30 APRIL 1967

LMSC-A847...

Study of Mission Modes and System Analysis for Lunar Exploration

MIMOSA

FINAL REPORT

CANDIDATE LUNAR EXPLORATION PROGRAMS

MIMOSA Technical Report — Vol. II

(NASA-CR-123835) STUDY OF MISSION MODES AND SYSTEM ANALYSIS FOR LUNAR EXPLORATION (MIMOSA). MIMOSA TECHNICAL REPORT, VOLUME 2: CANDIDATE LUNAR (Lockheed Missiles and Space Co.) 30 Apr. 1967 293 p
N72-75116
Unclas
00/99 37166

LOCKHEED MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

30 APRIL 1967 LMSC-A847942

Study of Mission Modes and System Analysis for Lunar Exploration

MIMOSA

FINAL REPORT

CANDIDATE LUNAR EXPLORATION PROGRAMS

MIMOSA Technical Report – Vol. II

Prepared Under Contract NAS 8-20262
for
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

LOCKHEED MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

FOREWORD

This document is Volume II of the MIMOSA Technical Report, which constitutes part of the final report on the Study of Mission Modes and Systems Analysis for Lunar Exploration (MIMOSA). This study was conducted by the LMSC MIMOSA team for the George C. Marshall Space Flight Center under contract NAS 8-20262. The entire final report covers work performed from 3 January 1966 to 3 February 1967 and comprises the following parts:

- MIMOSA Summary Digest
- MIMOSA Summary Technical Report
- MIMOSA Technical Report:
  Volume I – Lunar Exploration Equipment and Mode Definition
  Volume II – Candidate Lunar Exploration Programs
  Volume III – Recommended Lunar Exploration Plan
- MIMOSA Planning Methodology:
  Volume I – Planners' Handbook
  Volume II – Exploration Equipment Data Book
  Volume III – Scientific Programs

ACKNOWLEDGEMENTS

The Study of Mission Modes and Systems Analysis for Lunar Exploration (MIMOSA) was conducted by the MIMOSA team for the George C. Marshall Space Flight Center under contract NAS 8-20262. The contractor team consisted of the following organizations:

- Lockheed Missiles & Space Company. Prime Contractor
- AiResearch Manufacturing Company. Environmental Control and Life Support System
- Bell Aerosystems Company. Lunar Flying Vehicles
- Bendix Corporation, Aerospace Systems Division. Lunar Roving Vehicles Definition and Contributions to Scientific Program Formulation
- General Electric Company, Missile & Space Division. Electrical Power Systems

The technical management of the study was conducted by a government team composed of several organizations and their selected representatives. The Technical Supervisor and Contracting Officers' Representative for the National Aeronautics and Space Administration was David Paul 3rd of the Advanced Systems Office, Marshall Space Flight Center (MSFC). Contributing organizations and their representatives were as follows:

- Advanced Systems Office, MSFC

Gordon R. Woodcock	Luther J. Spears
William G. Huber	Robert J. Davies
Terry H. Sharpe	Edward E. Waggoner
Harold D. Trexler	Lynn L. Bradford

- Propulsion & Vehicle Engineering Laboratory, MSFC

  William W. Wales — Richard A. Love
  Walter A. Johanson — Michael J. Vaccaro
  Charles R. Darwin — Wilburn O. J. Randolph

- Aero-Astrodynamics Laboratory, MSFC

  Ronald D. Scott

- Research Projects Laboratory, MSFC

  Dr. Nicholas C. Costes — James A. Downey III

- Astrionics Laboratory, MSFC

  Edward E. Dungan

- Advanced Manned Missions Program Office, Office of Manned Space Flight, NASA Headquarters

  Philip E. Culbertson — Jerald M. Goldberg
  Lt. Col. Peter Grosz, USA — Donald A. Beattie

- John F. Kennedy Space Center, NASA

  Joseph T. Garo — Owen L. Sparks
  A. Robert Raffaelli — Warren L. Foss

- Manned Spacecraft Center, NASA

  Thomas R. Kloves — Clark Covington
  Norman Belasco — Milton A. Silveria

- Astrogeology Branch, U. S. Geological Survey

  Dr. Joseph T. O'Connor

- Extraterrestrial Research Agency, U. S. Army Corps of Engineers

  Donald W. Butler — James E. Malcolm

Dr. Harold Masursky of the Astrogeology Branch, U.S. Geological Survey, was consulted regarding geological experimentation, and Dr. William G. Tifft, Steward Observatory, University of Arizona, was consulted regarding optical astronomy. In addition, Dr. Alfred H. Webber of St. Louis University provided general advice on scientitic experimentation.

The study also drew on certain previous and concurrent studies for information. The most significant of these were as follows:

- Scientific Mission Support for Extended Lunar Exploration. North American Aviation, Inc., Contract NAS 8-20258 (William McKaig, Study Leader)
- Lunar Surface Mobility Systems Comparison and Evolution Study (MOBEV). Bendix Corporation, Aerospace Systems Division, Contract NAS 8-20334 (Carmelo J. Moscolino, Study Leader)
- Early Lunar Shelter Design and Comparison Study. AiResearch Manufacturing Company, Contract NAS 8-20261 (William L. Burriss, Study Leader)

The study was aided by an independent effort on the part of Mr. Wes C. Schmill of Atomics International, a Division of North American Aviation, Inc., who contributed to the definition of nuclear power systems.

CONTENTS

INDEX TO MIMOSA TECHNICAL REPORT
VOLUMES I AND III

Chapter

ILLUSTRATIONS

TABLES

INTRODUCTION

The objectives of the MIMOSA study were twofold – to produce a methodology for generating lunar exploration programs and to generate a recommended lunar exploration plan, using the developed methodology.

The MIMOSA study was divided into the following three phases:

- Phase I – compilation and generation of data for the later phases (these data are contained in the Exploration Equipment Data Book.)
- Phase II – development of the planning methodology that includes a computer program for the mechanization of data handling, generation of a broad spectrum of candidate programs, and comparative analysis to answer certain planning questions
- Phase III – formulation of a recommended plan of lunar exploration, generation of three selected lunar exploration programs for implementing the plan, and intensive design effort for the equipment used in these three programs

Generation of the recommended lunar exploration plan is described in the MIMOSA Technical Report. The methodology is presented in three volumes under MIMOSA Planning Methodology.

This document is Volume II of the MIMOSA Technical Report. It describes the activity and results of Phase II, covering (1) generation of lunar scientific programs, (2) formulation of candidate exploration programs, (3) description of the candidate exploration programs, and (4) analysis and evaluation of the candidate exploration programs.

Chapter 1
LUNAR SCIENTIFIC PROGRAMS

For the purpose of MIMOSA it was necessary to generate conceptual lunar scientific programs encompassing a broad spectrum of scientific disciplines and representing a wide variation in total effort invested in exploration of the Moon. Inasmuch as the acceptability of results from MIMOSA depends upon the validity of the inputs, it was important to conceive realistic scientific programs based upon expert opinion concerning the goals of lunar exploration. Also, since the principal purpose of MIMOSA was to develop a tool for comparative analysis of many possible approaches to exploration of the Moon, a systematic and flexible procedure for generating scientific programs of any desired scope, emphasis, and magnitude was needed. This chapter discusses the philosophy and procedure used in generating lunar scientific programs in accordance with the above purposes and requirements.

1.1 MAJOR SCIENTIFIC GOALS

The Space Science Board of the National Academy of Sciences, meeting at Woods Hole, Massachusetts, in the summer of 1965, undertook a study of the principal areas of space research including lunar exploration. The broad objectives of lunar exploration were identified to be (1) determination of the present structure and activity of the lunar interior, (2) determination of the composition of the lunar surface and the processes primarily responsible for the present appearance of the Moon, and (3) determination of the history or evolutionary sequence of events by which the Moon arrived at its present configuration. A more specific identification of the major goals of lunar exploration relevant to the above broad objectives was promulgated at the Woods Hole meeting in the form of 15 questions. The first 3 questions concern the first of the above broad objectives, questions 4 through 9 relate to the second objective, and questions 10 through 15 pertain to the third objective. These are the first 15 questions listed in Table 1-1.

Table 1-1

BASIC SCIENTIFIC QUESTIONS

Question No.	Question*
1	Is the internal structure of the Moon radially symmetrical like the Earth and, if it is, is it differentiated? Specifically, does it have a core and does it have a crust?
2	What is the geometric shape of the Moon? How does the shape depart from fluid equilibrium? Is there a fundamental difference in morphology and history between the sub-Earth and averted faces of the Moon?
3	What is the present internal-energy regime of the Moon? Specifically, what is the present heat flow at the lunar surface and what are the sources of this heat? Is the Moon seismically active and is there active volcanism? Does the Moon have an internally produced magnetic field?
4	What is the average composition of the rocks at the surface of the Moon and how does the composition vary from place-to-place? Are volcanic rocks present on the surface of the Moon?
5	What are the principal processes responsible for the present relief of the lunar surface?
6	What is the present tectonic pattern on the Moon and how is the tectonic activity distributed?
7	What are the dominant processes of erosion, transport, and deposition of material on the lunar surface?
8	What volatile substances are present on or near the surface of the Moon or in a transitory lunar atmosphere?
9	Is there evidence of organic or proto-organic materials on or near the lunar surface? Are living organisms present beneath the surface?
10	What is the age of the Moon? What is the range of the age of the stratigraphic units on the lunar surface and what is the age of the oldest exposed material? Is a primordial surface exposed?
11	What is the history of dynamical interaction between the Earth and the Moon?
12	What is the thermal history of the Moon? What has been the distribution of tectonic and possible volcanic activity in time?
13	What has been the flux of solid objects striking the lunar surface in the past and how has it varied with time?
14	What has been the flux of cosmic radiation and high-energy solar radiation over the history of the Moon?
15	What past magnetic fields may be recorded in the rocks at the Moon's surface?
16	What are the long-term effects of reduced gravity on various life forms, including man?
17	What lunar resources are available for exploitation?
18	What lunar environmental factors are most significant to the design of proposed lunar missions?
19	Are the basic postulates of general relativity valid?
20	What is the total inventory of stars and interstellar matter in a representative volume of our galaxy?
21	What processes account for the phenomena observed in the Sun, e.g., sunspots, flares, plages, faculae, and prominences?
22	What are the structures, compositions, and energy regimes of planetary atmospheres other than that of Earth?
23	What are the structures and compositions of comets?
24	What are the precise locations of discrete x-ray sources and what is the distribution of faint x-ray sources?
25	What is the distribution of radio stars having very long wavelength?

*Questions 1 through 15, inclusive, are taken directly from proceedings of the 1965 Woods Hole Conference and are concerned with the Moon per se. The remaining questions were stated or implied at the Woods Hole and Falmouth Conferences and are motivated by the potentialities of the Moon as a base for pursuit of astronomical and other extralunar scientific goals.

The scope of comprehensive lunar scientific programs should extend beyond exploration of the Moon, per se, and include exploitation of whatever advantages the Moon may offer as a base for laboratories and observatories concerned with objectives other than the Moon. The published proceedings of the Woods Hole meeting were perused for indications of extralunar objectives that could be pursued advantageously through lunar-based operations. To this end 10 additional questions were formulated identifying major goals relevant to biomedicine, astronomy, planetology, solar physics, and other extralunar areas of scientific endeavor. These are the last 10 questions listed in Table 1-1.

1.2 MAJOR SCIENTIFIC DISCIPLINES

The major scientific disciplines concerned with exploration and exploitation of the Moon were identified by the appointment of eight working groups at the NASA 1965 Summer Conference on Lunar Exploration and Science, which met at Falmouth, Massachusetts, immediately after the Woods Hole Conference. The emphasis upon geoscience in determining the objectives of lunar exploration is indicated by the fact that four of the working groups were entitled Geodesy, Geology, Geochemistry, and Geophysics. The remaining groups were Bioscience, Particles and Fields, Lunar Atmosphere, and Astronomy. Two additional major disciplines entitled Applied Science and Mission Support were adopted for the purposes of MIMOSA to accommodate objectives not adequately covered by the eight working groups of the Falmouth Conference. For convenience, as a means of categorizing lunar scientific activities, the 10 major disciplines were assigned code numbers in the order given in Table 1-2.

