PHILCO

A SUBSIDIARY OF Ford Motor Company

AERONUTRONIC DIVISION

GPO PRICE $ ____

CFSTI PRICE(S) $ ____

Hard copy (HC) 3.00

Microfiche (MF) 1.30

ff 653 July 65

FACILITY FORM

N67 16575 (ACCESSION NUMBER)

(THRU) 1

61 (PAGES)

(CODE)

CR-81309 (NASA CR OR TMX OR AD NUMBER)

30 (CATEGORY)

1C41

Publication No. U-3237

FINAL REPORT

STUDY OF THE AUTOMATED BIOLOGICAL LABORATORY PROJECT DEFINITION

VOLUME I OF VI - SUMMARY

Prepared for: Bioscience Programs Division
Office of Space Science and Applications
NASA Headquarters
Washington, D.C.

Under Contract: NASw-1065

Reporting Period: 10 August 1964 - 10 August 1965

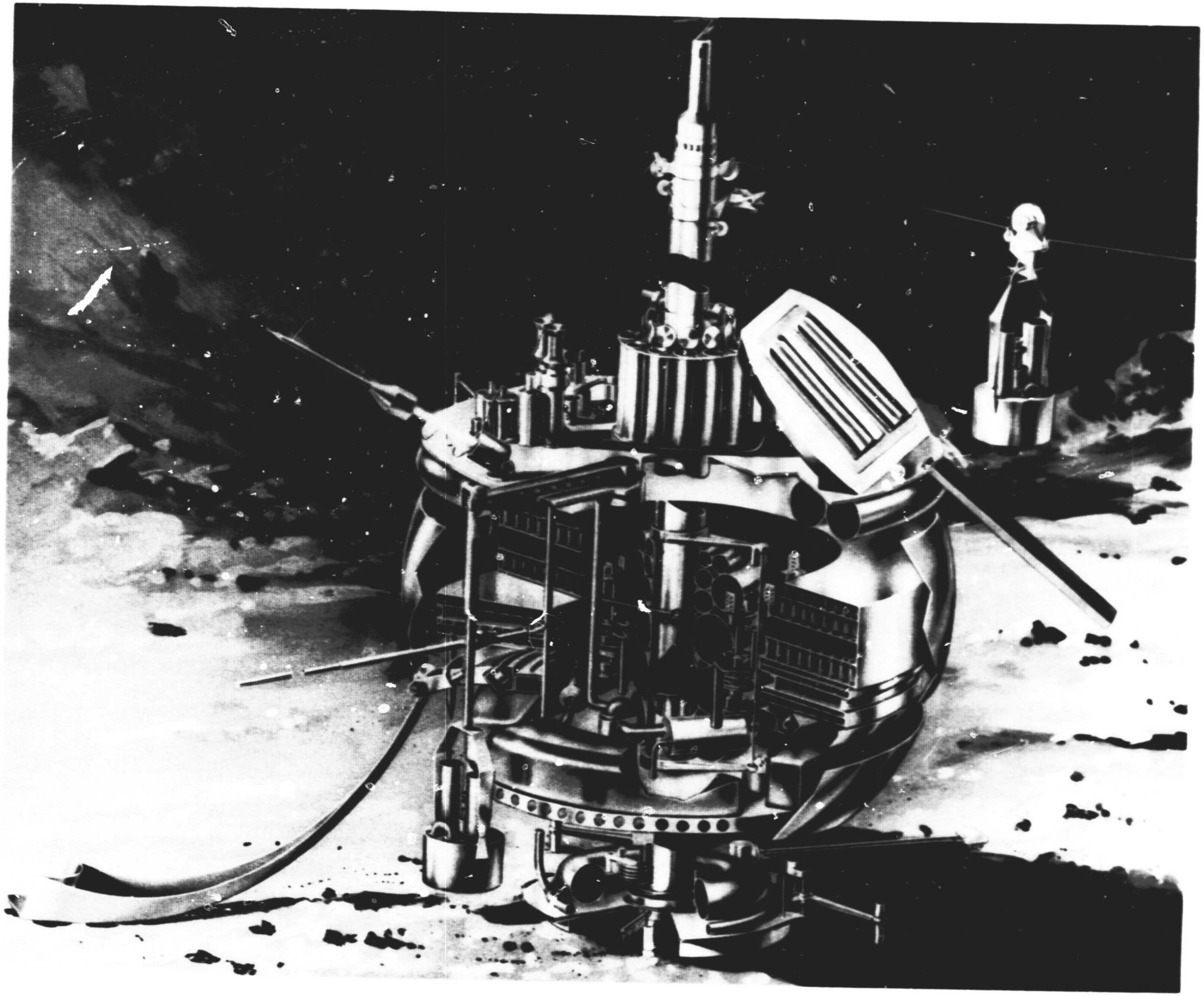
Prepared by: Temple W. Neumann
Temple W. Neumann, Program Engineer

Approved: William Hostetler
William Hostetler, Program Manager

10 September 1965

AERONUTRONIC
DIVISION OF PHILCO CORPORATION
A SUBSIDIARY OF Ford Motor Company,
FORD ROAD/NEWPORT BEACH, CALIFORNIA

ABL DESIGN POINT CONFIGURATION



ABL DESIGN POINT CONFIGURATION

ABSTRACT

This report, in six volumes, contains the results of a twelve-month study conducted for the Bioscience Programs Division, Office of Space Science and Applications, of NASA Headquarters by the Aeronutronic Division of the Philco Corporation. The feasibility of an automated biological laboratory (ABL) for use in the exploration of Mars was investigated. The objectives of the study included definition of the scientific objectives for such a mission, selection of a representative complement of experiments, definition of the required instrument complement, performance of a preliminary design feasibility study for a representative design point payload, and the execution of a program definition and development plan. The first objectives were attained in the study through interviews, discussions, and reviews with scientists in government, academic institutions, and industrial concerns. Desirable objectives and approaches to the biological exploration of Mars were defined. A great many possible experiments, both biological and physical, were evaluated and ranked numerically. A complement of 35 such experiments were selected for purposes of establishing a representative instrumentation payload for a Voyager-class landing mission to Mars in 1975. This payload was used as a basis for conducting a preliminary design feasibility evaluation of an automated biological laboratory.

The concept for an ABL investigated in this study was a departure from current concepts in scientific payload organization. In the ABL concept the experimental program is conducted, not with individually mechanized experiments, but by an integrated complement of basic instruments operated in a sequential fashion, in the same way biological experimentation is performed in terrestrial laboratories. The laboratory is controlled by an on-board computer, with command override capability provided for Earth-based scientists to select alternative experimental programs, or even to initiate completely new programs, in response to the results obtained from preceding experiments. The study results indicate several advantages accruing to the ABL concept. The most important of these is that far more

meaningful scientific results are possible from a given instrument complement operated in this manner than for the same instrument complement operated as fixed predesigned experiments. In addition, weight and reliability advantages are also demonstrated for the concept.

The design point landed payload was designed for two year (Earth) life on the surface of Mars and resulted in an approximately spherical configuration, 68 inches in diameter weighing approximately 1200 pounds.

SUMMARY TABLE OF CONTENTS

CONTENTS

ILLUSTRATIONS

TABLES

Section 1

INTRODUCTION

This report, in six volumes, contains the results of a twelve-month study conducted for the Bioscience Programs Division, Office of Space Science and Applications, of NASA Headquarters by the Aeronutronic Division of the Philco Corporation to investigate the feasibility of an Automated Biological Laboratory (ABL) for use in the unmanned scientific exploration of Mars. The study included definition of the scientific objectives for such a mission, selection of a representative complement of experiments, definition of the required instrument complement, performance of a preliminary design feasibility study for a representative design point payload, and the execution of a program definition and development plan. The first objectives were attained in the study through interviews, discussions, and reviews with scientists in government, academic institutions, and industrial concerns. Desirable objectives and approaches to the biological exploration of Mars were defined. A great many possible experiments, both biological and physical, were evaluated and ranked numerically. A complement of 35 such experiments was selected for purposes of establishing a representative instrumentation payload for a Voyager-class landing mission to Mars in 1975. This payload was used as a basis for conducting a preliminary design feasibility evaluation of an automated biological laboratory.

The concept for an ABL investigated in this study is a significant departure from current concepts of scientific payload organization. In the ABL concept the experimental program is conducted, not with individually mechanized experiments, but by an integrated complement of basic instruments opera in a sequential fashion, in the same fashion biological experimentation is performed in terrestrial laboratories. The laboratory is controlled by an on-board computer, with command override capability provided for Earth-based sci ists to select alternative experimental programs, or even to initiate completely new programs, in response to the results obtained from preceding experiments. The study results indicate a number of distinct advantages accruing to the ABL concept. The most important of these is that far more meaningful scientific results are possible from a given instrument complement operated in this manner than for the same instrument complement operated as fixed preprogramed experiments. In addition, weight and reliability advantages are also demonstrated for the concept.

The design point landed payload was designed for two-year (Earth) life on the surface of Mars and resulted in an approximately spherical configuration, 68 inches in diameter, weighing approximately 1200 pounds. A cutaway view of this payload is shown in the color illustration included as the frontispiece of this Volume.

Section 2

STUDY OBJECTIVES

Broad guidelines for the study were laid down by NASA in the work statement, as for example:

- "The purpose of the study is to define the biological experiments and associated support equipment that will comprise the integrated experimental package known as the Automated Biological Laboratory."

It was further defined that these objectives would be pursued by means of studies conducted in the following specific technical areas:

- Definition of the scientific objectives for the biological exploration of Mars.

- Definition of representative experiment and instrument complements for accomplishing such an exploration.

- Analysis of ABL automation.
- Analysis of a representative design-point ABL preliminary design.
- Analysis of the interfaces between the ABL and other Voyager systems.
- Analysis of some alternative system approaches.
- Analysis of the communication and data processing requirements of the ABL.
- Evaluation of potential landing site locations.
- Evaluation of the relationship between the ABL program and other NASA programs.
- Execution of a representative Program Development Plan.
- Laboratory investigation of the sterilization compatibility of a limited number of materials peculiar to the ABL mission.

Section 3

STUDY APPROACH AND CONSTRAINTS

3.1 INTRODUCTION

It was with a great deal of foresight that NASA undertook, in 1964, the systematic investigation of the concepts underlying an Automated Biological Laboratory (ABL) for use in the scientific exploration of the planets. It should be stated at the outset that these concepts embody a completely new approach to the scientific exploration of planets. They are, in short, a recognition that at some stage of Martian explorations, we must be capable of carrying out scientific investigations, rather than a number of pre-programed experiments. The fundamental difference between the manner in which scientific biological research is conducted in terrestrial laboratories by means of ordered sequential investigations building on preceding results, and the current methods of space investigations employing multiple, independent experiments, was basic to the recognition of a requirement for an ABL. Whatever else a space payload may be with regard to size, weight, complexity, or number of experiments, it falls short of achieving the objectives of an ABL if it fails to provide for this correlated sequential experimentation basic to sound biological research.

Implementing such a concept of planetary exploration is a significant undertaking. Laboratory procedures and techniques that are performed routinely by scientists and technicians must be performed remotely, automatically, and reliably for long periods of time without direct human intervention. The subtle and sophisticated reasoning, planning, and execution that lies behind well-conducted research in terrestrial laboratories must be incorporated into the careful original design and mechanization of ABL experiments, instruments, and a flexibly-formatted control system. While formidable, the task is by no means impossible. The analyses covered by this study have evaluated the many separate aspects of such a mission. Areas have been revealed in which improvements in today's state-of-the-art are required. However, these advances, without exception, are orderly and reasonable extrapolations of today's art and well within our capability of achieving mid-1970 launch dates. No quantum steps in technology improvement are required or have been postulated for the concepts presented in this report.

While admittedly a significant scientific and technical undertaking, the rewards accruing to the development of a planetary exploration research payload based on the ABL concept make it eminently worthwhile. The only possible exploration technique offering comparable scientific return is manned exploration. While an important long range objective of our space program, manned exploration entails long delays to achieve these same objectives. An ABL, soundly-based on established principles of well-conceived biological research, is a logical and efficient interim step between current exploration techniques and the complex manned missions to come. As will be described elsewhere in this report, other concepts for organizing unmanned exploration payloads cannot possibly achieve equivalent scientific results.

3.2 SCIENTIFIC OBJECTIVES

Because the concept of an ABL is so fundamentally related to the methods of science, it was essential that scientific objectives and methodology be considered in its development from the beginning. At the direction of NASA's Bioscience Programs Division, Aeronutronic was instructed to investigate the desirable scientific objectives and the experimental and instrumental composition of such a payload. In this task, we were directed to elicit comments, recommendations, and technical support from individual scientists (not necessarily working in the field of exobiology), established scientific bodies such as the National Academy of Science (and in particular, the Bioscience Subcommittee), various ad hoc and informal working and consultive groups in exobiology, and various individuals and organizations within NASA centers working in exobiology or related fields. The results of this effort are of great importance to the program since they define the complexity of the experimental complement required on an ABL, and indicate the long-term, complex nature of the exobiological exploration problem. A significant additional factor was that the direct contact of Aeronutronic scientists with individual scientists and groups of scientists served to stimulate the interest of the scientific community in the exobiology programs of NASA. For some scientists, this was their first contact with the NASA programs.

The following specific methods of obtaining information needed to determine scientific objectives of an ABL were employed.

- An analysis of published information by experts in the field of extraterrestrial biology and related areas.

- Personal consultation by Aeronutronic scientists with the scientific community including committees, scientific study groups, and interviews with individual scientists.

