Configuration

Figure III-6.– Organization of management and direction of LRC Mars probe/lander study.

Direction of AVCO's Study

As mentioned previously, the companies bidding on the Probe/Lander proposal had strengths in various areas and the competition was stiff. AVCO's strength was its analytical capability in mission analysis, parametric studies, structural analysis, etc.; compared to some of its competitors, it was weaker in the engineering hardware design and fabrication--in other words, the company was more research than engineering oriented. The company, no doubt, was selected because it was felt that analytical capability was the driving function in our study; i.e., the need to optimize entry shell weight, tradeoff trajectories, etc.

A mutually acceptable working arrangement was quickly worked out between Langley and AVCO. This arrangement consisted of close interaction; the work of the contractor was followed in detail so that the effort was a joint one rather than having the contractor work for a period of months, report his findings to a large review group, and obtain feedback redirection as befits and is normal for some studies. The PMTSC stayed out of the direct loop (except as Dr. Roberts reported progress at meetings) and the running of the contract was left to Dr. Roberts and his functional staff. AVCO had a similar function staff and it was the responsibility of the Langley staff member to monitor the work in his area. This was an extremely demanding period for me because a large amount of work in mission analysis was required to furnish input to the other disciplines. This interaction, in addition to being responsible for the actual design integration of subsystems required me to see the whole picture and know the interfaces. Normal working relationship between me and Mr. Ellis, AVCO's systems engineer, consisted of many phone calls, mailed data exchange, and bi-weekly meetings either at AVCO or at Langley when we analyzed and agreed as to where we were and where we were going. The LRC-AVCO relationships were excellent throughout owing to mutual respect and the mix of capabilities was advantageous for obtaining sound analytical and engineering objectives.

On the technical side, AVCO's parametric studies of the three candidate shapes (tension shell, cone, and Apollo) indicated that from weight-performance considerations they were near equal while from a packaging point of view the cone was superior. The tension shell's superiority in high drag and low weight proved illusionary--tunnel tests of 120° blunt cones indicated that they performed nearly equal in drag to the tension shell and the tension shell's estimated weight increased with buckling and bending problems. Thus, one of Langley's main selling points--its unique knowledge of low weight tension shell technology--was quietly discarded without notice. The PMTSC agreed to concentrate the study on the cone shape for the reentry vehicle because of its packaging capability and because its state-of-the-art was in keeping with schedule requirements.

Research Program To Support Voyager

The second action item of the PMTSC was to define a research program. It should be noted that this item is of tremendous importance to a Center like Langley. It furnishes the researcher with funds and objectives to follow his quest for knowledge in his specialty. One reason why Langley participates in mission projects is because of the technology (facilities included) fallout; in general, Langley desires a mix between missions and research, and strives to assure that projects do not overwhelm the research in importance. Projects are status symbols, good public relations, a source of funding, and many engineers prefer the type work. The defining of a research program, thus, goes to the heart of Langley.

The following program elements were defined and presented to PMTSC for approval and forwarding to JPL and Headquarters:

1. Wind Tunnel Test Program $330,000
2. Capsule-Heat Shield Development. 400,000
3. Parachute Development. 865,000

The parachute development program warrants a few words at this point. It was anticipated from our mission analysis studies that the mission would require a parachute approximately 84 feet in diameter to be deployed at about Mach 1.2. Deployments in this transonic range were beyond the state-of-the-art. Langley proposed a series of seven rocket flight deployments of sub-scale parachutes to select an optimum configuration, and a series of five full-size parachute deployments in the wake of a blunt cone to prove out the system and to study wake effects. The full-size tests would consist of a balloon launch to approximately 100,000 feet, cone release, firing rockets for additional altitude (120,000 feet to simulate Mars atmospheric density) and for Mach number requirements, and deployment of the parachute. Figure III-7 illustrates the concept and sequence of events.

An important decision was required with regard to this proposed parachute program. There was considerable controversy within the PMTSC as to whether this balloon launch, rocket assist concept was feasible technically. The alternative was for a standard rocket launch which would require a Little Joe II launch vehicle. The launch cost of a Little Joe II was estimated at $2,000,000 while the balloon launch was estimated to $100,000. Even the Assistant Director at LRC, Mr. Donlan, had grave doubts about the balloon concept. However, the cognizant Langley engineer, Mr. John McFall of AMPD, stood firm and carried the day--for five launches, the decision involved a total of about $10,000,000. The PMTSC and Langley management approved and proposed the balloon launch method and then stood its ground against JPL's questioning.

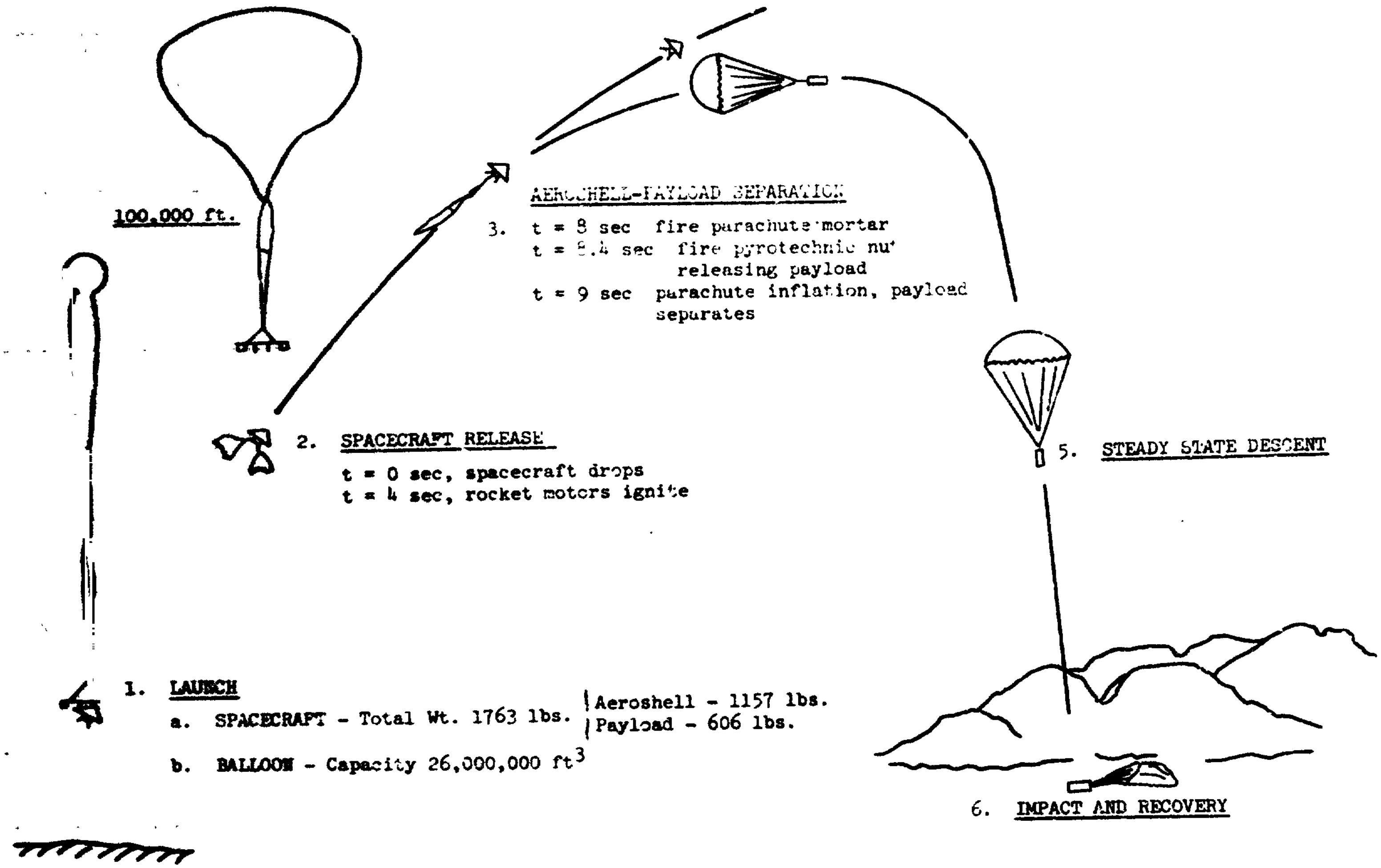


Figure III-7.--Sequence of events, balloon launch.

Working Out Arrangements With JPL

In working out arrangements with JPL, Langley had to consider JPL's unique position in the NASA organization. Formally, JPL is a research laboratory under the cognizance of California Institute of Technology. However, nearly all its contracts are performed for NASA; JPL is, in reality, an arm of NASA-OSSA. Although a contractor, JPL acts and considered to be more like a NASA Center. Pre-1964, JPL provided the initiative (through OSSA) for early unmanned lunar and planetary programs. Its early planetary ideas developed into successful Mariner missions to Venus in 1962 and to Mars in 1964. Its mode of operation is primarily to build in-house with the use of subcontractors rather than the utilization of prime contractor such as North American on Apollo or Boeing on Lunar Orbiter. JPL had, at this time, a near monopoly on NASA unmanned missions to the planets and, thus, was the only "Center" with proven capability. There were, however, some previously mentioned difficulties brewing in the NASA-JPL relationship; (1) NASA was under pressure from industry to contract work rather than performing the work in-house, (2) Congressional inquiries into problems associated with JPL's Ranger and Surveyor programs revealed that neither NASA nor Congress was satisfied with NASA's direct control over JPL and, thus, the programs, (3) the desire by OSSA to obtain overall NASA Center participation in unmanned missions and, thus, enlarge NASA's options and capabilities.

Returning to Voyager, it should be noted that Voyager was, at this time, only slightly larger and more complex than JPL's previous

Mariner missions. The important differences were: (1) use of Saturn 1B-Centaur instead of Atlas-Centaur as launch vehicle, (2) an orbiting spacecraft instead of flyby, and (3) a release of an entry capsule carrying a "hard" (impact attenuated ball) instrumented lander on spacecraft approach (see Figure III-8). The estimated cost of the 1971 Voyager mission was of the order of $400,000,000. JPL was officially assigned Voyager Project responsibility on July 14, 1965. The letter from Headquarters stated that "LRC would provide support in the area of entry technology"--this was precisely the role which the PMTSC had recommended to the Director in its aforementioned draft.

With that charter, JPL visited or, perhaps, descended on Langley to work out the details of how "LRC would provide support." JPL was represented by a staff of 12 high-level Voyager office personnel with the aim in mind of getting maximum "project" help from Langley. The personnel were obviously well qualified and well prepared for the meeting. Langley was represented by members of the PMTSC with Dr. Roberts as principal spokesman. It was quickly apparent that JPL and Langley had some diverse views as to Langley's participative role--and I don't believe that this came as a surprise to anyone since the dividing of the responsibility and funding is a serious and important matter. JPL was interested in getting Langley out of the "systems" area which JPL wanted to control and into narrow specific technology tasks (i.e., type of heat shield material) which would support its missions concept. Langley, on the other hand, took the

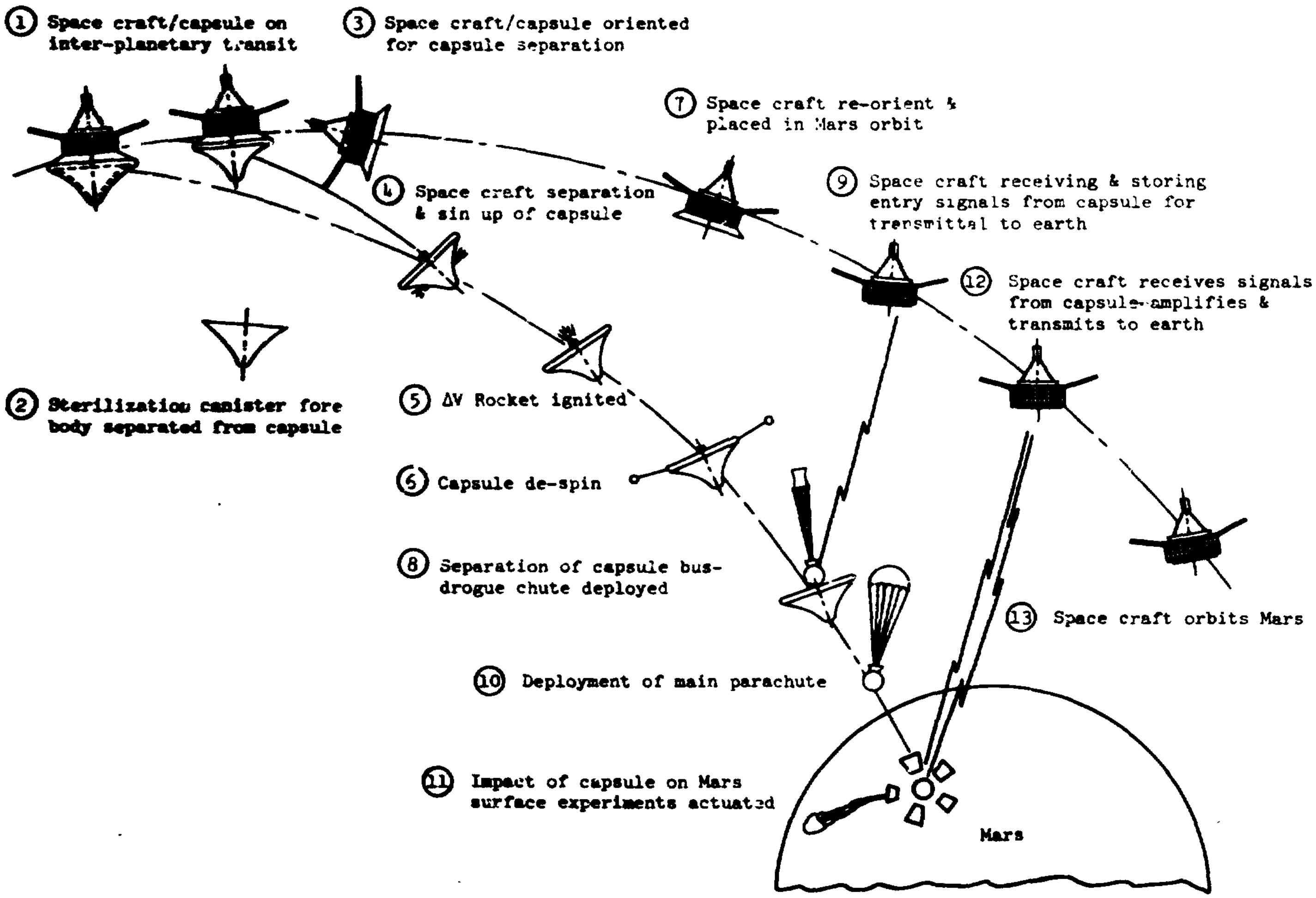


Figure III-8.- Mars probe lander sequence of events.

broad view that "support in the area of entry technology" included entry concepts and design methodology. As a member of the JPL group stated to me in words to the effect that "JPL knew LRC was interested in Mars missions and was soliciting contract assistance. We expected LRC to contract for a research oriented study and were very surprised when we read the work statement and found it systems oriented--we knew then that JPL had competition in unmanned planetary missions." JPL asked specifically that Langley's contract "systems effort be deemphasized to avoid preferential treatment to AVCO in subsequent Voyager capsule procurement."[7] The meeting was adjourned after a free discussion but few agreements; it was obvious that the feeling out period had started and much work or Headquarters direction would be required to define mutual roles.

[7] JPL letter June 29, 1965, to Dr. Roberts from D. P. Burcham, Voyager Project Manager.

Voyager Becomes a Multi-Billion Dollar Program

August and September were months of working the AVCO contract heavily and continuing the preliminary skirmishes with JPL. Then in October came a surprise Headquarters decision which changed the entire picture. Headquarters decreed that the launch vehicle for Voyager would be the Saturn V; this changed the program from a Mariner type to a mini-Apollo. This, together with the almost simultaneous data from the fly-by Mariner that the atmosphere of Mars was now estimated to much less dense than previously (5-10 millibars rather than previously defined 10-40 millibars), required the design of entirely much larger mission with much more difficult landing parameters. Neither JPL nor Langley had studied the Saturn V mission and recommended it to Headquarters. Headquarters' decision was unilateral and based on scant technical input insofar as the Centers were aware. The new guidelines dictated by Washington Headquarters were:

a. Saturn 5 vehicle

b. Only one vehicle for each opportunity

c. No "69" test flights

d. Two identical spacecraft and capsules on each launch vehicle for "71" and "73".

e. Delivery mode "out-of-orbit"

f. Type one trajectories only

g. Shroud 260" diameter maximum

h. Spacecraft science payload 250# maximum

i. No spacecraft science mission required in "71"

j. Objective of "71" mission

(1) Obtain atmosphere data

(2) Obtain surface winds

(3) Obtain surfaces topography

(4) Obtain surface hardness

k. Land a 200# automated biology laboratory type payload in 1977

l. Spacecraft mission to deliver capsule into orbit

m. Design to a 5 to 10 MB pressure

n. Spacecraft designed for 0-800# capsule weight for 1971 and 1973

o. Capsule entry weight to be 1000-3000# for 1975 and 1977

p. 1971 capsule entry mode to be ballistic with a minimum M/C_DA of .25.

q. Subsonic chute only for "71"

r. 1971 test capsule to be done on an in-house basis (like Ranger and Mariner) system contractor planned for no earlier than 1973.

The important points to note are:

a. Change in launch vehicle payload capability from about 10,000# to 100,000#

b. 1971 test capsule (lander) to be a relatively simple package and to landed by "subsonic chute only."

c. No 1969 test flights but a gradual growth in mission complexities every two years - 1971 through 1977.

The management responsibility was still in the hands of JPL but it was obvious that a project as large as Voyager was now defined would require the resources of many Centers--Marshall would, of course, supply the Saturn V--and, thus, the final project management would have to be redefined at a later date. Meanwhile JPL, with Langley's help, was to redesign the mission and make recommendations to Headquarters. Langley issued a change order to its AVCO contract to redirect its work on the Probe/Lander to be consistent with the new guidelines.

Headquarters' Rationale for Saturn V Decision

The two reasons publicly stated for making the launch vehicle switch were:

1. A funds squeeze existed owing to the demands of the Vietnam War and the Apollo priority. The switch to the developed Saturn V would free up funds needed to develop the Saturn 1B/Centaur combination and transfer launch vehicle costs until later fiscal years when Vietnam and Apollo wouldn't be so demanding.

2. The lower atmospheric density estimated at Mars could mean that a more complex and weightier landing system would be required which the Saturn 1B/Centaur coundn't handle--and the next bigger launch vehicle in the NASA stable was the Saturn V.

Other underlying reasons for the switch mentioned by various NASA officials which added impetus to the decision were:

1. Marshall was gearing up to produce six Saturn V's per year for Apollo and it was natural that NASA would need a market for the Saturn V's after Apollo. The decision was, thus, influenced by a desire to maintain a national space capability and to provide continuing work for the Marshall Center.

2. Scientists in OSSA and in the academia wanted the capability of landing large scientific laboratories on Mars. The scientific community at this time was almost totally in concurrence with the decision because, as it said by Voyager participant, "--- every biologist in the country could get his experiment aboard."

Reactions at Langley and JPL

The reactions by Langley management, as expressed to the PMSTC, was one of using Voyager as a focus of research programs. Mr. Donlan, Langley's deputy director, stated he had met with Dr. Adams, head of OART in Washington, and that "OART's mission is to develop technology required to support Voyager since Voyager is the only approved program after Apollo".[8] Mr. Dave Stone, who had recently served as program manager of the highly successful FIRE project, was appointed Langley's technology manager and was instructed to survey the Center, define technology programs, and work with JPL to obtain approval and funding. Our core of top level technical people working on the Mars mission were somewhat elated at the turn of events because we felt, in general, the larger and more important the mission, the more the opportunity to contribute and to advance in our professions.

Discussion with our project counterparts at JPL revealed that the reaction at JPL was very much different and reflected concern. JPL was concerned about both technical and management problems. In the technical area where they had had extensive interplanetary mission experience whereas Langley was a novice, JPL felt that the technology jump from Mariners to Saturn V missions was too great. Beyond this, they had examined the feasibility of larger scientific missions in-house and, despite the clamor of scientists for large experiments,

[8] Minutes of the ninth meeting of the Planetary Missions Technology Steering Committee, November 8, 1965.

had concluded that the scientific instruments were not available within reasonable cost or schedule limitations. In the management area, they forsaw that the mission was too big for JPL to manage alone and feared that a management structure would become big and unwieldy with JPL caught in the middle between several NASA Centers and Headquarters.

The Other Shoe Drops--Cancellation of '71 Voyager

Two months after the switch to the Saturn V, OSSA Headquarters cancelled the '71 mission and rescheduled the first Voyager mission to 1973. Lack of funds was the reason. The BOB (Bureau of Budget) cut NASA's overall request for funds from $5.6 billion to $5.1 billion. With Apollo, Surveyor, and Lunar Orbiter in hardware procurement, the new start programs bore the brunt of the cut. As a result, Voyager was approved for only $10 million out of the requested $150 million. Donald Hearth the Voyager program manager stated that "--- work on the spacecraft portion of the system will go on a low back burner basis for the next year and a half to two years before we pick it up again."[9] In the interim, the plan was for JPL and Langley to continue work on lander definition.

Thus, the year ended on a confused basis with an entirely new problem to start work on in the new year. The situation in brief was:

1. Langley's technical staff was broadening its technology base and increasing its expertise. The FVSD team was becoming an appreciable force within the staff.
2. Langley administration was taking its first steps to support a Mars program but had not made any organizational changes nor indicated a desire for any hardware commitment.
3. Headquarters had a "tiger by the tail" with the Saturn V Voyager program and no clear path was evident.

[9] Aviation Week and Space Technology, January 3, 1966

Synopsis

A synopsis of the second year's effort could be tabulated as indicated below:

1. Obtaining in-house capability in Mars mission studies by the formulation of Langley working teams in various technology areas.

2. Probe/Lander contract evaluation and award to AVCO.

3. Probe/Lander contract to serve as basis for Voyager entry capsule.

4. Langley becomes a semi-participant in the Voyager program with Headquarters and JPL.

5. Langley creates a Planetary Missions Technology Steering Committee with Dr. Roberts as chairman.

6. JPL awarded managership of Voyager.

7. Voyager to utilize cone configuration for entry vehicle rather than tension shell.

8. Langley proposes a parachute development program for Mars application--transonic deployment at low dynamic pressure.

9. Headquarters decrees Saturn V as Voyager launch vehicle.

10. Voyager 1971 mission cancelled.

CHAPTER IV

VOYAGER DEFINITION - 1966

Summary

On the technical level at Langley, the year was primarily spent on trying to understand the Saturn V Voyager program -- analyzing the technical problems, evaluating the trade-offs, and defining a rational technical approach. Other technical items of note which took place during the year included the completion of the AVCO contract and the initiation of research and development tests for a Mars parachute system.

At Headquarters the effort consisted of developing guidelines for the various systems (Spacecraft, Lander, Launch Vehicle, etc.) in order to furnish the various Centers and JPL some definition of their responsibilities and to provide charter interfaces. In addition, much effort was expended in attempting to determine a management organization to weld together the efforts of the many participating organizations scattered from coast to coast. Involved in this problem was the prime importance of defining Center assignments (management, spacecraft, lander, etc.) so as to obtain the best mix of capabilities and insure a "workable" management system.

Voyager-AVCO Interface

At the start of the year AVCO was engaged in revising its work to date to make it directly applicable to the 1973 Voyager mission--i.e., extrapolating the data they had worked up for the Saturn 1B/Centaur mission to the Saturn V mission. Since AVCO's work on the entry vehicle was to be used for program preliminary definition, it was essential that the guidelines AVCO was using reflected the mission as NASA Headquarters visualized it. As delineated in the previous chapter, Voyager was now defined as a continuous program evolving in complexity through four launch years (every other calendar year) from a first probe mission to a final landed "automated biological laboratory" mission. JPL's management was convinced that prime importance had to be given to definition of the first mission for costing and scheduling reasons--other items such as logical growth, future planning, and subsystem commonality were placed on the back burner until the first mission was defined.[1] In this regard, Edward M. Sullivan, LRC Liaison Coordinator, reports in a trip memorandum as follows:

> "Mr. Schurmeier [JPL Voyager Program Manager] expressed the thought they would like to get the first mission settled and defined.

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[1]Author's note: This JPL "obsession" with the current problem continually reflects itself in technical and management dealings with Headquarters and other Centers as the careful reader will note.

Then they should proceed ... and see what technology development schedule makes sense for '73 and '75 to support the '77 mission.

"I asked about a landed payload in the first mission. They were adamant in saying they did want to consider it. Mr. Schimandle offered the comment that the simplest landed payload, which did nothing but transmit a signal to indicate impact survival, would so affect the cost and engineering complexity as to jeopardize the entire capsule mission."

In accordance with the above, Langley had AVCO concentrate on a Probe mission. As AVCO stated in the final oral report "the purpose of this study is the design of a non-survivable probe to perform engineering experiments for the determination of Mars atmospheric and terrain properties. The mission is primarily engineering in nature in order to obtain Mars properties for the definition and confirmation of assumptions that are necessary for the design of future large soft-landers for advanced missions."[2] The sequence of events is illustrated in figures IV-1 and IV-2 and a summary of significant data from the final report is included in Appendix IV-A. A synopsis of the final conclusions is as follows:

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[2] Mars Probe, Final Presentation, Contract NAS1-5224, March 1, 1966

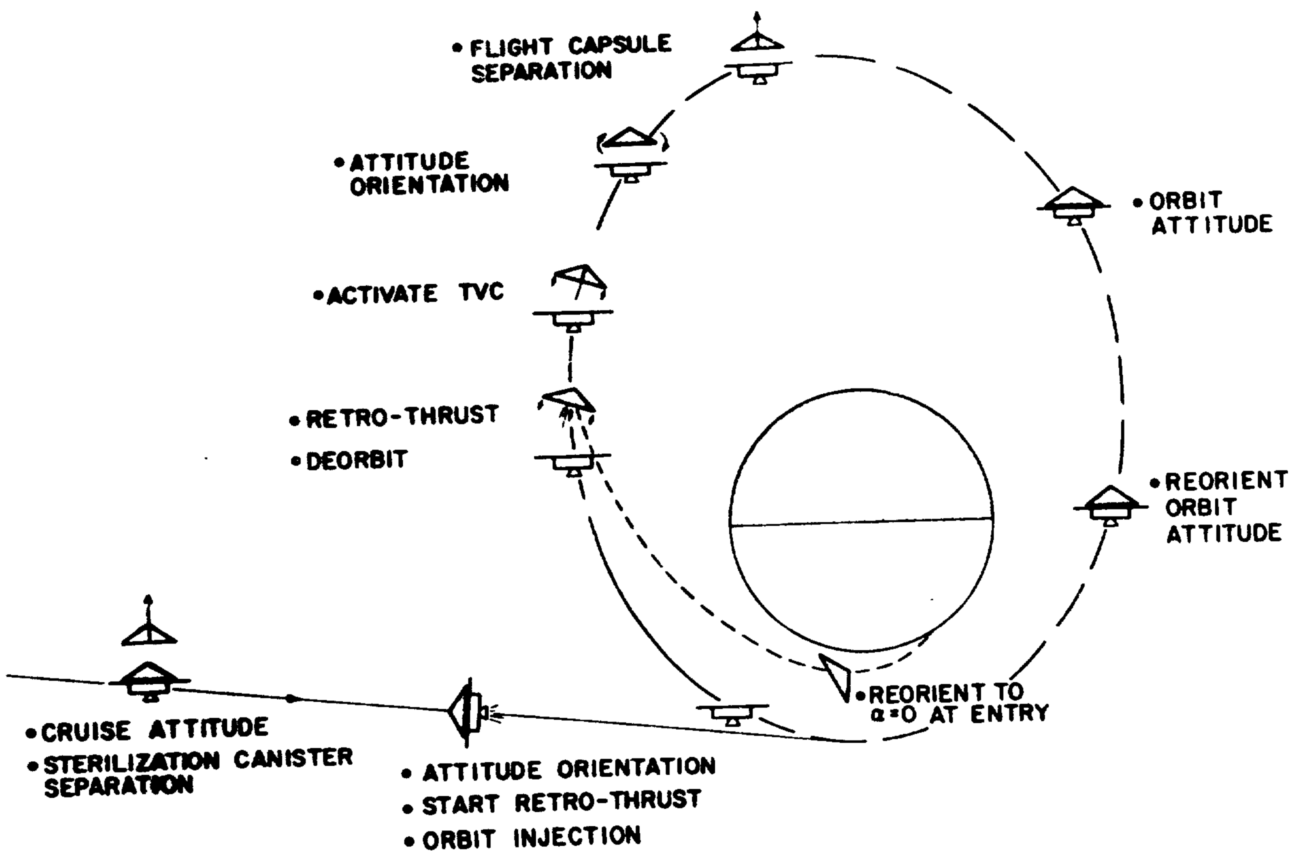


Figure IV-1.- Deorbit sequence.

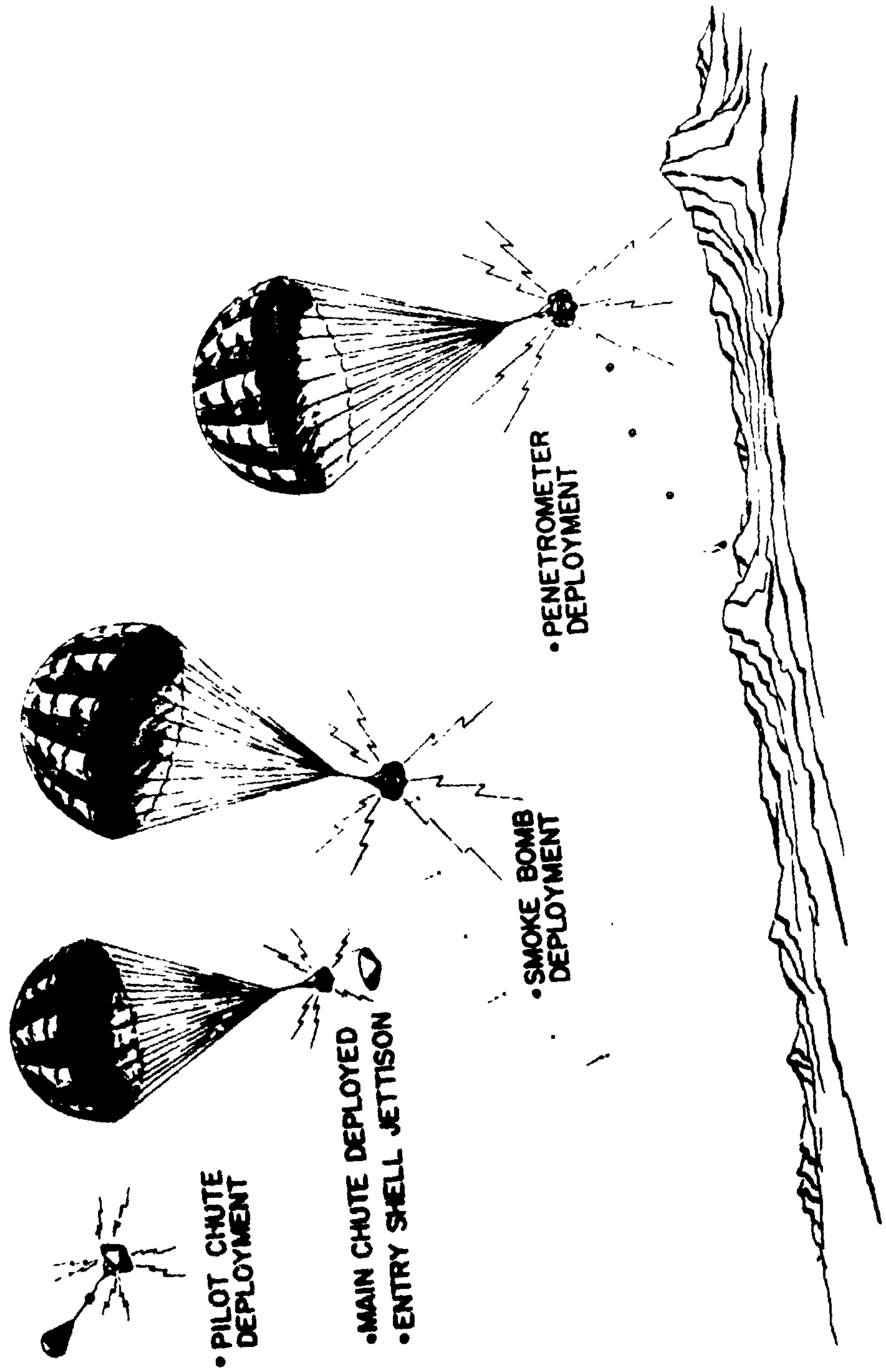


Figure IV-2.-Terminal descent sequence.

Experiments

- 3 camera TV
- 4 penetrometers to measure hardness
- atmospheric composition instruments

Entry Capsule

- 15 foot diameter cone
- weight = 2040 lbs.
- $M/C_DA = .22$

Only Technology Problem Area

- Development of parachute for low dynamic pressure deployment

AVCO's final report was well received; it was felt that the company did an exceptional job under trying circumstances involving guideline changes of the launch vehicle, mission magnitude and objectives. The realms of parametric data produced together with actual design weights for the baseline mission furnished a wealth of data to guide further studies and trade-offs for future missions. AVCO's study of the Saturn V Voyager mode was restrained to study of the capsule being released from the spacecraft while in orbit about Mars rather than being released on the spacecraft's approach to Mars and making a direct entry. The reasoning will be discussed in more detail in the next section because the controversy between direct and out-of-orbit entry is of prime importance in mission complexity, cost, and success; suffice to say at this time that with the guidelines of Saturn V with its large energy and with an orbiter specified, mission success requirements became the forcing function and the out-of-orbit mode became an obvious choice.[3] It should be recalled at this time that the contractor was required to study the out-of-orbit delivery mode by the original work statement (more or less as an afterthought to be certain we included the total problem). As a result of this foresight, the changes in AVCO's contract resulted in only a very small change of contract price in lieu of a complete rework.

[3]Author's note: We shall see this controversy arise time and again throughout the history.

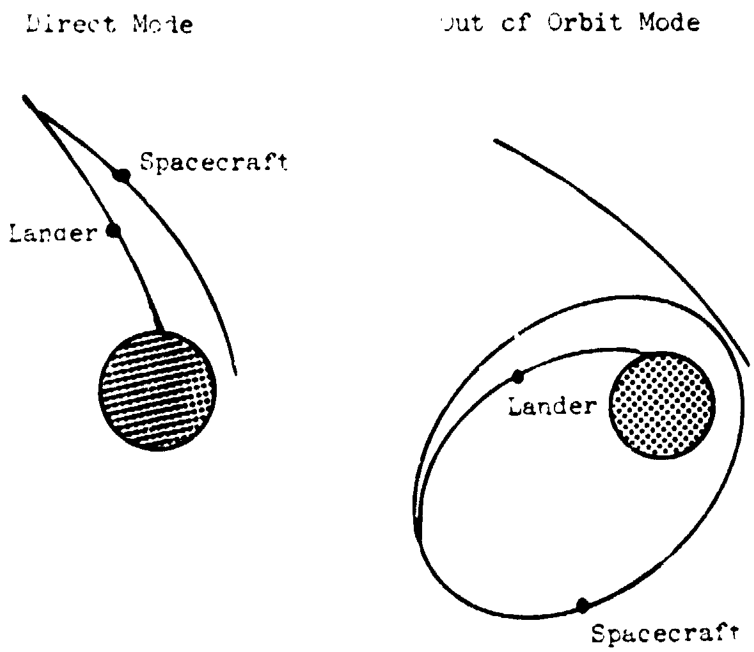
Out of Orbit/Direct Entry Trades

The alternate planetary approach modes are illustrated in figure IV-3 together with their appropriate entry velocities into the Martian atmosphere. The entry velocity for the out-of-orbit mode is considerably less than for the direct mode because the spacecraft must be slowed (by use of retro-propulsion) to effect its capture into orbit. This velocity decrement is reflected into a lower entry velocity.

Figure IV-4 summarizes the trades between the entry modes in terms of the parameters involved. Targeting the entry vehicle for entry into the Martian atmosphere at a specific point and direction is the crux of most entry problems. Figure IV-5 represents the general problem. As one can see, a γ_E of 0° to skip γ_E causes the vehicle to miss the planet entirely. The nominal (aim) γ_E is determined by adding the 3σ error tolerance to the skip angle. Design must account for entry at nominal $\gamma_E \pm 3\sigma$ tolerance angle. The reasons for staying as close to the skip angle as possible are:

1. longer path ("stroke") in the atmosphere thus reducing structural and heating loads.
2. more atmospheric breaking thus less energy to be removed by landing system.
3. lower velocities at parachute deployment altitude.

Examining the implications for the direct entry mode, we find:



Entry Conditions

	Direct Mode	Out of Orbit Mode
V_E	24,000 ft/sec	16,000 ft/sec

Figure IV-3.--Planetary approach modes.

Parameter	Out-of-Orbit	Direct
1. Entry velocity	Lower	Higher
2. Targeting accuracy	Higher	Lower
3. Entry angle	Lower	Higher
4. Loads and heating	Lower	Higher
Propulsion	Higher	Lower
Requires orbiter S/C	Yes	No
5. Landing footprint	Smaller	Bigger
Cost	Higher	Lower
6. Aerodynamic braking	Higher	Lower

Figure IV-4.—Entry parameters.

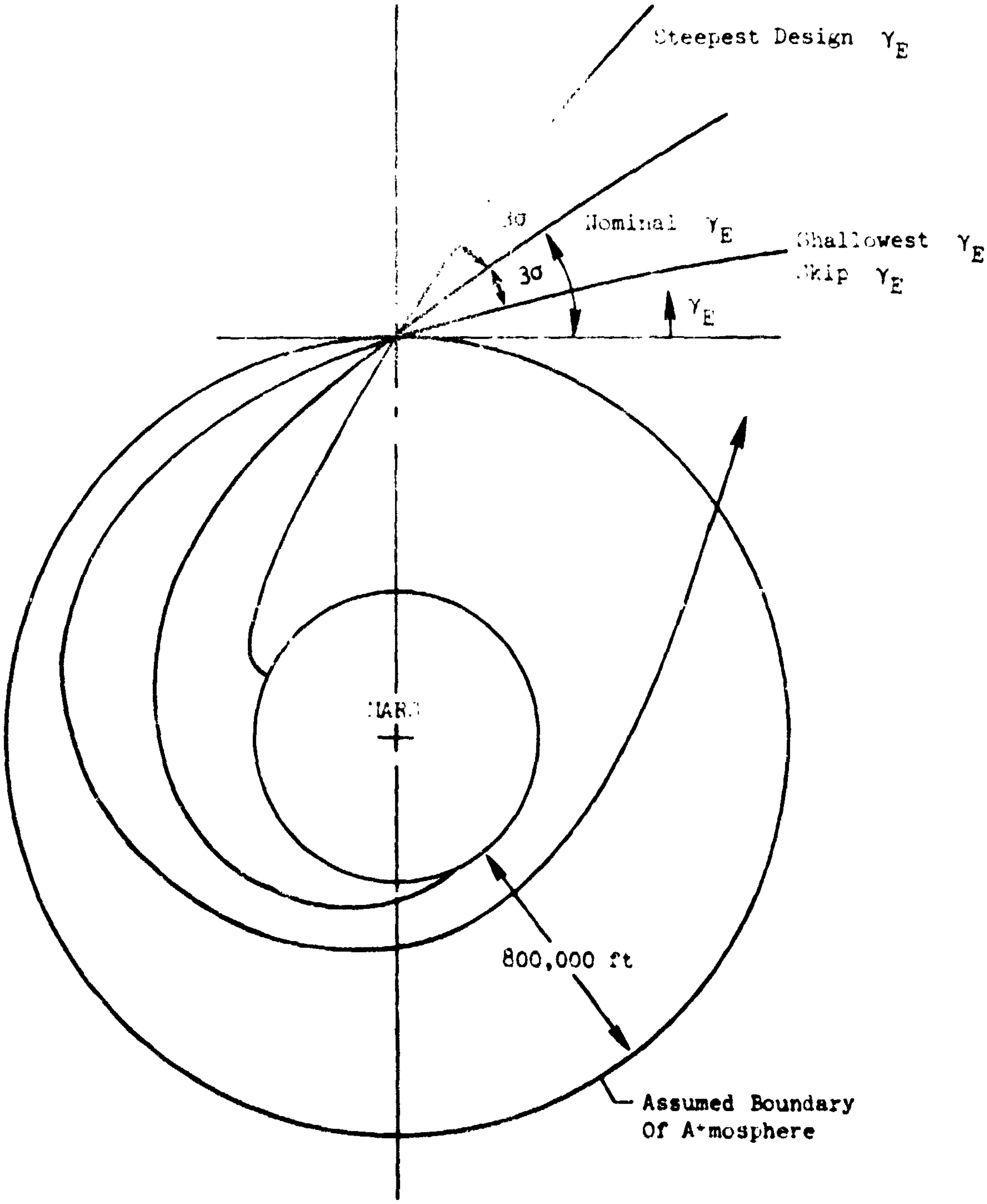


Figure IV-5.--Entry conditions.

1. skip γ_E is approximately 20° for V_E = 24,000'/sec.
2. 3σ error band could be only be estimated since the mission had never been done before--let alone enough times to get statistical data. The problem is complicated since it is not known exactly where Mars is. Based on an examination of the first Mariner data (Mariner missed its target on a flyby by at least a thousand miles which would result in a mission failure for an entry mission), it was felt by JPL and AVCO that enough was learned so that it should now be possible to design a mission with a 3σ value of 8°. This would result in a nominal entry angle of 28° with a maximum design entry angle of 36°.

For out-of-orbit mode, we find:

1. skip γ_E is approximately 13° for V_E = 16,000'sec.
2. the 3σ error band is determinant since it is within the state-of-the-art to assure spacecraft capture into some orbit; once the spacecraft has been captured, it is readily possibly (by checking the orbit through telemetry signals) to tune the orbit until the design orbit is achieved. Knowing the exact relationship between Mars and the orbit, the entry vehicle can be released to enter the atmosphere within a 2° 3σ value. This would result in a nominal entry angle of 15° with a maximum design angle of 17°.

The following parameters---loads and heating, landing footprint, and aerodynamic braking---indicated on figure IV-4 are related to this entry angle accuracy. As mentioned previously, the lower the entry angle, the lower the loads and greater the energy consumed in aerodynamic braking. For example a straight-in entry ($\gamma_E = 90^\circ$) would result in the entry vehicle being at a high supersonic speed when it closes in on the Mars surface---thus, making a landing extremely difficult if not impossible. Scientists prefer small landing footprints as they like to pinpoint the locations for their experiments. Thus, out-of-orbit entry mode is preferable to scientists because of the small entry dispersion angle and to the engineer for loads, heating, and velocity conditions. The parameter most favoring the direct entry approach is cost. Assuming that it is possible to target a vehicle from Earth to hit the planet, a high energy impact mission could be carried out at less cost because there would be no need for an orbiting spacecraft nor for the additional propulsion weight necessary to effect orbit. Thus, a smaller launch vehicle could be utilized and costs could be reduced all along the line.

New Headquarters Guideline--Lander in 1973

On March 9, 1966 a meeting of the Voyager Steering Committee was held attended by representatives of Langley, JPL, and Washington Headquarters, OSSA. OSSA stated that since 1971 mission had been cancelled that sufficient time was available to pursue a landing mission in 1973 to conduct surface experiments and, thus, to skip the Probe mission altogether--the mission that AVCO had just completed studying per OSSA's instructions. Again, Headquarters edicted a major mission change without technical input from the Centers and the blanket claim there is "sufficient time" is not substantiated. Thus, JPL and Langley were instructed to carry out a scientific lander mission without benefit of the prior Engineering mission which was planned to obtain design data for the lander mission.

JPL expressed the opinions "that the resources and time available do not comply with the guidelines--and that the OSSA mission proposed for 1973 is too ambitious."[4] Langley stated that "the guidelines were premature"[5] and should be subjected to more study. In his memorandum of the meeting, Mr. Kilgore, Langley, noted that "JPL, in their role as a contractor, reacts to OSSA guidelines as somewhat hard and fast requirements, which are subject to a minimum of question and changes. LRC could make a major contribution to the Voyager Program by studying and defining a series of missions for OSSA, which we feel would more logically focus on an end objective."[6]

[4,5,6] Memorandum to Associate Director from Chief, Flight Vehicles and Systems Division, March 14, 1966

In accordance with the above, Langley held a meeting of its PMTSC and decided that "LRC should pursue an in-house study aimed at evolving a logical Voyager sequence. A completion date of about September 1, 1966 was suggested so that the task results could influence the selection of the mission mode of the 1973 Voyager."[7] The study would use the parametric data developed under the AVCO contract as a base, Dr. Roberts would be program manager and I was assigned the project engineer responsibility. For the next several months, this was my prime responsibility--defining, delegating, directing and integrating tasks throughout the Center to define a rational Voyager mission sequence. This study was primarily carried out by the FVSD team under my direction with Research Division personnel used in a consultant capacity; of course, close contact was maintained with Dr. Roberts and Mr. Kilgore. Thus, while JPL was attempting to define the 1973 mission in terms of hardware, Langley was mainly involved in evaluating the broader problem in addition to pursuing the parachute development program which AVCO had identified as the major problem area. It should be noted that Headquarters did not take issuance with Langley proceeding with an in-house study to define a sequence of missions; further, Headquarters stated that it welcomed the assistance of Langley in this regard. Thus, there remained a doubt of how "hard" the lander guideline was.

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[7]Minutes of the eleventh meeting of the Planetary Missions Technology Steering Committee, April 15, 1966

Engineering Study of Fntry System

This section will be devoted to the methodology developed for the engineering systems synthesis performed by the technical staff to carry out the directions of the PMTSC.

As can be recalled, the problem was one of defining of the basic parameters (weights and diameters) of the Capsule Bus which would be compatible with OSSA science guidelines for Voyager missions 1971 through 1977. The terminology to be used is illustrated on figure IV-6 and is broken down into the following main elements:

1. Capsule Bus--this is the entire vehicle separated from the spacecraft in orbit including the subsystems needed for the deorbit maneuver and to protect the vehicle against contamination from microorganisms.

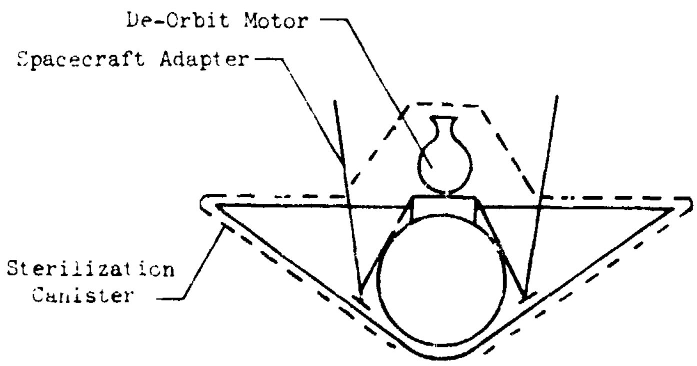
2. Entry Vehicle--this is the vehicle that enters the Martian atmosphere and takes the entry structural and heat loads--the capsule bus minus the deorbit motor, adapter, and sterilization canister.

3. Delivered System--this is the package delivered to the surface of Mars after separation from the heat shield. It includes the science package and supporting subsystems.

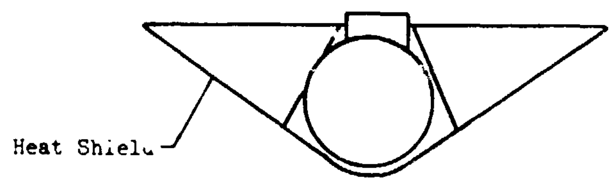
The block diagram illustrating the engineering systems synthesis performed is shown on figure IV-7. There are three basic inputs:

1. Entry vehicle parameters--the entry angle, entry velocity and drag coefficient are fixed constants; the ballistic coefficient and entry vehicle diameter are given parametrically through the range of

Allocated Capsule Bus Weight:



Entry Vehicle Weight:



Delivered System Weight:

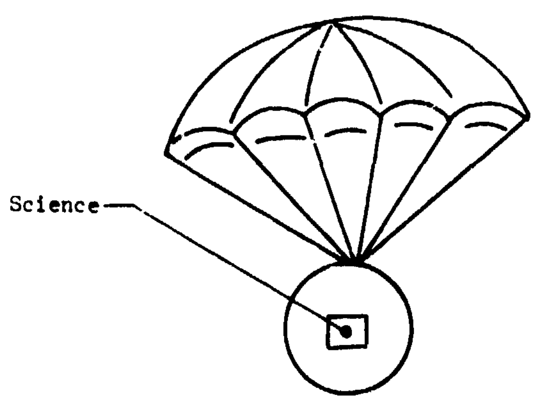


Figure IV-6.—Capsule bus terminology.

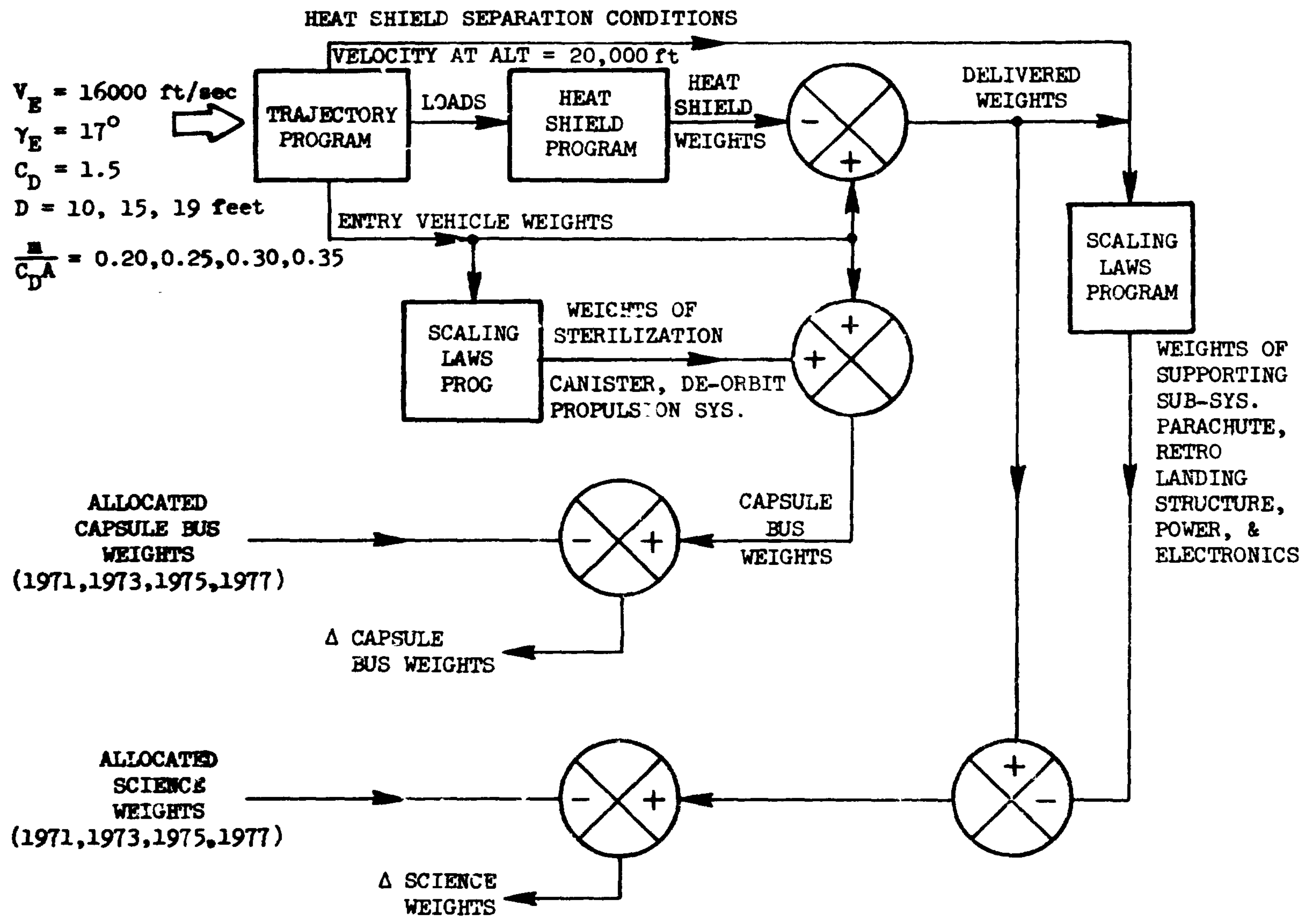


Figure IV-7.--Block diagram-weights synthesis.

interest to cover all weights and sizes.

2. The allocation of science weights for missions 1971 through 1977.

3. The allocation of bus capsule weights for missions 1971 through 1977.

Twelve cases (3 diameters with 4 ballistic coefficients) are run through the trajectory program which outputs the heat shield separation conditions for design of the parachute, the loads on the heat shield for its design, and the entry weight which is obtained by solving the m/C_dA for each parametric value of m/C_dA and diameter as follows:

Take $m/C_dA = 0.20$

$$A = \Pi D^2/4$$

$$A = 78 \text{ square feet (for } D = 10 \text{ feet)}$$

$$m = 0.20\ C_dA = 0.20\ (1.5)\ 78$$

$$= 23.6 \text{ slugs}$$

$$W_E = mg = 23.6 \times 32.2 = 760 \text{ pounds}$$

This is the minimum entry weight investigated; the maximum weight, corresponding $D = 19$ feet and $m/C_dA = 0.35$, is 4800 pounds.

The output from the trajectory program, thus, furnishes the basic input for calculating the weights of the other subsystems, i.e., the loads plus entry vehicle diameter are sufficient to define the heat shield weight, separation conditions plus delivered weight define the parachute, etc. From various scaling laws, the net weight available for science and total flight capsule weight are obtained for each of the twelve parametric vehicles studied. These values can be then compared to the weights allocated and a delta value noted. These data can then be examined to find the best fit for the various missions and, in addition, can be used to assess the weight penalties associated with standardizing various subsystems through a range of missions.

Exogenous Events Related to Voyager Program

During 1966, several events occurred outside the mainline of Voyager activity which greatly influenced the future flow of events in the development and management of the Mars lander program.

In March, the American Institute of Aeronautics and Astronautics (AIAA) sponsored a technical meeting in Baltimore with the title "Steppingstones to Mars." The meeting was chaired by Mr. Carlos de Moreas of the Martin Company. Papers were presented by industry and NASA centers--Dr. Roberts presented a paper which addressed the landing problem, identified the critical parameters, and discussed the trade-offs which would be necessary to define a mission mode. The meeting was well received by industry. In informal meetings, we (Roberts, Anderson, McNulty) were approached by Martin Company representatives who stated that they were initiating a large company funded effort and would make the results available to us for review and guidance. The informal arrangement worked to the mutual advantage of industry and Government; we obtained, in effect, additional technical data and the Martin Company received the necessary direction to obtain expertise in a technology new to them.

In June, JPL landed the first Surveyor on the moon. The chief technological achievement of interest to us was that the terminal retropropulsion soft landing technology was "in hand." The remaining mission elements were not compatible with Mars applications because of many differences:

1. the direct entry mode to the Moon could not be extended to a Mars application because the emphemeris of the Moon was well defined.
2. the fact that the moon has no atmosphere changed the entry problem completely. There was no need for a heat shield to protect the instrument package and there was no unknown aerodynamic braking to contend with. Thus, the propulsion could be defined with accuracy and all events timed precisely.
3. In summation, it was a "deterministic" mission.

The success of the soft landing terminal phase revised our thinking to consider how to utilize the technique in conjunction with a heat shield and a parachute.

In August, Langley successfully orbited a spacecraft (Lunar Orbiter I) around the moon to carry out extensive TV mapping in preparation for the selection of Apollo landing sites. While the mission was also deterministic like Surveyor, three items of interest were noted:

1. Langley demonstrated capability in unmanned planetary flights -- no longer did JPL have a monopoly in this area.
2. the program was a "model" program in that it utilized a small Langley staff in conjunction with a major contractor (Boeing) -- pleasing NASA Headquarters, Congress, and industry.
3. Schedule and costing difficulties were "minimal" compared with Surveyor--Langley management ability was demonstrated.

In the late fall, Langley, in its research program, successfully deployed three parachutes in the upper altitude (above 120,000') simulating Martian density. For the first time, it became known that parachutes could be deployed in a low dynamic pressure environment. Two flights were rocket launched and deployed at Mach numbers near 1.5 and a dynamic pressure of eleven pounds per square foot. One flight was balloon launched demonstrating deployment in the wake of a large cone (simulating a Mars entry vehicle); this deployment was initiated at a Mach number near 1.2 and a dynamic pressure of 6 pounds per square foot. While the test data on drag values did not prove conclusively that a parachute could meet all mission objectives, the results were very encouraging that Langley was on the right track in the development of parachutes.

Results of Langley In-House Voyager Study

In August, I reported the results of the Langley in-house study to the Planetary Missions Technology Steering Committee. Dr. Roberts requested that I make the presentation because he realized the work was primarily that of the FVSD staff and that he desired not to compromise his position of chairman of the PMTSC. The study, carried to substantial depth, included analyses of the entry vehicle size, use of parachutes in conjunction with a terminal retro system for final phase landing, standardization of mode and subsystems for future missions, efficiency weight studies of various concepts, and a rational sequence of Voyager missions throughout the 1970's to meet the end objective of landing an automated biological laboratory on Mars in 1979.

The study made the following firm conclusions:

1. Selection of a 19-foot cone, maximum diameter compatible with shroud, as the entry vehicle because it furnishes the maximum aerodynamic braking for the first entry phase. It was further recommended that the cone be standardized (designed for the later heavier missions and off-loaded in the first missions) in order to minimize costs of design and flight qualifying a number of differing entry vehicles. The weight cost of standardizing was determined to be minor and deemed a small price to pay.

2. Use of a parachute for landing in the first mission and to furnish a <u>transition mode</u> (as well as serving as the means of removing the landing package from the cone and furnishing efficient aerodynamic braking) between the cone mode and the terminal landing retro mode in later missions. This was the first time a parachute had been proposed as a transition mode and it allowed a common delivery mode (cone, parachute, retro) throughout the four planned Voyager missions to maximize standardization. An all retro landing system similar to Surveyor was studied and discarded for technological reasons as will be discussed in the next section.
3. Identified a ballistic number (function of weight) of 0.20 for the first mission which was compatible with a Mach 1.2 parachute deployment and a ballistic number of 0.32 for the 1979 mission which would require a Mach 1.6 parachute.
4. Described a mission sequence for 1973, 1975, 1977, and 1979 which allowed for a buildup of technology with minimum risk. A probe mission was recommended for 1973 to obtain the necessary data for the later lander missions--it should be noted that this recommendation goes counter to the OSSA guideline for the 1973 mission.

Figure IV-8 illustrates the basic mission mode concept.

The study report was endorsed by the PMTSC and was recognized thereafter as the Langley position relative to Voyager mode and mission sequencing. The work was subsequently condensed and published

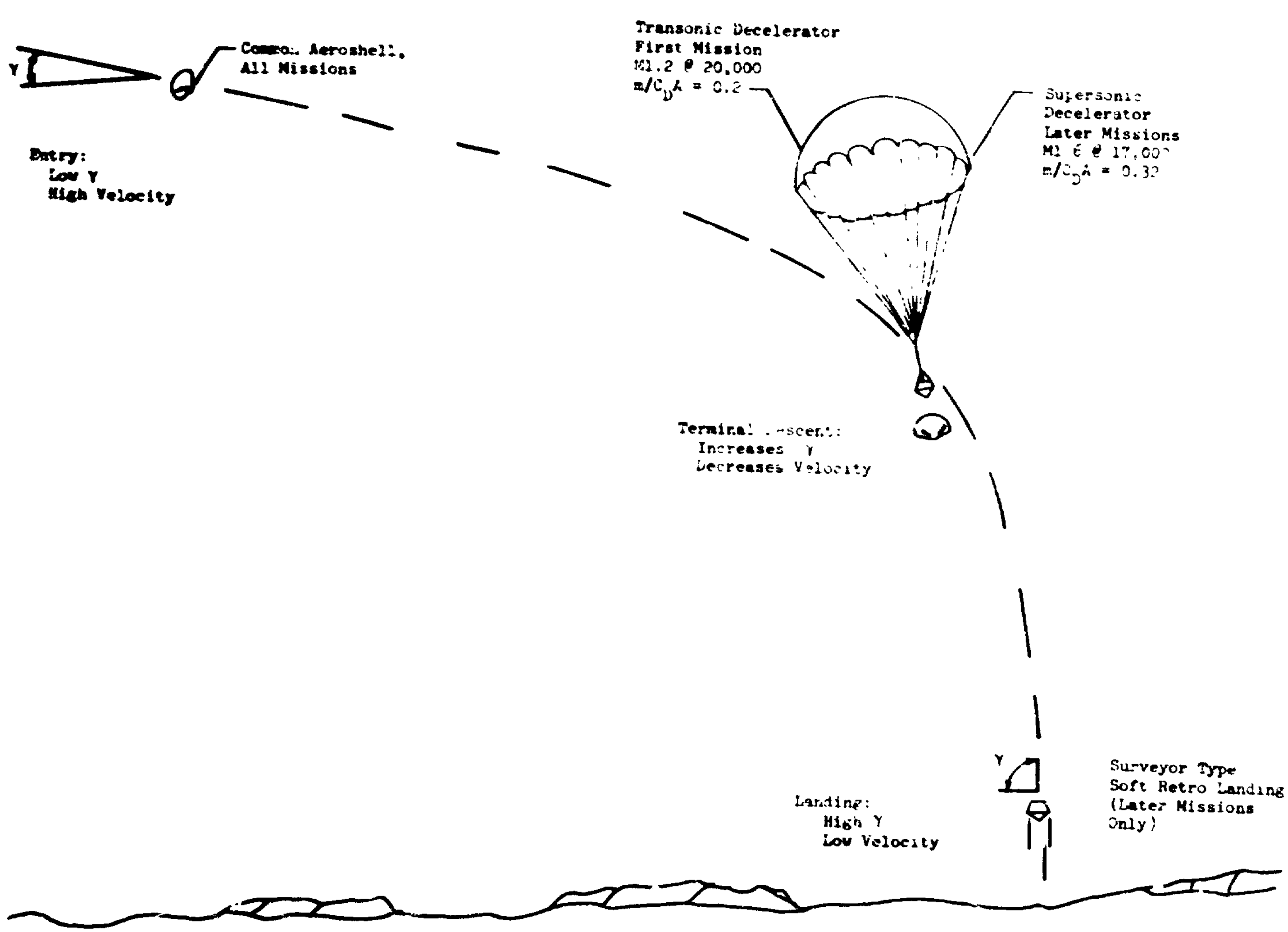


Figure IV-8.—Voyager mission mode.

as Langley Working Paper 326, Modal and Conceptual Design Comparisons for the Voyager Capsule by James F. McNulty, Daniel B. Snow, and Leonard Roberts. The study was a major contribution to Langley's understanding of the Voyager-Saturn V program and, because of its prime importance, is included as Appendix IV-B.

High Level NASA Meeting on Voyager Mission Mode

Headquarters OSSA called a high level meeting on short notice for September 26 to discuss the Voyager program to be attended by the heads and staffs from OSSA, OART, JPL, and LRC. Langley was represented by Dr. Thompson (Director, LRC), Mr. Kilgore, Dr. Roberts and me. JPL was represented by Dr. Pickering (Director) and senior staff Voyager Program Office members. OSSA was represented by Mr. Edgar Cortright (Deputy Director), Mr. Oran Nicks (Director of Lunar and Planetary Programs), and Mr. Donald Hearth (Voyager Program Manager). OART was represented by its director, Dr. M. C. Adams.

I recall with some degree of amusement now how Dr. Roberts and I scrambled the day before the presentation. As Langley had not as yet committed itself to any mainline responsibility, it was difficult for me to perceive what the "message" of our presentation would be. However, there wasn't sufficient time for us to think or worry about that. Dr. Roberts outlined the vu-graphs he wanted--not in any particular order as far as I could determine and I got busy getting them prepared, typed, reproduced, and made into vu-graphs. As a matter of fact, we had the Reproduction Division working overtime that night to get our work done. After we had a miscellany, to me, reproduced, we adjourned to my home where my wife fed us while we looked over the data, selecting some and wastebasketing the others. Finally, Dr. Roberts had a dozen slides he was satisfied with and my daughter stapled the copies together on the dining room table. After

Dr. Roberts left, I examined the dozen pages and I still didn't understand -- and so to bed, confused.

At the meeting, JPL led off with its presentation -- colored slides, the whole works, pulled from their files. Their presentation centered on their "VPE-14" (Voyager Project Estimate) which was their selected mission mode for the 1973 mission and it was well presented. JPL's mission mode is presented on figure IV-9. Basically, it is all propulsive mode. Ports in the cone open to allow the retro engines to fire for deceleration purposes. Next, there is a controlled explosion, more or less, to allow staging of the lander. Finally, there is the terminal retro landing system. JPL's presentation was honest and straightforward, a section of their report was devoted to engineering technological problems associated with their mission. These problems consisted of:

1. The mechanics of designing the ports so that the outer surface would remain smooth through reentry thus avoiding discontinuities during the scaling off of ablation material which could cause extreme hot spots or uneven aerodynamic loading. Also involved was the question of the ablation material melting over the port circumference to form a solid face so that the ports could not open.
2. The details of staging remained to be worked out to assure the integrity of the lander science and operation.
3. Because of the unknown density of the Martian atmosphere, the velocity of the cone at initiation of retro fire was

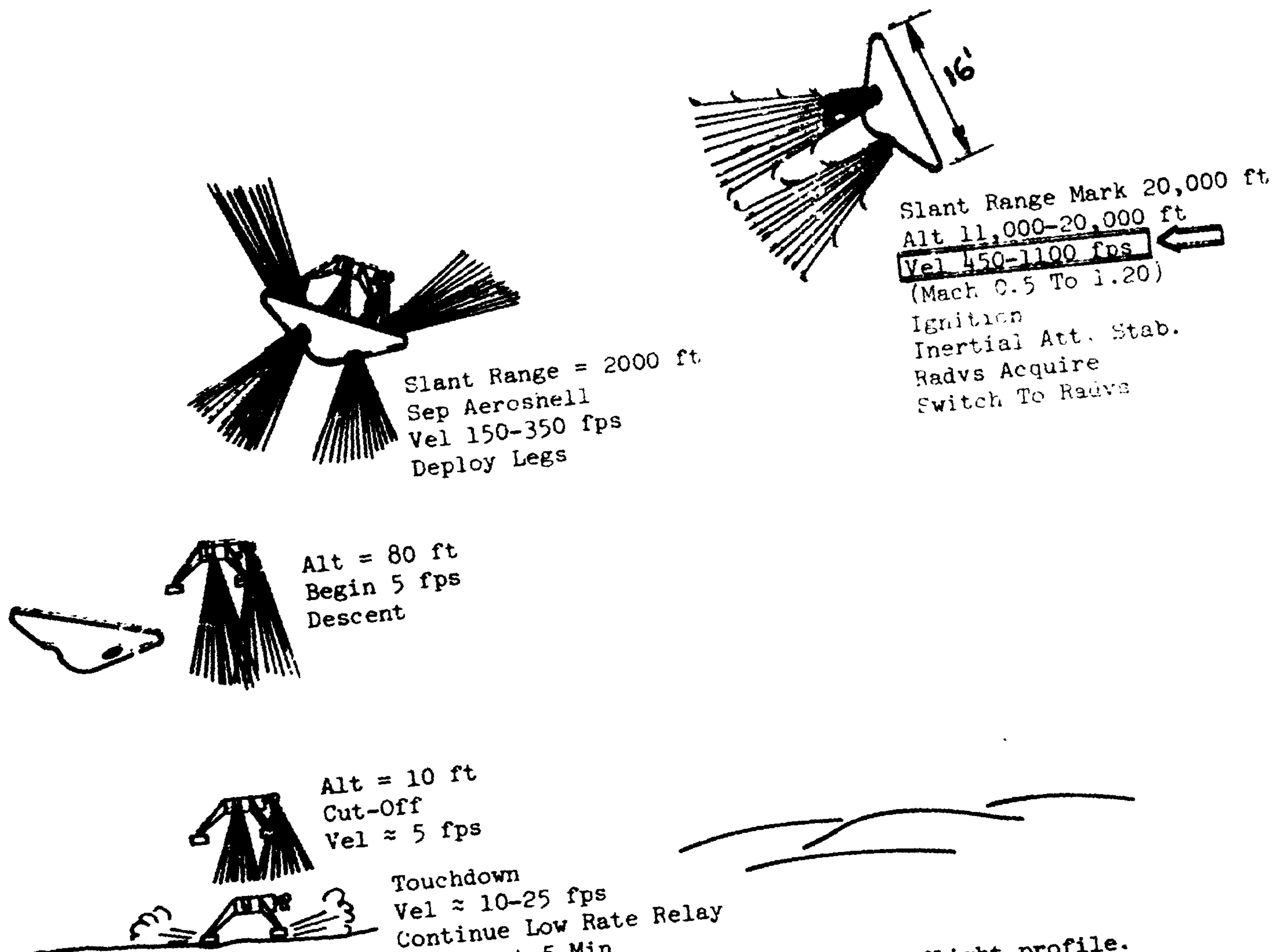


Figure IV-9.--VPE-14 project study, terminal descent flight profile.

unknown; it could be banded by a velocity range of 450-1100 feet per second. This velocity band caused two problems. The first being that sufficient fuel for the 1100 feet per second had to be carried all the way to Mars with a good possibility that most of it would be a dead weight penalty. The second disadvantage was that the engine would have to be highly throttable with complicated electronics to assure the correct velocity decrement was removed.

As JPL made their presentation, the pieces fell into place regarding Langley's dozen slides. Every time JPL mentioned a problem area, I'd note that that point was covered in one of our slides. I could hardly believe it; I felt that I could get up and make a very effective presentation with the same data that previously made no coherent story. And, if I felt that way, there was no doubt what Dr. Roberts could accomplish. For the first time in 48 hours, I relaxed and felt very comfortable.

Langley's presentation followed. As I anticipated, Dr. Roberts made a masterful presentation. He quietly started off describing the R & D programs which Langley was conducting to support Voyager. Then he branched off into Langley's system studies (the work reported to the PMTSC) which he indicated were being pursued to define needed technology areas but just might also have some application to the modal problems that JPL had been discussing. First, he pointed out (with hard data) that the cone diameter might better be 19 feet than 16 feet to obtain about 50% more aerodynamic braking. But the main thrust was the use of the parachute as a transition mode and the accompanying slide (figure IV-10) from the presentation was devastating to JPL's presentation. The Langley presentation is included as Appendix IV-C.

Following the presentation, Dr. Pickering (Director, JPL) made the following statement to the group, "I know now why we were asked to this meeting -- to be the straight man for Dr. Roberts." The meeting was all in good humour with high technical content but the handwriting on the wall was clear. If it had been any sort of competition, Langley had won hands down.

Once again the Langley management had remained, for the most part, in the background and allowed the technical staff full latitude. It was surprising that Dr. Roberts and I could prepare a presentation for a high level Washington Headquarters and Center Directors meeting without a "dry run" or even an informal review at the Langley level. Whether it was a question of complete faith or unsuspected knowledge, I know not -- but it certainly was effective and efficient.

SUMMARY OF PARACHUTE FUNCTIONS

- PROVIDES TRANSITION FROM AERODYNAMIC TO PROPULSIVE DESCENT
- PERMITS COMMON DELIVERY TECHNIQUE FOR ALL MISSIONS
- REDUCES SENSITIVITY TO SURFACE PRESSURE VARIATIONS
- PERMITS VERTICAL APPROACH TO SURFACE
- LONGER RESIDENCE IN LOWER ATMOSPHERE (DESCENT TV)
- REDUCE ENGINE THROTTLEABILITY FROM 10:1 TO 2:1

Figure IV-10.--Advantages of a parachute for Voyager.

Center Assignments on Voyager

Throughout 1966, NASA Headquarters wrestled with the problem of how to set up a management structure for as complex and large as undertaking as Voyager. Some way had to be found to parcel out pieces of program to all available Centers and then to integrate and manage the pieces. A Center similar to OSMF's Manned Spacecraft Center at Houston for Apollo would have been ideal to handle the overall project control -- but none existed for unmanned scientific programs. JPL, as noted previously, was a contractor to OSSA and Headquarters was reluctant to have a contractor manage NASA Centers. Langley was primarily research oriented with only a small program staff and the managing of large program like Voyager did not match its image or resources. Marshall, an OSMF Center, was a much closer fit in size and managership capabilities but it had no experience with interplanetary missions technology. Headquarters proceeded with the easy part of the problem -- that of breaking up the hardware into workable pieces: orbiting spacecraft, launch vehicle, capsule bus (entry and landing vehicle), surface laboratory, and tracking and data.

The method was, of course, to assign these pieces (by negotiation with the Center Directors) to the various Centers so as to obtain a best mix of capabilities. In a study, the Harvard Graduate School of Business reported on this situation:

"Marshall, of course, had the launch vehicle. Langley was evidently the first Center to be considered for one of the other systems, because it had shown interest and gained some relevant experience in spacecraft through its Lunar Orbiter program, and had done reentry aerodynamics work on the FIRE project.

"Much of the debate in this last half of 1966 centered on who was to get the lander (capsule bus) portion. This was acknowledged to be the 'juicy morsel' of the program: technological challenging and scientifically promising . . . at any rate, there was a complex series of proposals back and forth between the Centers and Headquarters during this period."[8]

As the end of the year drew to a close, NASA Headquarters succeeded in committing the various systems to the Centers while keeping the overall management for the time being under OSSA Headquarters. In a Memorandum to Distribution for all Centers on December 22, Mr. D. P. Hearth announced the system assignments for Voyager. Langley was assigned the capsule bus -- "the juicy morsel." This was met with enthusiam by the Langley who had been working Voyager problems, it was thought that we might be assigned the orbiting spacecraft system because of the success of the Lunar Orbiter. Other assignments are shown on figure IV-11 which is taken from the Memorandum.

The management structure defined by Washington Headquarters for the Voyager Program was a very complex one involving several Centers and JPL with program managership responsibility in Washington. With

[8] Harvard Graduate School of Business Administration, NASA Planning and Decision Making, Vol. 1.

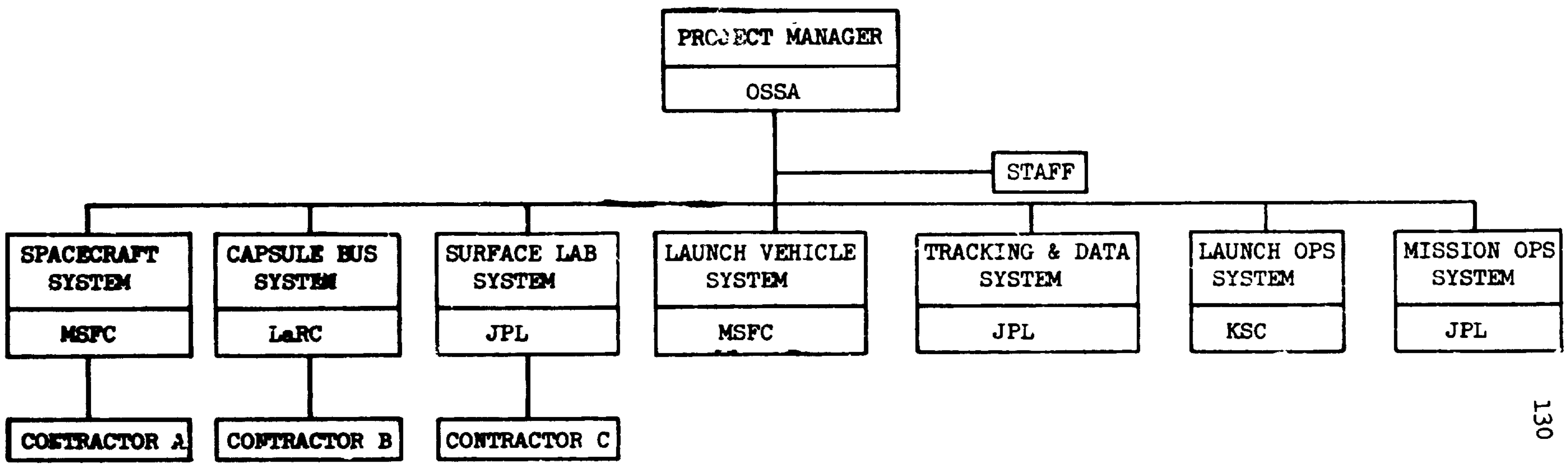


Figure IV-11.--Center assignments on Voyager.

a very complex program and responsibility scattered from coast to coast, the task of integrating and communicating appears formidable. However, an aim of Headquarters has been, for some time, to get the Centers to work together better and, thus, break down the parochialism of the Centers. Perhaps, if this objective could be accomplished, it would be an achievement that would pay great dividends on future programs. In any event, the structure is never cast in concrete and is subject to change if future events indicate that will not be successful.

The work of the technical staff in carrying out the broad entry system studies is believed to have influenced both Headquarters' decision to give the capsule bus responsibility to Langley and Langley's acceptance of the responsibility. From past experience, Langley is cautious about undertaking any responsibility without good assurance that the expertise resides at Center to fulfill its obligations. In addition to the Langley study effort, the research staff proceeded with timely testing of the parachute which put some realism and belief in the study recommendations. Regardless, Langley management showed courage by accepting the responsibility for the Capsule Bus System (the "juicy" morsel) because it was an extremely large undertaking for a research center. It is not obvious that the tail (project work) wouldn't be wagging the dog (research)--a position that Langley always strove to avoid.

On the other hand, JPL charged most of the year with full responsibility for carrying out the 1973 mission, concentrated its efforts entirely on defining a mission and examining it in depth--this meant that JPL couldn't cover the broad Voyager picture. By reacting strongly to changing Voyager '73 guidelines, JPL was forced to select a mission mode early in the year and then analyze it in depth. It appears that, unfortunately, JPL selected the wrong mission mode so that a large part of its effort of analysis has little utilization. In its behalf it must be said that JPL had the '73 mission responsibility which was a heavy one while Langley could afford to be loose. The forcing functions of a '73 launch window and Headquarters' directives together with responsibility for carrying out the mission might well have required total commitment and effort toward getting the 1973 mission underway.

Voyager Related Personnel Changes At Langley

In the late fall in anticipation of Langley assuming some mainline hardware responsibility in the Voyager Program, Langley management took the first step toward formalizing a project office to work on Voyager. Mr. Dave Stone was designated as the Langley focal point for Voyager. He set up a project office manned by 5 engineers from his FIRE Project Office plus 4 engineers on loan from the line organizations (including me). I was still to act as the interface between the project office and my line organization as much Voyager support work was going on in my line engineering division. Langley stated they would officially name a "Capsule Bus System Manager" at a later date.

In another, unrelated move, Dr. Roberts left Langley to accept a position of Division Chief of the Mission Analysis Division at NASA-AMES. I was extremely sorry to see Langley lose his talents because although analytically oriented he had an appreciation (if not an understanding) of engineering hardware and was extremely apt in defining engineering/research programs. However, with the switch of Mars lander missions from study to hardware, it was an appropriate time for him to move to other pastures. (He is currently Director of Aeronautics at Ames.)

Mr. Gene Love, a leading national and NASA authority in aerodynamics, was named to replace Dr. Roberts as chairman of the Planetary Missions Technology Board.

Synopsis

A synopsis of the third year's effort could be tabulated as indicated below:

1. Completion of the AVCO contract with definition of a Probe Mission.
2. New guideline -- lander on first mission.
3. Langley sets up study group with broad guidelines to define a rational Voyager program and mission mode.
4. Surveyor, Lunar Orbiter and Langley's parachute program have successful missions.
5. Langley completes in-house study. Defines mission mode with parachute performing as a transition function.
6. Headquarters holds top level review of Voyager mission mode. JPL and Langley make presentations.
7. Langley awarded Capsule Bus System responsibility.

CHAPTER V

VOYAGER IMPLEMENTATION AND CANCELLATION - 1967

Summary

During most of the year, Headquarters and the Centers were engaged in building up the technical and managerial staffs to carry out the Voyager program. The organizational arrangement for making binding decisions across system (or Center) responsibilities was complex and multi-tiered; rational decisions could be obtained, however, with perserverance from the technical staffs. In this period of organizational buildup, informal inter-center contacts and working relationships were established which allowed the technical work to proceed. Langley appointed a Capsule Bus manager in June and the control of Langley's effort was phased to his project office from the previous technical staff, PMTSC, and Langley line management.

Headquarters also set up an inter-center organization -- the Mariner Mars 1971 Probe Working Group -- to define a probe mission for JPL's 1971 Mariner mission to Mars. This mission was to be a precursor to the 1973 Voyager mission. Langley's contribution in this effort was primarily that of a consultant while the other Centers were in competition to get their scientific experiments included. While the group achieved its objective of defining the probe, the success of this experiment to achieve and demonstrate inter-center cooperation was open to question.

When Congress, in August, disapproved both Voyager 1973 and the Mariner probe in 1971, Headquarters OSSA was left without any interplanetary program for the 1970's. OSSA requested the Centers, primarily Langley, to study and recommend a less costly program including both Mars and Venus. At Langley, the only group with a background to respond upon short notice was the original technical staff which had worked the early studies. In December, Langley presented to OSSA its recommendations for a new program using the Titan/Centaur launch vehicle as a base.

Voyager

Project Organization

The Center Assignments on Voyager were given in the previous chapter (figure IV-11). Briefly, the setup was for OSSA to be project manager supported by a staff; under the project manager were seven systems (capsule bus, spacecraft, launch vehicle, etc.) assigned to various Centers and directed by Center system managers. The responsibility of the Voyager project office was vast including such elements as defining in detail the entire mission so that the various system managers could proceed with their individual system design and procurements, allocating funds and weight allowances to the various systems, coordinating the system outputs into a unified total vehicle, data keeping and reporting on entire project, and making final decisions in cases of dispute between Center system managers on interfaces and responsibilities.

In order to implement the project responsibilities, OSSA set up an interim project office (IPO) at the Union Bank Building in Pasadena, California where it could draw on the resources of JPL which was the only organization with the capability and resources able to undertake project management duties in this interim period. The organizational arrangements were extremely complicated and are described in full in Appendix V-A (Langley memorandum to the Associate Director from Edwin Kilgore, Chief, Flight Vehicle and Systems Division entitled "Meeting at Pasadena, California on March

22 and 23, 1967 at JPL to organize Interim Project office for Voyager Management"). A simplified schematic of the organization is given in figure V-1. As can be seen from the figure, Mr. Don Hearth was detailed to Pasadena from Headquarters to manage the IPO and was given a staff of about 60 people (mainly JPL personnel) to assist him. The key decision making group would be the Project Management Committee where the various Center system managers could be represented--since Langley had not appointed a Capsule Bus Manager, it was represented in the committee by Mr. Kilgore (Chief, FVSD) and Mr. Stone (Langley's Voyager focal point). This committee was to meet monthly and use the working groups and panels to resolve and advise on action items. While figure V-1 indicates that this is the way the organization would work, the descriptive data in page 5 of the aforementioned memorandum describes a mode not in keeping with the organizational chart. Mr. Robillard (JPL head of the IPO staff) states that the working groups "would serve for the IPO as a technical refree among systems." Since the working groups were chaired by IPO-JPL members, it was not clear as to whether the working groups were not, in reality, an arm of IPO rather than the Project Management Committee.

Implementation of Voyager Program

Many varied activities were undertaken by Langley and other Centers during 1967; it was an extremely busy and complicated time for all concerned. There were:

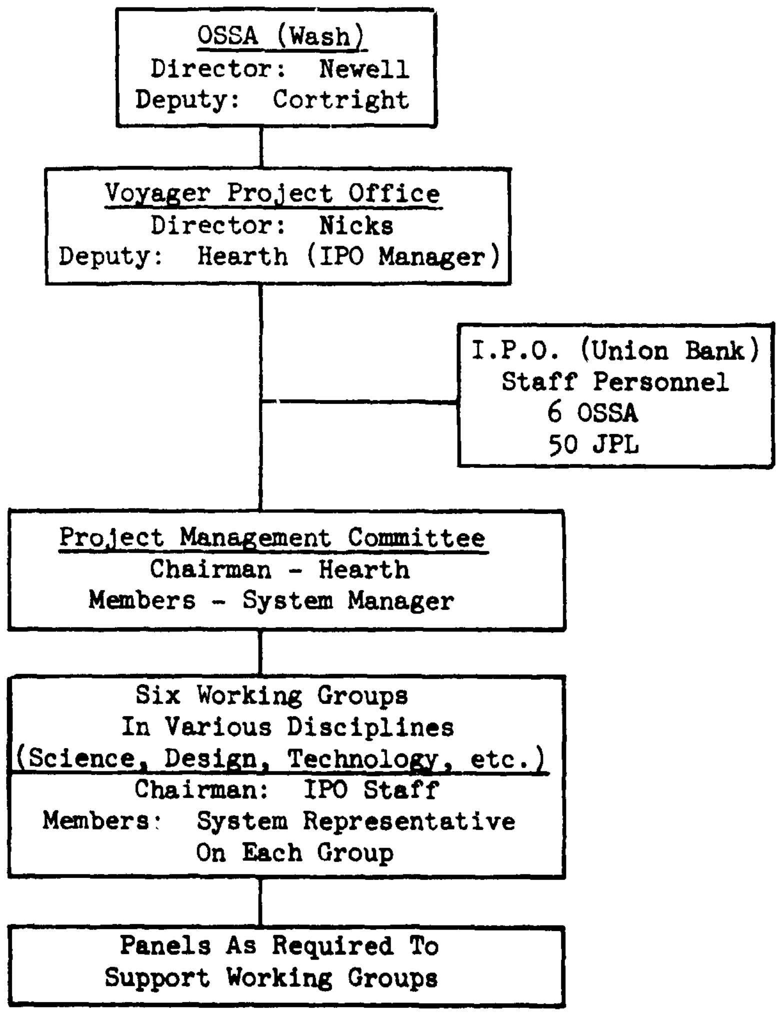


Figure V-1.--Voyager project office organization.

(1) technical exchanges by the technical staffs from the various centers with the purpose of communicating to assure that everyone was working the same problem.

(2) formal meetings at working group levels where JPL, acting as the coordinating arm for OSSA, attempted to define guidelines, schedules, and obtain interface agreements.

(3) directives from OSSA to all Centers specifying guidelines.

(4) meetings of the Project Management Committee wherein final binding decisions were arrived at.

(5) large increases in the project and research staffs at Langley which tended to confuse communications and the lines of authority during the learning period.

The Voyager program at the start of the year could be described, with some simplification, as follows. OSSA, with JPL staff support, was project manager; Langley was Capsule Bus Manager; Marshall was Launch Vehicle and Orbiter Manager; and JPL was Surface Lab System Manager. The mission mode was not defined nor was the responsibility for its definition. The problem that concerned Langley as Capsule Bus Manager was how much freedom did Langley have in the Capsule Bus System definition. Could Langley define the Capsule Bus mode from separation to landing or did OSSA, with JPL, dictate this as a mission requirement to Langley? A second item concerned the weight allotment for the Capsule Bus System. How would this be determined and how tight would be its restraining force on Langley's design?

The organization at Langley at the start of the year with respect to Voyager is shown in figure V-2. As indicated by the figure, there were three types of activities underway. Twenty engineers, under E. C. Kilgore, were working on design problems in engineering under my direction; nine engineers were engaged in project coordination under D. G. Stone; and approximately 60 research engineers were engaged in technology development with funding and results channelled through D. G. Stone. Both Kilgore and Stone were members of the powerful Voyager Project Management Committee as noted previously. The Kilgore and Stone activities operated somewhat independently; Kilgore's group was primarily concerned with technical design aspects while Stone's effort was mainly coordination with other Centers, OSSA, and research activities--for example, the intercenter working groups, panels, and project documentation were under Stone's cognizance. My efforts were divided between Kilgore's and Stone's as I was assigned to both, more or less on a "as required basis."