1.3 THE SCIENTIFIC INVESTIGATION MATRIX

The 25 questions identifying the major goals and the 10 major disciplines concerned with pursuit of those goals provide a framework for assembling a matrix of investigations aimed at acquiring data needed to develop answers to the 25 questions. Relevant to each question and each major discipline concerned with that question, a set of

Table 1-2

MAJOR SCIENTIFIC DISCIPLINES

Code No.	Title
0	Lunar Atmosphere
1	Geodesy/Cartography
2	Geology
3	Geochemistry
4	Geophysics
5	Particles and Fields
6	Biology
7	Astronomy
8	Mission Support/Engineering
9	Applied Science

investigations can be formulated which, in effect, outlines a portion of a scientific program contributing to the attainment of the goal in question. The investigations within any given set pertaining to a particular question and major discipline can be arranged in sequence on a "first-things-first" basis. This is done so that the degree of assurance in pursuit of any particular goal or the emphasis upon any particular major discipline can be varied at will according to where the line is drawn in specifying the number of investigations within each set.

The entire assembly of investigations for all questions and disciplines is called the scientific investigation matrix. The utility of the matrix in the formulation of lunar scientific programs will be discussed later.

The complete scientific investigation matrix upon which the MIMOSA lunar scientific programs are based is given in Appendix A. The three-part number system of item headings used in this matrix is interpreted as follows: The first part relates to the number of the question in accordance with Table 1-1. The second part corresponds to the code number of the major discipline according to Table 1-2. The third part represents the numerical order of the investigation relative to the question and discipline identified by the first two digits. Thus, item 1.4.3 represents the third investigation within the fourth major discipline (Geophysics) relevant to the first question, i.e., What is the internal structure of the Moon?

1.4 LUNAR SCIENTIFIC EXPERIMENTS

The primary source of data concerning scientific experiments and minor scientific equipment used in MIMOSA scientific programs was the NAA catalog of lunar scientific experiments,* which was a product of a NASA-funded study. This study was conducted concurrently with MIMOSA and was designed to provide a major input to MIMOSA. The same list of major disciplines used in MIMOSA to categorize scientific investigations also was used in the NAA study to categorize lunar scientific experiments. This greatly facilitated the correlation of scientific experiments from the NAA catalog with the appropriate investigations in the scientific investigation matrix.

It is pertinent at this point to describe the general format of the NAA lunar scientific experiment catalog and indicate the significant data inputs to MIMOSA from this catalog. The NAA lunar scientific experiment catalog consists of a set of IBM cards of which there are seven different types. The card types are identified by the code numbers 0 through 6, inclusive, punched in the first column on the left-hand edge of each card. The purposes of the card types are indicated in Table 1-3.

The verbal descriptions of experiments given by the type 0 cards in many instances are very detailed and are useful guides in determining the relative significance and interdependencies among experiments. However, the type 1 card was designed by the NAA study to serve as the principal input to MIMOSA concerning lunar scientific experiment requirements. The information summarized on the type 1 cards is somewhat in excess of the needs of MIMOSA as far as the present study is concerned. However,

---

* North American Aviation, Inc., "Scientific Mission Support for Extended Lunar Exploration," NAA SID Report 66-957, (in preparation).

Table 1-3

NAA LUNAR SCIENTIFIC EXPERIMENT CARD TYPES

Card Type	Purpose
0	Verbal description of the experiment
1	Summary of data of primary significance concerning the experiment
2	Tabulation of experiment operational requirements
3	Tabulation of experiment manhour requirements
4	Tabulation of scientific equipment requirements
5	Equipment description, development status, cost
6	Experiment data handling and telemetry requirements

subsequent studies of lunar exploration operations in greater depth and detail than was attempted here will find use for the scope of information contained in the NAA catalog.

The types 2, 3, 4, and 5 cards were useful to MIMOSA mainly as reference data sources where information more detailed than that on the type 1 summary card was needed. The present study made no attempt to account for data handling and telemetry requirements; therefore, the type 6 card was not used by MIMOSA.

Quantitative data from the NAA catalog actually used as inputs to the MIMOSA computer program included the following:

- Equipment mass
- Equipment volume
- Total energy
- Peak power
- Development time
- Year of earliest availability
- Nonrecurring cost
- First-item cost

- Earth-return mass
- Crew size
- Spacesuit and shirtsleeve manhours on traverses
- Spacesuit and shirtsleeve manhours at a base

Other information of a qualitative nature in the NAA experiment catalog, such as experiment location, mobility requirements, time-phase requirements, importance, urgency, and data output characteristics were used in the selection and assignment of experiments for purposes of program planning.

Each experiment in the NAA catalog is identified by an eight-digit code number in which the first digit correlates the experiment with the appropriate major scientific discipline. The remaining seven digits provide for subcategorization of experiments with respect to objectives and specialties. However, the subcategories adopted in the NAA format did not prove useful for the present purposes of MIMOSA; therefore, except for the first digit, the experiment code number serves only to distinguish one experiment from another. A list of the NAA lunar scientific experiments used by MIMOSA is given in Appendix B.

Correlation of scientific experiments with the appropriate investigations is an essential step in preparing the scientific investigation matrix for use as an aid in generating a scientific program. The first digit of the experiment numbers associates the experiment with the major scientific discipline. However, proper identification of experiments with the investigations under each basic question requires the judgment of experts in each major scientific discipline. The correlation of NAA lunar experiments with the scientific investigation matrix used in the present study is given in Appendix C.

Of the approximately 350 experiments described in the NAA catalog, only about 200 are listed in Appendix B of this report. There are two reasons for this. First, the scientific investigation matrix acts selectively upon the catalog of experiments. For example, omission of basic scientific questions concerning meteorology and oceanography and the low emphasis upon bioscience objectives discriminates against experiments in these categories. Second, there is considerable redundancy among the experiments in the NAA catalog. Hence, a selection must be made to avoid unnecessary duplication of results.

1.5 EXPERIMENT PACKAGES

Experiment packages consist of groups of compatible experiments that share a commonality in use. For example, a package of geoscientific experiments can be identified comprising those experiments to be performed a specified number of times in the vicinity of a lunar base. Similarly, experiment packages can be identified with respect to measurements made in a drill hole, or along a traverse, or in relation to a major piece of scientific equipment such as a telescope.

Experiment packages are identified by code numbers with the format 999999xx. This provides an efficient means for assembling and assigning scientific experiments. The total mass, manhours, energy, cost, and similar data pertinent to the entire group of experiments in a package are put into the computerized program for mission analysis by calling out the code number for the package.

A list of experiment packages and their contents used for scientific program planning in this study is given in Volume III of the MIMOSA Planning Methodology.

1.6 MAJOR SCIENTIFIC EQUIPMENT

Some experiments proposed for the Moon require equipment of such magnitude and complexity as to dominate the missions concerned with delivery and deployment of the equipment. Examples of experiments of this kind are the drilling of deep holes; the establishment and operation of large radio telescopes and astronomical observatories; and the establishment and maintenance of permanent bases for research in biology, medicine, and the applied sciences. The equipment used in these experiments is called major scientific equipment, and, for purposes of mission planning, it is treated in the same manner as major hardware systems.

Table 1-4

MAJOR SCIENTIFIC EQUIPMENT

Data Book No.	Title	Mass (kg)
3213-01	300-Meter Core Drill	9,243
3242-02	1-Meter Optical Telescope	1,300
3242-03	1.3-Meter Optical Telescope	5,025
3242-04	2-Meter Optical Telescope	13,950
3242-05	Solar Observatory	35,410
3243-01	Stellar Observatory	23,750
3231-01	X-Ray Telescope	1,620
3224-01	Mills Cross Radio Telescope	12,528
3223-01	Radio Telescope Dish	22,250
3132-02	Geochemical Laboratory	1,130

A list of the major scientific equipment defined for use in the present study is given in Table 1-4. Data relevant to these examples of major scientific equipment are given in the MIMOSA Data Book under the number indicated in Table 1-4.

1.7 LUNAR SURFACE EXPLORATION PATTERNS

A basic objective in the formulation of lunar exploration programs in this study has been to let the scientific requirements determine what the system capabilities should be. Concerning the manner and extent of lunar surface exploration needed to acquire the data demanded by the major scientific goals, it proved virtually impossible through scientific requirements to identify unique or characteristic sizes for areas that must be examined and distances on the surface that must be traversed.

A continuous spectrum of area sizes is associated with various lunar features of scientific importance. Similarly, the lengths of traverses required to explore lunar features are completely variable.

For the purposes of MIMOSA, the following set of relative magnitudes for exploration areas was adopted:

- Site. An area within a radius of about 1 km of a landing point
- Locale. An area within a radius of about 10 km of a landing point
- Region. An area with dimensions of the order of 100 km
- Territory. An area with dimensions of the order of 1,000 km

The appropriate ranges of traverses are related to the estimated amount of travel needed to explore areas in accordance with the above schedule of area magnitudes. Site traverse requirements are presumably satisfied by astronaut walk-around capability. Exploration of a locale can be accomplished by a number of closed-loop traverses with an average range of about 25 km, and totaling about 150 km. Similarly, a region may be explored with closed-loop traverses of about 25 km in length, and totaling about 1,000 km.

Although there are important lunar features of a size corresponding to territories, e.g., the larger maria and the Southern Highlands, preliminary evaluation of the total effort involved in manned surface exploration of an area as large as a territory soon led to the conclusion that territorial objectives are beyond the scope of any plausible manned mode of lunar surface exploration. Objectives on a territorial scale must be achieved through lunar orbital surveys.

At the opposite end of the spectrum, site exploration is appropriate to the scale of Apollo missions, but for the purposes of this study the degree of detail representative of site exploration was not considered necessary. Thus, the concepts of locales and regions proved most useful for present purposes in delineating exploration areas.

The targets of interest on the Moon are numerous and widespread. The targets may be approached separately by individual missions from Earth or a number of targets may be visited in one mission by traversing the lunar surface along paths joining the targets. The first is called the locale approach, and the second is called the path approach.

Figures 1-1 and 1-2 show the lunar Earth-side hemisphere on which are shown the lunar surface exploration patterns emphasizing the locale approach and the path approach in relation to one lunar scientific program. The same targets or the same kinds of targets are incorporated in both patterns.

Although either the locale approach or the path approach is amenable to the pursuit of the major scientific goals defined by the 25 questions, there are differences in the kinds of experiments favored by the 2 approaches. The locale approach readily accommodates intensive surveys of limited areas of the lunar surface, deep drilling, and fixed-base operations such as astronomical observatories and geochemical, biological, and medical laboratories. The path approach provides excellent opportunities for extended surveys across major lunar features and for long-range active seismology.

1.8 DESCRIPTION OF LOCALES, REGIONS, AND PATHS

A large number of lunar surface targets were identified as candidates for lunar missions. Those targets selected for lunar surface exploration patterns in this study are described in Appendix D. They consist of 22 locales, 4 regions, and 21 paths.