- Attendance and participation of Aeronutronic scientists at scientific meetings.

- Internal consultation among Aeronutronic scientists.

3.3 DEFINITION OF EXPERIMENT AND INSTRUMENT COMPLEMENTS

To evaluate the engineering feasibility of accomplishing the scientific objectives established for the ABL, it was necessary to postulate an experiment and equipment complement for use in the system engineering studies. While a broad spectrum of experiments (and processing and analytical instruments) was called for by the scientific objective defined, it seemed most reasonable to identify an equipment complement in relation to specific experimental capability, even though such a complement would not be limited to a specific experiment list once it was established. One important consideration was that the detailed instrument and laboratory requirements could be studied and identified with much greater clarity when analyzed in relation to well defined, specific experimental procedures. The decision to proceed in this manner required the identification of both biological and environmental experiments that would be representative of experiments likely to be recommended by scientists for the early- to mid-1970 Voyager missions. The selection of a complement of these experiments was needed which would require instrumentation and processing capabilities exhibiting the majority of engineering problems expected to be encountered in the ABL. The selection of these experiment and resulting instrument complements took place in two distinct steps during the course of the present study.

Initially, Aeronutronic performed evaluations of candidate experiments and instruments from a wide range of sources, utilizing evaluation procedures developed specifically for this task. These sources included the following:

- The life detection experiments under development for NASA were reviewed.

- Scientists who were interviewed suggested and described specific experiments.

- The information obtained at the NAS Space Science Board's Summer Study on Exobiology at Stanford University was analyzed.

- Specific experiments and analytical instruments were discussed with scientists at the Jet Propulsion Laboratory and NASA-Ames Research Center.

- The information gained by attending NAS Bioscience Subcommittee meetings was analyzed.

- A search of the literature was conducted by the Aeronutronic bioscience staff.

Information on experiments, both biological and physical, was subject to analysis and evaluation by Aeronutronic, and each experiment was rated numerically and ranked with others in its class, and resulted in a rationale for selecting an experiment complement.

Following, and concurrently with, these analyses by Aeronutronic personnel review and analysis of these same, and additional, experiments was undertaken by members of the Bioscience Subcommittee of the National Academy of Science, and other informal consultive and working groups from the scientific community and NASA. Recommendations from these groups were correlated with the results of Aeronutronic's own analyses and the resulting complement adopted for use in the ABL preliminary design study.

While it is felt that the resulting experiment and instrument complements fairly represent the best consensus of the many suggestions and recommendations received, it is recognized that others might also have been selected. It will be shown elsewhere in this report, however, that this factor was not critical to achieving the ultimate objectives of the engineering feasibility evaluation. This was true because the selected experiments defined a laboratory capability which was sufficiently comprehensive to accommodate the probable experimental programs that will be suggested by scientists for the early to mid-1970 time period. That is, most engineering problems expected in payloads of this kind have been revealed by the laboratory design selected. These problems have been analyzed in considerable detail in this study, and solutions have either been found, or the remaining critical factors identified and straightforward development requirements set forth.

3.4 SYSTEM ENGINEERING STUDIES

3.4.1 ABL SYSTEM DEFINITION

In order to perform the systems engineering evaluations based on the experiment and instrument complements selected by the foregoing studies, it was necessary to define, as precisely as possible exactly what the ABL system should include. Clearly the experiments, and the instrument and processing capability required for their performance, are an essential element of the ABL. Also essential are certain support systems required

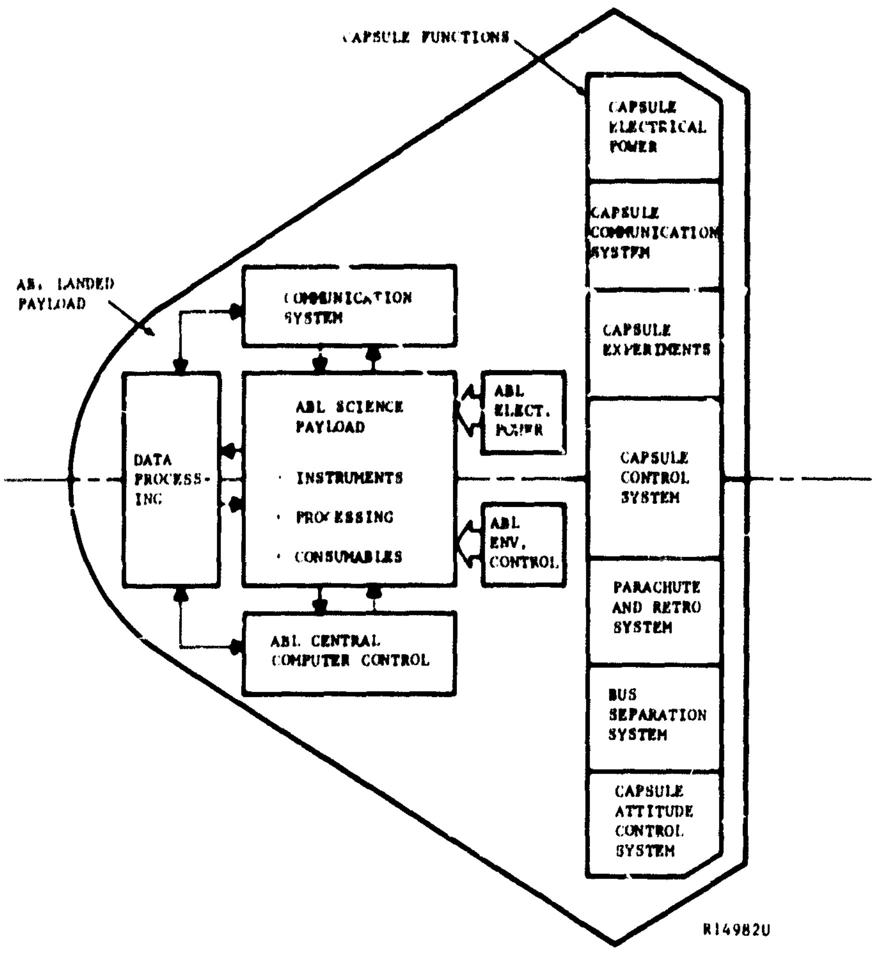


FIGURE 3-1 ABL FUNCTIONAL BLOCK DIAGRAM

for the proper functioning of the experimental payload. In order to define what these support systems are the functional block diagram shown in Figure 3-1 was prepared. The depicted concept assumes that the basic laboratory analytical capability is organized in a way that permits any experiment to utilize the full capability of the laboratory. It is also assumed that the operations are controlled by a central onboard computer in such a way that changes in preprogramed complement of experiments can be accomplished by means of internal feedback from previous experiments, from the results of other laboratory functions such as failure detection, or by Earth command.

It was clear at the outset of this study that certain of the subsystems shown in Figure 3-1 were so intimately related to basic ABL functions that they were inseparable from it in a system sense. Among these are the central onboard computer control and data processing subsystems. Other subsystems can be considered as either a part of ABL or as a part of the entry vehicle system, depending upon the specific mode of organization chosen for each; however, it appeared that the most thorough systems engineering analysis would result when all principal subsystems affecting the ABL's long-term operation were considered integrally with it. This approach was therefore adapted for this study and the term "ABL landed payload" established to designate this entity and to distinguish it from other terms in use such as the "science payload" and the "entry vehicle payload." The ABL landed payload is defined as the ABL or science payload (containing the instruments, processing equipment, and consumable laboratory supplies) plus its necessary supporting subsystems for complete long-duration independent operation on the Martian surface. These subsystems are electrical power, data processing and control, communications, environmental control and structure.

The total entry vehicle payload, then, is composed of the ABL landed payload plus the entry vehicle subsystems consisting of entry instrumentation, bus separation system, attitude control, parachute deceleration system and terminal retro and/or deceleration systems, if employed. A separate electrical power supply and communication system to provide for these entry vehicle subsystem functions may also be required, of course, depending on the details of the system mechanization.

It is recognized that other arbitrary definitions of what constitutes the ABL system can be advanced. It is important to note, however, that in the study results reported in the following section, certain significant performance and functional advantages do accrue to the definition adopted here in addition to the one advanced for its use in this study, i.e., that it permitted a more thorough and comprehensive system analysis to be performed.

3.4.2 STUDY APPROACH

In general, two broad categories of system study approaches can be taken, and the objectives are considerably different in the two cases. It is possible to pursue broad parametric studies in which the objectives are principally gross system optimization and comparisons with alternative approaches. Alternatively, it is possible to select a representative design point case and to examine that case in considerable depth by means of preliminary design studies so that engineering and development problems residing at the level of principal components and subsystems can be identified and evaluated. The ABL presented certain inordinately complex problems in the system engineering evaluation because of the broad scope of the mission (and the study) and because of the unique problems represented in combining the objectives and methods of research biology and space systems engineering. In order to achieve meaningful results in these areas, it was absolutely essential to pursue the definition of problem areas in sufficient detail so that critical aspects effecting system feasibility would be brought to light. Because the number of such potential problem areas was very large this objective represented a significant effort.

At the same time, it was not possible to ignore the gross system performance and its relationship to other approaches. However, it was concluded that because of the considerations stated above, and the fact that the evaluation of systems feasibility should be the principal study objective at this early stage, the major emphasis should be placed on a design point evaluation. Overall system optimization was curtailed thereby, although by no means eliminated from the study. NASA concurred in this decision and established the criteria defined below for the selection of the design point case to be examined.

3.5 STUDY CONSTRAINTS

The design point case represents a single set of parameters out of the entire matrix of possible parameters that could be selected. One overriding consideration in making this selection was that it is desirable to select parameters that define a payload which will exhibit all of the principal problems that can be reasonably expected for similar payloads in the time period of interest. The selection of the design point instrument complement previously discussed was accomplished with this objective in mind. The instrument complement defines, to a large extent, the other functions of the laboratory, and therefore resulted in a very comprehensive laboratory capability.

The remaining question regarding definition of the design point system parameters had to do with payload size and mission constraints. These were defined for the study by NASA and are described, along with many of the detailed implications which they created in terms of design criteria, in Section 5.2 of Volume III. The most important criteria are listed below in Table 3-I. Although the design point mission was 1975, those analyses which were time sensitive, such as the communications analysis, were evaluated over a range, usually from 1970-1980.

TABLE 3-I

PRINCIPAL STUDY CONSTRAINTS

MISSION TIME	1975
MISSION DURATION	Two Earth years on Mars
PAYLOAD SIZE	500 - 1000 pounds
MISSION PHILOSOPHY	The mission is to be a comprehensive biological and related environmental surface exploration, probably following orbital and possible simple entry or landing mission in 1969, 1971, and 1973.

Section 4

SUMMARY OF STUDY RESULTS

4.1 DEFINITION OF SCIENTIFIC OBJECTIVES

The investigation and evaluation of the several sources of information discussed in the preceeding section resulted in a very extensive amount of data being acquired relative to desirable scientific objectives for the exploration of Mars. The data gathered from the literature was analyzed to derive the goals which seemed to be implied from (1) assumptions concerning Martian biology, (2) stated objectives of contemplated probes, (3) specific techniques and equipment suggested for use in the scientific exploration of Mars, (4) suggested preparatory experiments to be conducted in terrestrial laboratories, and (5) the expressed desirability of the biological exploration of space.

4.1.1 BIBLIOGRAPHY

During the period between September 1964 and April 1965, a continuous current literature search was conducted. Pertinent articles were compiled and annotated. This exobiology bibliography contains 425 references dealing with various aspects of the problem of detecting extraterrestrial life, with special emphasis on techniques and instruments. This bibliography forms Volume V of this report.

4.1.2 INTERVIEWS WITH INDIVIDUAL SCIENTISTS

The initial effort by Aeronutronic scientists to contact members of the scientific community consisted of a letter to prominent scientists asking for an oral interview to discuss their ideas and opinions concerning the scientific objectives of an ABL. A follow-on letter explaining the program in more detail was sent to a number of scientists who wished additional information prior to the interview. Subsequently, 144 scientists were interviewed by senior members of Aeronutronic's Biosciences staff. The data are briefly summarized in Table 4-I. The information obtained by these

TABLE 4-I

SUMMARY DATA FROM INTERVIEWS WITH SCIENTISTS

No. Scientists Contacted by Letter:	355
No. Scientists Interviewed:	144
Disciplinary Distribution	
Biologists:	110 (incl. 40 Biochemists)
Chemists:	17
Physicists:	8
Engineers:	9
Professional Affiliation	
Academic Institutions:	75%
Industrial Concerns:	25%
Professional Activities	
Related to Exobiology:	25%
Not Related to Exobiology:	75%

(Note: Percentage distribution in 4 and 5 above has no correlation on an individual basis.)

consultations was analyzed in the same manner as that gathered from the literature. However, since this part of the investigation was especially sensitive to the sample of the scientific community contacted, additional detailed information about the nature of the interviews was prepared and evaluated. This information, together with an analysis of the interviews is contained in Appendix 2 of Volume VI of this report.

4.1.3 RESULTS OF THE STUDY OF SCIENTIFIC OBJECTIVES

The direct responses of scientists to interview questions and the search of the literature constituted the most tangible part of the effort to define the basis for the scientific objectives of the ABL. With few exceptions, life detection and its partial characterization were specifically stated to be the primary scientific objectives that should be attained. However, other (sometimes long-range) objectives emerged from the analyses. In general, the expressed objectives are included within one of the topics indicated in Table 4-II. Obviously, the information obtained was not always explicitly stated in the form given in the table and its position within one of these categories is subject to interpretation of the interviewer.