In the engineering activity, my assignment was to firm up the Langley concept of the Capsule Bus. Our OSSA guideline was to consider maximum commonality of subsystems in the planned missions growing to a maximum 7000 pound capsule bus and that "the impact of providing such growth on early missions is required to permit the proper decisions on design approach."[1] My studies revealed that in order to obtain the maximum commonality among the missions to assure

[1]OSSA memorandum, Don Hearth, January 18, 1967.

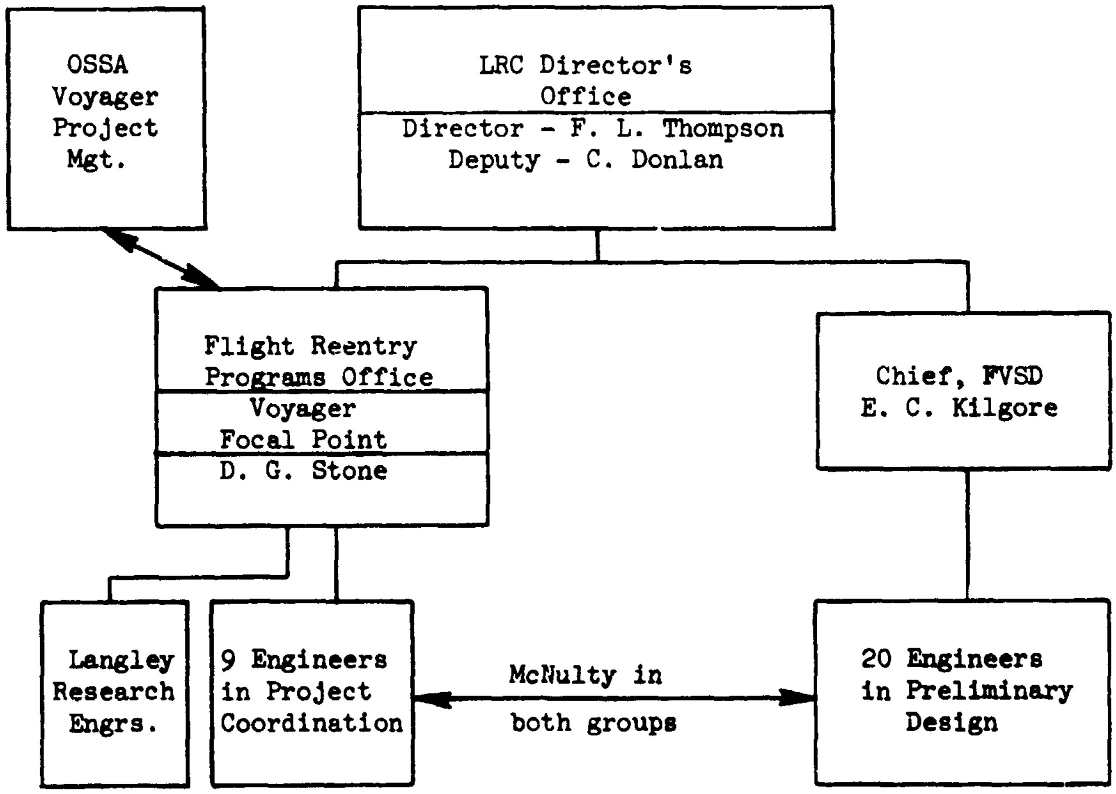


Figure V-2.—Langley Voyager organization, January, 1967.

minimum developmental costs, the Capsule Bus allocated weight in 1973 should be set at 6000 pounds.

My efforts in support of Stone's office was in two related areas. The first was to be a lead Langley representative in purely technical exchanges; three such exchanges were held--JPL at Langley on January 11, Marshall at Langley on February 1, and Langley at JPL on February 13. Langley's position regarding these meetings was for a free and frank exchange. The meetings were attended by solely the working engineers and were most productive. The contacts made at these meetings allowed for a continuing dialogue between working personnel by telephone calls and memorandums to assure proper technical interfaces. The second area involved my membership in inter-center working groups wherein all Centers attended and the meetings were chaired by a JPL staff member. The main emphasis in these meetings was on project management matters--definition of interfaces, system requirements, schedules, documentation and progress reporting. JPL, in its assumed role of acting for OSSA as project manager, was attempting to define the 1973 mission and pushed hard for Langley to concentrate on an all propulsive lander with a 4000 pound weight allocation. These criteriae were essentially those proposed by JPL in the VPE-14 document which were questioned by Langley previously. Since Langley's recommendations were for a 6000 pound weight allocation and a parachute-retro landing system, these meetings were somewhat unproductive except for pointing up problem areas. My instructions upon attending these meetings was to cooperate as fully as possible but not to commit Langley to any position which would limit its option insofar as the Capsule Bus was concerned--any broad inter-system decisions should be made by the Voyager Project Management Committee.

Despite the division of responsibilities between Stone's and Kilgore's groups, there was some conflict between members of the respective technical staffs. No longer was the FVSD group the prime force; in matters of day to day management, it supported Stone's office which was manned by Stone's men from "Fire." This concerned those members of the FVSD staff who had hoped to be implementers of any follow-on program to the study work. Members of Stone's staff were also uneasy because their knowledge of Mars missions was not yet equivalent to FVSD's staff. The hope of the FVSD staff to be main implementer was not a realistic one in that it lacked experience with big projects. That the FVSD staff had an opportunity to contribute directly through Mr. Kilgore to the Voyager Project Management Committee was an extenuating motivation which kept the group's performance at a high level.

The working relationships outlined above remained in force through the first half of the year. On June 23 Langley Director Floyd Thompson announced that Mr. James S. Martin would be Manager, Capsule Bus System. Mr. Martin had been Assistant Manager, Lunar Orbiter Project Office. Logical reasons for Mr. Martin's appointment were:

(1) Mr. Martin and the Lunar Orbiter team had proven manageship and hardware capability.

(2) A much enlarged team was required and the Lunar Orbiter staff was available.

(3) The previous technical staff had performed its function of expertise--the defining of the program which was now ready for hardware execution.

(4) A transfusion of "new blood" would furnish new ideas and fresh enthusiam--the previous staff had already worked the problem for four years and was susceptible to going stale.

Although this decision was expected from rational considerations (other possible candidates were Kilgore and Stone), it further deflated FVSD's role to a support basis and members of the FVSD staff began to look to Venus seriously. Mr. Martin would be assisted by a staff of five engineers from the Lunar Orbiter Office immediately with the plan that the remaining Lunar Orbiter staff of approximately 25 engineers would be assigned to Mr. Martin upon the completion of the Lunar Orbiter project in September. Therefore, Langley's Voyager organization was revised as shown in figure V-3 with Messrs. Kilgore, Stone, and Martin as members of the Voyager Project Management Committee. Mr. Martin's appointment brought strong, aggressive, and capable leadership to the Capsule Bus System; there was no doubt that Langley's decisions regarding Voyager would be made principally by him.

It was soon evident how Mr. Martin planned to manage the Capsule Bus System. He planned to rely principally on his proven and known Lunar Orbiter Staff for project implementation; he planned to use Kilgore's team (under my direction) as consultants and advisers to bring his staff up to speed; and he planned tight control of the

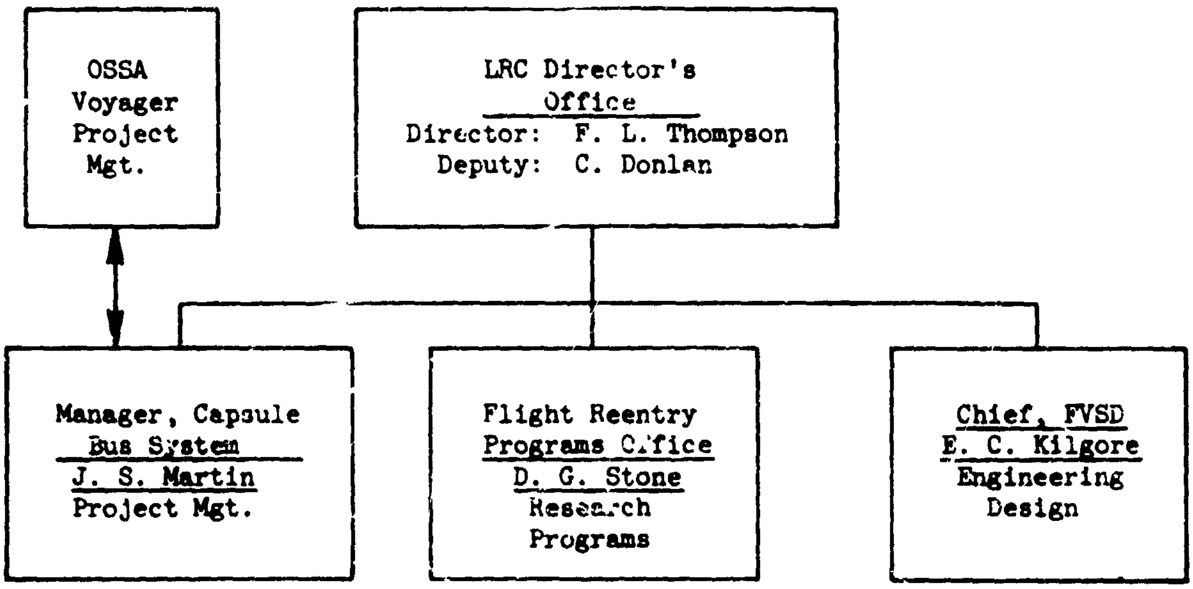


Figure V-3.—Langley Voyager organization, June, 1967.

funding to Mr. Stone to assure that the research was properly oriented to his needs. Even in the period before Lunar Orbiter was closed out, he was at work getting the Lunar Orbiter staff familiar with the Voyager project.

Prior to a meeting of the Voyager Project Management Committee, I prepared a memorandum[2] summarizing the implications of the weight allocation for the Capsule Bus; this memorandum was based on the studies performed by the FVSD staff. I was asked by Mr. Kilgore to brief Mr. Martin and Mr. Donlan (Deputy Director) on these study results. I did so in an informal meeting and found Mr. Martin impressive in his grasp of the salient points even though he did not have the background to understand the technical details. Following the Voyager Project Committee Meeting, OSSA issued a memorandum of "Revised Project Level Guidelines" dated July 10, 1973 which allocated a Capsule Bus weight of 6000 pounds. This was an important Project decision and again backed up Langley's recommendation. I drew two conclusions from this decision. One was that JPL had again spent many hours trying to define the wrong mission and force agreement, and the second was that, if one was firm and perservering, the engineering staff could make an impact at the highest level to change the course of a project.

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[2] Memorandum to LRC Representatives on Voyager Management Committee, J. F. McNulty, June 19, 1967, "Capsule Bus Weight Allocation, 1973 - 1975."

Cancellation of the Voyager Program

In late August, Voyager was cancelled to the complete surprise of NASA and to the engineers working on it. Only a couple of weeks previously, a joint House-Senate Conference Committee had approved a Voyager authorization of 42 million dollars for preliminary design. Washington OSSA Headquarters had been working closely with Congress--particularly Rep. Karth (Minnesota), head of the House Space Committee who was one of Voyager's most powerful supporters--and thought Voyager approval was assured. However, the House Appropriations Committee rejected all appropriations for Voyager.

While it is unknown whether the Vietnam war and the summer riots would have been sufficient driving forces to cause Congress to cancel Voyager regardless, there was another factor which might have influenced the decision. I recall that in the early summer two engineers from Houston's Manned Spacecraft Center visited Langley for consultation. They were directed to me and we discussed a manned flight to Mars. Their thinking was most ambitious and preliminary; it was obvious they had been working on the problem only a short time and had no appreciation of the landing problem. We discussed the problem for a short time and they left expressing their appreication. My feeling was one of amusement and wonder that they could even envision such a program without serious study; I felt it would be a long time before MSC would have a serious concept. However, in August in the midst of the Congressional deliberations on Voyager, MSF (a OSMF Center) issued a Request for Proposal to 28 companies for studies of manned Mars and Venus missions stressing coordination with Voyager flights. Thus, OSMF was planning "manned Voyager" flights at time when OSSA was depicting Voyager as an unmanned scientific mission. This astounded Rep. Karth and caused some confusion in Congress about Voyager being a precursor to a manned mission. Rep. Karth stated, "Very bluntly, a manned mission to Mars or Venus by 1975 or 1977 is now and always has been out of the question--and anyone who persists in this kind of misallocation of resources at this time is going to be stopped."[3] In any event, the House cancelled both Voyager and MSC's planned study.

[3]William J. Normyle, "Priority Shift Blocks Space Plans," Aviation Week, Sept. 11,1967, p. 27.

Mariner Mars 1971 Probe

In a letter dated March 16, Mr. Oran Nicks, Acting Director, Lunar and Planetary Programs, OSSA, Washington Headquarters requested Langley's participation in the atmospheric probe mission to be included in the Mariner Mars 1971 project. A Probe Working Group, chaired by OSSA, was to be established made up of representatives from JPL, Langley, Ames and Goddard with the objective of defining the probe, its mission definition, its instruments, and its development. I was selected as Langley's representative and met with Mr. Donlan and Mr. Kilgore to receive instructions regarding Langley policy with respect to the 1971 probe. I was advised by Mr. Kilgore that I was selected because of my expertise in Mars entry probes and my knowledge of Voyager. He further advised that I would have two main duties:

1. to try to influence the probe definition so that its results would be applicable to the Voyager Capsule Bus design.
2. to work with OSSA as a management adviser with regard to JPL planning since it was expected that most of the other representatives would be scientists.

Mr. Donlan cautioned me not to accept any "chores" from OSSA and that Langley was not interested in any hardware development responsibility for the Mariner probe since it was heavily committed to Voyager work.

At the group's first meeting on March 23, Mr. Nicks made the following points:

(1) The Probe Working Group (PWG) is an attempt to get all Centers working together in the decision making process for maximum utilization of resources and definition of objectives.

(2) The probe should be simple so as not to compete with the Voyager lander and objectives. OSSA's first priority is Voyager so Mariner should not impinge on Voyager perogatives.

It was obvious from the first meeting that it was a very diverse group; opinions varied widely as to both the type of probe and to the merits of various instruments. Five meetings (usually two days in length) were held from March to August and were quite fectious in nature. For example, JPL proposed an ambitious probe which incorporated a small lander on a parachute. As project manager, JPL thought the mission was viable (although risky) and would give the maximum return. The scientists from Ames and Goddard were more interested in atmospheric physics and wanted emphasis on instruments and scientific data. It was like comparing apples and oranges--JPL had "engineered" a mission whereas the scientists knew what data they wanted but did not have a mission plan to obtain the data. Since the PWG could not agree, the matter was "solved" by resorting to a vote by the Centers; this method became the standard means for selecting between alternative options. The vote was three to one for a "dual probe approach ... without survivable landing."[4] My sympathy

[4] Final Report, Mariner Mars 1971 Probe Working Group, page 5.

was with the JPL engineering approach but I felt I could not support it because of its possible conflict with Voyager objectives and, in any event, it would probably require Langley technical support which I was under instructions not to provide. It was also my impression that OSSA was using this forum of the PWG to put a rein on JPL and its approach to the 1971 mission.

Most of the other meetings were concerned with the selection of instruments. The merits of which were debated at length and when it was evident that agreement was impossible, among competing groups, a vote was taken with Langley usually being the "swing" vote which put me in a very uneviable position considering my lack of credentials. I tried to find my way out of the box by requesting "scientific advisers" from Langley to help me. While I got some help, Langley management wasn't too interested in the whole exercise (perhaps recognizing its futility), the advisers recognized the game and took a cautious stance. In this manner the PWG obtained its objective of defining a probe mission and its instruments. However, the objective of getting the Centers to cooperate was not ained--the discussions were competitive in nature, very little coope :ion was evident, and relations were strained. Dr. George Brooks (Langley) attended a NASA's Planetology Committee meeting where a presentation was made of the PWG efforts; the report noted that "there has been considerable disagreement among the representatives of the various Centers on the Working Group because of parochial viewpoints and the Group might be disbanded."[5]

The PWG effort, in any event, was an academic exercise because the probe funds were omitted from the authorization bill in order to furnish funding for Voyager which OSSA considered its major new start.

[5]Minutes of the twenty-third meeting of the Planetary Missions Technology Steering Committee, July 20, 1967.

A New Start

On September 6 Langley's Planetary Missions Technology Steering Committee was convened with a large number of other Langley personnel in attendance. The purpose of the meeting was to discuss the future of NASA planetary unmanned programs to Mars and Venus. Quoting from the minutes of the meeting: "Mr. Draley[6], Assistant Director, Flight Projects explained some of the background of the change of direction which was caused by a Congressional cut in funds. OSSA has been informed that the cut was predicated by lack of funds because of other higher priority programs and not because of any disapproval of the Voyager Program. Further, OSSA has requested assistance from the various Centers in defining a more modest program. An in-house informal study group is being formed with the objective of having a project concept by November 1, 1967, for submittal to OSSA."[7]

Details of the study objectives and the study group personnel were released on September 8 and the announcement is included as Appendix V-B. It was a very ambitious undertaking including the following tasks:

(1) Defining and prioritizing scientific mission objectives and instruments for Mars and Venus.

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[6]This is the first mention of Mr. Draley. Previous to this occasion, Mr. Draley was the responsible person in the Director's office for supervision of the Lunar Orbiter Project.

[7]Minutes of the twenty-fifth meeting of the Planetary Missions Technology Steering Committee, September 6, 1967.

(2) Evaluating payload capability of all launch vehicle systems smaller than the Saturn V.

(3) Preparing a conceptual spacecraft design for each selected launch vehicle.

(4) Costing the missions.

(5) Trading off alternatives.

(6) Recommending system to NASA Headquarters.

To perform this task in two months, a new organization (ad hoc) was formed with Mr. C. H. Nelson, former Lunar Orbiter Project Manager, as study manager, with thirteen working groups under him (a total of about 80 engineers) in various disciplines--for example, I was head of the probe definition group. The structure is shown on figure V-4; key people with expertise in Mars and Venus mission work are circled to identify them for the reader.

After a short period of time, Mr. Kilgore, recognizing the enormity of the task and the organizational problems, decided to initiate a parallel effort utilizing his Flight Vehicles and Systems Division (FVSD) technical staff under my direction which had been working Mars and Venus problems for several years. Our efforts to make a meaningful contribution was enhanced by two factors:

1. Mr. Kilgore kept in close communication with his OSSA contacts which he had engeniered during his stint on the Voyager Project Management Committee so that our work would be compatible with OSSA interests.

2. Our studies were restrained to only Titan based vehicles and science was only included to a weight allowance depth.

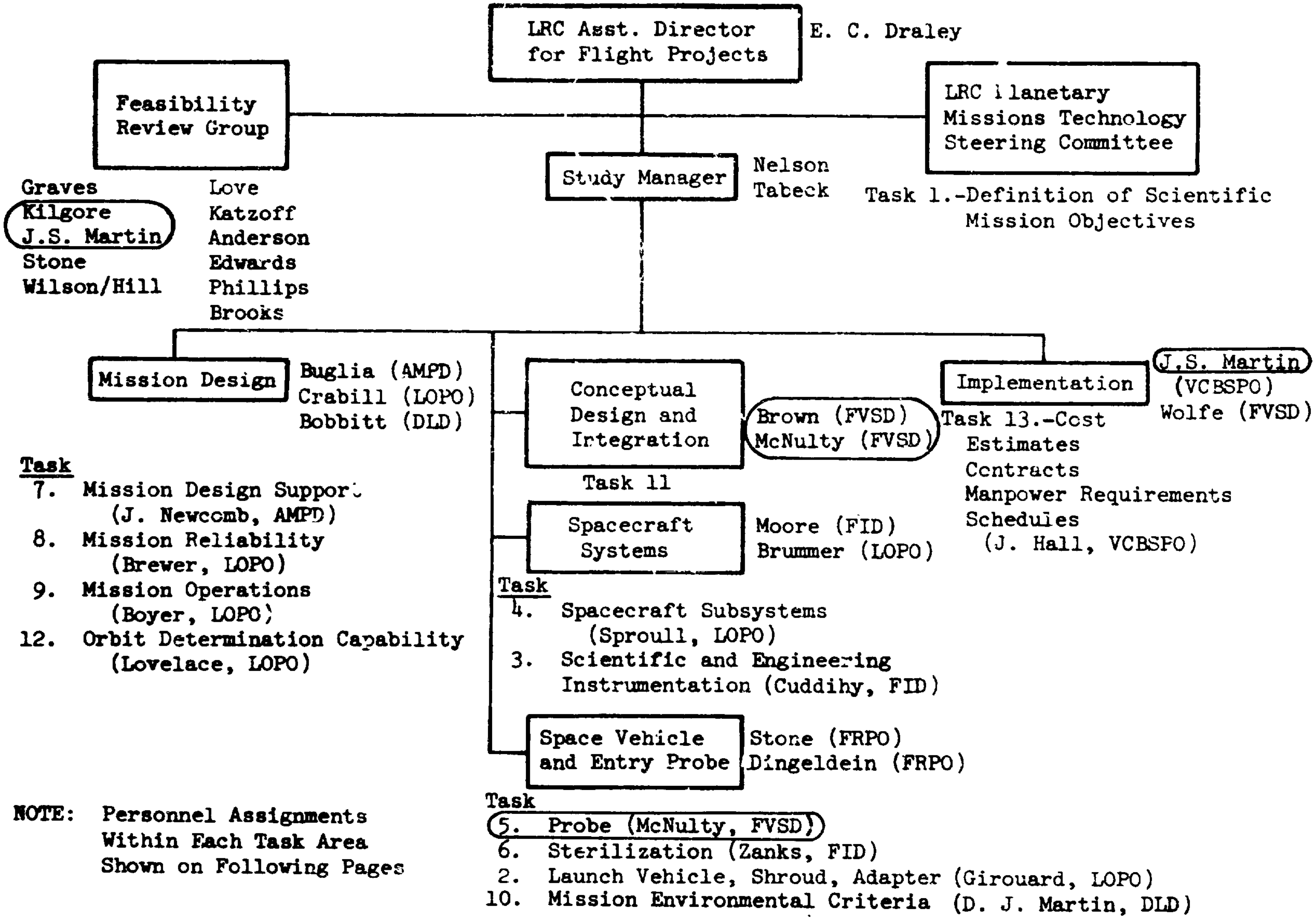


Figure V-4.--Management structure, LRC in-house feasibility studies-planetary exploration missions.

Given a new lease on life because of the emergency situation which required its unique expertise, the FVSD staff put forth a maximum effort and produced two definitive studies in a four month period. The first--Langley Working Paper 483, "A Building Block Approach to Mars and Venus Planetary Missions in the 1970's Utilizing a Modular Spacecraft"--was a broad examination into the flexibility achievable by varying Titan staging for various Mars and Venus mission weight requirements. The second--Langley Working Paper 547-- "Study of Titan IIIF/Centaur's Capability to Carry Out a 'Voyager-Type' Mission"--analyzed total Mars mission systems from launch to touchdown and concluded "that the Titan IIIF with a Centaur upper stage provides the performance capability to allow flexibility of mission design and logical growth from a Mars entry probe to a soft landed surface rover." (These Langley Working Papers are included in the Appendix: LWP 483 as V-C and LWP 547 as V-D.)

The actual assignments given to the Langley In-House study group and to the FVSD staff were formidable. To put the problem in the proper perspective, it will be recalled that OSSA had requested Langley to propose a "more modest" program than Voyager. This was taken by the Langley in-house study group, at the start of its study, to mean a mission with much lesser objectives and emphasis was put on studying the following type missions:

(1) Orbiting spacecraft only

(2) Direct entry capsule (probe or hard lander) with flyby spacecraft

(3) Direct entry capsule (probe or hard lander) with orbiting spacecraft.

It was the policy of NASA to utilize launch vehicles from the NASA stable--by developing and retaining the launch vehicle responsibility, NASA could retain control of its programs without dependence on the DOD. With the cancellation of NASA's Saturn 1B/Centaur development, NASA's launch vehicle stable was left with a large performance gap, insofar as appliable to Mars Missions, between the Saturn V and the Atlas Centaur as illustrated by figure V-5; DOD's Titan vehicle, with various staging options, could provide the capabilities shown in the shaded portion. Since the Saturn V mission was now disapproved, Langley's problem was reduced to what type of mission could be performed with the Titan or Atlas/Centaur launch vehicles. Before proceeding, it is well advised, at this point, to review the particulars of the Saturn V mission in order to grasp the magnitude of the problem. Figure V-6 shows a typical Saturn V mission. Of the 68,000 pounds launched toward Mars (53,000 pounds injected), it is noted that only 4,600 pounds of useful payload is landed on Mars after the various shroud, orbiter and heat shield separations together with the propulsions burns for orbit, de-orbit, and landing. Since the Saturn V was to be used to deliver dual spacecraft to Mars, the 4,600 pounds landed weight represents the weight available for two soft landers. Figure V-7 shows to scale the comparison between the Saturn V and the Titan; this comparison gives insight into the meaning of a "more modest" mission and the problem confronting Langley.

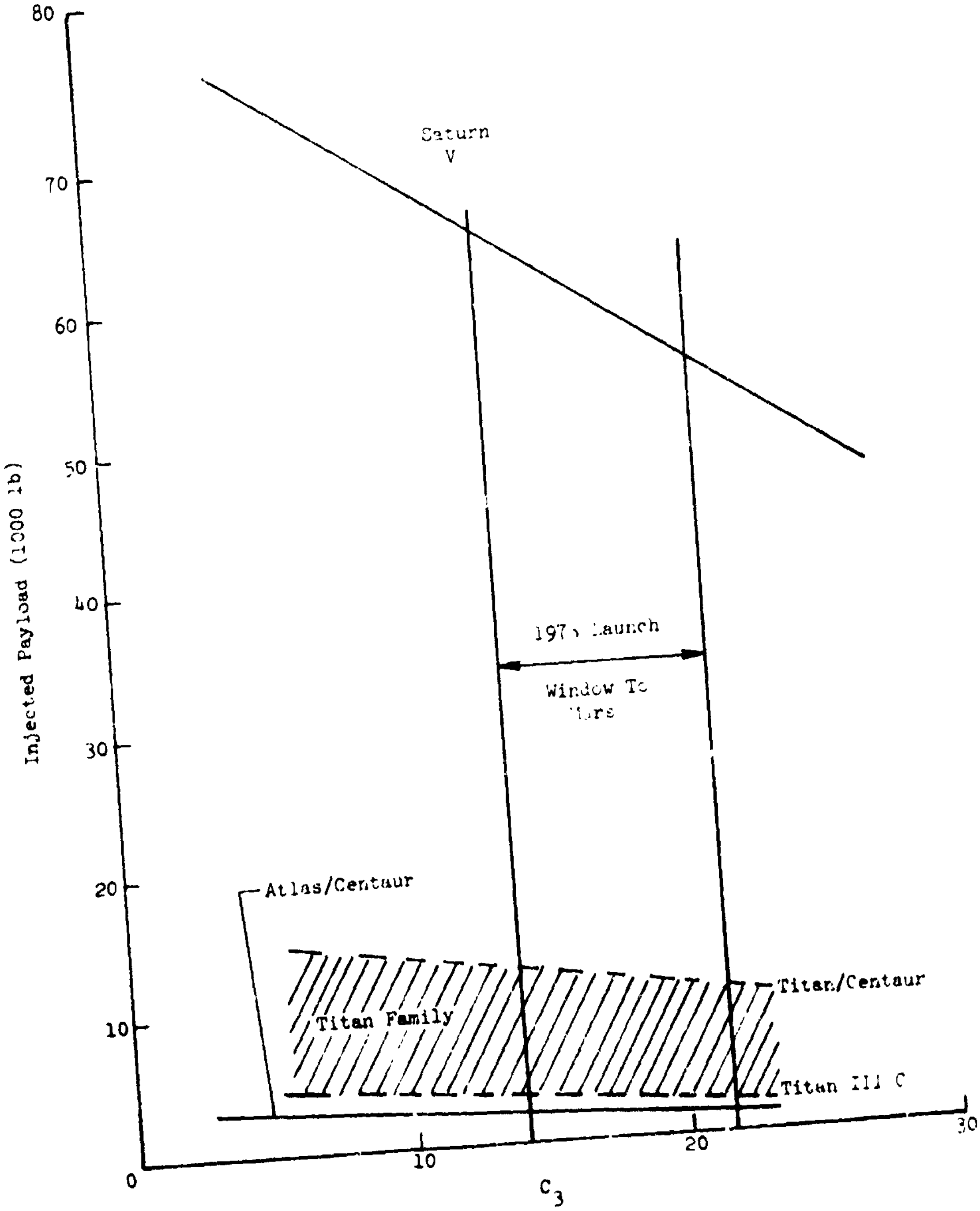


Figure V-5.--Launch vehicle capability comparison.

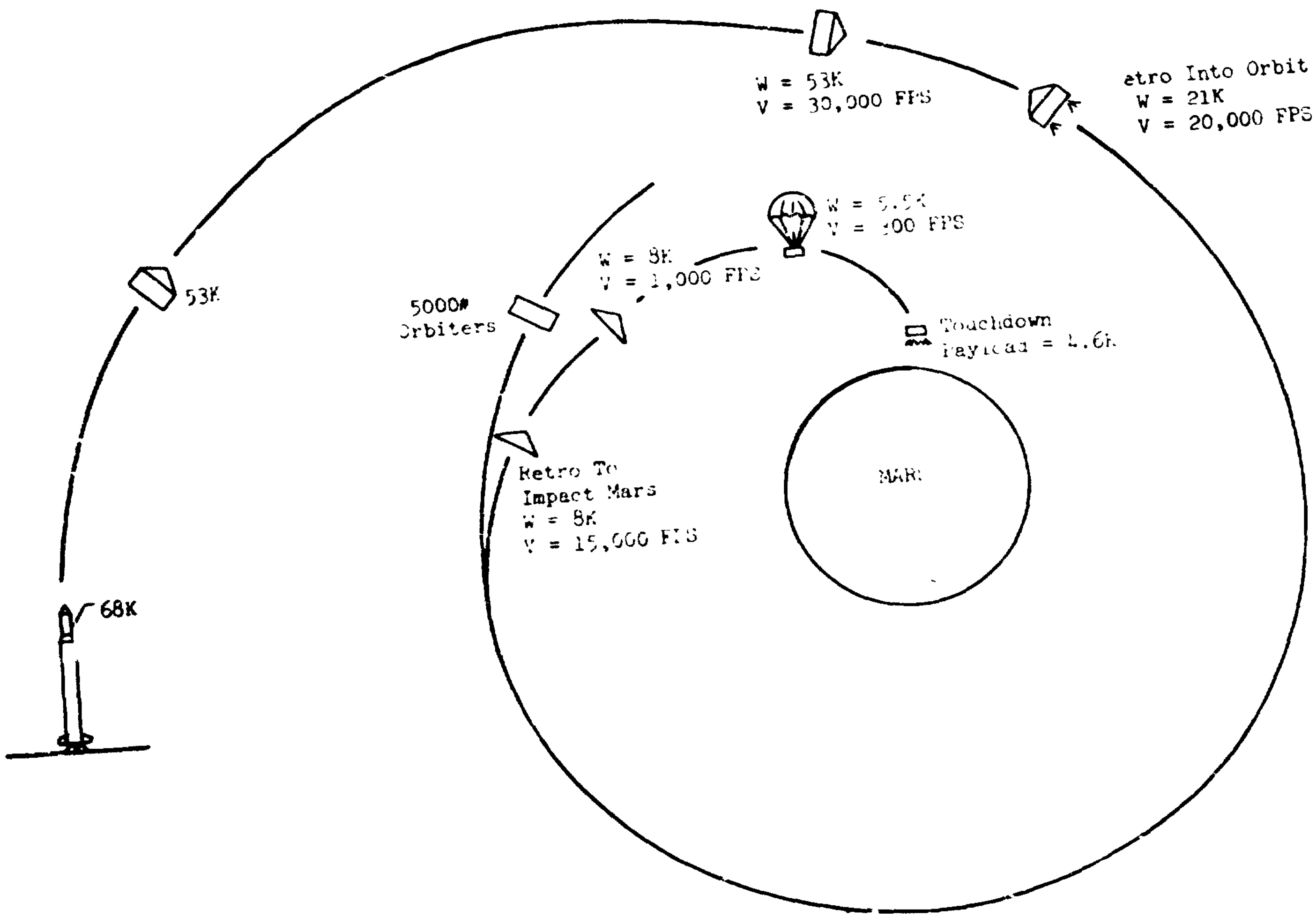


Figure V-6.--Typical Saturn V mission.

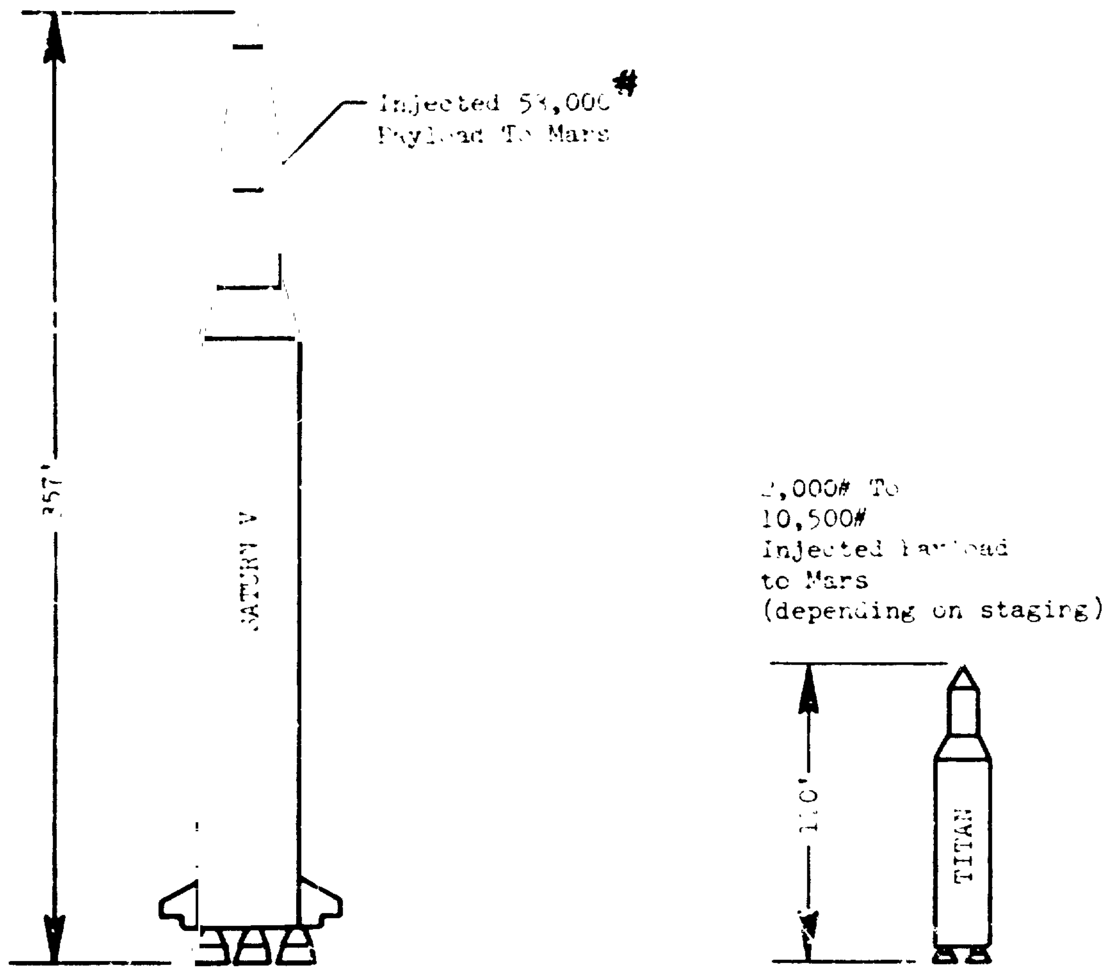


Figure V-7.--Saturn V - Titan comparison.

The problem as defined by the Langley in-house study group is shown schematically on Figure V-8. This block diagram could be considered a mathematical model of the progressions from launch weight to payload weight. For each candidate launch vehicle, there would be (after shroud separation) an injected weight to Mars representing a spacecraft-capsule combination. Three different mission modes are possible for this spacecraft-capsule; the options are:

Option 1--separate the systems while on approach so that the spacecraft flies by Mars while the capsule makes a direct entry.

Option 2--separate the systems on approach so that the capsule makes a direct entry and the spacecraft is orbited about Mars. Another possibility under this option would be to use the entire weight available for an orbiter and have no capsule.

Option 3--Orbit the combination and separate the capsule in orbit for an entry from orbit mode. This was the Saturn V Voyager mission mode.

For each of these options, the payload weight could be determined and compared with the various scientific alternates so as to guide the decision making process. As can be surmised, quantifying the numerous elements represents a major undertaking particularly when such a large group, with many members new to the technology, is involved. For example, the launch vehicle study group, a sub-element of the study team, analyzed the launch vehicle problem. Its

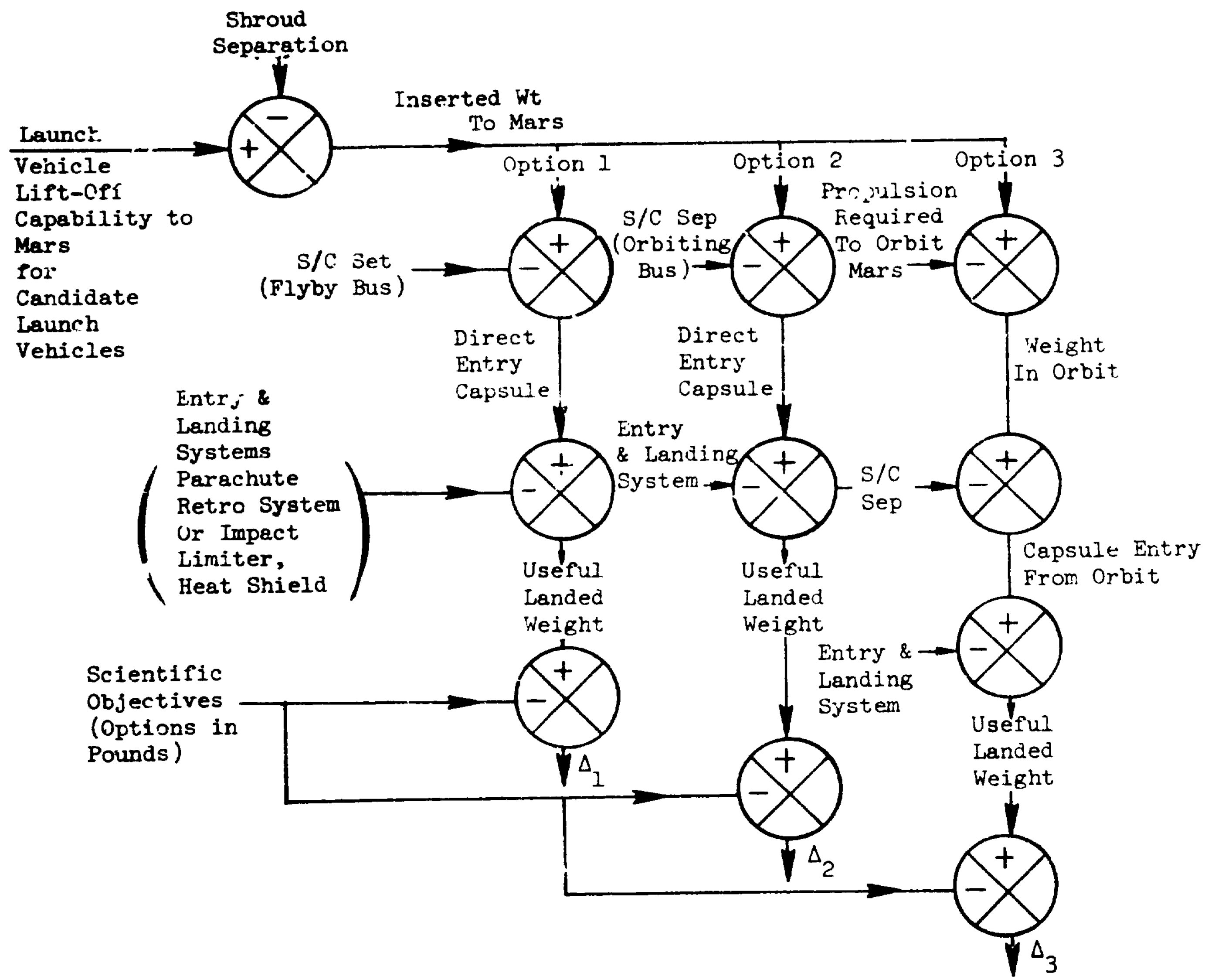


Figure V-8.--Block diagram for Launch Vehicle/Payload Analysis.

recommendation was that Langley "go forward based on use of Atlas/ Centaur providing spacecraft weight could perform scientific objectives. If this were not feasible, then the group recommended use of the Titan IIIC."[8] Two conclusions can be drawn from this recommendation:

1. The group was making a recommendation without knowledge of the mission mode or the required payload (scientific) weight.

2. In accordance with "more modest mission" requirement, the group was emphasizing minimum launch vehicles.

The FVSD staff study group approached the problem differently because of its past experience. Its previous mission mode work had convinced the group that, if the launch vehicle would allow, the best mission mode was to orbit the spacecraft-capsule combination and then release the capsule for an out-of-orbit entry. The staff group then formulated the following technical approach:

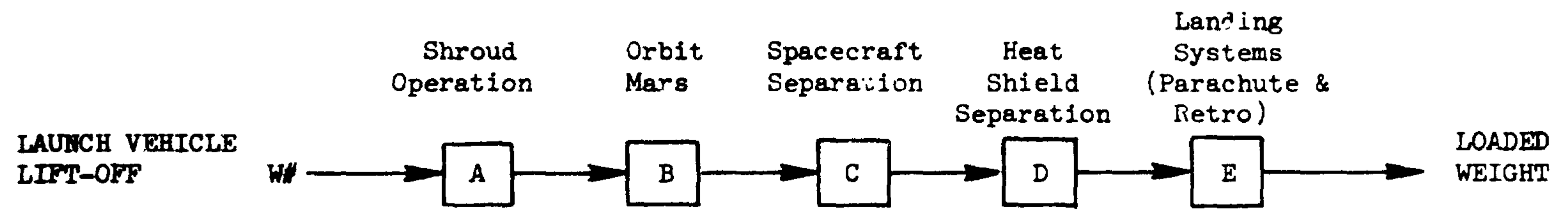
1. Investigate the capability of the vehicle, next smaller to the Saturn V in performance, to perform the out-of-orbit mission mode. This restrained the problem to the Titan/ Centaur which was still "more modest" than the Saturn V.
2. Investigate the problem from a "systems" viewpoint wherein constant feedbacks would be monitored among the launch vehicle, spacecraft and capsule so as to arrive at a unified concept.

[8] Memorandum to Study Manager, Planetary Exploration Missions from LRC Launch Vehicle Study Group, September 29, 1967.

3. Prepare a unique baseline preliminary design of the entire system.

A block diagram model of the systems approach used is given in figure V-9 together with a summary of the results of the final iteration. In block diagram terminology, the factors (A, B, C, D, E) represent multipliers of the input to give the resulting weights at various stage of the mission so that the final output represents the landed weight. While the diagram shows an open loop system without feedback, the process used was to define the factors from actual analysis, run the input through the system, and examine the result. If the result was unacceptable (less than the 1500 pounds required for a soft lander), the factors would be subjected to another analysis cycle with the aim to increase the landed weight. As revealed in the summary results, we were successful in obtaining the 1500 pound landed weight. A 11 percent efficiency $(\frac{\text{output}}{\text{input}})$ was achieved for the Titan/Centaur against 7 percent for Saturn V Voyager, an efficiency increase of 57 percent. This was possible mainly because the staff was familiar with all aspects of the subsystems interactions in order to define the system. For example, the major gains were related to:

1. "loosening" the orbit about Mars so that less propellant would be needed for capture. By making the orbit more elliptical, the orbiter's science would be degraded but the lander objectives could be achieved. This resulted in an increase of the orbit factor (B) from 0.40 to 0.60.
2. reducing the head shield weight factor, working within the



	SATURN V	VOYAGER	TITAN /	CENTAUR
	FACTOR	WEIGHT#	FACTOR	WEIGHT#
Lift-Off		68,000		13,500
A	0.78		0.78	
Inserted to Mars		53,000		10,500
B	0.40		0.60	
In Orbit		21,000		6,300
C	0.38		0.38	
Entry Vehicle		8,000		2,300
D	0.69		0.77	
Suspended on Parachute		5,500		1,800
E	0.84		0.84	
Landed Weight		4,600		1,500
$\frac{\textbf{Landed Wt}}{\textbf{Lift off wt}}$ **= ABCDE**	0.07		0.11	

Figure V-9.--Block diagram of Saturn and Titan system weights.

restraint of keeping the "Voyager" ballistic coefficient constant to ensure the identical satisfactory entry trajectory (M/C_DA = constant), the area (A) of heat shield could be reduced proportionally to the entry mass. After several iterations, it was found that a diameter of 14 feet was compatible with the ballistic number and a landed weight of 1500 pounds; this was a reduction from the 19 foot diameter for Voyager. Since the heat shield weight increases with the linear value cubed, the heat shield weight could be reduced to 40 percent $\left[\left(\frac{14}{19}\right)^3\right]$ of the 19 foot diameter weight; this resulted in an increase of the heat shield separation factor (D) from 0.69 to 0.77.

The result of this engineering systems work was that the FVSD staff provided the technical base which proposed that the much smaller Titan/Centaur could accomplish the Voyager objectives; it would, of course, require two separate launches whereas the Saturn V would have the capability to launch dual spacecraft with one launch.

There are three important points to make regarding the above work which are central to the overall NASA Mars landing effort:

1. For the first time, Langley demonstrated interest and capability in the entire mission from launch. On Voyager, Langley was only involved in the Capsule Bus entry system.
2. The proposal to use a DOD vehicle, the Titan, instead of a vehicle from the NASA stable was a departure from normal NASA operations.

3. The identical mode, identified previously by the Langley staff under Dr. Roberts, for Voyager was adhered to in totality, i.e. out of orbit, parachute, and retro landing.

With the completion of FVSD's staff effort, Mr. Kilgore arranged a meeting at Langley on December 4 under the auspices of the Planetary Missions Technology Steering Committee to be attended by OSSA representatives and all other interested parties--Draley, Nelson, Martin, et al. At the meeting, the FVSD staff reported the data included in the two working papers for the consideration of Langley and OSSA in their deliberations regarding a NASA Mars project.

Langley's In-House Group, in the interim, had produced a Langley Working Paper - "A Study of Orbiter-Probe (Titan III Class) for Mars and Venus Missions for the Purpose of Identifying Problem Areas"--and forwarded it to OSSA. The paper primarily dealt with sub-system options and demonstrated that Langley had a large staff experienced in the various disciplines. A block diagram of how Langley organized to meet OSSA's request for assistance in demonstrating a program is represented in conceptual form as figure V-10. The input, OSSA's request, was directed to the Langley Director who set up a large ad hoc Langley Study Group. Mr. Ed Kilgore, in his line organization position under the Langley Director, set up a parallel effort within his division; the dotted line on figure V-10 represents informal contacts with OSSA. The outputs from the two efforts in terms of Langley Working Papers were transmitted to OSSA; data from the FVSD's staff Working Papers were presented to Langley's Planetary Missions

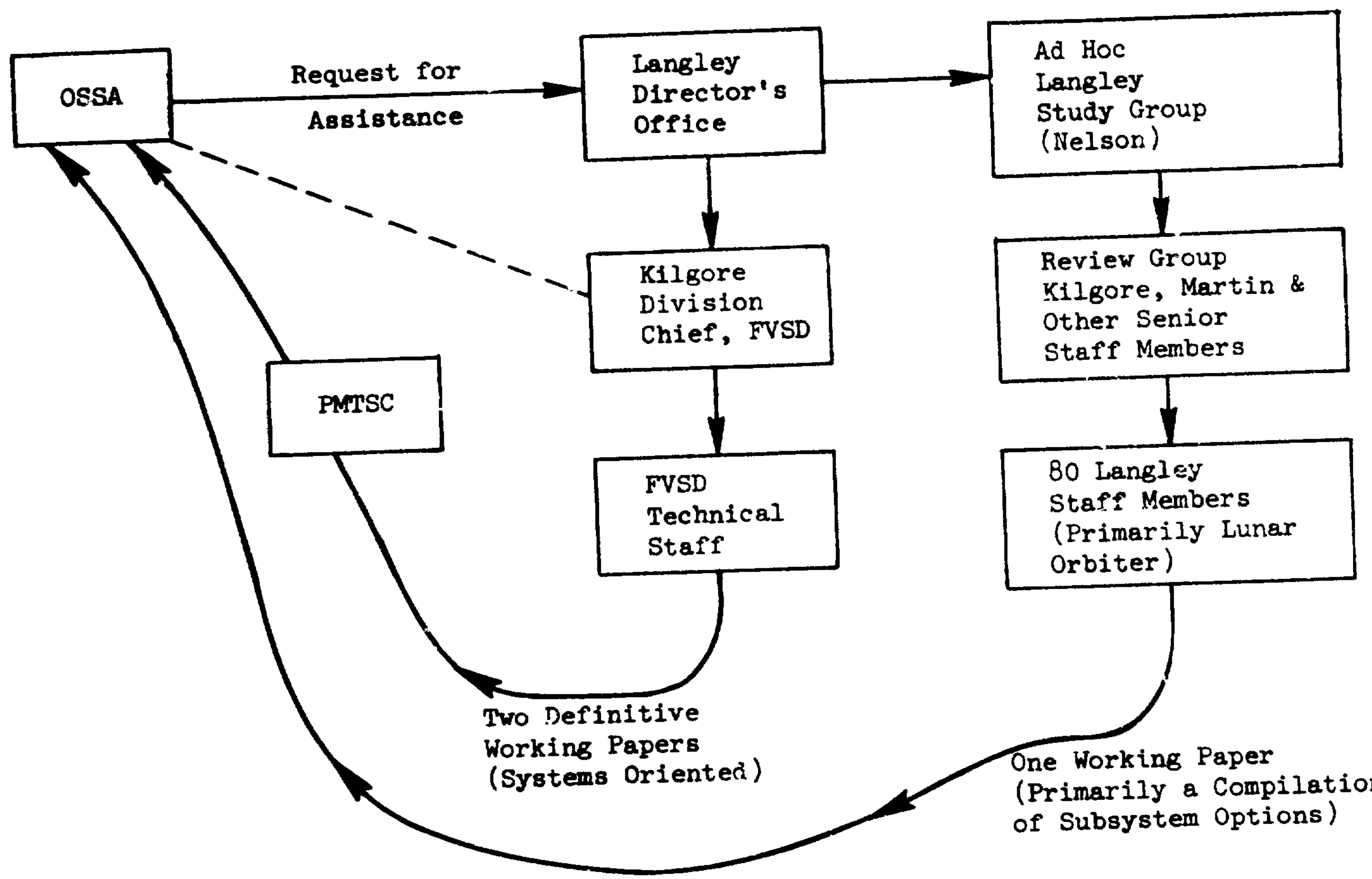


Figure V-10.--Block diagram of Langley study organization, September-December, 1967.

Technology Steering Committee with OSSA representatives in attendance.

While the official organizational arrangement set up at Langley to respond in a technical sense to OSSA's request was cumbersome, it should be noted that Langley did respond in full. The FVSD technical staff could work the problem outside the official structure with Langley's management's approval and present its findings directly to OSSA through the auspices of the Planetary Missions Technology Committee. Least this method of operation appear roundabout and unlikely to succeed, it must be argued that Langley management had relied on this mode with success for many years. It was fully in keeping with the Langley management practices as presented in Chapter I of allowing its staff freedom to pursue its interests and to provide forums for all parties to present their beliefs and data. From Langley's efforts in these studies, OSSA received support in three vital areas:

1. Wholehearted support in the political area by Langley management as evidenced by sincere interest and the assignment of a large Langley staff.
2. Acceptance and enthusiasm of the Lunar Orbiter team to begin working the problem of a Mars landing and, thus, indicate its potential of being a strong force in the future.
3. The definite technical recommendations made by the experienced FVSD staff which allowed progress to be made on a new problem in a short time frame.

Thus, at the year's end, there were groups at Langley, JPL, and in industry--Martin Company, at least--working on the problem and furnishing data and recommendations to OSSA. All options were open: types of science, launch vehicle, mission mode, hard or soft lander The only restraint was cost and that was only qualified ("modest") and not quantified.

Synopsis

A synopsis of the fourth year's effort could be tabulated as indicated below:

1. NASA Headquarters formally organizes Voyager Program with OSSA as project manager utilizing a Voyager Interim Project Office at Pasadena.
2. NASA Headquarters sets up an inter-center Mars Probe Working Group to determine probe concept for 1971 Mariner.
3. Langley appoints a Voyager Capsule Bus Manager and sets up a Voyager Project Office.
4. Congress disapproves both Voyager 1973 and Mariner probe 1971.
5. OSSA requests assistance in defining new program.
6. Langley's technical staff recommends a new program utilizing the Titan/Centaur launch vehicle to OSSA.

CHAPTER VI

VIKING DEFINED AND IMPLEMENTED - 1968/69

Summary

In 1968 there was a revitalized and concerted effort by Headquarters and Langley to define and obtain approval of a new Mars landing program. Langley obtained the services of industry through small study contracts to examine various candidate missions and Headquarters enlisted the support of National Academy of Sciences and Bureau of the Budget. A pivotal meeting was held at Langley in November with senior Headquarters personnel present where all contractors presented their findings and a mission decision was made.

Funding for the new Mars landing program--"Viking"--was approved by Congress. Contract documents for competitive proposals were prepared; the proposals evaluated; and in May, 1969 a contract was awarded by Langley to Martin Marietta as the prime contractor for the mission hardware.

Headquarters Activity (1968)

Dr. John Naugle, Associate Administrator for OSSA, issued guidelines to Langley "relative to studies and planning of potential missions to Mars" on February 12. The telegram, included as Appendix VI-A, stated the following:

1. Launch vehicle to be a Titan/Centaur or Titan IIIC.
2. Program cost estimate = $385,000,000.
3. Baseline mission = "Mariner" type orbiter with 800 pound hard lander.
4. Alternate missions:
    a. hard landers, with or without orbiters, direct entry or out-of-orbit entry.
    b. soft lander, with or without orbiters, direct entry or out-of-orbit entry.
5. Project management will be at Langley.
6. Fiscal year 1969 funding will be $20,000,000.

The principal items to note from the guidelines are (1) Langley will manage the project and (2) mission definition is open to include a wide range of options. The fact that the Titan/Centaur launch vehicle was included as a candidate gave credence that the recommendation of the FVSD's staff was still under consideration despite its highest cost.

In the spring of 1968, NASA Headquarters announced a personnel change which would affect both Langley and the Mars Landing program. Edgar Cortright was named director of Langley, Dr. Floyd Thompson having retired after long service at Langley. Mr. Cortright had been with NACA's Lewis Research Center for 10 years and joined NASA Headquarters soon after NASA was formed where he held high level positions in OSSA and OSMF. Voyager had been under his supervision while he was OSSA's Deputy Administrator, and he was recognized as a strong supporter of a Mars program.

NASA Headquarters also concentrated on mending its political fences during 1968 with regard to its interplanetary program. OSSA sponsored a National Academy of Sciences Summer Program to study and make recommendations regarding NASA's planetary program. The program's final report recommended a "vigorous" planetary program and furnished impetus to carrying out a Mars landing. Since the National Academy of Sciences is made up of authorities in the scientific community, its recommendations receive serious consideration in the Congress. In addition, NASA representatives met regularly with personnel from the Bureau of the Budget to work out a mutual agreement on funding and programs; the solid technical base furnished the needed confidence in NASA's position to obtain BOB's support. Finally Dr. Naugle testified before various Congressional Committees and emphasized the need for the planetary program and NASA's desire to work with Congress in its definition.

Langley Activity (1968)

Langley's effort in 1968 was primarily centered in two groups--Mr. Martin's project office and Mr. Kilgore's engineering division.

Mr. Martin personally was a driving force during this period and his office was a hub of varied activity. The primary function of the office was the gathering, integration and dissemination of data. Work statements were written and contracts let to industry to study the various types of missions. The contracts were let expediously and competently monitored primarily by members of his staff. For example, contracts were let to General Electric to study a hard lander, to McDonnell-Douglas to study a soft lander, and to Martin-Marietta to study the mission mode--direct and out of orbit entry. As a result, the project office obtained a complete documented record on all candidate missions. Mr. Martin also contacted and worked with JPL during this period to obtain JPL's support in the orbiter portion of the mission. Mr. Martin was constantly on travel during 1968--to industry, to JPL, and to Washington Headquarters--to obtain support for the program. It was his office that fed data to Washington Headquarters for its planning and to answer Congressional and BOB's questions; he assured that the program kept moving through his constant contracts with all parties including the scientific community. Mr. Martin has been credited by an industry representative as being the main force keeping a Mars project alive during this period.

Flight Vehicles and Systems Division's technical staff was charged with three responsibilities in 1968 by Mr. Kilgore. These were:

1. Conduct an in-house systems trade study among the options with the objective of advising Mr. Kilgore and Mr. Martin of FVSD's recommendations.
2. Respond to the project office's request for technical data so that the project office could disseminate the data to Headquarters, contractors, and JPL.
3. Monitor and critique the contractors' efforts in their studies to assure that problem areas were exposed and analyzed; in fact, Martin-Marietta's contract for mission mode studies was put under my direct supervision by an agreement between Mr. Martin and Mr. Kilgore.

These three assignments ran concurrently with item 1 being the primary effort. Items 2 and 3 were considered supportive to item 1. The result of FVSD's in-house trade off studies was documented[1] and transmitted to the project office (Appendix VI-B). The study analyzed soft and hard landers, direct and out of orbit entry from viewpoints of cost[2], technology base, risk, and growth potential. The summary chart from the memorandum is shown as figure VI-1. FVSD's technical

[1]Memorandum to Jame S. Martin, Jr. from James F. McNulty, 1973 Mars Mission, November 1, 1968.

[2]Costs for various systems were furnished by the project office from contractor data.

Recommend Titan/Centaur

Soft Lander Out-Of-Orbit

- Best Understood Mission
- Smallest Risk, Flexible in Operational Sense
- Lowest g's for Instrument Development
- Provides Platform for Instrument Deployment
- Less Demanding on Decelerator Systems
- Has Growth Possibilities with Same Technology

BUT

- Highest in Cost

Figure VI-1.--FVSD staff's recommendations and rationale.

staff's recommendatior again favored the out-of-orbit soft landing mission as presented to OSSA in December 1967 unless cost wr : an overriding factor. Martin Marietta Corporation's contract study of mission mode also recommended the out of orbit soft lander; its recommended entry system consisted of:

1. A 10.5 cone shaped entry vehicle with a ballistic number of 0.35.
2. A total flight capsule weight of about 2000 pounds, and 625 pounds of landed equipment.

The study conclusions[3] are contained in Appendix VI-C.

[3] Final Report, Study of Direct versus Orbital Entry for Mars Mission, Volume 0-Summary, Martin-Marietta Corporation, August 1968, pg. 89-90.

The Summary Meeting and Mars Decision

A full scale two week, 6 day a week, meeting was held at Langley October 28 through November 9, 1968 under the chairmanship of James S. Martin, Viking Project Manager to define the Mars Mission. The meeting was attended by the head of OSSA, Washington Headquarters; Center directors from JPL and Langley; and senior staff members at Langley.

The first week was devoted to the contractor's presentations of their final reports together with their recommendations. The second week was closed to contractors and was restricted to internal NASA deliberations. Members of Mr. Martin's Viking Project Office made presentations of their distillation of the contractor reports and pointed up the options available to management. The presentations were unbiased in that no recommendation was made; it was concluded that all options--hard lander, soft lander, direct entry, out-of-orbit entry--were technically feasible and could be engineered. The differences in cost, amount of science data obtainable, technical problems, and risk were defined. The meetings were carried out in an open fashion; many questions were asked from the floor to assure that the problems were understood.

Dr. Naugle, OSSA, and the Center Directors--together with consultants as required--then held a private meeting to deliberate their recommendations to Dr. Paine, NASA Director. It was felt by Langley's technical staff that cost might be an overriding factor and that the direct entry, hard lander mission would be the selection; the absence of absolute knowledge as to "weights" to be assigned to evaluation factors (cost, science, risk, etc.) was the primary reason that Langley did not make a hard recommendation on mission definition. Dr. Paine's decision to go with the most ambitious mission--the soft lander out-of-orbit--came as a distinct, happy surprise to Langley. His sources obviously encouraged him that he would get more support from Congress on Viking than he did on Voyager. Thus, the direction had been set--Langley was now responsible for mounting a Mars mission utilizing the soft lander with out-of-orbit entry. The decision resulting from the meeting reflected an understanding of the salient technical points and was a correct and popular decision from the technical point of view assuring enthusiastic support from the Project Office personnel. This support--together with Mr. Martin's leadership, Mr. Cortright's strong interest and backing, and the developed relationships with Headquarters and JPL--augurred well for the success of the project.

The Commitment to Hardware

Mr. Martin set up the organizational plan shown on figure VI-2. The main elements of this plan are:

1. Lewis Research Center to supply the launch vehicle.
2. JPL to supply the orbiter.
3. Langley to supply the lander and total system integration.

In much the same manner as the Lunar Orbiter Project, a large prime contractor to Langley would be responsible for the actual hardware development with Langley acting as the technical manager. It is interesting to note the differences between the Viking and Voyager management organizations. Where Voyager was complex and multi-tiered, the organizational plan for Viking was simple and straight forward. Responsibility passed directly from OSSA Headquarters to the Langley Director to the Project Manager; all other NASA elements reported to Mr. Martin. Two other factors also contributed to making the Viking plan more operationally stable, these were:

1. Mr. Cortright, as Langley director, could act as a shield against changes in Project guidelines by Headquarters primarily because of his space expertise and his stature with Headquarters personnel.
2. The firm designation of Langley as project manager. It is generally acknowledged that inter-center conflicts arise when there is competition for the lead Center role. The establishing of clear roles for the various Centers increases

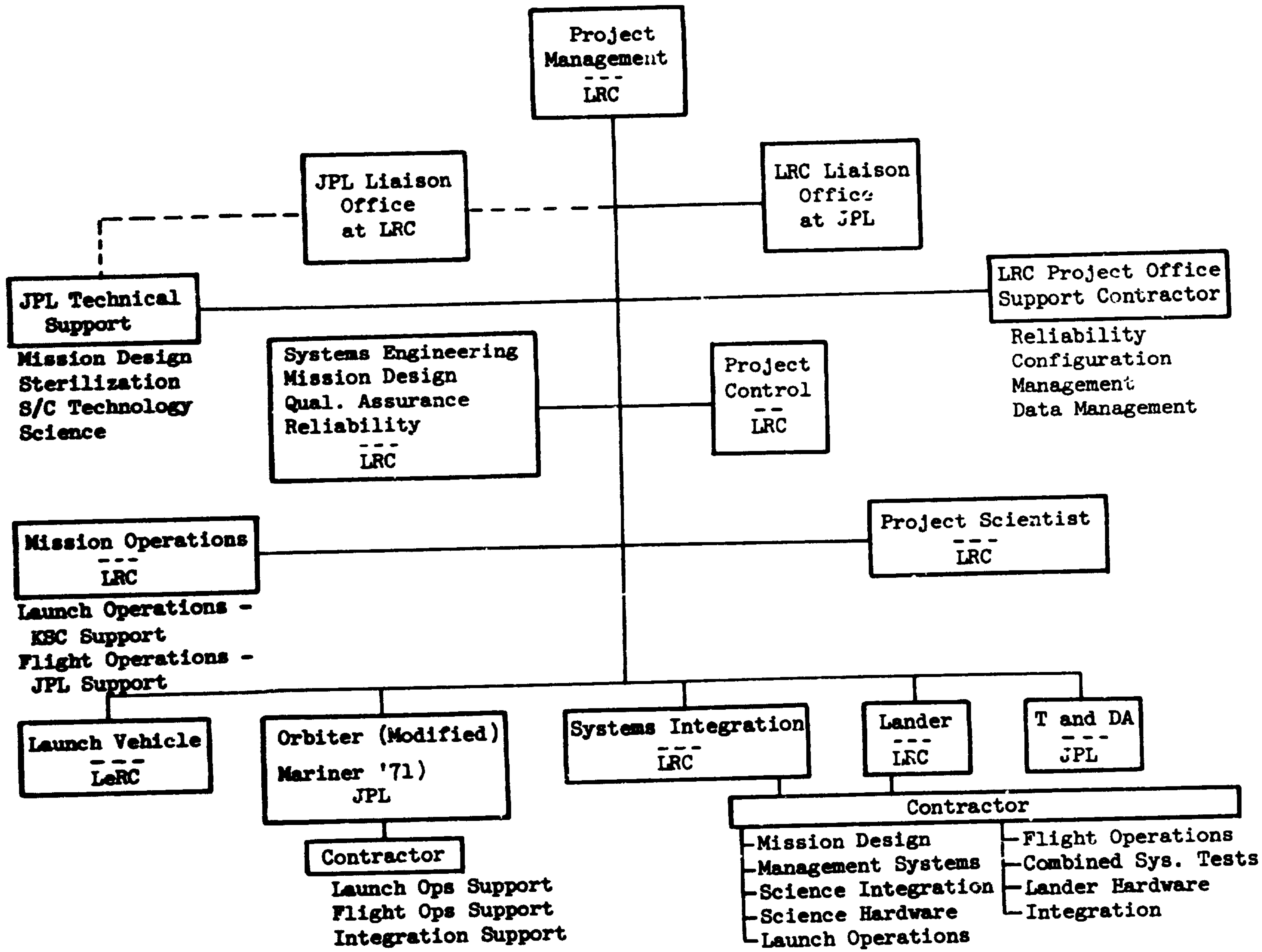


Figure VI-2.--Viking management proposal.

the cooperative aspects and allows all parties to concentrate on their respective responsibilities.

Given the authority to implement the Viking Project, Langley's Project Office proceeded quickly to get the major contract underway. The contract would provide for procuring the lander as well as the integration of the entire system--the build up of the lander with the Government Furnished Equipment (the GFE), the orbiters from JPL and launch vehicles from Lewis Research Laboratory. The technical statement of work (Appendix VI-D) was released for proposals on March 1, 1969. Proposals were received from the Boeing Company, Martin Marietta Corporation, and McDonnell-Douglas Corporation. The proposals were evaluated during April and May by a large group of NASA evaluators (Appendix VI-E). I supported the Management Evaluation Committee and was concerned primarily with evaluating the realism of the schedules submitted by the proposers for implementing the project; i.e., blocks of time designated for mission definition, design, fabrication and test.

Following a review of the findings of the evaluation by Dr. Fletcher, NASA Administrator, Mr. Cortright, Langley Director, announced on May 29, 1973 that Martin-Marietta Corporation would be awarded the major Viking contract. This selection was a reasonable one as Martin Marietta Corporation had been studying the Mars landing problem intensively for an extended period of time. With the award of the approximately 300 million dollar contract (not including launch vehicle and orbiter cost), NASA and the United States were finally firmly committed to carrying out a landing on Mars.

Synopsis

A synopsis of the 1968/1969 effort could be tabulated as indicated below:

1. OSSA issues guidelines that give Langley project manager responsibility for planning potential missions to Mars.
2. Mr. Edgar Cortright named Director of Langley.
3. Langley and industry study of matrix of potential Mars missions.
4. Study results presented to OSSA in a two week meeting at Langley.
5. OSSA approves "big" mission--soft lander with out-of-orbit entry.
6. Langley requests and evaluates proposals; awards contract to Martin Marietta Corporation for mission hardware.

PART II

THE ANALYSIS

CHAPTER VII

INTRODUCTION - TECHNICAL AND ADMINISTRATIVE MILESTONE SUMMARY

Summary

This chapter will delineate the key events, technical and administrative, in the development of the Mars project. These key events will be presented in an integrated milestone format depicting the interactions between the technical work and the administrative decisions. Also included will be a description of the arrangement and approach to be used in the subsequent Analysis chapters.

Technical and Administrative Milestone Summary

It is pertinent now to look at the project from an integrated point of view rather than in the fragmented yearly sequences. Figure VII-1 has been developed to show the important technical and administrative developments in the form of milestones with respect to time; action arrows are provided to detail the impacts of the technological base on administrative decision making and, vice versa, the administrative decisions on the technological base.

The chart divides the years 1964 to 1969 into three phases, each approximately two years long. Phase I was the Saturn 1B Voyager mission with JPL as project manager and Langley a consultant on entry technology. Phase II was Saturn V Voyager mission with OSSA as project manager and Langley the lander manager. Phase III was the Titan Viking mission with Langley the project manager.

The first phase was initiated by Dr. Roberts assembling a multidisciplined Langley staff, with the tacit approval of Langley management, to study Mars entry problems (milestone 1). This staff defined a novel probe concept utilizing a parachute to pull the instrument package from the heat shield--this parachute utilization remained a constant factor in all future refinements and played a highly important role in the program's evolution. Dr. Roberts recommended an in-depth contractor study be made of the concept (milestone 2). This recommendation impacted Langley's and Headquarters' administrative processes and its approval marked Langley's entree into interplanetary studies. Headquarters increased Langley's responsibility by requiring

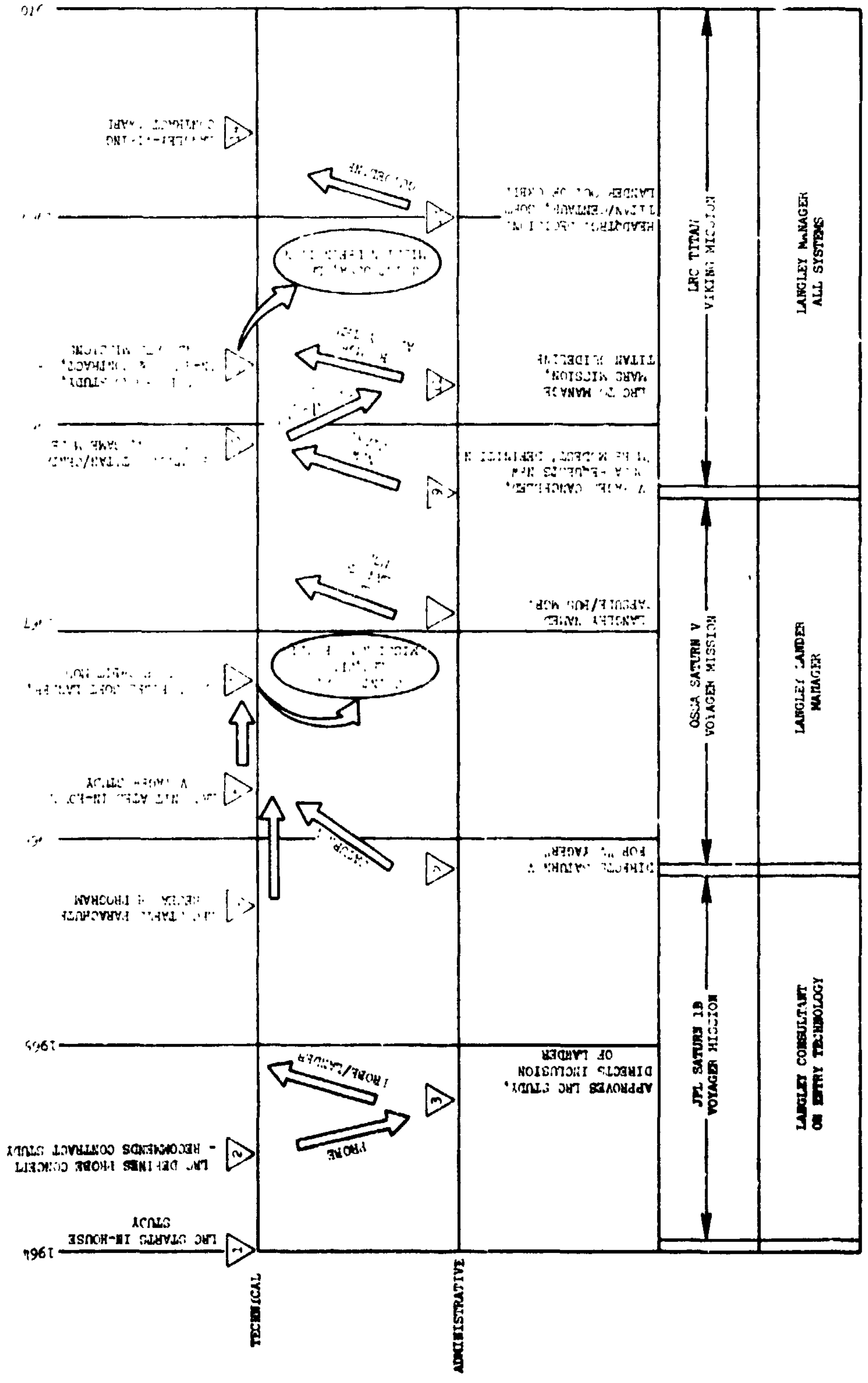


Figure VII-1.--Summary chart of technical-administrative interactions.

the inclusion of lander feasibility in the study. This edict impacted the technical staff by adding a new technology under its charter and further strengthened Langley's position (milestone 3).

Another important milestone during this phase was the initiation by Langley (based on a recommendation from its technical staff) of the development of a parachute suitable for operation in the Martian environment. This undertaking was important since it furnished the data which would later give credence to Langley's recommendations and, in addition, allow sufficient lead time for the parachute's development (milestone 4). Headquarters' direction to switch launch vehicles from the Saturn 1B to the Saturn V (milestone 5)--a change in the mission of more than one order of magnitude--signalled the end of Phase 1.

A Langley technical staff, made up primarily of FVSD personnel and directed by Dr. Roberts, carried out an in-house study of the Saturn V at the behest of Langley management (milestone 6). This study culminated in the definition of a landing mode (soft lander out of orbit with a parachute transition stage and retro landing). These data (milestone 7) were presented by Dr. Roberts and me to OSSA at a joint OSSA-Langley-JPL meeting where JPL presented a counter all-propulsive landing mode. The technical data was considered by OSSA and Langley was named lander manager (milestone 8) which demonstrated the impact of the technological base on administrative decision making. While NASA was gearing up to carry out a Saturn V mission, Congress cancelled "Voyager" owing to the funds squeeze; this ended Phase II.

A request from OSSA to study a "more modest" mission (milestone 9) impacted technological base requiring the technical staff to work to new guidelines. Because of its broad past experience, the FVSD technical staff was able to react quickly and recommend to OSSA a Titan/Centaur mission similar to Voyager in mission mode but more limited in weight (milestone 10). Shortly after receiving this recommendation, OSSA named Langley to manage a study effort of all Mars candidate missions using Titan as a base (milestone 11). Based on this impact, Langley initiated and carried out, in-house and contract, a broad based study of the candidate missions (milestone 12). This effort culminated a large joint technical-administrative meeting at Langley where all technical data was presented in-depth. After this meeting, the administrative decision was made for a Mars landing project (soft lander out of orbit) to be managed by Langley and using the Titan/Centaur (milestone 13). Finally, the project was committed to hardware by the contract award in May 1969 (milestone 14).

Approach to the Analysis

The analysis will be divided into three main categories. The first category will consider the Langley administrative system and the operation of technical staff within it. Formal system concepts will be utilized to illustrate "how" and "why" the system worked to allow its technical staff to make major inputs influencing a national program. The second category will examine the operations of Washington Headquarters as it endeavored to define a national program acceptable to NASA and the Congress. Its decision to promote a Saturn V Voyager mission and its creation of a 1971 Mars Probe Working Group to define a Mariner probe will be analyzed. The third category will be devoted to the final decision process wherein Washington and Langley were in agreement on objectives and the decision was a cooperative one. The alternate missions under consideration will be analyzed from a formal analytical viewpoint.

It is felt that this breakdown into three categories is particularly appropriate since it is consistent with the development of the program. During the first two phases of the program, the Saturn 1B and Saturn V phases as defined on figure VII-1, Langley and Washington acted more or less independently with only intermittent and formal interactions. Thus, during these phases, the operations can be examined somewhat independently. The third phase (Viking) was, however, a close, cooperative effort and can be best examined as a joint administrative-technical system.

CHAPTER VIII

ANALYSIS OF LANGLEY OPERATIONS

Summary

Langley's administrative system and the technical staff's role are analyzed for both the pre-Mars years and the Voyager period of Mars studies. The formal concepts of Easton on political systems, Homan on the technical staff's performance, and Kuhn on scientific breakthroughs are used as a backdrop for the study. Similarities are noted between Houbolt's work on Apollo and Roberts' work on Mars. Conclusions are drawn as to why Houbolt and Roberts were successful in defining the mission modes.

The Pre-Mars Years

Langley Administrative System

Langley's operation in the NACA days was characterized by high research quality and low visibility to the public (independent operation). The individual researcher had great freedom within his field to pursue his research and publish his results which were eagerly awaited by the scientific community. Supervisory positions were relatively small in number and the opportunity to progress up the management ladder was slim. Thus, the researcher who was desirous of more materialistic rewards or fame oftentimes would leave to accept positions with industry, universities, or to serve as a nucleus for a new NACA Center "mothered" by Langley. The system operated successfully because

(1) there was a sufficient supply of dedicated researchers and new graduates to keep the output high in quantity and quality.

(2) there were sufficient openings available elsewhere for a Langley trained researcher to siphon off "ambitious" researchers before they became disgruntled and sufficient in number to cause a stress on the system.

(3) the charter on the technology—aeronautical research—was well defined and understood by the researchers and by management. This restricted the researcher's opportunity to venture into new fields where management might lack expertise.

(4) the system was more or less a closed system in that, not being in the public's eye, it could operate in a near independent mode without being perturbed by outside forces.

Langley management took pride in achieving excellence in technical competence and, also, in its providing leaders to industry, universities and other NACA Centers. To perform excellently and to export leaders could almost be termed a Langley tradition. In my NACA days, I saw many promising engineers leave for want of an advancement that had been earned and that could have been given; it was the unwritten policy of Langley management not to "bargain" with individual employees. Based on the above, it is my conclusion that this attitude enhanced the operation of the system by preventing the system from overloading itself with too many high level researchers for the positions available while at the same time furnishing a channel for cross feeding the technology to the nation. Thus, by taking pride in its export of leaders, it does seem that Langley management found a way of "having its cake and eating it, too."

With the advent of NASA and the increased attention on space activities, Langley management strove to retain its system of operation rather than to make any wholesale reorganization to reflect the change in emphasis. Langley's effort changed from one near total dedication to aeronautics to one primarily devoted to space activities in about a year's time and without any noticeable change in the system's basic operation. To achieve this, Langley management gave up some of its authority to both Washington Headquarters and to the individual researcher. The individual researcher was given more freedom to work outside his aeronautical specialty and the work emphasis was shifted to reflect the desires of Washington Headquarters. The space work was, thus, co-opted into the existing system bringing the researchers with it. As the researchers acquired expertise in space work, they were given additional freedom to pursue their ideas within the system with lesser restraints than in NACA days partially because the top Langley management lacked expertise in space technology and also because the dynamic environment required action. The system continued to work and produce high quality results because

(1) the technical staff had been socialized into the system and could be depended upon to act in conformity with past tradition as much as possible.

(2) the researcher training which had stressed thoroughness and accuracy was most appropriate in the new technology which was emphasizing performance with cost a secondary consideration.

(3) Langley management except at the top level was primarily technical rather than administrative and was, thus, heavily engaged in mastering the new technology.

(4) there was no influx of new experienced space personnel with fixed ideas but rather a shift of work emphasis by most of the Center.

Based on the above reasoning, the significant contributions of Messrs. Houboult and Faget can be attributed to their researcher background of thoroughness and inquisitiveness together with the freedom given the technical staff to broaden its field of interest. The separation from Langley of Faget's group to serve as the nucleus of the Houston's Manned Space Flight Center follows in the Langley tradition and also resulted in Langley still remaining in its status quo position as a research center. Langley management's confidence in its technical staff and its socialization allowed Langley to undertake, at Washington Headquarter's request, the Lunar Orbiter Project and the construction of the Mercury Tracking Station with management's realization that these projects would be competently completed utilizing adjunct technical project offices without serious affecting Langley's normal operational mode. It is important to note that in the Houboult and Faget cases that it was the technical staff who perceived the national need without direction from higher authority (President Eisenhower termed Sputnik a "trick"), went to work on developing a sound technology base, and made a major impact on the direction of the nation's effort.

The Langley management system can be examined on the basis of formal system concepts. Utilizing the concept of Easton[1] wherein the Langley management mode could be considered as the political system, figure VIII-1 from Easton can, thus, be utilized as a model. The analogy seems appropriate and useful. Easton divides his system into environment, inputs, the political system, outputs and feedback loop. The total environment (endogenous and exogenous) furnish the inputs to the political system in the form of demands and support. The

[1]David Easton, A Framework for Political Analysis, (Englewood Cliffs, New Jersey, Prentice-Hall, Inc. 1965)

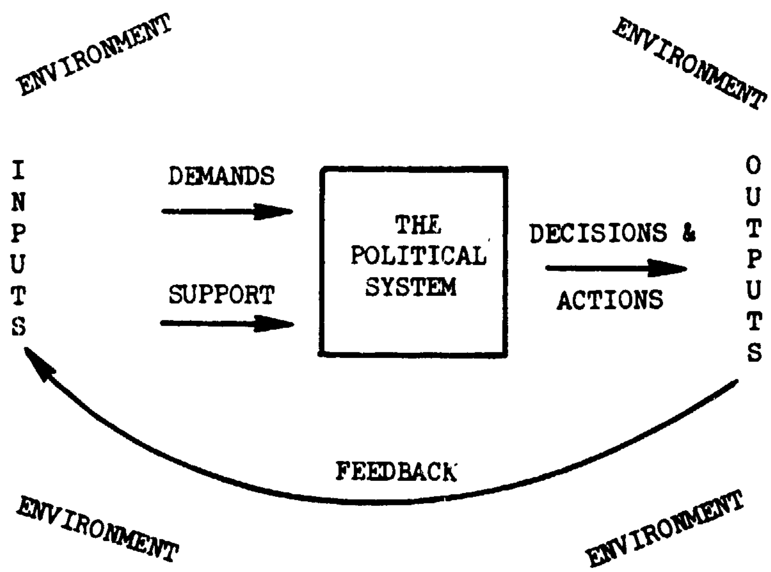


Figure VIII-1.—Model of a political system.

political system is the "black box" within which the process of conversion of the demands to decisions by the authorities take place. The political system has two essential unique elements (1) the capacity to make decisions and (2) the probability of their frequent acceptance by most members as binding. The operational mode of the "black box" will be dependent upon the management philosophy and I have indicated previously the major facets of the LRC management philosophy. The output of the political system is in the form of "authoritative allocations" which then feeds back to the society (Langley researchers) and, thus, affects society's (Langley researchers') demands and supports. The process can be visualized as a continuing exchange of society-government (Langley researchers-Langley management) system responses.

Easton defines "persistence" as the central question for theoretical inquiry by political systems analysis. He states the "members of a political system [LRC management] have the opportunity...to respond to stress in such a way as to try to assure the persistence of some kind of a system for making and executing binding decisions."[2] He proposes the following three conditions as necessary and sufficient for persistency: (1) regulation of the inflow of demands (2) maintenance of a minimum level of support and (3) the adoption of measures to cope with stress.

The response of the "black box" to stress determines what type of change (in the Langley operational mode) takes place. The "black box"

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[2]Ibid., p. 78

is considered to have enough flexibility (normal range) to allow for some changes - i.e., some project or mission concept work is permissible providing the basic research work retains the primary emphasis. For other changes caused by stress driving the system above the normal range, changes in the "black box" are needed to assure persistence, i.e., Langley would have to change its operational mode. The conclusion is evident that Langley management system had proved itself flexible enough through several stressful (not normal) episodes to persist without changing its "black box" operation--the main business of the Center remained basic research and the other elements (while important and performed diligently) were not regarded as normal Center pursuits. Thus, the Langley management successfully remained stable despite (1) changing technologies, and their technical paradigms[3], from aeronautics to space, and (2) including the execution of project missions in its charter. In a sense, it could be said that the fact that the Langley staff had been socialized into operating under the rules of Langley's NACA's administrative paradigm enabled the staff to switch technical paradigms efficiently. It is believed that had Langley's management mode, or paradigm, changed simultaneously with the technical change, considerable more stress would have been applied to the system with counter productive results.

[3]Paradigm—a term used to denote the conceptual umbrella or governing model under which normal science is carried out. In the strictest sense, it is the highest order of conceptual abstraction, a metatheory, upon which theory and conceptual frameworks are based.

The Technical Staff's Role

Given the stability and management methods of Langley, the question now arises of how has the individual researcher or the technical staff made the significant contributions that are a matter of record. To analyze this question, use will be made of the concepts and conclusions of Thomas S. Kuhn[4] in his study of scientific breakthroughs. Some of the concepts to be utilized together with my simplified interpretations are:

paradigm--the accepted or governing model or pattern

puzzle--a problem with a solution within the rules of a paradigm

anomaly--a novelty which does not fit the expectations of the paradigm

extraordinary science--the science proceeding outside the bounds of the paradigm to account for the anomaly

Kuhn's thesis is that science advances mainly through revolutions caused by the study of extraordinary science which overturn the established paradigm, i.e. step function advances rather than the historical concept of a gradual, bit-by-bit addition of scientific data. Interestingly enough, though, he credits normal science (the puzzle solving) as being the main ingredient to extraordinary science in that it uncovers the anomalies which lead to advancement of science by enlarging the concept of the paradigm or overturning it.

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[4]Thomas S. Kuhn, The Structure of Scientific Revolutions, 2nd ed. (Chicago and London: The University of Chicago Press, 1970)

Against this background, the Langley staff can be visualized as problem solvers working the unsolved problems of the governing paradigm and on the alert for anomalies. Because of the novelties uncovered by the Langley staff (slotted throat wind tunnels, "coke" bottle shaped aircraft nacelles, supercritical configured wings, etc.), the Langley management's mode had to be able to cope with both normal and extraordinary science without being perturbed.

The Houbolt episode, described in the narrative, will be examined to illustrate "how" the researcher makes the contribution within the system. Von Braun, since childhood, had been tantalized by space travel and had foreseen the possibility of men to the moon. Further, he visualized a concept of large booster going directly to the moon and returning. After World War II and his involvement with the United States booster research and development, he championed space travel and his concept. With President Kennedy's direction to NASA to land a man on the moon and return him safely in the 1960's, Von Braun, now director of NASA's Marshall Center, put his staff to work to solve the puzzles associated with his governing model (paradigm) of a direct landing on the moon. Meanwhile, Houbolt, not bound by Von Braun's paradigm, worked the problem differently and arrived at the "novelty" of a small ship (LEM) landing and returning to a mother spacecraft orbiting the moon. A striking parallel in reactions to data contrary to the governing paradigm can be drawn between a case cited by Kuhn and the Houbolt episode if Houbolt's solution is viewed as an anomaly to the Von Braun paradigm and an example of extraordinary science.