The targets were chosen to encompass a wide range of objectives. Some represent typical lunar features such as maria, highlands, rilles, and young and old craters, which are important in regard to obtaining ground-truth data of greatest general applicability in extending the interpretation of lunar orbiter remote sensor observations to the entire surface of the Moon. Examples of targets representing typical features are Locale 17 (Ranger VIII Landing Site), Locale 20 (Southern Highlands), Locale 1 (Hyginus Rille), Region II (Copernicus – a typical area in the neighborhood of a large, young impact crater), and Locale 2 (Alphonsus – an old crater). Some targets, representing unique or distinctive features, were chosen for their potentiality for providing data on the interior structure and composition of the Moon or records of lunar history. Examples of such targets are Locale 18 (Straight Wall), Locale 5 (Dark Halo Craters Southeast of Copernicus), Locale 16 (South Pole), and Path m (Mare Orientale – a partially filled basin). One target, Locale 21 (Grimaldi, Astronomical Location) was

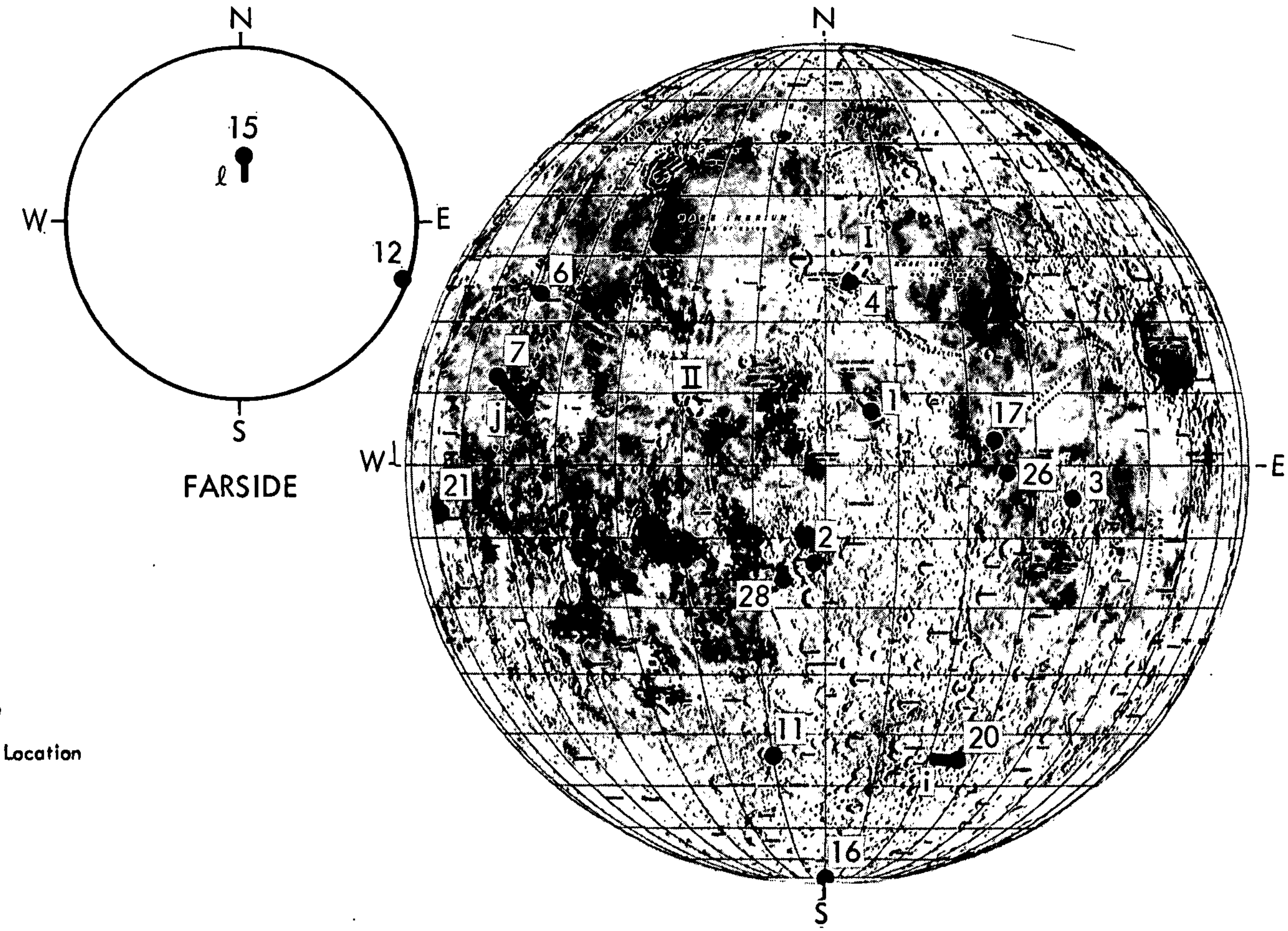
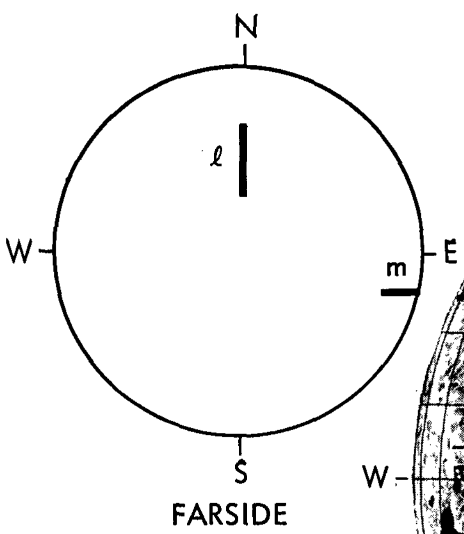
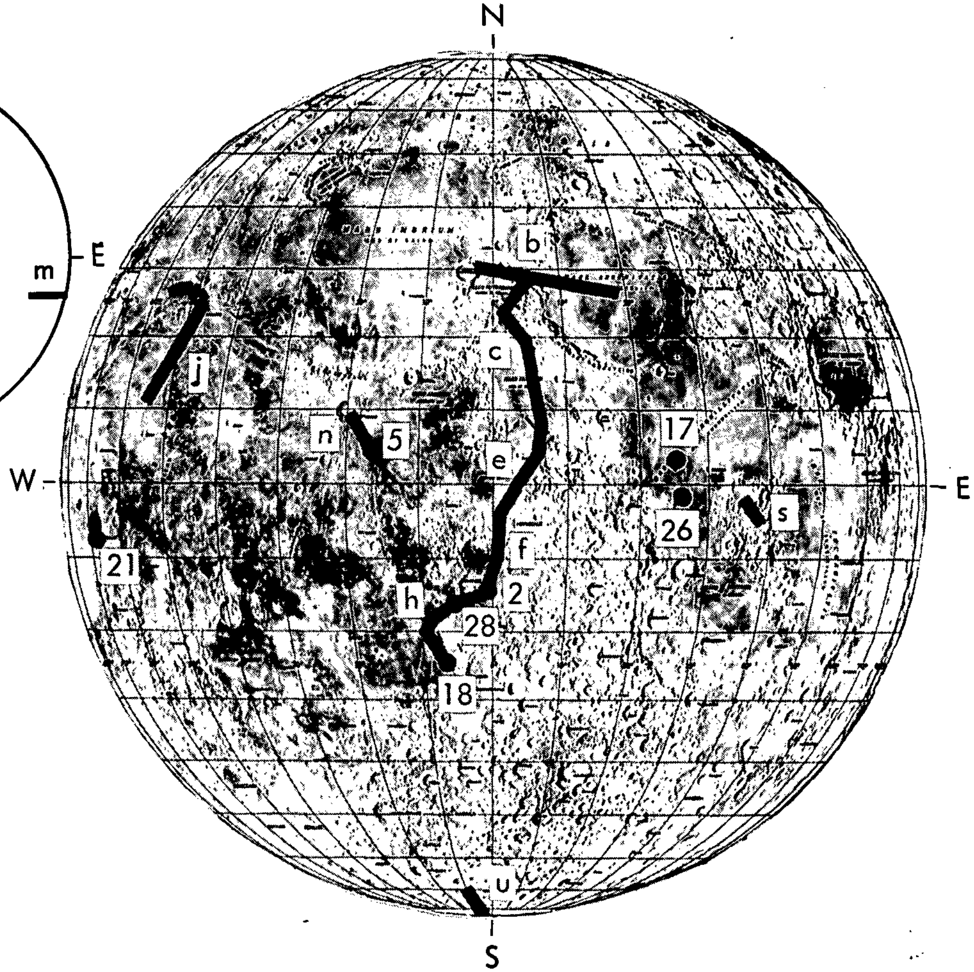


Fig. 1-1 Locale-Approach Surface-Exploration Pattern





Legend:

Locales

2 Alphonsus
5 Dark Halo Craters Southeast of Copernicus
17 Ranger VIII Landing Site
18 Straight Wall
21 Grimaldi, Astronomical Location
26 Moltke B
28 Mare Nubium

Paths

b Mare Imbrium – Mare Serenitatis
c Palus Putredinis – Mare Vaporum
e Sinus Medii
f Ptolemaeus – Alphonsus
h Mare Nubium – Straight Wall
j Marius Hills
ℓ Central Farside
m Mare Orientale
n Copernicus
s Capella M
u South Pole

Fig. 1-2 Path-Approach Surface-Exploration Pattern chosen to serve as a place for pursuit of extralunar objectives, i.e., radio, optical, and x-ray astronomy. This location is near the limb of the Moon, which facilitates shielding the optical telescopes from Earth-shine while permitting direct communication with Earth without the need for setting up repeater stations or satellite relays. The bulk of the remaining targets provide statistical support or augmentation of conclusions that may be drawn from observations made at typical and unique targets of the type mentioned above.

In addition to the lunar surface targets described above, it is important to regard lunar orbits as scientific targets, inasmuch as orbiters accomplish overall surveillance of the Moon in a manner not possible with surface exploration modes. Polar lunar orbits provide the greatest versatility for scientific purposes, since rotation of the Moon during 28 days brings every point on the surface within sunlit view of the orbiter.

1.9 SCIENTIFIC PROGRAM FORMULATION

The preceding sections describe all the ingredients of lunar scientific programs. It remains now to assemble the ingredients into programs. This involves a number of unavoidably subjective decisions by the program planner, who must do the following:

- Determine the scientific scope
  Range of scientific goals
  Emphasis upon particular goals
  Availability of major scientific equipment
  Total effort involved in lunar scientific activity
- Choose the operational approach
  Manned and/or unmanned
  Lunar orbital and/or lunar surface
  Locale and/or path
- Assign the scientific experiments in accordance with time and location requirements
- Present the scientific program in a format suitable for mission-mode matching

1.9.1 Scope Controls

The basic questions defining the major scientific goals provide the first scope-controlling factor in scientific program planning simply through the addition or omission of questions. For example, it will be noted that among the 25 questions defining the scientific program goals for this study there are no specific requirements for use of the Moon as a platform from which to observe Earth. The range of scientific goals could very well be extended by adding questions concerning meteorology and oceanography. On the other hand, omission of the last 10 questions reduces the range of scientific goals to the study of the Moon, per se.

The relative emphasis upon various scientific goals is controlled at several levels. The number of investigations relevant to any particular question and their degree of sophistication can be specified in the scientific investigation matrix. For example, it is evident from the investigation matrix constructed for this study (Appendix A) that the geoscience goals are heavily emphasized, as are also the goals of astronomy, while very little emphasis is placed upon bioscience goals.

Assumptions about the availability of major scientific equipment greatly affect the scientific scope of a program. Thus, the feasibility of accomplishing significant research in stellar astronomy on the Moon depends upon the establishment of competent radio and/or optical telescopes. The availability of a core drill capable of acquiring lunar samples at depths of 300 m or more is regarded as essential for the precise interpretation of seismic data, as well as for the mapping of the lunar subsurface structure in areas where surface exposure of the substructure is poor.

The scientific program planner applies considerable subjective judgment in determining the magnitude of scientific effort represented by the program. Major factors controlling the magnitude of scientific effort are the number of places at which experiments will be done and the number of replications of experiments in the vicinity of each place. Subjectivity enters directly into estimates of how much data of a given kind are enough to provide answers to a satisfactory degree of assurance.

In the present study, the conceptual lunar scientific programs were scoped to three different magnitudes and labeled Program A, Program B, and Program C with the first and last being, respectively, the largest and smallest in terms of total scientific effort. Program C, moreover, was further reduced in scope by omitting the last 10 of the 25 questions defining lunar scientific goals so that, as a minimal effort, Program C is confined solely to investigation of the Moon with no regard for extralunar goals.

1.9.2 Operational Approach

There is a choice of emphasis between lunar orbital observations as opposed to lunar surface experiments. The NAA catalog of experiments stresses lunar surface operations. Inasmuch as manned lunar surface operations place the greatest possible burden on exploration mode capabilities, it is appropriate in this study to focus attention upon that aspect of conceptual lunar scientific programs.

The principal operational alternative examined in this study was the choice between the locale approach and the path approach in prescribing lunar surface exploration patterns. The choice is essentially between short-range and long-range surface traverse capabilities. The effects upon emphasis of certain scientific activities have already been discussed in this chapter (1.7). However, the most profound effect of this choice is upon the total number of launches from Earth needed to accomplish a given scientific program. The relative cost effectiveness of the locale approach compared to the path approach is discussed in Chapter 3.