The majority of scientists expressed enthusiasm for a program directed toward the search for extraterrestrial life, but a number felt the scientific and technological fallout would outweigh any intrinsic scientific merits. There were a few scientists who were completely opposed to the program. A conscientious effort was made to include in the list members of the scientific community whose pronouncements had been unfavorable to a program for detection of life on Mars. Curiously, the majority of these individuals did not respond to the request for an interview. This result suggests that the sample interviewed may have been biased in favor of the search for life on Mars, or at least was not biased against such a search.

Both the literature survey and the interviews indicated that scientists expected Martian life to be constructed and to function in a manner

TABLE 4-II

EXPRESSED SCIENTIFIC OBJECTIVES
FOR THE BIOLOGICAL EXPLORATION OF MARS

1. Detect life.
2. Chemically and physiologically characterized the life forms detected.
3. Determine if such life has a common origin with life on Earth (this includes both the intertransfer of life between Mars and Earth and common chemical evolution).
4. Establish the evolutionary pathway of Martian life.
5. Determine the interaction of life forms with the environment.
6. If life is not found, discover the factors which prevented its development, and determine the state of chemical evolution on Mars.
7. Look for fossil life and if only fossils are found, determine the factors associated with the extinction of life.

analogous to terrestrial forms and to be based on the same chemical entities and physical principles as terrestrial life.

The scientific objectives for the biological exploration of Mars, as expressed by those scientists interviewed, are extremely broad. The expressed goals involve essentially the same type of studies being pursued in terrestrial biology today. Since most of these objectives have not been attained for terrestrial life, it is clear that all of them cannot be accomplished by a single biological probe on Mars. These findings, therefore, strongly imply the need for a progression of investigations, each increasing in complexity. The first investigations for use in the 1970's should be designed to achieve the basic objective of detecting life, since the detection of life is an essential forerunner to most of the other stated goals. Subsequent investigations should attempt progressively more detailed characterization of life forms detected.

4.1.4 IMPLICATIONS FOR EXPERIMENTAL DESIGN

Detection of alien life is probably one of the most difficult tasks which can be proposed, since no simple satisfactory definition of life has been made. Definitions which have been proposed make it necessary to consider a number of complex phenomena, and materials. One of the ways to define life is to enumerate the properties of systems which are considered to be living. The information obtained by the search of the literature and consultation with scientists indicates that the properties presented in Table 4-III are those most often mentioned in connection with living systems. It is apparent that life has many properties, no one of which is sufficient to define it. Consequently, the confidence with which one can

TABLE 4-III

MOST FREQUENTLY CONSIDERED
ESSENTIAL PROPERTIES OF LIFE

1. Transfer and conversion of energy.
2. Association with molecular aggregate of macromolecules.
3. Ability to replicate, reproduce and grow (including information storage, transfer, and processing).
4. Association with proteins, nucleic acids, lipids, carbohydrates, and certain other unique substances.
5. Possession of catalytic activity.
6. Organization, both macrostructural and molecular (including optical activity).
7. Ability to mutate.*
8. Ability to respond to stimuli (irritability).*
9. Functions in an aqueous environment.**

---

* No experiments suggested for these
** Considered an environmental measurement for purposes of this study.

conclude that an entity is a living system increases with the number of these attributes which can be demonstrated. Therefore to detect life, it seems most reasonable to conduct experiments which demonstrate these properties. This implies that a number of experiments designed to demonstrate different properties are needed and that experiments which demonstrate more than one property may be especially valuable.

In addition to life detection experiments, it is also essential to include environmental experiments which will provide information for use in the performance and interpretation of the biological investigation. The inclusion of the environmental experiments also provides capability which permits useful characterizations of other kinds to be performed, such as geological, meteorological, and paleontological. Such capability makes it possible to obtain useful information even if the selected life detection experiments produce negative results. For these reasons, a comprehensive complement of both life detection and environmental experiments should form the basis of any investigation to detect life on Mars.

4.1.5 CONCLUSIONS

The following factors are of particular importance in planning the scientific objectives and approaches for the ABL: (1) life cannot be detected with certainty; we can only become more confident in our judgment as the amount of correlative information increases, (2) the distribution of life within almost any possible sampling area is not uniform and the distribution patterns are unpredictable, (3) living things are extremely variable in the nature and number of properties they exhibit, and (4) life is a dynamic process which exhibits different properties at different times, often in an unpredictable manner.

These factors form the basis for the conclusion that successful life-detection experiments cannot be performed in the same manner as physical experiments which have been conducted previously as part of the space program. In most physical experiment the entity or phenomenon studied is easily defined with a high degree of confidence, and it exists uniformly or in a predictable pattern (which could be established if need be by the experiment) within the volume to be sampled. The entity, in general, behaves according to well understood physical principles. In addition, for each specific entity or phenomenon, the number and nature of the properties which describe it remain the same. Thus, there is a high degree of certainty and predictability in such physical experiments. Therefore it is possible to correlate, with confidence, the information obtained from separate experiments and to estimate the condition within the volume bounded by the data points. Life detection experiments, on the other hand, are uncertain and unpredictable simply because of the nature of life. Because of this uncertainty, the preferred methods for accomplishing life-detection experiments embody an integrated approach which maximizes the correlation of data and uses feedback to determine logical procedures for providing the greatest evidence upon which to base conclusions. These methods are those upon which the design of an integrated, automated biological laboratory (ABL) is based. An experimental package becomes an ABL because these preferred methods are incorporated in the design. It does not become an ABL because of its size, mechanical complexity, the presence of a particular piece of equipment, or the number of experiments it contains.

4.2 SELECTION OF EXPERIMENT AND INSTRUMENT COMPLEMENTS

In order to perform the system engineering studies identified in Section 2 of this Volume, it was necessary to select a representative design point experiment complement so that instruments and processing equipment could be defined. In accordance with the previously stated objectives for this study, it was essential that the resulting instrument complement be comprehensive enough to reveal the engineering and development problems likely to be encountered on mid-1970 ABL payloads. This was, in fact, an overriding consideration in selection of the experiment and instrument complement for the design point case. To accomplish the foregoing objectives, Aeronutronic began an analysis of both biological and physical experiments that had been suggested by the many sources consulted. Numerical rating systems were developed that considered sensitivity of the method, applicability to the search for Martian life, ambiguity of the method, and many other critical parameters. In the case of sensitivity, for example, actual sensitivity was calculated, in terms of the minimum number of organisms required for the method to detect their presence, and this value became one factor in the rating system. Biological and physical experiments were rated by similar, but different, rating systems. The detailed results of these studies are reported in Volume II of this report.

At the same time Aeronutronic was performing these evaluations, other groups were evaluating the same, as well as different experiments. Results from these evaluations included recommendations of the Committee on Martian Landers of the ad hoc Bioscience Working Group chaired by Dr. Wolf Vishniac, recommendations and suggestions provided by members of the Bioscience Subcommittee of the National Academy of Science at the April (1965) meeting held at Pennsylvania State University, and results of a study of a Minimum Biological Payload performed by Dr. George Hobby's organization at JPL. The results of these various recommendations were evaluated and a representative list of thirty-five experiments selected for use in performing the design point system engineering studies. These experiments and the instrumentation required for their performance are given in Table 4-IV.

To further define these experiments for use in the engineering analysis, detailed experimental procedures were developed, time-line event schedules were prepared for each procedure, and descriptions were prepared for each instrument required. In some cases, this required performing preliminary designs of some instruments which did not exist in the exact form required for the ABL application. All of these analyses are contained in Appendices 5 and 6 of Volume VI of this report.

TABLE 4-IV

EXPERIMENT/INSTRUMENT MATRIX

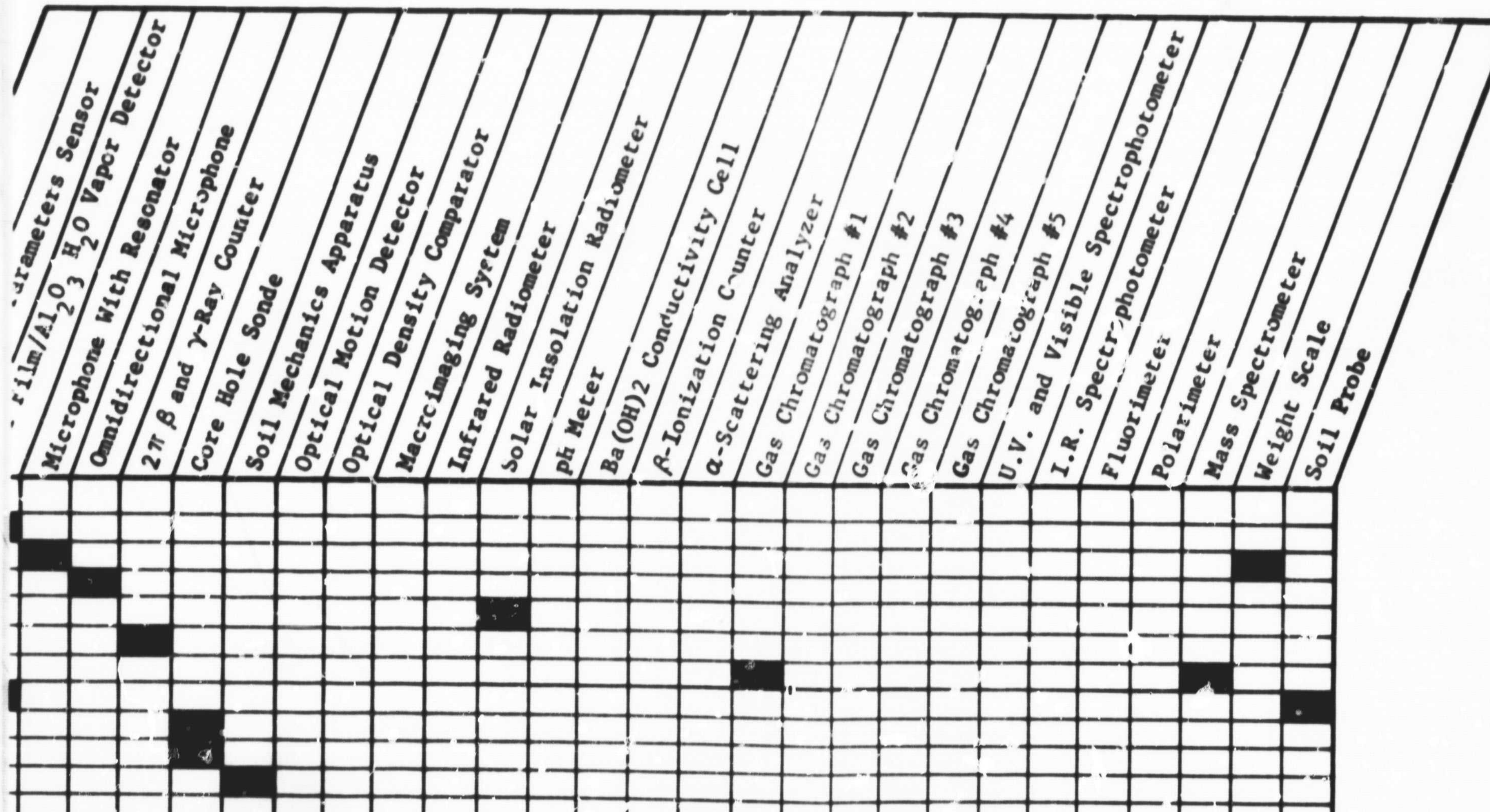
Experimental Priority Code

P_P - Most Primary

P - Primary

S - Secondary

Experiment Number		Relative Priority	Thermometer	Atmospheric	Gold
1.	Atmospheric Pressure, Temperature, and Wind	P	■	■	
2.	Determination of Atmospheric Humidity	P			■
3.	Wind Transported Particulate Matter	S			
4.	Acoustical Monitor	S			
5.	Ultraviolet and Visible Insolation	S			
6.	β and γ Radiation Background	S			
7.	Determination of Atmospheric Constituents	P	■		
8.	Soil Temperature and Water Content as a Function of Depth	P	■		■
9.	Soil Electrical Conductivity	S			
10.	Soil Density by γ-Ray Sonde	S			
11.	Soil Mechanics Determination	S			
12.	Soil Sample Encapsulation and Preservation	P_P			
13.	Elemental Soil Analysis	S			
14.	Soil Gas Analysis	P			
15.	Determination of Soluble Inorganic Ions and pH	P			
16.	Detection of Organic Material in Soil	P			
17.	Soil Gas Exchange	P	■		
18.	Amino Acid Analyses	P	■		
19.	Detection of Amino Acids and Optical Activity	P	■		
20.	Detection of Porphyrins	P	■		
21.	Detection of Flavins	P	■		
22.	Detection of Nonsaponifiable Lipids	P	■		
23.	Detection of Saponifiable Lipids	P	■		
24.	Detection of Macromolecules by Absorption in the Visible Spectrum	S	■		
25.	Detection of Macromolecules by Absorption in the Ultraviolet Spectrum	S			
26.	Optical Activity of Water Soluble Macromolecules	P			
27.	Detection of Water Soluble Macromolecules by Pyrolysis Gas Chromatography	S	■		
28.	Functional Group Analysis	S			
29.	Light Stimulated $C^{14}O_2$ Fixation and Dark $C^{14}O_2$ Fixation as a Function of Temperature	P	■		
30.	Evolution of CO_2 by Normal Metabolism	P	■		
31.	$C^{14}O_2$ Evolution from Labeled Substrate	P	■		
32.	$C^{14}O_2$ Uptake in Light-Dark Subsequent Evolution by Metabolism	P	■		
33.	Culture Evaluation and Growth Detection	P	■		
34.	Motion Detector	S			
35.	Microimaging and Infrared Scan	P_P			


...arameters Sensor
...Film/Al_2O_3 H_2O Vapor Detector
Microphone With Resonator
Omnidirectional Microphone
2π β and γ-Ray Counter
Core Hole Sonde
Soil Mechanics Apparatus
Optical Motion Detector
Optical Density Comparator
Macroimaging System
Infrared Radiometer
Solar Insolation Radiometer
pH Meter
Ba(OH)2 Conductivity Cell
β-Ionization Counter
α-Scattering Analyzer
Gas Chromatograph #1
Gas Chromatograph #2
Gas Chromatograph #3
Gas Chromatograph #4
Gas Chromatograph #5
U.V. and Visible Spectrophotometer
I.R. Spectrophotometer
Fluorimeter
Polarimeter
Mass Spectrometer
Weight Scale
Soil Probe

4.3 SYSTEM ENGINEERING STUDIES

4.3.1 INTRODUCTION

The design point system analysis was undertaken using the experiment and instrument complements defined above. The mission opportunity, payload size, and overall mission philosophy identified in Table 3-I and the design criteria that result from these assumptions formed the basis for this study.