Kuhn[5] cites a case of a short and controlled exposure of a series of playing cards; the paradigm being that it was a standard deck. "Many of the cards were 'normal', but some were made 'anomalous,' e.g. a red six of spades or a black four of hearts. Each experimental run was constituted by the display of a single card to a single subject in a series of gradually increased exposures... For the normal cards these identifications were usually correct, but the anomalous cards were almost always identified, without apparent hesitation or puzzlement, as normal (consistent with the expectations of the paradigm). The black four of hearts might, for example, be identified as the four of either hearts or spades. With a further increase of exposure to the anomalous cards, subjects did begin to hesitate and to display awareness of the anomaly. Exposed, for example, to the red six of spades, some would say: that's the six of spades, but there's something wrong with it.... Even at forty times the exposure [time] required to recognize normal cards for what they were, more than 10 percent of the anomalous cards were not correctly identified. And the subjects who then failed often experienced acute personal distress...In science, as in the playing card experiment, novelty emerges only with difficulty, manifested by resistance, against a background provided by expectation. Initially, only the anticipated and usual are experienced even under conditions where anomaly is later to be observed. Further acquaintance, however, does result in awareness of something wrong or

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[5] Ibid, p 62-64.

does relate the effect to something that has gone wrong before. That awareness of anomaly opens a period in which conceptual categories are adjusted until the initially anamoulous has become the anticipated."

Compare this with "Sure that he had the answer, Houbolt attended meetings of NASA's moon-shot planning group to promote the lunar-orbit-rendezvous (LOR) scheme. His reception was cool. 'Your figures lie,' shouted one excitable member of the group, 'I don't believe a word of it.' Wernher von Braun, present at the same meeting, dourly shook his head at Houbolt's proposal and said, 'No, that's no good'...Gradually [upon repeated exposures] others began to realize the virtues [accuracies] of Houbolt's scheme. One of the hardest to convince was Werner von Braun. But when he was finally converted to the LOR technique, he became a formidable advocate."[6] In a personal letter to Houbolt, von Braun apologized for his late conversion and attributed his delay in accepting LOR to the fact that he had lived with his direct concept [paradigm] for many years and it influenced his thinking. Another relevant facet of this episode is, that according to Kuhn, "Almost always the men who achieve these fundamental inventions of a new paradigm have been either very young or very new to the field whose paradigm they change."[7] This certainly applies to Dr. Houbolt whose previous work had been in structural mechanics where he was a recognized national authority and this was his initial endeavor into

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[6]"Space", Time, February 28, 1969

[7]Thomas S. Kuhn, The Structure of Scientific Revolutions, 2nd ed. (Chicago and London: The University of Chicago Press, 1970), p. 90

aerospace.

Returning now to the basic question of how the individual researcher or technical staff makes a significant contribution, the general conclusion drawn from the above is that it is through the combination of three elements:

1. the accuracy of his technology base
2. having available forums and channels to present his data
3. perseverance

The Voyager Years

Langley Administrative System

During the years 1964 through 1967, Langley management continued its normal operation mode established in the pre-Mars years. It was supportive of the technical staff's work in mission studies and in research, offered forums for the researcher to present its data, and guarded Langley's traditional responsibility to charter its own course. Until Langley management could see the end of the Lunar Orbiter project in 1967, it restricted its interest in a Mars project to consulting and supporting research. Once it became apparent that the Lunar Orbiter staff would be available, Langley moved to accept entry vehicle hardware responsibility on Voyager, set up a project office, and appoint a manager to interface with other NASA elements. Even then, Langley's management's instructions were firm that Langley should define its own charter for the entry vehicle rather than have its definition edicted by the overall project office. Langley's participation in the Voyager program was compatible with its previous position regarding project participation; i.e., project participation was a positive value provided that research remained the primary emphasis of the Center.

The following actions of Langley management during this period are cited to substantiate the thesis that Langley's management mode was supportive of the technical staff and consistent with its policies of allowing the researcher freedom of action and providing forums for the presentation of data:

(1) Approved Dr. Roberts initiating work in a new technology with a high level competent staff.

(2) Approved Dr. Roberts recommendation for a contractual study of $500,000 and acted as intermediary with Headquarters.

(3) Approved technical staff's recommendation to pursue a parachute research program including the approval of the utilization of the balloon launch technique although the Deputy Director was not convinced that that technical approach was optimum.

(4) Approved a request of Dr. Roberts and the Planetary Missions Technology Steering Committee that Langley study the Saturn V Voyager entry mission mode problem.

(5) Allowed Dr. Roberts to present his findings at a joint Washington Headquarters meeting with OSSA and JPL. Top Langley management attended the meeting evidencing support of technical staff.

(6) Appointed James Martin as manager of Capsule Bus system consistent with Langley's Lunar Orbiter policy of divorcing projects from research activity.

(7) Accepted the technical staff's findings regarding recommendation for allotment of capsule bus weight and assisted in obtaining a revision of JPL's allocated weight distribution.

Technical Staff's Role

The technical staff's role in the Voyager period will be examined in two particulars. First, an analysis will be made of the staff itself during the important initial effort in an attempt to explain the staff's productivity when viewed in the context of Homan's work group behavior model. Second, the staff's success in defining the Voyager mission mode will be analyzed in relation to the concepts of Kuhn.

As detailed in the narrative, the nucleus of the initial effort was a group consisting of Dr. Roberts (Loads Division), Mr. Roger Anderson (Structures Division), Mr. William Mace (Flight Instrumentation Division), and Mr. James McNulty (Flight Vehicles and Systems Division) with direction and assistance from the respective line organizations as required. This group within a period of five months, starting with a very limited knowledge of Mars mission technology, defined a probe concept including conceiving of a parachute to remove the instrument package from the heat shield. This work furnished the basis for Langley entering the Mars missions contractual studies which led eventually to Langley management of the Viking project. The conceptual scheme to be used to examine the group's high productivity is shown in figure VIII-2 and is based on the work of Professor George C. Homans.[8] This concept models the system as four main parts:

[8]Paul R. Lawrence and John A. Seiler, Organizational Behavior and Administration (Homewood, Illinois: Richard D. Irvin, Inc. and the Dorsey Press, 1965), pp. 154-164.

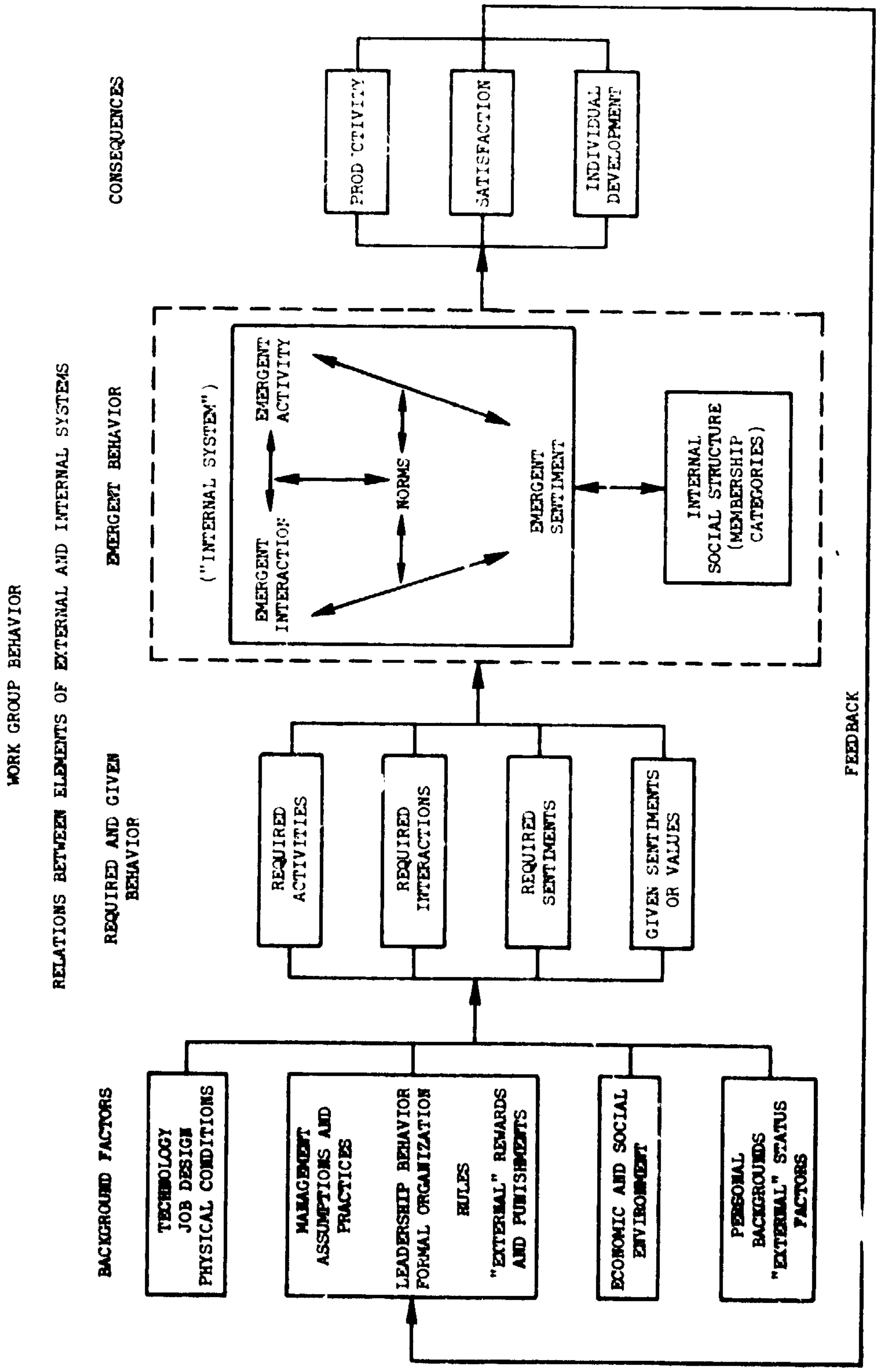

Figure VIII-2.--Homan's work group behavior model.

1. Background Factors: factors over which members of the group have little or no control--personal characteristics and backgrounds, external economic and social infleunces, management policies and practices, the supervisor's behavior, the technology, and the job design.
2. Required and Given Behavior: these are the activities, interactions and sentiments required by individual members of the group to accomplish the task together with the given sentiments which the individual members bring with them.
3. Emergent Behavior: This is the "black box" which is the actual behavior of the group members after the group has adjusted to a work mode. It is to be noted that different groups may determine different work modes for the same task--hence the term "black box" which implies an indefinite or mysterious working which cannot be formalized or directed by management outside the group.
4. Consequences: These are productivity, satisfaction, and individual development which can be used by management to measure the effectiveness of the system. By means of feedback, management can adjust these "consequences" by altering the "background factors" and "the required and given behavior."

In the background factors involving personal, economic and social factors, the members of the group were much the same. Each member had been socialized in the Langley tradition, was a respected researcher or engineer, was approximately the same age, and had demonstrated initiative and conscientiousness on past assignments. In accord with Langley's management assumptions and practices, the group was given nearly free rein to develop the new technology; further, competent leadership behavior and capability resided in the group.

The required activity of the group--to develop a focal point for Langley's activities in the form of a baseline concept--was one that required the interaction of all members. The required sentiments were that the individual researcher's parochial interests (structures, loads, or instrumentation) be set aside for a time while an integrated concept was defined. This caused no conflict with the given sentiments because, regardless of the details of the concept's definition, the output would define many problem areas in all disciplines requiring research programs.

The emergent behavior of the group became one of a solid front where problems were discussed and agreed upon by the group before presenting any results up the line. Dr. Roberts emerged as the unquestioned leader and spokesman to Langley management; he played the lead technical role as well as group's spokesman. Mr. Anderson acted as Dr. Robert's "deputy" and was interested in the overall mission aspects as well as the structural problems. Mr. Mace remained primarily an instrumentation consultant but, nevertheless, cooperated fully and was sympathetic to the group's objectives. From my engineering coordination experience as technical project engineer, I fit the role as an integrator to mesh the disciplinary inputs into realistic engineering designs. In addition to, or because of, my "chief engineer" duties, I also emerged as the focal center for data collection and transmittal; thus, I was relied upon by the group to draft reports, work statements, presentations, etc. In substance, the group's small size and discipline mix could be likened to a "critical mass" in nuclear energy. They were the "necessary and sufficient" conditions to accomplish the task; there were no extraneous elements to divide the responsibility or to drain the staff's energy from its main goal.

The consequences resulting from this emergent behavior was extremely high in terms of production, satisfaction, and individual development. The relationship and work requirements were stimulating and enjoyable. The group members felt they were making a contribution to Langley and NASA and the organization setup was compatible with the requirements of innovative thinking and approaches. The feedback that I received through my line organization was positive in that our group's efforts were recognized to be highly important.

The technical staff work later on the Saturn V Voyager will now be analyzed. As stated previously, the Langley staff could be considered puzzle solvers working on the border of normal science. When Dr. Roberts and the technical staff undertook to study and define a Mars mission mode, there was no Mars mode paradigm existing compared to the Von Braun paradigm for the moon landing mode. JPL had been working on the puzzle for some time, had a concept; the concept, however, had not been fully articulated and was not entrenched sufficiently to qualify as a paradigm. Thus, JPL and Langley were both trying to put the pieces of the puzzle together to obtain a fit of all pieces.

Langley's technical staff's solution to the puzzle was documented as Langley Working Paper 326, "Modal and Conceptual Design Comparisons for the Voyager Capsule," McNulty, Snow and Roberts (Appendix IV-B). The main elements of the mode were a 19-foot heat shield for maximum aerodynamic braking and a parachute performing the dual functions of removing the landing package from the heat shield and furnishing transition braking prior to a retro-propulsion landing.

A forum was arranged in Washington Headquarters for Dr. Roberts to present Langley's findings and for JPL to present its modal recommendation of an all propulsive landing. Both technical staffs were accompanied by their top management. Evidencing our newness into interplanetary study, Dr. Roberts remarked to me on the plane to Washington that he hoped no one would ask him if he ever saw a rocket; I replied, in kind, that if he got cornered, he should switch the subject to soil mechanics and "I'd kill them."

As detailed in the narrative, Dr. Roberts presented Langley's puzzle solution without contradiction. JPL's mode, on the other hand, had three pieces which did not fit the puzzle too well; they were:

(1) a smaller heat shield which did not furnish optimum braking.

(2) the retro firing through ports opening in the heat shield which represented technology beyond the state of the art

(figure IV-7).

(3) the requirement that excess propulsion be carried (reducing payload weight) because of the unknown density of the atmosphere to furnish braking.

Langley's mission mode work was judged sound enough for Langley to be awarded the capsule responsibility.

Further along in the program when the OSSA-JPL guidelines on capsule bus weight allocation threatened to limit the technical staff's position on design specifications, the FVSD staff was able to obtain a revision in project guidelines through an analytical study and push its recommendations through the multi-tiered project organization.

Thus, Langley's technical staff had created a governing model (paradigm) for landing an instrumented package on Mars; normal science could now proceed with the hardware design and development puzzles within that model. As in the Houbolt case, it should be noted that this paradigm development was in keeping with Kuhn's thesis that the pioneering work is achieved by those "either very young or very new to the field."

In summation, we find that the same three elements have combined in the Mars study as they did in the Apollo study to allow emergence of a model. To repeat, they are:

1. the accuracy of the technology base
2. the availability of forums
3. perseverance

CHAPTER IX

HEADQUARTERS' OPERATION IN VOYAGER YEARS

Summary

The chapter analyzes the operational system of Headquarters during the years 1964-1967 when it was attempting to define a major Voyager program. It discusses the factors influencing a decision while Headquarters (OSSA) is lacking adequate resources and a proven technology base. The Saturn V decision is examined analytically by use of a statistical mathematical model and insights into the ineffectiveness of the Mars Probe Working Group are provided through application of Homan's model.

Background Factors

OSSA, Washington Headquarters, relied on JPL to carry out limited interplanetary missions in the pre-Voyager years. Faced with a possible future requirement of mounting a major program to the planets after completion of Apollo, OSSA took a tentative step toward increasing its capability by approving Langley's entree into Mars entry and, later, landing technology. This step, however, was far from sufficient when viewed from the overall NASA program--a machine geared to a yearly budget over six billion dollars and the production of Saturn V's at Marshall. Despite the gathering political clouds described in the narrative, OSSA "bit the bullet" and proposed a Saturn V Voyager mission under OSSA managership and requiring cooperative support from JPL, Langley, and Marshall. Not having the Center resources that OSMF had for Apollo, OSSA realized that a new mode of cooperative effort from varied NASA centers would be required. To further a cooperative spirit among Centers, OSSA set up an inter-Center Mars Probe Working Group to define a probe for the 1971 Mars Mariner. With Langley, an OART Center maintaining its independence and JPL with a capability sufficient only for Mariner type missions, OSSA was in the unenviable position of making independent decisions with a limited data base. Two of its decisions will be analyzed, in retrospect, in the following sections. The Saturn V decision will be examined by constructing a mathematical model of the risks associated with the various mission alternatives available to OSSA in defining the Voyager program in October 1965. The effectiveness of the Mars Probe Working Group will be analyzed in terms of Homan's model for group behavior.

The Saturn V Decision

The situation prior to OSSA's decision to use the Saturn V as the launch vehicle was (1) OSSA had assigned Voyager project responsibility to JPL with Langley providing "support in the area of entry technology," (2) Langley's contract with AVCO was to be used to define the probe lander, and (3) the Saturn 1B and Centaur were to be mated as the launch vehicle. JPL was, at this time, to be responsible for the launch vehicle, orbiting spacecraft, operations, and overall management in the same manner as it had been on the Mariner missions. This existing relationship is shown on figure IX-1. Once the probe lander was defined, the total mission hardware responsibility would become concentrated in OSSA-JPL. This arrangement was reviewed by OSSA in October 1965 when it became evident that the 1971 mission was threatened by a lack of funds to allow the development of the Saturn 1B/Centaur launch vehicle. This, in addition to other factors including the need to define a major program to follow Apollo, required a reassessment by OSSA. These factors, as discussed in the narrative, are indicated on figure IX-2.

A mathematical model can be constructed to represent the probability of carrying out a successful Voyager mission in 1971. In developing the model, Bayesian statistics will be utilized as there is insufficient data to allow the use of classical statistics. Bayesian statistics incorporates the utilization of estimated or conditional probabilities based on previous knowledge and iteration of the process as better data becomes available.

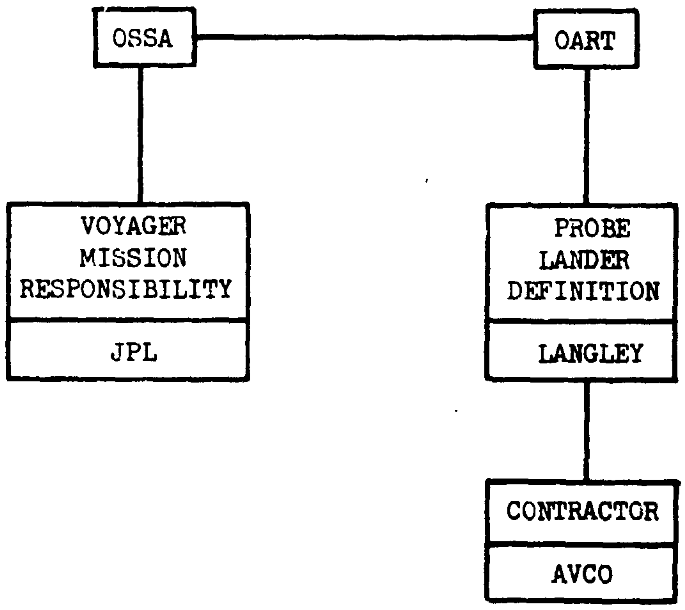

Figure IX-1.--Voyager organization plan (July, 1965).

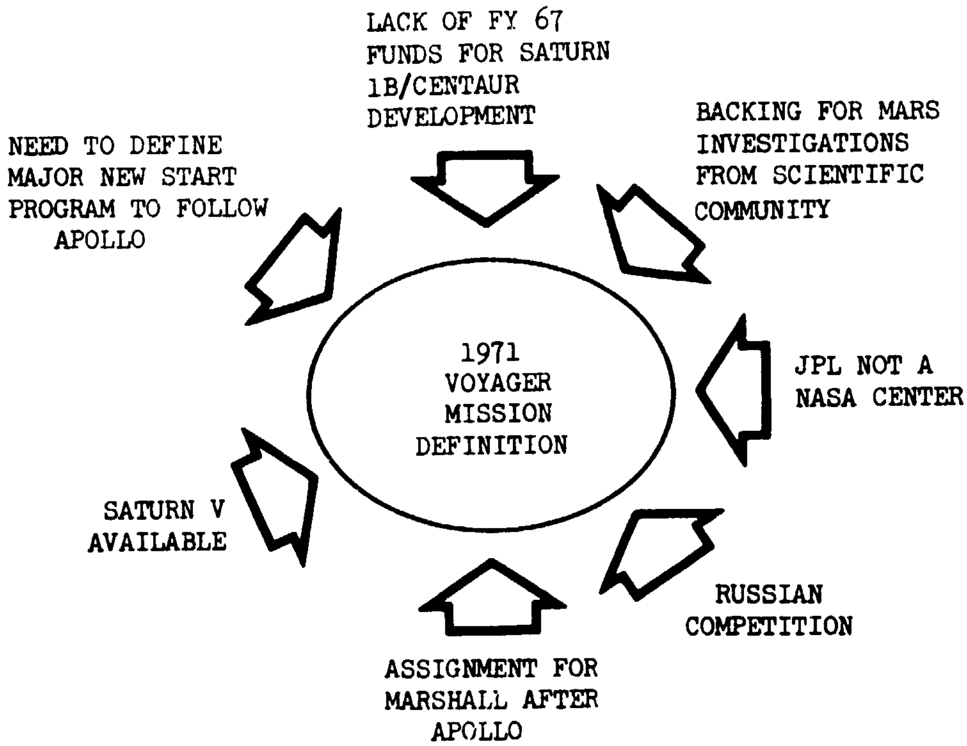

Figure IX-2.--Factors forcing a reassessment of Voyager Definition (October, 1965).

As stated by Tribus "We shall adopt the view that we are engaged in a chain of inductive logic and that at each point where an answer is required we shall report the best inference we can make based upon the evidence available to that point. As new evidence becomes available (which evidence may pertain to the truth of that which we had previously taken as given) we shall use the same procedures to update our inferences as was used in the first place. In this approach, nothing is ever considered to be settled with finality. All that can be said on any particular question is that the evidence is so overwhelming that it doesn't seem worthwhile to pursue the matter any further."[1] As an example, a simplified model to give insight into the problem is developed below:

Let

A = obtaining 1966 funding

B = obtaining sufficient subsequent yearly funding

C = solving the technological problems on schedule

D = defining a satisfactory management organization

X = state of knowledge based on past experience

The probability of a successful mission could be expressed as $p(ABCD|X)$ which is read as the probability based on past experience of obtaining 1966 funding and obtaining sufficient subsequent yearly funding and solving the technological problems on schedule and defining a satisfactory management organization. Expanding by the

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[1]Myron Tribus, Rational Descriptions, Decisions, and Designs (New York, N. Y.: Permamon Press, 1969), p. 26.

product rule, we obtain:

$$p(ABCD|X) = p(A|BCDX)\ p(BCD|X)$$
$$= p(A|BCDX)\ p(B|CDX)\ p(CD|X)$$
$$= p(A|BCDX)\ p(B|CDX)\ p(C|DX)\ p(D|X) \qquad \text{(Equation IX-1)}$$

First, equation IX-1 will be examined for the proposed 1971 Saturn 1B/Centaur mission. It is immediately evident that the schedule for the 1971 mission has zero probability of being successfully followed since the first term $p(A|BCDX)$ is known to be zero owing to the funds squeeze caused by Vietnam, Apollo, etc. However, equation IX-1 can be examined for compressing the schedule and waiting until 1967 funding to start the launch vehicle development. Now $p(A|BCDX)$ has a real number where A equals obtaining 1967 funding. Let us be optimistic and assume $p(A|BCDX) = 0.8$ because expert opinion is that the Vietnam war will be winding down. The second term $p(B|CDX)$--the obtaining of subsequent funding--will be assumed at 0.9 since the program would be an ongoing program gathering momentum and its budget would only be of the order of 200 million dollars per year out of a NASA budget of 6 billion dollars or 3%. The third term $p(C|DX)$--solving the technological problems on schedule--becomes significant. Past experience (X) shows that it took five years to develop the Atlas/Centaur and then there was an additional two and one-years before it was mated successfully with Surveyor. While a learning curve should shorten this interval, the $p(C|DX)$ should be less than 0.5 for shortening the interval to four years; assume $p(C|DX) = 0.33$. The last term $p(D|X)$--defining a satisfactory management organization--should be high based on JPL's Mariner experience (X); assign $p(D|X) = 0.95$. Thus, the estimated probability of a successful 1971 mission (with launch vehicle development delayed to 1967) is:

$$p(ABCD|X) = 0.8 \times 0.9 \times 0.33 \times 0.95$$
$$= 0.226 \text{ or } \underline{25\%}$$

Another alternative to be considered could be the postponing of the 1971 mission to the next launch opportunity in 1973. The funding requirement per year would then be decreased, and the Apollo and Vietnam pressures should be lessened. These factors tend to increase both $p(A|BCDX)$ and $p(B|CDX)$; assume $p(ABCD|X) = 0.9$ and $p(B|CDX) = 0.95$. $p(C|DX)$--the technical and schedule problems--should increase appreciably to about 0.85 and $p(D|X)$ remain unchanged. The probability for a successful 1973 Saturn 1B/Centaur mission would be:

$$p(ABCD|X) = 0.9 \times 0.95 \times 0.85 \times 0.95$$
$$= .69 \text{ or } \underline{70\%}$$

The model will now be used to estimate the probability of carrying out a successful 1971 Saturn V Voyager mission. The probability of obtaining sufficient 1966 funds to start the Voyager program was considered good since the deletion of funds for development of the Saturn 1B/Centaur was felt to be a sufficient reduction to NASA's proposed budget to obtain approval; assume $p(ABCD|X) = 0.75$. The estimation of the other three probabilities is less clear than for

Saturn 1B/Centaur case because of mission unknowns (the problems not previously studied) and that the much greater launch capability allows for a larger and more expensive mission. However, by assuming true ($p=1$) the OSSA guideline that the 1971 test capsule (lander) to be a relatively simple package and landed by subsonic chute only, it is possible to make rational probability estimates; the uncertainty concerning the guideline assumption ($p=1$) then means that the resulting overall probability will be on the optimistic side. The probability of obtaining sufficient funding in subsequent years $p(B|CDX)$ is influenced by two counter-acting forces, the inertia tending to increase the probability and the larger funding requirements for a Saturn V launch decreasing the probability because of its visibility and larger percentage of the NASA budget. Thus, it is estimated that $p(B|CDX)$ will remain at 0.75. The probability of solving the technical problems on schedule is estimated to be less than for the Saturn 1B/ Centaur mission simply because the problems have not been as deeply studied or defined; set $p(B|CDX)$ at 0.8. The defining of a satisfactory management organization becomes complicated with the addition of the Office of Space Manned Flight's (OSMF) Marshall Center to supply the Saturn V. The management organization, then in process, is shown in figure IX-3 and it is doubtful that JPL could exercise sufficient project control over Marshall; thus, some, as yet undefined, changes would be required. The project utilization of centers from three different Washington Offices would be a novel undertaking and require new management techniques; assume $p(D|X) =$

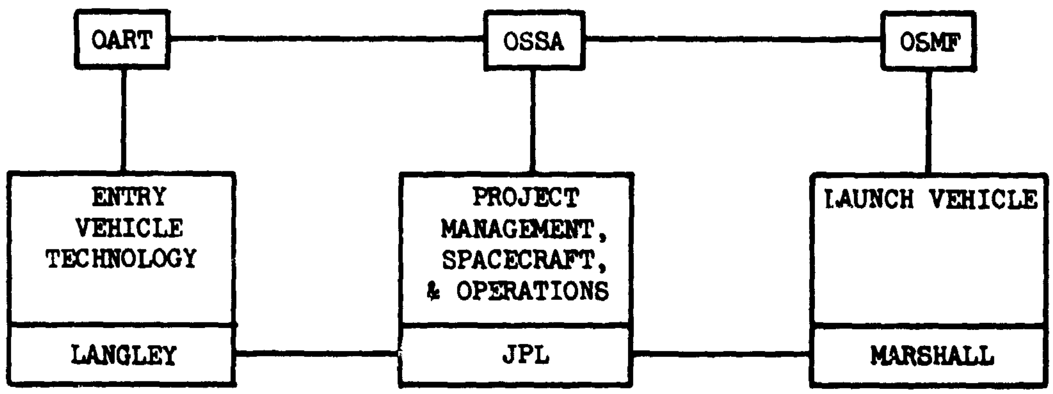

Figure IX-3.--Voyager organization plan (October, 1965).

0.67. The probability of achieving a successful 1971 Voyager Saturn V mission would be:

$$p(ABCD|X) = 0.75 \times 0.75 \times 0.80 \times 0.67$$
$$= .30 \text{ or } \underline{30\%}$$

A summary of these results are shown in matrix form below:

	p(A|BCDX) 1966 Funds	p(B|CDX) 1967-1971 Funds	p(C|DX) Technology	p(D|X) Management	p(ABCD|X) Mission Success
1971 Saturn 1B (1966 Start)	0	--	--	--	0
1971 Saturn 1B (1967 Start)	0.80	0.90	0.33	0.95	25%
1973 Saturn 1B (1967 Start)	0.90	0.95	0.85	0.95	70%
1971 Saturn V (1966 Start)	0.75	0.75	0.80	0.67	30%

An analysis of these data indicates the following:

1. A 1971 Saturn 1B mission (with a delay of one year in obtaining vehicle development funds) had only a 25% chance of mission success. The main factor in this low probability was the liklihood of solving the technical problems in the compressed time schedule.

2. Postponing the Saturn 1B mission to 1973 increased the probability of success to 70%.

3. Switching to the developed Saturn V for the 1971 mission only increased 1971 mission success probability to 30% from 25%. This was because the technology probability gain in changing to a developed launch vehicle was balanced, more or less, by an organizational complexity unique to NASA's experience which increased the uncertainty.

Headquarters, thus, had a choice among alternatives--a 1971 mission (Saturn 1B or Saturn V) with only 25-30% probability of success or a 1973 Saturn 1B mission with a 70% probability. It would appear likely that Headquarters would forego the 1971 mission and decide on the 1973 Saturn 1B mission; this conclusion, however, neglects other important factors influencing the decision. These factors, as mentioned previously are:

1. The need was great to define a new major program to follow Apollo. The overall "climate" at the time was such that NASA was expected to go on to greater things--exploration of the planets, space stations, lunar colonies, etc.

2. Of possible follow-on program alternatives, the science community favored a Mars program. "In October 1964, the Space Science Board of the National Academy of Sciences recommended that unmanned exploration of the planet Mars involving both physical and biological investigations, and expressly the search for extraterrestrial life, be made the primary objective of the nation's space effort in the decade following Project Apollo."[2]

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[2]Donald P. Hearth, "Voyager," Astronautics and Aeronautics, Vol. 3 No. 5, May 1965, p. 16.

3. The long lead time necessary from program initiation to execution required that a decision be made.

Thus, the utility value of a major program may well have been the major factor in the selection of Saturn V mission. It is also likely that OSSA considered data not available at the technical level regarding funding and management in its decision making process. However, as indicated by the low probabilities in the analysis, it appears that OSSA did not have a sufficient data base to ensure that the mission was viable.

Following the Saturn V decision, OSSA set up the Interim Project Office at Pasadena where it could rely on JPL for staff functions because of the limited resources available to OSSA. Again, while the organization (management committee, working groups, and panels) was complicated, the problem of managing and unifying diverse Centers from coast to coast required a new approach. Further, in the one case--that of allocating weights for the Capsule Bus described in the narrative--the organizational system was responsive to pressure from the technical staff in its decision making process. It is unknown whether the organizational arrangements would have proved viable in the long run. Opinions vary on this subject among those who were participating in the Voyager effort. Some felt that the organization was unwieldly and that overall project managment would be designated eventually to a Center--probably Marshall when it got familiar with the project. Others were encouraged with the way the Centers were cooperating at the technical staff levels and felt that once the system interfaces were agreed upon that the actual work could be carried out efficiently.

With regard to the Voyager cancellation, it is apparent that NASA Headquarters failed to evaluate correctly the political factors. The further lack of appreciation of the sensitivity of the OSMF procurement release for a manned Mars study (described in the Narrative) indicated the omission of an overall coordinated plan. Finally, when Voyager was cancelled, NASA Headquarters had not made any contingency plans and was left without a planetary program of any type. NASA's lack of expertise in this political area can be explained by the fact that it was a new agency created primarily to carry out a technical mission, Apollo, which did not require "marketing." However, with Apollo coming to a conclusion and the fiscal pressure building for social programs, NASA could have realized that NASA's operation was changing and given more emphasis to factors other than technical.

The Probe Working Group Experiment

The objectives of the Probe Working Group (PWG), as expressed by OSSA, were to obtain the definition of a 1971 Mars Mariner Probe and to promote inter-Center working relationships by including Center participation in the decision making process. As discussed in the narrative, the concept did not prove viable in the promotion of inter-Center cooperation. No favorable group sentiments evolved; from start to end, there were five separate factions--OSSA, JPL, Ames, Goddard and Langley. An examination of Homan's model (figure VIII-2) would have given indications that the PWG exercise would result in failure in this instance. For example, the following elements can be noted:

1. The Job Design was not clear. Was it a scientific job, an instrument job, or an engineering job? If all three, the time was too constrained to meet the objective.
2. The Physical Conditions were such that group sentiments could not develop--a large conference room with the various camps grouped together. In addition, the number of people were excessive--typically, six from OSSA, three from Ames, four from Goddard, five from JPL, and one from Langley; it was not unusual for over 30 people to be in attendance including experimenters.
3. The Social Environment was non-existent. The individual members, except for their own group, met only in the conference room.

4. In External Rewards and Punishments, the Center representatives, with the possible exception of JPL, were not beholden to OSSA but were dependent upon their own Center. In addition, OSSA managed the meetings in an authoritarian manner--with OSSA as a self designated leader; however, it is doubtful that any management behavior could have succeeded under the circumstances.

For an effort similar to the PWG to succeed, careful planning is essential. It is suggested that the following elements be considered:

1. Breaking up the group into teams
   (a) a scientific team to define the objectives
   (b) an instrument team to define the instruments
   (c) an engineering team to define the hardware and its development
2. Allowing each team to select its leader and do the job in its own way with OSSA staying in the background.
3. Keeping the teams together for a sufficient period of time to develop group sentiments--perhaps, a "retreat" type of work shop.

CHAPTER X

TECHNICAL-ADMINISTRATIVE INTEGRATION, THE VIKING YEARS

Summary

This chapter examines the means by which NASA "put it all together" to culminate all the previous work and define a Mars landing project. Topics will include the definition of objectives mutually satisfactory to the technical and administrative staffs, the technical and administrative efforts performed to obtain the necessary data for a decision, and the Viking decision. An analytical model will be presented to examine the "pay-off" associated with the various mission options and its correlation with the final decision will be analyzed.

The Uniting of Technical and Administrative Objectives

This section will examine how and why the technical and administrative factions became united in an approach to defining the Mars landing project. As will be recalled, OSSA requested assistance in defining a more "modest" Mars mission after the cancellation and Langley responded with full cooperation.

The Technical Staff's Role

The FVSD staff, given the freedom to pursue its concepts independent of Langley's mainline effort, derived a new model for the entire system, launch to landing, which utilized a new launch vehicle, the Titan/Centaur, in conjunction with the Robert's paradigm for the entry and landing mode. This was Langley's first attempt at solving the entire system mission puzzle; the solution was achieved within three months and documented as Langley Working Paper 547, "Study of Titan III F/Centaur's Capability to Carry Out a 'Voyager Type' Mission," Snow, McNulty, Carmines, and Falk. Again, a forum was arranged by Mr. Kilgore and Langley management where the findings of this small group could be presented directly to OSSA personnel by the technical staff personnel almost as Houbolt phrased it, in his case, "as a voice in the wilderness." The FVSD staff was able to make this contribution in such an effective manner because of the following elements:

(1) a highly motivated small team experienced in the technology.

FVSD staff had experience with the total system concept through studies of Venus missions.

(2) a well defined puzzle--largest possible mission without Saturn V.

(3) effective leadership by Mr. Kilgore, FVSD Division Chief, who filled the group's management role left void by Dr. Robert's departure.

Mr. Martin's technical staff, hindered by an ill-defined puzzle and too many participants, were working effectively in sub-system areas and demonstrating their ability to transfer their Lunar Orbiter technology to Mars applications. Their study of broader missions carried out with total dedication indicated their readiness to assume and carry out any project responsibility assigned to Langley.

Langley Management's Role

For the first time in the Mars program Langley management entered into a new policy of full cooperation with Headquarters on the definition of a more "modest" mission. A large staff was assigned by the Director to work on the problem and channels were furnished to Mr. Martin and Mr. Kilgore to present findings to OSSA. The evidence indicated that Langley management believed that a more "modest" mission would be within Langley's resources and mode of operation. Thus, the objectives of NASA management and Washington Headquarters coincided on the need to define and carry out a national Mars landing project.

The Union of Washington Headquarters and Langley

Two months after FVSD's presentation to OSSA, OSSA announced that Langley would be manager of a comprehensive contractual study effort of various mission options to Mars with all data to be obtained in about ten months. Some general OSSA guidelines, detailed in the Narrative, were included but near absolute technical responsibility was given to Langley on procurements and mode of operation. This action negated any competition between Centers and allowed the technical work to proceed without interruption or change in guidelines and, thus, obtain the necessary technical data. It further freed Headquarters from the technical area so it could concentrate on the political aspects--obtaining support from the scientific community, Bureau of the Budget, and Congress. Thus, responsibilities were set so that administrative and technical studies could proceed in a rational, methodical manner toward an end point.

Langley took the necessary steps to fulfill its responsibilities. Langley management gave full support to the project. It created a Viking Project Office under James Martin reporting at the Director level and supported the office in its dealings with Headquarters and in contractual procurements (studies and mission hardware). The Viking Project Office coordinated the mission planning by contracting various mission option studies to industry, working with JPL on spacecraft definition, and serving as a hub in data transmission to Headquarters. FVSD's technical staff served as a technical consultant to the Viking Project Office and continued to study and evaluate the various mission mode options. The results of its independent in-house studies on the relative merits of the options were documented and forwarded to the Project Office for consideration.

Headquarters, meanwhile, conducted a study of the political environment--obtaining and developing support from the scientific community, Bureau of the Budget, and Congress. Thus, near the end of 1968, all the pieces of the puzzle--technical and administrative--had been collected so as to determine a fit. It was the first time in the Mars program that there was technical and administrative agreement on the definition (not the solution as yet) of the puzzle.

The main determinants in obtaining sufficient data for the mission solution (answer to the puzzle) are judged to be:

(1) OSSA assigning full technical responsibility to one Center under broad guidelines which remain firm throughout the data collection period.

(2) Langley's management's full political support to OSSA, i.e., common objectives.

(3) The Viking Office's dedicated effort to obtain the technical data, i.e., team self motivated.

(4) OSSA emphasizing obtaining political support, i.e. getting a good sense of the political environment.

The Viking Decision

Once the pieces had been assembled, an innovative concept was used to assure that the technical data was communicated correctly to the decision makers. This concept was the two week meeting described in-depth in the Narrative, where various mission alternatives were detailed by contractors and NASA personnel. These options can be examined analytically by using a "utility" concept in a decision tree format to illustrate the problem which was facing NASA management.

Figure X-1 defines the major options presented to NASA management at the summary meeting. The lander options are based primarily on the choice of launch vehicle. The smaller Titan IIIC vehicle will allow either an orbiting spacecraft with a 200 pound atmospheric probe or a flyby spacecraft with a 1100 pound direct entry lander. The Titan/Centaur vehicle has sufficient capability to allow an orbiting spacecraft with a 1500 pound out of orbit lander. Costs for the various elements, total mission costs, and the mission science capability are also shown on the figure. It should be noted that option 3 (Titan IIIC, flyby spacecraft, and direct entry hard lander) most closely approximates the OSSA guidelines for cost and mission objectives.

An analytical procedure will now be developed to obtain a relative utility value per cost unit for the various options. It is first necessary to subjectively assign utility (U_i) to the scientific data obtainable for the various option missions. The following utility

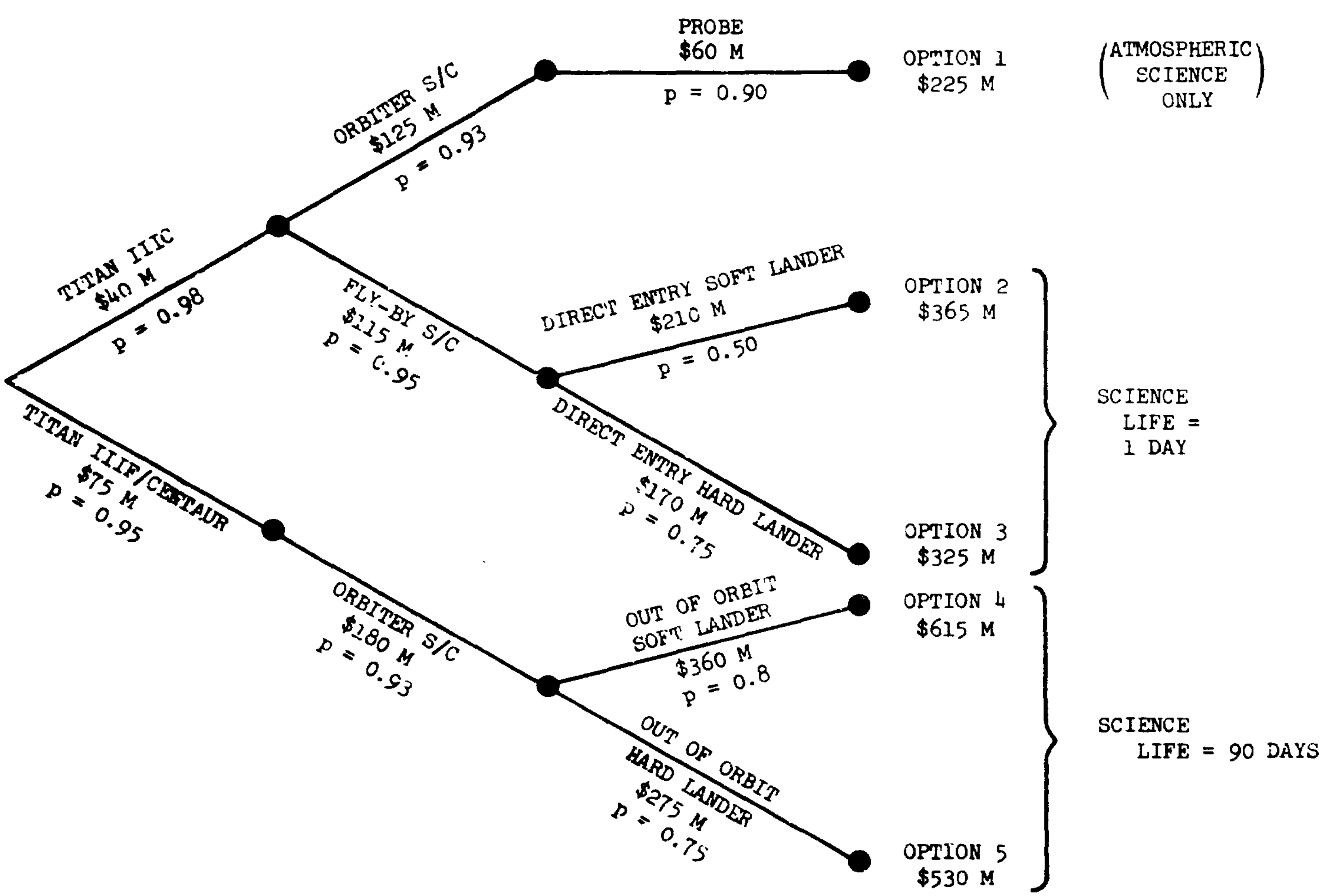

Figure X-1.--Decision tree options for Viking project.

values are assigned:

$U_1 = 100$

$U_2 = 500$

$U_3 = 500$

$U_4 = 2000$

$U_5 = 2000$

The rationale for these assignments is as follows:

The science for option 1 is only atmospheric data. This data is already known to some extent from indirect measurements from Earth and from orbiting spacecraft and the new data would only increase the accuracy and confidence level. In addition, it is felt that the mission would not be considered worthwhile by the general public. The value of 100 is assigned as a baseline measure.

The science for options 2 and 3 would include landed data but would be limited by the one day operation of the batteries. The total communication capability could be taken up by the transmission of a panoramic TV picture of the Martian planet; in any event, the time would be too limited to allow, for example, sophisticated instruments to take soil samples, analyze the sample, and transmit the data to Earth. The pictures of the Mars surface might well interest the general public in addition to providing the scientists with new data to analyze. A factor of 5 was applied to the U_1 baseline value.

The science for options 4 and 5 contains TV pictures in addition to sophisticated measurements taken on the Martian surface for an extended period of time. Expected data would include sufficient information for scientists to judge whether conditions are favorable on Mars to allow for any lifeforms to exist. The utility value for this data package was estimated to be four times that of the short landed mission.

The corresponding estimated required funding (F_i) in millions of dollars for the mission options are as follows:

$$F_1 = \$225$$

$$F_2 = \$365$$

$$F_3 = \$325$$

$$F_4 = \$615$$

$$F_5 = \$530$$

Lander and orbiter costs are taken from Viking Project Office document entitled "Discussion of Mars '73 Mission Baseline and Alternatives" dated February 12, 1968. Launch vehicle costs are taken from General Electric Corporation's final report "Direct versus Orbital Entry for Mars Mission" dated August 1, 1968.

In order to develop the utility value per cost unit, it is necessary that probabilities be assigned for each mission option. These probabilities are shown on figure VI-3 and their rationale is discussed below:

A_i: launch vehicles

Titan IIIC is proven launch vehicle; p = 0.98. Titan/Centaur mating does not appear to be problem and, in addition, will be flight tested prior to Mars' launch; p = 0.95.

B_i: spacecraft

Mariner orbiters have been successfully demonstrated; p = 0.93. Fly-by spacecraft would have slightly better reliability since orbit propulsion burn would not be required; p = 0.95.

C_i: landers or pro'e

Probe mission from out of orbit would be the simplest mission. Low ballistic number and low entry angle would minimize loads and allow use of subsonic parachute; p = 0.90.

Direct entry soft lander would be the hardest mission. High entry angle would challenge the terminal stage technology to safely effect a landing; p = 0.50.

Direct entry hard lander would have similar entry loading and deceleration problems but could be designed to take high impact loading; p = 0.75.

Soft lander out of orbit is well understood but environment is extremely demanding on terminal stage design; p = 0.8.

Hard lander out of orbit presents less demands on terminal entry technology but technology is not understood on how to orient the impact ball at the landing, remove impact attenuation material from ball, open ball, and deploy instruments; p = 0.75.

The expected utility per million dollars for each option can be expressed as:

$$\left\langle \frac{U_i}{F_i} \middle| E_i \right\rangle = \left(\frac{U_i}{F_i} \middle| E_i \right) p(O_i | E_i) \qquad \text{(Equation X-1)}$$

where

O_i = successful mission

E_i = evidence

and $p(O_i | E_i) = p(A_i \; B_i \; C_i | E_i)$

where

A_i = successful launch vehicle

B_i = successful spacecraft

C_i = successful probe or lander

F_i = funding required in millions of dollars

expanding by Bayes Equation

$$p(O_i | E_i) = p(C_i | A_i \; B_i \; E_i) p(A_i \; B_i | E_i)$$

$$= p(C_i | A_i \; B_i \; E_i) p(B_i | A_i \; E_i) p(A_i | E_i)$$

(Equation X-2)

The above equation could be expressed in the following manner:

"The probability of a successful mission is equal to probability of a successful landing (given a successful launch and spacecraft) multiplied by the probability of a successful spacecraft (given a successful launch) multiplied by the probability of a successful launch."

Equation X-2 can now be substituted into equation X- 1 to express the expected utility per million dollars as:

$$\left\langle \frac{U_i}{F_i} \middle| E_i \right\rangle = \left(\frac{U_i}{F_i} \middle| E_i \right) p(A_i|E_i)p(B_i|A_i\ E_i)p(C_i|A_i\ B_i\ E_i) \qquad \text{(Equation X-3)}$$

The elements of the above equation are quantified on figure X-1 and are shown in matrix form on figure X-2 together with the solution for the expected utility per million dollars for each option.

An analysis of the results on figure X-2 reveals two pertinent points:

1. the expected utility value per million dollars is much greater for landers out of orbit with the hard lander showing slightly greater utility.
2. the probability of successful mission for a soft lander out of orbit is 0.71.

A discussion of these two points is in order. On the hard versus soft lander option, it is acknowledged that the hard lander has the higher "mean" in a statistical sense. However, as mentioned previously, the hard lander data (technology) is based on less knowledge. It is, therefore, concluded that the result is less definite and its variance, in all liklihood would be much greater.

On item 2, it must be remembered that two independent launches are planned. Thus, the probability of the success of at least one mission can be calculated in the following manner to be approximately 90%:

Option i	U_i	$F_i \mid E_i$	$(\frac{U_i}{F_i} \mid E_i)$	$p(A_i \mid E_i)$	$p(B_i \mid A_i E_i)$	$p(C_i \mid A_i B_i E_i)$	$p(O_i \mid E_i)$	$\langle \frac{U_i}{F_i} \mid E_i \rangle = (\frac{U_i}{F_i} \mid E_i) p(O_i \mid E_i)$
1	100	225	0.44	0.98	0.93	0.90	0.82	0.36
2	500	365	1.37	0.98	0.95	0.50	0.47	0.64
3	500	325	1.54	0.98	0.95	0.75	0.70	1.08
4	2000	615	3.25	0.95	0.93	0.80	0.71	2.31
5	2000	530	3.77	0.95	0.93	0.75	0.66	2.49

Figure X-2.—Relative utility values for mission options.

Let $p(A+B) = 1 - p(ab)$

where

A = success in first mission

B = success in second mission

$A+B$ = A and/or B

a,b = denial of A,B (failure in mission)

ab = a and b

thus

$p(a) = 1 - p(A) = 1 - 0.71 = 0.29$

$p(b) = 1 - p(B) = 1 - 0.71 = 0.29$

$p(ab) = (0.29)^2 = 0.084$

$p(A+B) = 1 - p(ab)$

$= 1 - 0.084 = 0.916$

The selection of mission option can now be understood. For maximum utility per million dollars, landers out of orbit are a clear winner. The question becomes one of cost. Will Congress approve the more ambitious program? NASA management believed it would and selected option 4 at an estimated cost of about 600 million dollars. The selection of the soft lander in lieu of the less expensive hard lander also appears reasonable based on the small differences in utility and the larger difference in state-of-the-art of the technology.

The Viking model (paradigm) had now been established and would govern the definition of the design puzzles. This Viking paradigm would be made up of the FVSD system concept and incorporate the Roberts' paradigm for entry and landing.

That OSSA had made a clear reading of the political environment was substantiated subsequently by Congressional approval of the project. Viking is scheduled for launch the summer of 1975 under Lengley management.

In analyzing the reasons for the final success of translating concepts into models for actual hardware application, it is found that a fourth factor is essential in addition to the three factors previously defined. These three items are:

1. the accuracy of the technology base--evidenced by the accumulation of data.
2. the availability of forums--the two week in-depth meeting.
3. perseverance--by the FVSD staff to generate models and by the Viking Project Office to keep the project alive through constant technical and administrative efforts.

However, while these three items may be sufficient to establish a paradigm, they are not sufficient to allow the normal science to proceed under the paradigm. For work to proceed, the following determinant must be present:

4. the coincidence of technical and administrative objectives.

CHAPTER XI

CONCLUSIONS

Summary

Technical

The technical staff made major contributions in the definition of the Mars landing project leading to Langley Research Center being assigned project managership. The major contributions in the engineering systems area can be categorized as:

(1) The definition of the lander mission mode as soft lander out of orbit using a parachute for both removal of the lander from the heat shield and for a transition aerodynamic deceleration mode prior to retro ignition for landing. (LWP 326, Appendix IV-B). Shortly after Langley's recommendation, Langley was named Capsule Bus System (the "juicy" morsel) Manager for Voyager.

(2) The recommendation that the Titan/Centaur launch vehicle be used to carry out a more "modest" mission than Voyager but utilizing the previous Voyager mission mode (LWP 547, Appendix V-D). This is the definition of the present Viking project scheduled for launch in 1975 under Langley's managership.

The system analyses work carried out in the studies above were expressed in the formal systems concepts formats of block diagram and mathematical model flow chart form in Chapters IV and V; these concepts are judged viable and useful for planning, reviewing and documenting the work for these type studies.

The theories of Kuhn regarding scientific advances were found appropriate in explaining how the technical staff's concepts became the governing models for Viking and how major contributions affecting policy can and are often made from the lower technical levels.

The performance of the technical staff in carrying out its study effort was judged outstanding by Langley management. A formal systems analysis utilizing Homan's work Group Behavior Model (Chapter VIII) revealed that the staff's productivity, satisfaction, and individual development were compatible with theory and that Homan's model is a valuable concept for analyzing group behavior in an aerospace group. It is judged that a main reason for the staff's performance was its high degree of independence leading to self motivation. This judgment is substantiated, to some degree, by a recent NASA sponsored study which attempted to determine the main reason for NASA's success in space projects. The authors hypothesized that the determinant was the personal skills, characteristics, and management style of the project manager. Their intensive study of numerous managers resulted in no correlation; the hypothesis was judged false and the authors concluded that a main element was "teams whose members were highly committed to the project and who derived great satisfaction from selflessly contributing to the <u>team's</u>

purpose...organizational lines and personal ambitions were submerged in a common effort."[1]

Administrative

The administrative system of Langley (research oriented with emphasis on independent studies by the technical staff as discussed in depth in Chapter I and analyzed as a political system in Chapter VIII) provided the proper environment for the technical staff to carry out its studies. In addition, Langley's administrative system supported the in-house parachute technology development and provided mechanisms for transmitting the technical staff's findings to Washington Headquarters as detailed several times in the preceding chapters. Finally, Langley agreed to take the responsibility for the mission flight hardware when it was apparent that the expertise resided at Langley. The system analysis revealed that Langley's administrative system was stable and able to "persist" through perturbations to its normal research mode; its efficiency can be judged by its staff's major contributions to Mercury, Apollo, and Viking.

Headquarter's decision making in the planetary programs during the 1960's was made difficult by the lack of historical funding data and by external forces acting on NASA. Planetary programs were low priority when compared to Apollo. While it was believed that Mars

[1]NASA SP-324, Project Management in NASA--the System and the Men; Chapman, Pontious, and Barnes; National Academy of Public Administration, p. 120.

investigations would eventually supplant Apollo as NASA's prime program, there wasn't sufficient net funding after Apollo in the mid 1960's available to allow a gradual systematic buildup of fly-by spacecraft, orbiters, probes, and landers to a large Apollo-type program. The external forces--length of the Vietnam war, urban crises, environmental problems, general downgrading of technology and space investigations--were difficult, if not impossible, to prognosticate correctly. Thus, Headquarters decisions on mission types were tactical rather than strategic. As would be expected, decisions arrived at from a technical base (inputs from the Centers) were more often correct than those made unilaterally (the switch to the Saturn V). The probability of the Saturn V decision culminating in a successful mission was investigated by use of Bayesian statistics in Chapter IX; the analysis indicated that funding, technology, and management problems combined so that the decision had approximately only a 30% probability of resulting in a successful mission. The conclusion is drawn that the decision was made prematurely and without sufficient technical analysis. Conversely, the two week joint meeting at Langley to arrive at Viking definition was a innovative concept which led to a rational decision. The technology base, in this case, was extensive; the mission options had been examined in depth as described in the narrative and documented in the Appendix. A systems study using block diagram concepts was developed in Chapter V to show the applicability of the method to define the technical tradeoffs among competing options. Further a decision tree analysis, including the concept of a utility function, was generated in Chapter X to determine the option with the optimum benefits; the results of analysis substantiated the administrative decision. In the final judgment, it must be considered that despite Headquarter's decisions being overturned by events causing the study to proceed on some lost time tangents, the length of time from study initiation to hardware commitment was not exorbitant for a complex project and, at the same time, the enlarged technology base which resulted was useful in the final winnowing process among mission alternatives.

Concluding Remarks

Considering the exogeneous forces acting on NASA during this period, it is concluded that the definition and commitment to a Mars landing program was carried out in a most creditable manner. As with the Apollo and Mercury, early definitions which followed similar paths, the technical and administrative procedures utilized should serve as a general pattern for future similar projects. The main ingredients deemed essential are:

1. A small independent, self motivated technical staff to provide the technological base.
2. An administrative management which will (a) consult with the technical staff to get the essential input, (b) provide broad guidelines but not direction, (c) utilize the data for long range, overall NASA planning, and (d) carry out the necessary interfacing with OMB and the Congress.

It is also concluded that the problem of obtaining a cooperative effort amongst the centers is a major one requiring much planning and, perhaps, further research. It has been shown, by the Mars Probe Working Group experiment, that cooperation cannot be edicted. The Voyager Saturn V project organization planning by OSSA offered some promise of obtaining the necessary cooperation via an inter-center project management committee. However, the project was cancelled before it could be determined if the complex organizational method would be successful in the long term.

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PART III

THE APPENDIX

APPENDIX I

APPENDIX "I-A"

One Murray
Stop 334

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6
UNITED STATES GOVERNMENT

Memorandum

Langley Research Center

TO : Research Models and Facilities Division
Flight Vehicles and Systems Division

DATE: May 9, 1969

FROM : Deputy Chief, Engineering and Technical Services

SUBJECT: Duties of a Technical Project Engineer (TPE) and relationship to E&TS line management

The duties and responsibilities of the Technical Project Engineer have not changed significantly since the conception of the TPE system in 1962. TPE's will be appointed by the cognizant division chief. A suggested guideline to be used in determining which jobs require a TPE are those jobs involving two or more engineering sections with relatively complex interfaces or multiple desciplines. Project Engineers shall be used for the remainder of engineering jobs involving essentially one engineering section with no complex interfaces across section or division lines. Under the E&TS philosophy of engineering management, it is essential that the TPE act and operate as the Project Manager within E&TS for his particular job assignment. He is the one man in E&TS with total responsibility for cost, schedule, and performance. It is felt that the TPE and his line supervisors should understand this responsibility and work toward seeing that it is carried out. In order to describe the TPE's authority to meet this broad responsibility requires an understanding of the Vertical and Horizontal Organization concept with which we operate. The Vertical Organization is the line organization (division, branch, section). The Horizontal Organization is the functional organization for one project headed by the TPE. Personnel comprising the functional project organization may be located in several sections, however they must be responsive to the TPE and his overall project schedule and technical requirements. This in no way relieves the line supervisors of their responsibility for assignment and review of work of their personnel. If it is necessary to reassign or interrupt the work on a project in any section, the TPE should be notified and alternate arrangements made to either enable him to hold schedule or to make schedule changes rationally.

All segments of the E&TS organization must keep the TPE totally informed on matters related to his project. Similarly, the TPE must disseminate information to those parts of the line organization involved in his project.

Duties, responsibilities and relationships are more specifically detailed in the attachment.

Edwin C. Kilgore

Attachment

ECKilgore:gbm

TECHNICAL PROJECT ENGINEER

1. TPE - The engineer assigned prime responsibility for the ETS support of an LRC project.

2. TPE will be appointed by the Engineering Division Office having lead responsibility.

3. The TPE is the single point of contact for all engineering and technical service aspects of the project and is responsible for control of associated costs, schedules, and technical performance until released by the appointing division office.

4. In carrying out this assignment, the TPE is responsible for ensuring satisfactory performance of the following functions:

a. Establishing the technical approach from the research requirements
b. Preparation and update of cost estimates and allocations
c. Preparation and update of project schedules
d. Identifying required engineering and technical service support
e. Functional organization of an appropriate ETS team
f. Preparation of any required specifications, work statements or related documents
g. Coordination of all organizational interfaces
h. Information exchange throughout the project using project memos, meetings or other appropriate techniques
i. Continuing reviews of technical performance
j. Scheduling of and ETS presentations at reviews necessary under the LRC review system
k. Coordination and justification of project travel
l. Coordination and justification of project overtime
m. Keeping the research project engineers informed on all aspects of project
n. Keeping immediate supervisors informed of overall project status

5. In executing these functions, the TPE should deal directly with any appropriate level of line management necessary to obtain required support or seek solutions to problem areas. It is of particular importance that the TPE identify critical problem areas to the line managers at the earliest practical date so that coordinated action can be initiated to obtain appropriate resolution.

6. Appointment of a TPE in no way relieves engineering line supervisors of full administrative and technical responsibility for project activities within their organizational element. Specifically they will:

a. Advise the TPE in their area of competence
b. When the scope of the work merits, appoint a section project engineer to assist the TPE
c. Conduct technical reviews of the project work performed in their organization
d. Consult with the TPE on any decisions or actions which will impact the project

7. The TPE will utilize full ETS capability to achieve project goals. He should consult with the Technical Services Division supervisors concerning the assignment of lead technician support in areas where significant fabrication or operational technician effort is involved.

ECKilgore:gbm

APPENDIX II

Appendix II-A

STATEMENT OF WORK

COMPARATIVE STUDIES OF CONCEPTUAL DESIGN AND

QUALIFICATION PROCEDURES FOR A MARS PROBE/LANDER

L-5295A
Exhibit A

May 27, 1965

LANGLEY RESEARCH CENTER

LANGLEY STATION HAMPTON, VA.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background

During the next decade, NASA's Planetary Exploration may need an unmanned capsule to probe the Martian atmosphere and to land on the surface of Mars. This probe/lander capsule could be transported to the vicinity of Mars by a bus which may also serve as a communication link with Earth. This probe/lander could be used to obtain detailed information on the Martian atmosphere (inasmuch as the design of any subsequent spacecraft depends on this information) and could additionally acquire sufficient information on surface conditions to allow the formulation of subsequent definitive experiments to determine the nature of possible biological life and the surface environment. Moreover, the design of the probe/lander should allow for growth in weight into subsequent more elaborate landers while retaining many of the basic features.

The present sterilization requirements for a vehicle landing on the Martian surface will produce unique hardware problems. The sterilization procedures established to solve these problems should set the pattern for subsequent landers in the program.

The development and qualification of a sterile probe/lander must be accomplished in such a manner as to provide a maximum assurance of mission success. In addition to a comprehensive program of component and system qualification tests in ground-based facilities, a series of flight tests in the earth's atmosphere may be necessary to assure satisfactory operation of all systems and to qualify a prototype for mission use.

1.2 Objectives

The objectives of this study contract are to define a nonlifting probe/lander, its growth potential for more elaborate la[illegible]r missions, the procedures required to assure its sterilization, and the extent and value of a flight test program in the earth's atmosphere as a means of developing and qualifying a sterile probe/lander (including electrical, mechanical, and communication interfaces with the bus) for planetary missions. This study will be performed in sufficient depth to determine the most suitable approach, the conceptual design, and the development plan.

2.0 SCOPE

The contractor shall accomplish the necessary engineering investigations, analyses, studies, detailed conceptual design and planning required to accomplish the tasks described in 4.0, Contractor's Tasks, consistent with the restraints presented in 3.0, Guidelines. The tasks will be divided into two general parts as follows:

Part I will include comparative studies of the probe/lander and the definition of the impact of the probe/lander requirements on the bus design. It will also include studies of sterilization, ground test procedures, the feasibility of a flight test program in the earth's atmosphere as a means of developing and qualifying a sterile probe/lander for mission use, and the growth potential of the probe/lander for more elaborate missions. Part I will further include a preliminary development program plan and all costs associated with qualifying a probe/lander prototype.

Part II will include optimization of the selected systems together with a detailed conceptual design and detailed qualification procedures. Part II will also include the preparation of a comprehensive plan for the production, sterilization, and qualification of the selected system for mission use.

This study contractor is not responsible for the bus design within the scope of this study. It is anticipated that other NASA study contracts will be proceeding concurrently to define the bus and overall mission profile concepts; the NASA will keep the contractor apprised of information developed therein so as to assure that the overall results will be compatible.

3.0 GUIDELINES

The technical guidelines under which the tasks outlined herein shall be accomplished are as follows:

3.1 Mission Profiles and Analyses

(a) The mission profile of the probe/lander shall be consistent with the sampling times required for experiments and the communication time required to transmit data.

(b) The Saturn IB/Centaur shall be assumed to be the launch vehicle for the bus-probe/lander combination.

(c) The probe/lander shall be separated from the bus on the Mars approach path. Consideration shall be given to both fly-by and orbiting bus modes.

(d) A complete DSIF network shall be assumed to be available.

(e) NASA Mars model atmospheres are delineated in NASA TN D-2525

3.2 Bus

The bus may serve as a relay station for transmittal of probe/lander data to earth. The bus will not be sterile.

3.3 Probe/Lander

(a) Consideration shall be given in the design of the external shell to possible future lander missions wherein the same external structure will be used in conjunction with internal payloads whose weights will vary to a maximum consistent with the capability of the Saturn IB/Centaur.

(b) Three concepts shall serve as a basis of study and comparison:

(1) Tension shell

(2) Apollo shape

(3) Large angle blunted cone

Information on the above configurations consisting of (a) external coordinates, nondimensionalized and (b) force and moment coefficients will be given to the contractor for use during this study.

(c) (1) The experiments and instrumentation to be carried on the probe/lander shall be defined in the detail and scope specified by this document.

(2) The instrumentation shall include scientific instrumentation and engineering instrumentation to monitor the operating status of the probe/lander subsystems, structure and heat shield throughout the mission.

(3) Three scientific payloads shall be compared for the 1971 mission in Part I of the study and one selected for more detailed design during Part II. One advanced payload for the 1973 mission and one for the 1975 opportunity shall be studied during Part I to determine their effect on the growth potential of the 1971 probe/lander shell to later missions. These two payloads shall be designed in greater detail during Part II.

(4) The three payloads for the 1971 opportunity are defined as follows:

Payload Concept No. 1 - All recommended instruments are available or well along in development.

Payload Concept No. 2 - Recommended instruments are available or may be developed with a minimum effort.

Payload Concept No. 3 - Measurement technique is scientifically sound but instrumentation may not presently exist. However, there must be a reasonable assurance of its availability for the 1971 mission.

(5) The following measurements and instruments shall be considered as candidate items in the payload concepts, but the candidates shall not be restricted only to this list.

Measurement	Suggested Instrument
Density	Accelerometer
	X-Ray Backscatter
Altitude	Radar Altimeter
Composition	Mass Spectrometer (GSFC)
Trapped Radiation	Radiation detector
Ionosphere	(not selected)
Pressure	Electrical transducer
Temperature	Resistance Thermometer
Surface Roughness	Radar Altimeter
Surface Hardness	Penetrometer (LRC)
Surface Winds	Hot Wire Anemometer
	Pressure Probe
Soil Composition	Alpha Scatter
Dust Particles	Microphone
Solar Constant	Solar Cells

(6) The determination of the conceptual payloads shall be accomplished through a series of trade-off studies which should include such factors as: scientific merit, technical feasibility, performance margins,

availability, physical characteristics, interface problems, sterilizability, and reliability.

(7) The primary mission of the probe/lander in the 1971 opportunity is to obtain detailed information on the Martian atmosphere and to obtain such information on surface conditions which will permit formulation of definitive surface experiments to be carried out on later missions. The prime landing target is Syrtus Major unless mission and systems analyses during the study reveal this landing site to be too technically difficult to achieve

(8) The missions in 1973 and 1975 should utilize payloads of expanded performance capability including TV and biological experiments. Capability should be restricted to that associated with a stationary observatory. Mobile experiments should be considered beyond the scope of the 1973 and 1975 missions.

(9) In the evaluation of instruments, experiments and payload concepts all sources of data shall be explored to provide the most authoritative results and recommendations, including the literature, source agencies, and internal Avco sources.

(d) The probe/lander shall be designed so that subsonic speeds are achieved at an altitude of at least 15,000 feet above the surface.

(e) The primary deceleration system shall consist of subsonic parachute(s); the subsonic parachute(s) shall be designed to furnish sufficient dwell time in the atmosphere, and provide a terminal velocity (assuming no surface winds) not exceeding 60 feet per second.

(f) The surface of Mars shall be assumed sufficiently dense to support an instrument package. The following assumptions shall be used for design of the impact attenuation system:

(1) Surface shall be considered nonyielding.

(2) Maximum horizontal velocity at impact shall be taken as 100 feet per second and the package shall be arrested by a nonyielding vertical surface.

(g) Maximum landing deceleration shall not exceed 1000 earth g's.

3.4 Sterilization

(a) Components shall be capable of satisfactory operation after three cycles of heating in a dry atmosphere to a temperature of 145° C for 36 hours.

(b) Subassembly surface decontamination may be accomplished using ethylene oxide.

(c) Terminal sterilization of the probe/lander shall consist of heating in a dry atmosphere to a temperature of 135° C for 24 hours.

(d) The probability of allowing a viable organism to exist on the payload at any time subsequent to terminal sterilization shall be less than 1 in 10,000.

3.5 Qualification

A carefully planned qualification program shall be formulated to maximize the probability of mission success. This program shall delineate ground environmental tests and all required flight tests in the earth's atmosphe . Existing Government launch facilities shall be utilized in the flight testing. The qualification program should be aimed toward completely qualifying the probe/lander (including electrical, mechanical, and communication interfaces with the bus). Selection of equipment and procedures shall consider the needs of future heavier internal payloads.

3.6 Reliability

Prime and detailed consideration shall be given to the effects sterilization, testing, and long space flight time on system reliability. Inherent reliability shall be sought in all design areas through the means of minimum complexity and redundancy. Consideration shall be given to optimizing reliability in the design of probe/lander systems.

4.0 CONTRACTOR'S TASKS

The contractor shall furnish all necessary materials, equipment, personnel, and facilities to perform all investigations, designs, engineering, and documentation required to accomplish the tasks described herein, consistent with the restraints presented in section 3.0, Guidelines.

4.1 Part I (a) Technical Study Areas

In the accomplishment of the tasks, the technical study areas shall include, as a minimum, the following:

4.1.1 Mission Profiles and Analyses

(1) The contractor shall review the previous applicable Mars study reports for missions through 1975 and determine critical values for the following design parameters:

a. Bus fly-by periapsis altitude

b. Bus asymptotic approach velocity

c. Bus orbiter periapsis altitude

d. Bus orbiter apoapsis altitude

e. Bus orbiter weight and size

f. Bus fly-by weight and size

g. Shroud size

(2) The mission profiles of the bus and probe/lander from separation to the end of communications shall be defined.

(3) The guidance and propulsion requirements for the probe/lander shall be defined.

(4) Analyses shall be made to determine the extent of data obtained for various modes of failures and their effects on probe/lander mission success.

4.1.2 Bus

(1) The extent and makeup of the probe/lander data receiving, storage, and retransmission systems to be incorporated in the bus shall be defined.

(2) The mechanical and electrical interfaces with the probe/lander shall be defined.

(3) Means of assuring the ability of the bus to find and track the probe/lander shall be defined.

4.1.3 Probe/Lander

(1) An optimum size and strength of the external structure shall be determined to meet the requirements of the probe/lander and future lander missions; consideration shall be given to the influence of each of the following on future lander missions: (a) terminal guidance, (b) lander separation after orbit is obtained, and (c) establishment of model 2 atmosphere as governing design criteria. Graphs shall be prepared of the relationships between lander's total weight, its structural fraction, and size for the various entry conditions to illustrate the trade-offs associated with standardizing a single size multimission vehicle. Weights of the structural fractions (shell, thermal protection, propulsion units, retardation, and impact attenuation systems) shall be based on actual analyses except where the use of scaling criteria is established. As a partial fulfillment of the above, the contractor shall accomplish the following:

(a) Critical probe/lander aerodynamic loads and heating inputs, both convective and radiative, shall be determined independently for the ranges of trajectories and atmospheres under consideration.

(b) Item (a) above shall be repeated to determine the aerodynamic loads and heating inputs associated with utilizing the shell for the lander missions. The penalty involved in using the overall aerodynamic critical loads in the probe/lander design shall be assessed.

(c) A material analysis and structural approach shall be defined to result in a minimum weight structure to resist the combined critical aerodynamic and heating loads.

(d) Stress analysis, including thermal stresses, and weight estimates shall be made for the external structure with its thermal protection; additional thermal protection may be added to the basic shell for the future lander missions. Theoretical aerodynamics shall be used where experimental data are not available. The shell shall be investigated for all anticipated loading conditions, including launch.

(2) The experiments and instrumentation to be carried on the probe/lander shall be defined as follows:

(a) A master list of possible scientific experiments and associated instrumentation shall be compiled.

(b) Each scientific instrument in the master list shall be examined first to determine its development status and classified as a candidate for a payload concept, (described in paragraph 3.3(c)(4)) in accordance with its development status.

(c) Each scientific instrument shall then be evaluated in accordance with the comparative criteria of paragraph 3.3(c)(6) and rejected or assigned to one or more payload concepts.

(d) The three payload concepts shall be compared in accordance with the criteria of paragraph 3.3(c)(6) and one concept selected as the reference payload with approval of the Langley Research Center. The selection of the payload concept shall be subject also to proper mating with the reference probe/lander concept and its subsystems.

(e) Scientific experiments and associated instruments shall be formulated for application to advanced payloads for the 1973 and 1975 missions. Emphasis during this part of the study will be on the characteristics of the payload which will affect the probe/lander and its subsystems. The prime purpose shall be the definition of growth potential requirements for the probe/lander shell.

(f) Comparison studies of the engineering instrumentation for the 1971 mission shall be made and a reference system selected, for LRC review, which will provide an optimum tradeoff between the scope of status monitoring and the impact of the instrumentation on probe/lander size, complexity, data handling requirements and reliability.

(3) Determine the possible need for, and characteristics of, spinup and despin devices on the probe/lander.

(4) Determine motions of probe/lander during entry for design and possible off-design conditions.

(5) The motions of the probe/lander after entry shall be determined and considered in defining data transfer methods to the bus.

(6) Means of storing data obtained during blackout for subsequent transmission shall be defined.

(7) A method of packaging all internal systems and maintaining environmental control throughout the mission shall be defined.

(8) All propulsion units, including performance characteristics, configuration, and weight shall be defined.

(9) The subsonic parachute system shall be defined including:

(a) Mode of development.

(b) Analysis of ensuing motion of separated parts.

(c) Trajectory time history.

(d) Parachute size and weight estimate of system.

(e) Packaging methods.

(f) Stress analysis and load reactions including dynamic effects.

(g) The determination of system motions while penetrating 50-foot-per-second gusts of 10-second duration parachute descent.

(10) Detailed studies shall be made to define an impact attenuation system which will permit acquisition and transmission of data after landing.

(11) A complete weight breakdown to component level shall be made.

(12) An analysis shall be made to evaluate the influence on performance of adding a supersonic parachute, deployed at a maximum Mach number of 2.5, to the basic system.

4.1.4 Qualification

(1) Procedures, equipment, and facilities shall be defined to insure proper sterilization of:

(a) Components.

(b) Subsystem assemblies.

(c) Probe/lander through manufacture, assembly, handling, test, and launch phases. Assay procedures shall be defined whereby tests can be made to establish levels of contamination throughout all phases from manufacture to launch. Critical stages in each phase at which assay procedures should be undertaken shall be defined.

(2) Procedures, equipment, and facilities shall be defined to make maximum use of ground environmental testing. Value of long time exposure to vacuum conditions to verify satisfactory operation of components, subsystems, and systems shall be studied. Means of simulating and evaluating radiation, thermal, and structural loads on components, subsystems, and systems shall be determined.

(3) The contractor shall study the value and extent of flight tests in the earth's atmosphere in the development of subsystems and in the qualification of a probe/lander prototype. Trajectory and launch details of earth entry flight tests corresponding to Mars trajectories shall be identified for both scaled and prototype configurations insofar as environmental conditions are concerned. Degree of similitude achievable with respect to loadings, subsystem operations, and component motions shall be determined. The feasibility of checking out, during the flight tests in the earth's atmosphere, the electrical, mechanical, and communication interfaces with the bus shall be determined.

(4) The procedures established above, 4.1.4 (1), (2), and (3), shall include, to the maximum extent practicable, provisions applicable to

future landers. The growth potential of these procedures into a logical and overall qualification program shall be examined and assessed.

4.2 Part I (b) Contractor Recommended System and Preliminary Plan

4.2.1 System Comparison and Definition

Based on the results of task studies conducted in Part I (a), the contractor shall make comparison studies of the relative merits of the candidate probe/lander shapes and subsystems and shall define the complete probe/lander system which he considers optimum to satisfy the mission(s) requirements. The various trade-offs shall be detailed in sufficient depth so that NASA can make an independent evaluation and select the system for detailed study in Part II. The contractor shall establish and document the present development status of all subsystems and components considered in the trade-off studies.

4.2.2 Reliability Studies

Reliability shall be made an integrated major factor in all design areas, with reliability engineering data, studies, analyses, quantitative analyses, and predictions being used to enhance comparative studies and designs, optimization of the systems and subsystems, and to provide contributing data for the substantiation of conclusions and the conceptual design. The factors of minimum complexity and inherent reliability, redundancy, maintainability and elimination of potential sources of human-induced failure, and the effects of sterilization on parts and materials shall be given particular consideration in maximizing mission reliability. The effects of sterilization on the reliability of components, parts, and materials utilized in the design and means for improving reliability within this constraint shall be studied in detail, including research of published data and documented test data. The contractor shall perform such reliability studies, including quantitative probability analyses, as necessary to establish reliability objectives, requirements, and goals for the subsystems, systems, and the overall mission.

The contractor shall perform applicable planning for reliability program activities to be utilized in an assumed follow-on detail design and development program, including planning for any critical items which may require special emphasis with regard to development, testing, qualification, or reliability demonstration testing in order to achieve the design reliability goals.

The contractor shall submit as part of the final report a separate document containing the details and results of the reliability studies analyses and predictions, details of the study of the effects of sterilization on reliability and the proposed means for increasing the reliability and, as a separate section, proposed reliability program activities. This does not preclude the use of specific reliability data in other documents to support the conceptual design presentation and conclusions.

4.2.3 Comparison and Definition of Qualification Program

The contractor shall make a comparison study of qualification procedures to determine their relative merits and practicability in order to define an integral qualification procedure. The various trade-offs shall be evaluated and the contractor shall define a qualification program in sufficient detail so that NASA can select a qualification program for detailed study in Part II. The contractor shall establish and document the present development status of all qualification procedures considered.

4.2.4 Problem Area Identification

During the performance of Part I of the contract, the contractor shall make a continuing effort to search out and identify any long lead items which require accelerated development. The results of this effort shall be included in the Part I report.

4.2.5 Preliminary Plan

The contractor shall submit for NASA consideration a preliminary plan which shall include schedule and costs for the fabrication and qualification of a probe/lander (including electrical, mechanical, and communication interfaces with the bus) and any required GSE. The plan shall delineate the hardware requirements including all test items and the associated cost and schedule of manufacturing, sterilizing, ground testing, and flight testing. The plan shall be presented in sufficient detail so NASA can evaluate all phases of the plan and designate a program plan to be studied in depth in Part II.

4.3 Part II (a) Final Analysis and Conceptual Design

To provide assurance that the selected system will meet mission requirements, the contractor shall review and expand in depth the pertinent analyses (performed in Part I) as required to perform the conceptual design.

The contractor shall prepare a detailed conceptual design for the probe/lander (including electrical, mechanical, and communication interfaces with the bus) and furnish a draft of component performance specifications from which detail specifications can be written suitable for a possible follow-on competitive procurement. An assembly drawing of the probe/lander shall be prepared defining the internal arrangement, external structure, component weights, center-of-gravity location and moments of inertia. Conceptual drawings of the entire vehicle shall be prepared to illustrate (1) the mating of launch vehicle, bus, probe/lander, and shroud, and (2) arrangement of probe/lander and bus within the shroud. All interfaces and separation mechanisms relative to the probe/lander shall be defined.

Each instrument of the payload concept selected in Part I as the reference system shall be designed to the detail and scope necessary to completely and authoritatively define its criteria as listed in paragraph 3.3(c)(6). Evaluation and design of each instrument and the total payload shall be conducted in accordance with the procedures of paragraph 3.3(c)(9). Component performance specifications, from which detail specifications can be written suitable for a possible follow-on competitive procurement, shall be provided for each instrument.

Each instrument and experiment of the advanced payloads for 1973 and 1975 shall be designed in greater depth than the evaluation of Part I but not in the detail of the Part II design of the 1971 payload. The primary purpose will be to certify the Part I conclusions relative to the interface between the advanced payloads and the probe/lander to insure the growth potential of the probe/lander shell.

A detailed conceptual design of the reference engineering instrumentation system shall be formulated which will expand in depth the design studies of paragraph 4.1.3(2)(f).

4.4 Part II (b) Probe/Lander Development Plan

4.4.1 General

Based on the preliminary plan selected by the NASA at the end of Part I, the contractor shall prepare a complete development plan aimed at fabricating and qualifying the probe/lander (including electrical, mechanical, and communication interfaces with the bus) and any required GSE. The plan shall delineate the hardware requirements, including all test items, and the associated cost and schedule of manufacturing, sterilizing, ground testing, and flight testing. A format of the development plan shall be prepared for NASA approval at the start of Part II.

4.4.1.1 Project Work Breakdown Structure

A work breakdown structure shall be developed for the total program at a systems level and shall serve as the framework for the development of planning networks and the cost estimating.

4.4.1.2 Project Planning Networks

Planning networks structured in accordance with the work breakdown structure shall be developed for the total program. These networks shall not be in a fine level of detail and, generally, will be at the systems level with activities of from 2 to 4 months duration. Activities shall cover all phases of the program from start of design through launch and include development testing, qualification testing, environmental testing and prelaunch operations. These networks shall conform to the NASA PERT and Companion Cost System Handbook dated October 30, 1962.

4.4.1.3 Project Funding Plan

The funding plan shall present the contractor's estimate of the total project costs through a completed flight test program and, in addition, the costs associated with furnishing additional mission qualified probe/landers up to a maximum of ten. Using the work breakdown structure as a framework, cost estimates shall be developed for each system broken down by quarters for the same time span covered in planning networks. Separated subtotals shall be shown for spacecraft systems and vehicle systems.

4.4.2 Plans

4.4.2.1 Manufacturing

The contractor shall prepare a manufacturing plan including:

(1) Tooling plan, including unique major tools.

(2) Production plan, including test equipment.

(3) Assembly plan.

4.4.2.2 Sterilization

The contractor shall prepare a sterilization plan including activities required:

(1) During and after component manufacturing stage.

(2) During and after assembly.

(3) Handling.

(4) At launch site.

4.4.2.3 Environmental Test Program

The contractor shall prepare an environmental test plan including considerations of:

(1) Simulated space vacuum.

(2) Thermal balance.

(3) Micrometeoroid hazard.

(4) Radiation hazard.

(5) Ground handling conditions.

(6) Structural dynamics.

(7) Impact testing.

4.4.2.4 Flight Qualification Test Program

Based on the acceptance by the NASA (4.2.3) of the contractor determination and recommendation in Part I (a) (4.1.4 (3)), the contractor shall prepare a flight qualification test plan, including:

(1) Component and subsystem tests.

(2) Tests of integrated probe/lander.

(3) Launch vehicles, sites, and trajectories.

(4) Schedule.

4.4.2.4.1 Operations Plans for Flight Qualification Test

The contractor shall prepare a complete operations plan including:

(1) Assembly and shipping.

(2) Preflight checkout.

(3) Launch.

(4) Range requirements for tracking and data acquisition.

4.4.2.4.2 Postflight Qualification Test Data Evaluation Program

The contractor shall prepare a postflight data handling and evaluation plan including:

(1) Evaluation of performance of all subsystems.

(2) Comparison of results obtained from flight with known atmospheric and surface characteristics.

4.4.2.5 Facilities Plan

The contractor shall prepare a facilities requirements and utilization plan for paragraphs 4.4.2.1 through 4.4.2.4, specifying the major facilities that will be required. This plan shall delineate any unique facilities required for this project which are not currently available. Maximum use will be made of Government facilities in this plan.

5.0 NASA PARTICIPATION

5.1 This contract will be administered and monitored by the Langley Research Center of the NASA. The scope of the task requires that a number of NASA personnel of various disciplines be involved in the monitoring. The technical representative of the Contracting Officer will be the focal point of coordinating the means of exchange of information.

5.2 The NASA will participate in the program at any time and to the extent deemed necessary to assure satisfactory direction, emphasis, and progress. Joint NASA/contractor monthly meetings will be held alternately at the LRC and contractor's site to review the progress of the study and to exchange information. All information resulting from this contract will be available for dissemination by the NASA.

6.0 REPORTS AND DOCUMENTATION

6.1 General

Reports and documentation shall be furnished in accordance with Table I, Documentation Schedule.

6.2 Interim Reports

6.2.1 NASA Program Progress Reports together with cost reporting on NASA Form 533 shall be implemented and maintained in accordance with the provisions of the contract.

6.2.2 Monthly Progress Reports

The contractor shall furnish fifty (50) copies of a monthly progress report which shall comply with the following format:

(a) The initial page (limit two) shall present a brief narrative analysis of the work including:

(1) A summary outlook for the total effort.

(2) Overall status, such as significant progress, problem areas, plans, and change in plans since previous report.

(3) Any recommendations as to actions required to meet or improve schedules.

(b) The remainder of the report shall discuss briefly the progress, problems, and plans for each technical area defined in sections 4.1, 4.2, 4.3, and 4.4.

(c) Two copies, marked "preliminary," of all technical analyses prepared during the month's reporting period shall be included with the report.

6.2.3 Part I Oral Report and Supporting Documentation

At the completion of Part I, the contractor shall present an oral briefing to the NASA-LRC summarizing the contractor's work in Part I. This report shall present the contractor's assessment (1) of the systems and configurations together with his recommendations (with substantiating reasons) as to the final selection and (2) of the qualification procedures, together with his recommendation of a qualification program. Copies of the presentation slides and supporting documentation shall be transmitted to LRC for NASA evaluation at the end of the oral report.

6.3 Final Report

6.3.1 Oral Report

At the completion of Part II of this study, the contractor shall present an oral briefing to the NASA-LRC summarizing the contractor's work in Part I and Part II. Copies of the slides utilized in the presentation shall be transmitted to the LRC at the conclusion of the oral report.

6.3.2 Written Report

Within thirty (30) days following the completion of Part II, the contractor shall submit to the NASA-LRC one-hundred (100) copies of a comprehensive written report setting forth the results of this contract. The report shall conform to a general arrangement acceptable to the NASA and shall include:

(a) Brief summary and referencing of all previous reports.

(b) Detailed conceptual design - This report shall include, but not be limited to, design layouts, detail analyses and drafts of performance specifications. All design analyses used in the design together with their complete derivations, or literature references, shall be furnished. All assumptions used in the design shall be noted so that, if necessary, the design, calculations, and results can be verified.

(c) Drawings - The contractor shall furnish a complete set of drawings in sufficient detail so that detailed design and manufacturer's drawings can be completed. These drawings shall include, but not be limited to, primary structure, detailed dimensional layouts, system and subsystem arrangements, wiring schematics, bus interface, deployment mechanisms, and an overall assembly drawing. These drawings shall be prepared using the contractor's internal system and NASA's title block and numbering section. All drawings shall be approved by and become the property of NASA. One high-quality reproducible copy, such as Mylar, of each drawing shall be submitted with the final report.

(d) As a part of the final report, the contractor shall submit, as separate documents, the plans required under section 4.4 as well as the reliability document required by paragraph 4.2.2.