1.9.3 Assignment of Scientific Experiments

The scientific experiments can be separated into categories according to time and location requirements. Some experiments are chronologically dependent upon certain natural processes such as cyclic variations in solar activity. Most of the experiments must be chronologically ordered in a general way with respect to an evolutionary development of a scientific program from early to intermediate to advanced phases of lunar exploration and exploitation. For example, surface sampling and ground truth observations will be of primary importance during the early exploratory phase of a program. Deep drilling and extensive long-range active seismic probing of lunar subsurface structures are expected to occupy the intermediate phase of a program. The advanced exploitation phase of a lunar scientific program should emphasize use of the Moon as a base for extralunar goals in stellar astronomy, planetology, and solar physics as well as applied science.

Some experiments will be performed at every location visited; e.g., surface sampling, gravity and magnetic measurements, and multispectral photogeologic surveys. Other experiments are associated with particular types of locations such as volcanic formations, tectonic exposures of subsurface structure, or sites of suspected gas emission. The experiment packages discussed in this chapter (1.5) are correlated in some cases with activities at fixed bases and in other cases with operations along traverses. Thus, there are many factors affecting the distribution of experiments in time and location in a scientific program.

The program planner first distributes those experiments over the lunar surface exploration pattern that have definite time and location requirements. The planner then parcels out the remaining experiments, which are less critically or not at all dependent upon time and location, so as to fill out the total scientific activity assigned to each locale and path in a manner that seems appropriate. The assignment of experiments is examined for mutual compatibility at each location and for consistency with the magnitude of total scientific effort proposed for the program. Only the more obvious inequities in apportioning of experiments among locations need be adjusted at this point because the process of mission-mode matching that follows will very quickly identify precisely what adjustments must be made in the assignment and scoping of experimental activity at each location.

1.9.4 Presentation of Scientific Programs

The complete presentation of a lunar scientific program includes maps describing the lunar surface exploration pattern; a list of locales, regions, and paths in the preferred order of visitation; a list of available major scientific equipment; and instructions concerning the assignment of each experiment or experiment package, the number and frequency of replications, and the relationships among experiments. At this point the scientific program is ready for mission-mode matching and analysis.

The complete presentation of three different sizes of lunar scientific programs is given in Vol. III of the MIMOSA Planning Methodology. Programs treated in accordance with the locale approach are labeled A', B', and C'. The same designations without the primes are used for the corresponding programs using the path approach.

A summary comparison of the programs for all six cases is given in Fig. 1-3. It is noteworthy in all cases of the path approach that the mass of explosives for active seismology greatly exceeds the amount of explosives used in the corresponding cases based on the locale approach. In fact, the mass of explosives in each case of the path approach exceeds the total mass of scientific equipment.

The quantities of explosives implied by the path approach in this study are considered unnecessarily large. The results are based upon an operational concept of active seismology patterned too closely after the manner of performing such experiments on Earth. A preliminary reexamination of active seismological techniques in relation to lunar operational requirements indicates that reductions by a factor of 4 or 5 in the required mass of explosives can be achieved simply by greatly extending the patterns of geophones deployed on the lunar surface and correspondingly reducing the number of points at which explosive charges are detonated.

1.10 CONCLUDING REMARKS

The formulation of comprehensive conceptual lunar scientific programs is a complex and highly involved task, but it can be reduced to a systematic orderly process, as the above discussion demonstrates. There is, of course, an infinite variety of possible programs with any desired relative emphasis upon different scientific disciplines. In the present study, the assumed evolutionary development of lunar objectives gives

	PATH APPROACH			LOCALE APPROACH		
SCIENTIFIC PROGRAM	A	B	C	A'	B'	C'
NO. OF LOCALES	8	7	6	21	15	13
NO. OF PATHS	20	11	6	4	3	2
TOTAL PATH LENGTH, KM	8500	4800	2400	1700	600	200
NO. OF REGIONS	–	–	–	4	2	1
TOTAL REGION AREA, SQ KM	–	–	–	54,000	1800	1500
NO. OF EXPERIMENTS	198	177	113	188	165	121
SCIENTIFIC MANHOURS	54,000	30,000	7,000	54,000	30,000	9,000
MINOR SCI EQMT MASS, KG	45,000	30,000	17,000	33,000	23,000	15,000
MAJOR SCI EQMT MASS, KG	110,000	50,000	14,000	110,000	50,000	14,000
MASS OF EXPLOSIVES, KG	156,000	94,000	42,000	48,000	18,000	2,600
EARTH RETURN MASS, KG	12,000	6,200	3,100	10,000	5,300	2,600

Fig. 1-3 Summary of Scientific Programs

geoscientific exploration of the Moon the major role in the early phase of the program, while use of the Moon as a base for extralunar objectives such as planetology and stellar astronomy characterizes the latter part of the programs.

Geoscientific objectives are primarily responsible for determining the required extent of lunar surface exploration, and the manner of exploring the surface affects the relative emphasis upon certain kinds of experiments. For example, the path approach favors use of active seismology with a resultant demand for explosives in amounts considerably greater than are required in the locale approach.

It should be understood that the conceptual scientific programs presented here were designed primarily to provide requirements by which to test the capabilities of various exploration-system concepts. To the degree that the scientific investigation matrix procedure can identify experiments in each scientific discipline pertinent to the scientific goals of the programs and aid in the selection of appropriate experiments, the conceptual programs are good scientific programs. However, optimization of scientific programs so as to approach maximum efficiency in achieving program goals will require a penetrating analysis of the interactions between experiments in different scientific disciplines. This is an endlessly iterative process subject to continual revision on the basis of new knowledge. Needless to say, it was beyond the scope of the present effort to pursue in great depth the subtle interrelationships between different experiments and to evaluate their separate and mutual contributions to the scientific goals.

Chapter 2

FORMULATION OF CANDIDATE EXPLORATION PROGRAMS

For the purpose of MIMOSA, candidate lunar exploration programs were formulated with two principal objectives in mind:

- To evaluate a broad spectrum of post-Apollo lunar exploration programs
- To answer specific questions, posed by a planner, regarding alternate approaches to lunar exploration

A candidate lunar exploration program results from the planned performance of a particular scientific program with a given set of exploration equipment. The scientific programs generated for MIMOSA represent two basic approaches (locale and path) to Moon exploration and three levels of associated scientific activity. These scientific programs have been discussed in Chapter 1 and are fully described in Vol. III of the MIMOSA Planning Methodology. The set of exploration equipment is chosen such that a smooth evolution in equipment development and capability is achieved. This equipment evolution must be structured so as to ensure that effective utilization of the developed equipment is possible, that sensible steps in equipment capability are called for, and that equipment items of specific interest are included. The specific planning question to be examined is the controlling factor in the selection of a scientific program/equipment evolution combination.

2.1 MIMOSA PLANNING QUESTIONS

An ability to answer a variety of planning questions was an important consideration in the development of MIMOSA methodology. The only stipulation when using this methodology is that the questions be formulated in a precise manner. Typical questions that can be handled by the MIMOSA planning tool are given in Table 2-1. The first seven questions quoted are of immediate interest and constitute the basis for selection of the MIMOSA candidate programs.

Table 2-1

TYPICAL MIMOSA PLANNING QUESTIONS

Question No.	Question
1	What can be accomplished using S/AA equipment only?
2	What upratings of the Saturn V are required and when?
3	Is the LM/Truck approach to be preferred over the LLV or vice versa?
4	What personnel spacecraft should be developed (three- or six-man)?
5	Should the LOR or Direct Mode be used for personnel delivery after S/AA?
6	What are the mission equipment requirements for post-S/AA lunar exploration?
7	How does the scientific program's size influence equipment requirements and program cost?
8	How does a radical change in funding rate affect a given exploration program?
9	What is the impact of emphasizing unmanned lunar exploration?
10	What is the influence of postulated unexpected scientific discoveries?
11	What Earth support system augmentations are required to support a particular lunar exploration program?
12	How do requirements for planetary exploration influence a given lunar program?
	ETC.

2.2 CANDIDATE EQUIPMENT EVOLUTIONS

With the seven basic planning questions of Table 2-1 in mind, and the overall requirement to provide a broad spectrum of possible exploration program, the equipment evolutions given in Table 2-2 were derived. The major equipment elements comprising each evolution are identified. A full listing of all the systems utilized in these evolutions, together with the Data Book reference number, are given in the Exploration Program Summaries presented in Appendix E. In Table 2-2, equipment evolutions

Table 2-2

CANDIDATE EQUIPMENT EVOLUTIONS

Evolutionary Step After Apollo	Equipment Capability Group													
	Small	Medium							Large					
	Ia	IIa	IIb	IIIa	IIIb	IIIc	IVa	IVb	Va	VIa	VIb	VIc	VId	VIe
Step 1	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA	S/AA
Step 2														
Saturn V Rating (%)		100	100	100	100	125	100	125	100	125	125	125	125	150
Logistics Delivery		LM/Tr.	Dir. LM	LM/Tr.	LM/Tr.	LM/Tr.	LLV	LLV	LLV	LLV	LLV	LLV	LLV	LLV
Crew Delivery[a]		LOR(2)	LOR(3)	LOR(3)	LOR(3)	LOR(3)	LOR(3)	LOR(3)	LOR(3)	LOR(3)	LOR(3)	LOR(3)	LOR(3)	Dir. (3)
Shelter Crew		2	3	–	–	–	3	3	–	–	–	–	–	–
Roving Vehicle[b]		M(2)	M(3)	M(3)	M(3)	M(3)	L(3)	L(3)	L(3)	L(3)	L(3)	L(3)	L(3)	L(3)
Step 3														
Saturn V Rating (%)				100	125	125			175	125	150	175	200	150
Logistics Delivery				Dir. LM	LLV	LLV			LLV	LLV	LLV	LLV	LLV	LLV
Crew Delivery[a]				LOR(3)	LOR(3)	LOR(3)			Dir. (6)	LOR(6)	Dir. (3)	Dir. (6)	Dir. (6)	Dir. (3)
Shelter Crew				3	3	3			6	6	6	6	6	6
Roving Vehicle[b]				M(3)	M(3)	M(3)			L(3)	L(3)	L(3)	L(3)	L(3)	L(3)

(a) Number in parentheses indicates number of men on surface.
(b) M = medium (MOLAB-type) and L = large (MOBEX-type). Number in parentheses indicates crew size.

are categorized by system capability and by the number of evolutionary steps required to achieve a certain capability. The small-system capability evolution is essentially the proposed S/AA hardware — 100% Saturn V, two-man LM/Taxi, LM/Shelter, LSSM rover, and a modified LM (logistics LM) for delivery of logistics loads via LOR. Increased potential is obtained at the medium-capability level by use of the LM/Truck, direct LM, or LLV with either the 100% Saturn V or 125% Saturn V. Large-capability evolutions are characterized by the eventual use of Saturn upratings greater than 125 percent (with the exception of group VIa) and include all of the six-man delivery systems considered in the study. The large-capability evolutions utilize the LLV logistics delivery system and large three-man rovers. The major capability groups are further divided into subgroups according to the degree of commitment to new hardware.

Taking evolution group VIb as an example, the first evolutionary step after Apollo involves the standard S/AA hardware. The next improvement in capability is obtained through the use of a logistics LLV with a 125% Saturn V and maintaining the LOR delivery of a three-man crew but utilizing the uprated Saturn. The personnel taxi for transportation of crew to and from the lunar surface is designed to be compatible with the 125% Saturn. Mission equipment consists of a large three-man rover, which can also be used as a shelter, a general purpose flying vehicle, and any major scientific equipment demanded by the scientific program. The third evolutionary step calls for a 150% Saturn V, a logistics LLV, and a direct-delivery personnel system (three-man) and its associated Earth-return stage. At this level, the mission equipment is supplemented by the provision of a six-man shelter for extended base operations.

The equipment evolutions presented here are those derived for MIMOSA study analyses and were extracted from a much larger list of evolutions that was prepared early in the study. A planner may, at any time, devise new evolutionary groups and their associated systems, depending on the particular planning question or exploration concept that he wishes to investigate.