4.3.2 EVENT TIME PHASING STUDIES

The first step in the system studies was the development of time phasing schedules to identify the important sequence of events during the entire two-year life on the Martian surface. The detailed experiment time line event diagrams previously described were used to generate overall event sequence schedules which included laboratory engineering functions as well as experimental events. From these diagrams, data loads, command control events, and electrical power profiles were generated. A considerably simplified example of the results from these studies is shown in Figure 4-1. A period of approximately a month-and-a-half (43 days) is seen to repeat cyclicly. This period resulted from the detailed scheduling of experiments and represents one complete experiment cycle for all experiments at one sample site (and more than one cycle for the shorter experiments, of course). This period is a significant base time in many laboratory operations and is referenced in a number of the studies.

Three or four separate sampling sites are indicated and time sequenced to stagger the sampling power load and equipment availability. The diagram indicates that these basic cyices are repeated at each sample site once each Martian season. This type of scheduling was accomplished in order to size power, communication, and laboratory consumable requirements. However, one of the basic concepts of the ABL is that it can be reprogrammed to modify the preprogrammed experiments or even have new experiments added. Thus, the actual schedule is expected to deviate from the one shown in actual practice. The low level of laboratory activity shown approximately every five months is done intentionally to conserve laboratory consumable supplies so that data may be taken over the full two-year life. This period is also useful for recycling the laboratory to its original condition, for example, by reducing trace contaminants in the atmosphere which slowly build up during operation.

4.3.3 DESIGN POINT CONFIGURATION DESCRIPTION

The configuration of the ABL landed payload resulting from the preliminary design studies has been depicted on the frontispiece of this volume. A line drawing cut-away view of this same configuration with the principal elements identified is shown in Figure 4-2. The overall assembly is packaged into a spherical envelope 68 inches in diameter exclusive of impact limiting material that may be used to protect it on landing. This configuration weighs approximately 1200 pounds and can operate independently on the Martian surface for a period of two Earth years. The configuration is developed as a complete self-contained laboratory with its own power supply, data processing, communications, and environmental control subsystems. This design concept employs the integrated laboratory approach in which it is possible to use analytical instruments and processing equipment in a variety of combinations and sequences. The heart of the laboratory containing the reagent storage, chemical processing equipment, and the analytical instruments is distributed immediately above and below the central plane of the sphere. This portion of the laboratory is pressurized and has a controlled atmosphere. The primary sampling

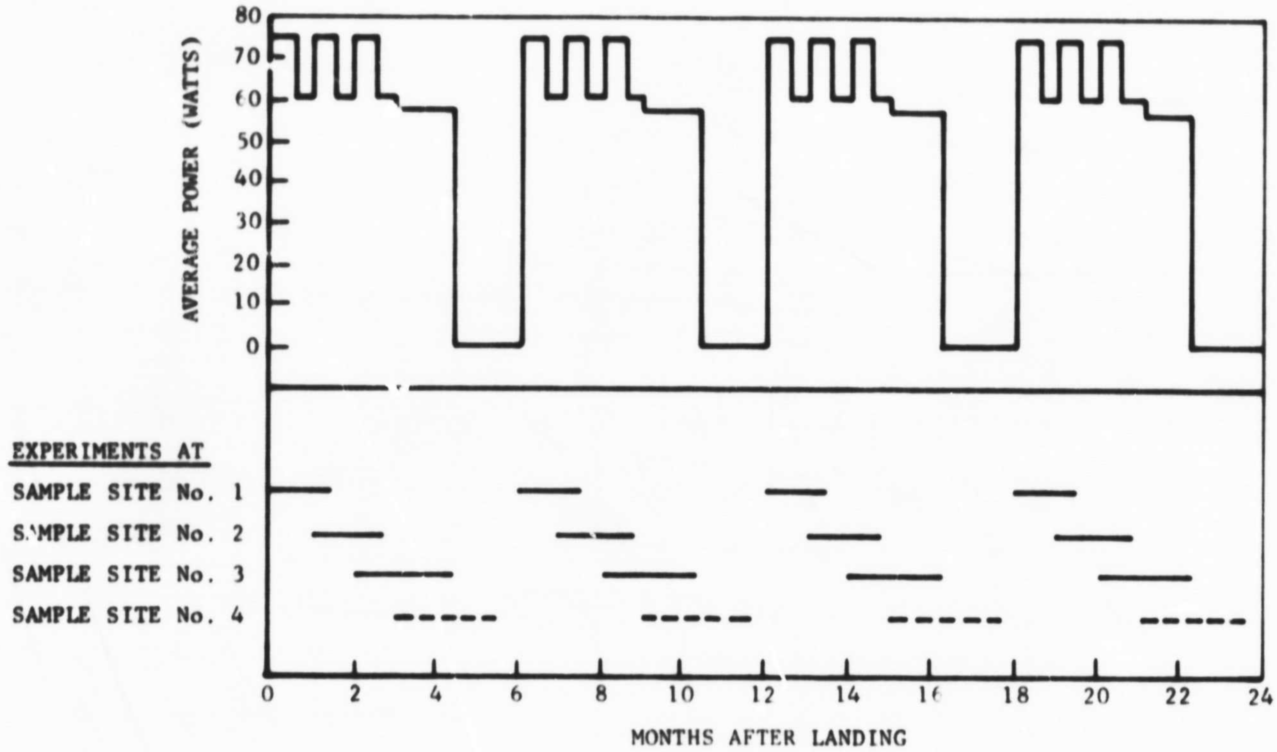


FIGURE 4-1. EXPERIMENT SCHEDULING AND POWER REQUIREMENTS

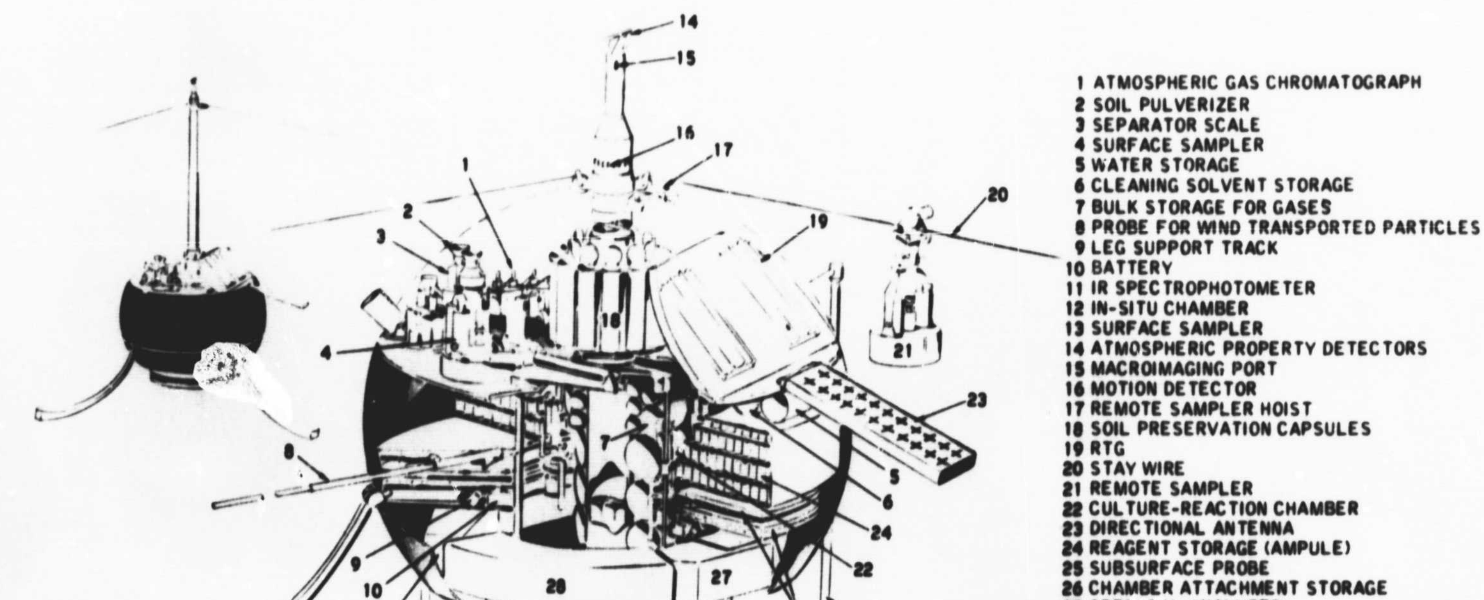


FIGURE 4-2. ABL DESIGN POINT CONFIGURATION

equipment and power supply are located on top of the laboratory with secondary sampling beneath. In its surface operational mode, the laboratory is supported and leveled by three legs, and extends a mast structure up to 15 feet containing experimental instrumentation. The mast also is used in conjunction with the deployment of the remote soil samplers.

The laboratory has been sized on the basis of performing the previously identified 35 experiments, with the capability of repeating each experiment approximately 60 times in the two-year lifetime. The biological experiments are supported by necessary environmental measures to provide correlative and interpretive data. The local environment of Mars is sampled by both visual and infrared scans of the surrounding terrain, by atmospheric gas samples, and by surface and subsurface soil samples.

The bulk of the sample processing is performed in a chemical processor capable of performing the following functions:

(1) Preparation of a soil extract using a solvent.
(2) Perform solution filtrations.
(3) Preparation of controlled concentrations and varieties of solutions.
(4) Preparation of soil extracts using liquid/liquid phase separation techniques.
(5) Controlled evaporation of solutions to dryness.
(6) Controlled pyrolysis or oxidation of solid samples.
(7) Conduct the incubation of a growth culture with a soil sample.

The chemical processor receives the required reagents by two means. Gaseous supplies and bulk solvents are fed through piping to a valve controlled mainfold at the processor. Specific small quantity reagents are stored in ampule form which are transported to the chemical processor with the internal mechanical transport system of the laboratory. The ampule is used as the dispenser for the reagent. Specialized empty versions of the ampule are used to function as a transport ampule to other parts of the laboratory. Thirteen chemical processing units are employed to attain reasonable experiment sequencing and are arranged circumferentially around the central bulk reagent storage. Regeant ampule storage is arranged in a cylindrical fashion around the chemical processor with sufficient space left between the chemical processors and ampule storage for the internal transport mechanism. Auxiliary to the chemical processors are dialysis chambers to reduce salt concentrations in solutions and culture evaluation chambers with optical densitometers to detect changes in turbidity. Each chemical processor utilizes throw-away elements such as filters and chamber sealing elements to provide the capability of easily cleaning and recycling the equipment to its initial condition. The capability to perform a dry heat bake sterilization cycle for the critical surfaces is incorporated into the design.

4.3.4 SUMMARY AND WEIGHT STATEMENT

The summary weight statement for the design point ABL landed payload is given in Table 4-V.

TABLE 4-V

SUMMARY WEIGHT STATEMENT

Item	Weight (lb)	
Analytical Instruments and Detectors	134	
Processing Equipment (including sampling)	268	
Chemical Processor Attachments	121	
Consumable Laboratory Reagents and Supplies	192	
Total Science Payload	715	
Support Systems		
Electronics (Communications and data processing)	84	
Electrical Power	166	
Thermal Control	30	
Structure	191	
Total Support Systems	471	
Total ABL Landed Payload		1186

4.3.5 SYSTEM FUNCTIONAL OPERATION

a. Launch and Interplanetary Transit. This phase of the mission, except for the size and complexity of the payload, will be almost identical to the current Mariner missions. Type I mission trajectories are anticipated because of their shorter elapsed time and more favorable communications range at encounter. For some mission opportunities, a Type II mission gives a more favorable arrival time at Mars from the standpoint of local conditions of interest such as the passage of the dark wave phenomena. However, 1975 does not appear to be such a year. Type II missions will arrive at Mars in the summer (northern hemisphere) or winter in the south. Type I missions appear, in fact, to be more interesting, arriving in the spring in the northern hemisphere.

The lower energy requirements for the Type II mission are expected to have little influence on mission type selection because of the above considerations and because of the adequate performance of the Saturn-class booster systems by 1975. Launch capability should be in the 8-9,000 pound payload classes at that time. The entry vehicle/ABL landed payload complete, as defined by this study, will weigh no more than 5500 pounds (and probably less depending on entry vehicle technology) resulting in ample weight for the bus, sterilization shroud structures, and other requirements.

b. Entry and Landing. The entry phase of Mars landing missions remains difficult to define precisely because of the continued lack of precise definition of the Martian atmosphere. The occultation data from Mariner IV will undoubtedly narrow this range. These data have not been published at the time of this report, however, and it is, therefore, still not clear what retro propulsion may be required to decelerate the landed payload below that velocity attainable with the entry vehicle alone.