TABLE I.- DOCUMENTATION SCHEDULE

Paragraph reference	Document	Issued to NASA	No. of copies to NASA	NASA action required
6.2.1	NASA Form 533 Financial Report	Monthly and quarterly	4	Information
6.2.1	Program Progress Report	30 days after contract and biweekly	12	Information
6.2.2	Monthly Progress Report	Monthly	50	Review
6.2.2(c)	"Preliminary" copies of Technical Analyses	Monthly	2	Review
6.2.3	Copies of figures used in Part I Oral Report and Supporting Documentation	3 months after award	20	Review
6.3.1	Copies of figures used in Part II Oral Report	At conclusion of Part II study	20	Review
6.3.2	Final Report	30 days after conclusion of Part II study	100	Information

Appendix II-B

GENERAL INSTRUCTIONS FOR THE
TECHNICAL AND BUSINESS MANAGEMENT PROPOSALS

PART I. GENERAL

A. Indiscriminate and premature release of information concerning proposed projects of the National Aeronautics and Space Administration can lead to public misunderstanding and confusion. To avoid this, your cooperation is requested. Specifically, we ask that your organization refrain from making public statements or issuing news releases concerning the work called for by this solicitation of proposals.

B. The offeror should set forth, in detail, the technical and management plans by which he intends to accomplish this work. These plans will be an important factor in the selection of the offeror, and should be specific and complete.

C. The offeror, in his Technical Proposal, shall present all information necessary to demonstrate his understanding of the problems, to evaluate his proposed solutions to the technical requirements, and to indicate his capability to successfully complete the objectives of this Mars Probe/Lander study. Evaluation of the proposal will be on the basis of the material presented and substantiated in the proposal and not on the basis of what may be implied. Legibility, clarity, and completeness of the Technical Proposal are important. The Technical Proposal shall be limited to the equivalent of two hundred (200) pages, $8\frac{1}{2}$ X 11 inches. This shall include all text, charts, graphs, drawings, photographs, figures and appendices. Necessary personnel resumes shall be added as an appendix to the proposal and will not be counted against the two hundred (200) page limitation. The offeror shall submit fifty (50) copies of the Technical Proposal.

D. The Business Management Proposal shall be completely separate from the Technical Proposal and shall contain all information relative to Cost and Financial Data. It is also requested that the Cost and Financial portion of the Business Management Proposal be prepared in such a manner that it can be separated from the rest of the proposal. The Business Management Proposal shall be limited to the equivalent of fifty (50) pages $8\frac{1}{2}$ X 11 inches. The offeror shall submit twenty-five (25) copies of the Business Management Proposal.

E. Elaborate format and binders are neither necessary nor desired for the proposals. The actual area of any fold-out or oversize pages will be counted against the limitations specified. Sheets printed on both sides will be counted as two (2) pages. All type shall be standard 12 point or larger, double spaced, and shall be printed black on white paper.

F. The Technical and Business Management Proposals and the factors thereunder, i.e., technical approach, technical qualifications, past performance and experience, relation of projected workload to capacity, management structure, and cost factors and financial capability are set forth in order of relative importance and shall be evaluated on this basis.

G. Classified material submitted with offerors' proposals will be in accordance with prescribed regulations, issued by the Department of Defense, governing the safeguarding of classified material.

PART II. TECHNICAL PROPOSAL

A. Criteria to be Considered in Evaluation of Paragraph B (Contents of Proposal)

1. Overall Technical Approach

a. Detailed Approach

During the evaluation, the offeror's approaches to the solution of the problems of each technical area outlined in paragraph B, and more specifically set out in section 4.0 of the Statement of Work, will be assessed for the excellence and applicability of proposed methods, ingenuity, and proper emphasis. The offeror's discussion of each technical area will be examined in detail sufficient for assessment of the offeror's understanding of the problems and his understanding of the current technology in the technical areas.

b. Substantiating Data and Analysis

The offeror's discussion will also be carefully assessed for the applicability and credibility of his reasoning, engineering and existing test data, and analytical procedures used or to be used to substantiate the proposed engineering approach and the basis for the proposed emphasis to be placed on each technical area.

2. Technical Qualifications

The offeror's discussion of each of the technical areas outlined in paragraph B, and more specifically set out in section 4 0 of the Statement of Work, will be examined for evidence of his ability to perform the study based on personnel and past experience. This evidence will be evaluated with emphasis on the excellence and suitability of the following:

a. Manpower, including types and number of men to be available, with the background specialty areas and the applicable experience of the key personnel to be assigned to the study and percentage of time to be spent on this project.

b. Previous company experience, the nature and extent of such work as related to large systems studies.

B. Contents of Proposal

In his proposal, the offeror shall discuss the problem areas and the trade-off studies associated with each of the technical areas included in section 4.0 of the Statement of Work. The offeror shall present the level of effort which he estimates can be accomplished with approximately 30,000 man-hours. To facilitate the evaluation, the offeror shall arrange his proposal into the technical sections listed below:

1. Subsystem Concepts and Associated Analyses

a. To demonstrate the soundness of approaches recommended in 2.c. and 2.d. below, the offeror shall discuss in detail, each of the areas listed below, relative to mission requirements.

(1) Communications, instrumentation, and electrical power subsystems.

(2) Structures and materials, including thermal protection and impact attenuation structure.

(3) Space flight and atmospheric entry performance (including thermodynamics, aerodynamics, and flight mechanics).

(4) Mechanical subsystems, including parachutes, separation, spin-up and despin devices, rocket motors, and environmental control.

b. The offeror shall also present the following:

(1) A preliminary layout of the probe lander (including an inboard profile and weight characteristics), having an external configuration based on the tension shell concept presented in Appendix B of the Statement of Work.

(2) Preliminary design concepts of all mechanical subsystems including parachutes, separation, spin-up and despin devices, rocket motors, and environmental control.

2. Overall System Concept and Integration

The offeror shall discuss each area noted below only to the depth necessary to demonstrate the overall conceptual philosophy and to divide the problem into defined elements for specialized discussion in items 1, 3, and 4. (In a. below, for example, the offeror shall restrict himself to a discussion of the scientific measurements required, means of making these measurements, and means of communicating these measurements to the bus. The details of achieving the desired communications and instrumentation design, such as specific instruments and components, should be discussed under 1.a.(1) above.)

a. Experiment selection, data sampling methods, and transmittal of data to the bus for relay to earth.

b. Mission profiles and analyses.

c. Optimization of external shell design considering size, weight, aerodynamic performance, and future lander utilization.

d. Optimization of internal payload design considering subsystem integration, sterilization, and environmental control.

e. Criteria and procedures to be used in establishing the value and extent of flight tests in the earth's atmosphere as a part of the overall qualification program.

f. Interrelation of areas a. through e. above and the associated trade-offs considered pertinent to provide an integrated system commensurate with overall mission requirements

3. Qualification Program

The offeror shall discuss the following items to be incorporated in the qualification program:

a. Criteria for establishing and the methods for implementing a detailed ground test program, including a preliminary ground test plan.

b. Criteria for establishing and the methods for implementing a detailed flight test program in the earth's atmosphere (including a preliminary flight test plan) in the event such a program is recommended.

c. The effect of the sterilization requirements on the ground and flight test programs.

d. A preliminary reliability program outlining the offeror's approach and proposed methods and procedures for the accomplishment of the reliability requirements as delineated in paragraph 4.2.2 of the Statement of Work.

4. Sterilization

The offeror shall present his capability to solve the problems relative to the sterilization requirements by discussing, in detail, the following:

a. Sterilization influence on component selection.

b. Establishment of sterilization and assay procedures.

c. Facilities required by b. above.

d. Sterilization control during manufacturing, handling, transportation, and checkout.

e. Sterilization's impact on schedule and costs.

5. Technical Management and Plans

The offeror shall outline:

a. A program plan (manpower, subcontractors, and schedule) to carry out the various elements of Contractor's tasks in the Statement of Work This plan shall include the estimated man-hours (including subcontractors) required for each of the technical areas in items 1 through 4 above.

b A detailed technical management plan, including a discussion of the offeror's planned organizational arrangement, lines of authority, communication, and coordination between the offeror, subcontractors, and the National Aeronautics and Space Administration.

PART III. BUSINESS MANAGEMENT PROPOSAL

The offeror shall present his Business Management Proposal in accordance with the details requested below. Paragraphs A through D are listed in order of relative importance.

A. Management Structure

1. Set forth in detail your understanding of the total management job, particularly as to management methods to be utilized in undertaking and executing the proposed work under this proposed contract with particular consideration given to the following elements:

a. Lines of authority, communication and control by the National Aeronautics and Space Administration and the prime Contractor predicated on the essential Government requirement that the company provide a Project Manager who reports to an individual in a top-management position.

b. The proposed communication and control between your company and subcontractors should be specified.

2. Submit a resume of all key personnel who will conduct the managerial affairs of this project, indicating the percentage of time that these key personnel will devote to this project. Indicate evidence of your company's willingness to devote company resources in other branches or divisions to help support this project with key personnel to solve difficult problems.

3. Submit evidence that the project can be properly staffed with qualified personnel, including the offeror's record with regard to work stoppages, strikes, lockouts, and labor disputes during the past three (3) years and date of expiration of labor contracts of crafts essential to this project, with comments as necessary.

4. You should submit clear and convincing evidence of your firm's participation in the NASA Cost Reduction Program; a cost reduction program which

is administered by any other Government agency; or a cost reduction program which is Contractor-sponsored. In the event that you have previously submitted evidence to this Center of participation in such a program, the response should so indicate. However, it is desirable that any previous submittal should be updated to ensure that complete evaluation of this segment of your proposal is possible. Further, if you are participating in the program under circumstances wherein administration is effected by another NASA Center or Government agency, your proposal should identify the source of administration.

B. Past Performance and Experience

The offeror should submit evidence of contracts in fields relating to this procurement which have been or are in the process of being performed by the company within the past three (3) years, specifically setting forth for each contract, the contract number, Government agency placing the contract, type of contract, brief description of the work, indicating for each cost-type contract amounts of overrun or underrun, reasons therefor, and percentage of fixed or incentive fee. For each contract, show the record of contract completion against the anticipated completion date at time of entering the contract, with explanations as considered necessary.

C. Relation of Projected Workload to Capacity

1. The relation of projected workload to capacity, giving consideration to:

a., The average and peak percentage of available capacity required for the task.

b. The schedule labor buildup.

c. The extent of new-hire labor requirements (including any relocation of personnel).

d. The possibility of interference with other projects at the plant.

2. Indicate availability of facilities required to accomplish the proposed work under this proposed contract by completing the forms attached hereto as Enclosure 1, Facilities Questionnaire and Summary Sheet, and Exhibit 1 thereto entitled "Additional Industrial Facilities Required". Consideration will be given to:

a. Current inhouse capability.

b. Principal vendors and subcontractors facility availability.

c. New facility requirements and cost thereof

(1) Offeror
(2) Subcontractors and vendors.

d. Government-owned facilities.

D. Cost Factors and Financial Capability

1. Cost Factors

The offeror shall submit a detailed Cost Proposal which will be prepared so as to include, as a minimum, all of the subdivisions of work and elements of cost shown in Attachment F, Estimated Cost and Fee Summary.

2. Financial Capability

A balance sheet for your last Fiscal Year and accompanying profit and loss statement must be furnished. Evaluation will be based on your current financial condition and general corporate rating.

Appendix II-e

LANGLEY RESEARCH CENTER ANNOUNCEMENT	**No.** 1-65
	DATE January 7, 1965

SUBJECT: Source Evaluation Board for Comparative Studies of Conceptual Design and Qualification Procedures for a Mars Probe Lander

Pursuant to Chapter 3 of the Source Evaluation Board Manual (NPC 402) I hereby designate the following individuals to serve as members of the Source Evaluation Board for the subject Mars Probe Lander contract:

<u>Chairman</u>:

Edwin C. Kilgore, Chief, Flight Vehicles and Systems Division

<u>Other Voting Members</u>:

Andrew G. Swanson, Technical Assistant to the Assistant Director for Flight Projects
Leonard Roberts, Dynamic Loads Division
Eugene S. Love, Aero-Physics Division
David B. Ahearn, Procurement Division
George T. Malley, Office of Chief Counsel
William T. O'Bryant, Office of Space Science and Applications, NASA Headquarters
Ralph W. May, Jr., (alternate: Peter A. Cerreta), Office of Advanced Research and Technology, NASA Headquarters

<u>Nonvoting Recorder</u>:

Henry J. Pratt, Procurement Division

The Source Evaluation Board will conduct its business in strict accordance with the provisions of the Source Evaluation Board Manual. It will be the responsibility of the Chairman to determine that each Board member (both voting and non-voting) is fully conversant with the instructions contained in this publication. Board duties will take precedence over other normal duties of the Board members.

Attention of the Chairman and each Board member is particularly directed to paragraph 102 of the Source Evaluation Board Manual which specifies who shall be authorized to select a source for the negotiation of a contract. It is emphasized that the findings of the Source Evaluation Board are only guides for the final selection process and must be presented in sufficient depth of information to permit the intelligent weighing of alternatives. All acceptable proposals will be evaluated, ranked and reported. The Board's written findings will give no consideration to elements which are extraneous to the technical and business capabilities of the contractors evaluated.

Attention of the Chairman and [illegible] further specifically directed to NASA PR 3.904-[illegible] which pr[illegible] [illegible]losure of information to anyone who is not a[illegible] participat[illegible] [illegible] evaluation proceedings. Prior to the opening of proposals, the Bo[illegible] [illegible] disclose such information as may be necessary for the proper develop[illegible] [illegible] the request for proposal and then only to the extent and to those pers[illegible] considered essential for that purpose. After the opening of proposals, a[illegible] information will be kept privy to the members (voting and nonvoting) of [illegible] Board and to properly designated committees, panels, advisers and consulta[illegible] on a need-to-know basis. The right to information on a need-to-know basis does not extend to the normal chain of supervision affecting any member of the Board or arising out of technical responsibility for the action being evaluated except as specifically approved by the Chairman on a case-by-case basis. Individuals designated by the Chairman will be notified by him, in writing, with respect to the privileged character of information.

Charles J Donlan
for Floyd L. Thompson
Director

Copies to:
Each Committee Member (through official channels)
NASA, Code R
NASA, Code S
Director
Associate Director
Assistant Directors
Chief, Engineering and Technical Services
Procurement Officer
All Engineering and Technical Services Division Chiefs
All Research Division Chiefs
Mechanical Service Division Branch Heads
Administrative Services Division
Files

No. 7-65

LANGLEY R... ANNOUNCEM...

DATE February 9, 1965

SUBJECT: ... Evaluation Committees to assist the ... proposals covering the Comparative ... ification Procedures for ... L-5295

1. Two evaluation ... Source Evaluation Board in evaluating different areas of the ... ned in Request for Proposal L-5295. Personnel are ...

A. Technical Evaluation C...

Leonard Robert..., Chairman, ...
Clarence T. Brown, Jr., ... and Systems Division

(1) Overall System... el

Roger ... ision
James ...
Carl A. ... on
James A. McN...
William H. Michaels, ...

(2) Subsystem Concepts and ...

Hubert K. Clark, Chairman ... Division
William D. M..., Technic... Director (Group 1)
William F. White, I...
James Benn, Instrument ...
Walt C. Long, Instrument ...
Lloyd J. F...
Percy J. Bobb..., Dynamic...
John C. ..., Jr., ... ision
John W. Willey, Jr., ... ision
Lawrence ...
Robert A. ...
Sheldon T. ...
Edwin C. Foudriat, Instrum...

(3) Qualification Test Program ...

Clarence L. Gillis, Chairman ... ics Division
Henry T. ..., Jr., ... Division
Joseph M. ..., Jr., ... Division
James W. May..., Flight ...
Jack F. Zank..., Instrument ...

(4) Sterilization Panel

Billy L. Dove, Chairman, Instrument Research Division
E. John Brock, Jr., Flight Vehicles and Systems Division
Charles H. McLellen, Aero-Physics Division
Harold E. Poole, Instrument Research Division

(5) Technical Management and Plans Panel

William C. Hayes, Jr., Chairman, MORL Studies Office
Marion B. Seyffert, Mechanical Service Division
Mark W. Cole, Jr., Electrical Systems Division

D. Business Evaluation Committee

Henry J. Pratt, Chairman, Procurement Division
John C. Page, Procurement Division
Harold Crate, Research Models and Facilities Division
Arthur R. Friend, Program Control Analysis and Budget Office

2. The duties of the committees will be to assist the Source Evaluation Board in arriving at its assessments of the proposals in the manner to be prescribed by the Source Evaluation Board previously established for this procurement.

3. Attention of all committee members is directed to NASA PR 3.804-4 which prohibits the disclosure of information regarding this evaluation to anyone who is not also participating in the same evaluation proceedings. The right to information does not extend to the normal chain of supervision affecting any committee member.

Edwin C. Kilgore

Edwin C. Kilgore
Chairman, Source Evaluation Board

APPROVAL:

Floyd L. Thompson

Floyd L. Thompson
Director, Langley Research Center

Copies to:
Each Committee Member (through official channels)
Director
Associate Director
Assistant Directors
Chief, Engineering and Technical Services
Procurement Officer
All Engineering and Technical Services Division Chiefs
All Research Division Chiefs
Mechanical Service Division Branch Heads
Administrative Services Division
Files

APPENDIX III

mcHuisty
5/3/65

II. b

OART's Role in Voyager Program

The Voyager Program is a major new-start program aimed at the exploration of Mars and Venus, and must precede any manned planetary exploration program. OART should place itself in a position to influence, to some extent, the objectives of the Program and to ensure that data which may be required for future manned missions is obtained on a timely basis. (The Voyager Program in the Planetary Program plays the same role as Surveyor and Lunar Orbiter play in the Lunar Program.)

Much of the technology associated with the Voyager Program relates to atmospheric entry, and is to be found in OART (i.e., Langley and Ames), rather than OSSA, and OART's participation is important if NASA is to achieve its program objectives in planetary exploration. The participation, moreover, would provide both focus and incentive for OART advanced technology in many diverse areas.

The mechanism for OART's participation in, and influence on, the Voyager Program lies in the OART Centers taking some responsibility for part of the Program. The extent of Langley's capabilities in the technologies required in the Voyager Program together with the alternate roles that Langley could assume in the Program are outlined below:

Langley Research Center's Capabilities

The technology associated with the development of the Voyager Capsule Bus is, in essence, the technology of atmospheric entry and landing, and includes the technical areas of entry vehicle design, thermal protection, communication, propulsion, impact attenuation and landing.

This technology has been pursued in depth at Langley Research Center for many years through ground and flight test programs and has resulted in such developments as Project Mercury, Project RAM (Radio Attenuation Measurements) and Project Fire. These projects in effect have established the state-of-the-art in design, communication, and heating for atmospheric vehicles in the velocity range 20,000 ft/sec to 40,000 ft/sec. Smaller, but nevertheless significant, projects at Langley Research Center include supersonic and high altitude parachute deployment programs, and the development of entry vehicle diagnostic instrumentation, data storage and data transmission systems.

The technology associated with the Capsule Experiments is primarily that of developing instrumentation to cover an extremely wide variety of measurements, including life detection, atmospheric properties, surface chemistry and physics, meteorological conditions, etc.

Langley Research Center has experience in many, but not all, of these areas and includes the development of flight instrumentation for the measurement of atmospheric properties, planetary horizon definition, surface strength characteristics, and landing dynamics (for Surveyor).

With this background, an in-house research program has been pursued at Langley Research Center for the past two years aimed at the technology required for the Voyager Capsule, recognizing that these are unique design problems that arise as a result of the tenuous Martian atmosphere, the requirement for sterilization, and the long spaceflight prior to landing.

The continuing program has included structural and thermal materials tests, wind tunnel tests, flight tests of atmospheric measurements instrumentation and currently includes contracted comparative studies of system design and of all development and qualification procedures. It is anticipated that entry vehicle structures and instrumented crush-up packages will be fabricated and tested during this year.

Alternate LRC Roles (Summarized in Charts 1 and 2)

I. LRC would have Project responsibility for the development of a Voyager Capsule (for use in 1971 and subsequent years) consisting of a multimission Capsule Bus together with the integration of Capsule Experiments to determine the atmospheric and surface characteristics of Mars. These experiments would be supplied from various sources, including JPL and NASA Centers, for integration into the Capsule system. Integration of the Capsule with the Spacecraft and Launch Vehicle would be JPL's responsibility (see Chart 3 for organizational plan).

II. LRC would have Project responsibility for the development of the Capsule Bus with JPL having responsibility for the Capsule System (i.e., integration of the Capsule Bus with Capsule Experiments). In this role, LRC would define the capsule bus, provide the experiments for measurement of Mars atmospheric properties, and provide the Project direction to develop the flight qualified capsule bus. (See Chart 4 for organization plan.)

III. LRC would not assume any Project responsibility but would supply definitive study information prior to Capsule development and continuing supporting technology during the early development phase. Such support would include flight testing of capsule subsystems and of the complete Capsule Bus, in the Earth's atmosphere. Additionally LRC would supply an Atmospheric Measurements Package for incorporation in the Voyager Program. (See Chart 5 for organization plan.)

Preferred LRC Role - Case II or III

A comparison of Cases I, II and III on Chart I shows that Case I involves the greatest Project responsibility and a corresponding large LRC manpower requirement of 120 people, more than half of whom would be associated with a Project Office. Cases II and III have lesser demands on manpower and for this reason appear more attractive.

Case II, requiring 80 people, represents a technology effort involving 50 people plus a Project Office of 30 people and would allow LRC to have Project responsibility and authority to develop the Capsule Bus for the Voyager Program whereas Case III represents the technology effort (i.e., 50 people) but without a Project Office (and without the corresponding Project authority). Thus, LRC could retain authority to implement technical decisions at a cost of 30 people in a Project Office.

The technology effort in Cases II and III would consist of three major elements:

1. Capsule Definition Program
2. Earth Atmosphere Flight Program
3. Atmospheric Measurements Package Development

These elements are described in more detail as follows:

1. Capsule Definition Program

The present LRC program consists of:

(a) An in-house study effort leading to a contractual study by the AVCO Corporation on "Comparative Studies of Conceptual Design and Qualification Procedures for a Mars Probe/Lander" which is due to begin May 20.

(b) An in-house research and technology effort in most of the areas that relate to the Capsule design.

It is proposed that the AVCO Study, together with the results of the in-house research effort, be used as the basis for the preparation of Capsule design specifications (i.e., these specifications would constitute "Preliminary Definition" and would be used in further design and development contracts). LRC would continue to participate in the Capsule Definition up to "Final Definition" through an increased level of effort on the supporting technology, particularly in the following areas.

Aerodynamics

Dynamics and Aeroelasticity

Structures

Thermal Protection

Communications

Diagnostic Instrumentation

Propulsion Systems

Retardation Systems

Mechanical Subsystems

Sterilization

Such a technology program would allow OART to contribute to and influence the Capsule design in a major way.

The application of these technologies to the Voyager mission is shown in Chart 6 and the phasing of the technology effort in relation to the Phase I - Phase II Capsule development is illustrated in Chart 7.

2. Earth Atmosphere Flight Program

Although the major part of the Capsule research and technology effort can be accomplished through the use of ground facilities, a limited program, designed to develop and test mission hardware in the Earth's atmosphere, is anticipated.

The scope of such a flight program is still under study but the possible major elements together with the flight objectives are outlined below:

- Small scale Capsule Configurations, using Scout, to investigate:
  - (a) rigid body dynamics
  - (b) thermal protection
  - (c) blackout (transmission through wake)
- Parachute development test, to determine:
  - (a) steady and transient performance of fullscale parachute
- Earth Atmosphere Entry of Capsule Bus, using Saturn IB to:
  - (a) qualify Capsule Bus subsystems including structure, heat shield, communication, diagnostic instrumentation, parachute deployment, etc.

The accomplishment of such a flight program is considered to be well within the capabilities of LRC and would utilize the past experience on Trailblazer, Scout, Project FIRE, Arcas (parachute program) and other projects.

3. Atmosphere Measurements Package Development

It is anticipated that the Capsule Bus, during its descent through the Martian atmosphere, will acquire detailed information on atmospheric properties (density, pressure and temperature profiles, composition, etc.) prior to impact on the surface. LRC proposes an

Atmospheric Measurements Package capable of acquiring, storing and transmitting, (prior to impact,) data on the Martian atmosphere. Such a package would contain instruments and components developed at LRC and elsewhere, and would include an x-ray backscatter device (for direct measurement of density), pitot system (pressure), mass spectrometer (composition); solid state memory, battery and antenna for data handling. This package would be developed under contract and ground and flight tested by LRC prior to incorporation into the Capsule.

LRC experience in the techniques of atompsheric measurements and interpretation of data are reflected in previous pr grams relating to determination of the Earth's atmosphere including a program leading to the definition of the 1962 Standard Atmosphere.

CHART 1

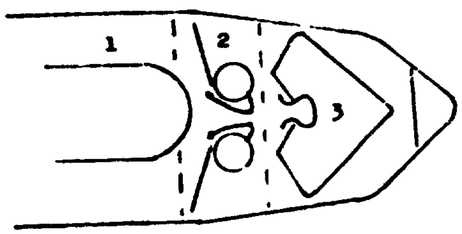
ALTERNATE LRC ROLES IN VOYAGER PROGRAM

	I	II	III
TOTAL SYSTEM INTEGRATION	JPL	JPL	JPL
S/C Bus	JPL	JPL	JPL
S/C Experiment Integration	JPL	JPL	JPL
S/C Experiments	From Experimenters		
Capsule Bus Development	LRC	LRC	JPL
Capsule Bus Definition Program	LRC	LRC	LRC
Earth Atmosphere Flight Program	LRC	LRC	LRC
Capsule Experiment Integration	LRC	JPL	JPL
Atmospheric Measurements Exper.	LRC	LRC	LRC
Other Experiments	From Experimenters		
LRC MANPOWER	120	80	50

CHART 2

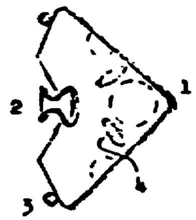
SUMMARY OF VOYAGER SYSTEM ELEMENTS

Total System



1. Launch Vehicle
2. Spacecraft
3. Capsule

Capsule System



Capsule Bus

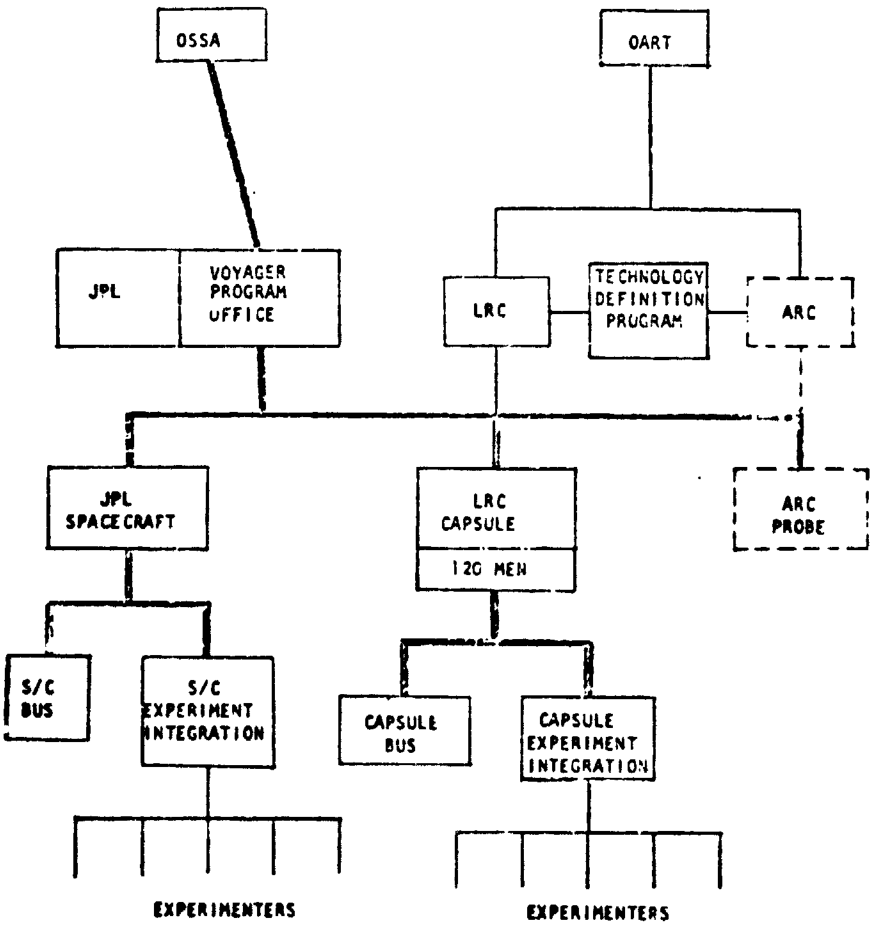
1. Entry Vehicle
2. Propulsion
3. Control System (Spin Rocket, etc.)
4. Parachute

Capsule Experiment Packages

1. Atmospheric Package
2. Surface Package

CASE I

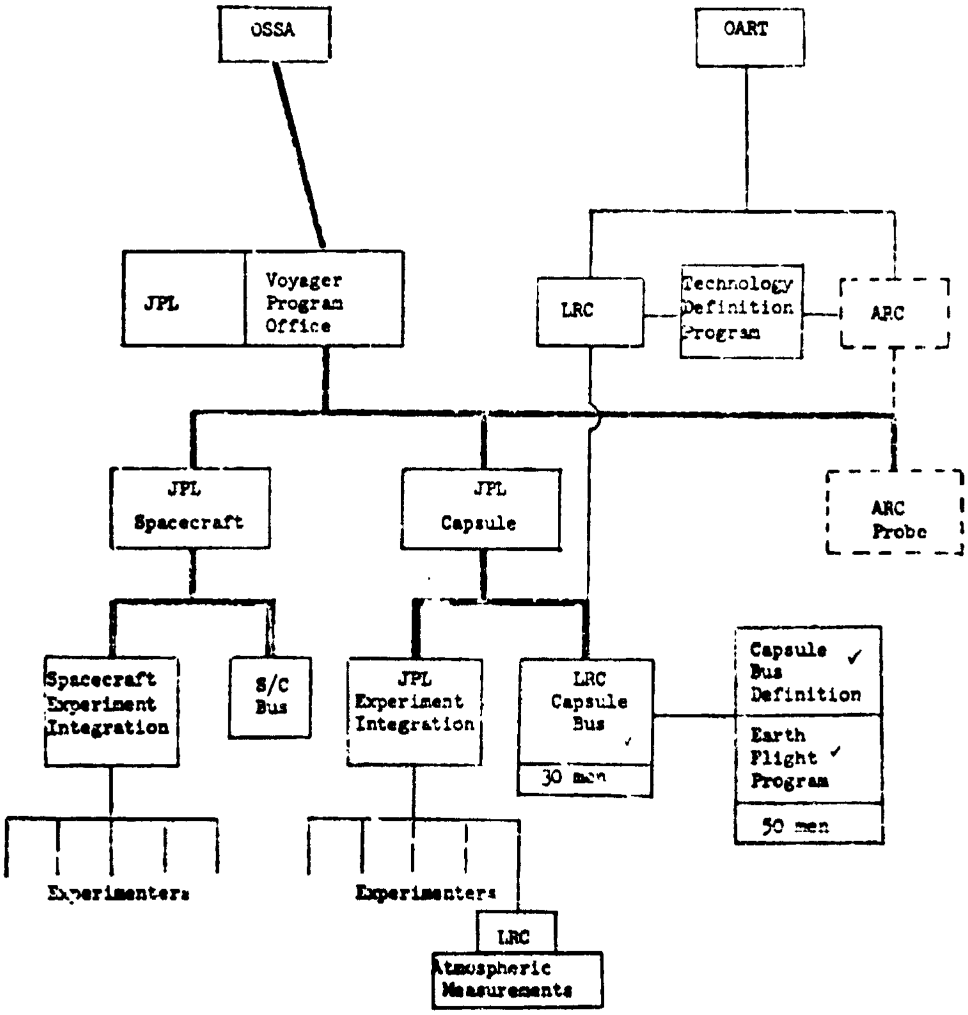
CHART 3



BY........DATE........ SUBJECT........ SHEET NO.......OF......
CHKD. BY......DATE........ JOB NO........

CASE II

CHART 4



BY........ DATE........ SUBJECT.................. SHEET NO.......OF......
CHKD. BY........ DATE........ JOB NO..................

CASE III

CHART 5

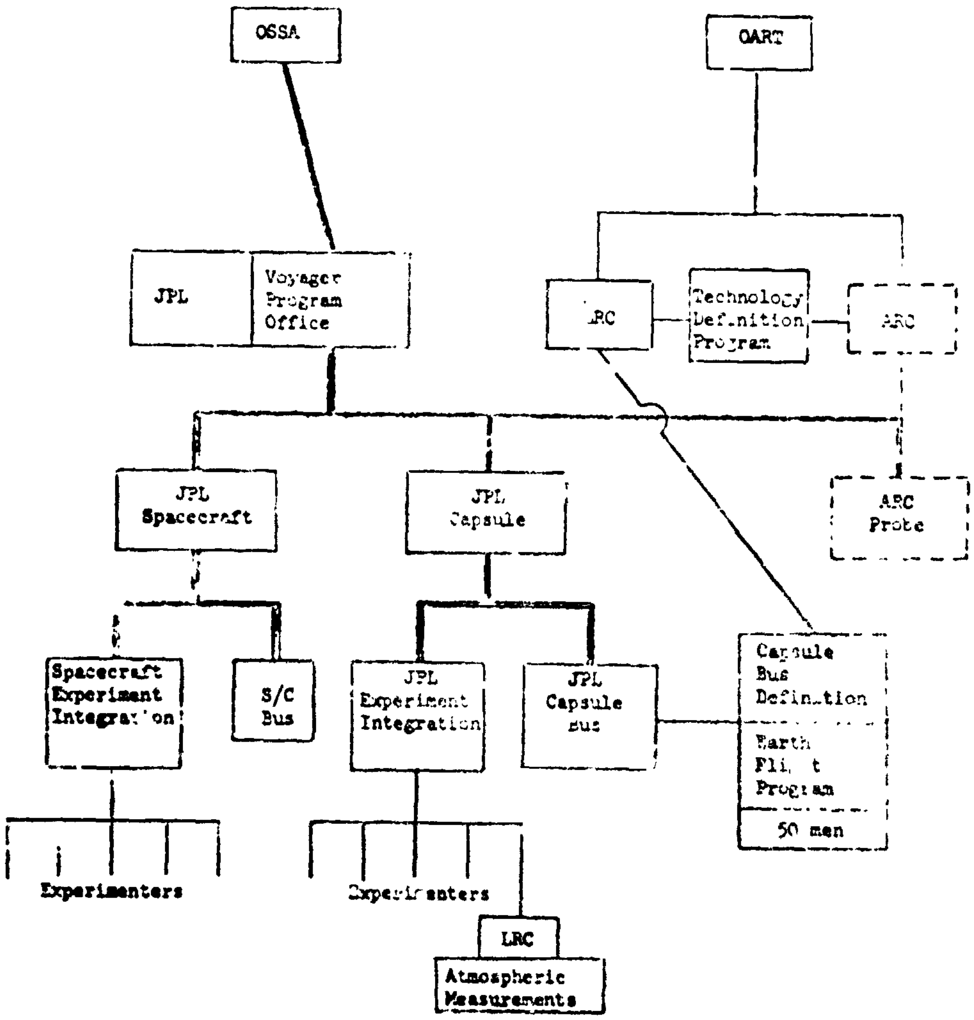
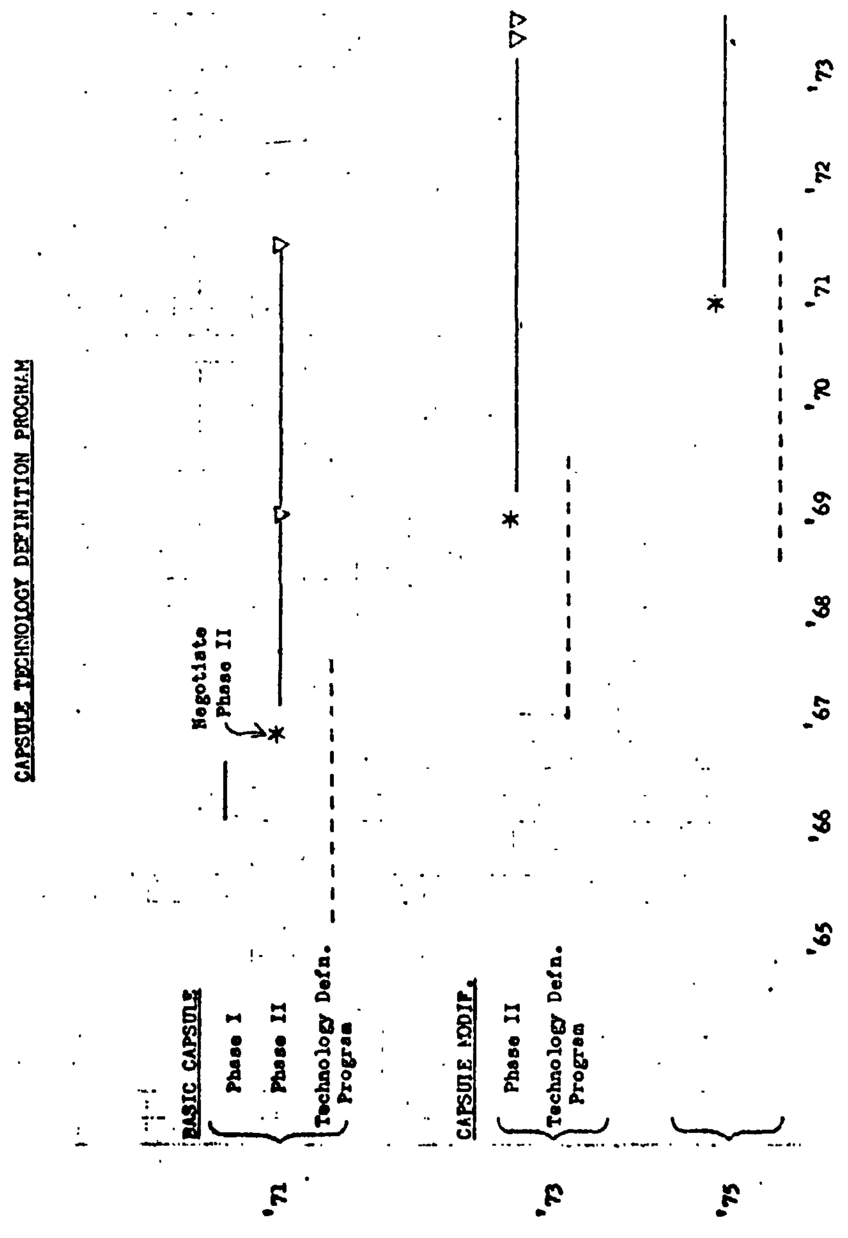


CHART 6

	MISSION CHARACTERISTICS	ASSOC. TECHNOLOGY
	8 MONTH SPACEFLIGHT	VACUUM, RADIATION, MICROM. EFFECTS; THERMAL CONTROL
	TERMINAL GUIDANCE	SENSORS; GUIDANCE & CONTROL
'71	TERMINAL MANEUVER	PROPULSION; SPIN & DESPIN MECH.
'73,'75	STERILIZED SYSTEM	STERIL. TECH; MATERIALS; COMPONENT RELIABILITY
	LOW W/C_DA ENTRY VEHICLE	AERODYNAMICS; STRUCTURES; MATERIALS
	TERMINAL PARACHUTE	SUBSONIC & SUPERSONIC HIGH ALT. DEPLOYMENT
	HARD IMPACT	CRUSH-UP, PACKAGING; COMPONENT PERFORMANCE
'71	ATMOS. & SURFACE MEAS.	INSTRUMENTATION
	DATA TRANSMISSION	DATA STORAGE; POWER SUPPLY
	POST ENTRY RETRO.	PROPULSION; AERODYNAMICS
'73,'75	SOFT LANDING	CONTROL; LANDING DYNAMICS
	LIFE, WEATHER MEAS.	INSTRUMENTATION

CHART 7


CAPSULE TECHNOLOGY DEFINITION PROGRAM
'71
BASIC CAPSULE
Phase I
Phase II
Technology Defn. Program
Negotiate Phase II
'73
CAPSULE MODIF.
Phase II
Technology Defn. Program
'75
'65
'66
'67
'68
'69
'70
'71
'72
'73

III-B

MANAGEMENT MANUAL
LANGLEY RESEARCH CENTER

CHAPTER 2-9
PAGE 1 of 2
DATE May 21, 1965

SUBJECT Planetary Missions Technology Steering Committee

1. GENERAL

This instruction establishes a Planetary Missions Technology Steering Committee, reporting to the Director, and sets forth its functions and membership.

2. FUNCTIONS

The functions of this committee are to.

a. Survey in-house and contractual supporting research and technology pertinent to planetary missions.

b. Recommend new effort or changes in effort in supporting research and technology.

c. Monitor research programs so that new results and developments can be made available to study contractors.

d. Participate in the definition of the scope and depth of contract studies.

e. Guide and review the progress of contract studies.

f. Evaluate results of studies and recommend future actions.

3. MEETINGS

a. Meetings are to be held on the call of the Chairman.

b. The Chairman is to appoint a Secretary to record the minutes of each meeting.

c. The minutes of meetings are to be submitted to the Director.

4. MEMBERSHIP

The following are designated to serve on the committee until relieved in the capacities indicated·

Chairman:	Dr. Leonard Roberts ✓ 122
Members:	Roger A. Anderson 182

T.S. 29

Thompson
Kaplan

Paul R. Hill
Edwin C. Kilgore
Eugene S. Love
William D. Mace
William H. Phillips
James E. Stitt

5. SUPPORTING COORDINATORS

a. To assist the committee in obtaining information to carry out its functions, division chiefs have designated personnel who are hereby appointed as coordinators for their respective divisions:

Aero-Physics Division	Robert A. Jones
Applied Materials and Physics Division	Edward M. Sullivan
Dynamic Loads Division	Harry L. Runyan, Jr.
Flight Vehicles and Systems Division	James F. McNulty
Full-Scale Research Division	Cornelius Driver
Instrument Research Division	Sheldon T. Peterson
Space Mechanics Division	John D. Bird
Structures Research Division	Lawrence D. Guy

b. The specific functions of supporting coordinators are to:

(1) Coordinate information between the committee and their divisions concerning existing and proposed research and technology pertinent to planetary missions.

(2) Participate in the formulation, technical review, and evaluation of contract studies.

(3) Disseminate the results of contract studies, as appropriate, within their respective divisions.

III. C. PRELIMINARY. McNulty!

RECOMMENDED LRC POSITION IN THE VOYAGER PROGRAM

The proposed LRC position in the Voyager Program is essentially one of technical responsibility and strong technical support in the area of Entry Technology and is described in terms of:

(1) supporting technical programs to be conducted by LRC

(2) working arrangements between LRC and JPL

This position is based on our current estimate of the technical needs of the Voyager Capsule Program in the areas in which LRC can make a major contribution and is subject to modification in the later phases, particularly in the area of flight testing, as more definitive requirements are established.

The Voyager Capsule phasing sequence is dictated in part by the need to develop the Voyager Capsule in parallel with the Voyager Spacecraft and so allow proper integration of the two systems. The recommended Voyager Capsule phasing schedule is shown in figure 1; also shown, for reference purposes, is the Voyager Spacecraft phasing schedule. In the Capsule phasing schedule, the Preliminary Definition Phase would be complete by January 1966. The Final Definition and Development Phase would be initiated by release of an industry-wide RFP leading to the selection of a single contractor by June 1966. With a single contractor selected at this early date, the Capsule development schedule can be made to parallel the Spacecraft Development schedule.

The recommended LRC position in the Preliminary Definition Phase and in the Final Definition and Development Phases for the Voyager Capsule is documented in the following paragraphs.

Preliminary Definition Phase of the Voyager Capsule

June 1965 - January 1966

It is recommended that the AVCO Study "Comparative Studies of Conceptual Design and Qualification Procedures for a Mars Probe/Lander" (see Appendices A and B), closely monitored by LRC and JPL, and supplemented by in-house efforts at LRC and JPL, be used as the basis for Preliminary Definition. In order to ensure compatibility with the overall Voyager System it is essential that JPL assist LRC during this phase particularly in the areas of electronics and Capsule/Spacecraft interface definition.

The recommended working arrangement between LRC and JPL during this Phase is shown in figure 2. LRC will have responsibility for management and technical direction through a Study Director reporting to the Office of the Director. The Study Director will be assisted by a management staff and functional staff consisting of technical monitors from appropriate LRC Divisions. It is recommended that JPL participate in the following manner:

(a) Establish, under the JPL Capsule Manager, a corresponding functional staff to work with LRC counterparts in the various technical areas.

(b) Provide JPL representatives at LRC throughout the study to accomplish the necessary coordination.

(c) Assure Voyager Capsule management participation by having the Voyager Capsule Manager attend reviews (midterm and final).

Final Definition and Development Phases

of the Voyager Capsule

February 1966 -

It is assumed that this phase of the Voyager Program will be managed by JPL with LRC performing a supporting technical role. To fulfill its technical role, LRC will assist JPL in the final definition of the Voyager Capsule, particularly in the area of Entry Technology including the instrumentation and communication methods to be used during entry; in addition, LRC will plan and execute a Supporting Technology Program. Specifically it is recommended that LRC assume the following responsibilities:

(a) Assist JPL in the preparation of the RFP for the Final Definition and Development Phase.

(b) Serve on the SEB and its technical committees.

(c) Conduct a supporting R & D ground program to permit final definition of the Voyager Capsule (see Appendix C).

(d) Review with JPL, design and specifications for Voyager Capsule.

(e) Plan and execute a supporting flight program in the Earth's atmosphere (see Appendix C). This flight program to be definitised during the Preliminary Definition Phase.

(f) Provide technical assistance to JPL in their performance of a full-scale prototype flight test in the Earth's atmosphere.

(g) Serve as consultants in the area of Entry Technology to JPL during hardware development as required.

The recommended working arrangement between LRC and JPL during this phase is shown in figure 3. JPL will have responsibility for the management and technical direction through a Voyager Capsule Project Office which will integrate LRC inputs into the overall program. Through a Planetary Missions Support Office (similar to existing Flight Reentry Programs Office), LRC will have the responsibility for the management and technical direction of the supporting flight program and for the coordination with JPL of the supporting R & D ground program. It is further recommended that LRC personnel attend pertinent JPL-contractor meetings and that the LRC Planetary Missions Steering Committee be represented at the major reviews.

VOYAGER CAPSULE TECHNOLOGY PROGRAM

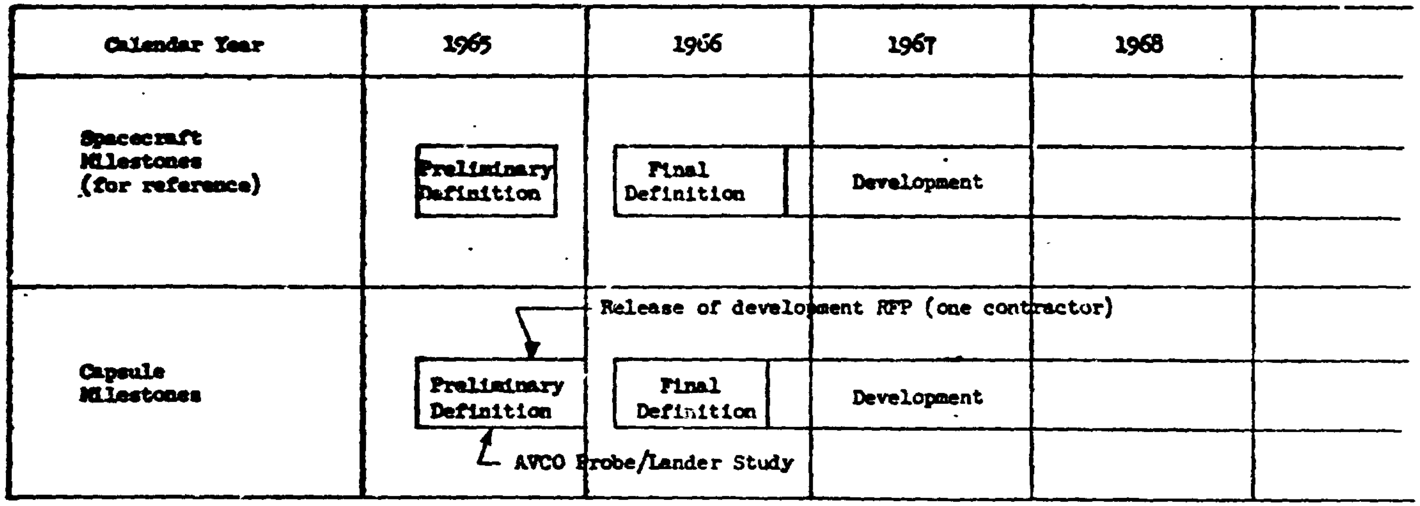


Figure 1

RECOMMENDED ORGANIZATION: Preliminary Definition Phase

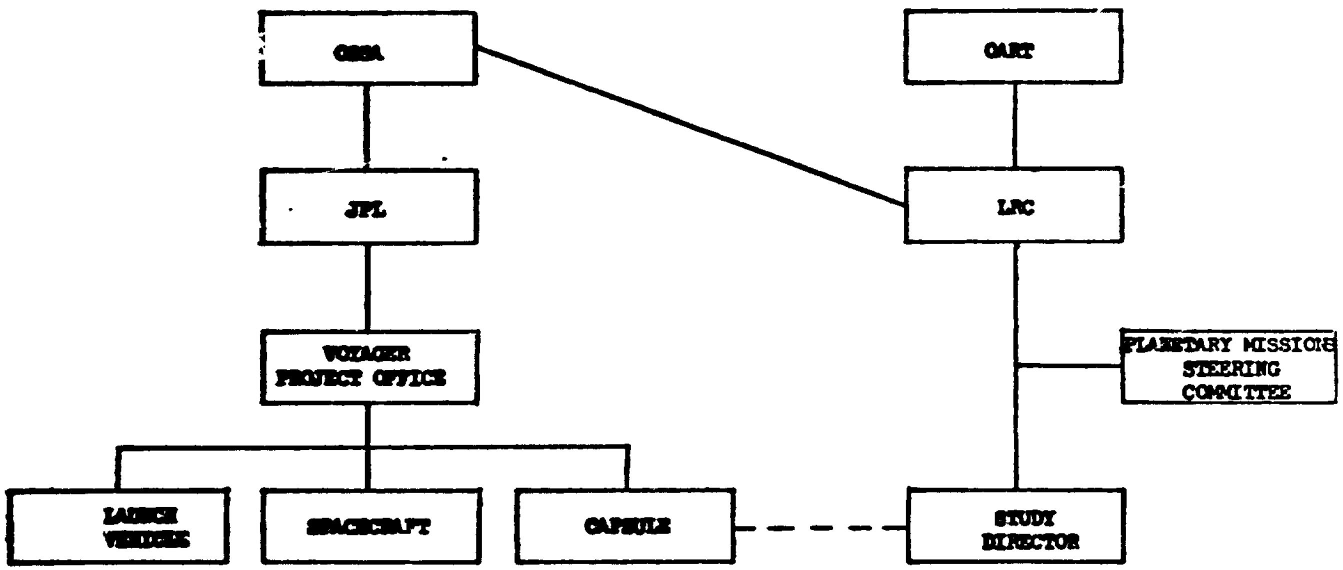
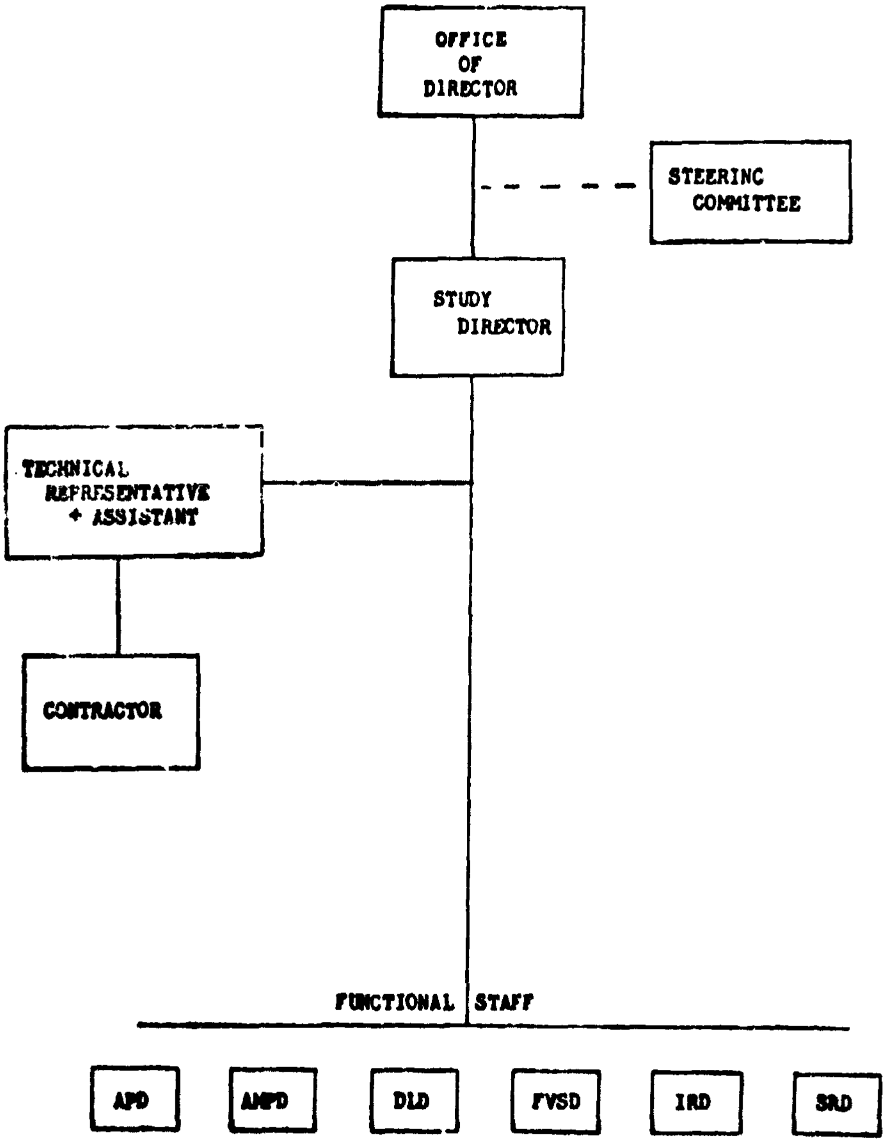


FIGURE 2

ORGANIZATION OF MANAGEMENT AND DIRECTION

OF LRC/AVCO MARS PROBE/LANDER STUDY



Study Director

Leonard Roberts, DLD	Technical direction of Study Technical direction of Functional Staff

Technical Representative

W. C. Hayes, MORL (plus 1 assistant)	Contract Negotiation Contract changes All communication with Contractor and JPL Financial Responsibilities Schedule Responsibilities

Functional Staff

1. R. A. Jones, APD	Aerodynamic Configuration Aerodynamic Heating
2. E. M. Sullivan, AMPD	Propulsion Decelerators Flight Test Program
3. P. J. Bobbitt, DLD	Entry Dynamics Entry Loads
4. J. F. McNulty, FVSD	System Integration Mechanical Design Environmental Control Qualification Program
5. S. T. Peterson, IRD	Communication System Instrumentation Tracking Sterilization
6. L. D. Guy, SRD	Structural Analysis Thermal Protection Impact Structure Structural Configuration

RECOMMENDED ORGANIZATION: Final Definition and Development Phase

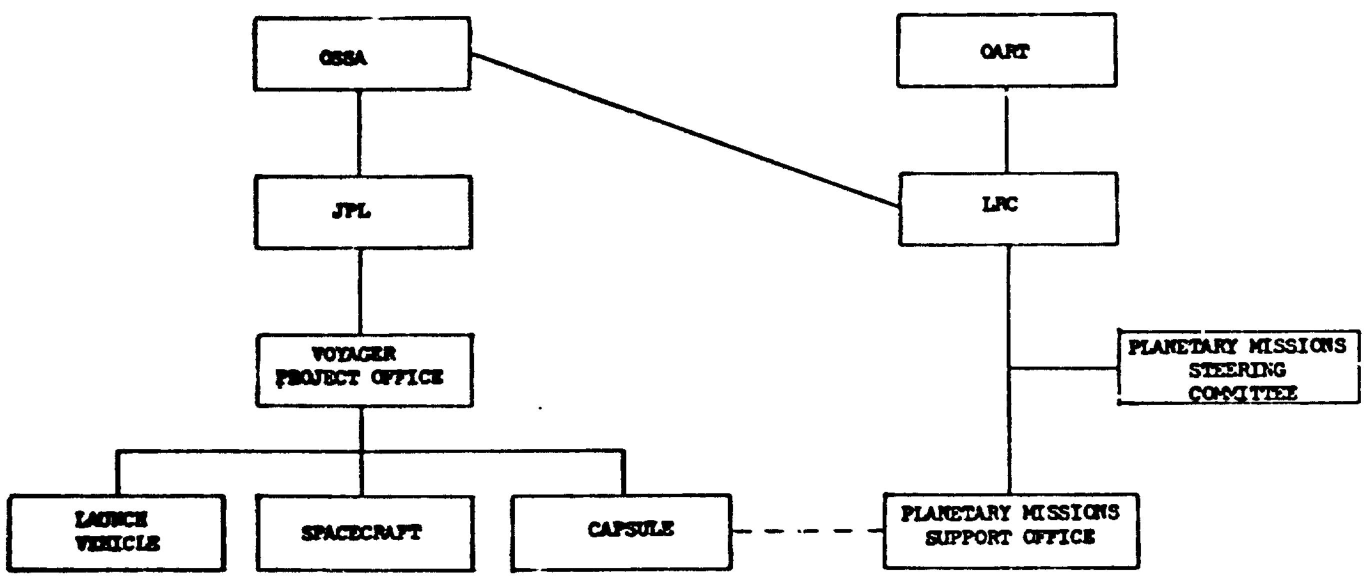


FIGURE 3

APPENDIX IV

Appendix IV - A
Summary of AVCO Final Report

SUMMARY SYSTEM CHARACTERISTICS

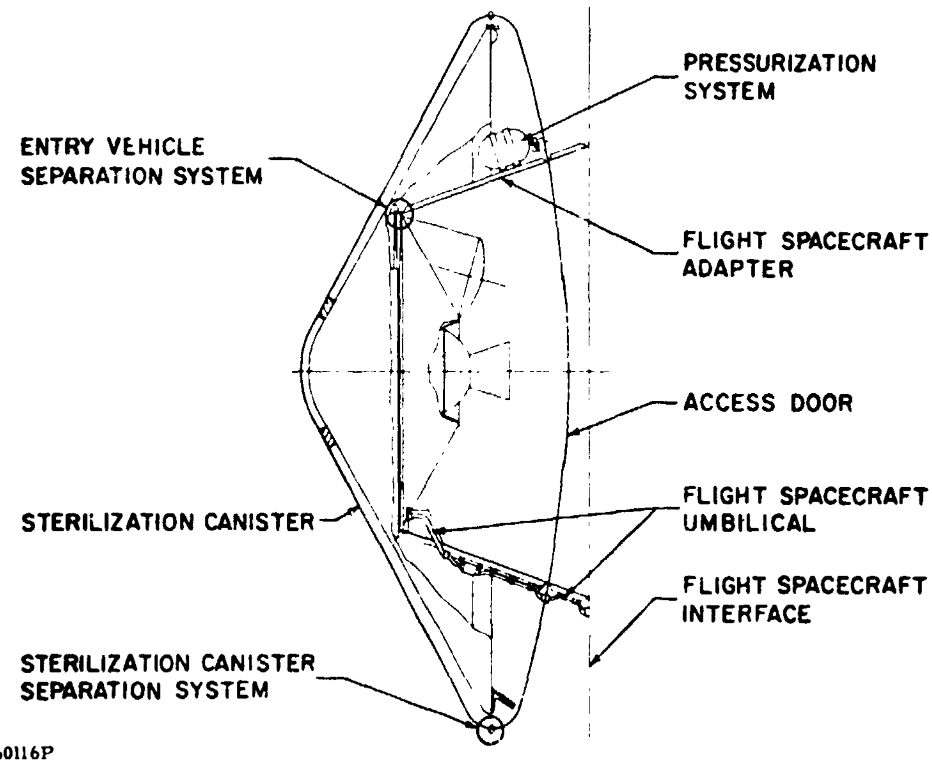
- EXPERIMENTS
  - 3 - Camera TV - 11-22 Pictures Depending Upon Atmosphere
  - TV Resolution from 30 FT. to 1/4 FT.
  - 4 Penetrometers for Surface Hardness
  - 3 - Leg Doppler for Wind Measurement
  - High and Low Altitude Radars for Surface Roughness
  - Atmospheric Composition and Structure Measurements
- DEORBIT CAPABILITY
  - From Elliptical Orbits
    - 700 - 1500 km Periapsis
    - 4000 - 20000 km Apoapsis
- FLIGHT CAPSULE (FC)
  - Shell $M/C_DA = 0.22$ W = 2040 Lbs. With Growth Margin
    - 15' Dia. Aluminum Honeycomb, Purple Blend Mod 5
  - ACS Active Cold Gas ACS and Maneuver
    - Solid Propellant Hot Gas TVC
  - Communications Redundant 30 Watt FSK 18000 BPS System
  - Deorbit Engine 1400 FPS Fixed
- FLIGHT SPACECRAFT (FS)
  - No Maneuver at Separation
  - Fixed Antenna

760141P

The major features of the FC System are indicated. The selected experiments are designed to obtain properties of the Martian atmosphere, including continuous measurement of wind velocity from .5,000 feet altitude until impact. Surface characteristics are obtained from television, impact penetrometers and radar.

The reference FC design is based on a sizeable vehicle with provisions for weight growth. The design is characterized by a high degree of redundancy, operational capability for deployment from a wide range of orbits and minimum FC restrictions on the FS and mission.

FLIGHT CAPSULE LAUNCH CONFIGURATION



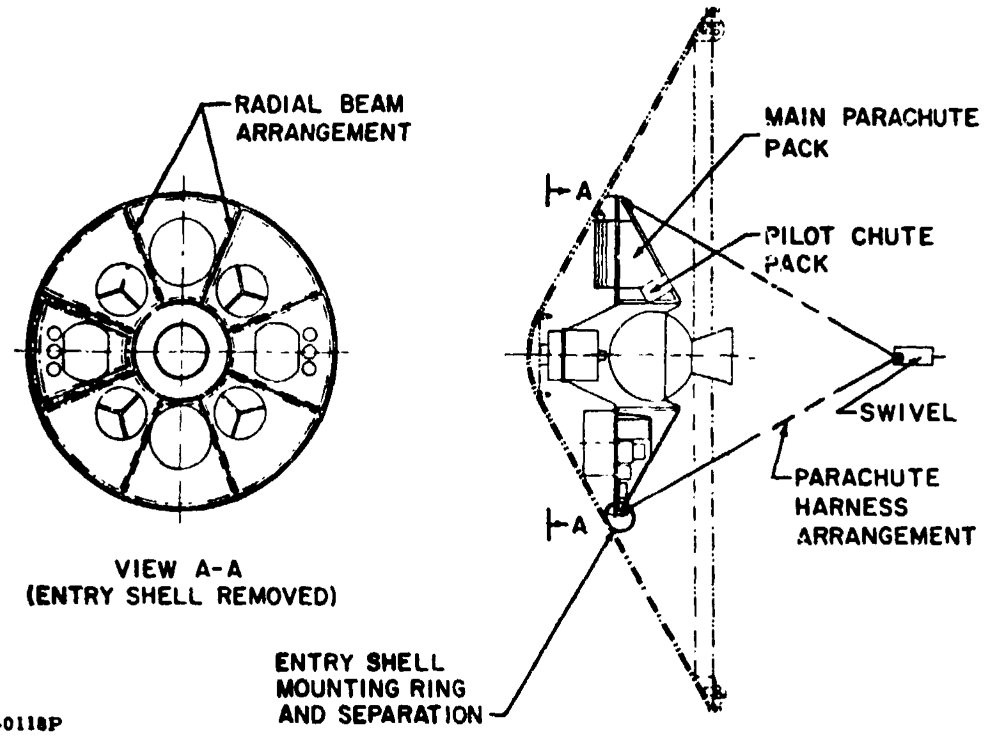
760116P

This chart, as well as the next four, present the physical layout of the FC to give an early indication of the salient features of the conceptual design.

The sterilization canister is made of thin aluminum monocoque construction in three major sections: 1) the lid, which covers the entry shell and is jettisoned prior to orbit injection, 2) the outer conical section of the base, which houses the separation system (linear shaped charge), and 3) the inner circular section of the base, which provides the access door for assembly of the deorbit motor. All three sections are welded together during assembly, together with the semi-monocoque FC-FS adapter running through the canister.

The FC-FS separation system is located at the forward end of the adapter and consists of a clamp-cable mechanism for tie-down. The FC is released by four explosive bolts, any one of which will release the system. Electrical separation occurs simultaneously with, and is caused by, mechanical separation. A pressurization system is provided in the canister to maintain a slight positive pressure differential (1 psi) across the canister during the time period from terminal heat sterilization to canister lid deployment.

SUSPENDED CAPSULE STRUCTURES



76-0118P

The complete suspended capsule structure is composed of two semi-monocoque structures, one forming the afterbody contour (60° truncated-cone) and the other a cylindrical section around the ΔV engine. These two structures are held together by a ring at the aft end, and eight radial beams and the entry shell mounting ring at the other end. The majority of the equipment is mounted on the eight radial beams in the front portion of the suspended capsule. The longerons joining the eight radial beams form the primary load path system for the ΔV engine thrust and for parachute opening loads. Parachute harness lines run from four points at the mounting ring to a central swivel joint from which a single riser line attaches to the parachute. The parachute system, including the pilot chute, is housed near the front of the structure and is deployed from its housing on the side of the afterbody.

SIGNIFICANT STUDY CONCLUSIONS

- Only Feasibility Question is Low q Parachute Opening
- New TV System Design (on Platform) Reduces Wind Gust Effects to a Remote Hazard
- FC System Has Adequate Performance and Weight Margins, a High Degree of Redundancy and Adequate Failure Mode Provisions

760218P

The design of a physically large FC has made it possible to accomplish mission objectives with conservative design. The system has sufficient weight contingencies so that major FC design changes will not be necessary to accommodate any reasonable increase in mission instrumentation requirements. All major possible failure modes have been considered in the design. This consideration has resulted in the inclusion, where appropriate, of redundant subsystems or increased design margins to overcome single failures in a given subsystem.

The incorporation of the two-axis gimballed TV platform slaved to the IRS makes it possible to obtain high resolution TV pictures even in the presence of high wind gusts. The TV platform maintains vertical orientation for capsule elevation angles less than 45°. Although capsule swing angles greater than 45° can occur with very high wind gusts, the capsule will return to an angle less than 45° within three to five seconds. When the capsule angle is greater than 45° TV shutter operation is inhibited.

It remains to be demonstrated that large parachutes can be deployed at low dynamic pressures.

PRE-ENTRY WEIGHT SUMMARY

	Calculated (C) or Estimated (E)	% For Contingency	Total Weight
FLIGHT CAPSULE	-	-	(2967.0)
Sterile Canister Lid	E	0	125.0
Pressurization Gas	C	50	15.0
PRE-F/C SEPARATION	-	-	(2827.0)
Sterile Canister Base	E	.0	163.0
Pressurization Tanks, Etc.	C	0	35.0
Adapter	C	20	125.0
Hdw., Cables, Bkts.	E	0	45.4
SEPARATED VEHICLE	-	-	(2458.6)
Propulsion Propellant	C	0	400.0
ACS Cold Gas Expelled	E	0	1.0
TVC Hot Gas Expelled	C	0	17.6
ENTRY VEHICLE	-	-	(2040.0)

760164P

The definition of Flight Capsule (FC) as used on the above table represents the complete weight of the FC as mounted to the FS. The weight summary is then presented in a breakdown starting at this point and subtracts subtotal weights of jettisoned or consumed elements to arrive at the next system weight. For example, the sterile canister is jettisoned and the pressurization gas is expelled prior to orbital injection. The sum of these weights is subtracted from the FC weight to arrive at the pre-FC separation or orbit weight. For each weight element, the above table indicates whether the weight was calculated (hence has supporting preliminary analysis) or estimated (usually a percentage of major weight categories). The percentage allowed for contingency is shown in the third column. This contingency percentage is over and above any safety factors, etc. that may be used in individual weight calculations. The last column shows the weight for each item, including contingency factor.

ENTRY WEIGHT SUMMARY

M/C_DA = 0.22 DIAMETER = 15 ft

	Calculated (C) or Estimated (E)	% For Contingency	Total Weight
ENTRY VEHICLE			(2040.0)
Entry Shell Heat Shield	C	20	370.7
Entry Shell Structure	C	20	343.0
Thermal Control	E	0	30.0
ACS - Reaction Control	C	20	36.0
TVC - Reaction Control	C	20	27.0
Hdw, Cables, Bkts.	E	0	81.0
Available for Growth	E	0	127.3
SUSPENDED CAPSULE			(1025.0)

760165P

The total entry weight of 2,040 pounds is based on an M/C_DA of 0.22 and a diameter of 15 feet. The diameter was selected to allow conservatism in design as well as allowing weight available for growth to accommodate increased mission objectives, further failure mode effects, etc. The entry weight consists of two major categories: 1) the entry shell and associated attachments (that portion jettisoned at parachute deployment) and 2) the suspended capsule (that portion suspended on the parachute, including the parachute weight).

A contingency factor is included in most of the subsystem weight categories over and above the usual factors of safety used on the operating loads for material sizing, etc. to account for unknown brackets, material tolerances, etc. that cannot be determined at the preliminary design point.

SUSPENDED CAPSULE WEIGHT SUMMARY

	Calculated (C) or Estimated (E)	% For Contingency	Total Weight
SUSPENDED CAPSULE			(1025.0)
Instrumentation	C	25	196.1
Altimeters, Doppler	C	25	54.4
Telecommunications	C	25	111.8
Power	C	25	160.0
Parachute	C	20	84.0
Inertial Ref. System	C	20	21.6
Structure	C	20	150.0
Afterbody Heat Shield	C	20	36.0
Propulsion Case	C	20	49.0
Hwn. ›kts, Cables	E	0	129.5
A› ›iable for Growth	E	0	32.6

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The instrumentation weight indicated in the above table includes both mission experiments and diagnostic instruments. The radar altimeters and the doppler radar are listed separately although they supply experimental data as well as performing other functions. The telecommunications weight includes all of the relay communication link subsystems as well as the data handling and storage subsystems. All subsystem weights indicated above include the weight of necessary associated hardware, i.e., mounting containers, wiring, fasteners, etc. All other bracketry, interconnecting cabling, and miscellaneous hardware are inc› ›d in the next to last weight category, which is estimated at 15% of the suspended c› ›sule weight, excluding the available for growth weight.

The inertial reference system must be located in the suspended capsule since it provides the orientation reference for the TV camera platform. Similarly, the ΔV rocket case weight is included in the suspended capsule weight since the ca›e is retained after deorbit thrusting.

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LANGLEY WORKING PAPER

MODAL AND CONCEPTUAL DESIGN COMPARISONS FOR THE VOYAGER CAPSULE

By James F. McNulty, Daniel B. Snow
and Leonard Roberts

Langley Research Center
Langley Station, Hampton, Va.

This paper is given limited distribution and is subject to possible incorporation in a formal NASA report.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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INTRODUCTION

With the reduction of the lower estimate of atmospheric pressure on Mars from 10 millibars to 5 millibars and the substitution of the Saturn V for the Saturn 1B as a launch vehicle, many technical areas in the Voyager Program previously studies must be reassessed. In reference 1, a thorough study was made of the entry from orbit mode for the currently predicted range of atmospheric pressures (5-10 mb), utilizing the Saturn V. However, this study was limited in scope in that it was concerned primarily with the entry phase of a single early mission and did not consider integration of this mission with future missions in a manner to assure logical development of subsystems with program growth.

In an effort to evaluate and identify the subsystem requirements throughout the Voyager Program, an analytical study was made of capsule systems required to land payloads of weights compatible with launch vehicle capability. Sizes and weights of flight capsules were investigated parametrically in order to determine the penalties associated with the standardization of subsystems for the capsule delivery system. Various decelerator modes were considered and a preliminary assessment was made with respect to weight, reliability, development time, and standardization. Terminal landing systems were also investigated and a trade-off comparison between modes was carried out.

In order to provide a basis for a meaningful analysis, it was necessary to bound the limits of the study with some specific guidelines.

These guidelines are defined in detail in the body of this report, but in general, restrict the study to solely the out-of-orbit mode, utilization of the Saturn V as launch vehicle, and to consideration of VM-1, VM-2, VM-3, VM-4, VM-7 and VM-8 as possible atmospheres. Specifically, the technical study could be divided into four phases. Phase I is trajectory analyses. Numerous trajectories were run to determine the load, velocity, altitude, and flight path angle relationship for the entire capsule weight range under consideration and, also, to cover capsules combined with supersonic decelerators. Phase II is the development of the parametric weights of subsystems as a function of capsule weight and size. These weights were, in general, derived by using scaling laws in combination with weights detailed in AVCO's final report (reference 1). Details of the scaling laws used are presented in this report. Phase III is the synthesizing of the above data into system estimates and presenting the system options in comparison form to illustrate the advantages and disadvantages of the various approaches. Phase IV is the conceptual representation of the selected mode, capsule and subsystems to be carried through the various missions of the Voyager Program.

SYMBOLS

A	cross sectional area, ft^2
C_D	drag coefficient
D	diameter, ft.
e	natural log base, 2.7182818
g	acceleration of gravity, 32.2 ft/sec^2
I_{sp}	specific impulse, $\frac{lb}{lb/sec}$
K	constant = 1120.

M	Mach number
m	mass, slugs
mb	millibar (atmospheric pressure)
q	dynamic pressure, PSF
RADVS	Radar Altimeter Doppler Velocity Sensor
V	velocity, ft/sec
VM	Voyager Model, used to designate a particular model atmosphere, as VM-3 or VM-8
W	weight, lb
α	angle of attack, degrees
γ	flight path angle, degrees
ρ	density, slugs/ft^3

SUBSCRIPTS

C	allocated capsule
D	delivery system
E	entry conditions
f	final, after rocket burn
I	impact
i	initial
IL	impact limiter
P	propellant
p	parachute
PL	payload
R	residual
RS	retro system
S	entry shell structure

SLS	soft landing system
T	total
t	terminal

GUIDELINES

The following is a list of basic system ground rules and constraints that were used throughout the study.

A. Booster - Saturn V

1. Geometric constraints placed on the capsule by the shroud and spacecraft are shown in figure 1.
2. The payload capability of the Saturn V is shown in figure 2.

B. Atmospheric Models

1. The model atmospheres considered are given in figure 3.
2. Hypothesized atmospheres having surface atmospheric densities less than 5 mb are assumed identical to the VM-8 atmosphere except for pressure and density.

C. Capsule Aerodynamic Shape

1. Configuration shall be 60° half angle blunt cone.
2. Drag coefficient = 1.5

D. Capsule Separation

1. Capsule is separated from the spacecraft while in orbit about Mars.
2. Capsule has active control system to attain and hold thrust vector control angle for de-orbit thrust and to control angle of attack ($\alpha_g = 0$) during entry.

E. Spacecraft Orbit

1. Only restrained to orbits which will allow the following:

   a. Capsule deorbit velocity increment = 1400 ft/sec.

   b. Capsule entry angle = -15°.

   c. Capsule entry velocity in the 12,000 to 16,000 ft/sec range.

   d. Spacecraft to serve as a communications relay.

STUDY RESULTS

Phase I - Trajectory Analyses

The entry trajectories were obtained by the use of the Langley Research Center's Analysis and Computation Division's Program No. 788. This program computes the point mass trajectory of a capsule entering the atmosphere of a spherical non-rotating planet.

Capsule trajectories.- Values of the trajectory parameters (altitude, velocity, time, deceleration, heating, and flight path angle) were obtained for the following input combinations in the VM-3 and VM-8 atmospheres.

m/C_DA = 0.15 to 0.30

γ_E = -10° to -20°

V_E = 12,000 to 16,000 ft/sec

and

m/C_DA = 0.32 to 0.75

γ_E = -15°

V_E = 12,000 to 16,000 ft/sec

Plots of the trajectory data are included as figures 4, 5, and 6. The representative parameters presented here (V_E = 12,000 ft/sec, $\gamma_E = -15^{\circ}$, and VM-8) are the assumed critical design conditions for the entry phase.

The following results are of interest on these plots. From figure 4, two points can be made:

1. For capsules with m/C_DA's <0.35, aerodynamic braking has reduced the capsule's velocity to about its terminal value; thus, deceleration has been accomplished with maximum efficiency. For m/C_DA's >0.35, the trajectories show that the capsules have not reached constant velocity and are still being decelerated at impact; i.e., the VM-8 atmosphere is too thin to decelerate efficiently the heavier capsules, therefore, an additional decelerator system (more weight) must be employed to take out this velocity increment above terminal.

2. A capsule with a $m/C_DA = 0.25$ reaches a condition of Mach 1.0 at an altitude of 15,000 feet. This altitude is sufficient to allow deployment of a transonic parachute prior to landing. Conversely, capsules with m/C_DA's greater than 0.25 will require some type of supersonic decelerator.

Figure 5 gives data on the capsule's flight path angle which is pertinent to the landing problem. As is obvious, the landing problem is simplified with near vertical descent of the capsule since both the retro firing angle and the look angles of the altitude measuring radar would not be changing rapidly with descent altitude. The primary conclusion to be drawn from these data is that for even a capsule with a m/C_DA of 0.25 the flight path angle is a relatively shallow -45° at an altitude of 12,000 feet.

The deceleration-altitude history is given on figure 6. The interesting points presented here are that the deceleration is relatively insensitive to m/C_DA variations and that the "g" level is low which indicates that capsule design may be restrained by minimum gage considerations under some conditions.

Trajectories of capsules supplemented by supersonic decelerator.- Two different types of supersonic decelerators were considered: (1) expandable afterbody type of high Mach number deployment ($M < 3.0$) and (2) supersonic parachute for deployment under Mach 3.0.

a. Expandable afterbody

Since this type of decelerator sould be compatible with the higher velocity deployments, i.e., heavier capsules, the parametric analysis was used to investigate capsules having a wide range of ballistic coefficients (0.32 to 0.75). A computer iteration procedure was used to determine the decelerator drag necessary to slow the capsule to Mach 1.0 at 15,000 feet for a variety of initial conditions.

$$\left.\begin{array}{l} V_E = 12{,}000 \text{ to } 16{,}000 \text{ ft/sec} \\ \gamma_E = -10^\circ, -15^\circ, -20^\circ \\ \text{VM-8 atmosphere} \end{array}\right\} \quad \text{Parametric Range}$$

Figure 7 summarizes the decelerator drag-deployment mach number relationship throughout the m/C_DA range for the most critical entry environment. The important items to note from this figure are that decelerator size requirements increase very rapidly with capsule m/C_DA and that deployment mach number also increases with capsule m/C_DA. For example, a capsule with an $m/C_DA = 0.75$ would require a supersonic decelerator ten times the size required by a capsule with $m/C_DA = 0.32$.

b. Supersonic parachute

This study was restricted to ballistic coefficients 0.30 to 0.50 in order to be compatible with deployment in the low supersonic range. A parametric study was made of different size parachutes deployed at various mach numbers to obtain the mach number-parachute size relationships which result in satisfactory conditions for utilization of a terminal landing system.

M = 1.0 to 2.5

Parachute m/C_DA = 0.02 to 0.08 Parametric Range

VM-8 atmosphere

Figure 8 shows how the parachute size-deployment Mach number relationship varies with entry capsule m/C_DA in order to obtain a terminal vertical descent velocity less than 300 ft/sec and a flight path angle steeper than -75° at an elevation of 10,000 feet above the surface of Mars. These velocity, flight path angle, and altitude restraints were selected in order to assure compatibility with the Surveyor soft landing system. Three items of interest are evident from the data plotted in figure 8. An extremely large (120-foot diameter) parachute, deployed at Mach 2.35, is required to decelerate an m/C_DA = 0.50 capsule. An 84-foot chute, deployed at Mach 1.75 would suffice for m/C_DA's up to 0.35 while a smaller parachute, 64-foot diameter, would meet the requirements for an m/C_DA = 0.35 capsule if deployed at Mach 2.5.

Phase II - Parametric Weights of Subsystems

Parametric weights of subsystems can be divided into two areas: area No. 1 is concerned with thos subsystems weights relating to the delivery system (aeroshell, deorbit motor, etc.) and area No. 2 relates to the subsystem weights of the landing system (impact attenuation, decelerators, etc.). Further, it is helpful to separate the analysis of the problem into the two phases of delivery and landing. For purposes of analysis, the objective of the delivery system will be to deliver the contents of the capsule (its "residual" weight), to a condition of Mach 1.0, at an altitude of 15,000 feet above the Martian surface; at this point, the landing system takes over.

Delivery system.- There is a delivered residual weight associated with each size and weight capsule launched and our objective is to define the capsule which maximizes this residual weight. This study is constrained, by the shroud, to capsules less than 20 feet in diameter, and by launch vehicle capability, to capsules less than 12,000 pounds. As the first step, this delivery mode is divided into two phases: Part I from orbit to entry and Part II from entry to an altitude of 15,000 feet. Weights of the appropriate subsystems are found as in the following manner:

The weight breakdown contained in AVCO's final report is used as a basis of scaling and is reproduced in this report as figure 9. The items listed below are subjected to scaling as detailed below in order to obtain parametric data for a variety of capsule sizes.

1. Sterilization canister lid and base - This was assumed to be a constant unit weight structure and was scaled as an area ratio or D^2.
2. Pressurization gas and valving - Since this gas is used solely to maintain a small positive pressure within the canister and its required volume is more a function of leakage than capsule size, this item was considered to be a constant.
3. Adapter and hardware items - These were scaled as functions of capsule weight since they will be sized by load criteria.
4. Deorbit propulsion system - The assumption of this study was that deorbit velocity change is equal to a constant. Thus, propellant system weight can be considered proportional to the force associated with the mass undergoing velocity change. Scale according to capsule weight.

5. Control gas system - Weights of the components for controls are considered proportional to the inertia of the capsule (WD^2) and inversely proportional to the moment arm between the nozzles (D). Thus, scaling factor is WD.
6. Entry shell heat shield - For environmental loads considered in this report, AVCO found that the ablation weight is relatively insensitive to m/C_DA (pg. 140, Vol. III, Bk. 1, Ref. 1). Ablation weight will be scaled according to surface area, D^2.
7. Entry shell structure - Minimum gage considerations vitiates any direct scaling procedure. Figure 10 is a plot of the parametric structural weights obtained from AVCO's machine program. Expressing the stagnation pressure as a function of m/C_DA and entry conditions, the following equation can be derived:

$$W_S = 120 \left(\frac{D^2}{100} + \frac{3}{4} (m/C_DA)(D-10)\right)$$

8. Thermal control - To be conservative in this report and with the lack of any clear-cut scaling criteria, this weight is scaled by volume (D^3) relationship assuming interior of the capsule must be kept at a specified temperature.

By using these scaling laws, the capsule's entry weight is calculated as a function of its allocated launch weight and diameter. This is carried out by noting from figure 9 those elements compr ‑g the difference between allocated weight and entry weight, and subtracti eir scaled weight from the allocated weight. This entry weight can be expressed as follows:

$$W_E = W_C - 1.28D^2 - 0.185\ W_C - 0.00042W_CD-21$$

This equation is plotted as figure 11 and the capsule's ballistic number can be found from figure 12 for the entry weight and diameter under consideration.

From the capsule's entry weight, the capsule's residual weight can be calculated in like manner from the scaling relationships. The residual weight can be expressed as follows:

$$W_R = W_E - 1.65D^2 - 120\left[\left(\frac{D^2}{100} + \frac{W_E}{50D^2}\right)(D-10)\right] - \frac{2D^3}{225} - \frac{W_E D}{333} - \frac{W_E}{24}$$

This equation is plotted as figure 13. The results shown on this figure assume that the Martian atmosphere is sufficiently dense to slow the capsule to a Mach 1.0 condition at 15,000 feet altitude by aerodynamic braking on the capsule. Should this not be the case, the weight of the required supersonic decelerator to accomplish this deceleration must be subtracted from the residual weight.

Landing system.- Once the residual weight has been delivered to the satisfactory conditions for initiation of the terminal landing system, it becomes essential to identify the landing mode in order that the residual weight can be divided into landing subsystems and payload. Unlike the delivery system weight investigation, these landing system weights are strictly dependent upon the landing mode.

The first item of interest, therefore, is the identification of this landing mode. Two basic landing modes were considered: 1) Hard landing a payload (surrounded by impact attenuation) with a parachute, and 2) Soft landing the payload in a Surveyor-like manner.

Many parameters were of concern in deciding between these two modes. In addition to weight, consideration was given to topographical effects, deployment of experiments, reliability, and growth. Figure 14 shows that either mode will land approximately the same payload fraction; this is because the hypothesized high wind velocity causes a high impact velocity for the parachute borne payload so that the weight of required impact attenuator is of the same order as the equipment and propellant required to effect a soft landing. The topography may determine which concept, ball or legs, is preferable. Legs offer stability on level ground under wind load but conceivably would not be satisfactory if the surface had sharp discontinuities. Deploying instruments through thick impact attenuation material presents difficult problems; in addition, there is the possibility that the impact attenuator will be scattered in the test area at impact thus effecting the purity of the testing. The Surveyor system has proved its reliability by landing an operating payload on the moon, while the engineering problems associated with the ball concept have yet to be thoroughly studies. In the final comparison area, it is felt that the soft landing concept is more compatible with growth considerations since manned soft landings will be an eventuality.

The soft landing concept was selected as the preferred landing mode as a result of the above evaluations. In addition, it is noted that a legged vehicle could be used to drop an instrumented ball should topography indicate that a spherical payload be advantageous.

Following selection of the basic landing mode, it is now possible to identify the candidate landing subsystems and to obtain approximate parametric formulas for the weight of each. This will allow the calculation of the landing system weight for various missions (capsule allocated weights) and determination of the optimum combination of candidate landing subsystems.

Transonic parachute.- The size of the parachute is determined by the terminal conditions desired. Its terminal velocity-size relation is given by:

$$C_D q A = W_S$$

$$C_D \rho \frac{V_t^2}{2} A = W_S$$

$$\text{or } A = \frac{2W_S}{C_D \rho V_t^2}$$

Since deployments will take place at very low dynamic pressures, it is anticipated that deployment loads (with reefing, if required) will be sufficiently low to allow use of a minimum gage structure. Thus, the parachute weight will be proportional to its size.

$W_p = \frac{K W_S}{V_t^2}$, where K represents the constant factors

Using the AVCO calculations where it was found that the parachute would weigh 70 pounds for a suspended weight of 1025 pounds and a terminal velocity of 128 ft/sec, the value of K is found to be 1120. Thus, the parachute weight can be expressed as

$$W_p = \frac{1120 W_S}{V_t^2}$$

Impact attenuation.- Considerable work has been done by AVCO and others in determining the payload fractions associated with balsa wood impact limiters. The payload fraction is defined as the ratio of the weight of the payload (W_{PL}) to the combined weight (W_T) of the payload and the impact limiter (W_{IL}). Balsa wood is being taken as reference because of its high energy absorption to unit weight ratio over a wide range of impact velocities.