2.3 SCIENTIFIC PROGRAM/EQUIPMENT EVOLUTION COMBINATIONS

The next step in the MIMOSA planning methodology is to select specific scientific program/equipment evolution combinations that will provide data for answering the planning questions. Table 2-3 summarizes the cases selected for analysis. In general, the lower capability equipment evolutions were utilized for the lower level of effort scientific programs, although the most promising evolutions from the large and medium capability groups were also exercised at each scientific level. Again, the seven basic planning questions of Table 2-1 were used as the basic criteria for selection of the cases but, as the actual analyses proceeded, it was also possible to select additional cases based on the experience gained. Scientific program A' was not used with any of the equipment evolutions. This was because it became apparent from analyses with scientific program B' that higher capability systems (particularly the long-range roving capability) could not be utilized efficiently with the high-level locale approach, whereas the lower capability systems would not be able to complete the scientific program.

2.4 GENERATION OF LUNAR EXPLORATION PROGRAMS

The exact procedure to be followed in the generation of lunar exploration programs is fully described in, Vol. I of the MIMOSA Planning Methodology. Only a summary of this procedure is given here.

The broad logic adopted in the MIMOSA planning methodology is illustrated in Fig. 2-1. The planning questions and basic assumptions represent the starting point and dictate the choice of scientific program and exploration equipment. The scientific program is specified in such a way that the mission planner can assign experiments to appropriate lunar locations with due regard to sequence, schedule, location dependency, and experiment interrelationships. Scientific missions can then be postulated together with their requirements in terms of manhours, equipment mass, traverse range, support activities, and major scientific equipment. Data on exploration equipment are generated independently and are contained in the Equipment Data Book. The equipments are organized into physically and operationally compatible assemblies, designated as exploration modes, for performance of the scientific program.

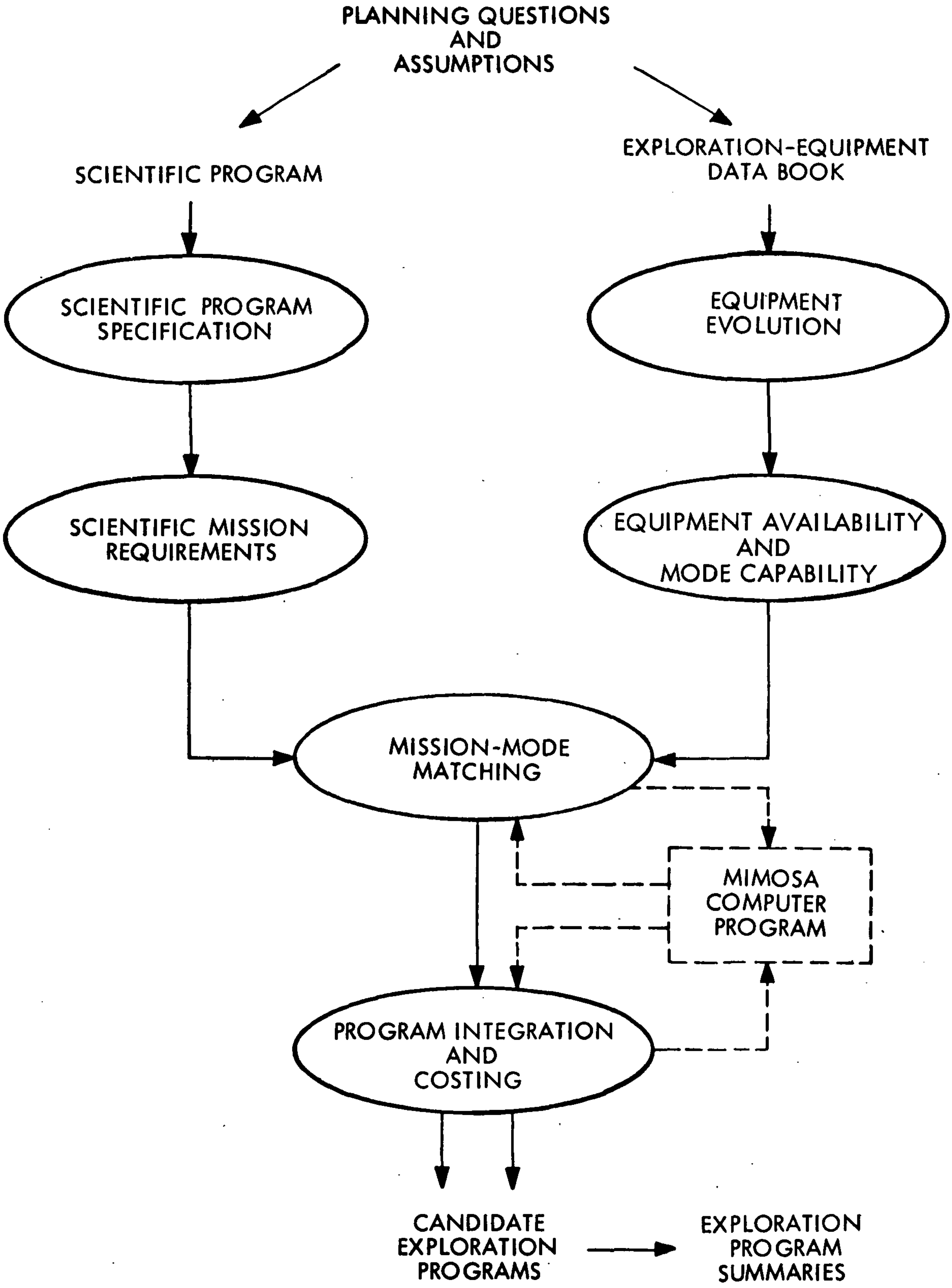


Fig. 2-1 Procedure for Generation of Lunar-Exploration Programs

Table 2-3

SCIENTIFIC PROGRAM/EQUIPMENT EVOLUTION
COMBINATIONS SELECTED FOR MIMOSA STUDY

Equipment Evolution	Scientific Program				
	A	B	B'	C	C'
Small					
I-a				o	●
Medium					
II-a		o		●	
II-b			●		
III-a			●		
III-b		o			
III-c	●	●	●		
IV-a		●		●	
IV-b	●	●	●	●	
Large					
V-a	●	●			
VI-a	●	●			
VI-b	●	●			
VI-c	●	●			
VI-d	●				
VI-e	●	●		●	

● Scientific Program Completed.
o Scientific Program Incomplete.

Scientific mission requirements and mode capabilities are compared in a procedure known as mission-mode matching. Mission-mode matching is an iterative procedure that utilizes the MIMOSA computer program as a bookkeeping and calculating aid to verify each match in detail. All relevant system, mode, and experiment data are stored on magnetic tape, and detailed computer printouts provide a description of the mission-mode comparison and the degree of matching achieved. Changes to the scientific mission or exploration modes are made by the planner as required to provide a better match. Normally, about three iterations yield an acceptable mission-mode match.

When all the missions have been successfully matched with available modes, program integration proceeds which results in an exploration program described in terms of equipment usage, schedule, and cost. The printouts of the mission-mode matching and integration routines provide detailed information on the candidate exploration program from which significant parameters are extracted and published as a Lunar Exploration Program Summary. (See Appendix E.)

Chapter 3
SUMMARY DESCRIPTION OF CANDIDATE EXPLORATION PROGRAMS

Because of the large amount of data associated with each exploration program, a detailed description of all the programs generated is not desirable at this point. Instead, some of the major program parameters are summarized and salient features indicated. In all, 29 basic exploration programs were generated. Twenty-six of these programs completed the assigned scientific programs. An additional 4 programs were generated that represent variations of a basic program where the dates of introduction of new equipment were changed. Appendix E contains Standard Lunar Exploration Summaries of the basic programs studied.

Major ground rules adopted for the generation of these exploration programs were as follows:

- Planning
  Planning period: post-Apollo through 1980's
  Smooth funding rate of 1 to 2 billion dollars per annum
  S/AA equipment to be used in the period 1970 – 73
- Equipment Usage
  Maximum use of Apollo technology
  Existing launch vehicles and their upratings only
  Evolutionary development of equipment capability
- Operations
  Suggested launch rates:
    1970 – 75: three to four per year
    1976 – 77: four per year
    1978 – onwards: six to eight per year
  Apollo missions: three in 1968, three in 1969
  Maximum crew stay time: 180 days

3.1 COST AND SCHEDULE SUMMARY

Cost and schedule data for those exploration programs that completed the assigned scientific program are summarized in Tables 3-1 through 3-5. The main constraint applied to the formulation of these programs was a fixed launch rate as long as the annual expenditure was in the range of 1 to 2 billion dollars. The Apollo run-out costs are not included in the total program cost but are accounted for in the average funding level. The total number of Saturn V launches include six Apollo launches for each program; in all cases, the use of S/AA hardware commenced in 1970. The operational introduction of increased capability systems, beyond S/AA, is indicated by the parenthetical calendar date. In each case the percentage value refers to the Saturn V rating.

The three exploration programs that were unable to complete the science program within a sensible time are summarized in Table 3-6. The amount of scientific effort accomplished is compared with the scientific requirements of the program in terms of scientific manhours.

Total program cost is a function of the equipment evolution used, the year of introduction of new equipment, and the scientific program attempted. The influence on program cost, resulting from introduction of an improved equipment capability, reflects a trade-off between the R&D investment, the recurring cost, and the improved potential of the equipment. The nonrecurring cost (R&D) for a given equipment evolution varies with each scientific program, due to the fact that the major scientific equipment is different for each program and the options used within a given evolution (e.g., use of a trailer or probe) depend on the demands of the scientific effort. Recurring costs are a direct function of the type and number of hardware systems procured.

The cost associated with the transportation systems represent major portions (approximately 80 percent) of the total program costs. To facilitate comparisons among the various exploration programs, the cost per launch of the transportation systems utilized in the study are given in Tables 3-7 and 3-8. Logistics transportation systems

Table 3-1

EXPLORATION PROGRAM CANDIDATES – COST AND SCHEDULE SUMMARY FOR SCIENTIFIC PROGRAM A

Equipment Evolution	Major Items of Equipment Evolution After S/AA and (Year of Introduction)	Average Funding Level ($B/yr)	Total[a] Saturn V Launches	Last Mission Start (year)	Post-Apollo Program Cost ($B)		
					Non-Recurring	Recurring	Total
IIIc	→ 125%[b] LM/Truck (1976) → 125% LLV (1979)	1.66	89	1986	4.19	21.30	25.49
IVb	→ 125% LLV (1976)	1.58	88	1986	3.65	20.21	23.86
Va	→ 100% LLV (1976) → 175% LLV (1980)	1.78	76	1985	6.43	19.34	25.77
VIa	→ 125% LLV (3 LOR (1976) → 6 LOR) (1984)	1.71	84	1985	5.19	19.42	24.61
VIb	→ 125% LLV (1976) → 150% LLV (1980)	1.70	89	1986	5.94	20.18	26.12
VIc	→ 125% LLV (1976) → 175% LLV (1981)	1.67	77	1986	6.85	18.74	25.59
VId	→ 125% LLV (1976) → 200% LLV (1984)	1.77	83	1985	6.84	18.79	25.63
VIe	→ 150% LLV (1976) (→ 6-Man Shelter) (1984)	1.55	84	1986	4.35	18.85	23.20

(a) Includes six Apollo launches.
(b) Percentage refers to Saturn V rating.

Table 3-2

EXPLORATION PROGRAM CANDIDATES – COST AND SCHEDULE SUMMARY FOR SCIENTIFIC PROGRAM B

Equipment Evolution	Major Items of Equipment Evolution After S/AA and (Year of Introduction)	Average Funding Level ($B/yr)	Total[(a)] Saturn V Launches	Last Mission Start (year)	Post-Apollo Program Cost ($B)		
					Non-Recurring	Recurring	Total
IIIc	→ 125%[(b)] LM/Truck (1977) → 125% LLV (1985)	1.70	84	1986	3.37	22.60	25.97
	→ 125% LM/Truck (1975) → 125% LLV (1984)	1.71	80	1985	3.37	21.30	24.67
IVa	→ 100% LLV (1974)	1.33	61	1985	2.81	15.03	17.84
IVb	→ 125% LLV (1975)	1.51	57	1982	3.50	12.93	16.43
Va	→ 100% LLV (1974) → 175% LLV (1977)	1.54	44	1982	6.70	10.25	16.95
VIa	→ 125% LLV (3 LOR → 6 LOR) (1975) (1982)	1.59	55	1982	5.09	12.62	17.71
VIb	→ 125% LLV (1974) → 150% LLV (1978)	1.46	52	1983	5.85	11.27	17.12
VIc	→ 125% LLV (1974) → 175% LLV (1978)	1.56	46	1982	7.12	10.15	17.27
VIe	→ 150% LLV (1974) (→ 6-Man Shelter) (1981)	1.41	50	1982	4.25	10.72	14.97

(a) Includes six Apollo launches.
(b) Percentage refers to Saturn V rating.