Except for this uncertainty, the remaining entry vehcile, payload separation, parachute deceleration, and terminal impact absorption requirements are straightforward applications of existing technology. The entry and landing sequence are depicted in Figure 4-3.

c. Surface Operation. A simplified operating schedule for the two year lifetime on the surface has been described and depicted in Figure 4-1. Figure 4-4 depicts the erection and deployment sequence of the laboratory on the surface following the landing operation. The first day of operation will initiate all those experiments not dependent on soil samples or a known orientation of the laboratory with surrounding terrain. During this day, the facsimile scanning system will go into a sun track mode to determine the proper orientation of the high gain communications antenna. This orientation is achieved by rotating the laboratory in its mounting ring attached to the legs. A fan-shaped antenna beam lying in the plane of the ecliptic will provide Earth-view times of three hours per day in which to transmit data and receive instructions. Subsequent realignment of the beam is performed periodically by electronic switching of the phased array to raise or lower the beam as required. After the communications link is established, the laboratory is free to begin all surface operations required during the two-year lifetime. It will monitor wind velocity and airborne particulate matter to prevent operation of critical elements during hazardous conditions as well as to obtain soil samples from possibly very remote locations.

The ABL will land on the surface of Mars with a set of experimental procedures and routines preprogrammed into its central control computer. These will have been selected from a shopping list of proven experimental concepts proposed by various experimenters in the fields of biology, chemistry, geology, and physics. Evaluation of the results of these experiments may shift the investigation techniques to emphasize

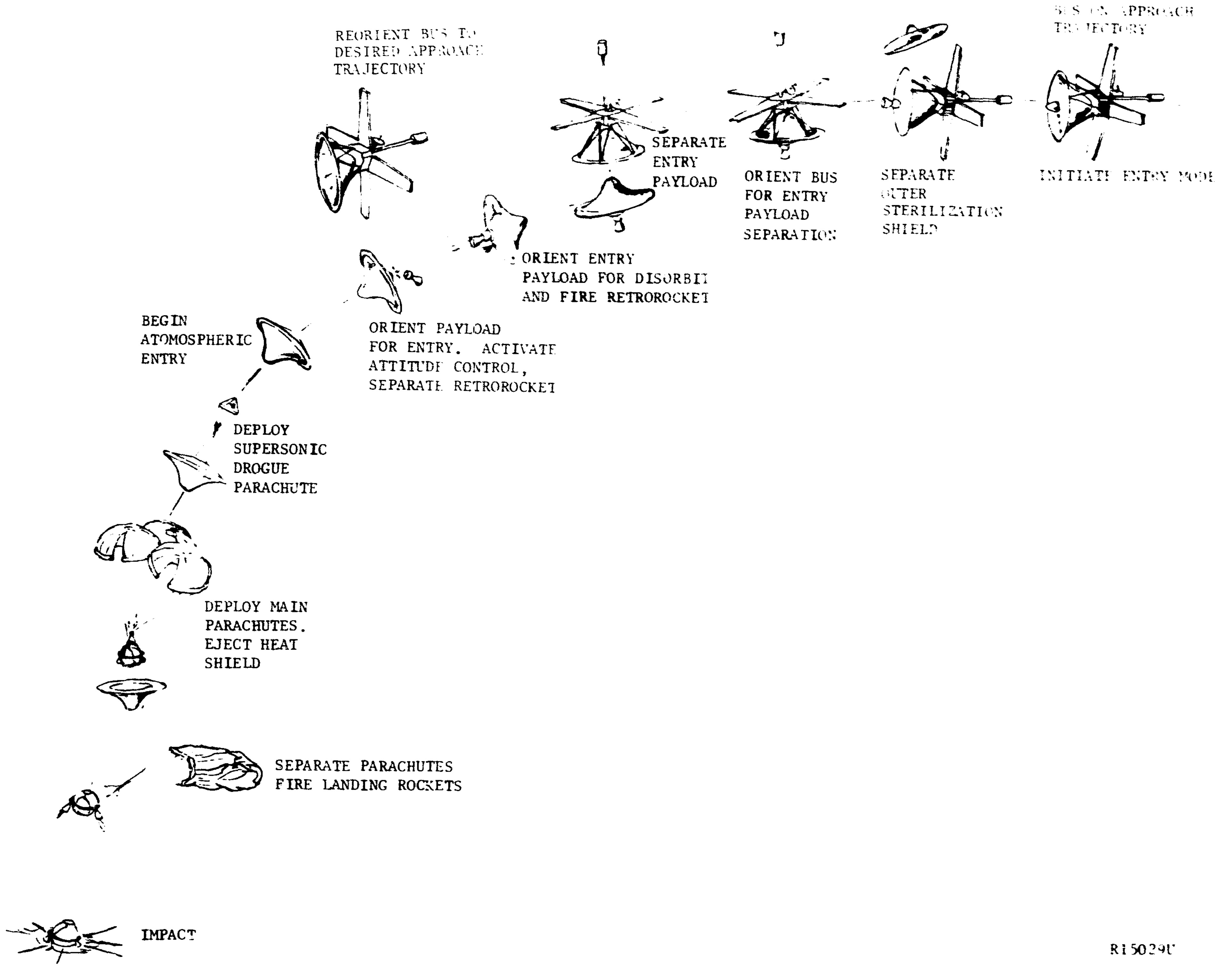


FIGURE 4-3. LANDING SEQUENCE

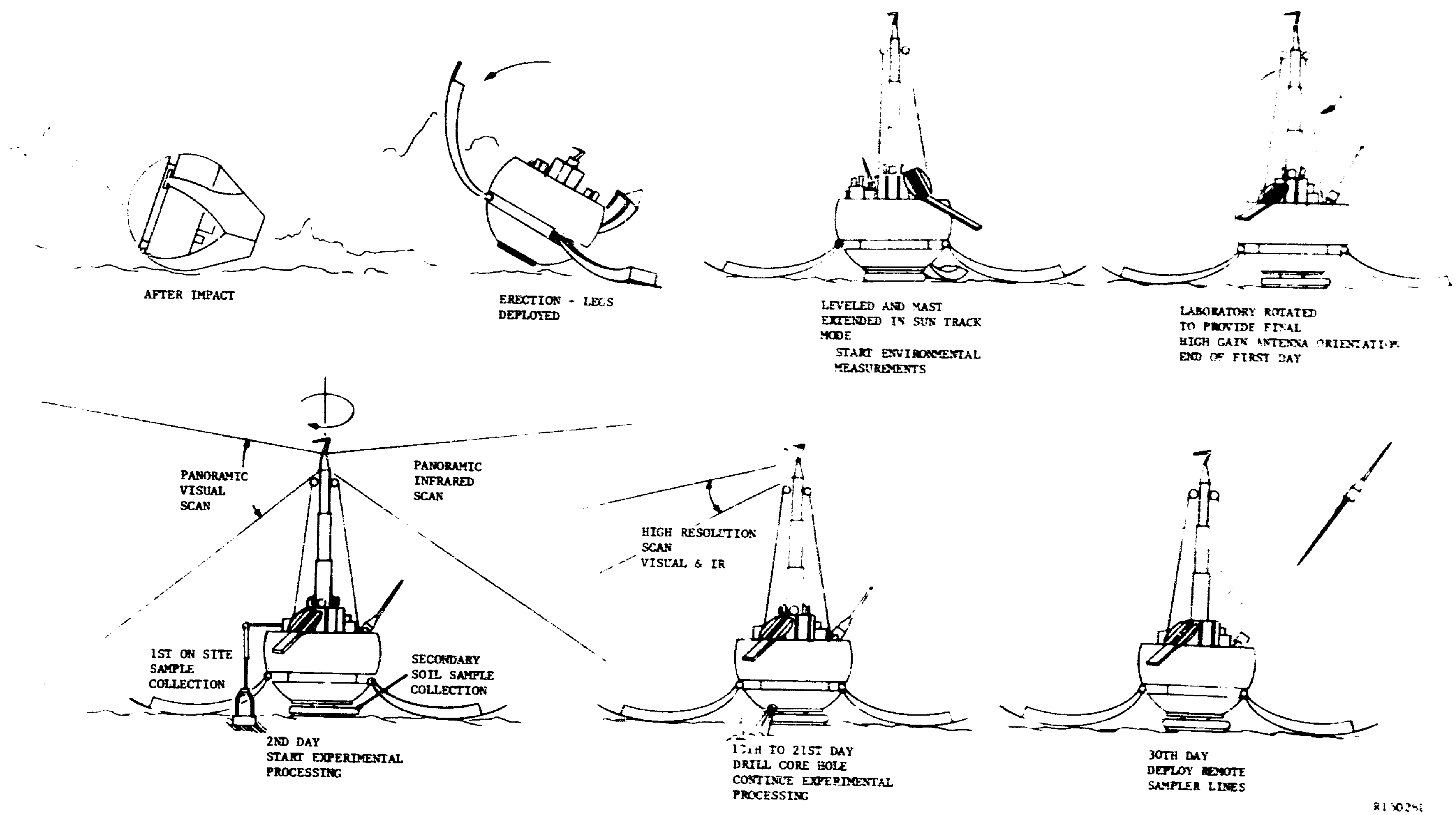


FIGURE 4-4. ABL LANDED PAYLOAD ERECTION AND OPERATIONAL SEQUENCE

biological experiments producing the most interesting results or it may, in case completely negative biological results are achieved, be shifted to physical experiments which could produce more rewarding results. The phasing of experiments and the rate at which they are performed can also be compressed or expanded to allow a more comprehensive evaluation of an interesting transient phenomena or to avoid the useless repetition of experiments when such is indicated. Thus, the experimenters must receive daily data in order to evaluate their experimental results and to coordinate this in terms of the overall operation of the ABL.

The ABL acquires atmospheric gases and atmospheric-borne dust particles by means of a suction blower system. This type of sampling is repeated on a limited basis. Soil samples are acquired at the laboratory landing site and two remote sites per season resulting in a total of 12 sample sites in the two-year lifetime. At each sample site, five subsample batches are collected as follows:

(1) An aerosolizing jet and brush with a pneumatic transport system is used to collect surface soil to a depth of one centimeter in particle sizes up to 300 microns in diameter.

(2) An auger-type cylindrical drill is used to collect soil samples to a depth of 20 centimeters. The soil sample is fed into a rotary pulverizer and the effluent from the pulverizer is graded by pneumatic sieving and transported into a combined cyclone particle collector and weight scale. The graded soil sample containing particles less than 300 microns is weighed and measured into a filter unit and transported to the appropriate chemical processor.

The on-site sampler is boom-mounted so that it may be rotated over the edge of the laboratory and lowered to the surface to collect a sample. By initially pressing the sample collector support structure into the surface, soil mechanics data are acquired as well as information on the nature of the surface.

Remote sampling sites are attained by ballistically deploying an anchor with an affixed cable in a high looping trajectory. After the anchor embeds itself in the soil, a winch takes up the excess cable and pretensions it. A sample collector similar to the boom-mounted version is then attached to a trolley drive system on the cable which is used to carry the sampler along the cable. Power and control are furnished to the trolley and sampler with a wire control link deployed from the laboratory as required. At any selected point, the trolley stops and cable tension is relaxed sufficiently to lower the sampler to the surface where it collects a sample. The cable tension is then re-established to lift the sampler from the surface and return it to the laboratory. This system eliminates the requirement of detail knowledge of the local terrain, thus simplifying the transport problem and increasing the reliability of retrieving the sample. Reasonable range limits of this system are approximately 800 feet over a flat level surface.

The total operating lifetime of the ABL will be determined by failures in the equipment, the power supply, and the rate at which experiments are being performed. The lifetime could be less than two years but a progressive failure rate has been anticipated in evaluating the data return. It is also possible that the lifetime could be appreciably in excess of two years. This is particularly true of those experiments not dependent on chemical supplies such as the environmental experiments, the visual and infrared scanning equipment, background radiation counters, and the mass spectrometer.

4.3.6 ENVIRONMENTAL CONTROL

The environmental control for the ABL must provide two essential functions; i.e., prevention of atmospheric contamination from either internal or external sources, and maintenance of thermal control of the laboratory environment. The chemical processing, reagent storage, and instrument sections of the laboratory are pressurized to essentially one Earth atmosphere with clean dry nitrogen. A closed loop internal circulation system is used to maintain uniform temperatures in the laboratory by convective heat transfer. A scrubber is located in this system to remove gases and compounds released into the internal atmosphere during processing. It also filters solid particulate matter out of the atmosphere which may come from sources such as wear of equipment and dust from soil samples being processed. The scrubber is also used to clean up Martian atmosphere, if it is used as a make-up gas to compensate for leakage. A by-pass on this closed loop circulation system is utilized to obtain waste heat from a RTG power supply as required to maintain the temperature of the laboratory above freezing. The net requirement for the laboratory is a heat input under most of the daily temperature variations encountered. The RTG operates at 5 to 10 percent efficiency and the remaining 90-95 percent rejected waste heat is available for heating the laboratory.