The ratio between gross payload fraction and impact velocity (V_i) is given in figure 15, as reported in reference 2. For making comparison evaluations, the following simplified linear equation will be used for the weight of the impact limiter:

$$W_{IL} = \frac{V_I}{600} W_T$$

Retro system.- The ratio of initial weight (W_i) to the final burned-out weight (W_f) can be obtained readily from the following formula and is dependent upon the specific impulse and the velocity increment:

$$\Delta V = I_{sp}\, g \ln \frac{W_i}{W_f}$$

this reduces to

$$\frac{W_i}{W_f} = e^{\frac{\Delta V}{9000}}, \text{ where } I_{sp} = 270 \text{ for solid propellant}$$

$$\frac{W_i}{W_i - W_p} = e^{\frac{\Delta V}{9000}},$$

$$W_p = W_i \left(1 - e^{\frac{-\Delta V}{9000}}\right)$$

Now to this propellant weight, it is necessary to add 20 percent to account for the auxiliary rocket hardware. Thus

$$W_{RS} = 1.2\, W_i \left(1 - e^{\frac{-\Delta V}{9000}}\right)$$

Inflatable supersonic decelerator.- Preliminary weight estimates were made for attached inflatable afterbodies required to decelerate various size and weight capsules to a condition of Mach 1.0 at 15,000 feet above the Martian surface. These estimates were based on in-house analyses assuming an inflatable torus at the base of the cone with fabric in tension between the aeroshell and the torus. These weight estimates are given in figure 16. Since these weights were calculated for a static condition to prevent buckling of the torus, a factor of at least 20 percent should be added to account for dynamic effects.

Soft landing system (Surveyor type).- Surveyor soft-landed on the moon with the aid of a radar altimeter and doppler velocity sensor (RADVS).

The terminal descent mode of the landing on the moon is given on figure 17; it should be noted that the vernier retro system takeover occurs at a velocity of 350 ft/sec and an altitude of 25,000 feet. Hughes Aircraft Company made a preliminary study to define the modifications required to make the system applicable to a Mars landing. The recommended Mars trajectory conditions are indicated in figure 18; the corresponding conditions for the vernier retro system takeover are a velocity of 400 ft/sec and an altitude of 10,000 feet. The primary difference in the concepts is that for a moon landing the primary deceleration is by a main retro burn while at Mars the deceleration is caused by aerodynamic braking.

It remains now to define the subsystem weight of the landing system so that the net residual weight available for payload can be determined. The subsystems can be placed into two categories--fixed weight items and items whose weight will vary with magnitude of the lander. As a result of discussion with representatives of Hughes Aircraft and JPL, together with in-house estimates, the following weight estimate was derived:

Fixed Weight Items:		840
Structure	300	
Flight Control (RADVS)	75	
Commun. and Power	120	
Cabling, Thermal Control	100	
Propulsion System	245	
Variable Weight Item:		
Propellant	$W_1 (1 - e^{\frac{-\Delta V}{9000}})$	

Figure 19 shows a residual weight comparison between two 19-foot diameter entry capsules. The dashed curves are for a capsule of 4360 pounds entry weight (maximum allowable for each of two equal-weight capsules in a Saturn V booster) and a ballistic number (m/C_DA) of 0.32. The solid curves are for a capsule of 3400 pounds entry weight and a ballistic number of 0.25 (the largest m/C_DA which will permit deceleration to Mach number 1.0 at 15,000 feet from capsule aerodynamic braking in VM-8 atmosphere with V_E = 12,000 ft/sec and γ_E = -15°).

The 0.25 m/C_DA curve represents a system designed to enter a 5 millibar pressure atmosphere and the associated delivery system (W_D = 1600 pounds) is designed for the conditions encountered in this atmosphere. Its weight, therefore, is fixed. If the atmosphere is found to be greater than 5 mb, which would allow more entry weight (greater W_R and higher m/C_DA), the delivery system would be unable to accomodate it from a structural standpoint. Consequently, 1800 pounds of residual weight (W_R) is the maximum which can be accomodated with the 1600 pound basic delivery system. The straight sloping line shows the residual weight capability for atmospheres of less than 5 mb. For example, at 4 mb the W_R = 1120 pounds. If an additional decelerator system is used to decelerate the capsule to Mach 1.0 at 15,000 feet in a 4 mb atmosphere, the residual weight is 1700 pounds as read on the curve arcing down to the left. This curve shows the added residual weight which can be obtained in low pressure atmospheres by the addition of a supersonic decelerator.

Using the maximum capability of the Saturn V booster, a system can be designed which would provide 4360 pounds of entry weight (shown on the m/C_DA = 0.32 curve). The delivery system weight for this case would be

Thus, the following equation will be used for the weight of the soft lander bus:

$$W_{SLS} = 840 + W_1 \left(1 - e^{\frac{-\Delta V}{9000}}\right)$$

Phase III - System Synthesis

Again, the device will be used of dividing the capsule into two systems: a delivery system and a landing system. The objectives will be to determine an optimum aeroshell for delivering the payload and to define the method of soft landing the payload on the surface of Mars.

Delivery system.- While it is important to obtain maximum utilization of the Saturn V booster capability in delivering an instrumented payload to Mars, prime consideration must be given to the sizing of a capsule which results in delivering the maximum residual weight to the terminal landing conditions. It is, therefore, necessary to select a capsule with the optimum ballistic number (m/C_DA) that will permit deceleration to the desired terminal altitude-Mach number conditions, for the probable range of atmospheric pressure, without incurring an unacceptable delivery weight penalty for the instrumented payload. Residual weight, as used herein, is defined as follows: "The weight residing in the aeroshell (W_E-W_D) which is delivered to an altitude of 15,000 feet above the surface of Mars at velocity equal to Mach 1.0."

This study provides comparison of residual weights achievable with a variety of capsules, varying from the heaviest capsule or dual capsules which can be accomodated by the Saturn V to minimum capsules of the Apollo and Mercury size. Parametric weight equations derived in the preceding section B were used to determine the capsule weight allocations, entry weights, and residual weights.

1800 pounds and would carry 2560 pounds of residual payload for an atmospheric pressure of 6.4 mb or greater. For lower pressure atmospheres, the arcing line shows the residual weight capability with a supersonic decelerator system and the straight sloping line shows the residual weight capability of the delivery system without a supersonic decelerator.

It is easily shown, by observing the two straight sloping lines, that if a delivery system is designed for maximum booster capability without a supersonic decelerator aid and the atmospheric pressure turns out to be less than 5.3 mb, a weight penalty exists. This penalty is 200 pounds from 5 mb down.

Figure 20 makes the same comparison as shown in Figure 19 except that the capsules are 13.45-feet in diameter; an area factor of 1/2 for comparison with the 19-foot diameter. For this capsule size, the weight penalty for using the maximum booster capability without a supersonic decelerator aid occurs at pressures below 6.05 mb and amounts to 360 pounds at all pressures below 5 mb.

It is obvious from Figure 19 and 20 that if a capsule of maximum capability is used, the 19-foot diameter design is advantageous for all pressures below 10.7 mb. It can also be seen that the 19-foot capsule provides greater capability for the case where $m/C_DA = 0.25$.

With only a 200 pound penalty for the maximum capability system and the potential for much greater residual weights at pressures above 5.3 mb, a 19-foot diameter capsule designed for loads compatible with a ballistic number of 0.32 presents advantages which make it attractive as an entry capsule configuration.

An additional comparison can be made of the residual weights available from one capsule and from two capsule systems. It is apparent from figure 21 that two 6000-pound capsules will deliver more residual weight than a single 12,000-pound capsule for the anticipated atmospheric pressure range. At pressures above 11.5 mb the one capsule concept becomes preferable from the residual weight standpoint. Since it is unlikely that the atmospheric surface pressure will exceed 10 mb, the sole advantage of utilizing a single 12,000 capsule would be to deliver, in a single package, a residual weight greater than 2500 pounds (limited to a maximum of 3600-pounds in a 5 mb atmosphere).

On the basis of the above, the following selection is made: use the largest size capsule (19-foot diameter) and the dual capsule system. This selection offers many advantages.

The 19-foot diameter capsule will allow:

a. Parachute deployment at Mach 1.2 in the early mission because aerodynamic braking will reduce velocity sufficiently.

b. A common aeroshell for all missions since it minimizes the $m/C_D A$ range among missions.

c. Parachute deployment at less than Mach 2.0 in the later heavier capsule missions.

d. A common delivery mode of aeroshell and parachute to deliver payload to terminal conditions for the landing system.

The dual capsule system will allow:

a. Delivery of more payload weight.

b. More flexibility in site and science experiment selection.

c. Redundancy.

d. Use of low supersonic (Mach 2.0) decelerators (one capsule concept would require approximately Mach 5.0 decelerators).

Landing system.- In a previous section, it was determined that a soft landing controlled retro mode was superior to hard landing a payload suspended from a parachute. The problem is now reduced to determining the best means of conveying the landing payload from the impact trajectory of the basic $m/C_DA = 0.32$ capsule to this soft landing condition. The alternate means of retro deceleration and aerodynamic braking to effect this transfer are indicated on figure 18; while a two-burn retro system is indicated, a one burn system could be utilized if it were highly throttleable. It is emphasized that the transfer points among deceleration modes can be moved from the locations indicated if trade-off studies show better efficiency can be obtained. However, such an in-depth trade off study is beyond the scope of this report and the location of the deceleration interfaces as shown in Figure 18 will be assumed valid for purposes of comparison.

The following landing systems were considered and comparisons made on the basis of the $m/C_DA = 0.32$ capsule.

a. Aeroshell, retro, RADVS - In this mode, after the aeroshell decelerates the capsule to 1100 feet/second at an altitude of approximately 19,000 feet, a retro system is initiated which decelerates the capsule (by firing through openings in the aeroshell) to a velocity of about 400 feet/second). RADVS takes over at this point and lands the capsule. Two alternate landing modes are possible: 1) land the aeroshell on its apex at a low velocity so that minimum impact attenuation is required for the payload or 2) retro-separate the aeroshell near the surface and land with legs. Principal characteristics of the system are illustrated on figure 22.

b. Aeroshell, parachute, RADVS - This mode (figure 23) is identical through the braking phase provided by the aeroshell. At approximately 19,000 feet a parachute is deployed (Mach 1.6) and the aeroshell jettisoned. The payload is decelerated to 300 feet/second and its flight path angle increased to near vertical (-75°) as it descends by parachute to the 10,000 foot elevation. At this elevation, the parachute is released and the payload descends under controlled retro fire. In addition to soft landing, this mode offers the additional advantages of 1) long stay time in atmosphere for atmospheric experiments without spewing rocket exhaust which could affect data measurements, 2) being adaptable to release of instrumented spherical ball shortly before impact since payload could be supported in an open framework, and 3) a parachute operation which is practically independent of atmosphere as it will reach a satisfactory terminal velocity at the desired altitude for RADVS operation.

The efficiency of the two systems were investigated by making weight estimates of the operational payloads the systems could land. The results are summarized below:

	Aeroshell-Retro-RADVS	Aerosehll-Parachute-RADVS
Capsule Weight	6000 lbs	6000 lbs
Separated before entry	-1640	-1640
Entry weight	4360	4360
Separated at 19,000 ft	0	-1800
	4360	2560
Expended by 10,000 ft		100
		2460
Soft Landing System	1530	1040
	2830	1420
Aeroshell	1800	
Payload	1030	1420

Because of the parachute mode's greater efficiency, its flexibility to adjust to varying atmospheres and payloads, and its state-of-the-art technology (the performance of retro-propulsion systems in the presence of payloads are considered to be of two types: those suitable for early missions (1973, 1975) where emphasis will be on atmospheric properties and gross surface characteristics, and those payloads for later missions (1977, 1979) where the objective is primarily biological.

Figure 25, "Probe," and 26, "Probe/Lander," represent the early mission payloads. The Probe mission is, in essence, the mission studies by AVCO (reference 1) which was a non-survivable atmospheric probe with descent TV. The Probe/Lander is a duplicate of the Probe with the addition of a survivable 210 pound ball to obtain some surface data. It is felt that either of these missions can be carried out in 1973. The choice will depend on the economics involved and on the feasibility of developing a worthwhile scientific surface package within the weight limitation. Figures 27, "Semi-soft Lander," and 28, "Advanced Lander," represent the later mission payloads where experiments performed on the surface take precedence. The overall weight is restrained by the launch vehicle's capability but it is evident that the net weight deliverable to the surface, for either mode, is sufficient for an Automated Biological Laboratory; the Philco study (reference 3) indicates that 1200 pounds of payload is required for the ABL. The choice between Landers in this category will depend upon the topography. The TV system in early missions is planned so as to furnish the necessary data to guide selection of the landing mode: omnidirectional or legged.

It should be noted that these four payloads use the same delivery system (aeroshell) and landing system (parachute-retro); further, each is designed to be mounted inside the aeroshell. In addition, the concept makes possible a clean interface between the scientific payload and the landing system for ease in integration.

an oncoming supersonic flow and the logic to control the retro fire so as to perform the mission requirements in an unknown atmosphere are regarded as more difficult problems), the aeroshell-parachute-RADVS system is selected as the preferred mode.

Phase IV - Conceptual Design

In addition to presenting concepts for the various facets of the problem such as mission mode, capsule definition and candidate payloads, it is an objective of this phase to indicate how these various items integrate to form a unified system.

As defined in the preceding sections, the selected mission mode uses the maximum diameter aeroshell to make optimum use of the capsule's aerodynamic braking. The capsule's braking allows the deployment of a parachute (at a maximum mach number of 1.6 for the heavier dual capsule concept) which accomplishes two objectives; it decelerates the payload and separates the payload from the aeroshell.

The large diameter of the capsule is in keeping with the concept of growth. The same aeroshell structure can be used for the early and the subsequent Voyager missions with a small weight penalty. In addition, the capsule's size allows the capsule to house a variety of payloads from early mission probes to late mission landers with a minimum of interface problems. This capability of the capsule is illustrated in figures 24 through 28. Figure 24 presents a simplified drawing of the capsule's delivery system and indicates the volume available for transporting a payload; the weight of this delivery system is noted so that complete systems for various candidate payloads can be determined. The candidate

Advanced-Lander: This mission is the same as the above mission exept the lander bus is landed in the Surveyor manner on legs with the ABL mounted on the lander. It is necessary that sufficient topographical data, either from TV and/or from the engineering landing experiment on a previous mission, be obtained prior to using this mode.

SUMMARY

The following items represent the main findings of this study:

1. Selection of the two 6000-pound capsule systems, rather than one 12,000-capsule system, because it lands greater total weight and affords more flexibility for landing sites and redundancy.

2. Selection of a 19-foot diameter capsule, maximum diameter compatible with shroud restraint, because it furnishes maximum aerodynamic braking and is compatible with future growth packaging and weight considerations.

3. Standardization of aeroshell for all missions. This results in a minor weight penalty on early missions.

4. Selection of a propulsive type lander system because it permits soft landing even in the presence of winds.

5. Use of a parachute to provide the transition from capsule trajectory to propulsive descent. Parachute deployment Mach number will vary from 1.2 in early missions to 1.6 in the later missions.

6. Employment of a common mission mode for all lander missions 1973 - 1979. The mission mode should consist of aeroshell-parachute-propulsive soft landing which allows for the maximum commonality of subsystems.

Figure 29 through 32 indicate the mission modes that are compatible with the above payloads. These modes are briefly described below for the respective payloads.

Probe: The parachute is deployed at a Mach number of 1.2 at an altitude of 21,000 feet. The major experiments (including TV) are made during the parachute descent and the descent package does not survive impact. Some preliminary information can be obtained on surface hardness by the deploying of penetrometers shortly before impact.

Probe/Lander: This mode is a duplicate of the above mission until the parachute is jettisoned at about 5,000 feet. With the vernier motors controlled so that the capsule obtains zero velocity a short distance above the surface, a 200-pound ball is released to impact at less than 50 feet/second. This package will relay impact accelerometer data and will monitor atmospheric conditions at the surface for a short period in order to note any variations with time.

Semi-Soft Lander: On this mission, the parachute is jettisoned at approximately 10,000 feet and the lander descends under active vernier control. A 1400-pound ball (an omni-directionally protected Automated Biological Laboratory) is released near the surface as in the Probe/Lander mode. It is noted that an engineering experiment of attempting to land the lander bus on legs could be included without endangering the success of the prime mission.

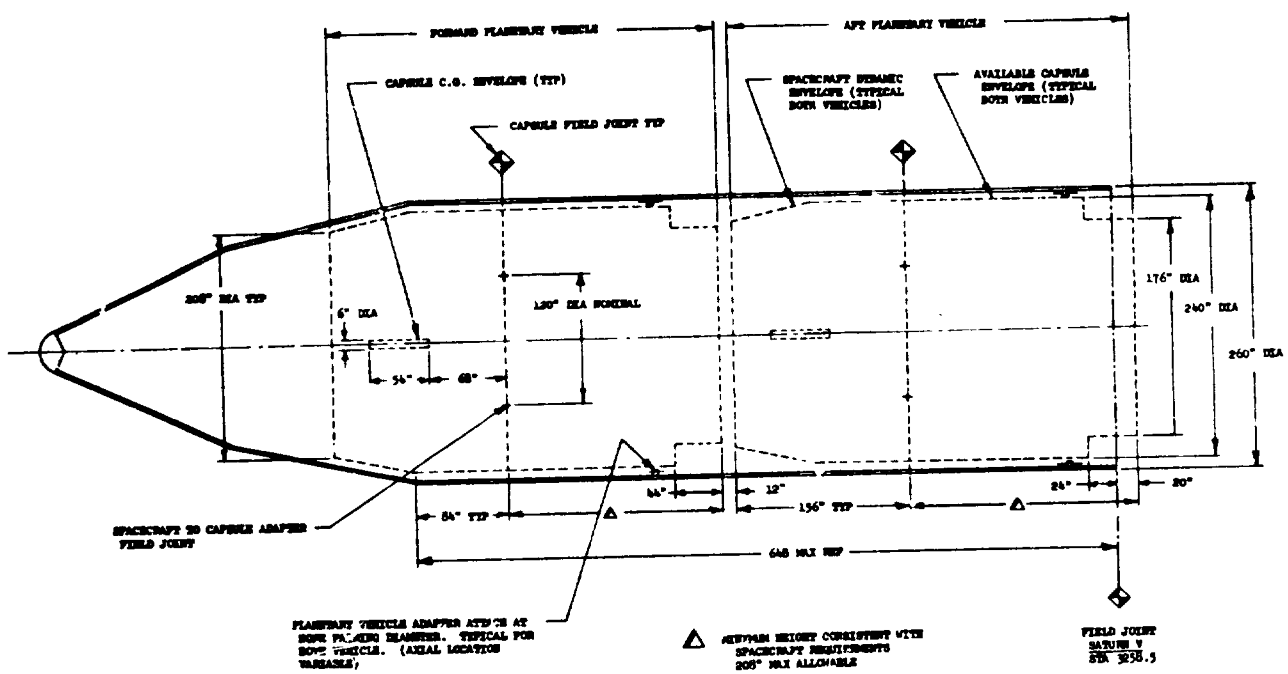


Figure 1.- Planetary vehicle arrangement and dynamic envelopes

REFERENCES

1. AVCO Corporation, AVCO Space Systems Division: Mars Probe, Final Report, Contract No. NAS1-5224.

2. Astronautics and Aeronautics, July 1966, The Practical Problem of Landing on Mars, by R. P. Thompson, Jet Propulsion Laboratory.

3. PHILCO Corporation, Aeronutronic Division: Study of the Automated Biological Laboratory Project Definition, Final Report, Contract No. NAS1-1065.

SATURN V/VOYAGER

MAXIMUM PAYLOAD WEIGHT ALLOCATION (LB.) FOR ALL OPPORTUNITIES

Nose Cone	3,500
Cylindrical Shroud	11,500
Forward Planetary Vehicle	27,000
Aft Planetary Vehicle	27,000
Total Payload Weight	69,000

PLANETARY VEHICLE WEIGHT ALLOCATION (LB.)

	1973-1975 Missions	1977-1979 Missions
Flight Capsule	3,500	6,000
Spacecraft Propulsion	15,000	15,000
Spacecraft Bus	2,500	3,500
Planetary Vehicle	21,000	24,500
Planetary Vehicle Adapter	1,500	2,500
Total	22,500	27,000

Figure 2.- Launch vehicle capability and capsule weight relationship

PROPERTY	SYMBOL	DIMENSION	VM-1	VM-2	VM-3	VM-4	VM-7	VM-8
Surface Pressure	P_o	mb	7.0	7.0	10.0	10.0	5.0	5.0
		lb/ft^2	14.6	14.6	20.9	20.9	10.4	10.4
Surface Density	ρ_o	$(gm/cm^3)10^5$	0.955	1.85	1.365	2.57	0.68	1.32
		$(slugs/ft^3)10^5$	1.85	3.59	2.65	4.98	1.32	2.56
Surface Temperature	T_o	°K	275	200	275	200	275	200
		°R	495	360	495	360	495	360
Stratospheric Temperature	T_s	°K	200	100	200	100	200	100
		°R	360	180	360	180	360	180
Acceleration of Gravity	g	cm/sec^2	375	375	375	375	375	375
at Surface		ft/sec^2	12.3	12.3	12.3	12.3	12.3	12.3
Composition								
CO_2 (by mass)			28.2	100.0	28.2	70.0	28.2	100.0
CO_2 (by volume)			20.0	100.0	20.0	68.0	20.0	100.0
N_2 (by mass)			71.8	0.0	71.8	0.0	71.8	0.0
N_2 (by volume)			80.0	0.0	80.0	0.0	80.0	0.0
A (by mass)			0.0	0.0	0.0	30.0	0.0	0.0
A (by volume)			0.0	0.0	0.0	32.0	0.0	0.0
Molecular Weight	M	mol^{-1}	31.2	44.0	31.2	42.7	31.2	44.0
Specific Heat of Mixture	C_p	cal/gm°C	0.230	0.166	0.230	0.153	0.230	0.166
Specific Heat Ratio	γ		1.38	1.37	1.38	1.43	1.38	1.37
Adiabatic Lapse Rate	Γ	°K/km	-3.88	-5.39	-3.88	-5.85	-3.88	-5.39
		°R/1000 ft	-2.13	-2.96	-2.13	-3.21	-2.13	-2.96
Tropopause Altitude	h_T	km	19.3	18.6	19.3	17.1	19.3	18.6
		kilo ft	63.3	61.0	63.3	56.1	63.3	61.0
Inverse Scale Height (stratosphere)	β	km^{-1}	0.0705	0.199	0.0705	0.193	0.0705	0.199
		$ft^{-1}x10^5$	2.15	6.07	2.15	5.89	2.15	6.07
Continuous Surface Wind Speed	$\bar{v}$	ft/sec	186.0	186.0	155.5	155.5	220.0	220.0
Peak Surface Wind Speed	v_{max}	ft/sec	470.0	470.0	390.0	390.0	556.0	556.0
Design Vertical Wind Gradient	$\frac{d\bar{v}}{dh}$	ft/sec/1000ft	2	2	2	2	2	2

Figure 3.- Model atmospheres

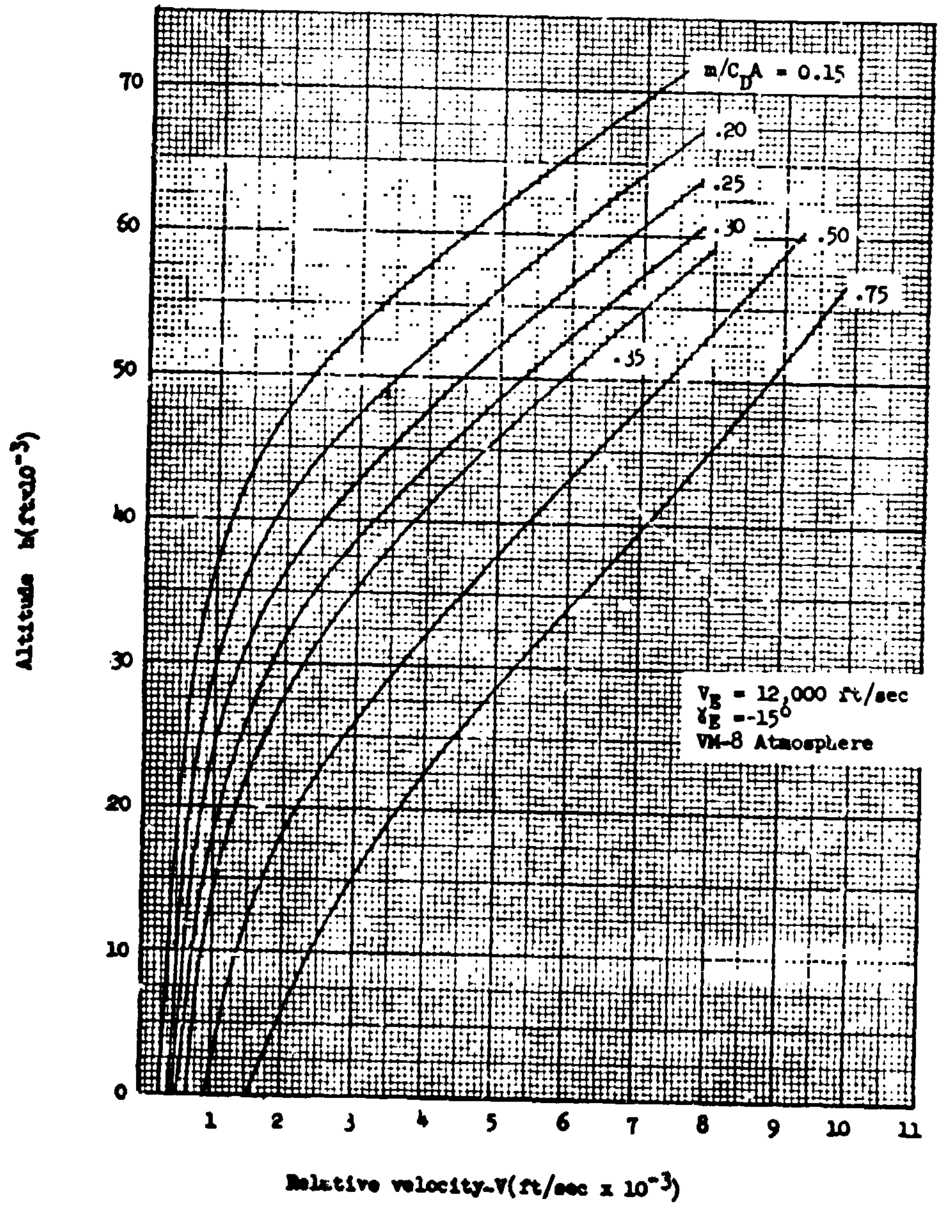


Figure 4.- Capsule velocity

567

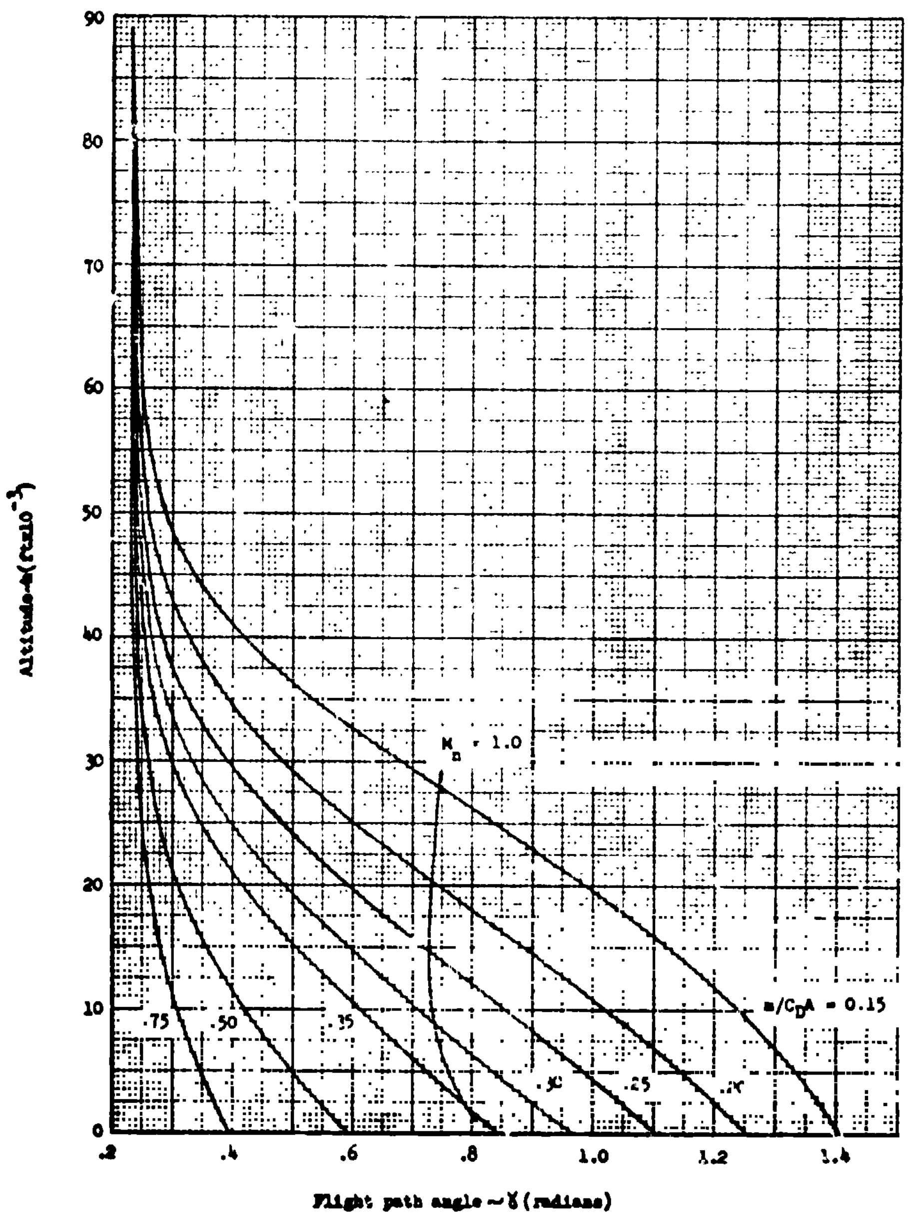


Figure 5.- Capsule flight - path angle

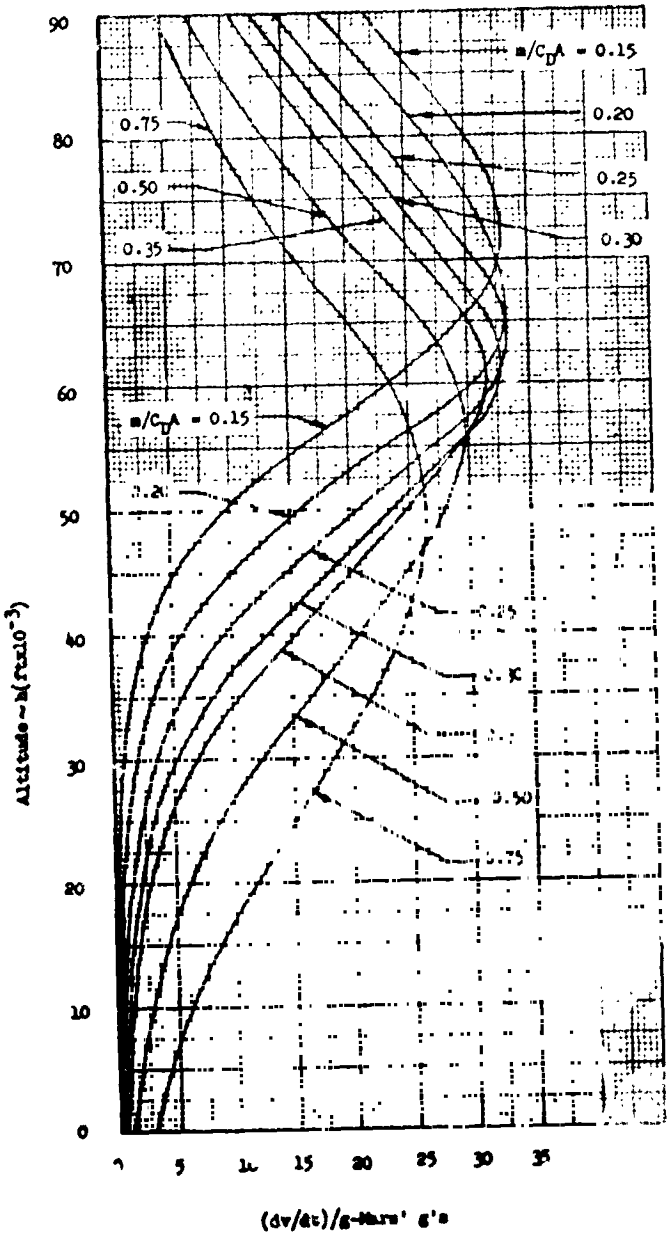


Figure 6.- Capsule deceleration loads

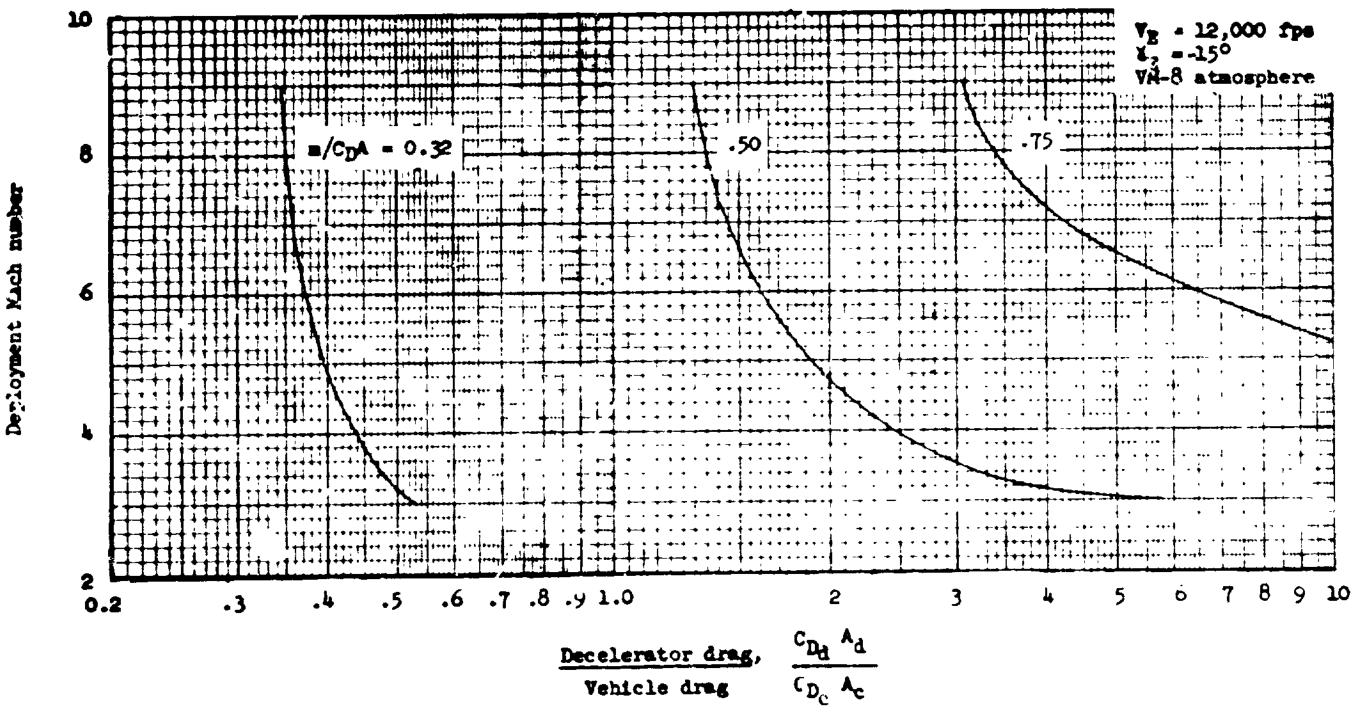


Figure 7.- Decelerator size requirements for capsules with m/C_DA's > 0.30

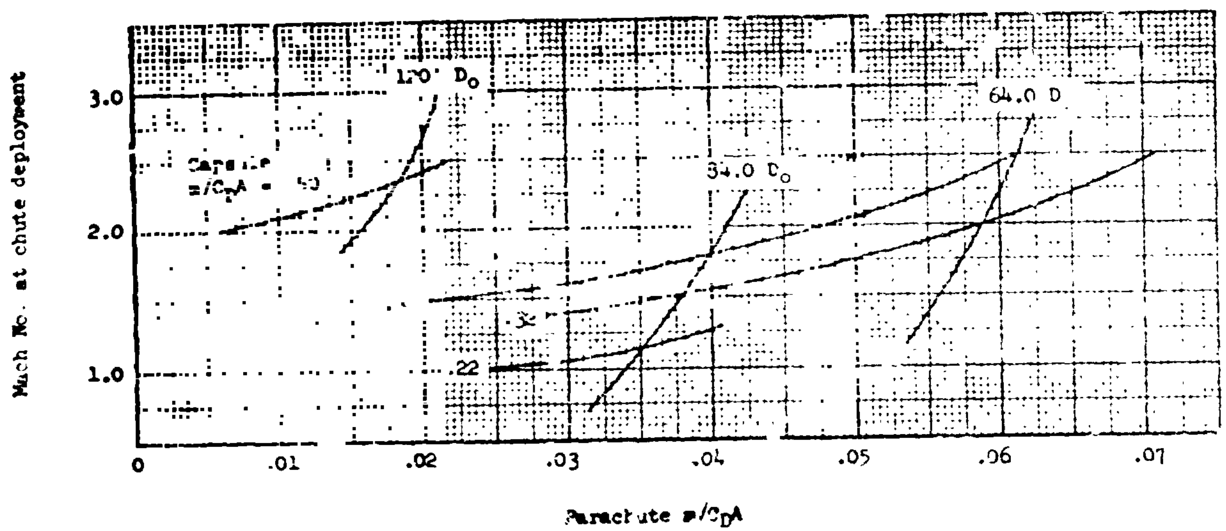


Figure 8.- Parachute size and deployment conditions for various capsule m/C_DA's

TABLE VI

WEIGHT SUMMARY
$M/C_DA = 0.22$ slug/ft^2
Diameter - 15 feet
$C_D = 1.628$

Flight Capsule		2922.1
Sterilization canister lid	125.0	
Pressurization gas	15.0	
Pre-FC Separation		2872.1
Sterile canister base	163.0	
Pressurization nozzle valves	6.0	
FC - FS adapter	125.0	
Hardware, brackets, cables	29.5	
Separated Vehicle		2458.6
Propulsion propellant	400.0 ✓	
ACS gas expelled	1.0	
TVC gas expelled	17.6	
Entry Vehicle		2040.0
Entry shell heat shield	370.7	
Entry shell structure	343.0	
Thermal control	30.0	
ACS - reaction control	42.4	
TVC - reaction control	48.5	
Hardware, brackets, cables	83.5	
Available for growth	96.9	
Suspended Capsule		1025.0
Instrumentation	205.6	
Radar	56.9	
Telecommunications	117.4	
Power supply	178.0	
Parachute	84.0	
Inertial reference system	21.6	
Propulsion case	49.0 ✓	
Structure	96.0	
Hardware, brackets, cables	131.0	
Programming and sequencing	23.6	
Afterbody heat shield	36.0	
Available for growth	25.9	

Figure 9.- Weight summary for probe mission

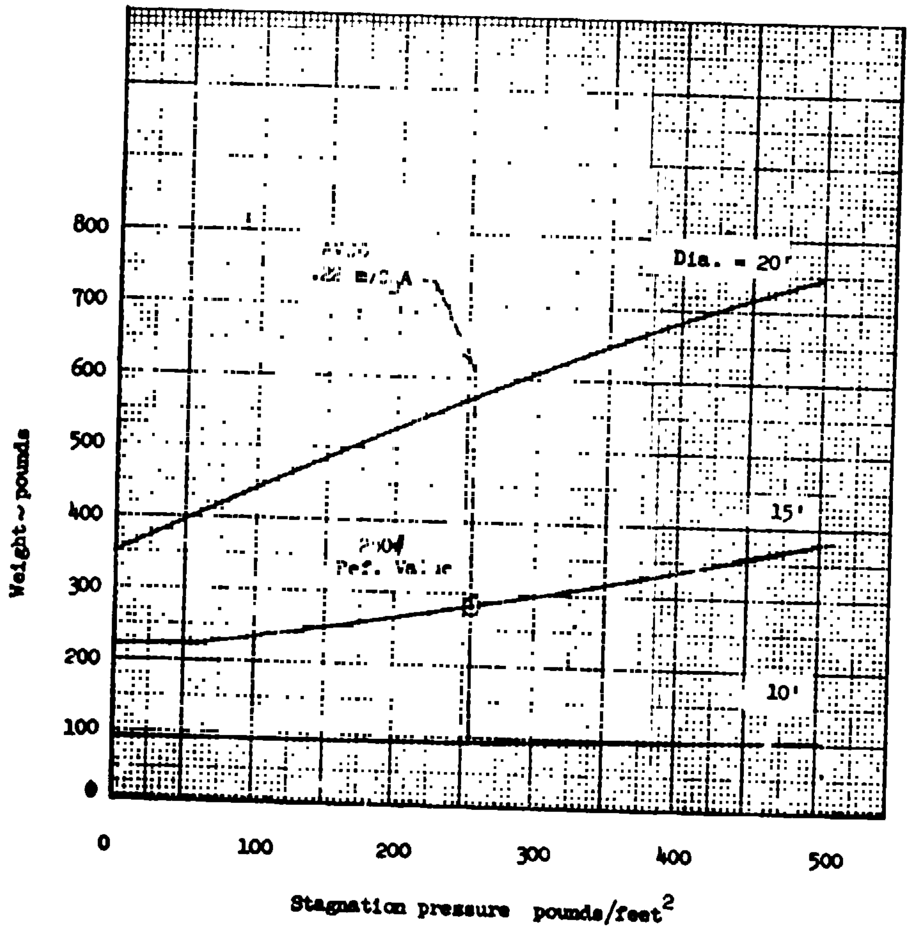


Figure 10.- Entry shell structure weights

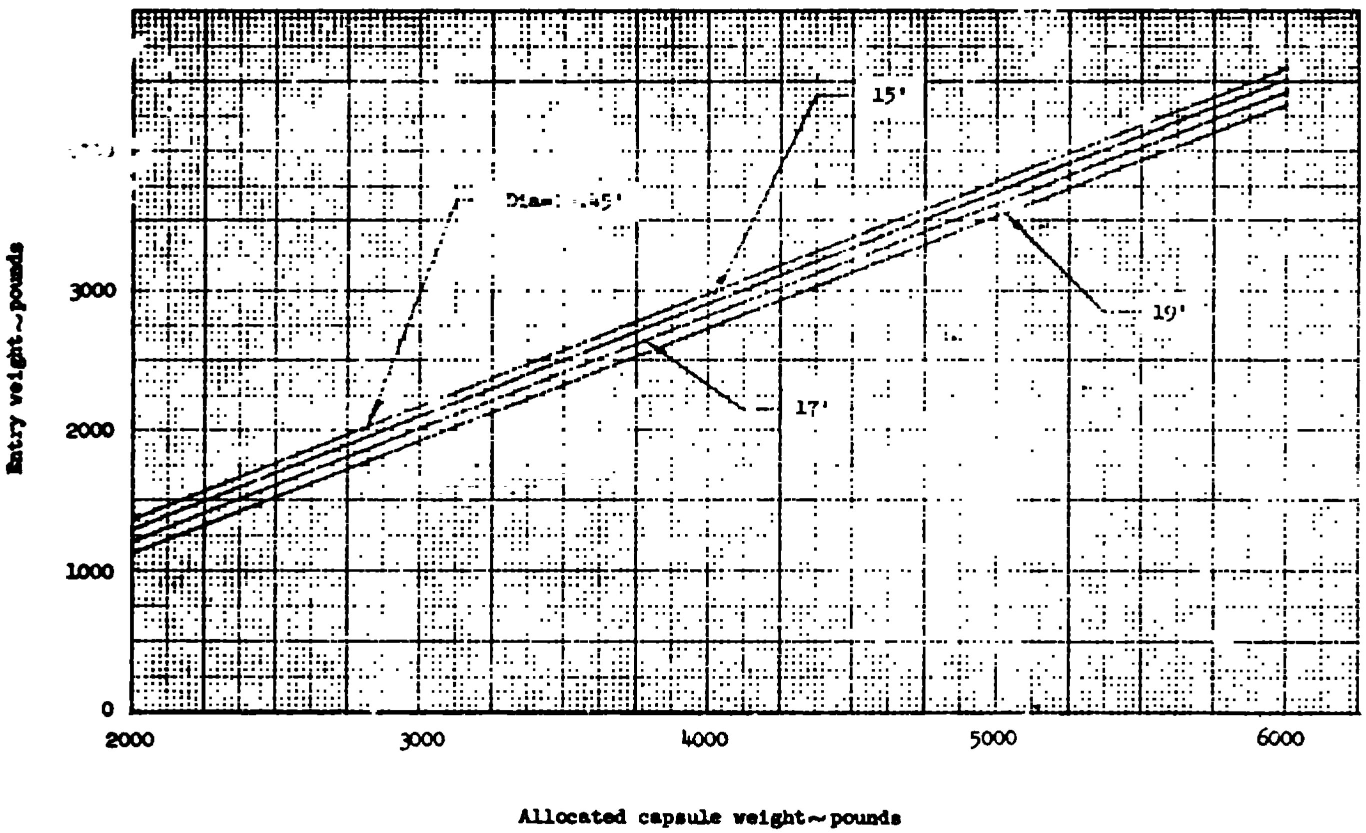


Figure 11.-Capsule Entry weight as function of allocated weight

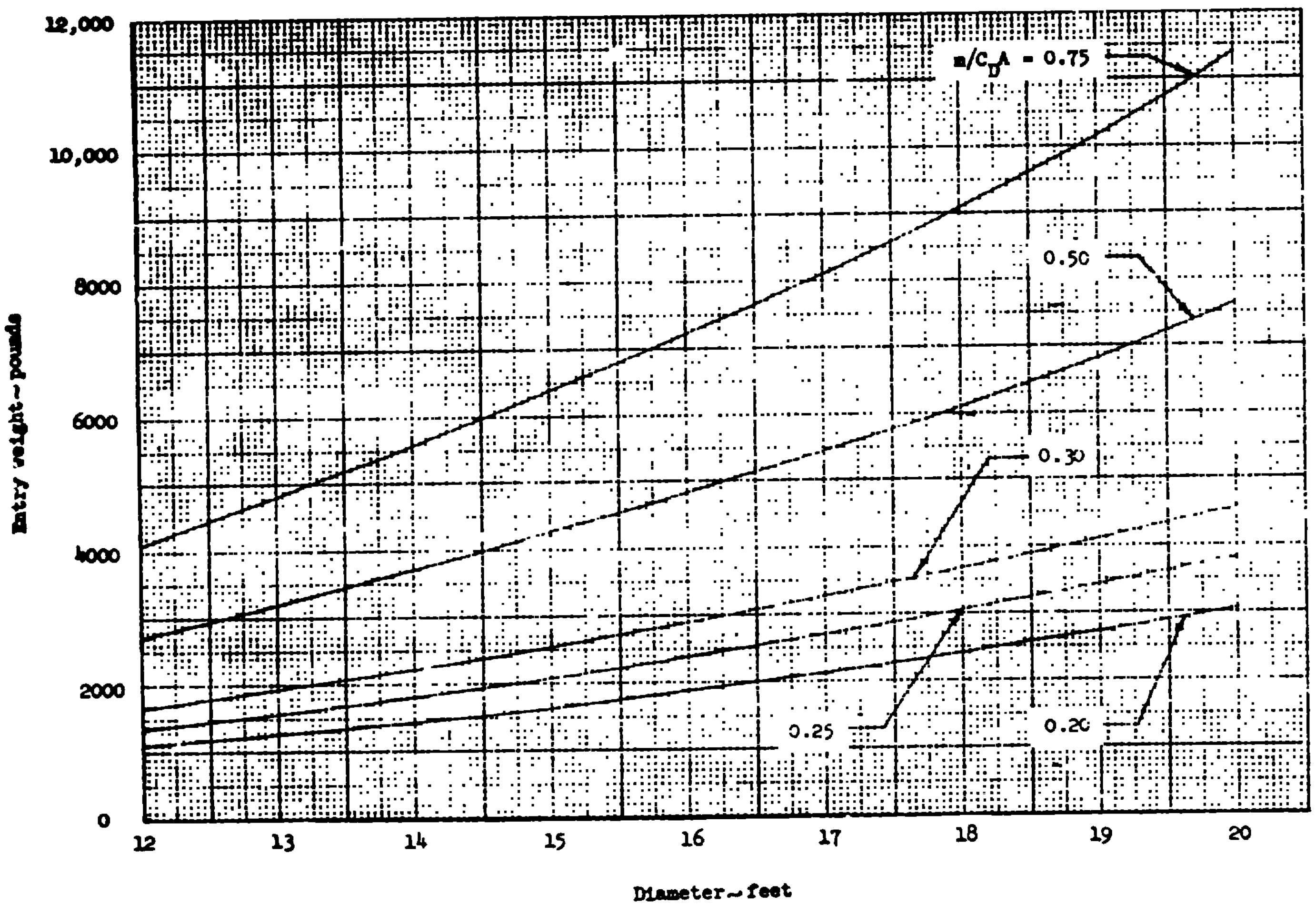


Figure 12.- Capsule ballistic number parametric chart

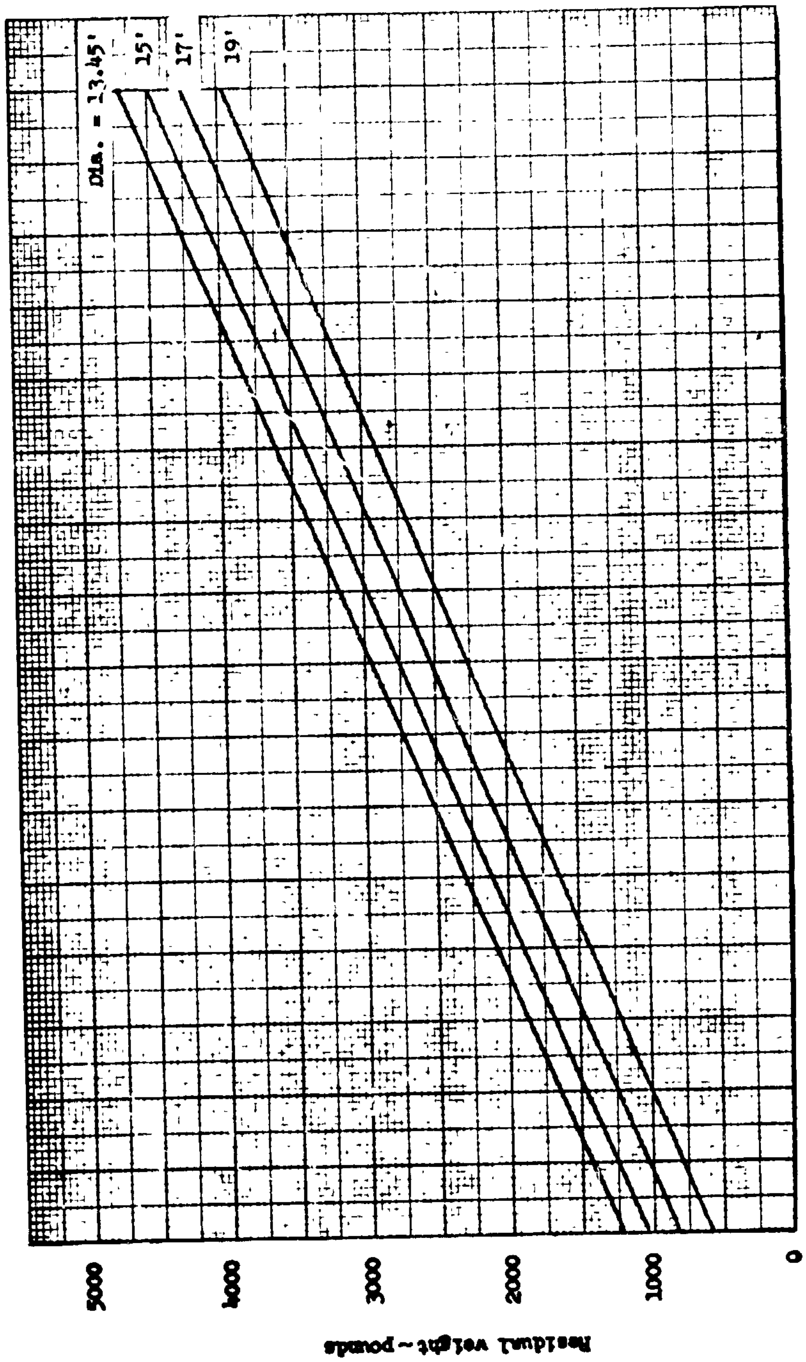


Figure 13.- Capsule residual weight as function of entry weight

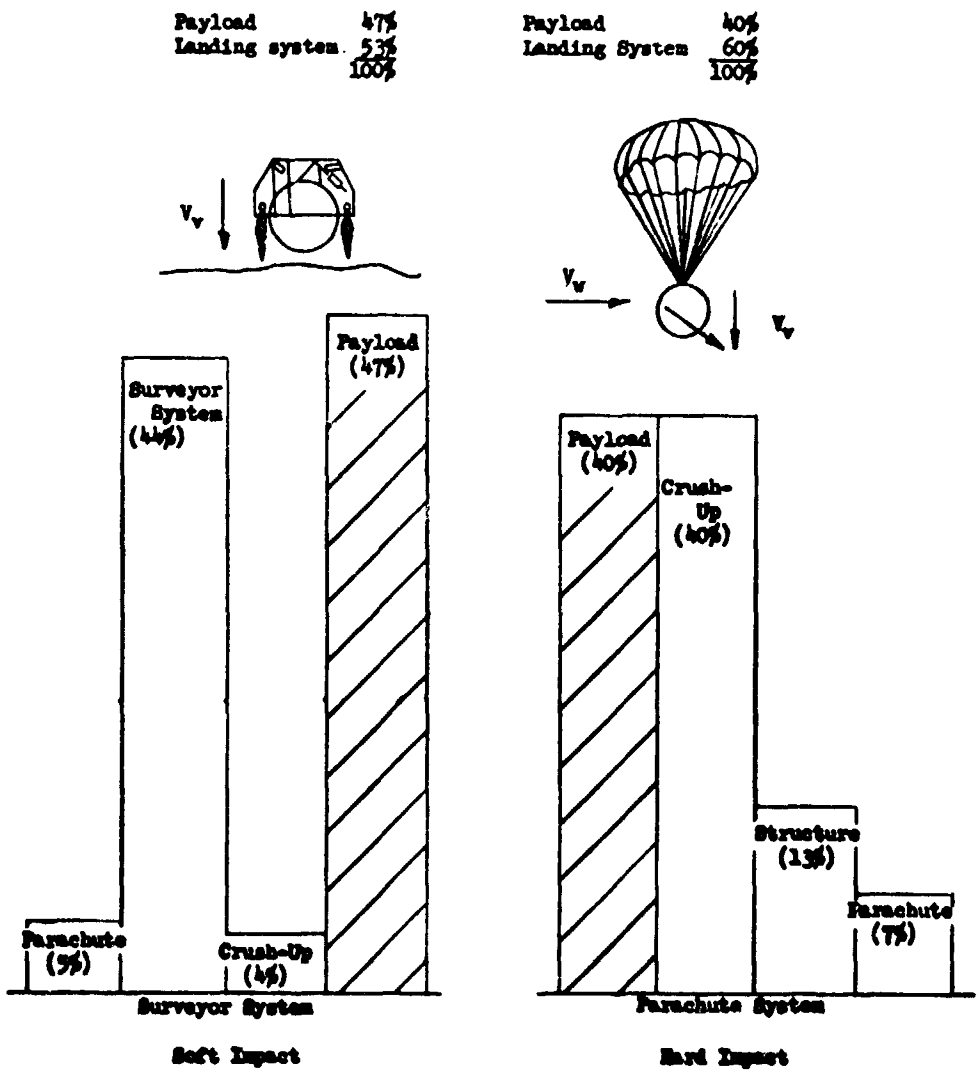


Figure 14.- Payload fractions for hard and soft landing systems

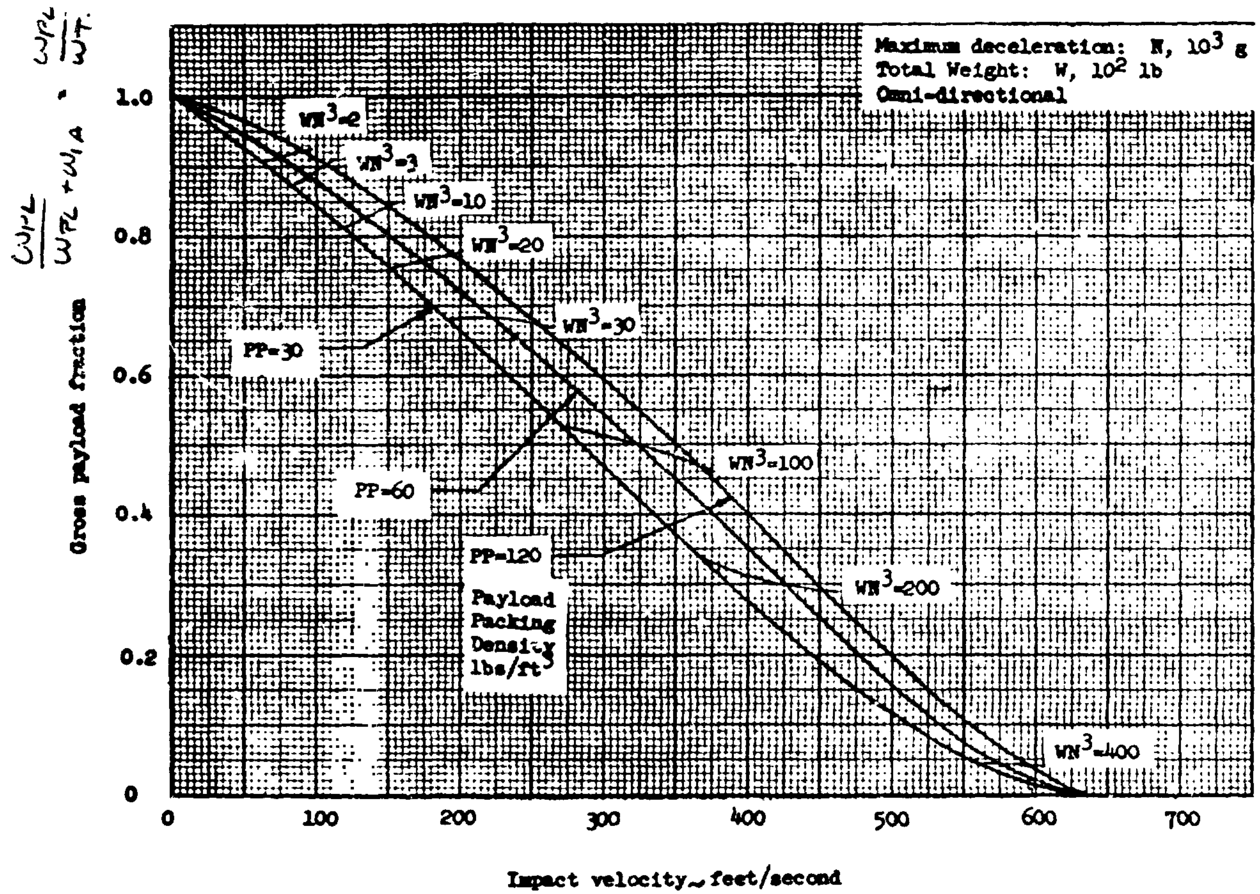


Figure 15.- Payload fraction for a balsa wood impact limiter

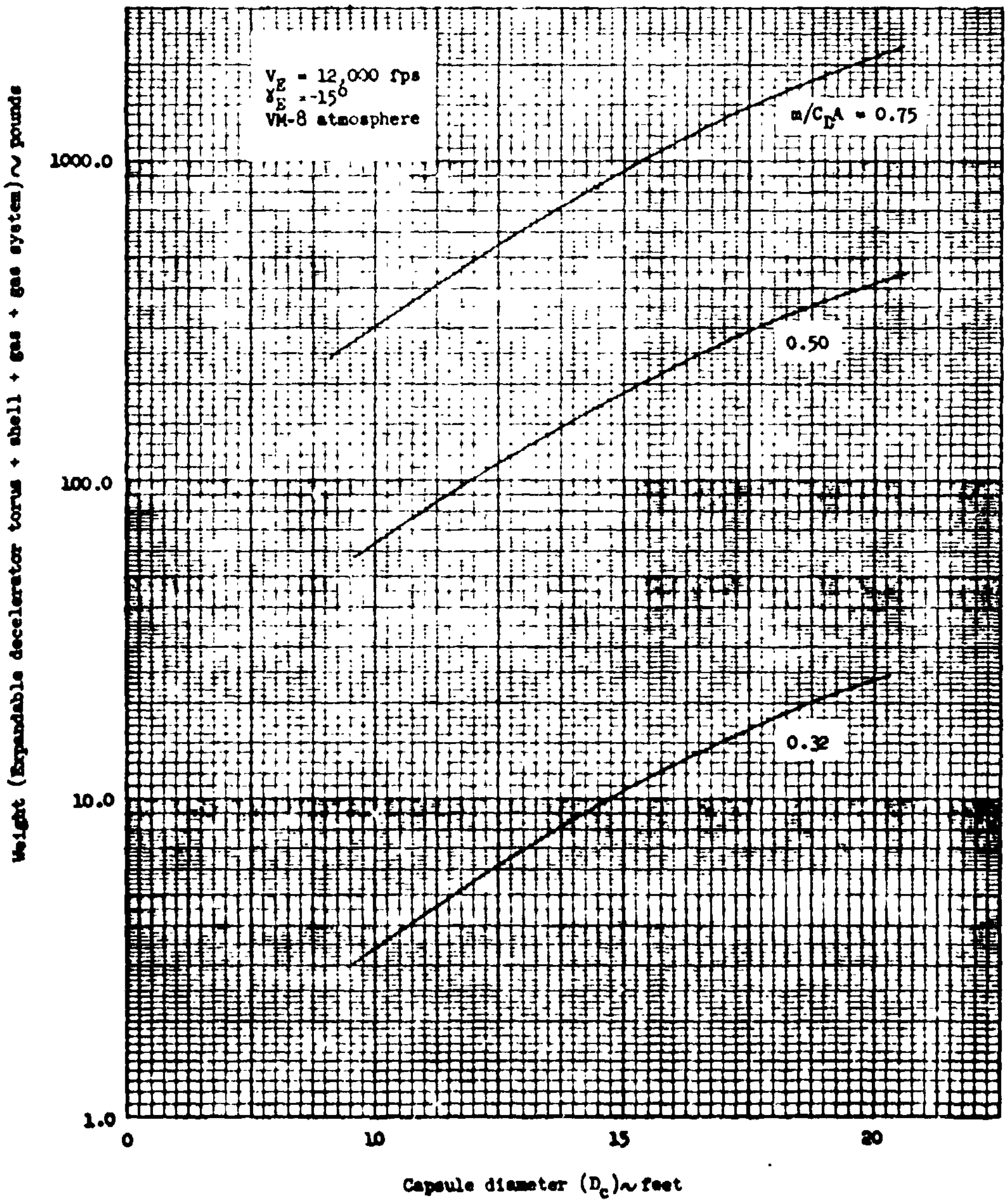


Figure 16.- Weight estimates of attached supersonic inflatable decelerators

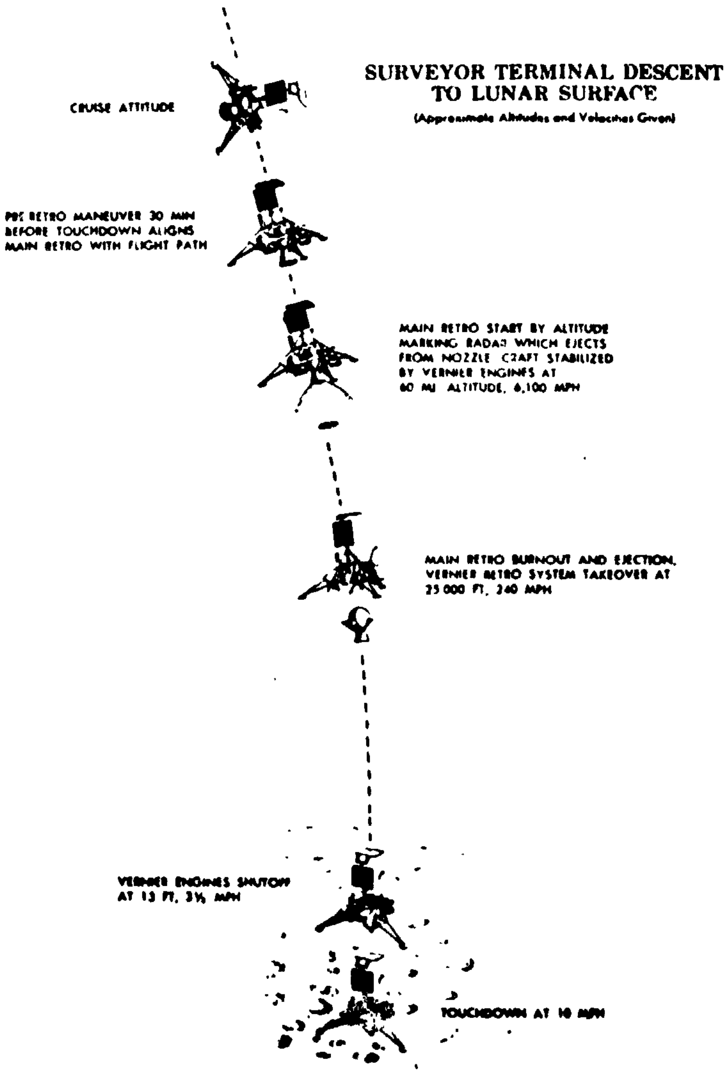


Figure 17.- Surveyor terminal descent to lunar surface

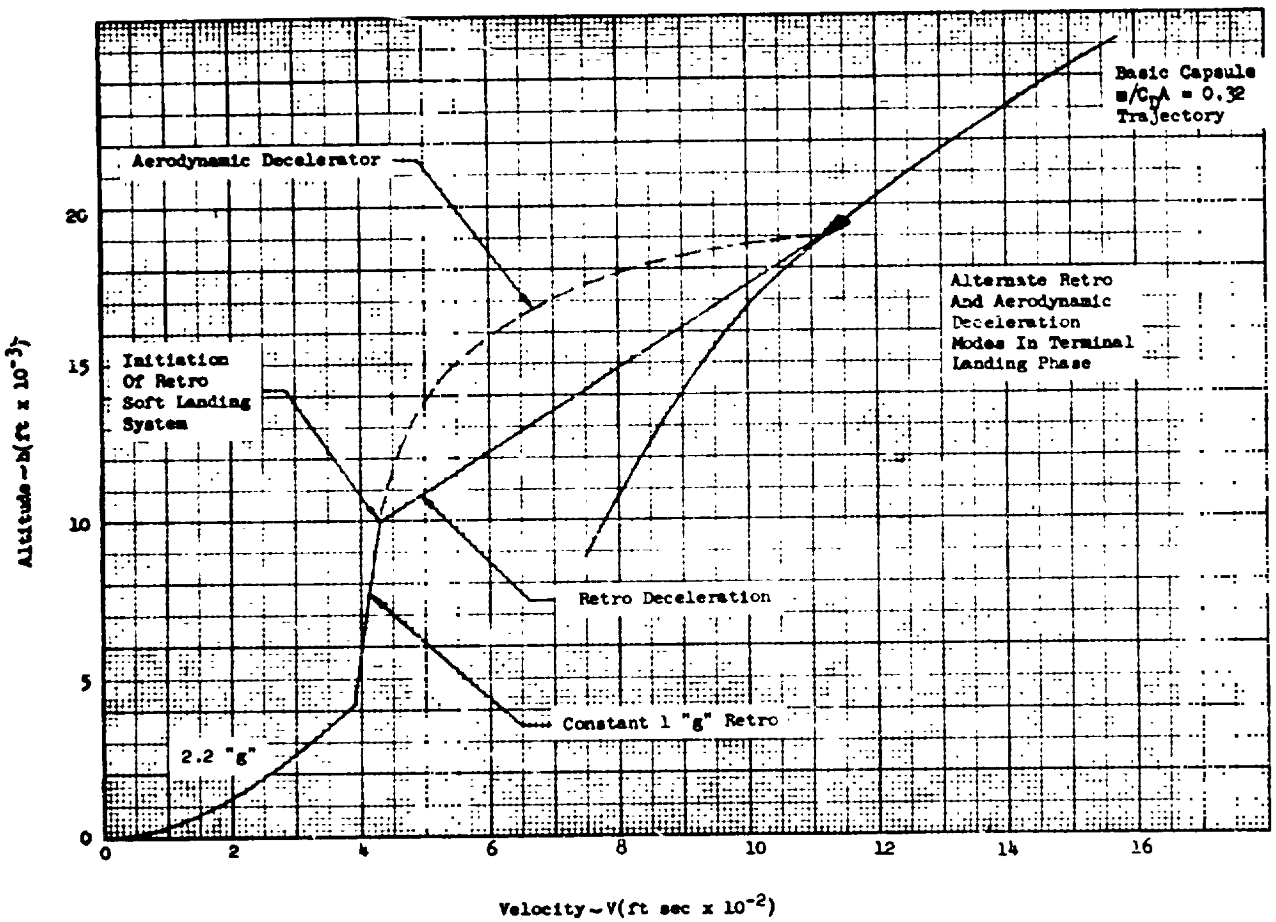


Figure 18.- Recommended Mars trajectory for Surveyor type landing

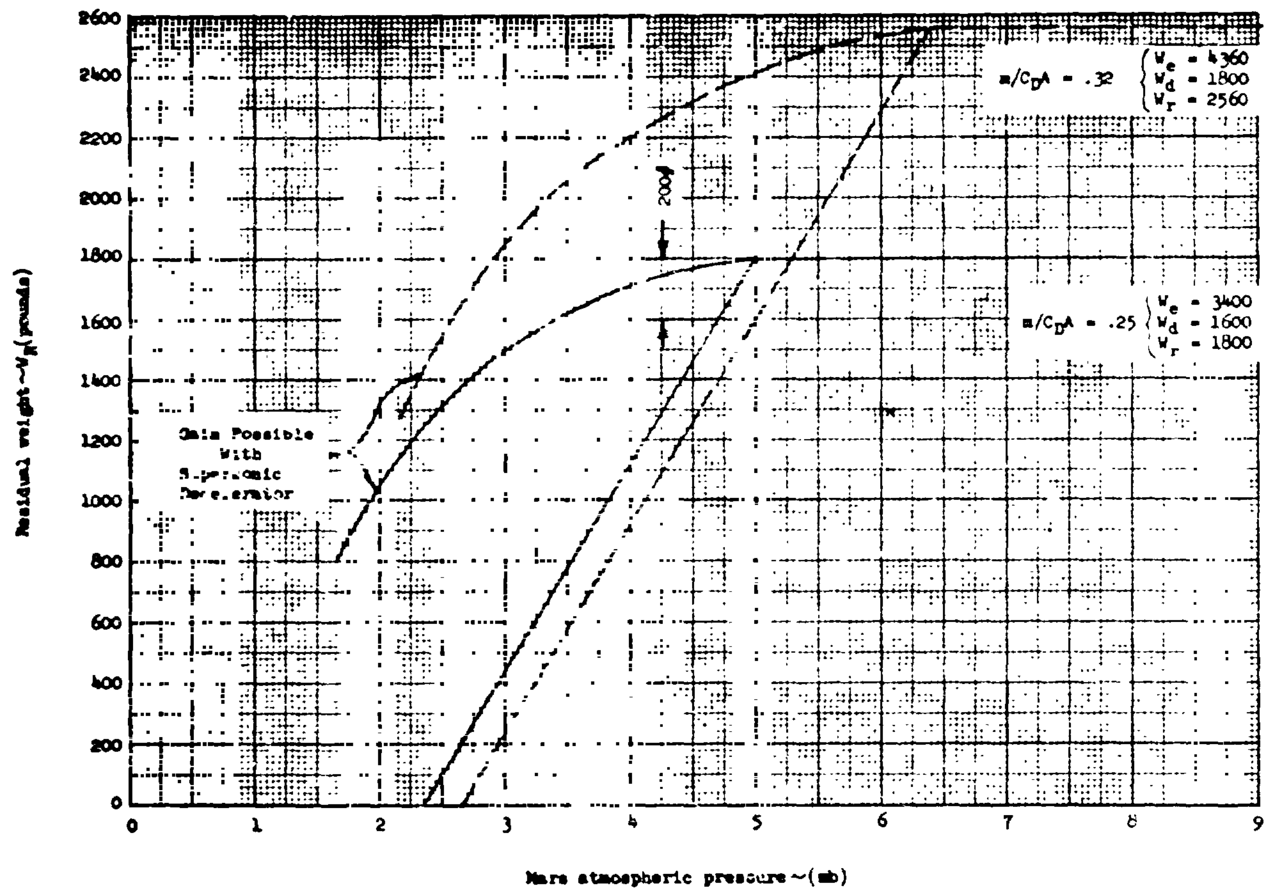


Figure 19.- Reisudal weight comparison 19 ft. dia., dual capsule system

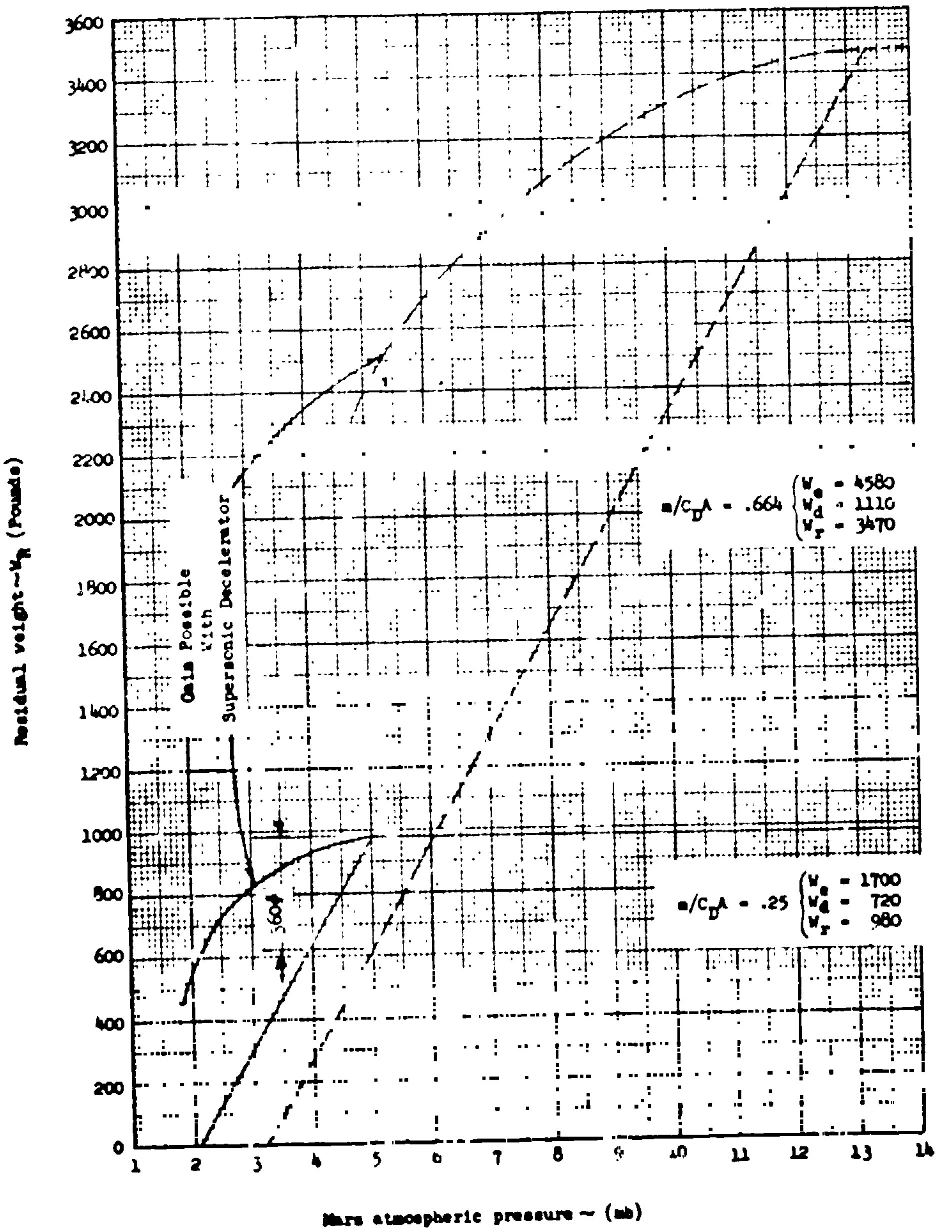


Figure 70.- Residual weight comparison 13.45 ft. dia., dual capsule system

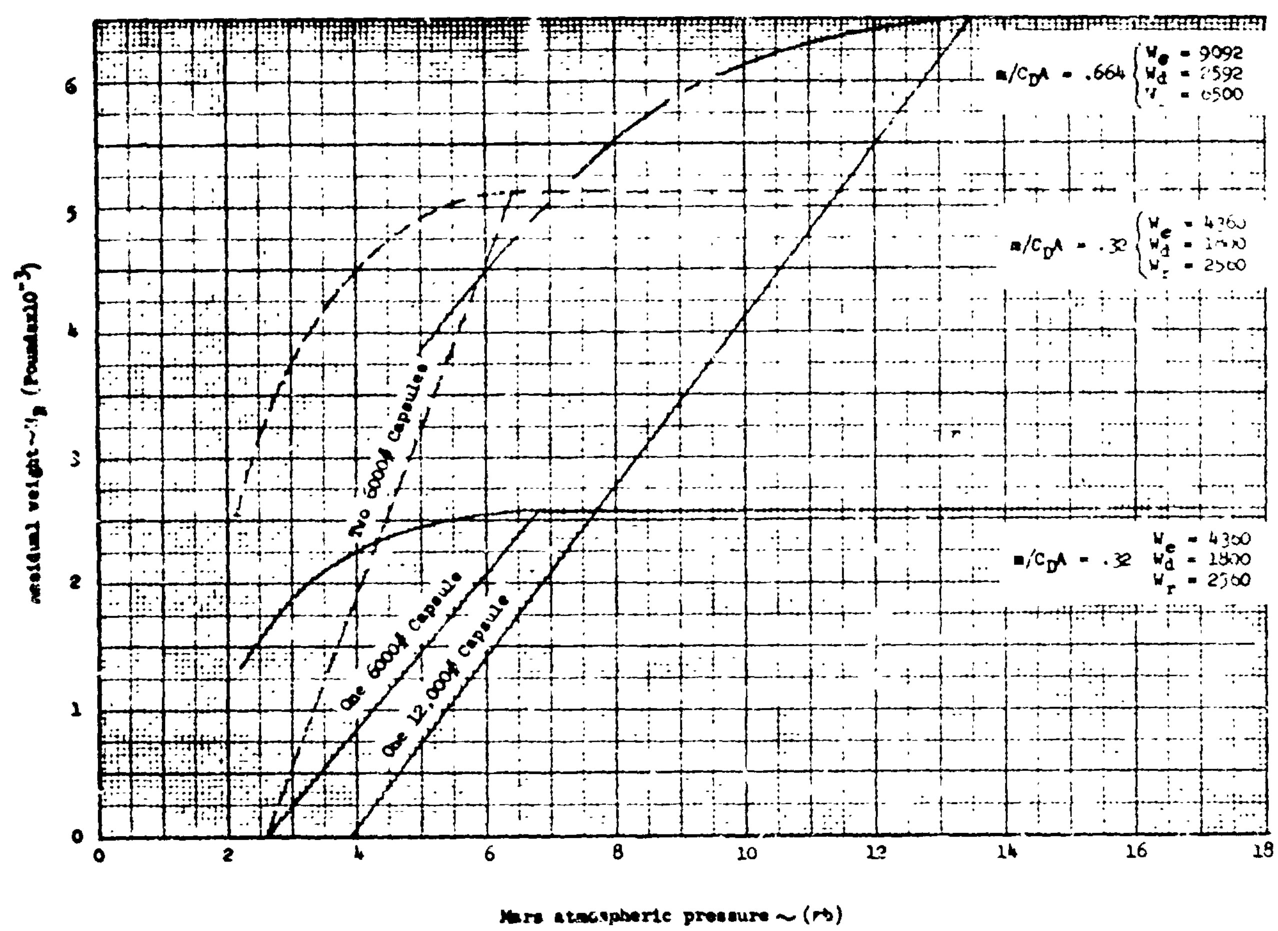


Figure 21.- Residual weight comparison for one and two capsule systems

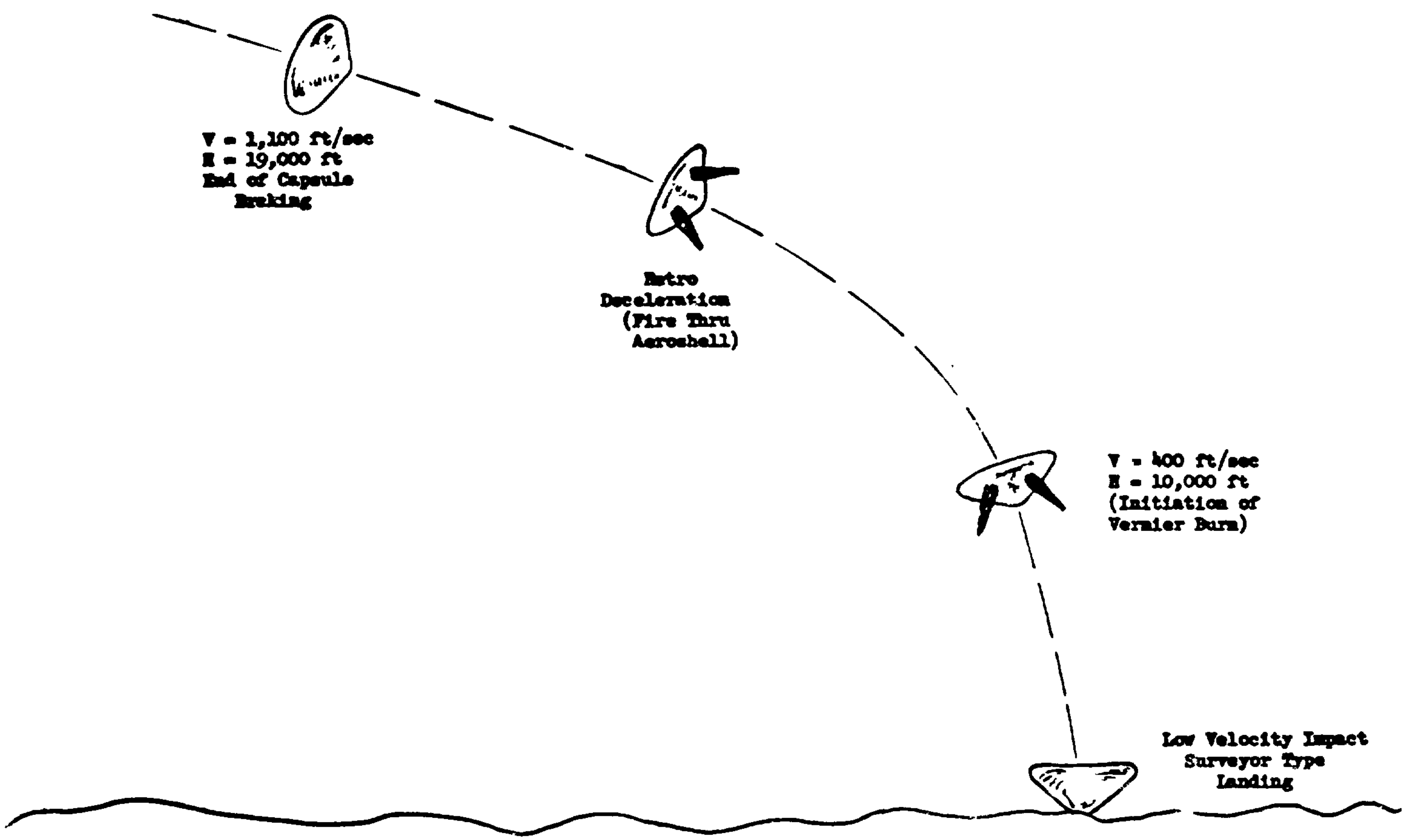


Figure 22.- Aeroshell-retro-RADVS landing system

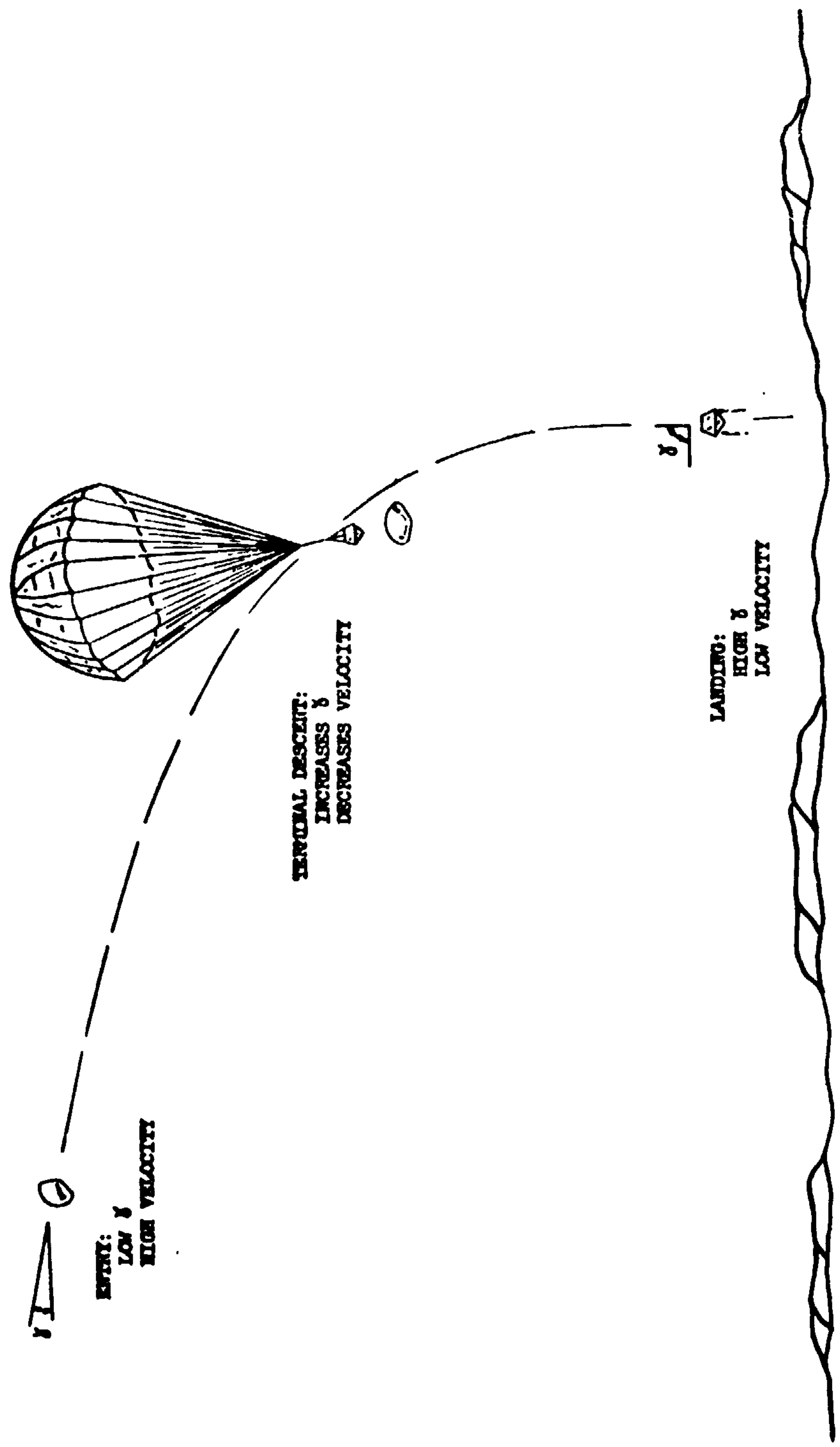
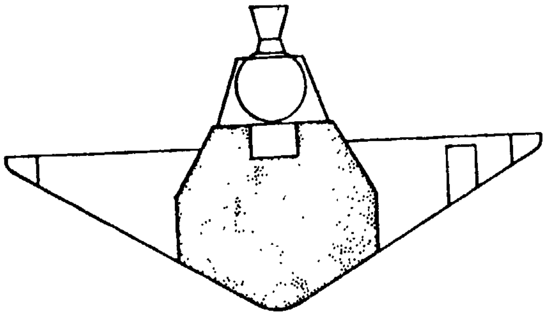
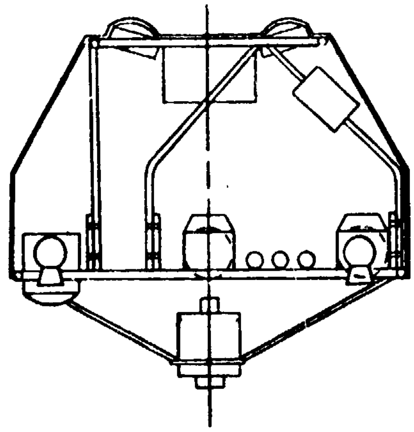