Table 3-3

EXPLORATION PROGRAM CANDIDATES – COST AND SCHEDULE SUMMARY FOR SCIENTIFIC PROGRAM B'

Equipment Evolution	Major Items of Equipment Evolution After S/AA and (Year of Introduction)	Average Funding Level ($B/yr)	Total[a] Saturn V Launches	Last Mission Start (year)	Post-Apollo Program Cost ($B)		
					Non-Recurring	Recurring	Total
IIb	→ 100%[b] Dir. LM (1974)	1.79	84	1985	3.00	23.07	26.07
IIIa	→ 100% LM/Truck → 100% Dir.LM (1974) (1977)	1.87	86	1985	3.11	24.36	27.47
IIIc	→ 125% LM/Truck → 125% LLV (1973) (1980)	1.53	74	1986	3.89	18.95	22.84
IVb	→ 125% LLV (1973)	1.50	73	1985	3.64	17.17	20.81
	→ 125% LLV (1976)	1.48	77	1986	3.64	18.34	21.98
	→ 125% LLV (1978)	1.49	81	1987	3.64	19.92	23.56

(a) Includes six Apollo launches.
(b) Percentage refers to Saturn V rating.

Table 3-4

EXPLORATION PROGRAM CANDIDATES – COST AND SCHEDULE SUMMARY FOR SCIENTIFIC PROGRAM C

Equipment Evolution	Major Items of Equipment Evolution After S/AA and (Year of Introduction)	Average Funding Level ($B/yr)	Total[a] Saturn V Launches	Last Mission Start (year)	Post-Apollo Program Cost ($B)		
					Non-Recurring	Recurring	Total
IIa	→100%[b] LM/Truck (1975)	1.74	76	1984	1.11	22.30	23.41
	→100% LM/Truck (1978)	1.79	84	1985	1.11	24.91	26.02
IIIc	→125% LM/Truck → 125% LLV	1.61	47	1980	2.65	12.06	14.71
IVa	→100% LLV (1974)	1.38	42	1980	2.00	9.80	11.80
IVb	→125% LLV (1974)	1.32	40	1980	2.69	8.28	10.97
VIe	→150% LLV (1974)	1.36	39	1980	3.26	8.24	11.50

Table 3-5

EXPLORATION PROGRAM CANDIDATES – COST AND SCHEDULE SUMMARY FOR SCIENTIFIC PROGRAM C'

Equipment Evolution	Major Items of Equipment Evolution After S/AA and (Year of Introduction)	Average Funding Level ($B/yr)	Total[a] Saturn V Launches	Last Mission Start (year)	Post-Apollo Program Cost ($B)		
					Non-Recurring	Recurring	Total
Ia	→ S/AA (100% LM) (1970)	1.77	81	1985[c]	0.44	24.99	25.43

(a) Includes six Apollo launches.
(b) Percentage refers to Saturn V rating.
(c) Scientific program completed except for two 100-km paths.

Table 3-6

SUMMARY OF EXPLORATION PROGRAMS THAT COULD NOT COMPLETE SCIENTIFIC PROGRAM

Eqpmt. Evol.	Major Items of Equipment Evolution After S/AA	Sci. Prog.	Term-ination (year)	Scientific Time (manhours)		Scientific Mass (kg)		Total Saturn V Launches to Term.[a]	Total Post-Apollo Prog. Cost to Term.($B)
				Total Accomp.	Total Req.	Total Del.	Total Req.		
IIa	→100% [b]LM/Truck	B	1987	10,850	30,000	135	174	97	29.56
IIIb	→100% LM/Truck→125% LLV	B	1987	8,900	30,000	140	174	89	28.24
Ia	→100% LM	C	1979[c]	3,200	7,000	31	73	45	13.17

(a) Includes six Apollo launches.
(b) Percentage refers to Saturn V rating.
(c) Program terminated when paths encountered.

(Table 3-7) comprise all the flight systems used in a launch but do not include the payload. The LM derivatives (with the exception of the direct LM) use LOR manrated systems and, therefore, show relatively higher costs when compared with systems that employ the direct landing technique. Personnel transportation system costs (Table 3-8) are higher than those for logistics systems but a smaller number of these systems are used in a given exploration program. It must be remembered, however, that procurement costs are reduced considerably as the quantity procured increases (learning curve). Thus, if two new transportation systems are introduced during a program, the cost penalty is high since full advantage is not taken of the learning curve reduction effect. This fact, together with the increased costs associated with the additional R&D, means that two-step increases of capability in an equipment evolution usually results in relatively poor cost effectiveness when compared with an evolution that reaches a similar capability through a single step.

Table 3-7

COST PER LAUNCH OF LOGISTIC TRANSPORTATION SYSTEMS (INITIAL PROCUREMENT)

Transporation System	Payload to Lunar Surface (kg)	Recurring Cost ($M)	Cost Per Kilogram ($T)
100% LM* – LOR	4,900	297	60.6
100% LM/Truck – LOR	4,200	296	70.5
100% Dir. LM – Direct	8,900	219	24.6
125% LM/Truck – LOR	7,300	297	40.7
100% LLV – Direct	12,100	191	15.8
125% LLV – Direct	16,300	192	11.8
150% LLV – Direct	20,800	205	9.9
175% LLV – Direct	25,400	215	8.5
200% LLV – Direct	28,300	217	7.7

*Percentage refers to Saturn V rating.

Table 3-8

COST PER LAUNCH OF PERSONNEL TRANSPORTATION SYSTEMS
(INITIAL PROCUREMENT)

Transportation System	Crew to Lunar Surface	Recurring Cost ($M)	Cost Per Manhour ($M)
100% Saturn* – LOR	2	330	165
100% Saturn – LOR	3	337	112
125% Saturn – LOR	3	338	112
125% Saturn – LOR	6	415	69
150% Saturn – Direct	3	308	103
175% Saturn – Direct	6	356	59
200% Saturn – Direct	6	357	59

*Percentage refers to Saturn V rating.

3.2 LUNAR EXPLORATION SUMMARIES

Comprehensive Summaries of each exploration program are presented in Appendix E. These consist of convenient summaries of the salient features of the exploration programs generated during the MIMOSA study. They contain a general description of the exploration program together with data on the scientific program, operational accomplishments by mission, exploration program cost and schedule, and equipment usage. These summaries represent the final step in exploration program generation and provide, in a concise, standard format, the type of information required by a planner.

The first few pages of Appendix E contain a brief review of the scientific programs together with a lunar reference map indicating the exploration pattern and locations to be visited in a particular program. Normally, these are given with each program summary but for the purposes of this report the scientific program descriptions are brought together at the front of Appendix E to avoid repetition.

The General Description contains the assumptions and guidlines used in generation of the program and gives a brief description of the content of the exploration program.

The Cost and Schedule Summary presents major cost and schedule requirements for the program. Cost data are given under two major categories – nonrecurring and recurring. The nonrecurring cost is further broken down to include R&D (Research and Development) and C of F (Cost of Facilities), and the recurring cost is reported under equipment procurement and operations. Total and annual funding requirements are provided. The Apollo run-out costs are indicated but these are distinguished from the actual post-Apollo exploration program costs. However, the six Apollo launches are included in the launch total quoted.

All missions accomplished in the exploration program, together with mission dates and geographical locations, are listed in the Post-Apollo Mission Summary. Mass delivered, stay time, and manhours data are also given. Total cargo mass refers to the total useful landed mass (mission equipment + scientific equipment). The mass reserve represents the unused mass delivery potential of the mode (i.e., landed payload capability – total cargo). This figure, therefore, represents the amount of "overkill" of the mode and exists because a fixed scientific program was performed. In practice, the scientific requirements would be tailored to produce more efficient usage of the mode capability. Traverse range given in this table is the actual distance traveled in the performance of the mission and this often exceeds the scientific requirements.

The Equipment Usage and Cost Summary records major items of exploration equipment used in the program together with the quantities procured and specific system costs. The identification numbers given for individual exploration equipment allows easy reference to the MIMOSA Data Book which contains detailed descriptive information and performance data on each system.

An approximate representation of scientific return that can be obtained from an exploration program is provided by the Scientific Program Operation Summary. Cumulative scientific manhours and cumulative scientific equipment mass (which includes the mass of explosives for the active seismology experiments) are presented as a function of calendar time. In addition, cost per scientific manhour and cost per kilogram of scientific mass, both based on total cumulative program cost, are given as a function of time.

Chapter 4
ANALYSIS AND EVALUATION OF CANDIDATE EXPLORATION PROGRAMS

As previously described, the MIMOSA candidate lunar exploration programs were devised to provide data for answering specific planning questions and to cover a representative spectrum of approaches to lunar exploration. The actual manipulation of MIMOSA program results depends on the particular problem in hand and the specific interests of the planner. The analyses presented here are aimed at the evaluation of significant factors that will influence the choice of equipment to be used in post-Apollo exploration of the Moon and are illustrative of the use of the MIMOSA technique.

To illustrate the relevance of the postulated planning questions to lunar program planning and to clarify the arguments presented here, the main elements of a lunar exploration plan are shown pictorially in Fig. 4-1. This "road map" of lunar exploration reflects a general philosophy derived from the overall MIMOSA studies and embodies recommended approaches expressed by the Space Science Board and NASA. Distinct increases in equipment capability are visualized for the performance of various phases of the exploration program. Manned lunar landings with limited scientific capability will be accomplished by the Apollo program. Reconnaissance missions with small roving capability can be achieved by the proposed Saturn/Apollo Applications (S/AA) program. The exploration phase, which includes the use of temporary lunar stations and long-range mobility systems, would require a medium capability (as defined in Table 2-2). Large capability systems would be utilized for the performance of the exploration phase to provide a quasipermanent base for more detailed examination of the Moon itself and to use the Moon as a platform for the observation of extralunar phenomena. In a nominal lunar exploration program, the capability increase steps are assumed to occur as shown in Fig. 4-1. However, various options are available. These must be considered at each decision point that is associated