4.3.7 ELECTRICAL POWER SUBSYSTEM

The major power loads for the basic 43 day experiment cycle are given in Table 4-VI. The way in which these loads are distributed on a long term power profile has been shown previously on Figure 4-1. As indicated under environmental control considerations above, a strong interaction exists between the electrical power supply and the thermal control of the laboratory. The RTG (radioisotope thermoelectric generator) is ideally suited to provide for these thermal requirements as well as for the electrical loads of the ABL. The RTG is, in fact, such a perfect match to the operating

TABLE 4-VI

MAJOR POWER LOADS FOR A 43 DAY CYCLE

Load Description	Power	Time	Cycles	Average Power	Time	Energy
Experimental Power - 43 day cycle				8 W	Continuous	7,880 W-H
Includes peak powers:	Power	Time	Cycles			
1. Soil Sampler	100 W	1 hr	1			
2. Soil Processor	15 W	2 hr	1			
3. Pyrolisis Oven	400 W	1 min	10			
4. Evaporation Oven	100 W	10 min	7			
Transmitter and Receiver				200 W	3 hrs/day	25,800 W-H
Data Processor				30 W	Continuous	31,700 W-H
Tape Recorder				10 W	3 hrs/day	1,490 W-H
Coolant Pump				25 W	3 hrs/day	3,210 W-H
Core Drill (Used in first cycle only)				500 W	1 hr/day for 8 days	4,000 W-H
					Total	74,080 W-H

requirements of the ABL landed payload that its availability on time and in the proper sizes and configurations for the mission is mandatory. No particular problems are anticipated in this regard, but some continued development is required. Fuel availability, fuel element packaging, general overall system performance upgrading, and, in particular, improvement in the shock and vibration sensitivity of the units are areas in which work should be pursued.

The design point ABL has requirements for a unit with 70 watts peak power output, and two such identical units are carried for redundancy. One peculiarity of the RTG system is the fact that it must dissipate heat continually from the time it is assembled. When the RTG is enclosed within another system (such as the landed payload), means must be provided for removal of this heat, or the unit and adjacent equipment can be damaged. During the Earth-Mars transit phase, this must be done by means of a cooling loop [illegible] the exterior of the entry vehicle sterilization shroud.

This forms essentially the only critical interface with the capsule. During the terminal sterilization operation, this heat is used to advantage by being shunted into the interior of the ABL payload in a controlled fashion to bring the internal temperature up to the sterilization level in less time and with less severe thermal gradients than if the payload were heated only from the outside.

4.3.8 COMMUNICATIONS

Communications requirements for the ABL can be handled with very conservative extrapolations of today's technology. A direct Mars surface-to-Earth link was found to be optimum in this study and was adopted for the primary mode. However, this does not preclude the use of an orbiter relay to attain higher bit rates if desired. Command control is maintained over the lab by means of an omnidirectional antenna and a command receiver on the ABL. Because of the extremely long range at Earth-Mars conjunction, and the use of a low gain omnidirectional receiving antenna for reliability, it was necessary to postulate the use of a 100-kw transmitter at all three DSN facilities. At present, this capability exists only in experimental, but operating, form at Goldstone.

The main telecommunication data link from the ABL to Earth is by means of an 80-watt transmitter working through a fan beam antenna of 15.5 db gain. The fan-shaped pattern of the antenna is oriented once on landing to lie in the ecliptic plane and is oriented symmetrically about the Mars-Sun line at noon; thus, each day the Earth passes through the long dimension of the beam cross section. For the design point case, this gives a 3-hour transmission time per day. For the parameters disucssed, the communication link capacity varies from about 58 bits/sec at encounter to about 19 bits/sec six months later at conjunction. From this point, the bit rate again increases to a value of approximately 300 bits/sec as Earth and Mars approach the next opposition. Assuming reasonable system mechanizations, this capability will result in a total data load of approximately 3 x 10^8 bits being transmitted in the two year period. The actual data load computed for the design point ABL system is 7 x 10^7 bits, giving a performance capability of approximately 4 times the design point load. These relationships are shown in Figure 4-5, along with the capability of two orbiter relay links investigated.

4.3.9 DATA PROCESSING AND CONTROL

Data generated by the operation of the laboratory equipment must be processed before it is transmitted to Earth. It is necessary to encode the data into transmission format with suitable identifying information and possible with error coding to prevent inadvertant loss of data in the transmission process. In addition, it will be desirable to perform some form of data compression on some of the raw data as they come from the experimental equipment. Redundant data within an experiment output, or between experiments, can be removed in this way without loss of information. Considerable reduction of data from imaging experiments can be achieved by various forms of coding to reduce the load on the communications link. The bulk of data will be stored on magnetic tape units for processing in this way before transmission. The required memory capacity for this function is provided by means of two separate magnetic tape units of 10^8 bits capacity each.

The sequencing of the experimental activity of the laboratory, and the control of essential engineering functions of the ABL landed payload, are performed by a central computer system. This computer contains, in addition to the temporary magnetic tape memory discussed above, a central arithmetic and control unit, a main thin film or core memory of 6 x 10^5 bits capacity in which the executive control and preprogrammed portion of the experimental procedures are stored, and a back-up wired memory of less than 10^5 bits capacity in which critical executive routines and instructions are stored against the possibility of their inadvertent loss from the main memory. All computer functions, including complete redundancy in the auxiliary tape

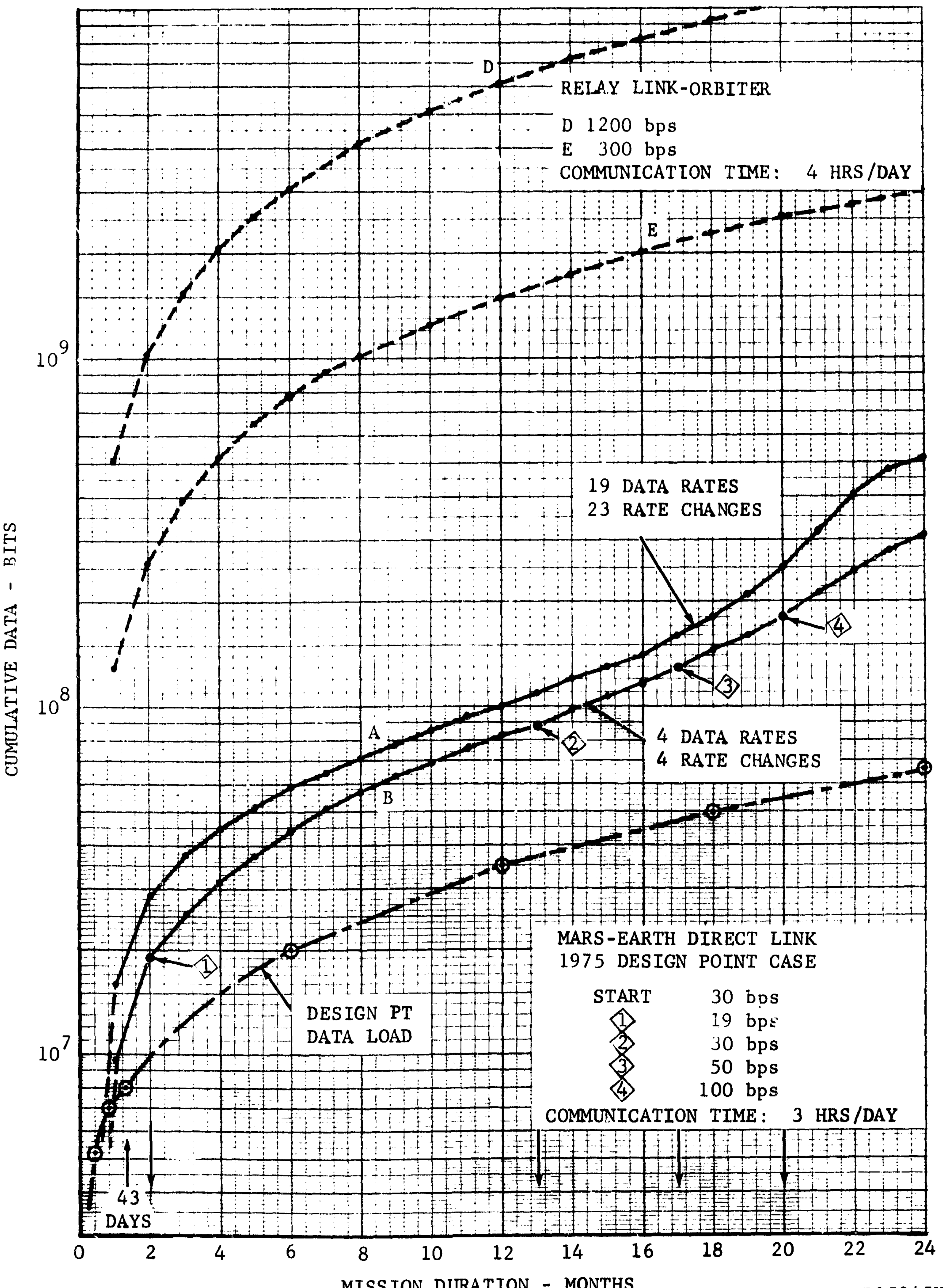
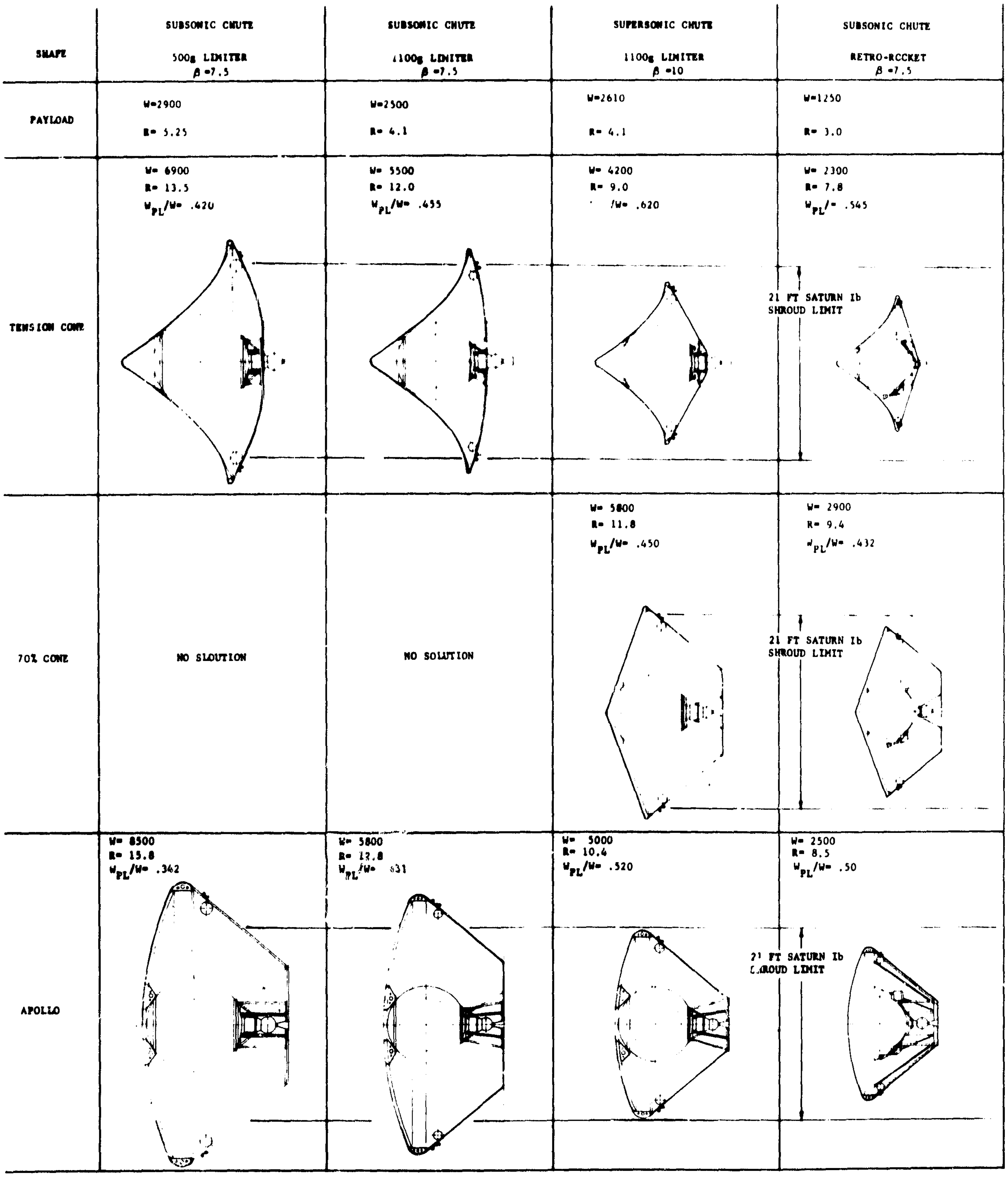


FIGURE 4-5. ABL CUMULATIVE DATA CAPABILITY



R15053U

FIGURE 4-6. COMPARISON OF CONCEPTUAL ENTRY VEHICLE DESIGNS storage, is accomplished for a weight of 17.5 pounds and requires 20 watts average power.

4.3.10 CAPSULE INTERFACE

The ABL landed payload was evaluated as a separate entity from the entry vehicle. The resulting payload (of a given weight) was found to have little influence on the entry vehicle since the entry vehicle is sized by the requirement to attain a low ballistic coefficient in the low density Martian atmosphere. The separable payload configuration used was shown to exhibit both performance advantages (improved payload ratios) and functional advantages over the case where the individual payload components are integrated directly into the entry vehicle structure. The effect of integrating the ABL landed payload with three different entry vehicle concepts was evaluated considering both supersonic and subsonic parachute deployment, two levels of landing impact (500 g and 1100 g) by means of orthotropic passive impact limiters, and one case of retro propulsion and/or other terminal deceleration. The matrix of results from this analysis is shown as Figure 4-6. The analysis was based on a 14 mb surface pressure atmospheric model and essentially current entry vehicle technology. A number of combinations are seen to yield valid solutions (real solutions falling within the Saturn Ib shroud limits).