Figure 23.- Aeroshell-parachute-RADVS landing system



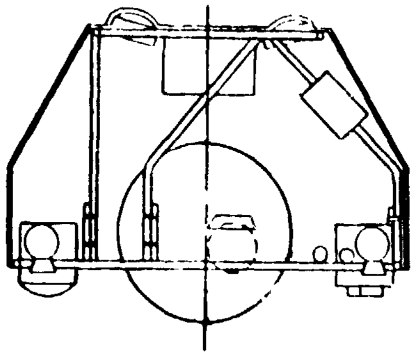
Aeroshell Structure	700#
Thermal Protection	600
ACS and TVC	250
Misc. Hardware (Cabling, Supports, Mechanisms)	185
Thermal Control	65
Aeroshell Separation Weight Including Fuel Expended After Entry	1800#

Figure 24.- Common aerodynamic delivery system



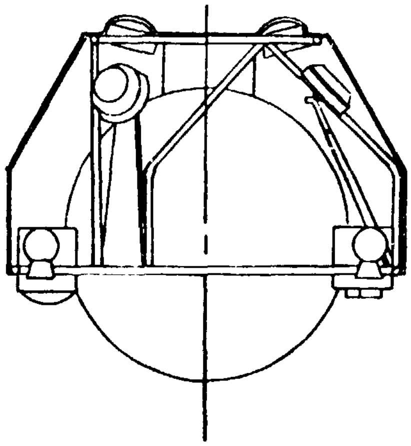
Entry Weight (m/C_DA = 0.237)		3240
Delivery System		-1800
Residual Weight		1440
Landing System		-1040
Parachute	10[illegible]	
Flight Control	75	
Structure	[illegible]00	
Communication & Power	1[illegible]0	
Cabling, Thermal Control	10[illegible]	
Propulsion System	[illegible]	
Propellant	[illegible]00	
Payload		400
Science (incl. TV)	[illegible]00	
Communications & Power	200	

Figure [illegible] - Probe



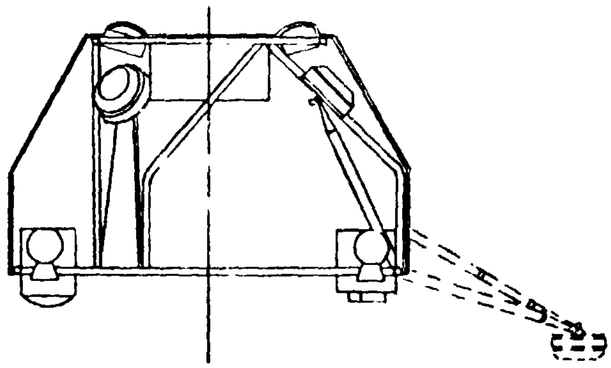
Entry Weight (m/C_DA = 0.255)		3500
Delivery System		-1800
Residual Weight		1700
Landing System (Same as probe except propellant weight increased to 150 lbs)		-1090
Payload		610
Probe Experiments	400	
Landed Ball	210	
Instrumentation	80	
Support Systems	80	
Impact Attenuation	50	

Figure 26.- Probe/Lander



Entry Weight ($m/C_DA = 0.32$)		4360
Delivery System		-1800
Residual Weight		2560
Landing System (Same as Probe except propellant weight increased to 200 lbs)		-1140
Payload		1420
Soft Landed Ball		
Instrumentation	650	
Support Systems	650	
Impact Attenuation	120	

Figure 27.- Semi-Soft Lander



Entry Weight (m/C_DA = 0.32)		4360
Delivery System		-1800
Residual Weight		2560
Landing System (Same as Figure 27)		-1140
Payload		1420
Instrumentation	710	
Support Systems	710	

Figure 28.- Advanced Lander

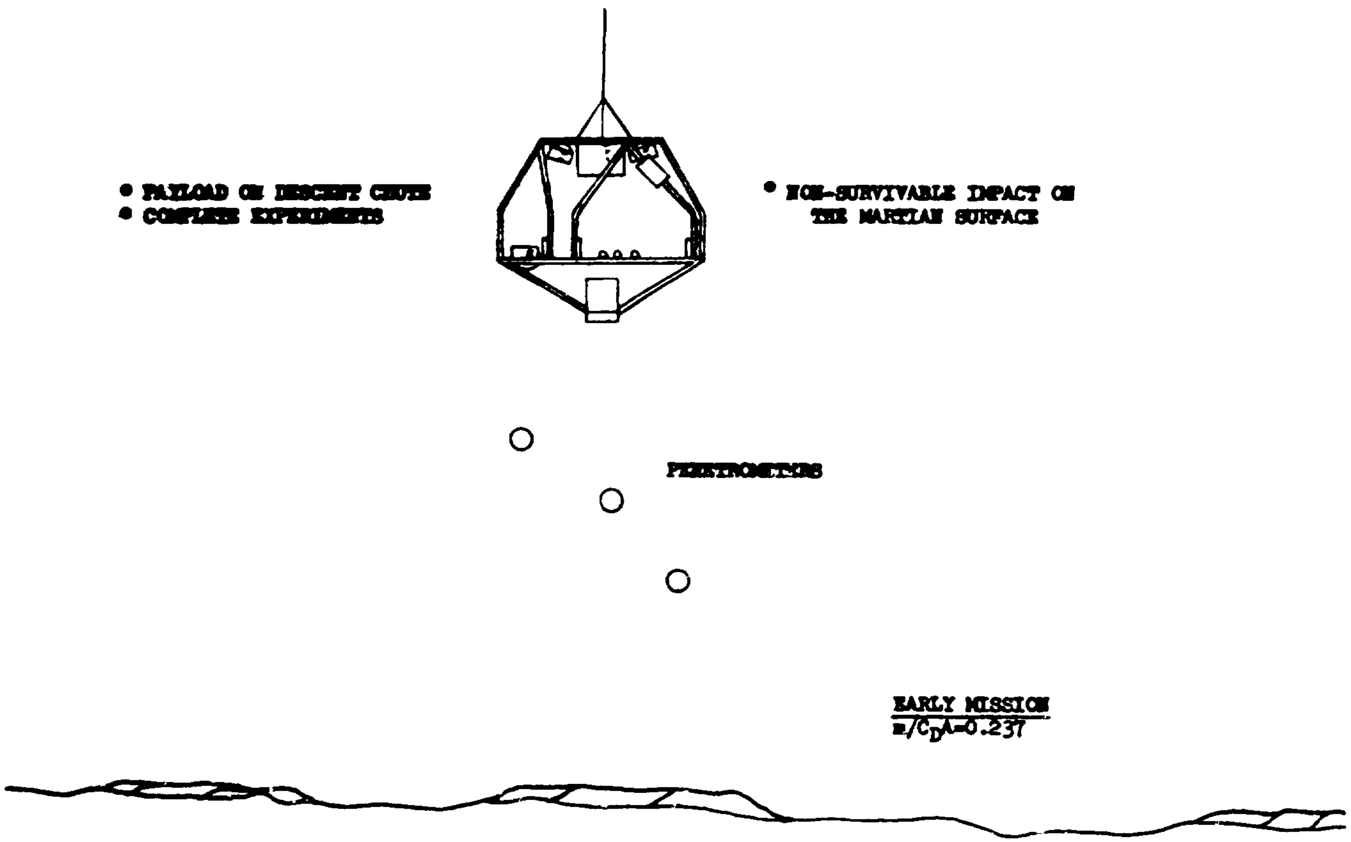


Figure 29.- Atmospheric probe mode

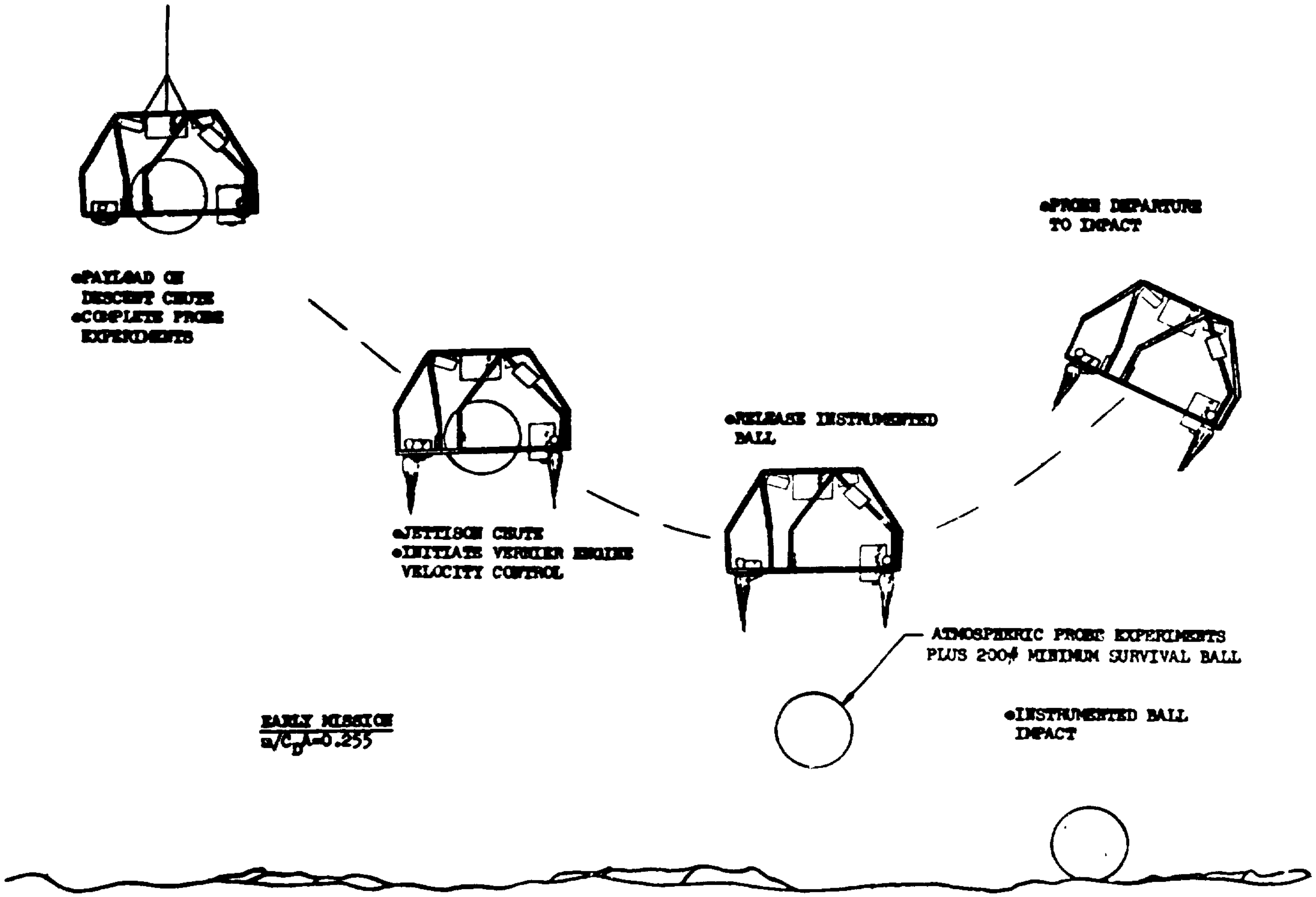


Figure 30.- Probe/Lander mode

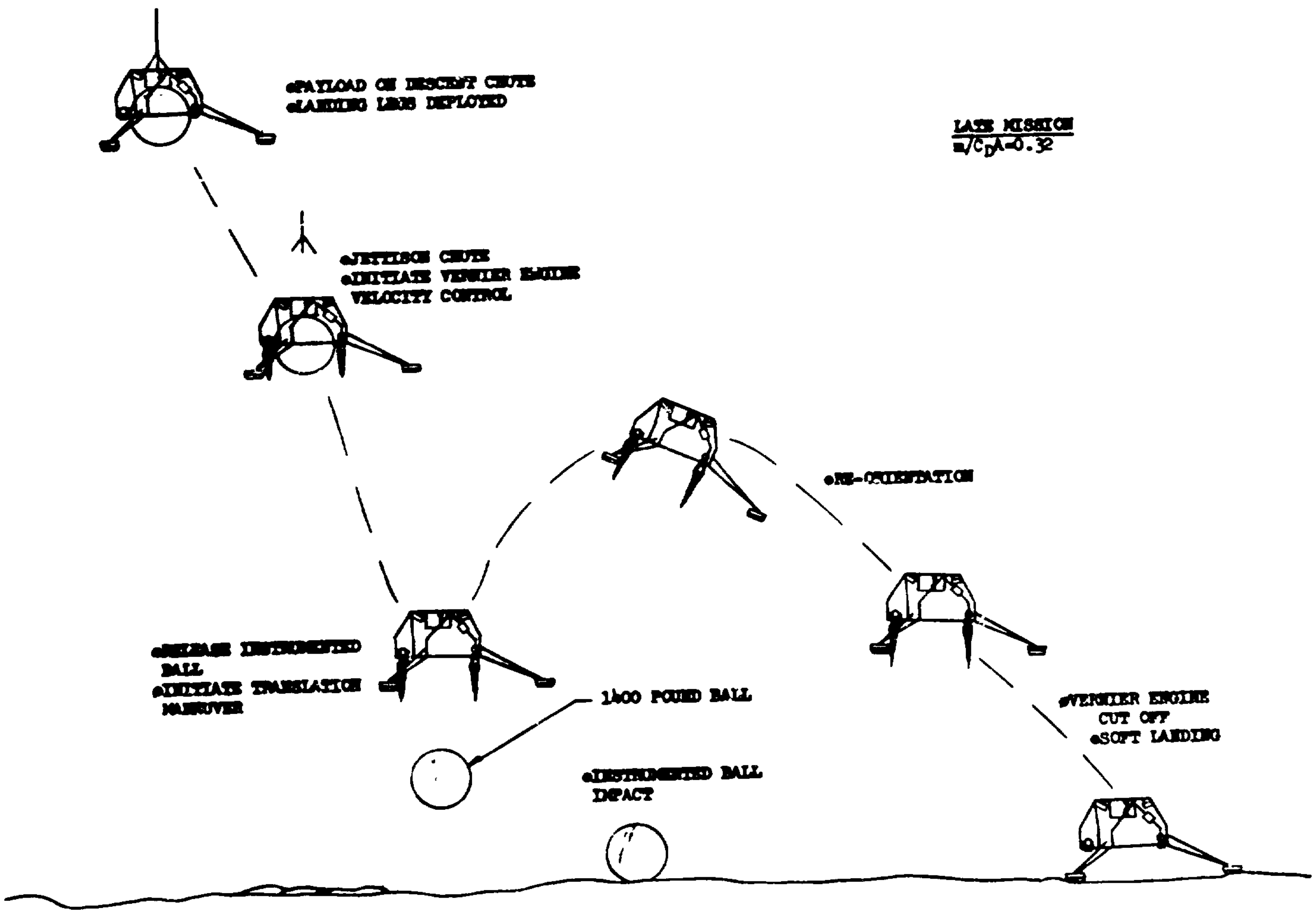


Figure 31.- Semi-soft lander mode

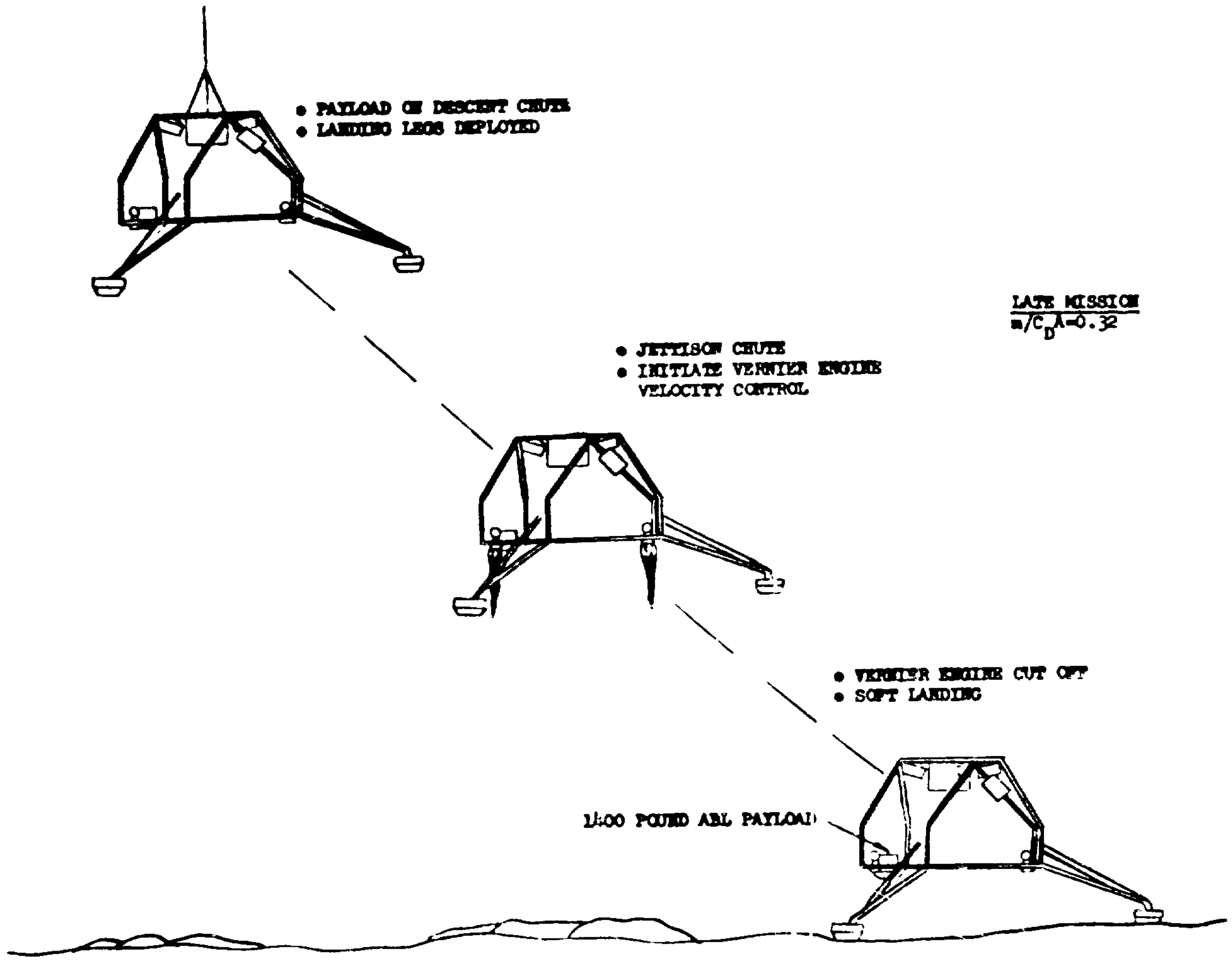


Figure 32.- Advanced lander mode

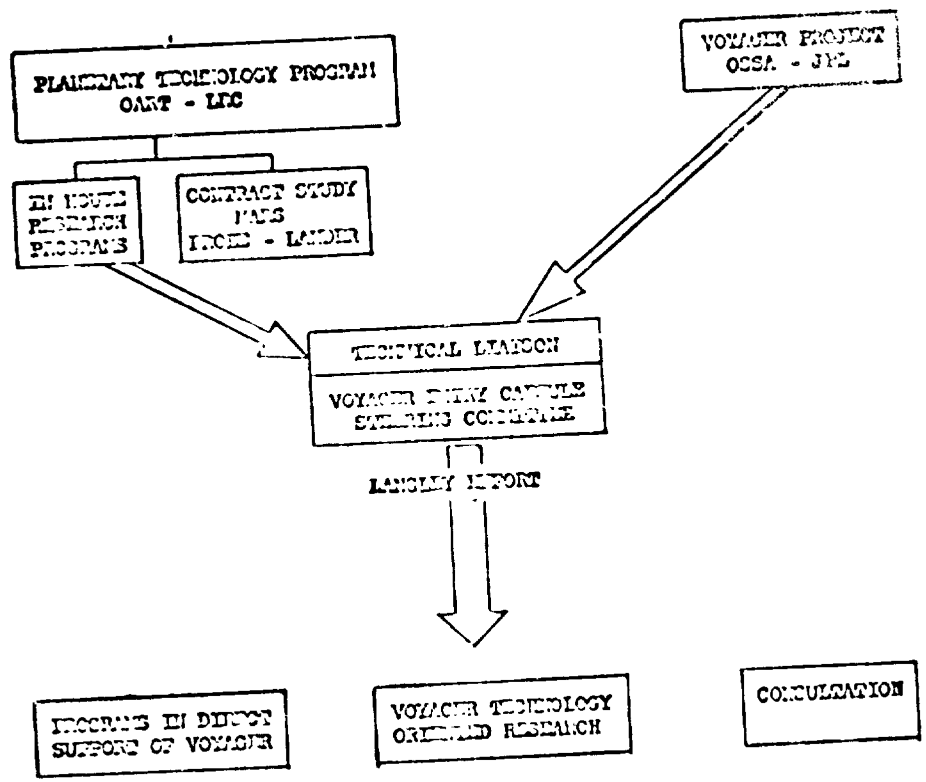
Appendix IV-C

LTC VOYAGER ... PROGRAM

PRESENTED AT ... , D. C.

SEPT ... , 1966

LRC VOYAGER SUPPORT - ORGANIZATION



LRC VOYAGER SUPPORT PROGRAM

- CONDUCT CAPSULE STUDIES TO DETERMINE REQUIRED TECHNOLOGY
- CONDUCT TECHNOLOGY PROGRAMS IN ATMOSPHERIC ENTRY, DESCENT, AND LANDING

CAPSULE STUDY OBJECTIVES

- EXAMINE A VARIETY OF MISSIONS (PROBE TO ABL) FOR COMPATIBILITY WITH A COMMON DELIVERY CONCEPT
- EVALUATE CAPSULE CONCEPTS
- IDENTIFY CRITICAL TECHNOLOGY ITEMS

5

MISSION ALTERNATIVES

CONCEPT	PROBE	PROBE/LANDER	ADVANCED LANDERS
Scientific Objectives	Atmospheric profiles Wind levels Terrain features	Detailed atmosphere prop. Landing site features Surface Mech. and Phy. and Chem. properties	Biology Seasonal Meteorology Sub-surface characteristics Detailed biology, Meteorology Atmos./Surf. Inter. on a seasonal basis
Engineering Objectives	Descent from Orbit Approach to surface Communications	Sur. landing Communications from Surface	Soft Landing Exp. control from Earth Long life on surface

CONCLUSIONS

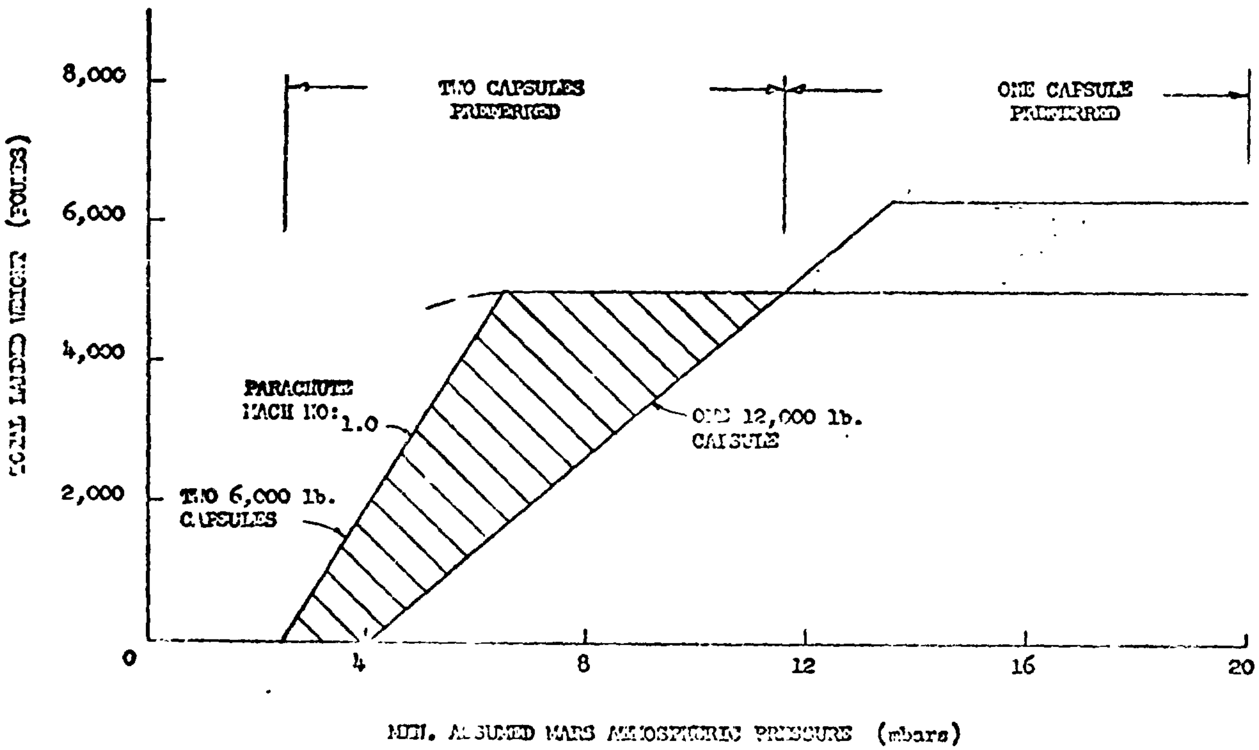
- TWO 6,000 POUND CAPSULES RESULT IN:
  1. GREATER TOTAL LANDED WEIGHT
  2. GREATER FLEXIBILITY

- CAPSULE SYSTEM SHOULD CONSIST OF TWO MAJOR ELEMENTS:
  1. AERODYNAMIC DELIVERY SYSTEM (AEROSHELL + PARACHUTE)
  2. DESCENT PROBE OR LANDER SYSTEM

- PROPULSIVE LANDER SYSTEM PERMITS:
  1. CORRECTION OF WIND DRIFT
  2 SOFT LANDING

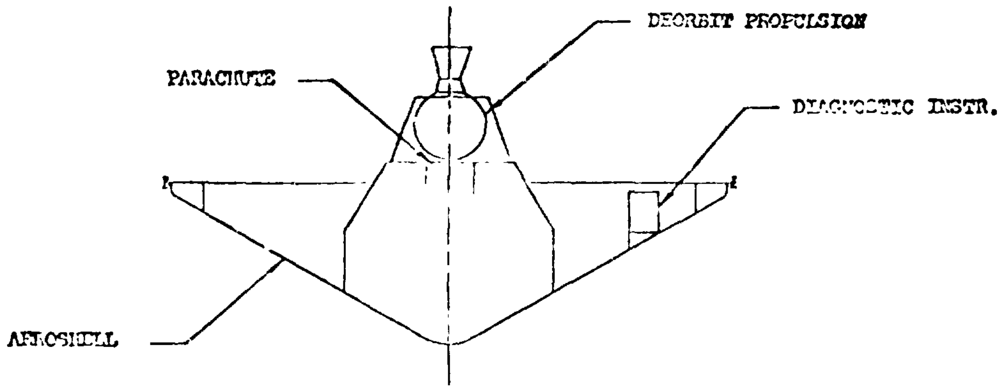
LANDED WEIGHT COMPARISON

(19' DIAMETER CAPSULE)

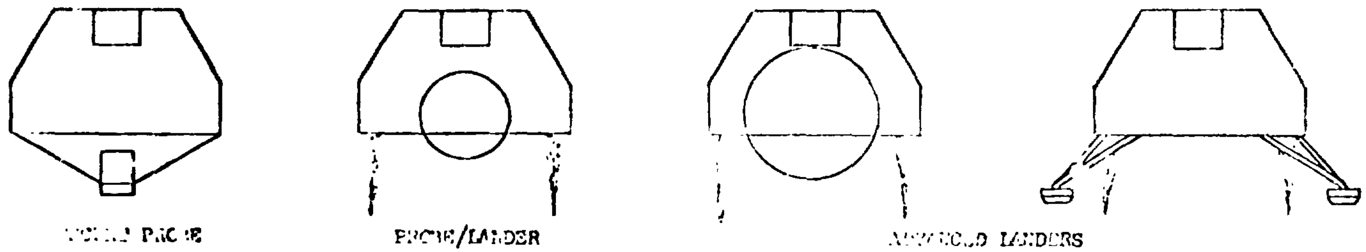


(8)

COMMON AERODYNAMIC DELIVERY SYSTEM

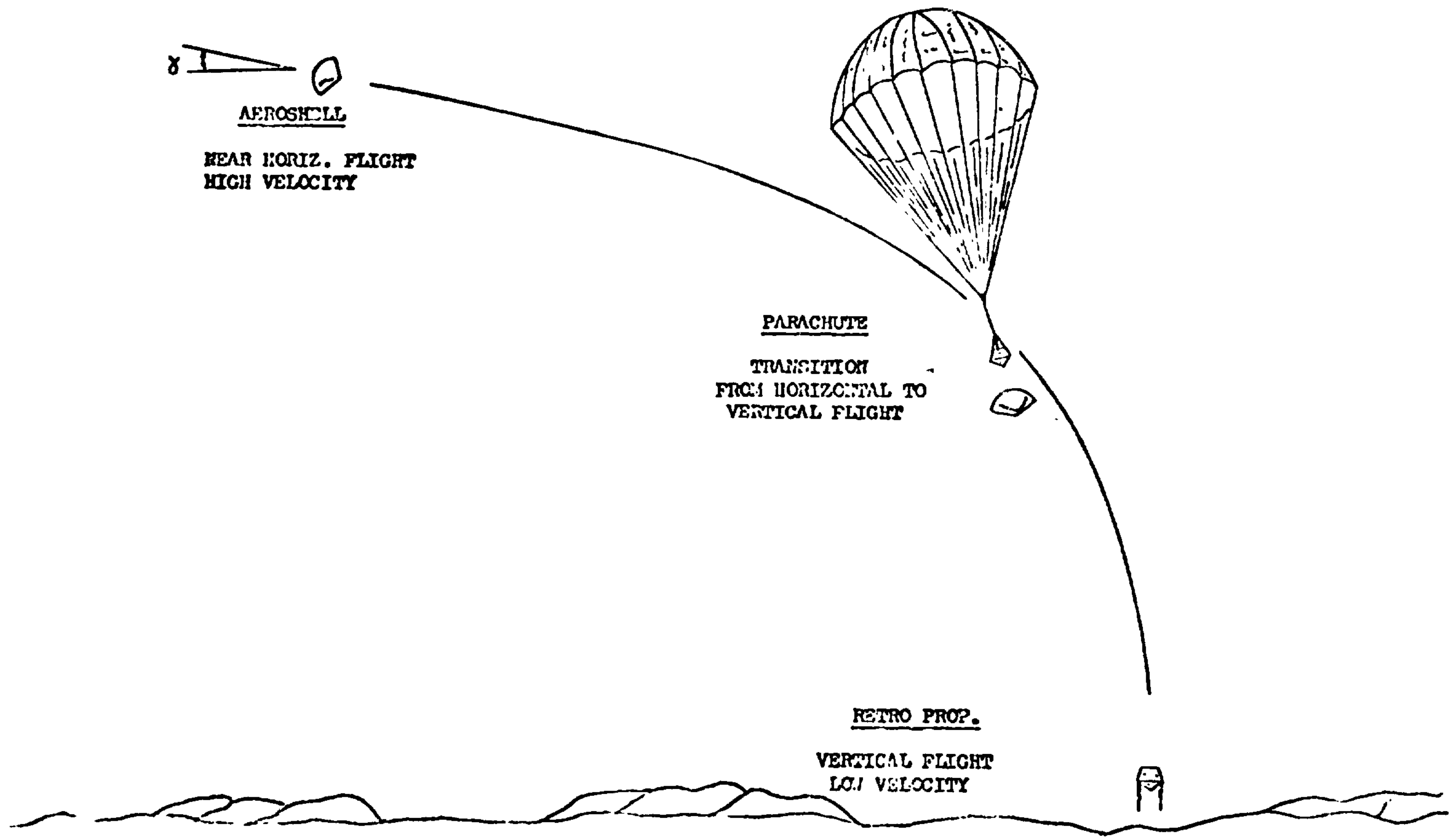


DESCENT PROBE AND LANDER SYSTEMS



9

DESCENT AND LANDING MODE



PROPULSION [illegible] TERMINAL DESCENT

	LUNAR (SURVEYOR)	MARTIAN (VOYAGER)	
		PARACHUTE	NO PARACHUTE
Descent Contour	2 Lunar G	2 Martian G	2 - 10 Martian G
Retro Throttle	2:1	2:1	10:1
Ignition Vel.	390(±100) ft/sec	300(±100) ft/sec	750(±250) ft/sec
Max. Attitude (from Vertical)	45°	40°	60°
Useful Landed Weight	248 lbs	1300 lbs	1000 lbs

11

SUMMARY OF PARACHUTE FUNCTIONS

- PROVIDES TRANSITION FROM AERODYNAMIC TO PROPULSIVE DESCENT
- PERMITS COMMON DELIVERY TECHNIQUE FOR ALL MISSIONS
- REDUCES SENSITIVITY TO SURFACE PRESSURE VARIATIONS
- PERMITS VERTICAL APPROACH TO SURFACE
- LONGER RESIDENCE IN LOWER ATMOSPHERE (DESCENT TV)
- REDUCE ENGINE THROTTLEABILITY FROM 10:1 TO 2:1

(12)

CRITICAL TECHNOLOGY ITEMS

- LARGE DIAMETER AEROSHELL
- HIGH ALTITUDE SUBSONIC PARACHUTE
- HIGH ALTITUDE SUPERSONIC PARACHUTE
- RETRO PROPULSION - AERODYNAMICS INTERACTION
- LANDING AND IMPACT DYNAMICS
- ENTRY AND DESCENT INSTRUMENTATION AND COMMUNICATION
- STERILIZATION

APPENDIX V

Copy for: C T/Brown

ppendix I-A

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA GEN. REG. NO. 27

UNITED STATES GOVERNMENT

Memorandum

Langley Research Center

TO : Associate Director

DATE: March 27, 1967

FROM : Chief, Flight Vehicles and Systems Division

SUBJECT: Meeting at Pasadena California on March 22 and 23, 1967 at JPL to organize Interim Project Office (IPO) for Voyager management (see agenda, attachment 1)

The following members of the Project Management Committee attended the subject meeting:

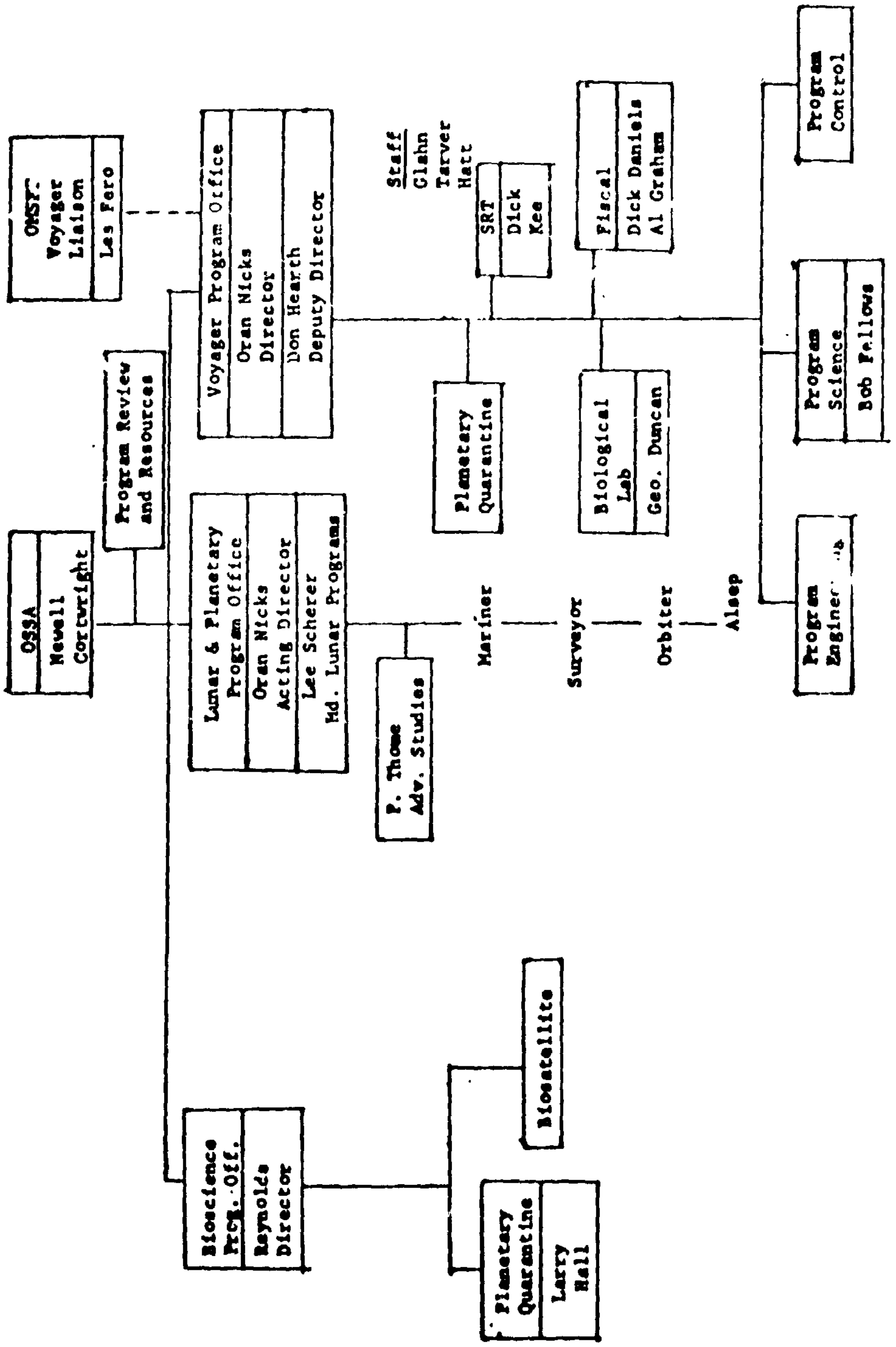
Donald P. Hearth - (Acting Project Manager) (Interim Project Office)
George Nash - (Sec. .ary from Earl Sample's group) (Interim Project Office)
Robert Hock - (KSC Launch Operations)
C. H. Foss - KSC
G. Robillard - JPL (Project Office Support Head) (I.P.O.)
Leonard R. Piasecki - JPL (SLS Manager)
Nick A. Renzetti - JPL (SFOF) (T & DA Manager)
Charles Chambers - MSFC - L/V
Dave Newby - MSFC - S/C Bus
Don P. Burcham - JPL
Walt F. Eichwald - JPL - MOS Manager

Mr. Don Hearth announced that he had talked to Mr. Oran Nicks who appeared with Dr. Homer E. Newell before the House Space Committee (Rep. Karth) on March 22 to review the Lunar and Planetary program. Mr. Nicks felt that the committee's reaction to the Voyager project was very favorable. Also he reported that the 1971 Mars fly-by with atmospheric probe had a favorable reception.

The OSSA Headquarters' Voyager Program Office at present is as follows according to Mr. Hearth:

(see attached Chart 1)
page 2

CHART 1


OSSA
Newell
Cortwright
Program Review and Resources
OMSF: Voyager Liaison
Les Fero
Voyager Program Office
Oran Nicks Director
Don Hearth Deputy Director
Lunar & Planetary Program Office
Oran Nicks Acting Director
Lee Scherer Hd. Lunar Programs
P. Thome Adv. Studies
Mariner
Surveyor
Orbiter
Alsep
Staff
Glahn
Tarver
Hatt
SRT
Dick Kee
Fiscal
Dick Daniels
Al Graham
Planetary Quarantine
Biological Lab
Geo. Duncan
Program Control
Program Science
Bob Fellows
Program Engineer
Bioscience Prog. Off.
Reynolds Director
Biosatellite
Planetary Quarantine
Larry Hall

Mr. Hearth described the Voyager Interim Project Office setup to date. The office is located on the top two floors of the Union Bank Building in Pasadena California (corner of Lake and Cordova Streets). He stated that he would serve as the interim project manager and would spend approximately half his time in Pasadena. The final Project Office is to be formed no earlier than July 1967 and no later than October 1967.

The I.P.O. is as follows with lead personnel named where they have been selected.

(see chart 2)
page 4

Mr. Robillard discussed the mode of operation for the Mission Analysis and Engineering Group. He stated that they will concern themselves with mission and design problems which interact across systems such as communications and weight. Also they would serve for the I.P.O. as a technical referee among systems. It is intended to keep this group in operation at least until October 1967 to insure compatibility of designs and RFP's for Phase "C" procurements. Some technical capabilities will be needed in the Project Office subsequent to October 1967. The Mission Analysis and Engineering Group will support the Mission Design Working Group (discussed later). Data for buy-off by MDWG will be generated by the MD & E group.

To provide participation, visibility, and review by key systems personnel an interim management arrangement was discussed and agreed upon as a means of coordination, and integration among the Voyager Systems. This is headed by a Project Management Committee chaired by the Interim Project Manager (Hearth). The committee is composed of a member or members from each Voyager system (S/C, CB, SLS, MOS, TDS, L/V, LO). The PMC would serve to coordinate, exchange information and review output of working groups. The mode of operation would be interim meetings (probably monthly) called by Mr. Don Hearth. MA&E would support the group technically and action items would be taken back to the Centers' involved for work and resolution.

A series of working groups would report to the PMC. These groups would be made up of members from the Systems involved chaired in most cases by a man assigned to the Interim Project Office. Again, the working groups would function through perodic meetings with members taking action items back to their Centers for work and resolution.

Some working groups would appoint panels to break the work into smaller units.

Technical commitment and interface for Centers will be made through the working groups with review by the Project Management Committee. All agreed that the groups should primarily concern themselves with items which interact among all systems. For example, interfaces between only two systems should be settled by the systems involved.

The entire structure for Interim Management is shown as follows:

(see chart 3)
page 5

CHART 2

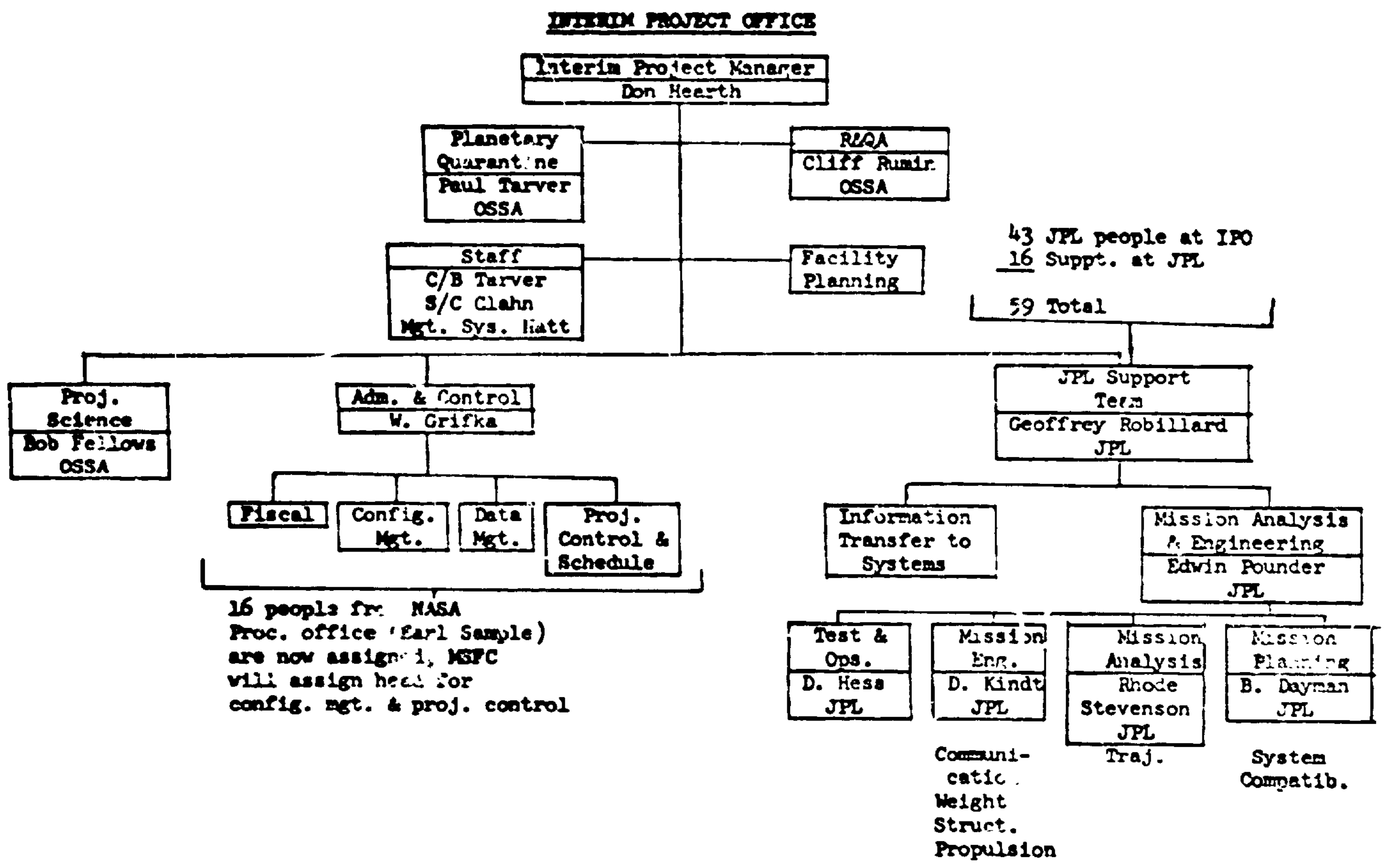
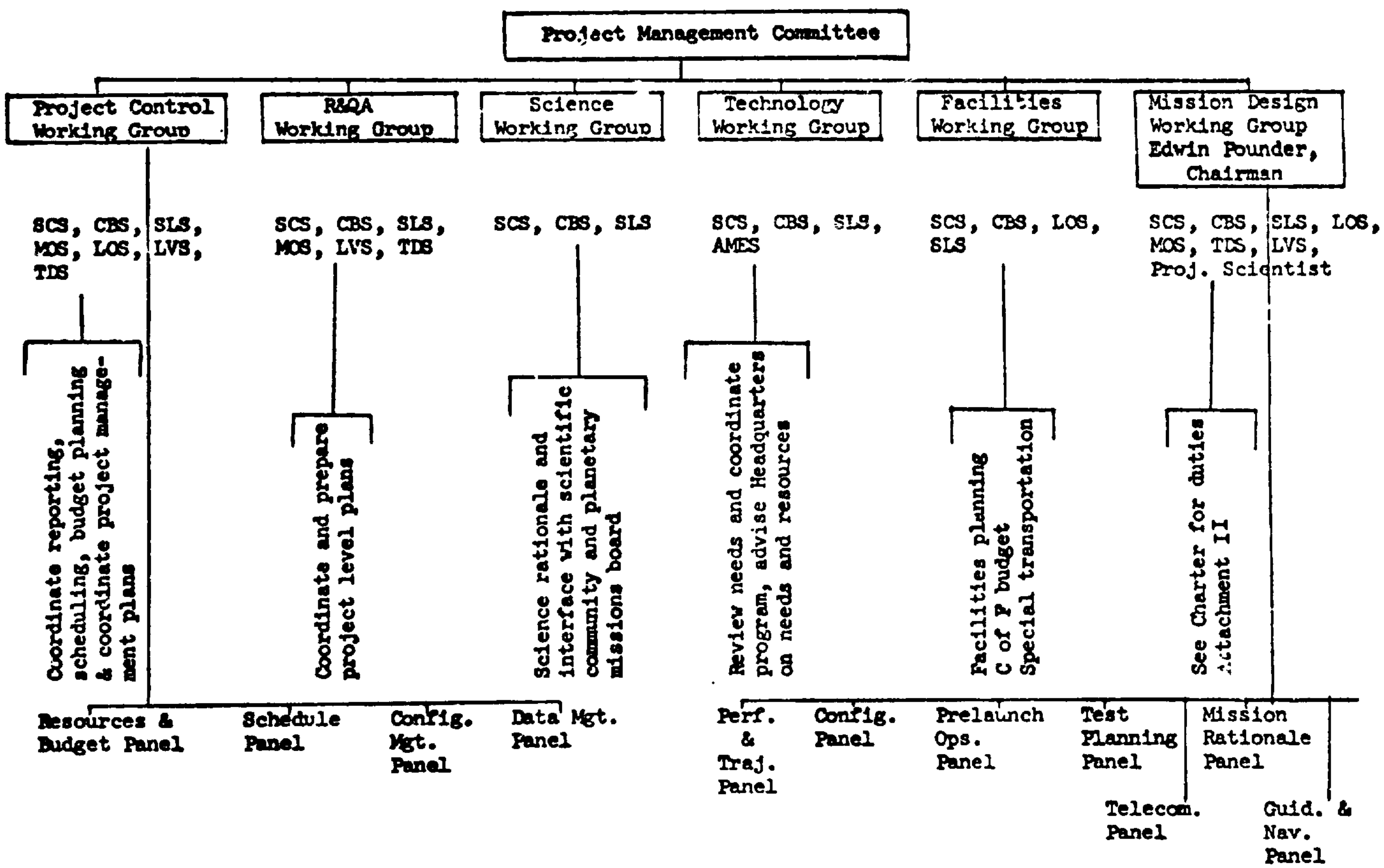

INTERIM PROJECT OFFICE
Interim Project Manager
Don Hearth
Planetary Quarantine
Paul Tarver
OSSA
R&QA
Cliff Rumir
OSSA
Staff
C/B Tarver
S/C Clahn
Mgt. Sys. Hatt
Facility Planning
43 JPL people at IPO
16 Suppt. at JPL
59 Total
Proj. Science
Bob Fellows
OSSA
Adm. & Control
W. Grifka
Fiscal
Config. Mgt.
Data Mgt.
Proj. Control & Schedule
16 people fr. NASA
Proc. office (Earl Sample)
are now assigned, MSFC
will assign head for
config. mgt. & proj. control
JPL Support Team
Geoffrey Robillard
JPL
Information Transfer to Systems
Mission Analysis & Engineering
Edwin Pounder
JPL
Test & Ops.
D. Hess
JPL
Mission Eng.
D. Kindt
JPL
Communication
Weight
Struct.
Propulsion
Mission Analysis
Rhode
Stevenson
JPL
Traj.
Mission Planning
B. Dayman
JPL
System Compatib.

CHART 3



Project Management Committee
Project Control Working Group
R&QA Working Group
Science Working Group
Technology Working Group
Facilities Working Group
Mission Design Working Group Edwin Pounder, Chairman
SCS, CBS, SLS, MOS, LOS, LVS, TDS
SCS, CBS, SLS, MOS, LVS, TDS
SCS, CBS, SLS
SCS, CBS, SLS, AMES
SCS, CBS, LOS, SLS
SCS, CBS, SLS, LOS, MOS, TDS, LVS, Proj. Scientist
Coordinate reporting, scheduling, budget planning & coordinate project management plans
Coordinate and prepare project level plans
Science rationale and interface with scientific community and planetary missions board
Review needs and coordinate program, advise Headquarters on needs and resources
Facilities planning
C of F budget
Special transportation
See Charter for duties Attachment II
Resources & Budget Panel
Schedule Panel
Config. Mgt. Panel
Data Mgt. Panel
Perf. & Traj. Panel
Config. Panel
Prelaunch Ops. Panel
Test Planning Panel
Mission Rationale Panel
Telecom. Panel
Guid. & Nav. Panel

Mr. Walt Eichwald of JPL talked on the preliminary Mission Operations System plans. He stated that the MOS would be responsibile for the hardware and software for missions operation and control. MOS would also be responsible for MOC (Mission Operations Complex) design. JPL is setting up design team to familiarize mission operations sequences and interfaces and to implement. It was not clear as to the systems contract responsibilities in the MOS and MOC area. It is recommended that Mr. Boyer and Mr. Martin of LOPO review the preliminary documents (attachments 3 & 4) prepared by Mr. Eichwald.

Mr. Eichwald requested that LRC assign personnel to the MOC design team.

Project guidelines were reviewed. Decisions were made on some. Others were left open for more study.

1. Will use two planetary vehicles on one Saturn V
2. Backup launch vehicle. No decision was made but two alternates were discussed.

a. Two Saturn V's erected simultaneously on pad 39. Shift planetary vehicles to backups in case of problems.

b. Move launch to next launch window (two to three months later) and change trajectory (type 1 to type 2)

3. Lifetime - No decision reached; however, two days on surface most probable. To be examined as to use of batteries or RTG. It was felt that the capsule should be designed thermally for the RTG in 1973.

4. Capsule weight - No decision reached. However it was decided to consider 5000#, 6000# and 7000# capsule weights and determine trade-offs and penalties for designing 73 mission for heavier weights. MSFC will examine design of S/C Bus for 7000# capsule.

5. Design largest size capsule which will fit in shroud.

6. Two planetary vehicles identical for 73 missions.

7. Design for Mars only as starting point.

8. Capsule Bus will be entered out of Mar's orbit.

9. Type I trajectory will be used as starting point. (Type I has encounter at less than 180°, Type II has encounter more than 180°). Type II is double trip time and distance for Type I but allows more payload weight.

10. Sample payloads (experiments) will be furnished by IPO as starting guideline.

11. Mar's model will be furnished by the IPO as starting point; density, terrain, etc.

The phase "C" schedule was reviewed, moving the RFP release date from October 67 to November 67 to allow more time to take advantage of information from the Phase B contractual and in-house studies was discussed. All parties were asked to look at their system procurement schedules in detail and discuss these at the next PMC meeting.

Mr. Hearth asked for a discussion and recommendations from each system at the next PMC meeting on the role and responsibilities of the Launch Operations System (KSC).

1. Who heads up assembly and checkout team at the Cape?

2. Do systems contractors participate?

It was requested that all systems review the f.y. 67 and 68 budget (attachment 5) and be prepared to discuss their specific requirements at the next PMC meeting.

A discussion on reporting was held. A preliminary document (attachment 6) for review was submitted by Mr. Hearth. The proposed system is based on the MIC System used by LRC on the Orbiter. Comments on the proposed document were requested by Mr. Hearth by March 31, 1967.

ACTION ITEMS (Next PMC meeting is scheduled for mid-April 1967)

1. Comment on MOS plan by next PMC meeting.

2. Appoint Working Group representatives by April 5, 1967.

3. Don Hearth, JPL, and LRC will meet next week on capsule and SLS interfaces.

4. Review and comment on Phase C schedule by next PMC meeting.

5. Arrive at recommended position on operations at KSC prior to next PMC meeting.

6. Review recommended reporting system and comment by March 31, 1967.

7. Make recommendations for chairman for Facilities Working Group. All attendees felt someone who is recognized and respected by Cof F personnel in Headquarters is needed. CofF budget must be prepared by May 67 if possible.

8. Review budget for f.y. 67 and 68 by next PMC meeting and recommend concurrance or changes (attachment 5).

9. The writer discussed the Voyager experiments with Mr. Newby of MSFC, Dr. Burcham of JPL and Mr. Don Hearth. All agreed that the experiment hardware development should be a project responsibility. Mr. Hearth agreed that the entry experiments in particular were primarily engineering experiments needed to determine and analyze the operation of the Capsule Bus and possibly could be handled in a manner similar to the Lunar Orbiter experiments. Mr. Hearth suggested that Langley representatives should contact Bob Fellows of OSSA on this matter in the near future.

E. C. Kilgore

Edwin C. Kilgore

I - B

Revised September 8, 1967

IN-HOUSE FEASIBILITY STUDIES - PLANETARY EXPLORATION PROGRAM

Objective

The objective of this in-house study is to enable the Langley Research Center to recommend to NASA Headquarters alternate approaches for planetary exploration, in view of the present deferment of the Voyager Program.

Method of Approach

Scientific and engineering objectives will be specified and prioritized for planetary exploration in the period 1971-73 for both Mars and Venus. The payload capability of the spectrum of available launch vehicle systems smaller than Saturn V will be evaluated and a limited number selected and used for this study.

A conceptual spacecraft design shall be created for each selected launch vehicle to carry out as many of the stated scientific objectives as practicable. A mission plan will be evolved for each spacecraft/launch vehicle combination to verify over-all feasibility. All recommended combinations shall be examined for future growth capability. The need for advancements or additional study into technology areas will be identified.

Trade-off studies among the various configurations shall be carried out leading to the final LRC recommendation to NASA Headquarters.

Guidelines

A. The following guidelines and/or constraints shall govern during the performance of this study:

1. Planets to be considered - Mars and Venus
2. Launch dates: Mars - 1971, 1973; Venus - 1972, 1973 } OR OTHERS
3. Configurations - Orbiter spacecraft with and without probe
4. Orbit characteristics - polar orbit desired to provide full planet coverage.
5. Orbit lifetime for a nonsterilized orbiter spacecraft to be 50 years as required by NASA planetary quarantine criteria.
6. Entry probes to be sterilized in accordance with NASA agreements.
7. Length of mission - a goal of coverage of a planet seasonal change is desired for Mars; Venus needs further study.

8. For each launch opportunity, there shall be two launches; a third spacecraft should be prepared and available at the launch facility as a back-up to help assure the intended launches.

9. It is desired that each launch window be not less than about 30 days in duration.

10. The launch facilities at ETR are to be utilized.

11. Planning shall be on the basis of using the existing capabilities of the Deep Space Network (Deep Space Stations and the Space Flight Operations Facility).

12. Maximum use shall be made of space-proven hardware.

13. This study shall not consider the development of a new launch vehicle.

14. A minimum periapsis altitude of 1000 km shall be used for purposes of this study for both Mars and Venus.

B. The following areas need to be investigated early and related guidelines established:

1. Transit time - available error analyses should be used to establish the approach trajectory criteria in order to determine the spacecraft payload capability.

2. Desired length of mission at Venus needs to be determined.

Implementation

A. The management structure for the in-house feasibility study is shown in figure 1.

B. Following is the schedule on which the study is to be carried out:

SEPT. 25
~~October 1~~, 1967 - Interim status report due along with identification of areas which should be supplemented by contractor effort.

November 1, 1967 - Results of the task area activities available for assembly into an integrated report for presentation to NASA Headquarters.

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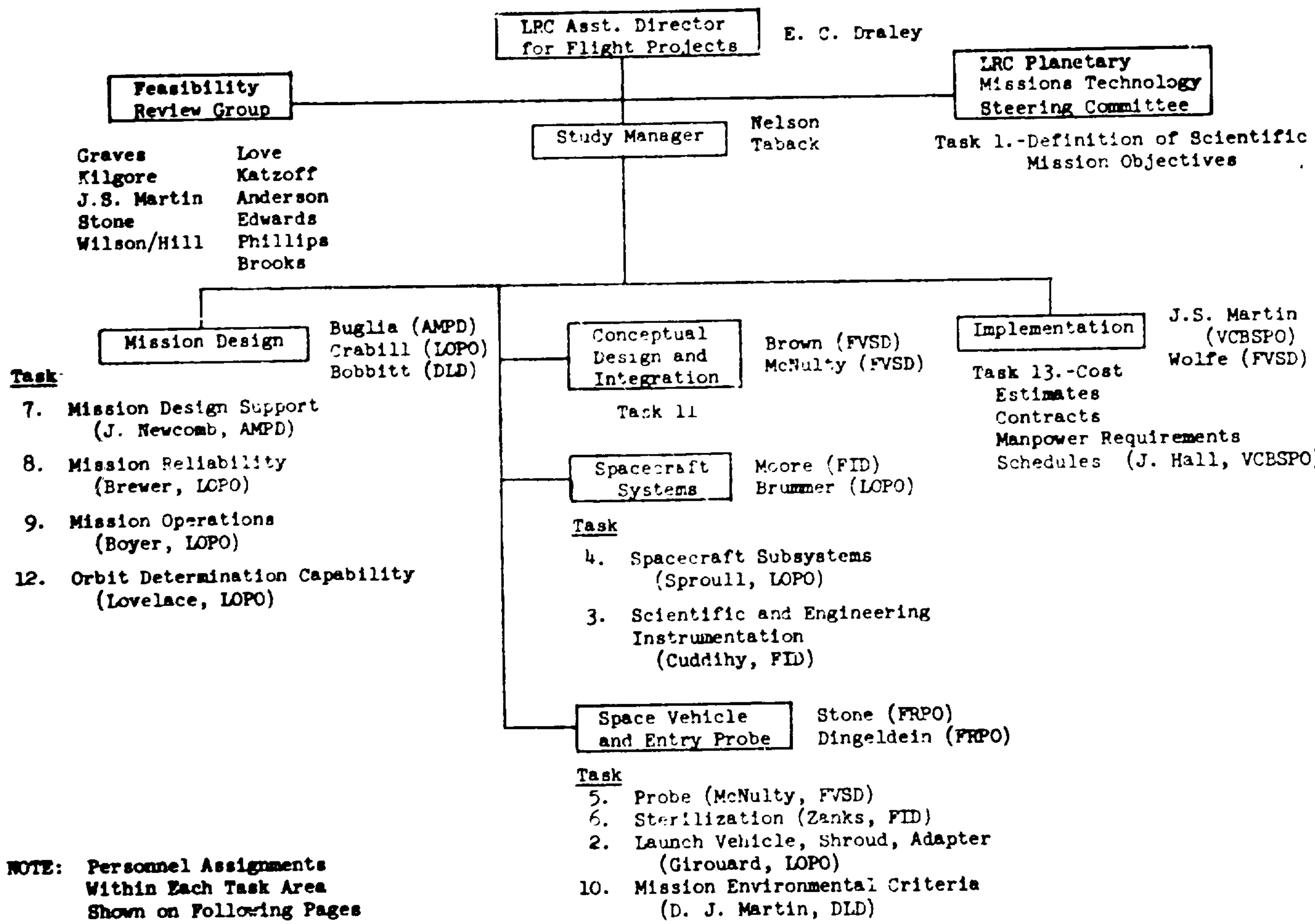
MANAGEMENT STRUCTURE

LRC IN-HOUSE FEASIBILITY STUDIES - PLANETARY EXPLORATION MISSIONS



NOTE: Personnel Assignments Within Each Task Area Shown on Following Pages

FIGURE 1

PERSONNEL ASSIGNMENT TO TASK AREAS

Task No. and Name	Personnel
1. Definition of Venus and Mars Scientific Mission Objectives	LRC Planetary Missions Technology Steering Committee, E. Love, Chairman
	W. J. O'Sullivan (AMPD) C. T. Brown (FVSD) A. T. Young (LOPO)
	LRC Planetary Missions Technology Steering Committee, Subcommittee
	G. Brooks (DLD), Chairman J. Stitt (FID) G. Wood (APD) W. Michael (SMD)
2. Launch Vehicle	R. Girouard (LOPO), Leader J. Cannady (AMPD) J. Unangst (AMPD) G. Lawrence (AMPD) C. T. Brown (FVSD)
3. Instrumentation for Scientific Measurements	W. Cuddihy (FID), Leader G. Wood (APD) F. Staylor (APD) C. Broome (LOPO) R. D. Smith (LOPO) P. Yaeger (IRD) J. D. Lawrence (IRD) I. MacConochie (FVSD) D. Cauchon (FRPO) W. Sherman (SMD) E. Goyette (ESD)
4. Spacecraft Subsystems	R. Sproull (LOPO), Leader
a. Structures, Mechanisms, Thermal	E. Hankinson (LOPO), Leader D. Carter (AMPD) W. Slemp (AMPD)

Task No. and Name	Personnel
b. Power	J. Harris (LOPO), Leader
c. Communications	W. Moore (FID), Leader C. Green (LOPO) T. Bundick (LOPO)
d. Attitude Stabilization and Control	J. Reid (FID), Leader C. Engle (LOPO)
e. Velocity Control	D. Carter (AMPD), Leader R. N. Green (AMPD) R. Averill (FVSD)
5. Probe	J. McNulty (FVSD), Leader J. Dixon (FVSD) H. Tolefson (DLD) W. Moore (FID) L. Fisher (SRD) L. Vosteen (SRD) K. Hughes (LOPO) G. Walberg (AMPD) W. Erickson (AMPD) C. Gillis (AMPD)
6. Sterilization	J. Zanks (FID), Leader L. Daspit (VCBSPO) E. Mason (FVSD) H. Hendricks (AMPD)
7. Mission Design Support	J. Newcomb (AMPD), Leader R. N. Green (AMPD) W. Hampshire (AMPD) D. Snow (FVSD) J. Williams (SMD) B. Lightner (LOPO)
8. Mission Reliability	G. Brewer (LOPO), Leader J. Miny (LOPO) O. Childress (LOPO) H. Ricker (FID) T. Bonner (FVSD)

Task No. and Name	Personnel
9. Mission Operations	W. Boyer (LOPO), Leader J. Graham (LOPO) D. H. Ward (LOPO)
10. Mission Environmental Criteria	D. J. Martin (DLD), Leader S. Clevenson (DLD) R. Girouard/J. Lovell (LOPO) T. Bonner (FVSD)
11. Conceptual Design and Integration	(Organization to be identified by FVSD)
12. Operational Orbit Determination Capability	U. M. Lovelace (LOPO), Leader W. Mayo (LOPO) A. Mayo (AMPD) L. Hoffman (AMPD) G. Young (AMPD)
13. Cost Estimates, Contractual Considerations, Manpower Requirements, Schedules	J. Hall (VCBSPO), Leader F. Jennings (VCBSPO) C. McKee (VCBSPO) R. Parker (VCBSPO) D. Church (VCBSPO) R. Anderson (SRD)*

*Will furnish inputs relative to Headquarters Study Contract, "Cost Effective Design for Future Space Systems"

IN-HOUSE FEASIBILITY STUDY TASKS - PLANETARY EXPLORATION MISSIONS

1. DEFINITION OF VENUS AND MARS SCIENTIFIC MISSION OBJECTIVES
2. LAUNCH VEHICLE
3. INSTRUMENTATION FOR SCIENTIFIC MEASUREMENTS
4. SPACECRAFT SUBSYSTEMS
5. PROBE
6. STERILIZATION
7. MISSION DESIGN SUPPORT
8. MISSION RELIABILITY
9. MISSION OPERATIONS
10. MISSION ENVIRONMENTAL CRITERIA
11. CONCEPTUAL DESIGN AND IMPLEMENTATION
12. OPERATIONAL ORBIT DETERMINATION CAPABILITY
13. COST ESTIMATES, CONTRACTUAL CONSIDERATIONS, MANPOWER REQUIREMENTS, SCHEDULES

IN-HOUSE FEASIBILITY STUDY TASKS - PLANETARY EXPLORATION MISSIONS

1. DEFINITION OF VENUS AND MARS SCIENTIFIC MISSION OBJECTIVES

A delineation of scientific objectives for missions to Venus and Mars during the 1971-1973 period is required. The recommended scientific measurements should consider the use of an orbiting spacecraft as well as a combination orbiter and probe.

2. LAUNCH VEHICLE

Performance study and configuration selection to support mission design for planetary investigations. The medium space launch vehicles - smaller than Saturn V - expected to be available for the mission time period will be examined for maximum performance and to best support spacecraft requirements. Mission restraints imposed by launch vehicle systems and trajectories will be identified as well as payload weight capability and envelope size.

3. INSTRUMENTATION FOR SCIENTIFIC MEASUREMENTS

Analysis of the instrumentation approaches for satisfying the scientific mission requirements; comparison of various approaches to satisfy a given measurement requirement; ability to make measurements with required degree of accuracy; present state of theory and experience of each proposed instrumentation technique; suitability and characteristics of presently available instrumentation; possible required extensions in theory and instrumentation development to satisfy objective. The analysis and study should be guided by such factors as the basic mission parameters (e.g., altitudes from which measurements will have to be made), the use of a probe for atmospheric survey, the need to minimize instrumentation weight, size and power consumption, the need for matching measurement rates to communication-link data-rate capability, the duration of the missions and the resultant effect on data rate and instrumentation design and reliability, etc. To satisfy mission objectives for the measurement of planetary fields, particles, environment and surface characteristics will involve the consideration of instrumentation such as:

- imaging systems
- mapping radar
- radar altimeter
- micro-wave radiometer
- ultraviolet spectrometer
- infrared spectrometer
- infrared radiometer
- magnetometer
- micrometeoroid detectors
- radiation detectors
- pressure sensors
- temperature sensors
- water vapor sensors
- RF occultation

4. SPACECRAFT SUBSYSTEMS

Identify requirements for and investigate problem areas of the following subsystems relative to a Mars/Venus spacecraft.

a. Structure, Mechanisms, Thermal

b. Power

c. Communications

d. Attitude Stabilization and Control

e. Velocity Control

5. **PROBE**

Study of the ability of the intended class of spacecraft to carry and deploy an atmospheric probe; investigation of probe types and configurations in consideration of weight limitations, desired atmospheric measurements; definition of data transmission problems and possible solutions; evaluation of possibility of probe surviving impact on the planet surface; probe propulsion requirement.

6. **STERILIZATION**

Determine the most feasible approach to terminal sterilization of an entry probe. i.e., oven, hot gas, other. Also determine the bio clean requirements for assembly areas of the entry probe necessary to meet the required contamination level prior to terminal sterilization of the probe. Determine the compatibility of ethylene oxide decontamination of an orbiting spacecraft and evaluate methods of handling and ejecting the sterile probe aboard the spacecraft.

7. **MISSION DESIGN SUPPORT**

To support mission designs basic studies of launch opportunities, launch energy requirements, transit/arrival times, deboost ΔV, planetary orbit designs and variation with time, mission duration, planetary seasons, variation of communication distances with mission time from launch, sun occultation periods, Canopus occultation periods, etc., are required. To develop error analyses indicating ΔV and VACS requirements for midcourses, deboost, orbit trim, pointing for photography or other planet imaging devices in terms of acceptable orbit determination. (To investigate and establish if minimum periapsis altitudes less than 1000 KM can be utilized.)

8. **MISSION RELIABILITY**

To study the mission requirements for long lifetime operation of the spacecraft/probe system and relate those requirements to subsystem design approaches (e.g., redundancy, duty cycle, etc.) component selection, quality assurance approaches, etc.; establish the required reliability goals for each subsystem; for the final conceptual designs, predict the expected reliability as a function of mission duration.

9. MISSION OPERATIONS

To define major elements of plan to operate the mission in all phases, from launch, interplanetary encounter, and orbiting phases. In view of centralized or decentralized control, number and location of tracking and/or command sites, site and control center hardware and software requirements, site-to-center communications requirements, operational requirements on design and operation of spacecraft and scientific instrumentation and mission design.

10. MISSION ENVIRONMENTAL CRITERIA

To define the major environmental restraints from the design area through fabrication, testing, launch and terminating at the planet surface.

11. CONCEPTUAL DESIGN AND INTEGRATION

To relate and integrate the subsystem and system elements of the spacecraft, probe and space vehicle into conceptual over-all designs to demonstrate and support the feasibility of the proposed mission concept. This will involve obtaining basic component and subsystem characteristics from each appropriate task area, conceiving and integrating all elements of the spacecraft, probe and space vehicle into an optimum arrangement in accordance with thermal, environmental and other considerations, establishing over-all weights to be utilized in mission design, etc.

12. OPERATIONAL ORBIT DETERMINATION CAPABILITY

To study the capability of expected tracking systems to provide the required data for orbit determination, the accuracy with which the state vector and orbital parameters can be determined with various amounts of tracking data during the various earth-planet geometries, including the effect of uncertainty in the planetary gravitational field and the presence of moons about Mars; relationship of such uncertainties to mission design and the ability to satisfy the mission objectives; definition of possible improvements required in tracking systems or orbit determination programs.

13. COST ESTIMATES, CONTRACTUAL CONSIDERATIONS, MANPOWER REQUIREMENTS, SCHEDULES

To formulate and establish for the selected mission over-all cost estimates; contractual documentation and coordination aspects; review and outline manpower requirements; coordinate and provide over-all schedules.

CHNelson
Clifford H. Nelson
Study Manager

EAB
RHB

426

J.F McNULTY

LWP - 483
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LWP - 483

LANGLEY WORKING PAPER

A BUILDING BLOCK APPROACH TO MARS AND VENUS PLANETARY MISSIONS IN THE 1970'S UTILIZING A MODULAR SPACECRAFT

By Flight Vehicles and
Systems Division Study Team

Langley Research Center
Langley Station, Hampton, Va.

This paper is given limited distribution
and is subject to possible incorporation
in a formal NASA report.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

November 1, 1967

LWP - 483
November 1, 1967

LANGLEY WORKING PAPER

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Prepared by

Flight Vehicles and
Systems Division Study Team

Approved by Edwin C. Kilgore

Edwin C. Kilgore
Chief, Flight Vehicle and Systems Division

LANGLEY RESEARCH CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Working Paper No. 483

A BUILDING BLOCK APPROACH TO MARS AND VENUS PLANETARY MISSIONS IN THE 1970'S UTILIZING A MODULAR SPACECRAFT

By Flight Vehicles and
Systems Division Study Team

SUMMARY

A program for planetary missions to Mars and Venus in the 1970's which utilizes the Titan family of launch vehicles and a spacecraft modular concept to promote maximum commonality between missions is defined in the paper and is outlined on figure 6. It is felt that this program outline can be used to pinpoint various technology areas requiring development so that the leadtime required for future planetary missions is minimized.

The Titan III-C* was selected as the launch vehicle for missions to Mars and Venus in 1971 to 1975 opportunities. The Titan III C supplies sufficient energy to orbit a 1,400 spacecraft (150 pounds of science) and, depending on mission, to carry a 150- to 300-pound probe to investigate the atmosphere.

These orbiting spacecraft can be made up of instrument and propulsion modules with much commonality; additional propellant tanks would be required for the Venus missions. This spacecraft modular approach can be extended to

*For the purpose of this study, the following designations are used to describe various Titan launch vehicles:

T III-C	Basic Titan with two five-segment strap-on solid motors and the Transtage.
T III-D	Same as the T III-C except no Transtage.
T III-F	Same as the T III-D except solid strap ons are seven-segment instead of five-segment. The T III-F is the non-man rated complement of the Titan III-M.

the later missions when a higher energy launch vehicle and lander are phased into the program.

Saturn V and Titan III-F Centaur are satisfactory candidate launch vehicles in the 1975 to 1977 opportunities. A Titan III-F Centaur vehicle can be staged and hammerheaded to carry a 4,000-pound capsule bus into orbit for separation and landing.

This program allows each succeeding mission to build on the technology of the preceding mission, thus minimizing development costs and enhancing reliability.

INTRODUCTION

In order to provide a basis for the definition of the required technology to support a planetary exploration program for Mars and Venus in the early 1970's which demonstrates steady growth to the landing of a surface laboratory system planned for the late 1970's, a study was conducted to determine payload weight allocations and general planetary vehicle configurations using the Titan III-C launch vehicle. In particular, an attempt is made in this paper to delineate mission parameters such as launch dates, energy requirements, orbit dimensions, etc., and to show, through conceptual drawings, the modular concept permitting commonality between missions and growth capability.

After reviewing launch vehicle payload capability as supplied by Lewis Research Center personnel, the Titan III-C Transtage was selected as the early mission vehicle on which the study would be based. The problem then was to select an orbit which would utilize a minimum of propellant for orbit injection, while permitting relatively close observation of the planet for a long period of time from an orbiting spacecraft. Orbits of the order of 1,000 x 20,000 to

1,000 x 30,000 km appeared to best satisfy these requirements and were therefore selected as parameters.

With available payload information, it was then possible to determine the planetary vehicle weight, propellant weight, and orbiting (dry) weight. From these data, trades were developed which demonstrate allowable weights for deployed probes; consideration was given to deploying probes both from orbit and from approach prior to insertion of the spacecraft into orbit. This weight breakdown was generated on the basis of three different spacecraft weights - 1,200 pounds, 1,300 pounds, and 1,400 pounds - and resulted in various probe weights.

In the preparation of a conceptual design of the spacecraft, an approach was selected to permit maximum utilization of common systems between missions. A modular concept permitting growth and commonality was made the objective of the design; this objective was to be realized by changing only the propulsion module and capsule sizes as the allowable mission weights increased.

The performance and weight data contained herein were developed on a minimum time basis and are therefore presented as approximate values. This information, however, is valid for illustration of concepts and approach techniques.

SYMBOLS

C_3	twice the total injection energy per unit mass (km^2/sec^2)
V	velocity (km/sec)
V_H	hyperbolic excess velocity at launch (km/sec)
V_∞	hyperbolic excess velocity at encounter with target planet (km/sec)

S/C	spacecraft not including probe
ΔV	velocity increment required for spacecraft velocity change including orbit insertion (km/sec)
g	gravitational acceleration (ft/sec^2)
ACS	attitude control system
m/C_DA	mass/(drag coefficient x cross-sectional area)
M	Mach number
α	angle of attack (degrees)
γ	flight-path angle (degrees or radians, measured negative downward from the local horizontal)

Subscript

E	entry conditions

RESULTS

A. Mission Requirements

An analysis was made to determine the pertinent mission parameters for missions to Mars and Venus in the 1972 to 1975 opportunities. These parameters are tabulated in table I. The launch energy (C_3) required in each of the opportunities is shown which determines the planet payload for the various launch vehicles. Also tabulated is the planet approach velocity (V_∞) which defines the propulsion requirements for orbit. Finally, the ratio of spacecraft weights, before and after orbit, is given for representative orbits of 1,000 km x 20,000 km and 1,000 km x 30,000 km.

The results of a parametric study of planetary vehicle system weights for the various opportunities compatible with a Titan III-C launch vehicle are given in tables II and III. For various weight spacecraft (orbit weights of 1,200, 1,300, and 1,400 pounds), table II defines the propellant requirements for a 1,000 x 30,000 km orbit and shows the net weight available for probe(s) either separated on planet approach or after orbit has been obtained. Table III gives similar data showing the effect of tightening the orbit to 1,000 x 20,000 km.

B. Probes

While it is anticipated that any probe will be configured to fit the particular mission insofar as weight and volume are involved, several studies have identified probe sizes and weights required to accomplish specified probe objectives. These probes are summarized in appendix A and were designed for the following functions:

1. Ames/AVCO Probe for Venus and Mars - a 125-pound probe to make indirect measurements of the atmosphere.

2. Buoyant Venus Station for Venus - a 500-pound probe system to result in a balloon hovered station for direct measurements of the atmosphere.

3. LRC Parachute Probe for Mars - a 440-pound system for direct measurements of the atmosphere.

4. JPL Probe and Lander for Mars - a 340-pound system to make indirect measurements of the atmosphere and put 5 to 10 pounds of science in a semihard lander.

These probe data can be used in trade analysis where the probe weight can be evaluated against spacecraft weight and orbit definition. If probe data are of a high priority, the spacecraft weight can be reduced and orbit eccentricity increased from the data given in tables I, II, and III.

C. Spacecraft and Vehicle Conceptual Design

Spacecraft were configured for the various opportunities with a design goal to utilize common modules as much as possible. In order to evaluate the dynamic envelope restraint of the spacecraft with various size capsules, studies were made utilizing dynamic envelopes of 100 inches (standard Titan), 170 inches (hammerheaded Titan), and 240 inches (Saturn V). It was found that the 100-inch dynamic envelope was satisfactory for the early missions although it would require solar panels to be stored in a compact folded package and would limit the probe diameter to about 5 feet. The 170-inch envelope would be required on the Titan growth mission where the shroud would be hammerheaded and a large capsule carried. The 240-inch envelope is required for the full Voyager capsule of 19-foot diameter which is consistent with Saturn V launch capability. These spacecraft, planetary vehicle envelopes, and launch vehicle integration are shown on figures 1 through 5.

100-Inch Dynamic Envelope

As shown on figure 1, the spacecraft propulsion module is basically a tubular truss structure with an aft ring which interfaces with the launch vehicle adapter and provides the separation plane for the planetary vehicle. A forward ring provides the field joint for mating with an eight-point tubular truss adapter which terminates in a field joint at the aft end of the instrumentation module. The propellant is contained in four spherical tanks which are attached to the basic structure of the propulsion module. Two cylindrical N_2 pressurant tanks are provided and are located diametrically opposed and nested between the propellant tanks. A 300-pound thrust engine is gimbaled and supported by tubular members which are mounted to the aft ring of the module structure. This engine could be a scaled-up version of the 100-pound thrust Lunar Orbiter engine or an engine developed for another program. Should this engine not be developed, the 100-pound engine could be used and burned a longer time although this would be less efficient. The reaction control thrusters would be outrigged near the aft end of the module structure at the longitudinal center of gravity of the system. The tankage displayed in this configuration is adequate for a Mars 1973 mission and by simply replacing the spherical propellant tanks with cylindrical tanks having the same diameter as the spherical tanks, sufficient propellant for a Venus 1972 mission can be accommodated. Two additional N_2 pressurant tanks can be provided in the two diametrically opposed void spaces provided which are not used for the Mars mission.

The instrumentation module, which is octagon shaped, is 60 inches across the flats and 19 inches high. Approximately 30 cubic feet of storage volume is provided to contain all proposed ACS electronics, spacecraft science, data handling, telecommunications, data storage, batteries, programers, etc. This module is designed as a common module, capable of satisfying the requirements of a Mars or Venus mission, as well as a Voyager mission. The vidicon requirements of a Mars mission are satisfied by mounting the three-camera pack, on a scan platform, exterior to one of the module's flat surfaces. The vidicon package is envisioned as a self-contained, thermally controlled bolt-on module. For a Venus mission where fewer cameras or different cameras may be required, the Mars video module could be replaced by one tailored to the Venus requirements. The steerable 6-foot diameter, high-gain antenna can be stored parallel to the longitudinal axis or, by using a longer boom on the antenna, it could be extended forward in front of the probe. The solar panels must be stored in a compact folded package and deployed subsequent to shroud ejection. The instrumentation module is basically a tubular truss structure terminating at a ring on the aft end which provides the field joint interface with the propulsion module. A forward ring provides the field joint interface with the probe adapter. Internal structure is provided for instrumentation mounting, and the total module is covered with a metal skin to provide a thermal compartment. Figure 2 shows this spacecraft integrated with a probe, shroud, and the Tital III-C launch vehicle.

170-Inch Dynamic Envelope

The same propulsion module as previously described is shown on figure 3. However, there is clearly more volume available for tank extension should a larger and heavier capsule be used within this shroud restraint. The instrument module is identical to the unit previously described. The added volume eases the problem of the mounting of the solar panels and the antenna. The steerable 6-foot diameter high-gain antenna is attached near the aft end of the instrumentation module and utilizes an extendable boom for deployment to a position outboard of the probe. A fixed solar panel ring extends outboard from the aft face of the instrumentation module, and mounted at the periphery of the fixed panels are eight deployable panels which combined can provide about 200 square feet of solar panel area. The experiment arrangement for a Mars mission is shown on figure 3.

Figure 4 depicts the most advanced planetary vehicle concept envisioned for a Titan launch. Shown is a 4,000-pound, 14-foot diameter capsule (12,000-pound total planetary vehicle weight) adapter to a Titan III-F Centaur with a hammerhead shroud which is 180 inches in diameter. This Titan III-F launch vehicle is defined as two seven-segment, 120-inch diameter solid rocket motors for the zero stage with two liquid core stages. The first stage is stretched about 5 feet and employs two engines with a 15:1 expansion ratio. It is the non-man rated complement of the Titan III-M. The spacecraft orbiter utilizes the common spacecraft instrument module in conjunction with a mission designed propulsion module.

240-Inch Dynamic Envelope

A larger propulsion system, the LEM engine, is used in the configuration shown to accommodate the larger weight associated with Voyager. The common instrument module is compatible with this concept and is adapted to the larger capsule and propulsion unit. A significant increase in volume is also evident and is used for storage of a steerable 6-foot diameter high-gain antenna, 288 square feet of solar panels and other equipment which may be necessary on later missions. The capsule shown in this configuration could be any of a variety of 19-foot diameter 6,000-pound capsule concepts which evolved during Voyager Phase B Study.

DISCUSSION

A. Mission Designs

An analysis of the mission parameter data (table I) reveals that energy requirements for Mars missions in 1973 and 1975 are nearly equal; Mars 1973 requires about 5 percent more propellant to obtain orbit. The Venus 1972 and 1973 have high approach velocities and low C_3 requirements when compared to Mars. This means a larger payload can be sent to Venus but a high penalty will be paid for orbiting the spacecraft since a large ΔV will be required.

Mars 73 and 75	- $\Delta V \approx$ 1,500 km/sec
Venus 73	- $\Delta V \approx$ 2,000 km/sec
Venus 72	- $\Delta V \approx$ 3,000 km/sec

As can be inferred, the orbit of Venus in 1972 requires approximately twice as much propellant as for Mars and 50 percent more than Venus 1973.

Table II shows that a Titan III-C vehicle will send about 2,500 pounds to Mars in 1973 or 1975 and about 3,600 pounds to Venus in 1972 or 1973. A 1,400-pound spacecraft has been estimated (see table 4) for the Mars missions including about 150 pounds of science as shown in figure 3. Using this weight as a basis, it is now possible to investigate the trades among propulsion weight, probe weight, and orbit geometry. For both Mars missions, it appears reasonable to select a combination of a 1,400-pound spacecraft, 1,000 pounds of propellant, and a 125-pound Ames/AVCO probe released on planet approach. For Venus, it appears advisable to loosen the orbit slightly to reduce ΔV in order to gain some weight for probe experiments in 1972. This is dictated by the planet's dense atmosphere which is of interest to the scientists, plus the cloud cover which restricts a photographic mission. It is felt that a 300-pound probe, released on approach, could carry a minimum instrumented parachute payload to make direct measurements while slowly descending through the dense atmosphere. This 300-pound probe added to the standard 1,400-pound spacecraft would allow a net of 1,900 pounds of propellant which is sufficient to orbit the spacecraft in a 1,000 km x 40,000 km orbit. For the 1973 opportunity to Venus, the approach velocity is reduced and, thus, it would be possible to fly a heavier probe such as the buoyant station and/or to tighten up the orbit.

A Mars 1971 mission was analyzed. The data are not included herein since 1971 represents a much more favorable opportunity than 1973 or 1975 and, in any event, the mounting of a more sophisticated mission in 1971 than for 1973 is not contemplated.

The possible growth of the Titan vehicle to transport a capsule bus capable of soft landing a surface laboratory system was investigated. The finding was that a Titan III-F Centaur vehicle could be developed which would be capable of sending a 12,000-pound payload to Mars in 1975. This payload allowance would be sufficient for orbiting a spacecraft with about a 4,000-pound capsule bus. This capsule bus would be separated in orbit for a landing on Mars.