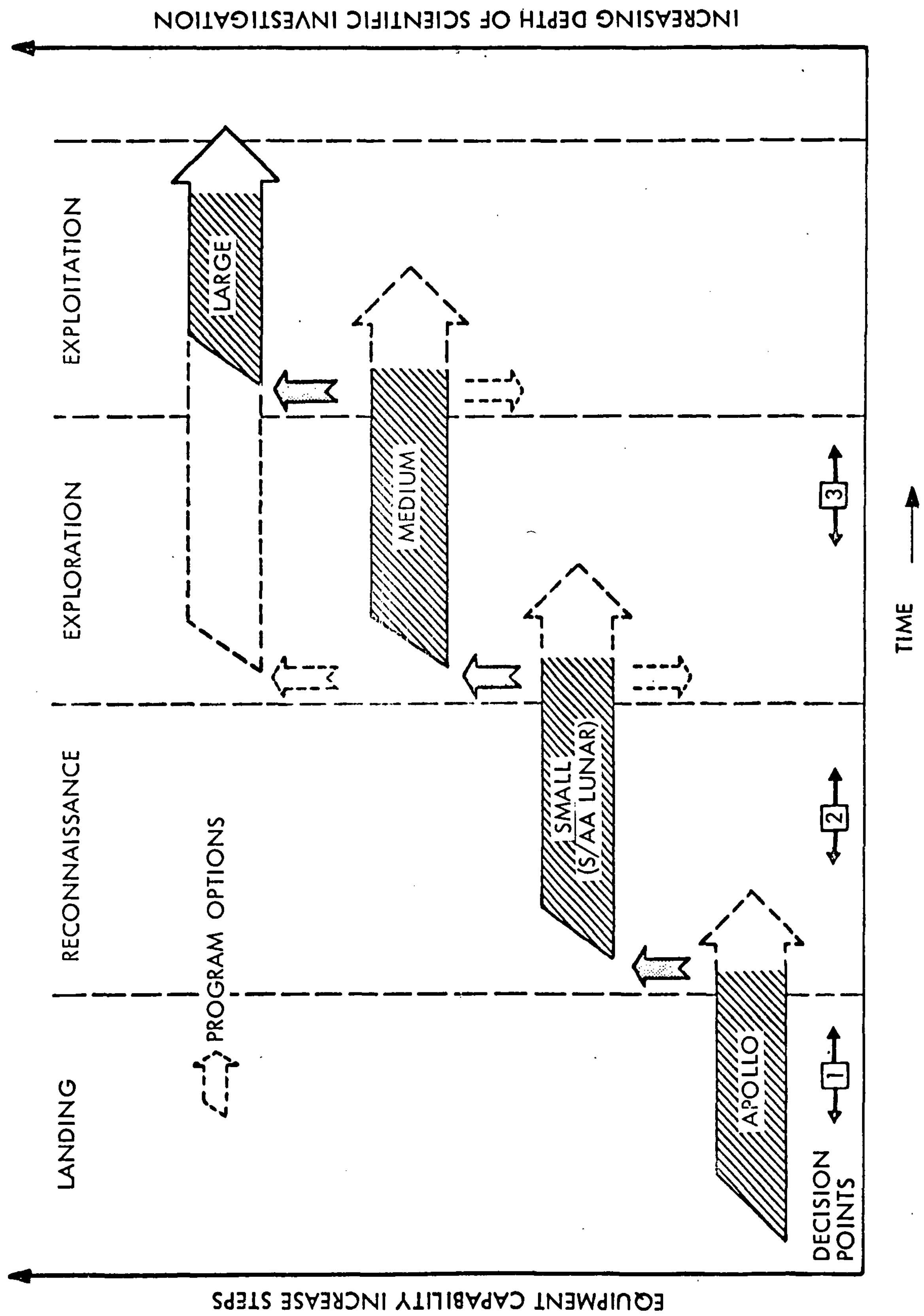


Fig. 4-1 Basic Elements of a Lunar Exploration Plan

with any capability change. For instance, at decision point 2, four possibilities exist. These are as follows:

- Continuation at the S/AA level
- A one-step capability increase to the medium level
- A two-step capability increase to the large level
- Termination of lunar exploration

The level of scientific activity to be attempted represents another factor that must be considered. In general, scientific depth corresponding to the A, B, and C levels of scientific effort are associated with the small, medium, and large capabilities, respectively, but this is by no means a fixed rule.

The problem facing the planner, then, is to provide answers to the specific questions posed at each decision point. In the process of solving the problem, a number of exploration programs are generated that utilize distinct equipment evolutions and particular scientific programs. The elements of each exploration program must then be evaluated and the results synthesized into an exploration program that exhibits maximum flexibility with respect to possible future changes in requirements.

A variety of evaluation criteria are available from the exploration program data. These include:

- Total program cost
- Annual funding requirements
- Number of Saturn V launches
- Flexibility of exploration equipment
- Lunar stay time
- Scientific manhours performed
- Scientific equipment mass delivered
- Total mass reserve

None of these criteria alone is absolute and all factors must be considered. In the analysis of MIMOSA study results, emphasis was placed on minimum program cost and equipment flexibility.

This chapter is concerned with the evaluation of candidate exploration programs generated during the study.

4.1 PLANNING DECISION POINTS

Three decision points are identified in Fig. 4-1, all relating to the alternate options available for changing exploration equipment capability. For the purposes of the MIMOSA study it was assumed that decision 1 had been made and that the immediate post-Apollo era would utilize S/AA equipment capability. Decision point 2 is considered the most important for the MIMOSA study because of its proximity in time and because of its possible commitments to advanced hardware development. Decision point 3 is less important at this time and will be strongly influenced by an environment that cannot be forecast accurately at present. However, the possible influences of decision point 3 options on decision point 2 must be borne in mind.

Each decision point, of course, precedes the operational introduction of equipment providing a capability change. Answers to the following planning considerations will influence decisions made at 2 and 3:

- Decision Point 2
  - Implications of continued use of S/AA equipment
  - Requirements for Saturn V uprating
  - LM/Truck or LLV
  - Influence of scientific program
  - Timing of capability change
- Decision Point 3
  - Requirements for Saturn V uprating
  - Three- or six-man delivery system
  - LOR or direct personnel delivery mode

Influence of scientific program
Timing of capability change

Equipment evolution/scientific program combinations were chosen, as reported in Chapter 2, to provide insight into these problems. The resulting exploration programs are described in Chapter 3.

4.2 FACTORS INFLUENCING DECISION POINT 2

Provisional NASA planning for the S/AA lunar program calls for orbiter and surface missions during the period 1971 – 74. Any post-Apollo exploration program must include the S/AA missions as a starting point. Bearing in mind the development lead times associated with new equipment, decision point 2 could occur as early as 1970. The available options at this point and the effects of delaying the decision must now be examined.

4.2.1 Continued Use of S/AA Equipment

The S/AA capability is represented by equipment evolution 1a which contains a 100% Saturn V, two-man LM Taxi, LM Shelter, LSSM, and logistics LM. The compatible scientific program is C or C'. However, because of the limited roving capability of this evolution, the long traverse requirements of C could not be satisfied and the program was abandoned on completion of the locale-type science missions. The equipment is quite capable of coping with the C' science and the exploration program (C'-Ia) is completed by 1985 with the exception of the two 100-km paths which represent a very small part of the scientific requirements. Scientific return, in terms of manhours and mass, is shown in Table 4-1.

Annual funding requirements for both programs are given in Fig. 4-2. Due to the limitations of the mission equipment employed in this evolution, the cost effectiveness is poor when compared with higher capability evolutions to be discussed later. Essentially, the locales of scientific program C are contained in C', and up to this point of achievement the program costs are identical. However, the average costs per

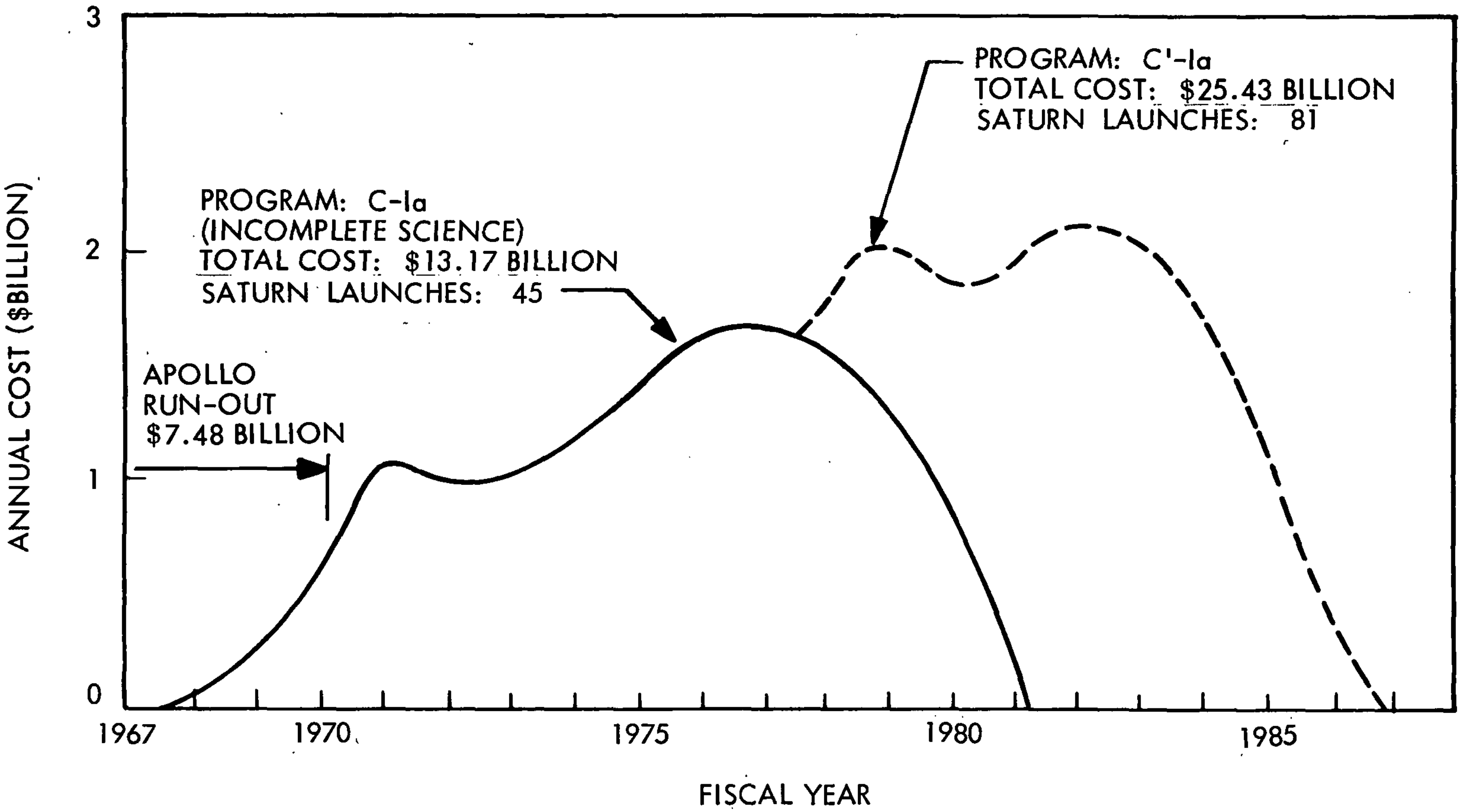


Fig. 4-2 Funding Requirements for Exploration Programs Utilizing S/AA Equipment

Table 4-1
SCIENTIFIC RETURN

Item	Scientific Program	
	C	C'
Total scientific manhours performed	3,200	7,500
Total scientific mass delivered (kg)	31,000	40,000
Average cost per scientific manhour ($M)	4.1	3.4
Average cost per scientific kilogram ($M)	0.4	0.6

scientific manhour and per scientific kilogram for exploration program C'-Ia differ from those for program C-Ia. This is due to the fact that in the post-1980 period longer mission stay times are required and these are achieved by logistics resupply of expendables. This shows up as a reduction in unit scientific manhour costs and an increase in unit scientific mass costs.

It is evident from these results that S/AA equipment can be used to increase our knowledge of the Moon through performance of the lower-level scientific program, but at a relatively high cost. The addition of a cabin-type rover, with a range of 50 to 100 km, to the S/AA inventory would improve the efficiency of this equipment group. Without this expanded mobility potential, the S/AA equipment is most effectively employed in the performance of a scientific program using the locale-region exploration pattern. Lunar exploration may be terminated at any time without serious losses since the R&D investment is quite small. The amount of science achieved depends on the year of cessation and can be deduced from the C'-Ia summary contained in Appendix E.

4.2.2 Use of Medium-Capability Hardware Systems

If the S/AA system capability is considered inadequate for continued lunar exploration, the equipment capability may be improved by a small increase step to the medium level or by a large step to the large-capability level. Medium-capability evolutions (groups II through IV) are characterized by increased logistics capability (over S/AA); in particular, a rover with a range in excess of 300 km may be delivered to the lunar surface. This increased mobility potential makes the path approach to exploration attractive and it is likely that any increased capability will be associated with a scientific program at the B or A level.

At the lower end of the medium-capability spectrum are the LM derivative systems. When used with the 100% Saturn V, these evolutions are not very effective. Evolutions IIa and IIIb (based on the 100% LM/Truck) were exercised against scientific program B, but could not complete the science program within the time frame examined (i.e., up to 1987). Evolutions IIb and IIIa, that utilize the direct LM, successfully completed scientific program B', but program costs would exceed $26 billion. Introduction of the 125% Saturn V (evolution) improves the cost picture, as seen from Table 4-2. However, all of the improvement results from utilization of the LLV which is introduced into the program in 1980 and results in a saving of 10 Saturn V launches when compared with the case using the 100% direct LM (program B'-IIIc versus B'-IIb). An analysis of the missions contained in these two programs indicates that, if the LLV had not been introduced, the program cost for an evolution using the 125% LM/Truck throughout is about the same as for that using the 100% direct LM. If the LLV is introduced directly after completion of the S/AA missions (circa 1974), a further reduction in program cost is obtained (program B'-IVb).