4.3.11 SYSTEM TRADE-OFF STUDIES

In addition to the entry vehicle studies reported above, a number of other significant system tradeoffs were evaluated during the study. Some of these will be summarized here.

a. Payload Internal Organization. Using the 35 experiments previously identified, and a similar complement of 13, a tradeoff was conducted to evaluate the effect of mechanizing these experiments as individual experiments in the manner of current space payload practice and as an integrated payload as proposed for the ABL payload studied. The weight differential for the analytical instruments alone (including sampling) for these two approaches is shown on Figure 4-7. The lower curve for the separate experiments employs an integrated sampling system identical to that assumed for the ABL. The upper curve assumes an individual sampler of the simplest kind employed on the ABL for each of the individual experiments. Figure 4-8 shows the same cases but with added weights for consumables, support systems, and the required entry system complete. The weight savings for the integrated system approach is seen to be significant.

b. Effect of Staytime. The design point ABL landed payload was evaluated for staytimes less than the design point two Earth years. Consumables, tankage and structure were reduced proportionally with time. No reduction in power supply weight was assumed since the minimum 43-day experiment cycle (below which it is not reasonable to operate a payload as comprehensive as ABL) established the power level at its design value. No reduction in weight with staytime is available from the RTG due to its constant level of output for its useful life (which appreciably exceeds the two years). The results of this tradeoff are shown on Figure 4-9.

c. Effect of Reducing Laboratory Capacity. Weight effects from removing two significant groups of laboratory equipment were evaluated. Proportional reductions in structure, consumables, and power were estimated when appropriate. Removing the core drill and sonde equipment produced a net weight reduction of 32 pounds (<3 percent). Removing 7 of the 13 chemical processing units resulted in a net weight reduction of 132 pounds ($\sim$11 percent).

4.4 DEVELOPMENT PLAN

In defining the ABL development program, it is assumed that the ABL would be the primary payload for the 1975 Mars mission. A summary milestone schedule of the necessary program is shown in Figure 4-10.