B. Growth and Commonality

The growth and commonality aspects of a planetary vehicle associated with the Titan class launch vehicle is illustrated in figure 6. A suggested program utilizing a modular concept is outlined which maximizes the continuing developing technology so as to reduce the cost of new start programs and developments. For 1971, 1973 Mars and 1972, 1973 Venus missions, the basic building block is a 1,400-pound common spacecraft. This spacecraft consists of two modules: (1) an instrument module and (2) a propulsion module, with a maximum of common subsystems. Additional tanks and propellant are added for the Venus mission but the same propulsion system is utilized. An appropriate probe is mated to the spacecraft and the planetary vehicle is mounted on the Titan III-C launch vehicle within the standard 10-foot shroud.

Growth to a lander in 1975 or 1977 is indicated conceptually with various spacecraft propulsion modules substituted as shown. Hammerheading the Titan III-F Centaur will allow the incorporation of a large diameter, 4,000-pound capsule bus; hammerheading has been investigated in wind-tunnel studies and is not anticipated to be a serious problem. The use of the Saturn V will allow the use of the 19-foot diameter, 6,000 capsule as previously envisioned for Voyager.

Either launch vehicle would allow the capsule bus to be released out of orbit so as to minimize the near Mars velocities for utilization of about a Mach 2.0 parachute as an aerodynamic decelerator. The Saturn V, in addition to incorporating a heavier capsule bus, would allow for the transporting of two planetary vehicles per launch.

C. Unresolved Fundamental Issues

The study outlined in this paper is based primarily on the theoretical performance of various Titan launch vehicle configurations. Little consideration was given to detailed interface problems which may exist between payload and launch vehicle or between payload and launch facilities. For this reason, several basic areas of interest are listed below which require resolution to evaluate the feasibility of the overall program. No attempt is made to resolve these questions within this paper.

1. The structural capability of the Centaur may be exceeded with a 12,000-pound payload and/or a hammerhead shroud.

2. Thus far, launches of the T III-F are planned only for the Western Test Range.

3. Launch facilities may not have the capacity to handle the cryogenic propellants used by the Centaur.

TABLE I.- MISSION PARAMETERS

	Mars 1973		Mars 1975		Venus 1972		Venus 1973		Mars 73
Trajectory type	I		II		II		II		
Launch	July/Aug.		Sept.		April		Nov.		
Trip time (days)	210		350		165		165		
Required C_3 (km^2/sec^2)	17		17		10		10		
V_H (km/sec)	4.1		4.1		3.1		3.1		
V_∞ (km/sec)	3.1		2.9		6.0		4.3		
Periapse (km)	1,000		1,000		1,000		1,000		
Apoapse (km)	20,000	30,000	20,000	30,000	20,000	30,000	20,000	30,000	13,000
S/C ΔV (km/sec)	~~1.600~~ 1.349	~~1.490~~ 1.250	~~1.475~~ 1.185	~~1.322~~ 1.125	2.970	2.665	2.160	1.850	1.61
Fueled S/C weight / Orbiting S/C weight	1.75	1.66	1.67	1.59	$e^{1.14}$ ~~2.81~~ 3.16	$e^{1.03}$ ~~2.53~~ 2.80	$e^{.86}$ ~~2.12~~ 2.36	$e^{.75}$ ~~1.91~~ 2.12	1.92

INCL ΔV ≈ 150 m/s FOR MIDCOURSE

$$\frac{w_i}{w_f} = e^{\frac{\Delta V}{I_{sp} g}}$$

$$1.66 = e^{.51}$$

= .51

$\boxed{I_{sp} = 250}$

$= e^{.655} = 1.925$

TABLE II.- MISSION WEIGHT ALLOCATION 1,000 × 30,000 KM ORBIT
BASED ON TITAN III-C CAPABILITY

	1,200-pound S/C				1,300-pound S/C				1,400-pound S/C			
	Mars		Venus		Mars		Venus		Mars		Venus	
	1973	1975	1972	1973	1973	1975	1972	1973	1973	1975	1972	1973
Payload*	2,550	2,550	3,530	3,630	2,550	2,550	3,530	3,630	2,550	2,550	3,530	3,630
S/C	1,200	1,200	1,200	1,200	1,300	1,300	1,300	1,300	1,400	1,400	1,400	1,400
Propulsion	800	710	1,850	1,100	860	770	2,000	1,190	930	830	2,130	1,280
Probe(s) from approach or	550	640	480	1,330	390	480	230	1,140	220	320	---	950
Probe(s) from orbit	330	400	190	700	235	300	90	600	130	200	---	500

*Exclusive of S/C support equipment.

TABLE III.- MISSION WEIGHT ALLOCATION 1,000 x 20,000 KM ORBIT
BASED ON TITAN III-C CAPABILITY

	1,200-pound S/C				1,300-pound S/C				1,400-pound S/C			
	Mars		Venus		Mars		Venus		Mars		Venus	
	1973	1975	1972	1973	1973	1975	1972	1973	1973	1975	1972	1973
Payload*	2,550	2,550	3,530	3,630	2,550	2,550	3,530	3,630	2,550	2,550	3,530	3,630
S/C	1,200	1,200	1,200	1,200	1,300	1,300	---	1,300	1,400	1,400	---	1,400
Propulsion	900	800	2,200	1,350	975	860	--	1,450	1,050	920	---	1,550
Probe(s) from approach or	450		130	1,080	275	390	NO MISSION	880	100	230	NO MISSION	680
Probe(s) from orbit	260	330	---	510	160	230		410	---	140		320

*Exclusive of S/C support equipment.

TABLE IV.- PLANETARY VEHICLE WEIGHT SUMMARY (MAR)

INSTRUMENTATION MODULE			
Structure	100		
ACS Elect.	60		
Programer	30		
Telecommunications	220		
Power	290		
Thermal Control	30		
Probe Relay Equipment	20		
Mechanisms	20		
Science	150		
Total	920		920
PROPULSION MODULE			
Structure	200		
Velocity Control Inerts	120		
ACS Inerts	50		
Thermal Control	30		
Separation and Mech.	50		
ACS Gas	50		
Dry Total	480		480
ORBITING S/C WEIGHT			1,400
Propellant	1,025		1,025
		S/C with Propellant Total	2,425
Probe (Direct)	125		125
		Total Separated from L/V	2,550
ADDITIONS FOR VENUS			
Propellant	875		875
Probe (Direct)	175	(Total Probe = 300 pounds)	175
		Total Separated from L/V	3,600

APPENDIX A

PROBES FOR MARS AND VENUS
1970 - 197?

APPENDIX A

PROBES FOR MARS AND VENUS
1970 - 1973

SUMMARY

This report is a brief summary of possible probes for atmospheric investigations of Mars and Venus. The basic concepts of the probes with pertinent technical information are presented. Table I-A gives the weight allocations for the various missions considered. Table II-A shows the compatibility of the probe systems with these missions for a minimum weight spacecraft.

PROBE DESCRIPTION

Code Letter A
AVCO/Ames Probe

Application: Mars and Venus

Probe System Weight 125 Pounds

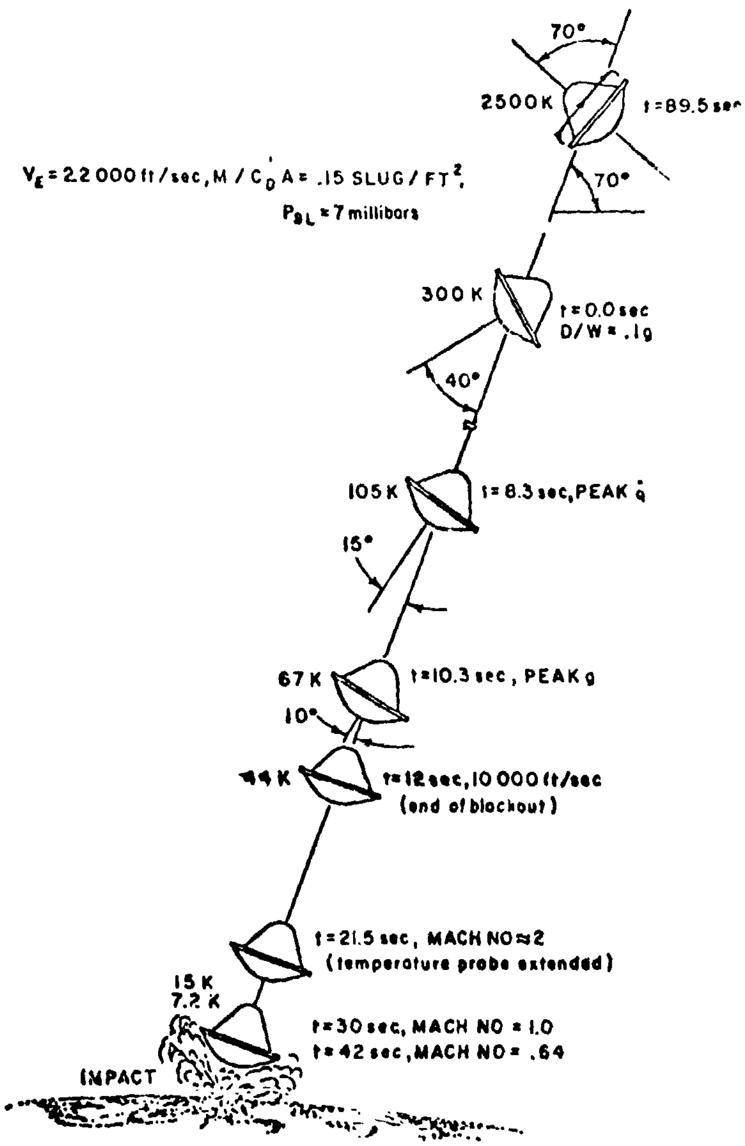
Entry Shape 110° Blunt Cone; 3-Foot Diameter

Entry Weight 50 Pounds $m/C_DA = 0.167$

Instrumentation	Weight
Accelerometers	1.8
Pressure and Temperature	3.5
Radiometer	2
Mass Spectrometer	9
	16.3

Transmitter: 20-watt relay to S/C 10 to 1,000 bps

Data period 20 to 60 sec (Mars)



PROBE ENTRY SEQUENCE
(TYPICAL FOR SEPARATION ON APPROACH TO MARS)

CODE LETTER A

PROBE DESCRIPTION

Code Letter B
Buoyant Venus Station

Application: Venus

Probe System Weight 500 Pounds

Entry Shape 120° Blunt Cone; 6-Foot Diameter

Entry Weight 390 Pounds Buoyant Station Weight 200 Pounds

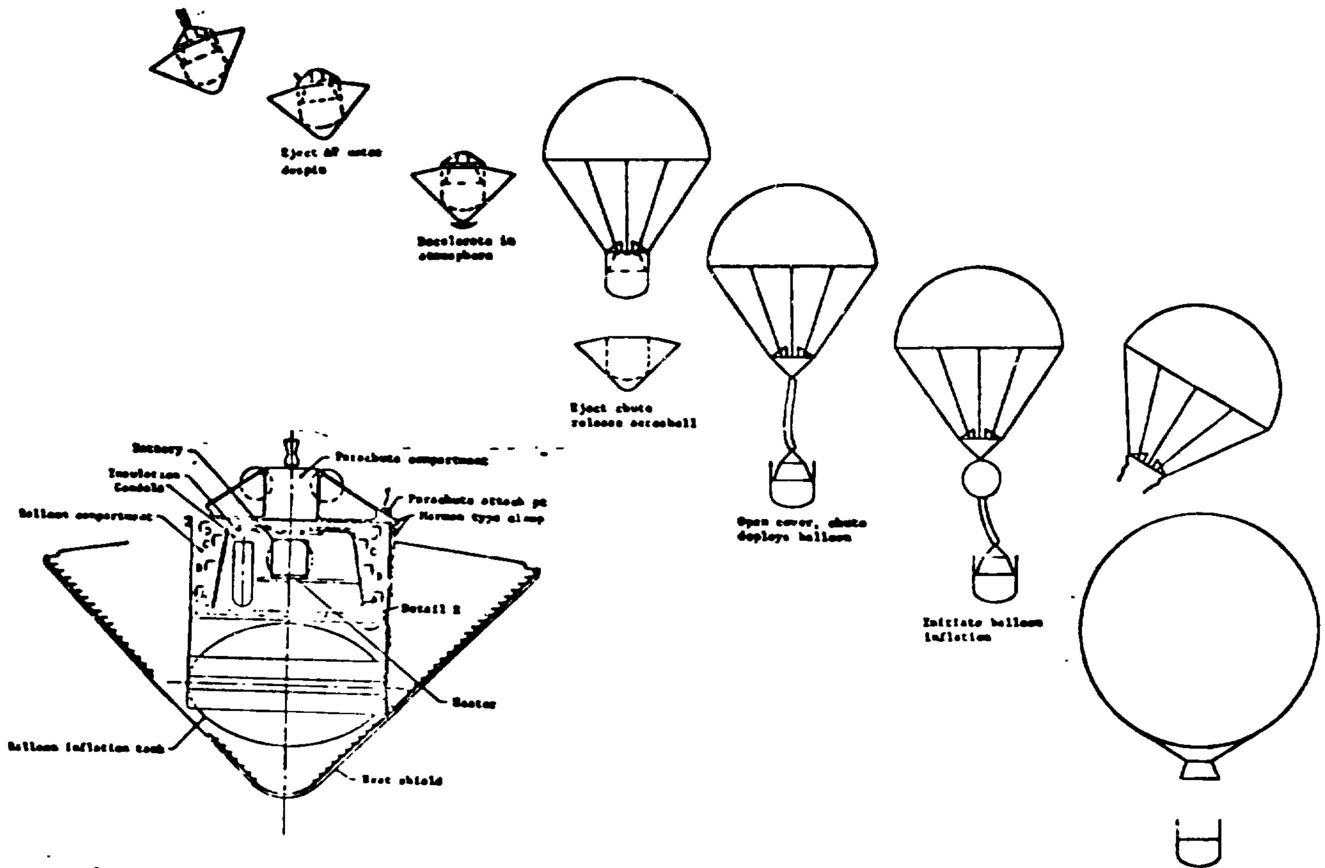
Entry Instrumentation	Weight
Accelerometers	2
Pressure and Temperature	4
Radiometer	2
	8

Buoyant Station Instrumentation	Weight
Temperature	1
Pressure	3
Composition	
H_2O	1.5
N_2	1
O_2	1.5
A	1.5
CO_2	1
Density	3
	13.5

Two (2) Drop Sondes	Weight
Temperature	0.5
Pressure	1.5
H_2O	1
	3.0

BVS Transmitter: 5 watt 30 bps; command relay to S/C

Data period 7 days



General Arrangement

Deployment Sequence
CODE LETTER B

PROBE DESCRIPTION

Code Letter C
LRC LWP-328

Application: Mars

Probe System Weight 440 Pounds

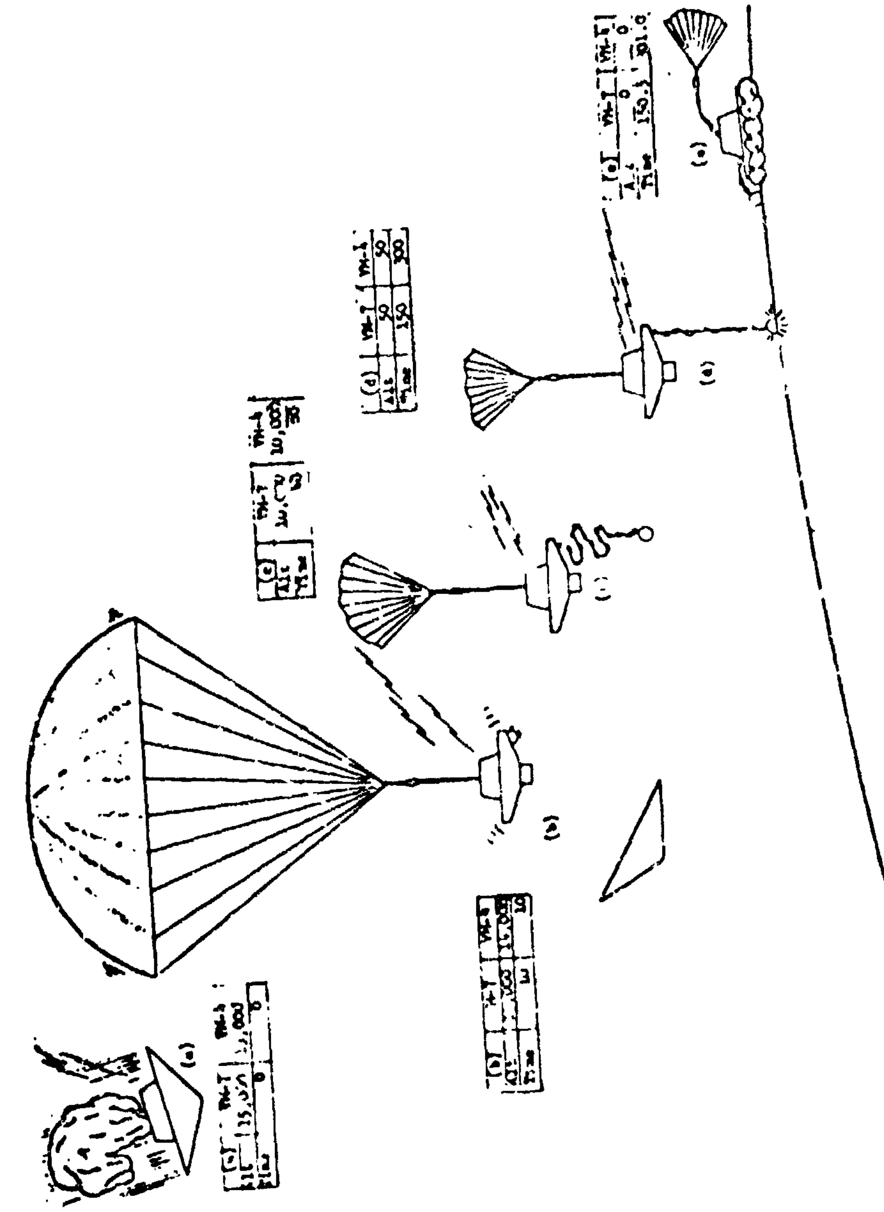
Entry Shape 120° Blunt Cone 6-Foot 9-Inch to 7-Foot 6-Inch Diameter

Entry Weight 340 Pounds m/C_DA; 0.25 to 0.15

Instrumentation	Weight
Temperature	0.9
Pressure	1
Accelerometer	2
Radar Altimeter	8
Mass Spectrometer	9
Penetrometer	8
	28.9

Transmitter: 40 watts relay to S/C, 280 bps

Data period 140 to 300 sec



Terminal descent sequence

CODE LETTER C

PROBE DESCRIPTION

Code Letter D
JPL EPD 427

Application: Mars

Probe System Weight 340 Pounds

Entry Shape 120° Blunt Cone 6.5-Foot Diameter

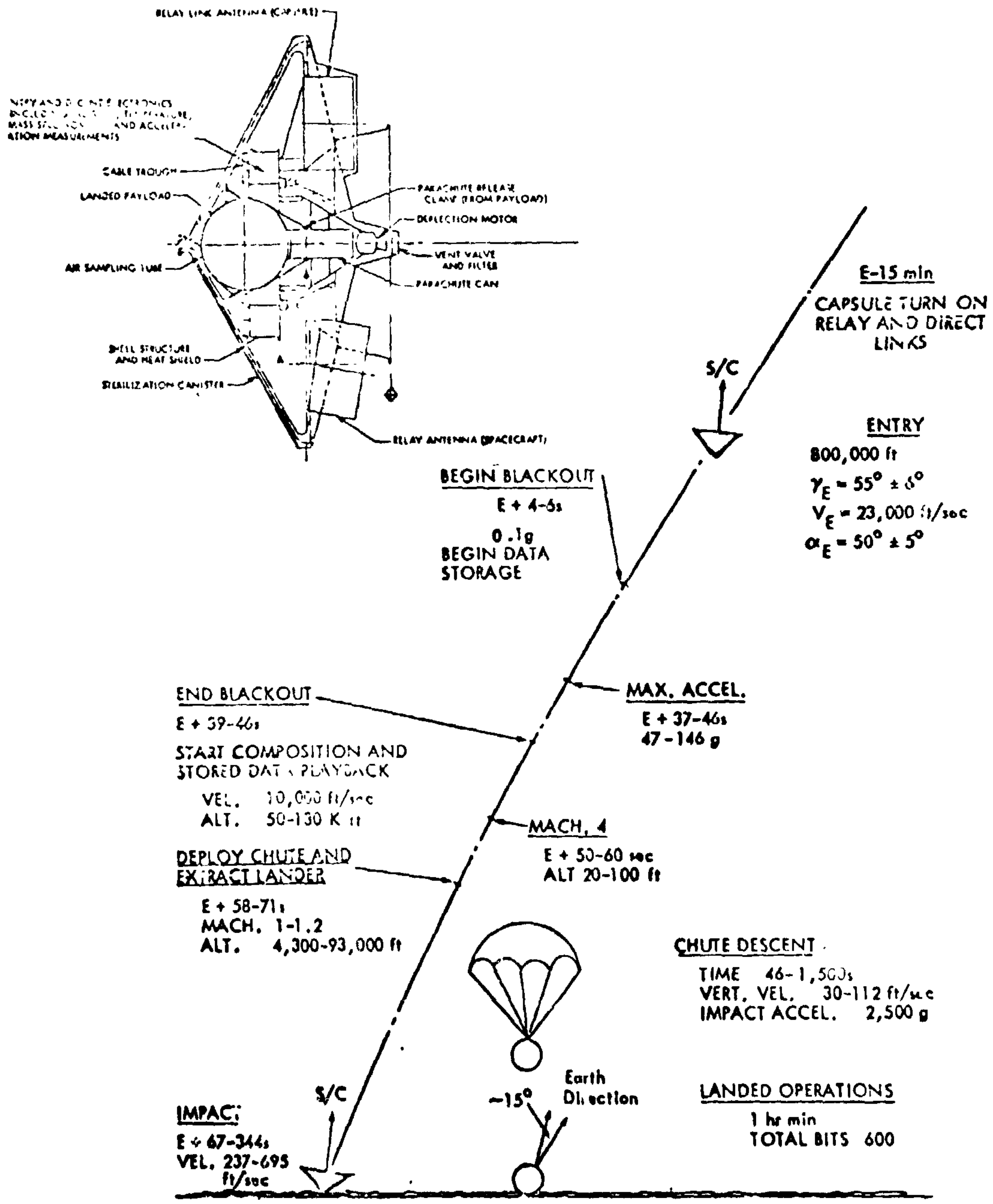
Entry Weight 180 Pounds $m/C_DA = 0.12$

Lander Weight 45 Pounds, 16-Inch Sphere

Probe instrumentation	Weight	Optional landers		
		Life detection	Environmental	Atmospheric
Accelerometers	1.5	Gulliver 4 lb	Wind 1 lb	Mass spec. 8.0 lb
Pressure	1.5	Pres. 1 lb	Pres. 1 lb	Pres. 1.0 lb
Temperature	1.5	Temp. 1 lb	Temp. 1 lb	Temp. 1.0 lb
		6 lb	H_2O 1.7 lb	10.0 lb
Mass spectrometer	8.0		"g" 1 lb	
	12.5		O_2 1.3 lb	
			7.0 lb	

Probe Transmitter: 8 watts, 500 bps, relay to S/C
Lander : 3 watts, 1 bps, direct Earth

Entry Data Period 20-250 sec
Lander Data Period 1-2 hours



Capsule Entry and Landed Phase
CODE LETTER D

TABLE I-A.- WEIGHT ALLOCATIONS

SLV 3C-Centaur

		25-hour orbits				40-hour orbits			
		1971 Mars		1973 Mars		1970/72 Venus		1973 Venus	
	Mission	Orbiting S/C	Flyby S/C	Orbiting S/C	Flyby S/C	Orbiting S/C	Flyby S/C	Orbiting S/C	Flyby S/C
WEIGHTS:	Payload	1,820	1,820	No Mission	1,390	1,820	1,820	1,920	1,920
	Spacecraft*	1,500	850		850	1,750	850	1,420	850
	Probe from approach	320	970		540	70	970	500	1,070
	Net Probe from orbit	161				34		299	

T III-C TRANS. (INCREASE PAYLOAD WEIGHT 160-170 POUNDS FOR SLV 3X-CENTAUR)

		1971 Mars		1973 Mars		1970/72 Venus		1973 Venus	
	Mission	Orbiting S/C	Flyby S/C	Orbiting S/C	Flyby S/C	Orbiting S/C	Flyby S/C	Orbiting S/C	Flyby S/C
WEIGHTS:	Payload	3,450	3,450	2,550	2,550	3,530	3,530	3,630	3,630
	Spacecraft*	1,500	850	1,420	850	1,750	850	1,420	850
	Probe from approach	1,950	2,600	1,130	1,700	1,780	2,680	2,210	2,780
	Net Probe from orbit	1,105		677		865		1,325	

*Orbiting S/C weights include orbit propulsion requirement for S/C only.

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TABLE II-A.- PROBE COMPATIBILITY

		Mars				Venus			
		1971		1973		1970/72		1973	
		Orbiter S/C	F/B S/C	Orbiter S/C	F/B S/C	Orbiter S/C	F/B S/C	Orbiter S/C	F/B S/C
SLV 3C-Centaur	Orbit Probe	A						A	
SLV 3C-Centaur	Approach Probe	A	A C D		A C D		A B	A B	A B
T III-C	Orbit Probe	A C D		A C D		A B		A B	
T III-C	Approach Probe	A C D	A C D	A C D	A C D	A B	A B	A B	A B
		25-hour orbit 1,000 × 33,500 km				40-hour orbit 1,000 × 97,500 km			

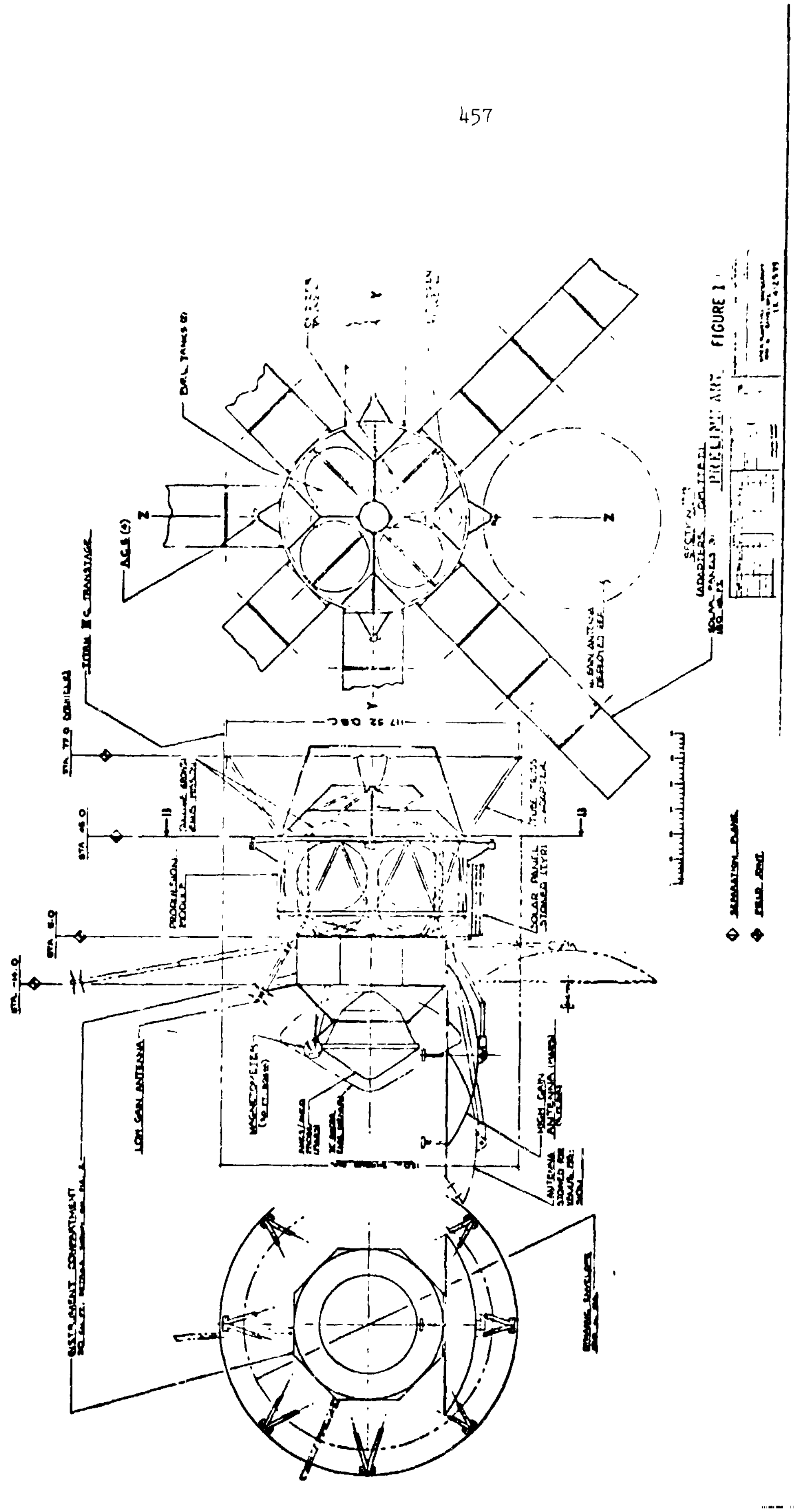
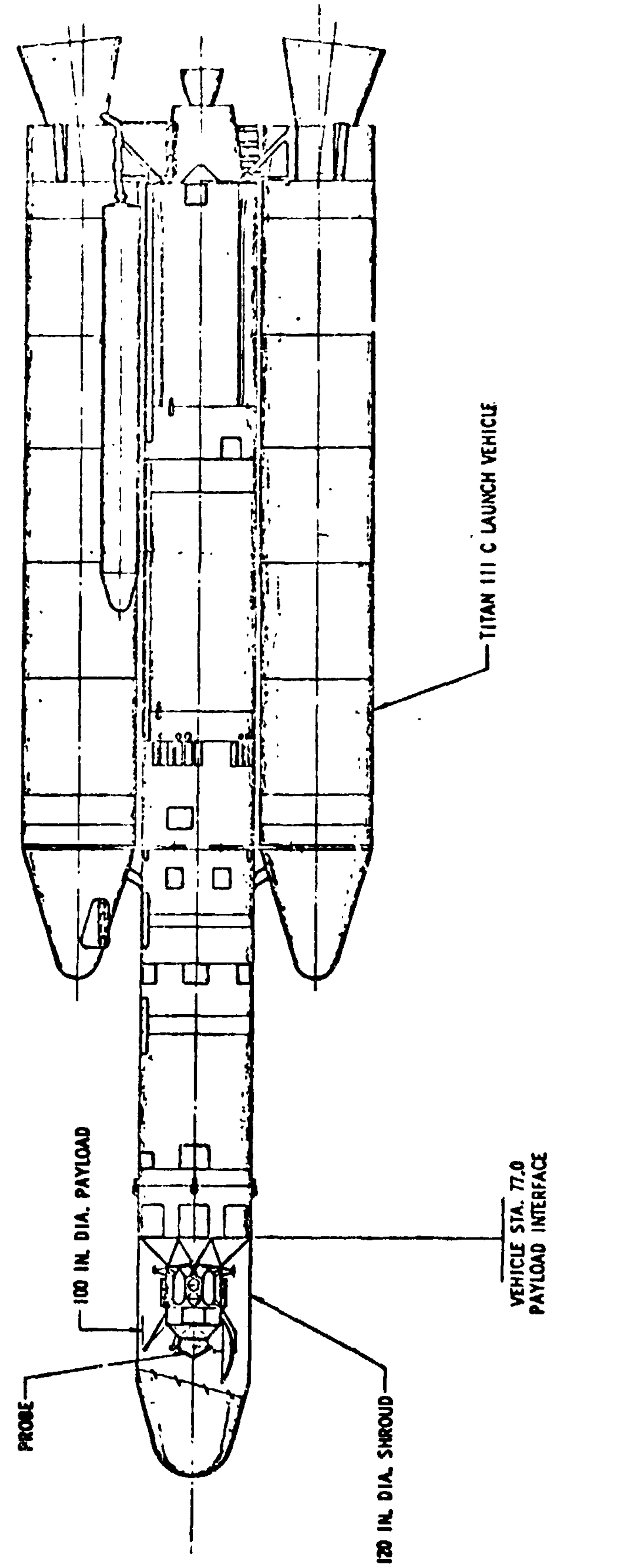


FIGURE 1
LOW GAIN ANTENNA
PROPULSION MODULE
SOLAR PANEL STOWED (TYP)
SEPARATION PLANE
FIELD JOINT

FIGURE 2
INTERPLANETARY SPACECRAFT
100 IN. ENVELOPE CONCEPT
TITAN III C LAUNCH VEHICLE



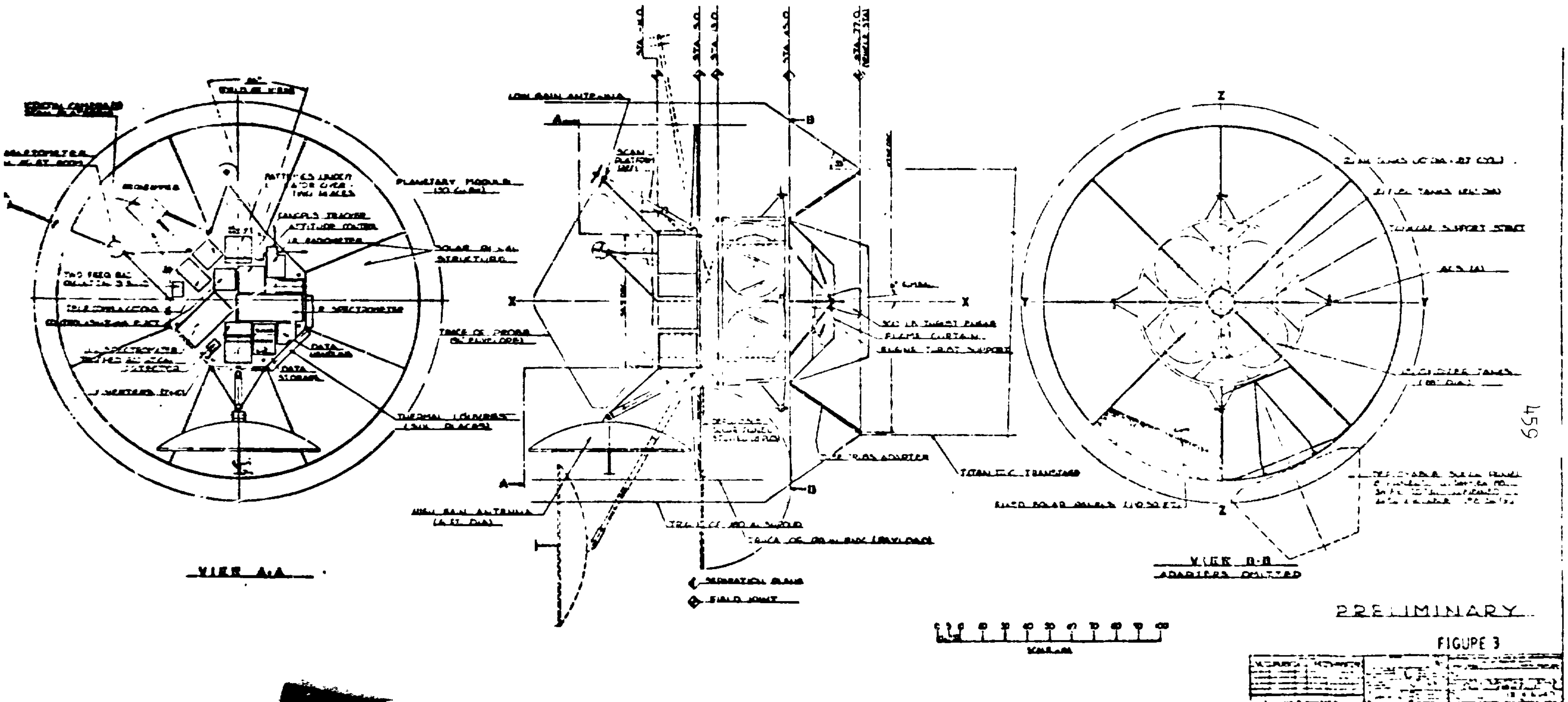

VIEW A-A
PLANETARY MODULE
LOW GAIN ANTENNA
SCAN PLATFORM
HIGH GAIN ANTENNA
THERMAL LOUVERS
DATA STORAGE
STA 5.0
STA 13.0
STA 43.0
STA 77.0
SEPARATION PLANE
FIELD JOINT
TITAN III-C TRANSTAGE
VIEW B-B
ADAPTERS OMITTED
PRELIMINARY

FIGURE 3

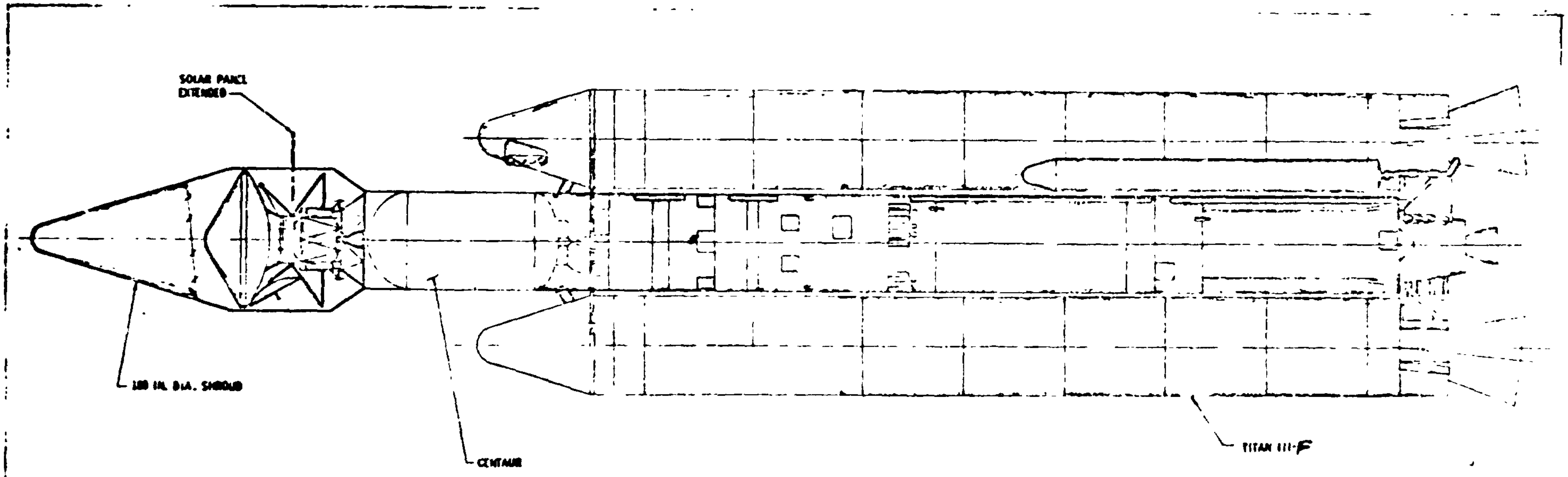
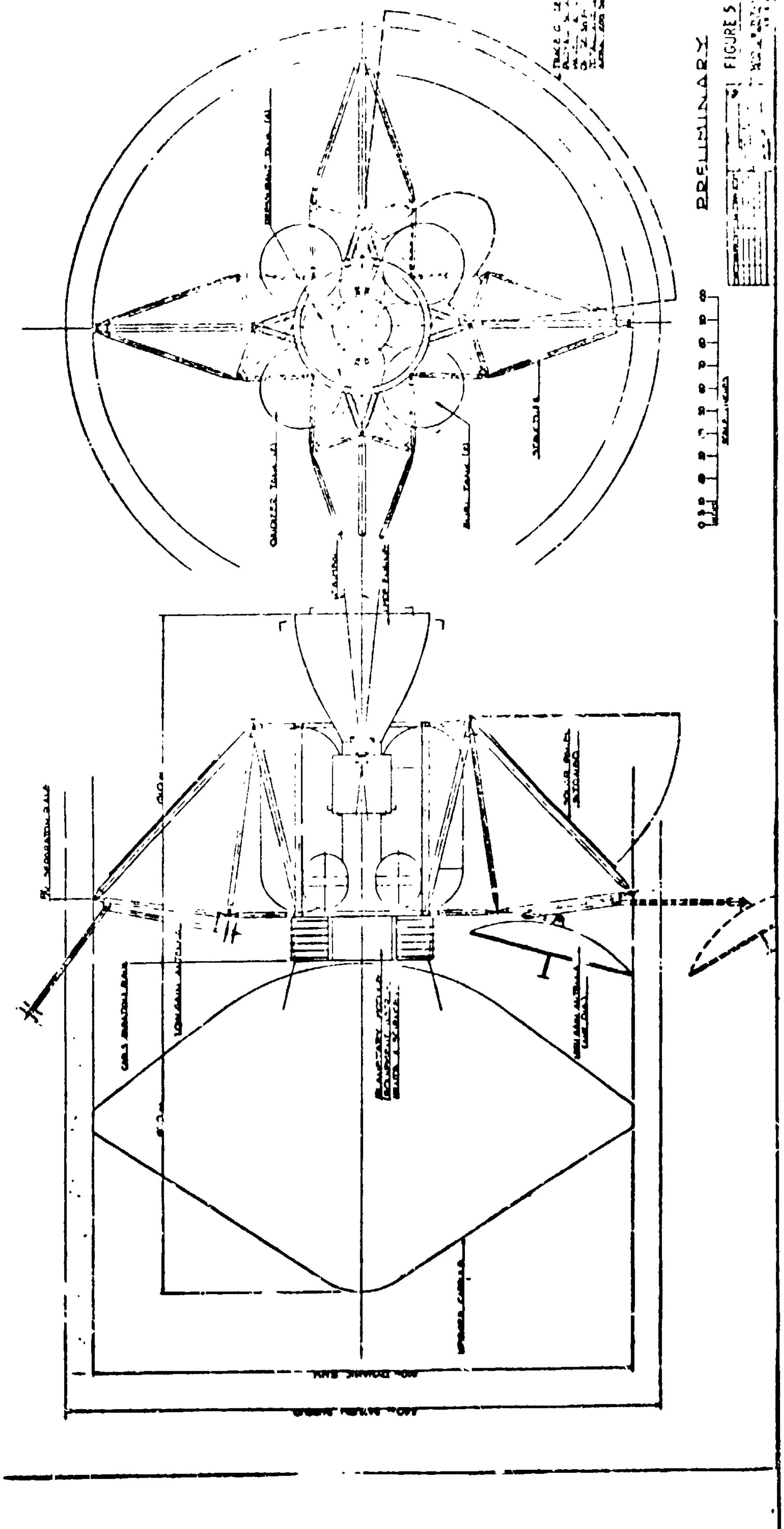


FIGURE 4

INTERPLANETARY SPACECRAFT
170 IN. ENVELOPE CONCEPT
TITAN III D-CENTAUR VEHICLE


PRELIMINARY
FIGURE 5

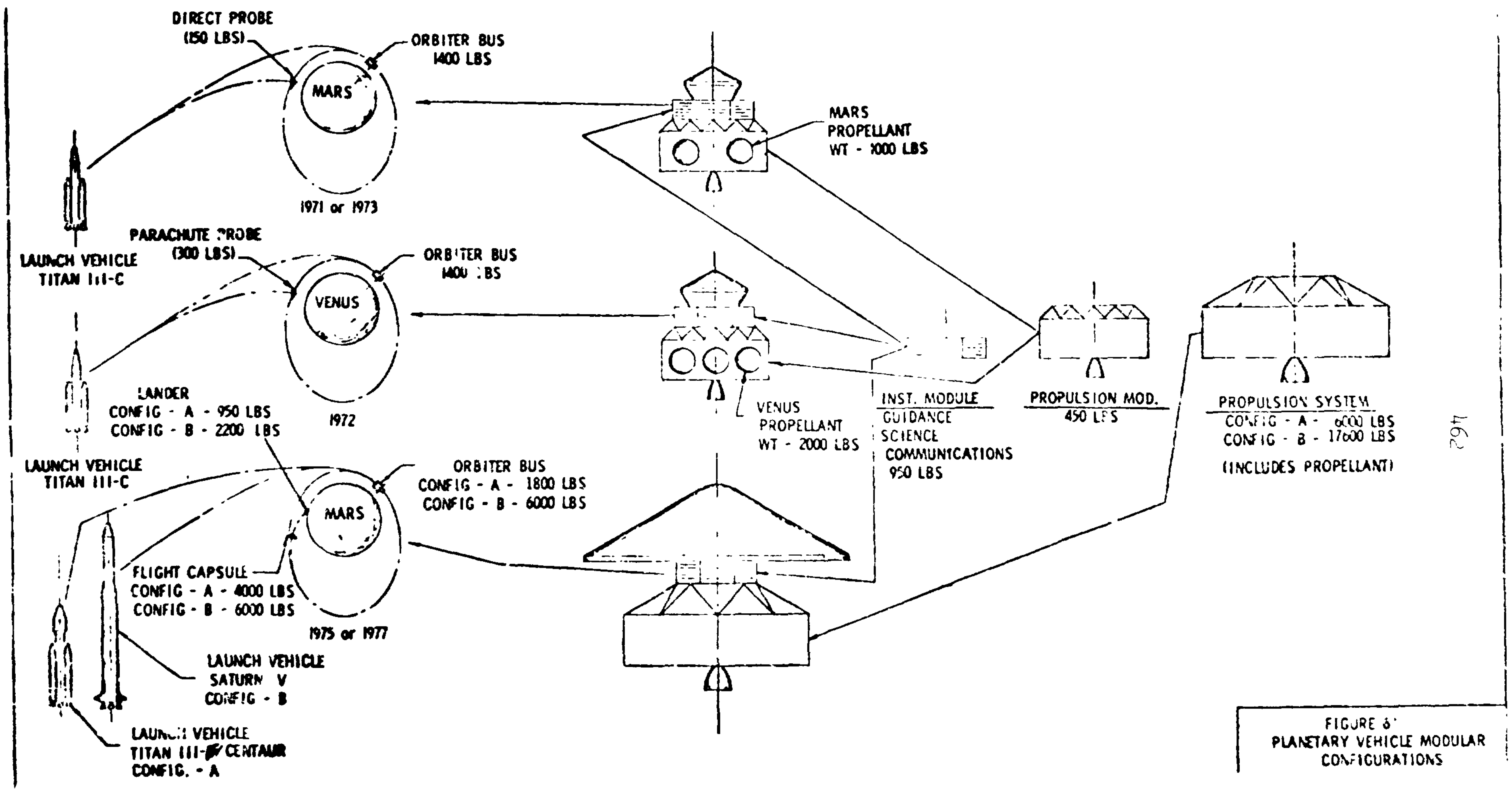


FIGURE 6
PLANETARY VEHICLE MODULAR CONFIGURATIONS

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LANGLEY WORKING PAPER

STUDY OF TITAN III F/CENTAUR'S CAPABILITY TO CARRY OUT A "VOYAGER-TYPE" MISSION

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TO CARRY OUT A "VOYAGER-TYPE" MISSION

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SELECTION OF A PLANETARY VEHICLE AND LAUNCH VEHICLE FOR A TITAN III F CLASS MARS MISSION

SUMMARY

Described within this paper are the results of a study conducted to establish a realistic and significant mission to the planet Mars in the mid 1970's using a Titan III F booster. Previous studies have shown that the Titan III C, with Transtage or Agena, is weight and performance limited. This weight limitation results in designs specifically suitable for one mission with little potential for use of commonality of hardware and growth for later missions. This study indicates that the Titan III F with a Centaur upper stage provides the performance capability to allow flexibility of mission design and logical growth from a Mars entry probe to a soft landed surface rover. The concept provides for an entry capsule with a 14-foot diameter aeroshell which is common to all missions. The capsule can be loaded from 2000 pounds to 4000 pounds to successfully provide a probe mission, a lander mission, and a rover mission for 1973, 1975, and 1977 opportunities, respectively. This design concept also provides the opportunity for accelerating the more ambitious lander and rover missions to an earlier opportunity if the justification and funds necessitate this course of ... Also, the same 14-foot diameter capsule system can be adapted to ... n V launch vehicle for later missions if this is desirable.

This study indicates that the original Voyager objectives ... ight of scientific instrumentation) can be accomplished with a... y 6000 pounds of hardware (spacecraft and capsule systems) versus the ...0 to 12,000 pounds proposed for Voyager Saturn V concept. This reduction in hardware weight and

use of the less expensive Titan III F Centaur booster should result in a substantial overall program cost reduction.

INTRODUCTION

To date several studies have been conducted to delineate and solve the problems associated with the execution of a successful entry missions to Mars. These problems include aerodynamics, guidance and control, propulsion, communications, etc., as well as conceptual design, packaging techniques, and mission mode analyses. Among the studies performed in these task areas are:

1) AVCO Corporation's study of a Probe/Lander which (a) investigated entry problems for capsule separation from planet approach and out-of-orbit, (b) evaluated Saturn IB and Saturn V as launch vehicles, and (c) selected science (including TV) for entry and surface data acquisition.

2) Langley Research Center's team study of the Voyager Capsule which (a) made subsystem trade-offs and selections for a Saturn V mission, (b) defined a baseline mission mode for the 1973 Voyager, and (c) evaluated growth and commonality of subsystems for 1973 - 1977.

3) McDonnel and Martin-Marietta Corporations' Voyager Phase B Studies which furnished additional background and analyses. These studies evaluated the overall Voyager program in order to select a preferred mission mode and a capsule design. In-depth analyses of the various aspects of the mission were required in these studies to clearly define each phase of the mission and each component of the capsule

The work performed in these studies has provided the information to define the overall mission mode as well as the capsule descent mode, the latter of which is shown in figures 1 and 2. Although these studies have demonstrated the technical feasibility of Saturn V launched Voyager/Mars missions in the 1973 - 197[illegible] time period, the cost associated with such a program makes evaluation of alternate missions advisable. For this reason a study of missions which would be compatible with both scientific objectives and lesser budget requirements was undertaken. The data contained within this paper reflect the efforts of this study.

PRESENTATION OF DATA

In order to define the planetary vehicle (PV) the science objectives for the capsule and spacecraft were first established; then the capsule and spacecraft which would support the science equipment were defined; and finally, the orbital insertion propulsion module was defined.

Capsule Weight

Based on this method of approach three capsules of varying scientific capability were defined. These capsules were of the 2000, 3000, and 4000-pound class. Figure 3A illustrates the type of mission anticipated for the 2000-pound capsule. Langley Research Center's Planetary Missions Technology Steering Committee has defined the science instruments for the entry portion of the first Voyager mission putting emphasis on obtaining atmospheric data and surface pictures. This package, which would cease to operate after impact, would weigh approximately 1000 pounds during parachute descent and would include 80 pounds of science.

Figure 3B illustrates the capability of a 3000-pound capsule. This concept retains the 80 pounds of entry science equipment, as used in the 2000-pound capsule, with a 1600-pound soft lander. Of the 1600 pounds, 170 pounds are the science equipment defined by JPL for the Voyager SLS. The rest of the 1600 pounds is required for structure, thermal control, descent propulsion, communication, etc.

The most ambitious concept is shown schematically in figure 3C. This figure represents the incorporation of a rover vehicle into the capsule. This rover, with its 220 pounds of science equipment, permits data acquisition at points remote to both the lander and the propellant contaminated planet surface. The 80-pound entry science package is again retained on the lander in this concept making a total science package of 300 pounds.

When selecting the science packages for the above capsules, an attempt was made to achieve the same scientific objectives in these Titan launched missions (3000- and 4000-pound capsules) as were planned in the larger (5000- and 7000-pound capsules) Saturn launched Voyager missions. To accomplish this within the lesser weight bounds, the prior separation of capsule bus and SLS systems was abrogated and the systems integrated into common power sources, communication links, etc. As a result of this decrease in equipment and weight, it was possible to package the required equipment into a smaller volume; this, in turn, reflected in weight savings in many other areas. Figure 4 shows the weight savings which allow the 1973 Mars mission to accomplish Voyager objectives with a 3000-pound capsule instead of a 5000-pound capsule. A complete and more exact weight breakdown for each of the three proposed capsules is shown in figure 5.

Capsule Size

Having based this study on the Titan III F class of launch vehicle requires that not only the capsule weight be reduced significantly, but that the capsule diameter be similarly reduced. In order to keep ballistic numbers (m/C_DA)

compatible with those found optimum for the Voyager program the diameter of capsules considered in this study were reduced to a value which would yield an area approximately one-half the area of the Voyager (19-foot diameter) aeroshell. Thus, by reducing the weight and area both by approximately the same factor (2), the ballistic number remains the same as Voyager's permitting utilization of present Voyager technology. This comparison of capsule sizes is shown in figure 6; on this basis, selection of a 14-foot diameter aeroshell with 2000, 3000, and 4000-pound capsules is made.

To check the required altitude-Mach number relationships of the above capsules for low altitude atmospheric descent, trajectories were computed and the data plotted as shown in figure 7. These data show that parachute deployment falls within the established guidelines including a requirement for deployment above 10,000 feet to permit the landing radar to lock-on the surface. This mode allows descent propulsion, where used, to burn a sufficient time and effect a soft-landing on the surface. Entry conditions shown on this figure are considered to be nominal for missions as presently envisioned.

Spacecraft Weight

In establishing the weight of the spacecraft, the same guideline was used as for the capsule; that is, identification of the science first. Figure 8 shows the results of spacecraft weight studies which have been prepared by several sources. The three Voyager spacecraft contractors shown are the Boeing Company, TRW, and General Electric; the Langley Planetary Exploration Program Study Team is comprised primarily of personnel from the Lunar Orbiter Project Office with assistance from some specialized personnel from other divisions at Langley Research Center; and the current weight allocation columns represent the science requirements established by the authors of this paper.

Three main areas of investigation have been selected by most study groups as being critical to the mission. These include topography, atmospheric definition, and field and particle data; instruments to examine these areas are given in the second column of figure 8. Imagery has been given increased importance in the first (1973) mission primarily as a result of the success of Lunar Orbiter. To provide a significant mission in this area, 300 pounds has been allocated which would permit the use of a sophisticated film system with vidicon backup. Such a system would provide 50 feet of 35 mm film with selected readout. In the event TV is preferred, the weight availability exists to provide any of a variety of combinations of medium and high resolution cameras or a reduced capability film system with a different vidicon backup system. It is anticipated that the imagery capability would be reduced considerably in later missions. Other weights shown in figure 8 also reflect the importance placed on the spacecraft for the first mission in order to increase the probability of a large return of meaningful data.

Using 400 pounds as the total science allocation for 1973, other subsystems and components were determined after reviewing current existing data as shown on figure 9. These subsystem weights, which represent the entire spacecraft weight excluding the orbital insertion propulsion system and propellant, established the current allocated weight of 1700 pounds.

Propulsion Module

Data from previous studies (LWP No. 483) were used to determine propulsion requirements. These data, shown in figure 10, are conservative to provide sufficient capability over a reasonable range of requirements.

Utilizing these data together with a desired useful orbiting weight in 1973 of 5500 pounds (1700-pound spacecraft + 3800-pound capsule), the weight of the propulsion module, both hardware and propellant, was calculated. This 1973 weight is shown in figure 11 and the off-loading of propellant for the better 1975 and 1977 opportunities is indicated. It should be pointed out that the propulsion engine and tankage is common for all three missions and is based on the requirements of the most demanding mission. Therefore, the total orbital insertion propulsion weights are 5000, 4790, and 4700 pounds for 1973, 1975, and 1977, respectively.

Launch Vehicle

Now that weights for the capsule (3800 pounds for 1973), the spacecraft (1700 pounds) and the propulsion module (5000 pounds) have been established, the launch vehicle can be selected which has the required capability (10,500 pounds to the planet).

The data shown in figure 12 are a compilation of booster capabilities as supplied by the Titan booster prime contractor - Martin Marietta Corporation. Six combinations of Titan III F, Transtage, Agena, and Centaur are shown in this figure. After reviewing Martin's data, it was decided that the capabilities, which were optimized in several respects, were slightly optimistic for the conservative tone of this study. For this reason the blocked-in numbers, as shown in the "Weight To Planet" line of figure 12, were arbitrarily reduced by 10 percent to the more realistic values as shown in figure 13. Only three booster combinations are shown in figure 13 since these reflect a cross-section of various Titan III F capabilities. All values shown are based on 1973 Type I trajectories.

Titan III F/Transtage capability (column 6) permits only a 525-pound capsule to be carried in 1973; a weight far below the 3000 - 4000 pounds previously defined.

Titan III F/Transtage/Agena (column 3) permits a total weight to the planet of 7200 pounds. In this configuration the Agena, which itself weighs approximately 1570 pounds, has been modified to serve as the spacecraft by the addition of nearly 1300 pounds of science and support equipment. This vehicle allows a capsule weight of 1455 pounds - still below the weight necessary.

Titan III F/Centaur (column 5) however, permits the full 10,500 pounds, as established earlier, to be sent to Mars. This configuration puts 6300 pounds in a 1,000 × 30,000 km orbit. This weight includes a 800-pound dry propulsion module as well as the 1700-pound spacecraft and a 3800-pound capsule which were established as maximum mission requirements.

The Titan III F/Centaur has been selected by this study as the launch vehicle for the 1973 - 1977 Mars missions. To demonstrate its capability in the various opportunities, the data in figure 14 are presented. This figure shows that while using a common propulsion module for the three missions progressively heavier capsules may be flown for each opportunity, with the last two missions showing capability well in excess of the 4000-pound Rover Capsule described earlier. These last two missions are, however, based on Type II trajectories permitting greater weight to be placed in Mars orbit.

Systems Integration

Of the three capsule concepts shown in figure 3, the rover (3C) is by far the most sophisticated design and thus presents the greatest challenge in the areas of packaging and integrating. For this reason the rover configuration is selected here in order to illustrate the design approach as well as integration into the flight capsule and, subsequently, the spacecraft and launch vehicle. Figure 15 illustrates the basic size and shape of a rover concept with major communications and science components depicted in "black-box" manner. The RTG power system shown represents capability for considerable mobility as well as a lifetime of several months. Figure 16 shows the rover, with the lander, packaged in a 14-foot aeroshell and encapsulated in a sterilization canister. Also shown in this figure are the propulsion system on the lander, attitude control system, parachute package and many electronic components. The lander, which delivers the rover to the planet's surface, has been designed to land on a slope of 34° or less and absorb impact loads of 20 earth "g's" or less. The loads are absorbed by attenuators located within the legs.

The entire capsule is illustrated in figure 17 mated to the 1700-pound spacecraft and its propulsion module. Solar panels are shown in a stowed (folded up) position and a louver design on the spacecraft provides thermal control in order to hold temperatures within the desired range. This entire planetary vehicle is shown in figure 18 attached to the Centaur and enclosed within a hammerhead shroud of 180-inches diameter. The shroud is tied into the Titan to prevent the Centaur tankage from realizing any aerodynamic load. The weight of the planetary vehicle, however, is borne by the Centaur. This configuration is shown in figure 19 with the overall Titan III F stack-up.

CONCLUSIONS

The conclusions drawn from this study are based on the premise that a 1973 Mars mission must make a significant contribution to the scientific community at minimum cost while being the first step in an integrated program. These conclusions are listed below:

1. The Titan III F/Centaur provides performance capability for mission growth and commonality of hardware.

2. The Flight Capsule diameter of 14.0 feet provides volume for all missions.

3. The Capsule could be one of the following:

	Capsule Sys. Wt.
a) Probe mission (Voyager Entry Science)	2340#
b) Lander mission (Voyager Entry + SLS Science)	3310#
c) Rover mission (Voyager Science + 50 Pounds)	4000#

4. The following common systems should be used for the three missions (1973, 1975, and 1977):

   a) Bioshield

   b) Deorbit Propulsion System

   c) Aeroshell

   d) Radars

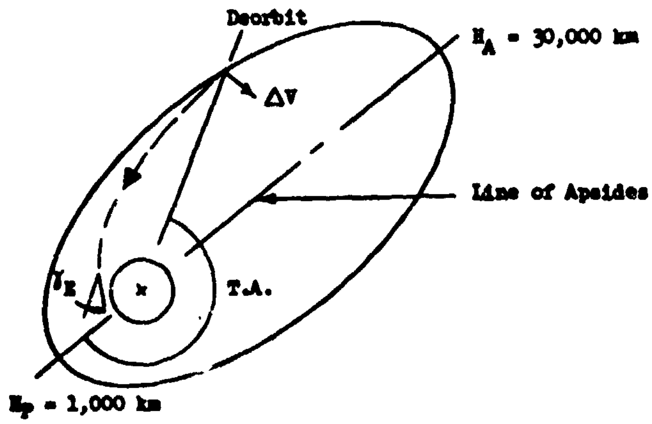
   e) Communications

   f) Attitude Control System

   g) Landing Propulsion System

5. The probe mission would permit additional weight to be put into the spacecraft providing additional capability in such areas as orbital plane changes, increased communications, etc., compatible with extended imagery objectives.

RECOMMENDED MISSION MODE

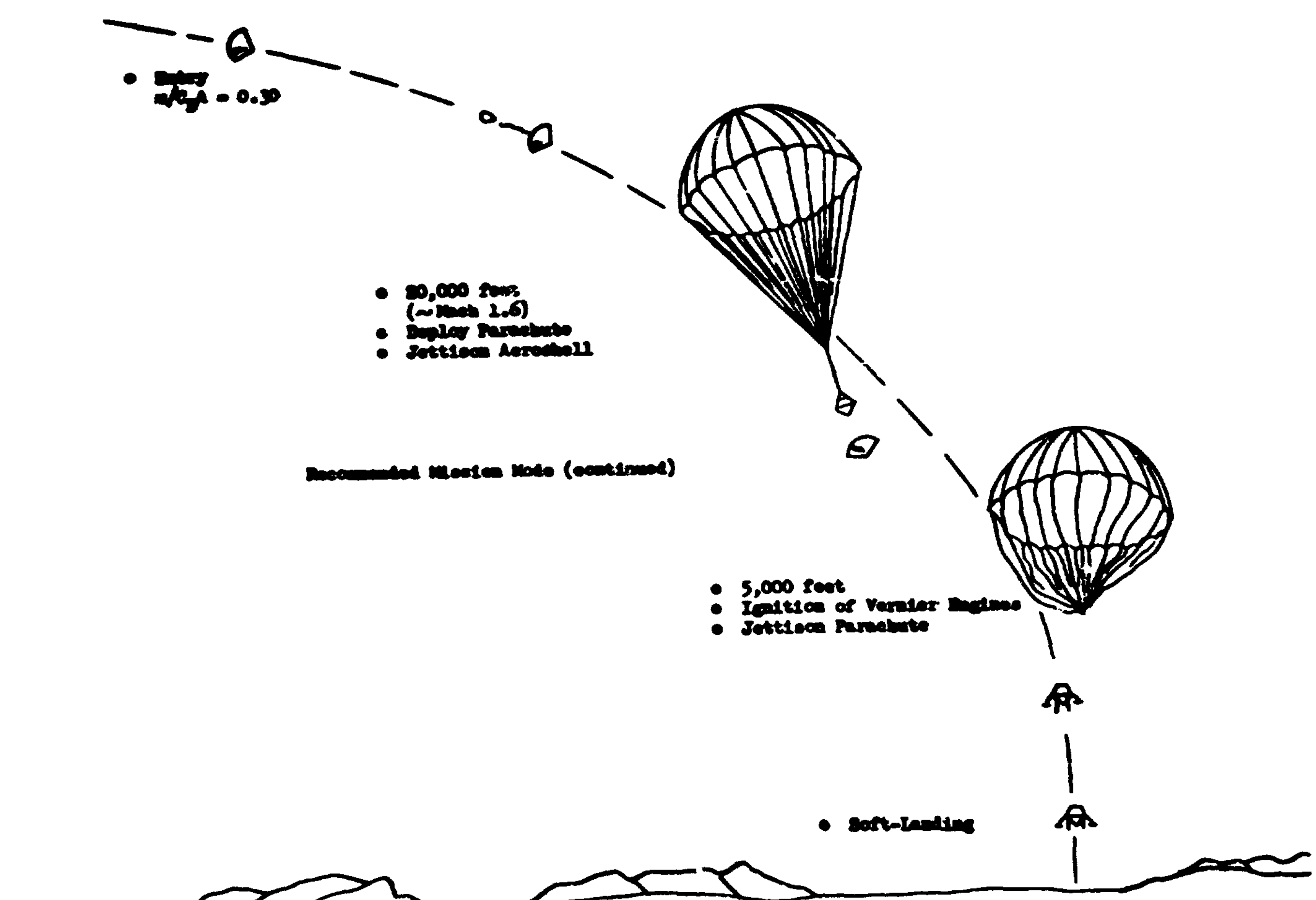


Parameters: T.A. - True Anomoly of the deorbit maneuver
ΔV - Decorbit velocity increment
γ_E - Entry Flight-Path Angle
m/C_DA - Ballistic coefficient

Desire : Min. Propulsion Weight
Shallow Entry Angle Loads Decelerator
Good Lighting for TV
Good Communication Link
Minimum m/C_DA

Results : ΔV = 200 meters/second
T.A. = 234°
γ_E = 16° ±1° @ 800,000 feet
m/C_DA = 0.30

FIGURE 1



Recommended Mission Mode (continued)

FIGURE 2

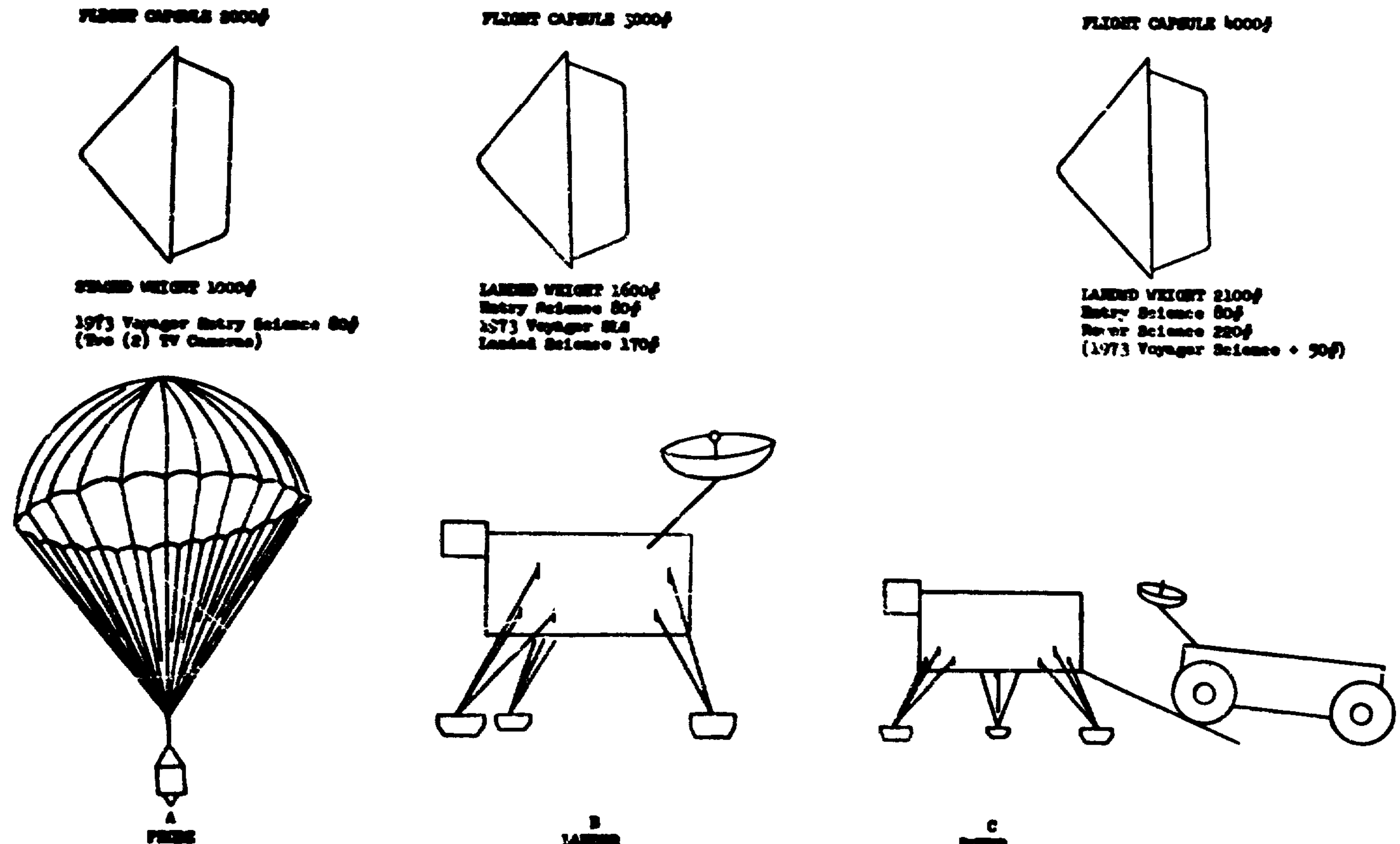

FLIGHT CAPSULE 2000#
STAGED WEIGHT 1000#
1973 Voyager Entry Science 80#
(Two (2) TV Cameras)
FLIGHT CAPSULE 3000#
LANDED WEIGHT 1600#
Entry Science 80#
1973 Voyager SLS
Landed Science 170#
FLIGHT CAPSULE 4000#
LANDED WEIGHT 2100#
Entry Science 80#
Rover Science 220#
(1973 Voyager Science + 50#)
A
PROBE
B
LANDER
C
ROVER

FIGURE 3

WEIGHT REDUCTIONS WHICH
ALLOW VOYAGER 1973 MISSION
FOR 3000# INSTEAD OF 5000#

Canister Weight	350#
Deorbit Propulsion	300#
Aeroshell	475#
Adapters, Miscellaneous Hardware	200#
Descent Propellant	100#
Communications and Power	300#
Thermal Control and Cables	50#
Control Systems	75#
Total Reductions	1850#

FIGURE 4

WEIGHT ESTIMATES
FOR COMMONALITY BETWEEN MISSIONS

	PROBE	LANDER	ROVER
Flight Capsule	(2340)	(3320)	(4000)
Bio-Shield System	270	270	270
Adapter & Mechanisms	180	180	230
Deorbit Propulsion Sys.	250	300	350
Entry Weight	(1640)	(2560)	(3150)
Ballistic No.	(0.22)	(0.35)	(0.43)
Aeroshell	470	470	470
Afterbody & T.C.	130	130	130
Staged Weight	(1040)	(1960)	(2550)
Parachute	125	125	125
Propellant	-	200	275
Landed Weight	-	(1635)	(2150)
Structure, Mech. Sys.	250	550	550
Control System	100	100	100
Main Propulsion Sys.	-	150	150
Electronics	335	335	335
Power	150	250	400
Rover Vehicle	-	-	315
Science	(80)	(250)	(300)
Entry	80	80	80
Landed Science	-	170	220

FIGURE 5

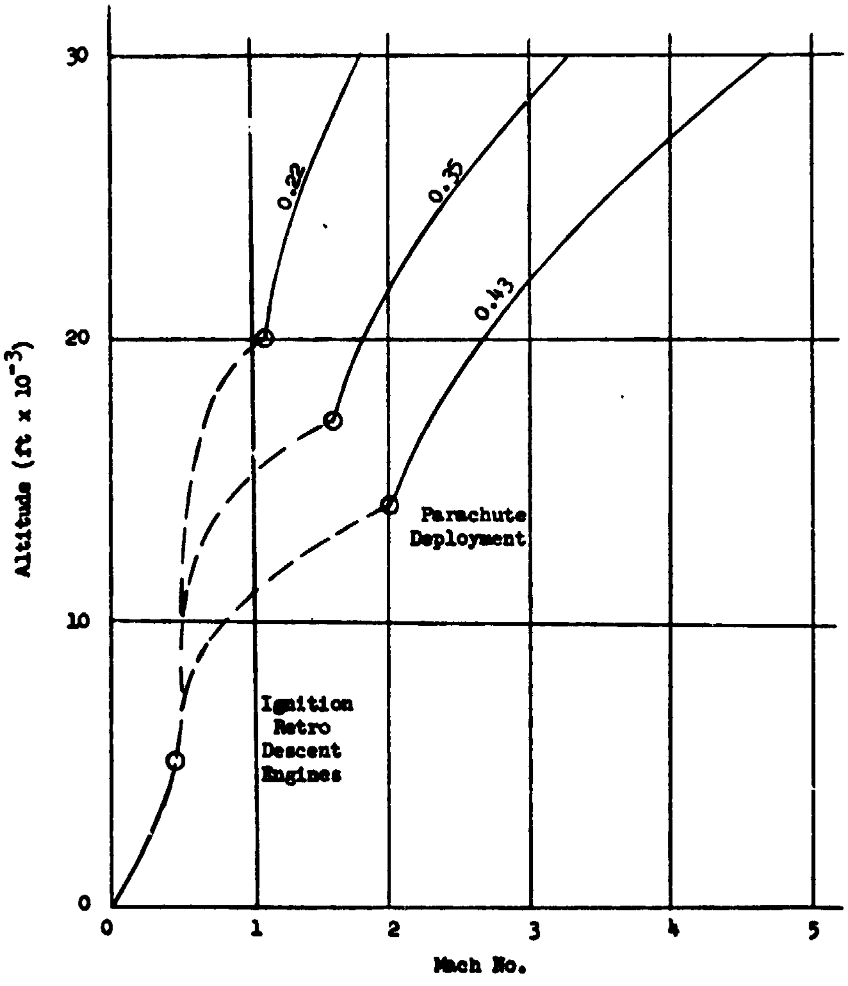
CAPSULE SIZE

	Weight	m/C_DA	Dia.	Decelerator Deployment
1975 Voyager	7000	0.40	19.0	Mach 2.0
1973 Voyager	5000 - 6000	0.32	19.0	Mach 1.5
Probe	2000	0.22	14.0	Mach 1.0
Lander	3000	0.35	14.0	Mach 1.5
Rover	4000	0.43	14.0	Mach 2.0
Lander	3000	0.67	9.0	Mach 5.0

o Conclusion: Select 14.0-foot diameter and 2000 - 4000# range

FIGURE 6

DESCENT TRAJECTORIES



VM-8 Atmosphere
V_E = 14,000 ft/sec
γ_E = -17°

FIGURE 7

SPACECRAFT SCIENCE

	OBJECTIVE	INSTRUMENT	VOYAGER WEIGHT ALLOCATION			LANGLEY PLANETARY EXPLORATION PROGRAM STUDY TEAM	CURRENT WT. ALLOC.		
			Contractor A	Contractor B	Contractor C	1973	1973	1975	1977
I	Topography	TV (vidicon) or Emulsion System	150	100	99	47	300	110	110
II	Atmospheric Structure Composition	IR and UV Spectrometers IR Radiometer RF Occulation Mass Spectrometer	122	86	63	71	70	35	-
III	Field And Particles	Magnetometers, Radiation Detectors, Micrometeoroid Detectors	31	-	-	32	30	15	15
	TOTAL SCIENCE		303	186	162	150	400	160	125

FIGURE 8

SPACECRAFT WEIGHT DEFINITION
(EXCLUDING PROPULSION MODULE)

	Martin Marietta Corp.	Langley Planetary Exploration Program Study Team	Current
Power	350	290	350
Telecommunications, Data Storage, etc.	250	225	250
Guidance and Control	220	155	220
Structure and Mechanism	235	235	235
Programmer	50	30	50
Pyrotechnics	30	-	30
Thermal Control	55	40	55
Cables, Brackets, etc.	110	75	110
Science	200	150	400
TOTAL	1500	1200	1700

FIGURE 9

ORBITAL INSERTION PARAMETERS

	Mars 1973	Mars 1975	Mars 1977
V (km/sec)	3.1	2.9	2.5
Orbit (km)	1,000 × 30,000	1,000 × 30,000	1,000 × 30,000
Required ΔV (km/sec)	1.250	1.125	1.070
$\frac{\text{Fueled Planetary Vehicle Wt.}}{\text{Orbiting Planetary Vehicle Wt.}}$	1.56	1.59	1.54

FIGURE 10

ORBITAL [illegible] PROPULSION

	1973 Mars	1975 Mars	1977 Mars
Propellant	4200	3990	3900
Propulsion System	800	800*	800*
Total	5000	4790	4700

*Common system based on 1973 requirements

FIGURE 11

1973 TYPE I CAPABILITY TO MARS

Booster Park Orbit	1 circ.	1 ell.	2 circ.	2 ell.	3 circ.	4 circ.	5 circ.	6 circ.
Booster payload	18309	19929	20729	23019	19090	19040	48699	32907
Booster adj.	2109	2109	2109	2109	600	600	2602	560
Adj. Booster P/L	16200	17820	18620	20910	18490	18440	46097	32347
Inject prop.	11550	10520	13300	1300	10190	10240	29858	22795
Wt. to transfer	4650	7300	5320	7610	8300	8200	16239	9552
Burnout wt.	--	--	1380	1380	--	--	4114	4572
Wt. adjustment	--	--	--	--	--	--	200	120
P/L to transfer	4650	7300	3940	6230	8300	8200	11925	4860
M/C prop.	110	193	105	170	200	195	305	125
Wt. to planet	4540	7107	3835	6060	8100	8005	11620	4735
Insert prop.	1640	2487	1515	2380	2910	2865	4495	1890
Wt. in orbit	2900	4620	2320	3680	5190	5140	7125	2845
Burnout wt.	1720	1720	280	450	1720	1720	845	355
P/L in orbit	1180	2900	2040	3230	3470	3420	6280	2490

Boosters: 1-T IIIF/N_2O_4 AG; 2-T IIIF/N_2O_4 AG/SC; 3-T IIIF/TS/N_2O_4 AG;
4-T IIIF/ST TS/N_2O_4 AG; 5-T IIIF/CENT/SC; 6-T IIIF/TS/SC

FIGURE 12

LAUNCH VEHICLE CAPABILITY IN 1973

11620
1160
10460

	(6) Titan III F Transtage Spacecraft	(3) Titan III F Transtage Agena	(5) Titan III F Centaur Spacecraft
Total weight to Planet	4260	7200	10500
Total weight in Orbit (1,000 x 30,000 km)	2550	4320	(6300)
Spacecraft	1700	2865	1700
Capsule	525	1455	3800

7125
712
6413

FIGURE 13

TITAN III F - CENTAUR LAUNCH VEHICLE CAPABILITY

	1973 Type I	1975 Type II	1977 Type II
Total to Mars	10500	10750	11050
Less propellant (1,000 x 30,000 km orbit)	4200	3990	3900
Total in Orbit	6300	6760	7150
Propulsion System	800	800	800
Useful Weight in Orbit	5500	5960	6350
Spacecraft	1700	1700	1700
Capsule	3800	4260	4650

FIGURE 14

MOBILE SURFACE LABORATORY

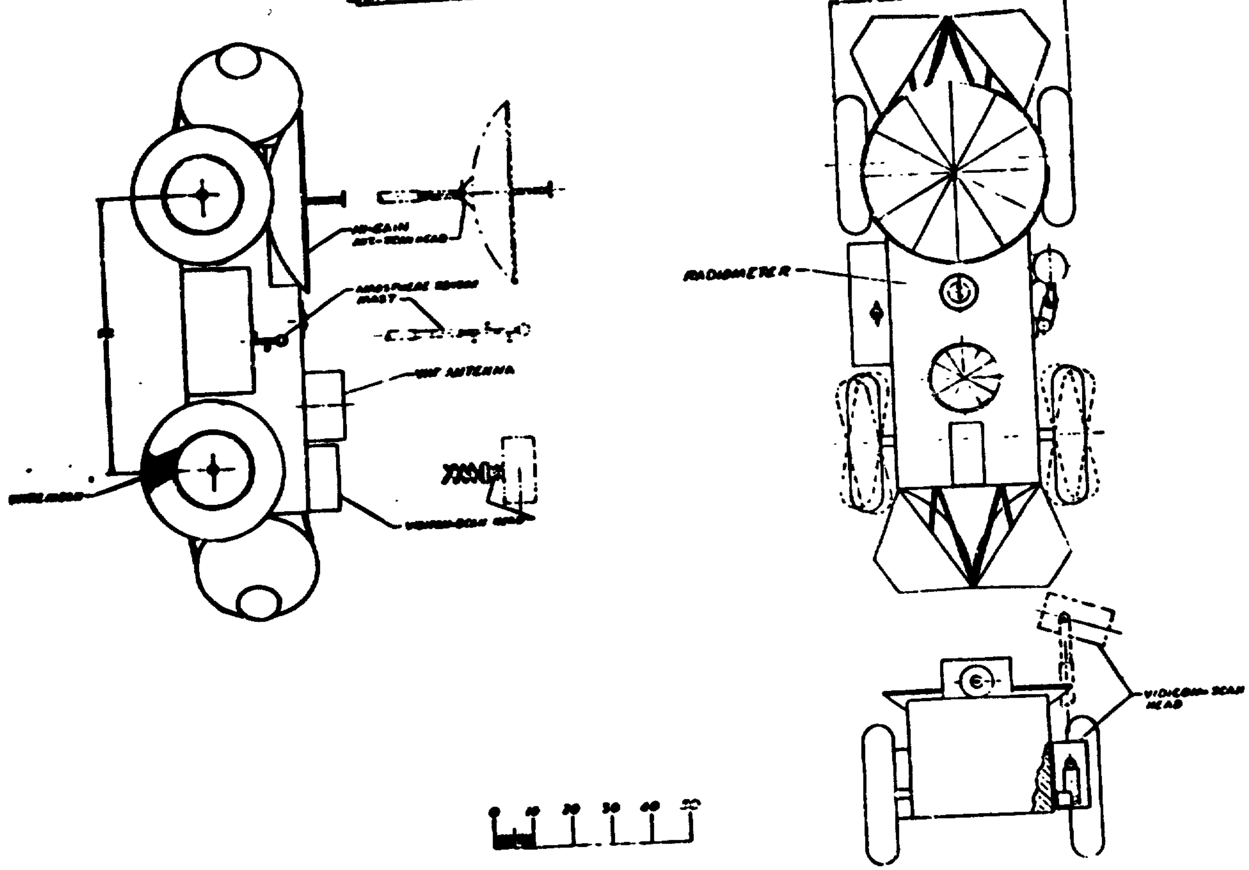


FIGURE 15

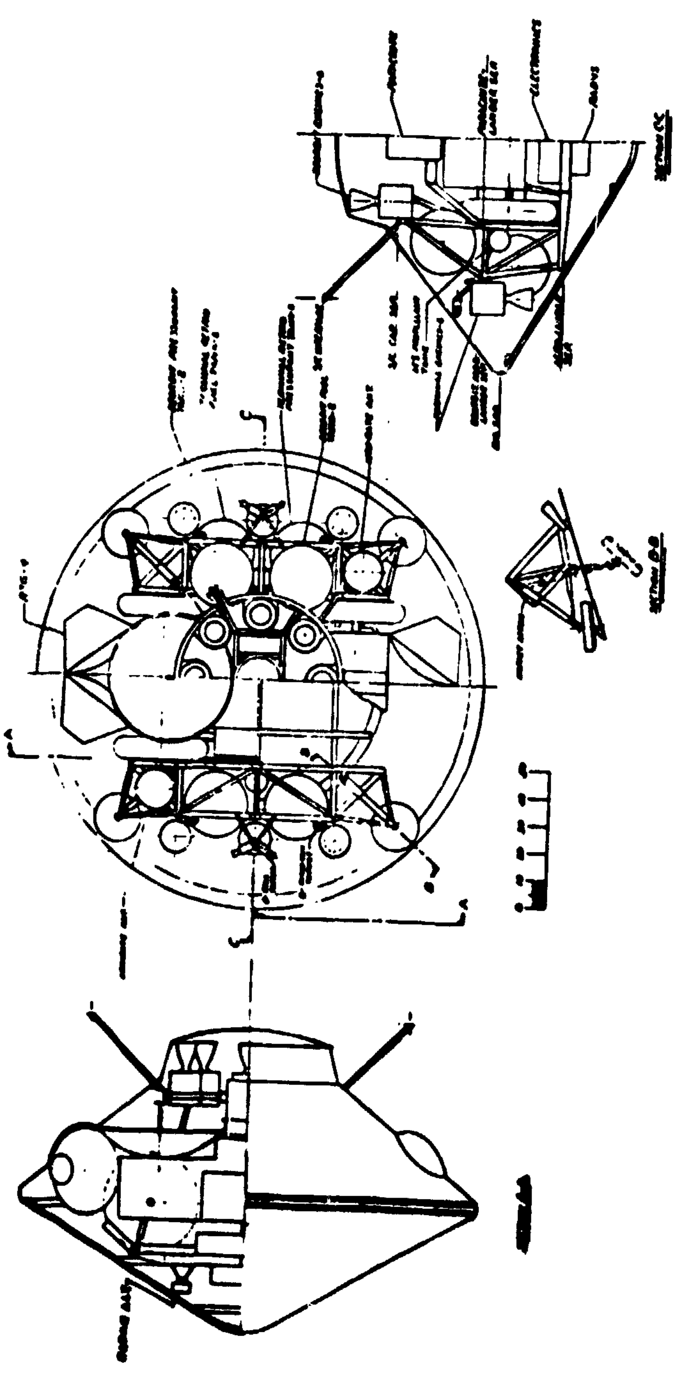
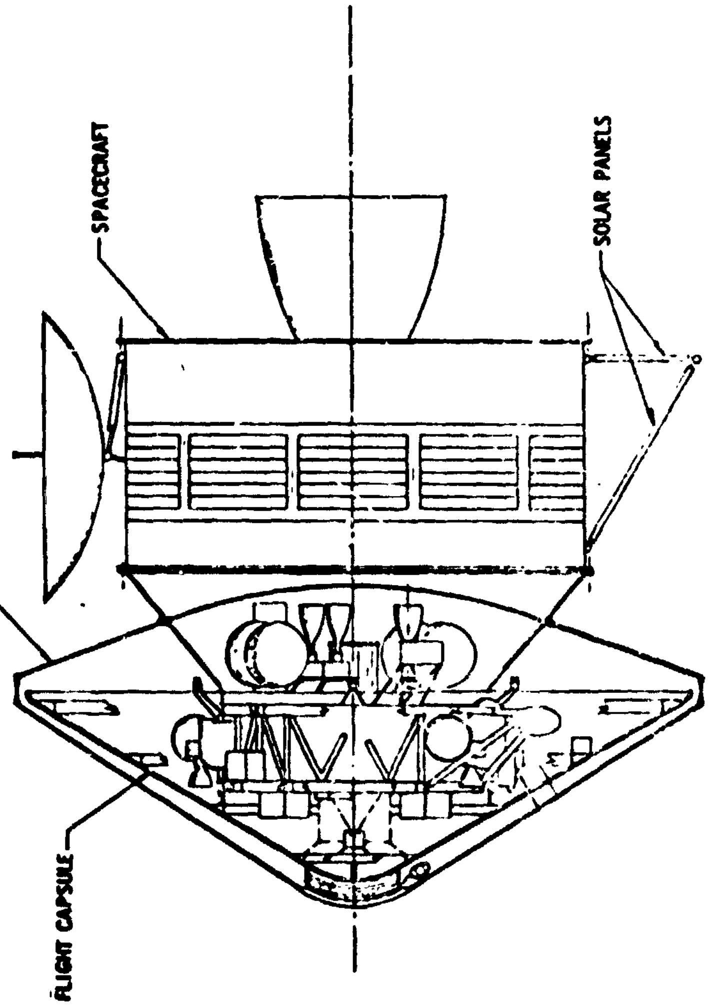
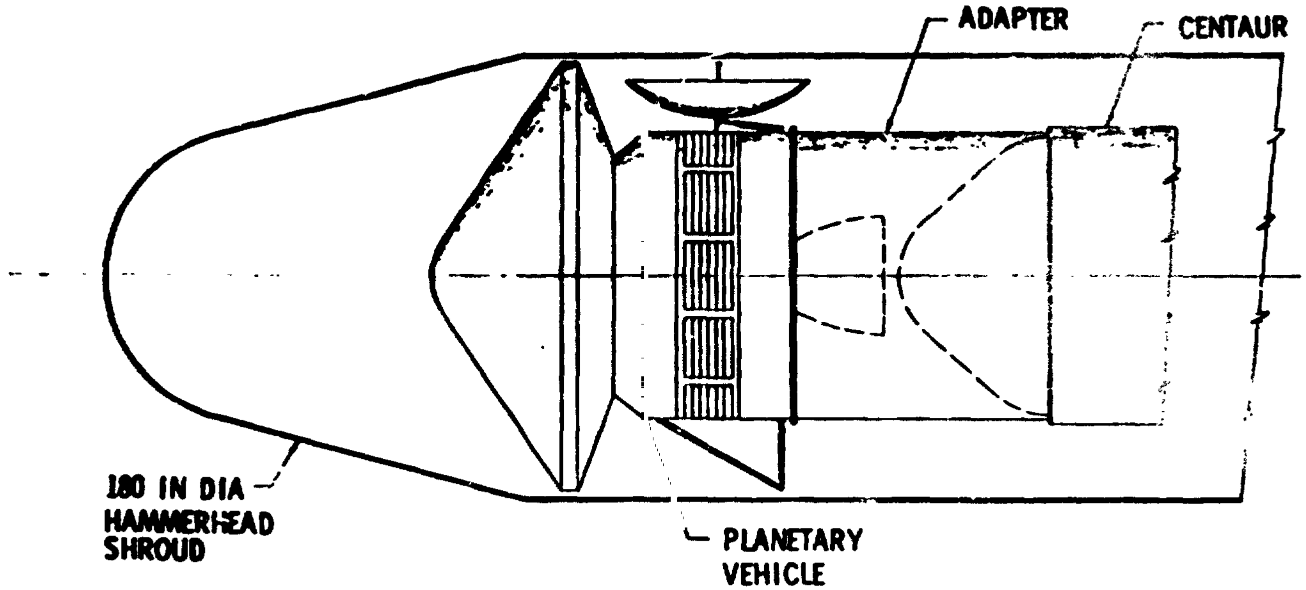


FIGURE 16

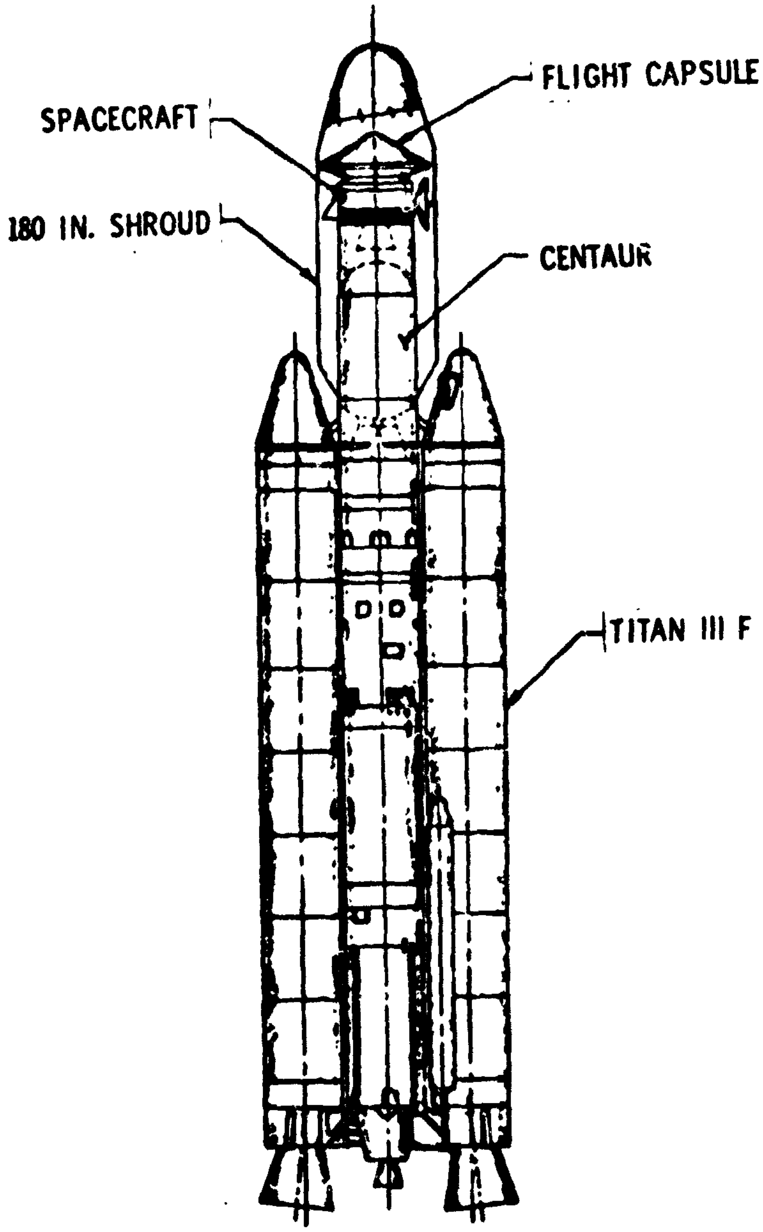


PLANETARY VEHICLE CONFIGURATION
3000 LB F/C 14 FT DIA AEROSHELL
FIGURE 17



PLANETARY VEHICLE ARRANGEMENT WITHIN SHROUD

FIGURE 18



LAUNCH CONFIGURATION

FIGURE 29

APPENDIX VI

VI-A

MAIN FILE

PRIORITY

COPY OF THIS MESSAGE ROUTED		
TO:	RECD BY	TIME
File		
Deputy Director	BL	9:10
REMARKS:		

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COMM. CENTER

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FM NASA ~~HQDRS WASH D C~~

TO NALANG/LANGLEY RESEARCH CENTER

INFO NALANG LANGLEY RESEARCH CENTER REm-1.1 REm-6.7

VOJETL/JET PROPULSION LAB

BT

UNCLAS SL-148. ATTN LRC/MR CHARLES J DONLAN DEPUTY DIRECTOR.