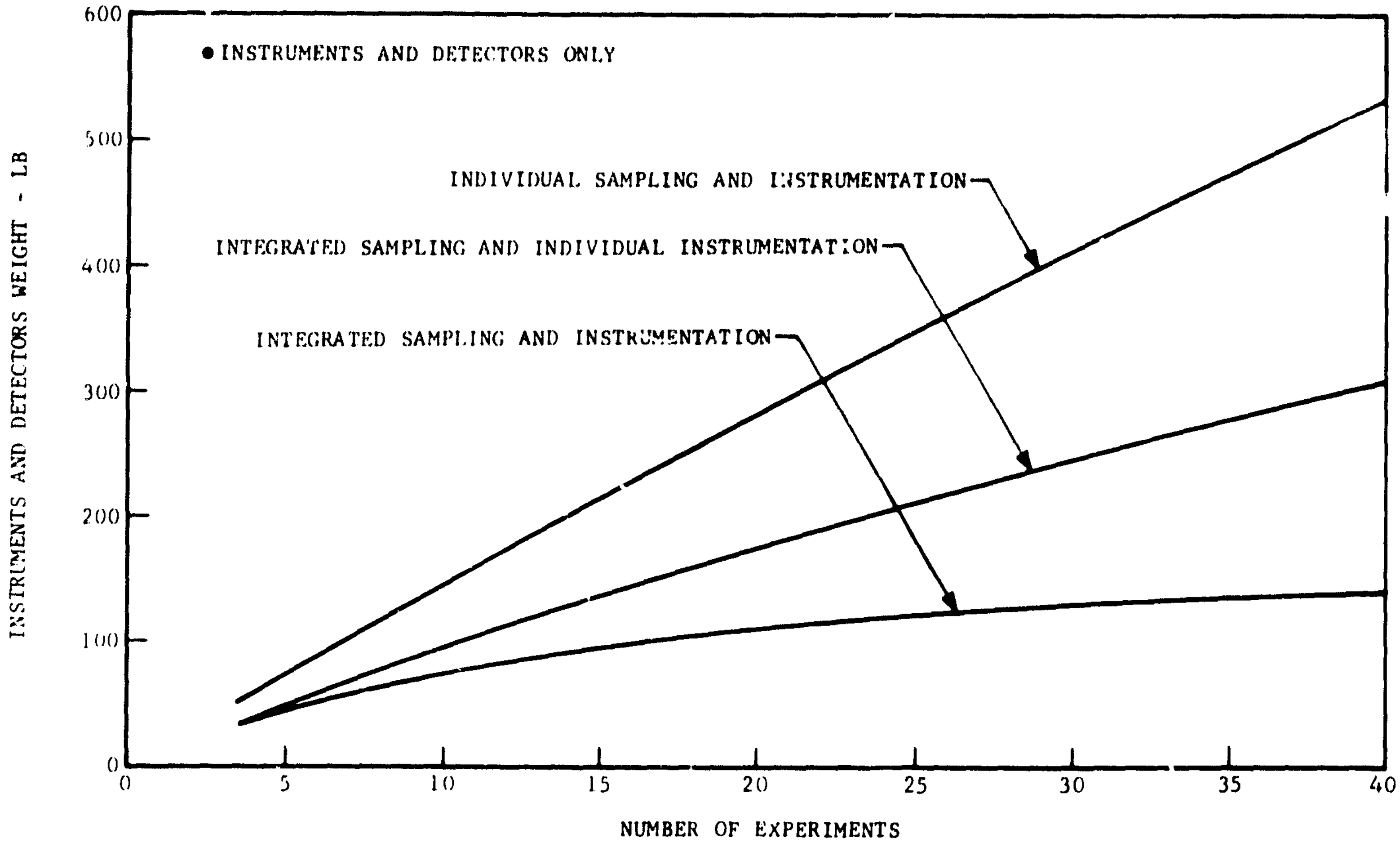


FIGURE 4-7. WEIGHT COMPARISON ANALYTICAL INSTRUMENTS AND RELATED SAMPLING

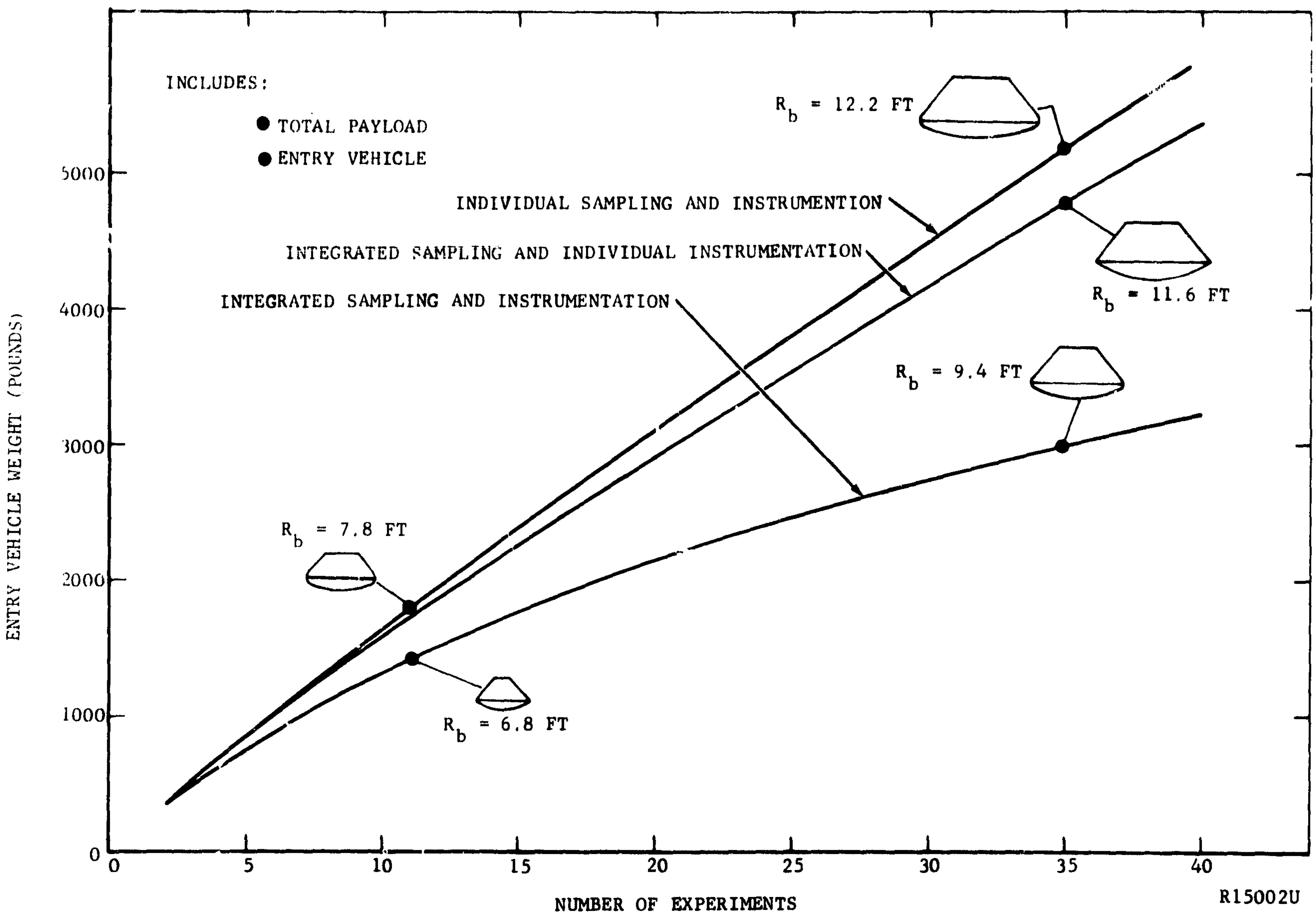


FIGURE 4-8. WEIGHT COMPARISON - ENTRY VEHICLE COMPLETE

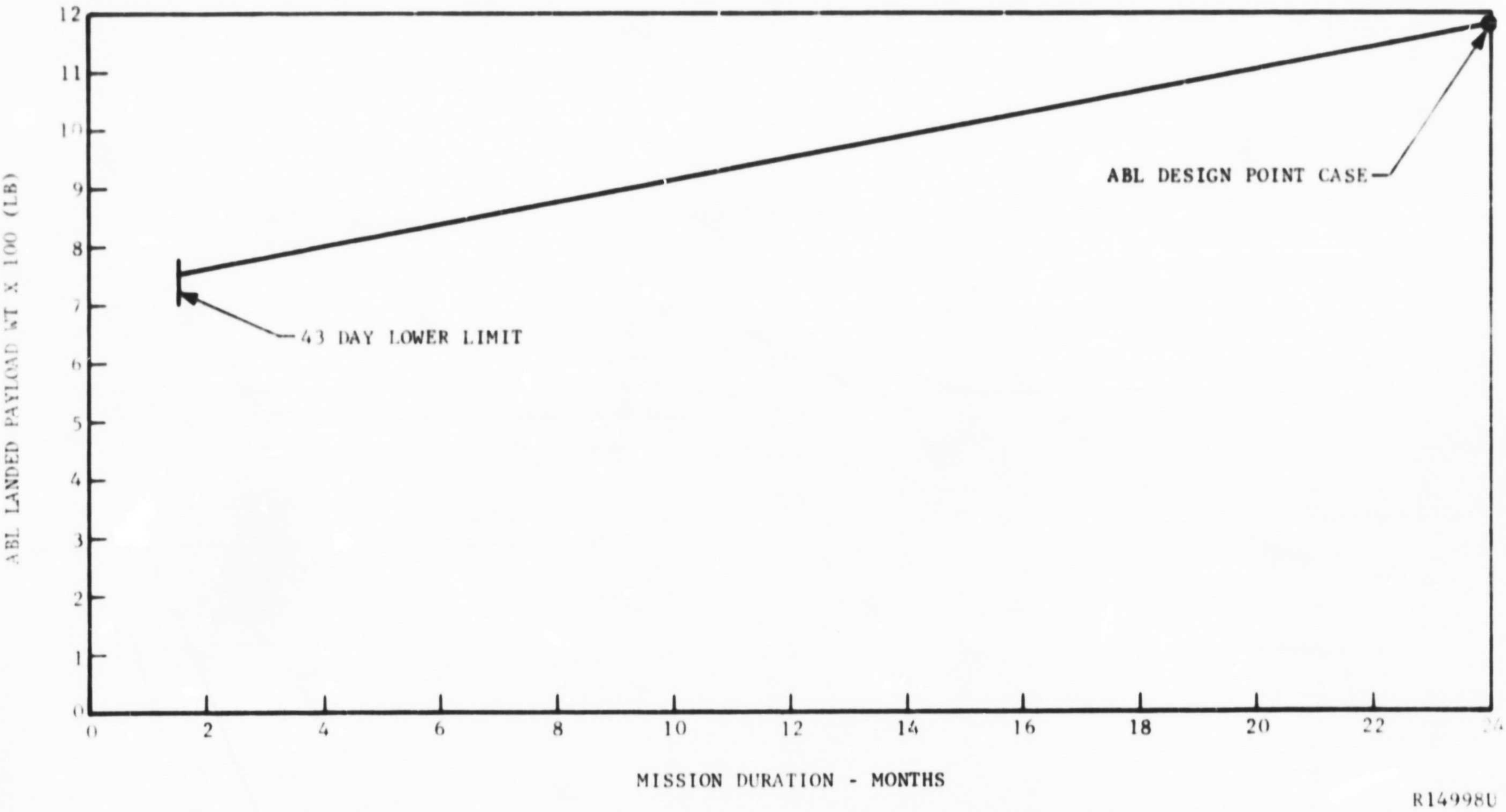


FIGURE 4-9. WEIGHT REDUCTION VERSUS MISSION TIME

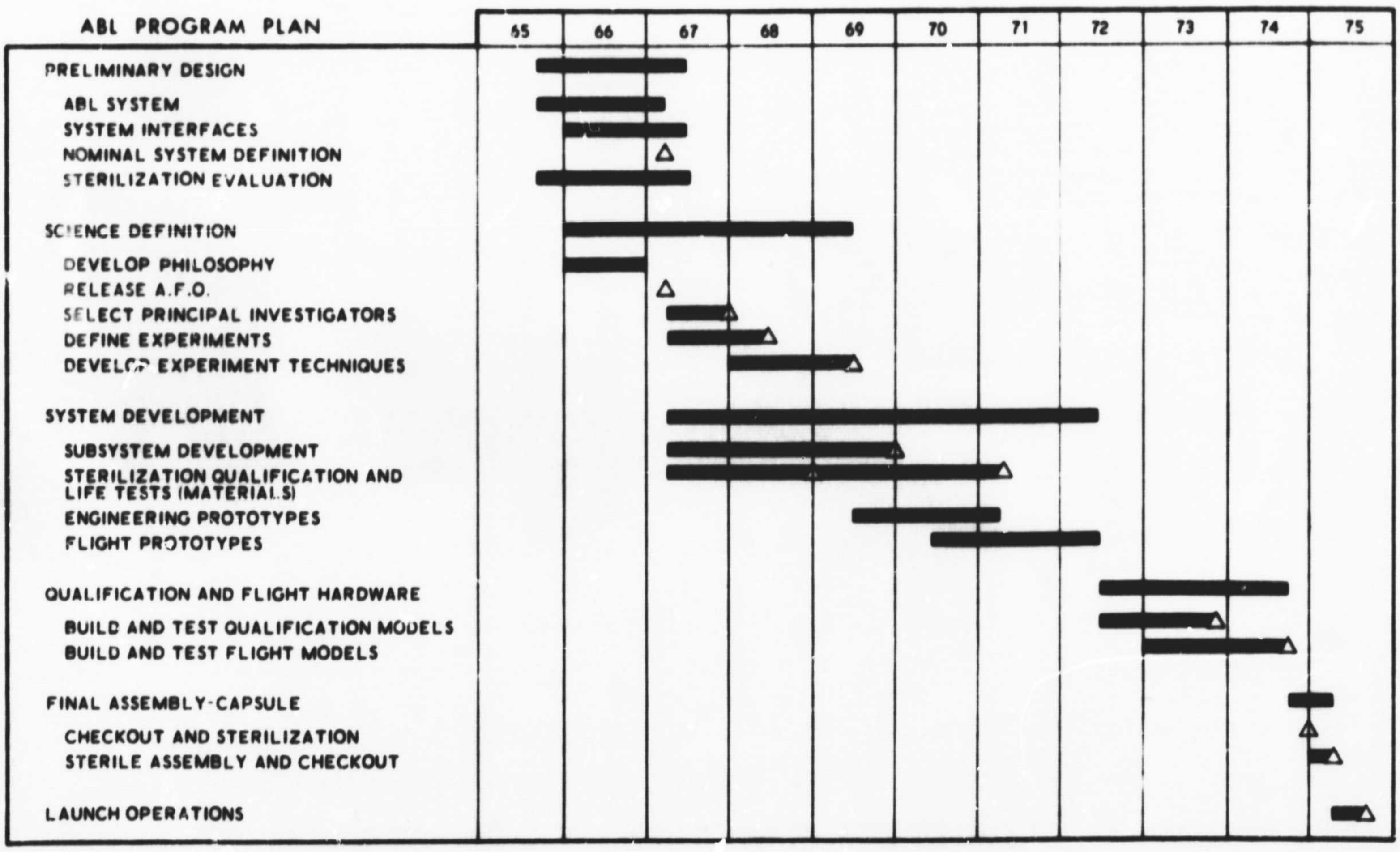


FIGURE 4-10. ABL PROGRAM PLAN

This program considers a nominal eighteen-month preliminary design program to define the scientific capability of the ABL. This information would be used by NASA, along with other separately developed mission parameters, to select principal investigators and define the specific science mission. Development of the ABL subsystems would proceed concurrently in support of the science definition program, with early emphasis on scientific instrument and processing subsystems.

A thorough subsystem hardware development and test program is contemplated. The first system prototype will be available in mid 1970 with updating and testing continuing into 1971. The optimized design will be verified with a second prototype test series starting in 1972; accelerated life tests will be conducted into 1973, being completed prior to qualification test of the flight units. Extended life tests will continue for a two-year period to to about the first of 1974.

The requirement for sterilization will have a basic influence on the ABL design. All prototype units will utilize components that have been at least short-term qualified for sterilization; the same will be done on breadboard hardware to the maximum extent possible.

Qualification and flight hardware subsystems will be fabricated simultaneously, with the first assembled unit used for qualification test and the subsequent ones for flight units. Delivery of three flight systems is planned--two for launch and one for backup.

It is presumed that the ABL and capsule assemblies will be sterilized simultaneously at a specified facility, and will be assembled and sealed in the sterile shroud in the "caterpillar access" sterilization chamber prior to delivery to the launch site. About one year is allowed for sterilization, assembly, checkout, delivery, and pre-launch operations.

Surface operations on Mars will require essentially continuous monitoring and data analysis at the Space Flight Operations Facility to optimize utilization of the ABL command control capability. This will require continuous duplication of the actual operations on Mars and simulation of proposed experiment modification commands prior to committing the ABL on Mars. Comprehensive support of these operations is planned.

The total cost estimated for the ABL development program is summarized in Figure 4-11. These costs include support of the NASA directed science definition program, but do not include capsule subsystem development such as communication system or power supply. The rate of expenditure is relatively low during the early part of the program, peaking during the FY 1970 to FY 1973 period to about 14 million dollars per year.

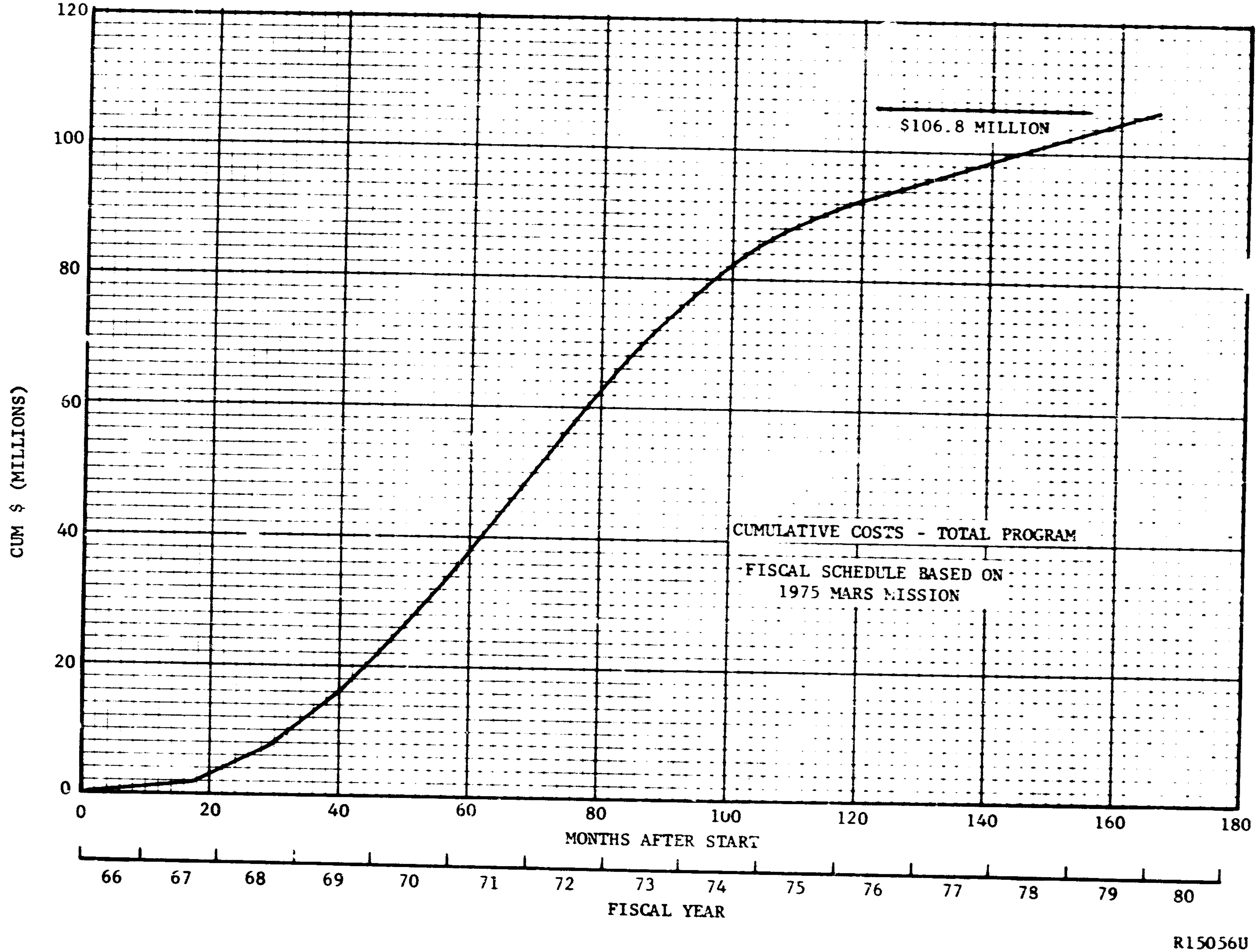


FIGURE 4-11. ABL PROGRAM COSTS

Section 5

CONCLUSIONS AND RECOMMENDATIONS

The principal study results can be summarized as follows.

A representative ABL configuration has been shown to be a feasible concept for a Voyager-class landed payload in the 1975 time period. Such a payload can be mechanized well within booster performance capability for that time period and all technologies are currently available or are reasonable nominal extrapolations of today's art.

Significant advantages have been shown to accrue to a biological payload organized as an integrated ABL. These advantages include the following:

(1) Far more meaningful scientific results are possible from a given instrument capability organized as an integrated ABL than from the same equipment mechanized as individual experiments.

(2) Weight advantages for equal instrument capability are roughly a factor of 2 over individual experiments using common sampling, and a factor of 3.5 over individual experiments using reasonable, but considerably less comprehensive, individual sampling capability.

(3) The weight advantages in the instrument complement reflect as weight and size advantages in the total entry system. Weight advantages for a typical entry vehicle mechanization are a factor of 1.6 and 1.75, respectively, for the two cases previously cited. Corresponding size advantages in this particular example reflect the difference between a feasible and a marginal solution if Saturn Ib shroud limits are considered to control the entry body size.

(4) Reliability advantages (reported in Volume III) have been shown to accrue to the ABL concept both because of the flexibility of the laboratory for performing a given experiment using alternative sensors, and because alternative experiments can be performed to achieve essentially similar knowledge about the sample.

It has been shown that a science payload organized as an integrated automated laboratory is relatively independent of the specific experiments which are to be performed when the laboratory is sufficiently comprehensive. This important result means that engineering development of instruments and laboratory hardware need not be delayed until the final selection of experimentors and experiments.

Both performance and functional advantages have been shown for the ABL organized as a separable landed payload, and this approach is recommended.

The RTG (Radioisotope Thermoelectric Generator) form of electrical power supply has been shown to provide such a perfect match to both the electrical load and environmental control requirements of the laboratory that its availability in the correct capacity and configurations for the ABL mission should be considered essential. Additional development should be continued on these units in the areas of general performance upgrading, fuel availability, and packaging, the latter particularly with the objective of improving the shock and vibration resistance of the units.

The heart of ABL is the chemical processing capability. It has been shown that a form of mechanical batch processing is probably optimum for the ABL application, and early development work should be initiated on this piece of processing equipment, regardless of the final complement of experiments selected, because of its very general use in the ABL payload.

The design point case analyzed in this study has provided a definition in some detail of a single feasible concept. It is now necessary to evaluate the cost in terms of weight, power, complexity, reliability, etc., of variations in the system capability around this design point case. These evaluations should consider improved sample collection coverage, earlier and later mission time periods, more complex equipment and procedures (e.g., video and electron microscopy), and the effects of, and proper methods to be used for, the eventual employment of terrestrial biological material in Martian experiments.

A unique feature of the ABL is the interplay between the experimenter on Earth and the laboratory operating on Mars. This function implies Earth-based facilities different from those required for current generation space missions. The scientist must be provided with information on the status of the laboratory and on the progress of experiments; he must be provided the facilities for evaluating results returned in order that he can make decisions and determine the consequences of commands to be transmitted to the laboratory. The analysis of these requirements deserves further study.

While certain specific material sterlization incompatability problems were investigated in this study, no results justify a conclusion at this date that any specific payload can or cannot meet the NASA sterilization objectives. It is clear only that much additional specific analysis and test data are required. It also appears that considerable further study is warranted of alternative methods of achieving sterilization without compromising the NASA sterilization objectives.