INFO LRC/J S MARTIN. JPL/R J PARKS.

THE FOLLOWING GUIDELINES ARE PROVIDED RELATIVE TO STUDIES AND PLANNING OF POTENTIAL MISSIONS TO MARS IN 1973:

GENERAL

THIS STUDY SHALL CONSIDER A TITAN III CLASS MISSION TO THE PLANET MARS IN 1973. THE OBJECTIVE OF THIS STUDY IS TO EVALUATE THE BASELINE MISSION SUBMITTED TO THE CONGRESS, AS DEFINED BELOW, TOGETHER WITH ALL PROMISING ALTERNATIVES, TO PERMIT A MISSION DEFINITION FOR THE 1973 OPPORTUNITY. THE EFFORT IN FY 1968 IS INTENDED TO ADVANCE THE STATE OF THE ART OF SUCH POTENTIAL MISSIONS AND WILL NOT BE DIRECTED AT A SPECIFIC FLIGHT PROJECT UNTIL SUCH A PROJECT IS AUTHORIZED BY THE ADMINISTRATOR.

BASELINE MISSION

I

DIRECTOR	100
DEP DIR	106
AD-FP	116
AD-G1	116
AD-G2	116
AD-G3	116
SES	116
S ASST	117
BUDGET	104
BRD	103
EDIT	149
REC	122
ACD	157
AMPD	213
APD	106
DLD	242
FID	476
FMTD	246
FSRD	403
IRD	233
SMD	210
EHD	306
NASA HQ	
ETS	112
ENGR	107
AA-ABSE	111
CE C	145
PA	154
ELC	319
FISC	119
AFD	111
PHOTO	100
PERS	150
PROC	104

FROM Ellison

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Copy II

Copy II
J.S.Martin 159

2/15/68.
Dolan
Nelson
Drake
Martin
Imbeck
Brewer
Boyd
Crabill
JRHall
EABrand
Spamill
Gemmill

PAGE 2 NASAHQ 148 UNCLAS

THE BASELINE MISSION INCLUDES THE FOLLOWING:

1. TWO LAUNCHES IN 1973.

2. LAUNCH VEHICLE TO BE EITHER A TITAN III X (1205)/CENTAUR OR A TITAN III C WITH MULTIBURN SPACECRAFT PROPULSION FOR INTERPLANETARY INJECTION AS WELL AS ORBIT INSERTION.

3. EACH LAUNCH VEHICLE TO CARRY A MARINER 71 CLASS ORBITER AND A ROUGH-LANDING CAPSULE. THE CAPSULE MAY EITHER ENTER THE MARS ATMOSPHERE DIRECTLY OR FROM ORBIT.

4. THE 1973 MISSION IS CONSTRAINED TO A TOTAL PROGRAM COST OF $385M, INCLUDING LAUNCH VEHICLES. THIS IS BELIEVED TO BE CONSISTENT WITH THE USE OF A MINIMUM-MODIFIED MARINER 71 ORBITER AND AN 800 POUND CLASS ROUGH LANDER. THE JPL CSAD DESIGN IS TOO SMALL FOR THIS MISSION BUT IS A GOOD EXAMPLE OF THIS TYPE OF LANDER.

5. THE SCIENCE OBJECTIVES SHOULD INCLUDE THE FOLLOWING:

A. ORBITER: CARRY PAYLOAD SIMILAR TO MARINER 71

B. ENTRY VEHICLE: MEASURE ATMOSPHERIC TEMPERATURE, PRESSURE, COMPOSITION, AND 3-AXIS ACCELERATION

C. LANDER: TRANSMIT LIMITED IMAGERY AND MEASURE

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ATMOSPHERIC TEMPERATURE, PRESSURE, WIND, SOIL COMPOSITION, AND SUBSURFACE MOISTURE.

THESE ARE OBJECTIVES ONLY, SUBJECT TO THE ABOVE CONSTRAINTS. THE FINAL SELECTION OF INSTRUMENTS WILL NOT BE MADE UNTIL AFTER THE SCHEDULED 1969 MARS FLYBY.

ALTERNATE MISSION

CONSIDERATIONS SHOULD INCLUDE THE FOLLOWING ALTERNATES:

1. HARD LANDERS, WITH OR WITHOUT ORBITERS, DIRECT ENTRY OR OUT OF ORBIT ENTRY
2. SOFT LANDER, WITH OR WITHOUT ORBITERS, DIRECT ENTRY OR OUT OF ORBIT ENTRY

MANAGEMENT

PROJECT MANAGEMENT RESPONSIBILITY FOR THE MARS 73 MISSION SHALL BE ASSUMED TO BE AT THE LANGLEY RESEARCH CENTER. LRC SHOULD STUDY AND MAKE APPROPRIATE RECOMMENDATIONS RELATIVE TO THE MANAGEMENT AT THE SYSTEM LEVEL. POTENTIAL AREAS WHERE JPL CAN CONTRIBUTE TO THE OVERALL EFFORT SHOULD BE INCLUDED IN THESE CONSIDERATIONS. THIS SHOULD INCLUDE SYSTEM MANAGEMENT OF EITHER THE ORBITER OR LANDER. LRC AND JPL SHOULD DEVELOP A PLAN WHEREBY JPL STUDIES SUPPORTED BY OSSA APMT FUNDS WILL BE IN SUPPORT OF LRC.

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CONSIDERATION SHALL ALSO BE GIVEN TO THE SIGNIFICANT INVOLVEMENT OF THE LUNAR AND PLANETARY MISSIONS BOARD IN THE PROGRAM DEFINITION ACTIVITY, INCLUDING THE RELATIVE MISSION EMPHASIS BETWEEN THE ORBITER AND LANDER.

STUDY CONTRACTS

IT IS REQUESTED THAT THE HEADQUARTERS PLANETARY PROGRAM OFFICE BE FURNISHED WITH INFORMATION COPIES OF CONTRACTUAL WORK STATEMENTS AT LEAST THREE WORKING DAYS PRIOR TO THEIR RELEASE TO POTENTIAL CONTRACTORS. CONTRACTS SHOULD MEET THE GENERAL GROUND-RULE THAT THEY MUST ADVANCE THE STATE OF THE ART OF PLANETARY TECHNOLOGY, RATHER THAN BE OF USE TO ONLY ONE SPECIFIC MISSION.

RESOURCES

PLANNING SHOULD BE BASED ON HAVING ONLY THE APPLICABLE APMT RESOURCES IN FY 68. FY 69 FUNDING OF $20.0 M HAS BEEN REQUESTED. THE TOTAL RUNOUT COST, INCLUDING LAUNCH VEHICLES, SHALL BE APPROXIMATELY $385.0 M.

SCHEDULE AND REPORTING

A STUDY SCHEDULE AND REPORTING ARRANGEMENT CONSISTENT WITH EXISTING NASA REQUIREMENTS SHALL BE DEVELOPED JOINTLY BETWEEN LRC AND THE HEADQUARTERS PLANETARY PROGRAM OFFICE.

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JOHN E NAUGLE ASSOCIATE ADMIN FOR SPACE SCIENCE & APPLICATIONS

BT

This copy to → J. T McNulty, M/S 334
Exhibit II-B

Langley Research Center

November 1, 1968

Head, ASPO
Mr. James S. Martin Jr.

Head, Spacecraft Structures Section - FVSD

1973 Mars Mission

With the conclusion of the study phase for the 1973 Mars Mission, it appears timely for me to summarize FVSD's efforts in this area and to present for your consideration some comments regarding the 1973 mission.

Charts 1 and 2 summarize the FVSD effort in-house and supervising contracts from the 1964 probe/lander studies to the present mission mode studies.

Chart 3 illustrates the mission options requiring a selection for 1973 and the items influencing this decision. It is assumed in this analysis that the emphasis is on a lander mission and no orbiter science is required, the orbiter or flyby spacecraft serves as a lander "bus" and relay station. The items bearing on the mission selection are cost, risk, and compatibility with technology development.

Chart 4 details the cost guidelines used. Costs were taken from ASPO Progress Report, October 2, 1968. Chart 5 presents a simplified matrix of mission options showing that mission costs range from $\$260 \times 10^6$ for a direct hard lander with flyby module to $\$360 \times 10^6$ for a soft lander out-of-orbit. When the funding level has been determined, the possible missions can be defined from this chart.

In like manner to the cost picture, the relationship of risk to mission mode is illustrated on Chart 6. In general, the direct mode represents a high risk mission because there is minimum room for error whereas in the out-of-orbit mode one can trim the orbit and carefully select deorbit conditions for entry. This, in turn, allows for a shallower entry angle, more atmospheric damping, and less demands on the decelerator system. Chart 7 illustrates the relationship between ballistic number (B), entry angle (γ_E), and atmospheric pressure to allow parachute deployment at Mach 2.0 for the out-of-orbit and direct modes. The 3 σ entry corridor for the out-of-orbit mode is well defined; maximum entry angle can be well within 20°. The 3 σ entry corridor for the direct mode is not so well defined and is subject to how optimistic one is about the developing technology; estimates for maximum entry angle range from 25° to 30° and above. Capsule ballistic numbers under consideration are in 0.3 to 0.4 range. The chart shows that, for the out-of-orbit mode, a 5 mb atmosphere and a B = 0.4 are compatible at γ_E = 20° and that a 4 mb atmosphere can be designed for by using a B = 0.3 and an $\gamma_E = 18^\circ$. Even using an optimistic maximum $\gamma_E = 25^\circ$ for the direct entry mode, B must be less than 0.3 for the VM-8 atmosphere; further, a 4 mb atmosphere is beyond the design range. Conclusion, the direct mode is a borderline mission for B = 0.3.

Chart 8 defines the relation between the mission options and the required technology base. The out-of-orbit soft lander is a standout by this criteria. It has been extensively studied and is well understood. Its mode of shallow entry allows for the heaviest capsules and, thus, prepares a technology base for future missions whereas the direct entry mode could be a dead end. The mating of the Titan/Centaur combination, needed for future heavy payloads, is another plus.

In summation, while realizing that funding may be the overriding criteria, it is recommended that the Titan/Centaur soft lander out-of-orbit be given very serious consideration. Chart 9 summarizes its characteristics.

James F. McNulty
2635, M/S 334

Attachments

cc:
CTBrown, M/S 314
EBGeer, M/S 107
HLCrabill, M/S 159
JFMcNulty, M/S 334
FVSD/PCO, M/S 314
SSS File, M/S 334

JFMcNulty:ald

CHART 1

Missions Studied By FVSD (In-House)

A MARS ATMOSPHERIC PROBE MISSION - LWP-328
(Atlas/Centaur, Mariner Flyby, and 400-Pound Capsule - 1971 Mission)
Presented at OSSA in Washington, D.C., February 1966.

MODAL AND DESIGN COMPARISONS FOR THE VOYAGER CAPSULE - LWP-326
(Proposed Out-Of-Orbit Concept with Parachute and Retro Landing)
Presented at joint OSSA, OART, and JPL meeting in Washington, D.C., September 1966.

VOYAGER CAPSULE BUS SYSTEM BASELINE AND MISSION MODE DESCRIPTION - 1973 MISSION ON SATURN V; LWP-478

A DESIGN APPROACH FOR A COMMON CAPSULE BUS SYSTEM FOR SATURN V - VOYAGER MISSIONS - LWP-625
(Recommended system weight allocations for 1971 Compatible with Common Subsystem Growth Considerations).

A BUILDING BLOCK APPROACH TO MARS AND VENUS PLANETARY MISSIONS IN THE 1970's UTILIZING A MODULAR SPACECRAFT - LWP-483
(Parametric Analyses Using Titan III C - III F For Multi-Missions With Propulsion Changes on Common Spacecraft)
Transmitted to OSSA in November 1967.

STUDY OF TITAN III F (CENTAUR'S CAPABILITY TO CARRY OUT A "VOYAGER-TYPE" MISSION - LWP-547
(Revealed Compatibility of LV with "Voyager" Objectives Including A Rover. Urged Start of Titan/Centaur Mating for Maximum Mission Benefits)
Presented at Joint Meeting of LRC's PMISC and Washington Representatives (OSSA and OART).

CHART 2

Contracts Monitored By FVSD

AVCO Probe/Lander Study (December 1964 - May 1966)
Saturn 1B to Saturn V
Entry from Approach and Orbit
Hard Lander, Descent TV.

Martin And McDonnell Phase B Voyager (February 1967 - September 1967)
Saturn V
Entry from Orbit
Soft Lander

Martin Mission Mode Study (April 1968 - October 1968)
Titan Family
Entry from Approach and Orbit
Soft Lander

CHART 3

1973 Lander Mission Parameters

• Type Lander (Soft or Rough) • Entry Mode (Direct or Out-Of-Orbit)	As Influenced By	• Available Funding • Risk • Technology Base For Future Missions

CHART 4

Assumed Costs

• **Landers**			
Hard (1400#)	-	$\$170 \times 10^6$	min.
Soft (1700#)	-	$\$210 \times 10^6$	science
• **Spacecraft**			
Flyby Module (400#)	-	$\$\ 50 \times 10^6$	
Mod. Mariner Orbiter (700#)	-	$\$100 \times 10^6$	
• **Launch Vehicles**			
Titan III C	-	$\$\ 40 \times 10^6$	
[redacted] III C/Centaur	-	$\$\ 50 \times 10^6$	

CHART 5

Mission Costs

Out-Of-Orbit Entry		Direct Entry	
Titan III C/Centaur		Titan III C	
Mod. Mariner Orbiter		Flyby Module	
Soft	Hard	Soft	Hard
$\$360 \times 10^6$	$\$320 \times 10^6$	$\$300 \times 10^6$	$\$260 \times 10^6$
	← Possible Missions →		
	↑ Available Funding {Not Determined At This Time}		

CHART 6

Mission Risks

ITEM	OUT-OF-ORBIT III C/CENTAUR		DIRECT III C	
	SOFT	HARD	SOFT	HARD
Missing Entry Corridor (Skip Past Planet or Too Steep Entry For Decelerator System)	Negligible Risk	Negligible Risk	Highest Risk	High Risk
4 Millibar Atmosphere (5 mb present design min.)	Okay	Okay	Crash!	May Work
Instrument Development Cost and Operation	Low Risk	High Risk	Low Risk	High Risk
Payload Weight	Big Margin	Big Margin	Small Margin	Small Margin
Mission Operations	Flexible, can change plans if required (Hold in Orbit as needed)		Fixed From Launch	

NOTE: Decelerator System Requires Less Altitude For Hard Lander

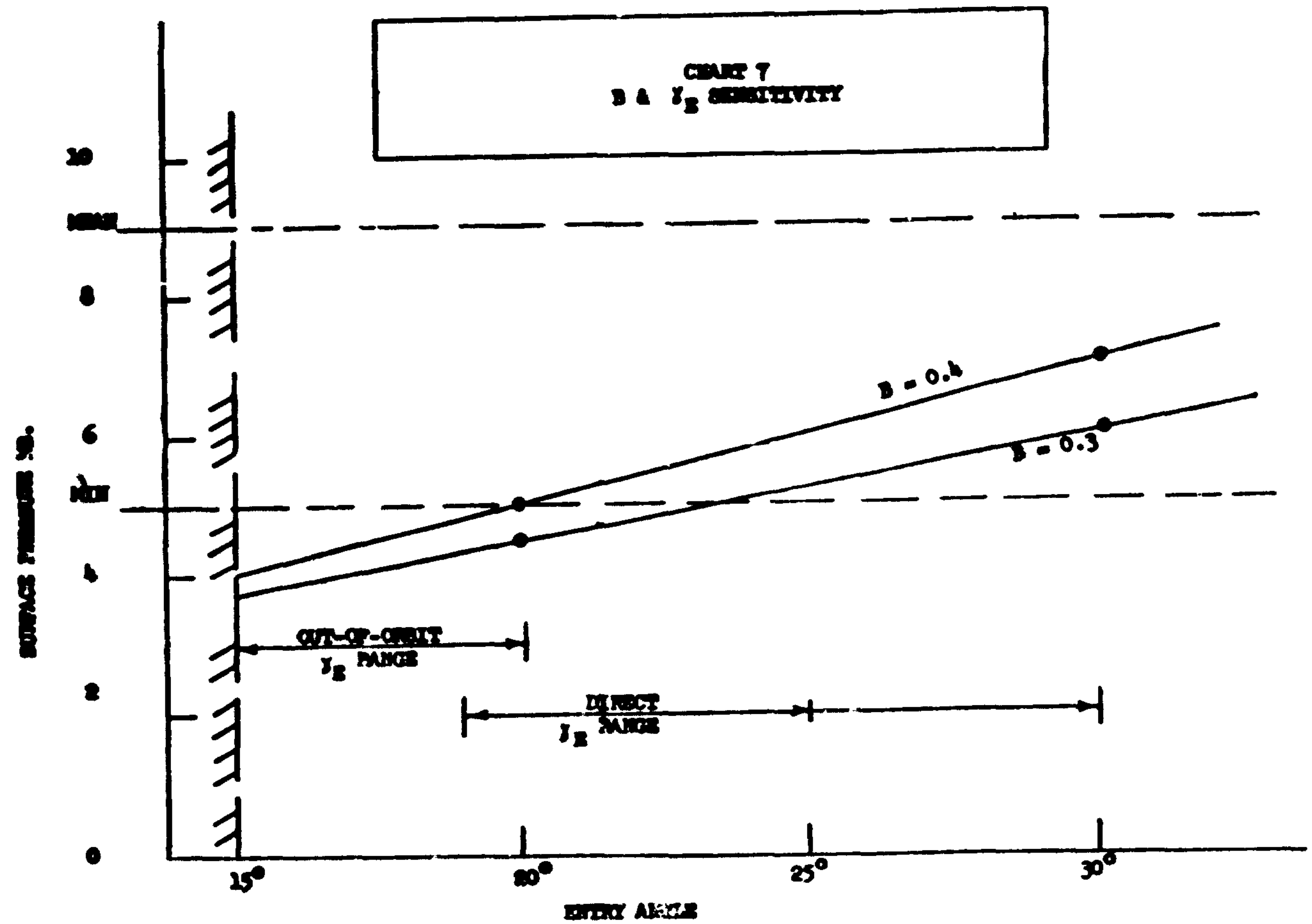


CHART 7
B & γ_E SENSITIVITY
SURFACE PRESSURE MB.
10
MEAN
8
6
MIN
4
2
0
B = 0.4
B = 0.3
OUT-OF-ORBIT
γ_E RANGE
DIRECT
γ_E RANGE
15°
20°
25°
30°
ENTRY ANGLE

CHART 8

Mission Technology Base

ITEM	OUT-OF-ORBIT III C/CENTAUR		DIRECT III C	
	SOFT	HARD	SOFT	HARD
Understanding of Mission	Highest, Voyager Background	Mode Okay but Hard Lander Not Fully Understood	Entry Problems Less Well Understood	
Preparation of Future Missions	Highest, Can grow to Rover	No Future	Future Heavy Payloads Will Require Shallow Entry Angle, Out-Of-Orbit Entry	

CHART 9

Recommend Titan/Centaur
S/C Lander Out-Of-Orbit

- **Best Understood Mission**
- **Smallest Risk, Flexible In Operational Sense**
- **Lowest g's for Instrument Development**
- **Provides Platform for Instrument Deployment**
- **Less Demanding on Decelerator Systems**
- **Has Growth Possibilities With Same Technology**

BUT

- **Highest in Cost - $360,000,000**

Appendix V-C
Martin Marietta's Study Conclusions

CONCLUSIONS

There are no primary flight capsule concept differences resulting from the selection of mission mode. Both the direct and out-of-orbit modes are equally feasible, although the direct mode entry environments are slightly more severe. The main differences between the modes are concentrated in the flexibility and confidence in mission operations. The specific conclusions are tabulated below and on the following page.

Out-of-orbit mode recommended.

Of the point designs studied, Configuration 1B (10.5-ft aeroshell, $B_E = 0.35$) is recommended.

Titan IIIC/Centaur launch vehicle required for either mission mode when orbiter science capability is desired.

Bulbous shroud required for direct mode, and probably required for out-of-orbit mode when using a Mach 2 parachute, VM atmopshere, 6000-ft terrain height, and 10% margins.

Targeting capability is the same in either mission mode when considering only flight profile constraints. However, superimposing any time or orientation constraints decreases the direct mode landing site selection flexibility.

Accuracy of atmosphere structure determination not significantly different between mission modes.

Science, propulsion, telecommunications, power and pyrotechnics, and thermal control (autonomous capsule excepted) subsystems are not affected by mission mode choice.

All subsystem components are either present state-of-the-art technology or can be developed for the 1973 launch opportunity.

Terminal descent and landing radar (TDLR), altitude measuring radar (AMR) antenna, inertial measurement unit (IMU), engines, isotope heaters, sterilizable batteries, sterilizable solar cell adhesives, aerodecelerators, and certain science components are long lead efforts which must start in Phase C.

Out-of-orbit mode	Direct mode
More in-flight mission flexibility	Can use Mariner Mars '71 orbiter, but at sacrifice of targeting and orbital science objectives
Site survey before separation	Slightly larger launch vehicle performance margin
Choose for science objectives **Avoid poor capsule surface environment or adverse weather patterns**	**More extensive development required**
Targeting can be to different site after launch	Higher entry environment
Checkout with time for malfunction correction	**More severe base heating**
Second lander can benefit from first lander's data return	Increased aerodynamic sensitivities to tolerances and misalignments
Can fit within 10-ft shroud; use of a Mach 2 parachute allows for no margins. To provide margins, an 11.5-ft shroud is required	Larger aeroshell and canister
Can fit within 10-ft shroud and provide margins by using a Mach 5 ballute	More comprehensive aerothermodynamic test program
Requires additional orbit insertion propulsion added to Mariner Mars '71 orbiter	Additional and more sophisticated equipment on orbiter for approach guidance
Requires successful orbit insertion maneuver for successful capsule mission	

McNulty

STATEMENT OF WORK

VI-D

VIKING LANDER SYSTEM

AND

PROJECT INTEGRATION

L10-9800

MARCH 1, 1969

LANGLEY RESEARCH CENTER
LANGLEY STATION HAMPTON, VA.

Attachment C

VIKING LANDER SYSTEM AND PROJECT INTEGRATION

STATEMENT OF WORK

TABLE OF CONTENTS

APPENDIX INDEX

Appendix No.	Document Title
1	Viking Mission Definition, M73-101-3
2	Titan/Centaur Data Supplement for Viking Project
3	Viking Baseline Orbiter Conceptual Design Description
4	Radioisotope Thermoelectric Generator Baseline Description
5	Handbook of Unmanned Spacecraft Operations at ETR
6	Tracking and Data System Estimated Capabilities for the Mars 1973 Mission
7	Mars Engineering Model for Viking Project, M73-106-0
8	Viking Navigation Capability Estimate
9	Project Control for Viking Project
10	Planetary Quarantine Provisions for Viking Project, M73-109-0
11	Reliability Program Provisions for Space System Contractors, NPC 250-1
12	Modifications to NPC 250-1 for Viking Project
13	Quality Program Requirements for Viking Project, M73-104-1
14	Range Safety Manual, AFETRM 127-1
15	KSC Management Instruction, KMI-1710-1A
16	Science Management Plan for Viking Project, M73-105-0
17	Imagery Quality Requirements for Viking Project, M73-108-0
18	Science Instrumentation Description, M73-107-0
19	Criteria to Establish RF Compatibility Between DSIF and Spacecraft Projects, JPL EPD-435

1.0 PROJECT OBJECTIVES AND DESCRIPTION

1.1 General

The Viking Project is part of a program for the exploration of Mars with the use of unmanned spacecraft. The Mariner IV initiated this program by performing scientific investigations during a flyby of the planet in mid-1965. Mariner '69, Mariner '71, and Viking will continue this exploration program. The Mariner '69 Project will conduct two flyby missions with Mars encounters occurring in mid-1969. The Mariner '71 Project will conduct two orbital missions to be performed in late 1971. The Viking mission will utilize the 1973 opportunity to conduct scientific investigations from Mars orbit, during entry, and on the surface. This will be the first opportunity in the Mars exploration program to obtain direct measurements within the Mars atmosphere and on the Mars surface.

1.2 Project Objectives

The general objective of the Viking Project is to obtain, using Spacecraft consisting of a Lander and an Orbiter, scientific data which will significantly increase our knowledge of Mars with particular emphasis on providing information relevant to life on the planet.

The Lander surface and entry science measurements are of primary importance in satisfying the Project objectives. The surface measurements are to visually characterize the landing sites, search for organic compounds, search for the presence of living organisms and investigate the ability of the environment to support life. Entry measurements will investigate atmospheric composition and structure.

The Orbiter science measurements, which will be utilized in a manner that will maximize the usefulness of the landed science measurements, will provide gross area surveillance of the landing area and will study the dynamic characteristics of the planet and its atmosphere from orbit. In addition, the Orbiter will relay data from the Lander to Earth.

The detailed objectives to be accomplished in satisfying the Viking Project objectives are specified in section 4.0 of appendix 1.

1.3 Project Description

Two Viking Spacecraft, each consisting of an Orbiter and a Lander, will be used to accomplish the Viking Project objectives. The Spacecraft will be separately launched by Titan/Centaur Launch Vehicles from the Eastern Test Range during the 1973 Mars launch opportunity. Each Spacecraft will be placed into orbit about Mars. The scientific instruments onboard the Orbiter will be used to obtain data to aid in the selection of landing sites for the Lander. After the landing site has been selected, the Lander will separate from the Orbiter and descend to the designated landing area. The Lander will make scientific measurements during entry and on the surface of Mars. The Orbiter will act as a relay station between the Lander and Earth, obtain periodic coverage of the Lander surroundings, and make scientific measurements. The Deep Space Instrumentation Facility and the Space Flight Operations Facility will be utilized for tracking, command, data reception, and control.

1.4 Management

Viking Program management is at NASA Headquarters, Office of Space Science and Applications, Office of Planetary Programs. The Langley Research Center, Viking Project Office, has responsibility for the overall Viking Project management, the Lander System, the Spacecraft System, and the Launch and Flight Operations System. The Jet Propulsion Laboratory is responsible for and will furnish the Orbiter System and the Tracking and Data System. The Lewis Research Center is responsible for and will furnish the Launch Vehicle System. Figure 1 defines the management structure.

1.5 Hardware Terminology

The hardware terminology used in this Statement of Work is given in table 1 and figures 2 and 3.

2.0 SCOPE

The Contractor shall provide all services, materials, facilities, and equipment, except those provided by the Government, necessary to furnish a Viking Lander System. He shall also provide all services, materials, facilities and equipment, except those provided by the Government, required to integrate the Lander into the Spacecraft and the Spacecraft into the Space Vehicle as defined herein. The Contractor shall provide the management, overall planning, integration, control, and operations necessary to successfully carry out all aspects of this Statement of Work.

3.0 GOVERNMENT-FURNISHED DATA, EQUIPMENT, FACILITIES, AND SUPPORT

The listed items are to be considered Government-furnished for purposes of accomplishment of the tasks described in section 4.0.

3.1 Launch Vehicle System

3.1.1 Two Titan/Centaur Launch Vehicles with nose fairing and supporting services (fig. 4 and appendix 2).

3.1.2 Titan/Centaur ITL facilities (Integration - Transfer - Launch) at the Eastern Test Range (ETR) (appendix 2).

3.1.3 Launch Vehicle injection error analysis (appendix 2).

3.1.4 Titan/Centaur estimated injected payload capability (fig. 5).

3.1.5 Spacecraft axes definition (fig. 6).

3.1.6 Targeted launch trajectories and firing tables.

3.1.7 Supporting services to launch the Titan/Centaur.

3.1.8 Launch Vehicle test items required for Spacecraft interface tests.

3.2 Orbiter System

3.2.1 Three flight-qualified Orbiters (appendix 3) including the Spacecraft Launch Vehicle adapter (fig. 2).

3.2.2 Orbiter test models and AGE.

3.2.3 Supporting services to operate the Orbiter during all Spacecraft level tests.

3.3 Lander System

3.3.1 Flight-qualified Radioisotope Thermoelectric Generator Systems (appendix 4).

3.4 Launch and Flight Operations System

3.4.1 Launch Operations

3.4.1.1 Spacecraft facilities at KSC/ETR (appendix 5).

3.4.1.2 Range facilities of ETR and KSC (appendix 5).

3.4.1.3 Building and building-services at ETR to house and support Contractor-furnished sterilization equipment.

3.4.1.4 Facility equipment which is defined as all equipment other than AGE, OSE, mechanics hand tools and/or office supplies that are required by the Contractor to support operations.

3.4.1.5 The services and facilities to mate the Spacecraft with the Launch Vehicle.

3.4.2 Flight Operations

3.4.2.1 Facilities and equipment of the Tracking and Data System and support services required to provide this system for the Contractor's use (appendix 6). AGE, OSE, hand tools, and office supplies are excepted.

3.4.2.2 Plans, estimates of trajectory control capability, procedures, software programs, and personnel in an integrated system to perform the design and operational execution of the precision navigation task of the Project from interplanetary injection to the establishment of the orbit from which the Lander descent to the planet will be made. Thereafter, to perform the same function for the Orbiter.

3.4.2.3 Plans, procedures, software programs and personnel in an integrated system to perform the design and operational execution of the tasks required to analyze the performance of the Orbiter from launch to completion of the mission.

3.4.2.4 Post-landing position determination of the Lander for mission operations use.

3.5 Data

3.5.1 Mars Engineering Model (appendix 7).

3.5.2 Navigation Capability Estimate (appendix 8).

4.0 CONTRACTOR TASKS

The Contractor shall manage and control his effort in accordance with plans specified in the tasks of this section. All such plans shall be developed by the Contractor, updated as necessary, and submitted for Langley Research Center approval or review, as required.

4.1 Management and Technical Integration

The Contractor shall provide the management, overall planning, implementation, and control necessary to successfully carry out all aspects of this Statement of Work. He shall accomplish the overall technical integration of the Viking Lander, Orbiter, Spacecraft, Launch Vehicle, associated ground support equipment, software, launch and flight operations, and supporting services. His planning shall recognize other Government and Contractor agreements. The tasks below are by way of description and not limitation:

4.1.1 Management

The Contractor shall manage and control his effort in accordance with an approved Management Plan which shall include his organizational concept and employment of resources (manpower, facilities, etc.), his plan for providing effective control, the identification of the systems to be used in reporting to the Langley Research Center in order to implement this Statement of Work. In developing and implementing the plan, the Contractor shall include the requirements contained in appendix 9.

4.1.1.1 Master Schedule - The Contractor shall develop a Master Schedule which will include all major elements of the Viking Project. The approved Master Schedule shall be maintained by the Contractor.

4.1.2 Configuration Control

The Contractor shall develop and implement a Configuration Control Program based on an approved plan. The plan shall describe the control and reporting effort associated with the Lander System and the interfaces with other Viking Systems.

4.1.3 Planetary Quarantine

4.1.3.1 Policy - The Contractor shall adhere to a probability of contamination per launch of less than 1×10^{-6} for each landing vehicle and 3×10^{-5} for all other flight hardware. The period of quarantine is 20 years from the first known landing on the planet.

4.1.3.2 Planetary Quarantine Program - The Contractor shall develop and implement a Planetary Quarantine Program for the overall mission in accordance with an approved plan which is consistent with section 4.1.3.1 and which satisfies the requirements and constraints stated in appendix 10.

4.1.4 Mission Assurance

4.1.4.1 Project Mission Assurance Program - The Contractor shall develop and implement a Project Mission Assurance Program in accordance with an approved plan which is in conformance with appendices 11, 12, and 13. The Contractor will not be responsible for mission assurance activities related to Government-furnished Project elements. However, he shall utilize and incorporate in his analyses and program the mission assurance data provided by the Government on those elements.

4.1.4.2 Lander System - The Contractor shall accomplish the following Lander mission assurance activities in accordance with approved plans.

4.1.4.2.1 Reliability assurance - The Contractor shall develop and implement a Lander System Reliability Assurance Program in accordance with appendix 11 as modified by appendix 12.

4.1.4.2.2 Quality assurance - The Contractor shall develop and implement a Lander System Quality Assurance Program in accordance with appendix 13.

4.1.5 Reviews

The Contractor shall plan, conduct, and participate in technical and management reviews related to his work effort. The Contractor shall participate in but will not be responsible for reviews covering the design of Government-furnished equipment (GFE). However, he shall include in his reviews those interface factors with GFE affecting his effort under this Statement of Work. The Contractor shall submit for approval a review plan and agenda preceding each review. Reviews shall include at least overall Project reviews, design reviews of flight hardware and supporting ground equipment and related software, acceptance reviews, launch and flight readiness reviews, and post flight analysis summary reviews. One specific review required is a NASA management design review six months after contract go-ahead which shall cover all elements of the Project.

4.1.6 Data Management

The Contractor shall prepare a Data Management Plan for approval. That plan shall list all required documents, including Government furnished, the schedule on which they are needed, and their control and traceability. The controlling, Contractor-prepared, Project document shall be the Viking Mission Specification. The Contractor shall prepare all documents related to his tasks and identify whether they shall be submitted for approval, review, or information. An approval document requires formal Langley Research Center approval before implementation. A review document permits implementation if Langley Research Center response is not received within an agreed-upon period of time. Information documents do not require Langley Research Center response.

4.1.7 Logistics

The Contractor shall plan and provide all logistics affecting his tasks under this Statement of Work in accordance with an approved plan. He is not responsible for logistics of Government-furnished items until they are delivered or otherwise interface with his tasks.

4.1.8 Spares

The Contractor shall provide spares for the equipment he furnishes as necessary to assure a high probability of mission success. The Spares Plan shall be submitted for review.

4.1.9 Safety

The Contractor shall accomplish all effort under this Statement of Work in accordance with an approved Safety Plan which is in conformance with appendices 14 and 15. He shall also comply with all applicable Federal, State, and local laws, regulations, ordinances, and codes relating to safety. The Contractor shall immediately report to the Langley Research Center any accident or incident resulting in a fatality, disabling injury or property loss of $10,000 or more or which causes serious delay endangering the meeting of required launch dates. The Contractor shall thoroughly investigate all such accidents and incidents and furnish the Langley Research Center with a report of the findings and the proposed and/or completed corrective actions to prevent recurrence. The Contractor shall assure that his subcontractors adhere to the approved Viking Safety Plan and other applicable safety procedures.

4.1.10 Technical Integration

The Contractor shall accomplish all technical integration required to achieve the Project objectives, such as: integration of the Viking Lander Capsule and Viking Orbiter to produce the Viking Spacecraft; integration of the Viking Spacecraft with the Launch Vehicle; integration of the Viking Spacecraft with the Tracking and Data System, etc. This work shall be accomplished in accordance with approved plans. All planning and implementation affecting other Agencies and Contractors shall be accomplished through the Langley Research Center.

4.2 Science Integration

The Contractor shall integrate all science requirements that affect the achievement of Lander science objectives. The Lander science requirements will be provided by the Langley Research Center as a part of the periodic mission definition. Appendix 1 is the first such mission definition. The schedule for subsequent definitions is given in appendix 16. The Contractor shall incorporate this mission definition schedule in his overall planning.

4.2.1 Requirements

The minimum scientific investigation, lifetime, and landing site requirements shall be as defined in appendices 1 and 17. The Contractor shall conduct performance analyses to insure that these can be met or exceeded. He shall define the quality and quantity of data to be returned for each scientific investigation as a function of significant Spacecraft, mission, and operations functions. These analyses shall include coverage, measurement accuracy, measurement range, etc. Each analysis shall be submitted for review.

4.2.2 Integration Plan

The Contractor shall develop and submit for approval a Science Integration Plan which includes all requirements affecting Lander science objectives. The plan shall consider items such as schedules, reviews, and the interface requirements between the Viking Project Office, the Contractor, and the Scientists participating in the Viking Project. This integration plan shall utilize appendices 1 and 16.

4.2.3 Strategy

The Contractor shall develop and update as necessary the strategy for site selection, the complementary use of the Lander and Orbiter, and the use of two Spacecraft. The strategy shall be consistent with appendix 1. The strategy shall consider the Spacecraft, mission, operations capabilities, stay time in orbit before Lander release, real time data analysis, and other pertinent factors. This strategy shall be documented and submitted for approval. Recommended modifications to the Orbiter and/or Orbiter science instruments relevant to strategy shall also be submitted for approval. The Government will implement any approved modifications.

4.2.4 Lander Constraints

The Contractor shall design a Lander to meet the constraints defined in sections 4.2.4.1, 4.2.4.2, 4.2.4.3, and 4.2.4.4 and others dictated by his specific design. The Contractor shall conduct, where necessary, a test program to demonstrate that the constraints have been met.

4.2.4.1 Radiation - The design shall be such that the Lander science instruments be protected from onboard radiation. Protection requirements for the Government-defined instruments are given in section 5.5.8 of appendix 18. Protection from external radiation shall be provided if necessary to assure a high probability of proper instrument performance.

4.2.4.2 Sample Acquisition - The organic analysis, biological, and bound water investigations require that multiple samples of Martian soil be delivered to the science instruments. The Contractor shall deliver a soil sample of at least 5 cubic centimeters for each of the analyses defined in appendix 1.

The Lander Capsule design shall be such that the soil samples used for the biological investigation consist of 80 percent or more Mars soil that has been heated to no more than 10°C above the maximum surface temperature at the landing site for the day of the analysis. Consideration shall be given to heating by the terminal propulsion system, sample collection and delivery system, and all other external sources.

The Lander Capsule design shall be such that soil samples used for the organic analysis and bound water investigations are heated to no more than 50°C above the local surface temperature at the time of sample gathering during the sample collection and delivery process.

The Lander Capsule design shall be such that the soil samples used for the organic analysis investigation contain less than one part per 10 million organic material released from the Lander Capsule.

The Lander Capsule design shall be such that soil samples used for the bound water investigation consist of less than one part per 10 million water released from or produced by the Lander Capsule.

4.2.4.3 Water - The Lander Capsule design shall be such that the humidity and free water investigation environments consist of less than one part per 10 million water released from or produced by the Lander Capsule.

4.2.4.4 Entry Data Return - The Lander Capsule design shall be such that all entry data are obtained independent of landing success. It is desirable that as much entry data as practical be stored onboard the Lander for subsequent transmission in case of relay link malfunction.

4.3 Mission Analysis and Design

4.3.1 Mission Analysis and Design Plan

The Contractor shall prepare for approval a Viking Project Mission Analysis and Design Plan describing all aspects of the Project mission analysis and design activities from contract go-ahead through the post-flight analyses of the mission. This plan shall be consistent with the Viking Mission Definition (appendix 1) and shall use the Government-supplied capabilities and constraints for the Launch Vehicle, Orbiter, and Tracking and Data Systems (appendices 2, 3, and 6).

4.3.2 Parametric Mission Analyses

The Contractor shall perform and utilize all parametric mission studies required to establish design limits for Project hardware and software. These studies shall be based on the environments described in appendix 7. The design limits shall be derived from parameter ranges resulting from parametric studies of missions targeted to land anywhere between 20°S latitude and 30°N latitude. The Contractor shall also investigate parameter ranges and corresponding systems requirements resulting from missions targeted to land between 30°N latitude and 75°N latitude. In addition, he shall perform parametric studies for alternate missions corresponding to partial system failures. Based on the results of these studies, the Contractor shall recommend suitable system design requirements for all elements of the Project. These shall be included in a Viking Mission Specification Document. After the various hardware and software system designs have been established and approved by the Langley Research Center, the Contractor shall analyze, define, and document the capabilities of the various systems to perform nominal and alternate missions and update as required.

4.3.3 Mission Design

4.3.3.1 Reference Mission Design - Based on the results of the parametric mission analyses and the resulting Viking System capabilities the Contractor shall analyze in detail a limited number of nominal and alternate reference missions. These shall be developed in accordance with the mission definitions indicated in appendix 16. The reference missions shall include the strategy for the use of two spacecraft and be developed in sufficient detail to permit analyses which cannot be conducted on the basis of parametrics. These analyses, which the Contractor shall perform, shall include preliminary operations planning, development of specific sequences of events, development of programer and command requirements, estimates of the quality and quantity of the scientific data to be returned, and the requirements for trajectory control.

4.3.3.2 Operational Mission Design - In response to Mission Definition No. 4, appendix 16, the Contractor shall perform and document the detail design of the operational missions. The overall operational mission designs shall cover (for nominal and alternate missions) the entire mission from lift-off to cessation of data return from Mars, and shall include at least a definition of the launch arrival, landing and end-of-mission periods, the sequences of events, spacecraft control parameters, the trajectories and trajectory-related parameters, the requirements for trajectory control, and an analysis of the science data to be returned.

4.4 Orbiter System

The Contractor shall recommend to the Langley Research Center for approval the interface requirements between the Viking Orbiter System (VOS) and other Viking systems. The Contractor shall identify and control through the Langley Research Center all technical and schedule interfaces related to the VOS as they affect his tasks under this Statement of Work.

4.4.1 Orbiter Baseline Description

A description of the Government-furnished Orbiter baseline design is given in appendix 3. The Contractor shall participate in the development of the final Orbiter design by defining Orbiter requirements as part of his Spacecraft integration task. Orbiter requirements, as approved by the Langley Research Center, will be implemented by the Government.

4.4.1.1 Orbiter-Mounted Lander Support Equipment - The Contractor shall develop the requirements and performance specifications for all Orbiter-mounted Lander support equipment.

4.4.1.2 Orbiter Baseline Modifications - The Contractor shall identify any Orbiter baseline modifications which would enhance the achievement of the Project objectives.

4.4.2 Test Models and Simulators

4.4.2.1 The Contractor shall furnish Lander test models and simulators for Orbiter development and testing.

4.4.2.2 The Contractor shall identify and submit for approval the requirements for Orbiter test models and simulators for Lander development and testing.

4.4.3 Interface Identification and Control

The Contractor shall identify and control through the Langley Research Center all technical, schedule, and other interfaces between the Lander and Orbiter.

4.5 Lander System

4.5.1 General Requirements

The Contractor shall accomplish all activities such as design, development, fabrication, and assembly of the Viking Lander System. The associated testing responsibility is identified in section 4.7 of this Statement of Work. Three flight-ready Lander capsules are to be provided and be mated with the Government-furnished Orbiters: two of the resulting Viking Spacecraft shall be mated with and launched on separate Launch Vehicles in the Mars 1973 launch opportunity; the third will be a flight backup. Additional Lander capsules as well as components, subsystems, and systems shall be furnished by the Contractor to support the development and testing activities.

4.5.2 Performance Requirements

4.5.2.1 General - The Viking Lander Capsule consists of many components, subsystems, and systems which must function in an overall interrelated manner to accomplish a soft landing and provide the required entry and surface science measurements. Delineated below are only those systems for which there are special requirements. Constraints, including those given in section 4.2, shall be adhered to by the Contractor in designing the Lander.

4.5.2.2 Science - The Contractor shall furnish all required entry and surface science instruments in accordance with appendices 1, 16, 17 and 18.

4.5.2.3 Power - The Contractor shall provide a Lander power system that utilizes Radioisotope Thermoelectric Generators (RTG's) for power generation. A baseline design description of the RTG, which will be Government-furnished, is given in appendix 4. The Contractor shall identify to the Langley Research Center for approval any changes required to the baseline RTG design in order to satisfy Lander power and integration needs. The Contractor shall prepare the Safety Analysis Report required to obtain approval for the launch of an RTG system.

4.5.2.4 Communications - The Contractor shall furnish a Lander communication system capable of: (1) relaying Lander data via the Orbiter, and (2) transmitting data directly to Earth and receiving commands directly from Earth. The communication system shall include the data handling and storage capability required to satisfy all data requirements including those identified in section 4.2.4.4 and appendices 1 and 19.

The direct-to-Earth link shall have the capability to provide: (1) range and range-rate data while simultaneously transmitting Lander telemetry data other than imagery, and (2) simultaneous transmission of imagery and telemetry. The criterion for link design shall be that the performance margin is equal to or greater than the linear sum of the adverse tolerances of all link parameters.

Relay link capability shall be such that about 10^7 bits of surface data can be transferred from the Lander during each communication session with the Orbiter; direct-link capability shall be such that about 10^6 bits of surface data can be transferred each day through the 90th day after landing. The Lander shall be capable of receiving commands from Earth at distances up to 400×10^6 km. Adequate command storage/programer capability to accomplish the planned mission shall be provided onboard the Lander.

The functional interface of the relay communication link with the Government-furnished Orbiter shall be at the RF path.

The Contractor shall accomplish the overall design for the relay communication system including the development of the requirements and performance specifications for all elements of the link and for implementing those hardware elements which are Lander-mounted. Upon Langley Research Center approval, the recommended Orbiter-mounted equipment will be provided by the Government.

The relay communication system shall be designed so that any Orbiter can serve as a relay for any Lander.

4.5.3 Lander-Orbiter Adapter

The adapter between the Lander Capsule and the Orbiter (fig. 2) shall be furnished by the Contractor. The Government will provide a suitable mounting face on the Orbiter to which the adapter can be attached.

4.6 Launch Vehicle, Nose Fairing, and Titan/Centaur Launch Facilities

The Contractor shall recommend to the Langley Research Center for approval the interface requirements between the Spacecraft and the Launch Vehicle, nose fairing, associated ground equipment and the Titan/Centaur launch facilities. The Contractor shall identify and control through the Langley Research Center, all technical and schedule interfaces related to his tasks under this Statement of Work.

4.6.1 Launch Vehicle

The Contractor shall utilize the Launch Vehicle data given in figures 4, 5, and 6 and appendix 2 in accomplishing his tasks.

4.6.2 Nose Fairing

The Contractor shall use a Spacecraft dynamic envelope, within the Government-furnished nose fairing, not to exceed 12-1/2 feet in diameter by 19 feet in length.

4.6.3 Titan/Centaur Launch Facilities

The Contractor shall utilize Government-furnished ETR Titan/Centaur facilities to the maximum extent possible. He shall define and submit to the Langley Research Center as soon as practical his Titan/Centaur ETR facility requirements.

4.6.4 Required Modifications

The Contractor shall identify and furnish his requirements for any mission-peculiar Launch Vehicle or nose fairing modifications. He shall also identify any mission-peculiar Spacecraft or engineering measurements to be transmitted via the Launch Vehicle telemetry system.

4.6.5 Launch Vehicle Availability

The Contractor's plans shall recognize that only one launch pad (No. 41) is available for the Viking Project and that the time between the launch of the first vehicle and the availability of the second Launch Vehicle on the pad, ready for mounting of the Spacecraft, will be approximately 10 days.

4.6.6 Spacecraft Test Models and Simulators

The Contractor shall furnish Spacecraft test models and simulators for Launch Vehicle development and testing.

4.6.7 Supporting Analyses and Data

The Contractor shall provide mission-related data and analyses necessary to support the development by the Government of Launch Vehicle trajectory and firing tables, vehicle loads analysis, etc.

4.7 <u>Testing</u>

The Contractor shall develop and implement a test program that will provide a high level of confidence that all Project objectives will be achieved.

4.7.1 Master Integrated Test Plan

The Contractor shall prepare, submit for approval, and periodically update a Master Integrated Test Plan. The plan shall define the test objectives, concepts, specifications, requirements, locations, configurations, facility and support requirements, flows, schedules, and data reporting for all tests necessary during the development, qualification testing, acceptance testing, proof testing, mission simulation and other phases of the Project. The Contractor shall also submit for approval recommendations for flight acceptance and proof test environmental levels. The Langley Research Center will supply data on Government-furnished items as required by the Contractor for the integrated test plan.

4.7.2 Lander Capsule Component Tests

Component tests shall be performed to verify compliance with Lander Capsule component level specifications prior to, during if applicable, and after exposure to Viking Lander Capsule component Flight Acceptance Test (FAT), and/or Proof Test (PT) environments representing all phases of the mission, including sterilization.

4.7.3 Viking Lander Capsule Tests

Tests shall be performed to verify compliance with Lander specifications prior to, during if applicable, and after exposure to FAT and/or PT environments, including sterilization. Lander compatibility with the Tracking and Data System shall also be demonstrated in accordance with the requirements of appendix 19.

4.7.4 Viking Spacecraft Tests

As a minimum, tests shall be performed to verify (1) Lander/Orbiter functional compatibility; (2) the ability to perform in specification prior to, during if applicable, and after exposure to FAT and/or PT environments; (3) Launch Vehicle and Tracking and Data System compatibility; (4) prelaunch testing at the space vehicle level sufficient to commit to launch.

4.7.5 Aerospace Ground Equipment (AGE)

The Contractor shall furnish all AGE such as that required to develop, assemble, test, sterilize, handle, transport, checkout and service the Viking Lander Capsule and Viking Spacecraft, except for the Government-furnished equipment (section 3.0). AGE is defined in table 1.

4.8 <u>Launch and Flight Operations System</u>

4.8.1 General

The Contractor shall plan, design, develop, implement, test, and participate in the operation of the Launch and Flight Operations System required to accomplish the mission. He shall integrate, through

..e Langley Research Center, the Government-furnished elements into that system.

4.8.2 Planning

The Contractor shall prepare a Master Launch and Flight Operations Integration Plan which outlines the overall system planning approach. To implement that approved Master Plan, the Contractor shall prepare a detailed plan for each major subsystem or element for approval. Examples of such plans include: Launch Operations Plan, Flight Operations Plan, Software Development Plan, Simulation and Training Plan, Operations System Test Plan, and Operations System Design Plan.

4.8.3 Design and Development

The Contractor shall utilize the approved plans to design and develop the Launch and Flight Operations System, including establishment of the requirements for Government-furnished data, equipment, facilities, and support.

4.8.4 Implementation

The Contractor shall furnish all facilities, equipment, software, services, and materials required to implement the system design with the exception of those items which are Government-furnished. He shall prepare and maintain all required operations system schedules. All software and equipment utilized in the Launch and Flight Operations System, whether Contractor or Government-furnished, shall be identified and referred to as Operational Support Equipment (OSE). It is an NASA policy to exclude Contractor-furnished OSE in those facilities which constitute the Tracking and Data System. Deviations from this policy require special approval. The Contractor shall identify to the Langley Research Center for approval any mission-dependent OSE required in the Tracking and Data System. If such OSE is not presently identified as Government-furnished, it will be provided by the Government. OSE is defined in table 1.

4.8.5 Compatibility Testing

The Contractor shall conduct tests to demonstrate compatibility between the Launch and Flight Operations System and its major interfacing Project elements in accordance with an approved plan.

4.8.6 Training

The Contractor shall train Government and Contractor personnel for the conduct of launch and flight operations in accordance with an approved plan. Training shall be conducted by the use of classroom sessions and mission simulation exercises.

4.8.7 Operations

The Contractor shall participate with the Government in the operation of the Launch and Flight Operations System in accordance with approved plans.

4.8.8 Mission Data

Mission data are defined as all data generated from launch through cessation of data return.

4.8.8.1 Mission Data Plans - The Contractor shall prepare plans and associated procedures for the collection, indexing, handling, processing, reduction, delivery and reporting of all mission data.

4.8.8.2 Data Collection Indexing and Delivery - The Contractor shall collect, index, and deliver all mission data except for Launch Vehicle data and the Government-prepared master data records in accordance with approved plans. The Contractor shall package and transport these data from the point of origin to the Langley Research Center and/or other locations to be specified by the Government.

4.8.8.3 Supporting Information - The Contractor shall develop and provide all necessary entry and Lander science support information including, but not limited to, instrument calibrations and imagery supporting data such as photo orientation, location, sun angle, photo geometry scale, and resolution.

4.8.8.4 Data Reduction and Reporting - Launch Vehicle, Orbiter, and Tracking and Data System performance data compilation and analysis will be performed by the Government. The Contractor shall utilize those data along with his Lander performance analysis to produce overall mission performance reports in accordance with approved plans.

4.8.8.5 Post-Mission Data Processing - The Contractor shall identify the requirements for post-mission data processing. He shall generate the software required, perform the necessary operations, and deliver the processed data to the Langley Research Center.

5.0 NASA PARTICIPATION

The NASA will determine Project objectives, requirements, and policy during the fulfillment of the contract. Throughout the course of the contract the NASA will assess the performance of the Contractor in his execution of the contract and will participate to the extent deemed necessary, within the terms and conditions of this contract, to assure satisfactory management, planning, integration, and implementation as required to successfully achieve the Project objectives.

VIKING PROJECT HARDWARE TERMINOLOGY AND DEFINITIONS

Viking Lander System (VLS) - The Lander Capsule and all associated ground equipment.

Viking Lander Capsule (VLC) - All elements of the Lander Capsule (bioshield, aeroshell, parachute, lander, etc.) transported to Mars by the Orbiter.

Viking Lander (VL) - Those elements which accomplish the soft landing on the planet surface.

Bioshield Cap - The section of bioshield jettisoned prior to Lander separation.

Bioshield Base - The bioshield afterbody which remains attached to the Orbiter after the Lander separation.

Viking Lander Capsule Adapter - The interstage structure which joins the Viking Orbiter and the Viking Lander Capsule.

Viking Orbiter System (VOS) - All Orbiter flight hardware and ground equipment.

Viking Orbiter (VO) - The flight article which transports the VLC to the release point in Mars orbit and makes orbital science measurements.

Viking Spacecraft (V S/C) - The VLC-VO combination excluding the Launch Vehicle to V-S/C adapter.

Launch Vehicle (LV) - The Titan/Centaur as modified for the Viking mission.

Viking Spacecraft Adapter - The adapter between the Viking Spacecraft and Launch Vehicle including the isolation diaphragm.

Launch Vehicle System - The Titan/Centaur and all Launch Vehicle flight hardware (nose fairing, etc.), launch facilities and associated ground equipment.

Viking Space Vehicle - The entire vehicle that leaves the Earth's surface.

Aerospace Ground Equipment (AGE) - All equipment and associated software required to develop, assemble, sterilize, checkout, test, handle, transport, and service the VLC, VO, and V-S/C prior to countdown and launch.

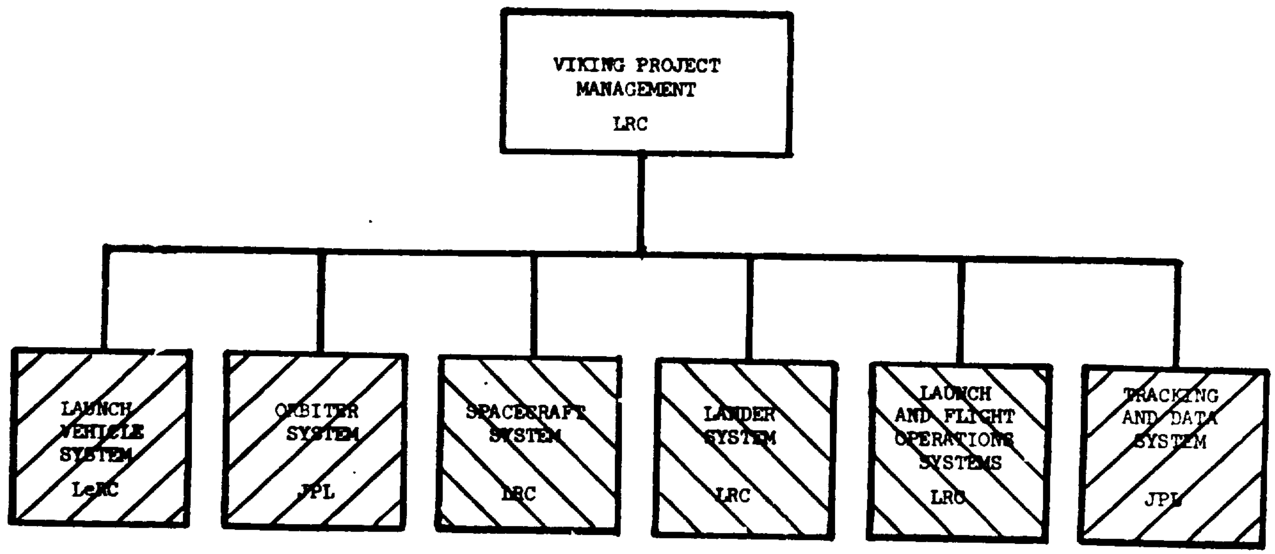
Operational Support Equipment (OSE) - All equipment and associated software required to support the training, countdown, launch and flight operations.

TABLE 1

VIKING PROJECT HARDWARE TERMINOLOGY AND DEFINITIONS - TABLE 1 Continued

Launch and Flight Operations System - Equipment, software, personnel and procedures to conduct spacecraft prelaunch and launch operations and the flight control of the spacecraft in accomplishing the mission objectives.

Tracking and Data System - A selected collection of Earth-based equipment, personnel, and procedures that acquires, transmits, and processes information for the determination of a space vehicle's position, velocity, and performance.



<u>CONTRACTOR FUNCTIONS</u>

Analyze requirements and provide interface management

Plan, design, develop, test and implement

FIGURE 1

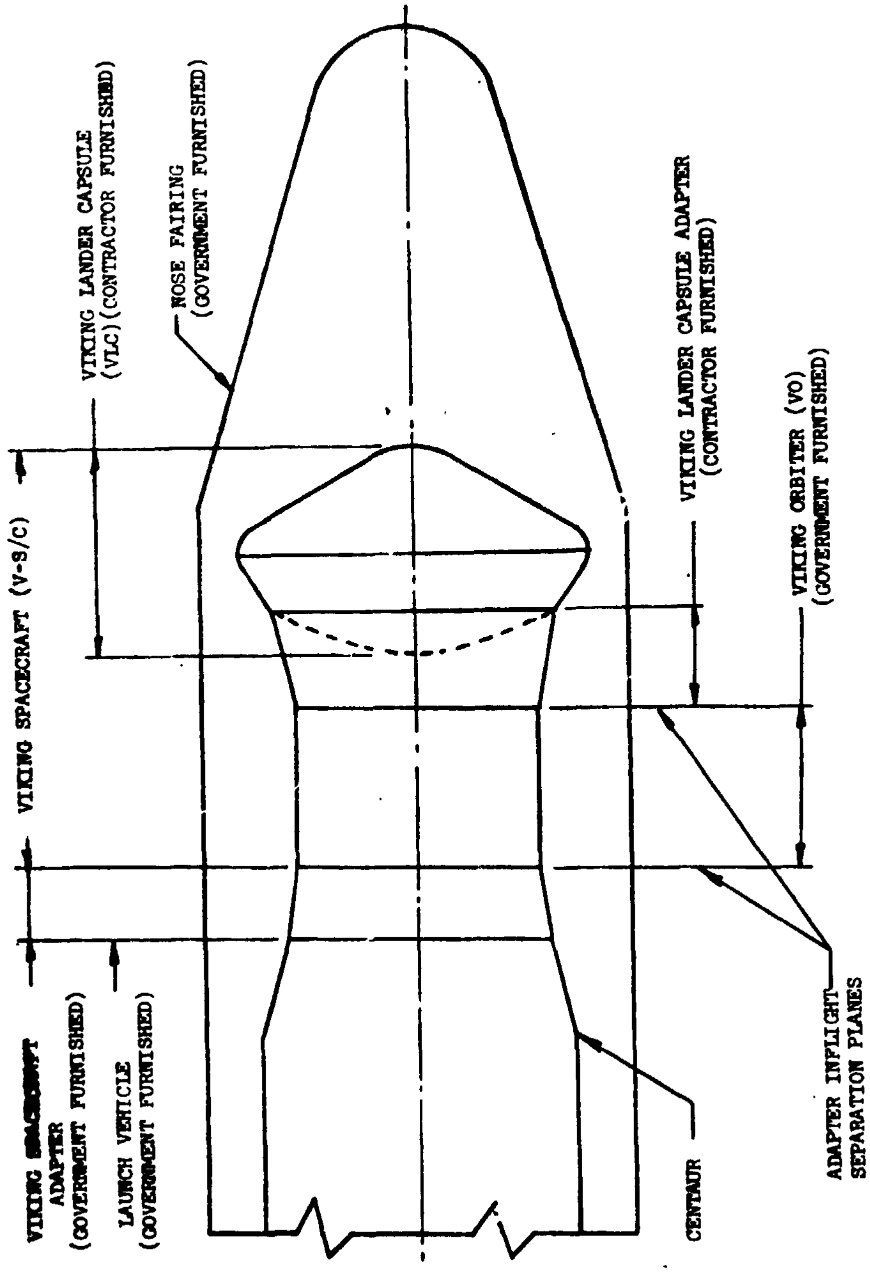
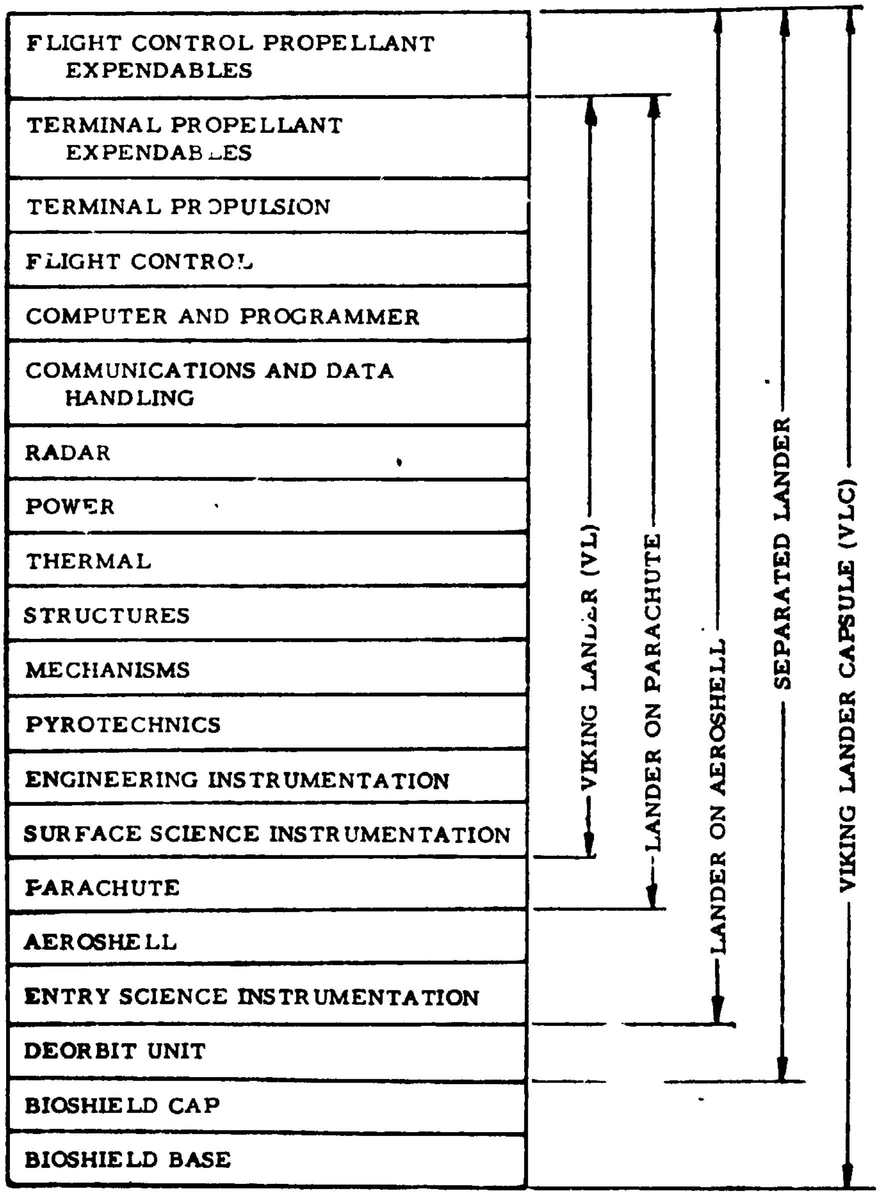


FIGURE 2 - VIKING FLIGHT HARDWARE NOMENCLATURE AND RESPONSIBILITY



VIKING LANDER CAPSULE
FLIGHT HARDWARE TERMINOLOGY

FIGURE 3

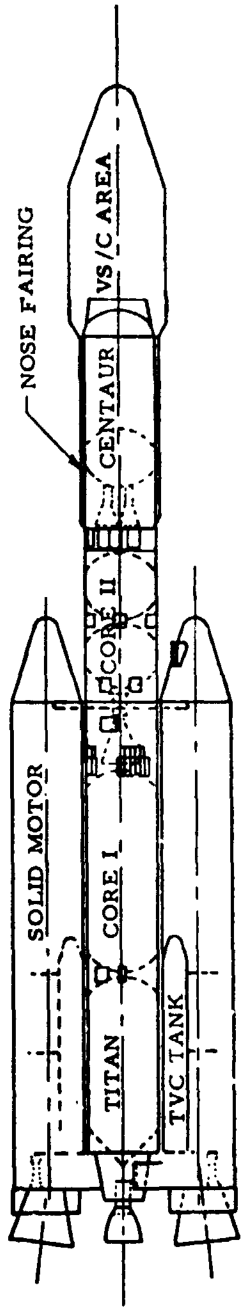


FIGURE 4 - VIKING SPACE VEHICLE

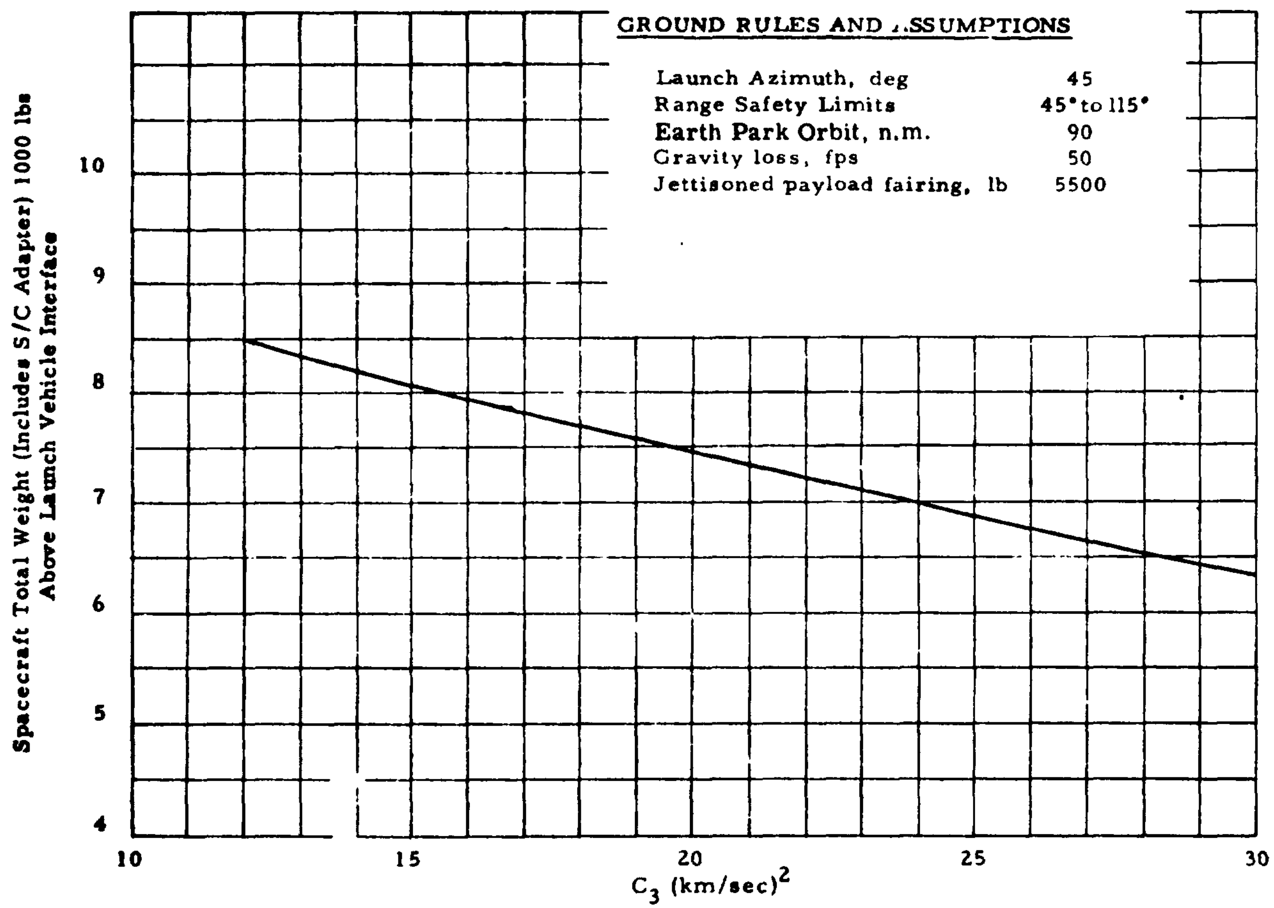
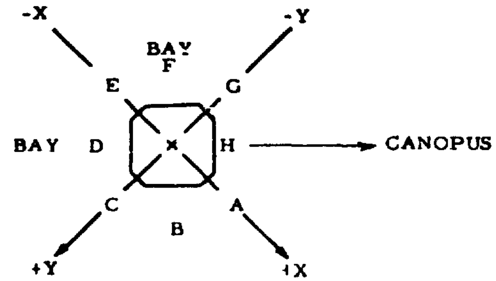
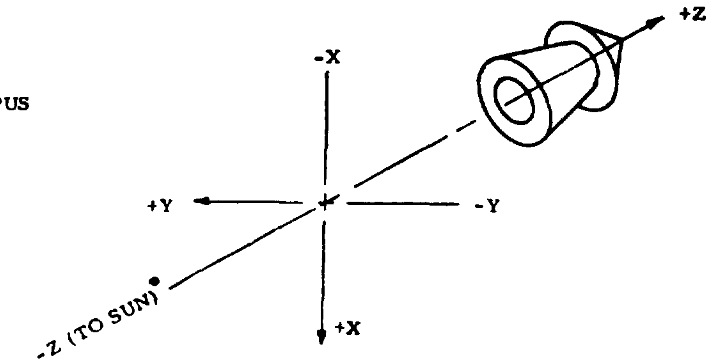


Figure 5 - Titan/ Centaur Estimated Injected Payload Capability



S/C LOOKING FWD

(Equipment Bay Nomenclature Indicated)

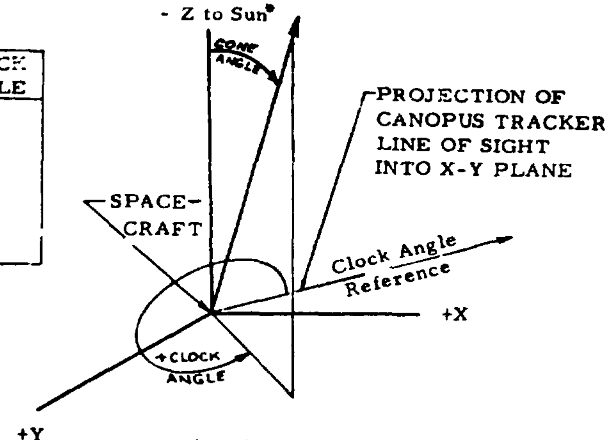


S/C STANDARD COORDINATE SYSTEMS

DIRECTION	AXIS SYMBOL	POSITIVE ROTATION	ANGLE	CONE ANGLE	CLOCK ANGLE
Transverse	X	Y to Z	Pitch	See Sketch	
Transverse	Y	Z to X	Yaw		
Longitudinal	Z	X to Y	Roll		

1. Y - Y axis of Centaur and spacecraft are aligned
2. Forward is up when on launch pad
3. The spacecraft minus Z axis points toward the sun in flight

* NORMAL CRUISE ATTITUDE



S/C CONE/CLOCK ANGLE

FIGURE 6. - SPACECRAFT AXES DEFINITION

NASA-Langley, 1968

J. F. Mc Nulty 334

No. VI-E 732
9-69

LANGLEY RESEARCH CENTER ANNOUNCEMENT

DATE February 19, 1969

SUBJECT: Establishment of Technical and Management Evaluation Committees - Viking Lander System and Project Integration - NASA Request for Proposal L10-9800

1. Two Evaluation Committees are hereby established to assist the Source Evaluation Board in evaluating different areas of the proposals covering subject requirement, as contained in Request for Proposal L10-9800, which will be required to accomplish the objectives of this procurement. Personnel are assigned as follows:

I. Technical Evaluation Committee

I. Taback, Chairman, Viking Project Office, Langley
L. D. Guy, Structures Research Division, Langley
E. A. Brummer, Viking Project Office, Langley
W. J Boyer, Viking Project Office, Langley
N L. Crabill, Viking Project Office, Langley
E. B. Geer, Flight Vehicles and Systems Division, Langley
C. L. Gillis, Applied Materials and Physics Division, Langley
J. M. Hallisey, Jr., Applied Materials and Physics Division, Langley
G. A Soffen, Viking Project Office, Langley
J. E Stitt, Flight Instrumentation Division, Langley
A. T Young, Viking Project Office, Langley
F. E. Mershon, Viking Project Office, Langley

II. Management Evaluation Committee

E. C. Kilgore, Chairman, Engineering and Technical Services, Langley
C. T. Brown, Flight Vehicles and Systems Division, Langley
W. R. Glenny, Procurement Division, Langley
A. Guastaferro, Viking Project Office, Langley
R. H. Sproull, Viking Project Office, Langley
D. G. Stone, Analysis and Computation Division, Langley
D. B. Ahearn, Procurement Division, Langley

2. The Technical Evaluation Committee will be assisted by panels which will have the following membership:

I. Science Panel

G. C. Broome, Chairman, Viking Project Office, Langley
W. H. Michael, Jr., Aeronautical and Space Mechanics Division, Langley
M. A. Mitz, NASA Headquarters
G. A. Soffen, Viking Project Office, Langley
G. P. Wood, Aero-Physics Division, Langley
A. T. Young, Viking Project Office, Langley
S. T. Peterson, Instrument Research Division, Langley

II. Mission Analysis and Design Panel

N. L. Crabill, Chairman, Viking Project Office, Langley
J. F. Newcomb, Jr., Viking Project Office, Langley
C. H. Robins, Jr., Viking Project Office, Langley
R. H. Tolson, Viking Project Office, Langley
G. R. Young, Applied Materials and Physics Division, Langley
E. F. Harrison, Aero-Physics Division, Langley

III. Electronics Panel

E. A. Brummer, Chairman, Viking Project Office, Langley
E. M. Bracalente, Flight Instrumentation Division, Langley
W. T. Bundick, Flight Instrumentation Division, Langley
W. F. Cuddihy, Viking Project Office, Langley
R. P. Faust, Viking Project Office, Langley
C. H. Green, Jr., Viking Project Office, Langley
R. F. Harrington, Viking Project Office, Langley

IV. Power and Electrical Integration Panel

R. D. Smith, Chairman, Viking Project Office, Langley
J. L. Patterson, Flight Instrumentation Division, Langley
R. C. Wells, Flight Vehicles and Systems Division, Langley

V. Propulsion and Guidance and Control Panel

H. J. E. Reid, Jr., Chairman, Flight Instrumentation Division, Langley
T. B. Ballard, Flight Instrumentation Division, Langley
D. J. Carter, Jr., Viking Project Office, Langley
H. K. Clark, Flight Vehicles and Systems Division, Langley
L. J. DeRyder, Jr., Viking Project Office, Langley
C. D. Engle, Viking Project Office, Langley
J. L. Jones, Jr., Viking Project Office, Langley
P. R. Kurzhals, Applied Materials and Physics Division, Langley
R. O. Staib, Analysis and Computation Division, Langley

VI. Engineering Mechanics Panel

F. E. Mershon, Chairman, Viking Project Office, Langley
L. D. Guy, Structures Research Division, Langley
P. J. Bobbitt, Dynamic Loads Division, Langley
T. W. E. Hankinson, Viking Project Office, Langley
J. C. McFall, Jr., Applied Materials and Physics Division, Langley
I. W. Ramsey, Viking Project Office, Langley
J. D. Timmons, Viking Project Office, Langley
R. E. Turner, Applied Materials and Physics Division, Langley
W. C. Falk, Flight Vehicles and Systems Division, Langley

VII. <u>Sterilization and Planetary Quarantine Panel</u>

L. P. Daspit, <u>Chairman</u>, Viking Project Office, Langley
O. S. Childress, Jr., Viking Project Office, Langley
D. G. Fox, NASA Headquarters
J. F. Zanks, Flight Instrumentation Division, Langley

VIII. <u>Launch and Flight Operations Panel</u>

W. J. Boyer, <u>Chairman</u>, Viking Project Office, Langley
J. B. Graham, Jr., Viking Project Office, Langley
U. M. Lovelace, Viking Project Office, Langley
D. H. Ward, Viking Project Office, Langley
D. D. Webb, Viking Project Office, Langley

IX. <u>Testing Panel</u>

W. I. Watson, <u>Chairman</u>, Viking Project Office, Langley
R. L. Girouard, Viking Project Office, Langley
N. A. Holmberg, Viking Project Office, Langley
H. L. Smith, Jr., Flight Vehicles and Systems Division, Langley

X. <u>Mission Assurance</u>

E. H. Britt, <u>Chairman</u>, Office of Director, Langley
G. W. Brewer, Viking Project Office, Langley
M. J. Pilny, Viking Project Office, Langley
H. H. Ricker, Jr., Flight Instrumentation Division, Langley
M. B. Seyffert, Fabrication Division, Langley
W. L. Ervi, Jr., Viking Project Office, Langley

3. The Management Evaluation Committee will be assisted by panels which will have the following membership:

I. <u>Management Effectiveness Panel</u>

D. G. Stone, <u>Chairman</u>, Analysis and Computation Division, Langley
A. Guastaferro, Viking Project Office, Langley
C. T. Brown, Flight Vehicles and Systems Division, Langley

A. <u>Management Control and Procedures Subpanel</u>

A. Guastaferro, <u>Chairman</u>, Viking Project Office, Langley
T. N. Bartron, Flight Vehicles and Systems Division, Langley
H. B. Bland, Resources Programming and Control, Langley
W. R. Glenny, Procurement Division, Langley
J. R. Hall, Space Vehicle Design Criteria Office, Langley
E. J. Janota, Procurement Division, Langley
H. T. Thornton, Jr., Flight Vehicles and Systems Division, Langley
F. V. Moore, Procurement Division, Langley

B. Schedule and Implementation Subpanel

C. T. Brown, Chairman, Flight Vehicles and Systems Division, Langley
H. J. Curtman, Jr., Applied Materials and Physics Division, Langley
J. E. Harris, Viking Project Office, Langley
F. E. Jennings, Viking Project Office, Langley
J. F. McNulty, Flight Vehicles and Systems Division, Langley
J. M. Michael, Resources Programming and Control, Langley
* W. M. Moore, Flight Instrumentation Division, Langley
J. D. Pride, Jr., Flight Vehicles and Systems Division, Langley
H. V. Fuller, Flight Instrumentation Division, Langley

II. Qualification and Cost Panel

D. B. Ahearn, Chairman, Procurement Division, Langley
R. H. Sproull, Viking Project Office, Langley
W. R. Glenny, Procurement Division, Langley

A. Capability and Capacity Subpanel

R. H. Sproull, Chairman, Viking Project Office, Langley
V. W. Anderson, NASA Headquarters
W. E. Craig, Jr., Flight Instrumentation Division, Langley
C. M. Lord, Jr., Procurement Division, Langley
J. W. Mayo, Flight Vehicles and Systems Division, Langley
J. L. Raper, Applied Materials and Physics Division, Langley
I. G. Recant, Viking Project Office, Langley
C. Thiele, Fabrication Division, Langley
E. J. Wolff, Flight Vehicles and Systems Division, Langley

B. Cost, Fee and Incentives Subpanel

* W. R. Glenny, Chairman, Procurement Division, Langley
* D. B. Ahearn, Procurement Division, Langley
* C. T. Brown, Flight Vehicles and Systems Division, Langley
* A. Guastaferro, Viking Project Office, Langley
A. J. Hansbrough, Resources Programming and Control, Langley
* W. M. Moore, Flight Instrumentation Division, Langley
* F. V. Moore, Procurement Division, Langley
W. R. Nixon, Procurement Division, Langley
* D. G. Stone, Analysis and Computation Division, Langley
* R. H. Sproull, Viking Project Office, Langley
* E. J. Wolff, Flight Vehicles and Systems Division, Langley

(* Dual Capacity - Costing information to be received approximately two weeks after submittal of basic proposal.)

4. It is anticipated that the Committee , Panels, and Subpanels cited above will be augmented by Jet Propulsion Laboratory, Goddard Space Flight Center, Manned Spacecraft Center, Kennedy Space Center, and Ames Research Center personnel. Names of these individuals will be provided prior to the due date of proposals.

5. The duties of the Committees, Panels, and Subpanels will be to assist the Source Evaluation Board in arriving at its assessments of the proposals in the manner to be prescribed by the Source Evaluation Board. In this connection, an Evaluation Plan will be provided prior to receipt of proposals.

6. Attention of all Committee, Panel, and Subpanel members is directed to NASA Procurement Regulation 3.804-4 which prohibits the disclosure of information regarding this evaluation to anyone who is not also participating in the same evaluation proceedings. The right to information does not extend to the normal chain of supervision affecting any panel member.

Eugene C. Draley
Chairman, Source Evaluation Board

APPROVED:

Edgar M. Cortright
Director

Copies to:
- Each Committee Member (through official channels)
- Director
- Associate Director
- Assistant Directors
- NASA Hqs., Code SL
- NASA Hqs., Code SB
- NASA Hqs., Code BX
- Chief, Engineering and Technical Services
- Procurement Officer
- Viking Project Office
- All Engineering and Technical Services Division Chiefs
- All Research Division Chiefs
- Administrative Services Division
- Assistant Personnel Officer
- Office of Chief Counsel
- Files