The strong influence of the logistic mode is even more noticeable in the performance of scientific program B, which involves a larger requirement for explosives than program B' and fully utilizes the long stay times required for path exploration. In this case (Table 4-2), the use of the 100% LLV and 125% LLV evolutions result in considerably lower costs than obtained with the evolution that includes the 125% LM/Truck. In the latter case, the LM/Truck was retained until 1984 and the LLV was used for the astronomy base missions only. Analysis showed that if the LM/Truck had been used for the astronomy missions, the resulting program cost would have been $26.6 billion and an associated 86 Saturn V launches. In addition, the program would have been extended by an additional year.

Table 4-2

EXPLORATION PROGRAM COSTS – MEDIUM CAPABILITY

Equipment Evolution	Major Items of Equipment Evolution (After S/AA)	Exploration Program Cost ($B)			
		Scientific Program B'	Scientific Program B	Scientific Program A	Scientific Program C
IIa	→ 100% LM/Truck[a]				23.41
IIb	→ 100% Direct LM	26.07			
IIIa	→ 100% LM/Truck → 100% Dir. LM	27.47			
IIIc	→ 125% LM/Truck → 125% LLV	22.84	24.67	25.49	14.71
IVa	→ 100% LLV		17.84		11.80
IVb	→ 125% LLV	20.81	16.43	23.86	10.97
VIe[b]	→ 150% LLV		14.97	23.20	11.50

(a) Percentage refers to Saturn V rating.
(b) Large capability evolution given for comparison.

A similar picture emerges if the medium capability systems are used in the performance of scientific programs A or C. Again, the evolutions containing the LLV with the 100% or 125% Saturn V result in the lowest program costs. In program A-IIIc, the LM/Truck was replaced by the LLV in 1979. A later introduction of the increased logistics capability would have meant that the scientific program would not have been completed by 1990.

It is interesting to compare the scientific return obtained for a given total dollar investment for the various transportation systems used in the LM/Truck and LLV evolutions. Fig. 4-3 illustrates this in terms of manhours and Fig. 4-4 gives the scientific mass as a function of program costs for two typical exploration programs. These curves show cumulative manhours and mass against cumulative total program cost; the slopes indicate the efficiencies of the transportation systems involved. Since the program costs include both recurring and nonrecurring contributions, the values represent the total investment required to provide a certain number of scientific manhours and the use of a certain mass of scientific equipment. Thus, the slopes are perturbed by a large R&D investment and also by a mission structure that, say, demands a large amount of mission equipment in support of a small scientific mass (as in the case of the breaks in the curves of Fig. 4-4). In general, the minor perturbations have been smoothed out. However, in terms of manhours, it can be seen from Fig. 4-3 that base-type operations are more efficient for a given system than those associated with locales or paths. The approximate operational efficiencies represented by the slopes of these curves are as follows:

	$M/manhour	$M/kg
S/AA	4.3	0.7
125% LM/Truck (Path)	1.6	0.07
125% LM/Truck (Base)	0.20	0.12
125% LLV (Path)	0.94	0.04
125% LLV (Base)	0.07	0.04

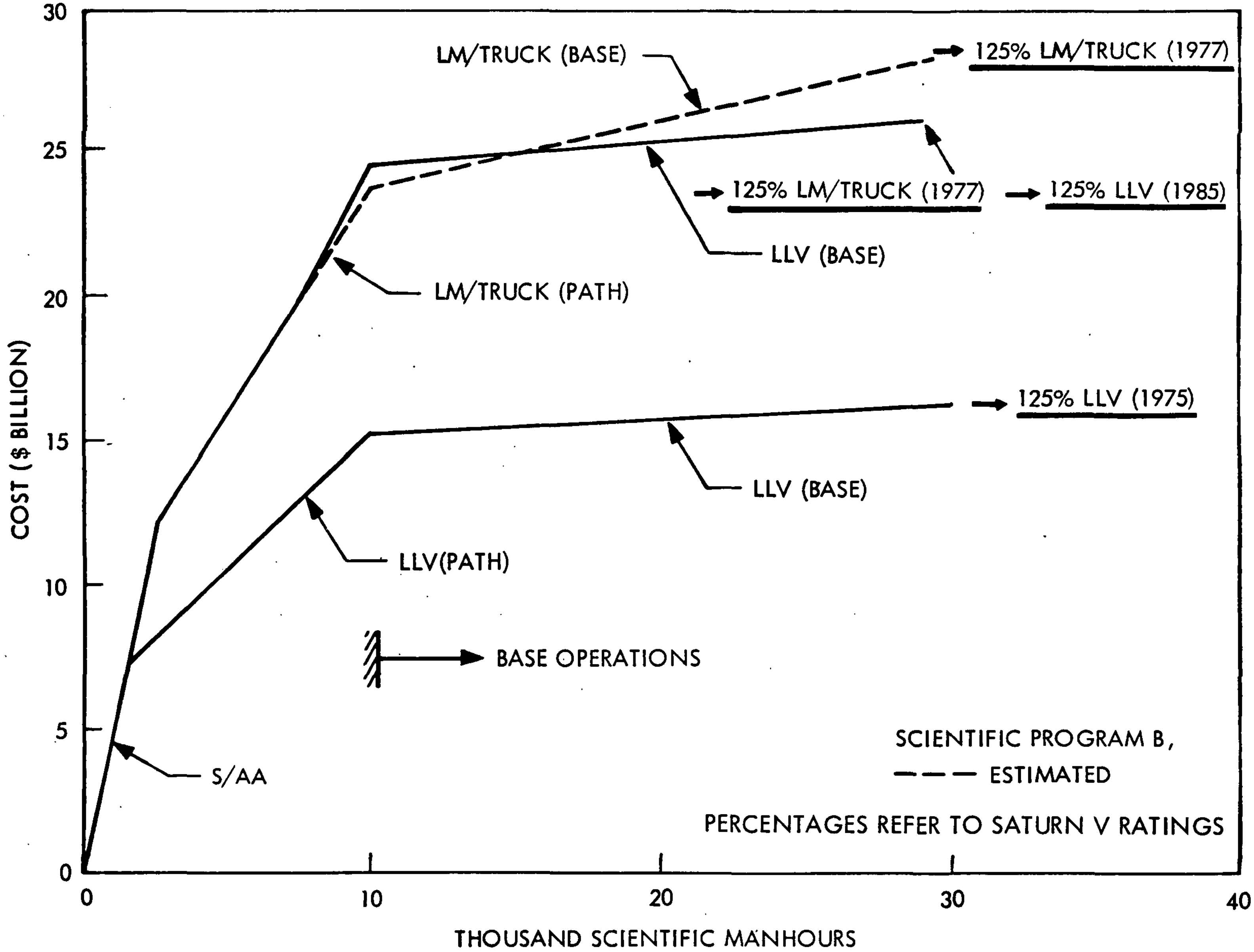


Fig. 4-3 Scientific Return From LM/Truck and LLV (manhours)

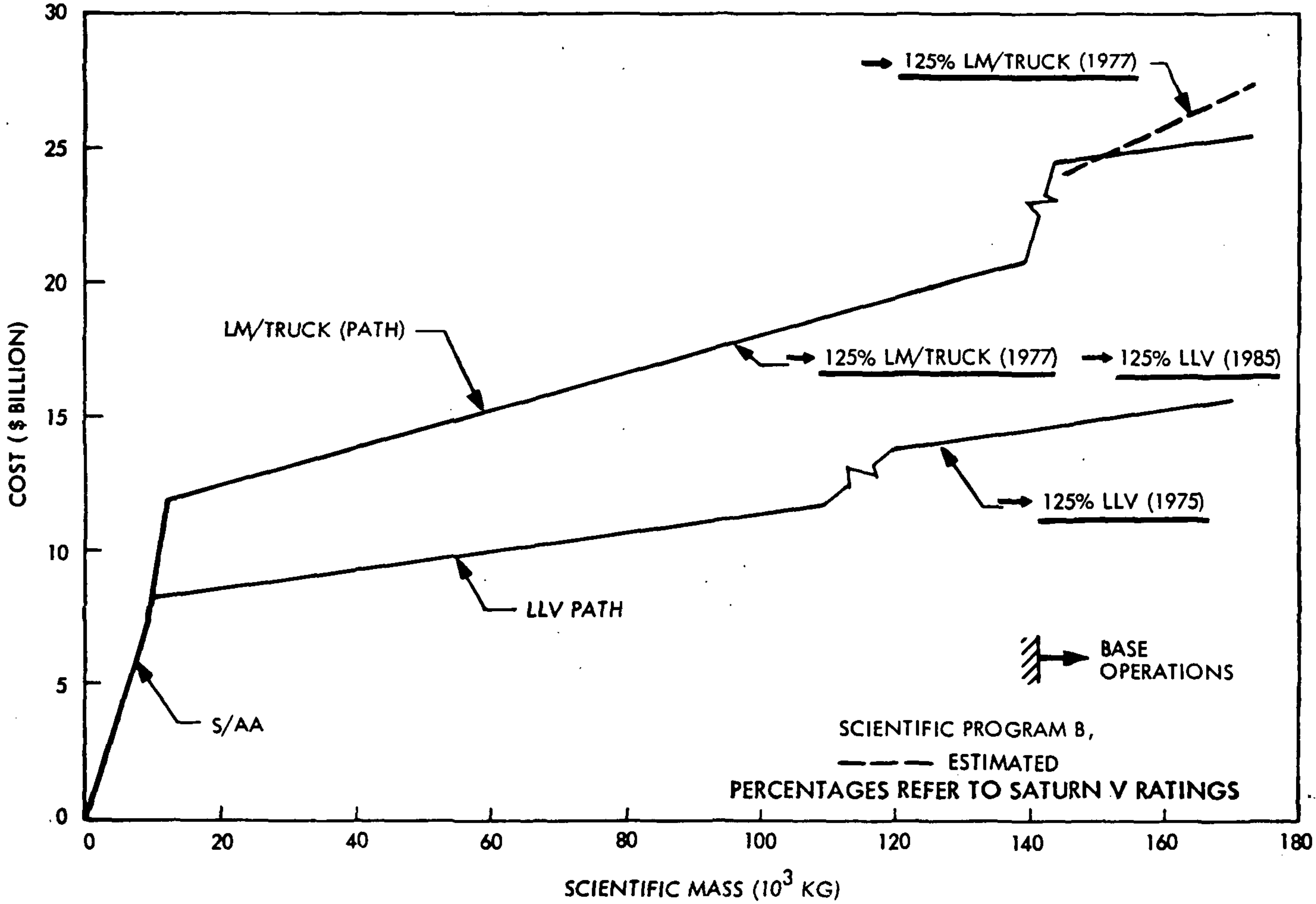


Fig. 4-4 Scientific Return From LM/Truck and LLV (mass)

As a result of the better efficiencies exhibited by the LLV systems, total program costs are lower, Saturn V launches are less, and the scientific program is completed faster by LLV-based evolution as compared with LM/Truck-based evolutions.

4.2.3 Use of Large-Capability Hardware Systems

The most practical large-capability evolution that might be considered at decision point 2 is that which uses the 150% Saturn V, LLV, and associated mission equipment (evolution VIe). This evolution involves a relatively low investment risk and still provides a significant increase in capability; it also represents the lowest Saturn uprating that permits direct delivery of a three-man crew. It was found that this evolution gave the lowest total program costs to perform scientific programs A and B (Table 4-2). In view of its good performance against the higher level scientific programs, the 150% LLV evolution was also exercised against scientific program C. Again, the performance was excellent. In addition, a large mass reserve is available at each scientific level, which is indicative of greater scientific potential than was actually utilized in the fixed scientific programs and offers more flexibility to mission changes.

4.2.4 Decision Timing

The date of introduction of a higher performance system into the exploration program and, thus, the time at which the decision to commit initial R&D funds are important planning considerations. At decision point 2, a decision delay involves the prolonged use of S/AA equipment. To examine this effect, the dates of introduction of the LM/Truck, and LLV and their associated systems into programs B-IIc and B'-IVb, respectively, were varied and the resulting total program costs established. The results are summarized in Fig. 4-5. The timing of the decision point is not very critical. In the case of the LLV, a 3-year delay in the operational introduction date (1973 to 1976) involves a cost increase for the total program of about 5 percent, whereas a delay of 5 years (1973 to 1978) involves a cost increase of 13 percent.

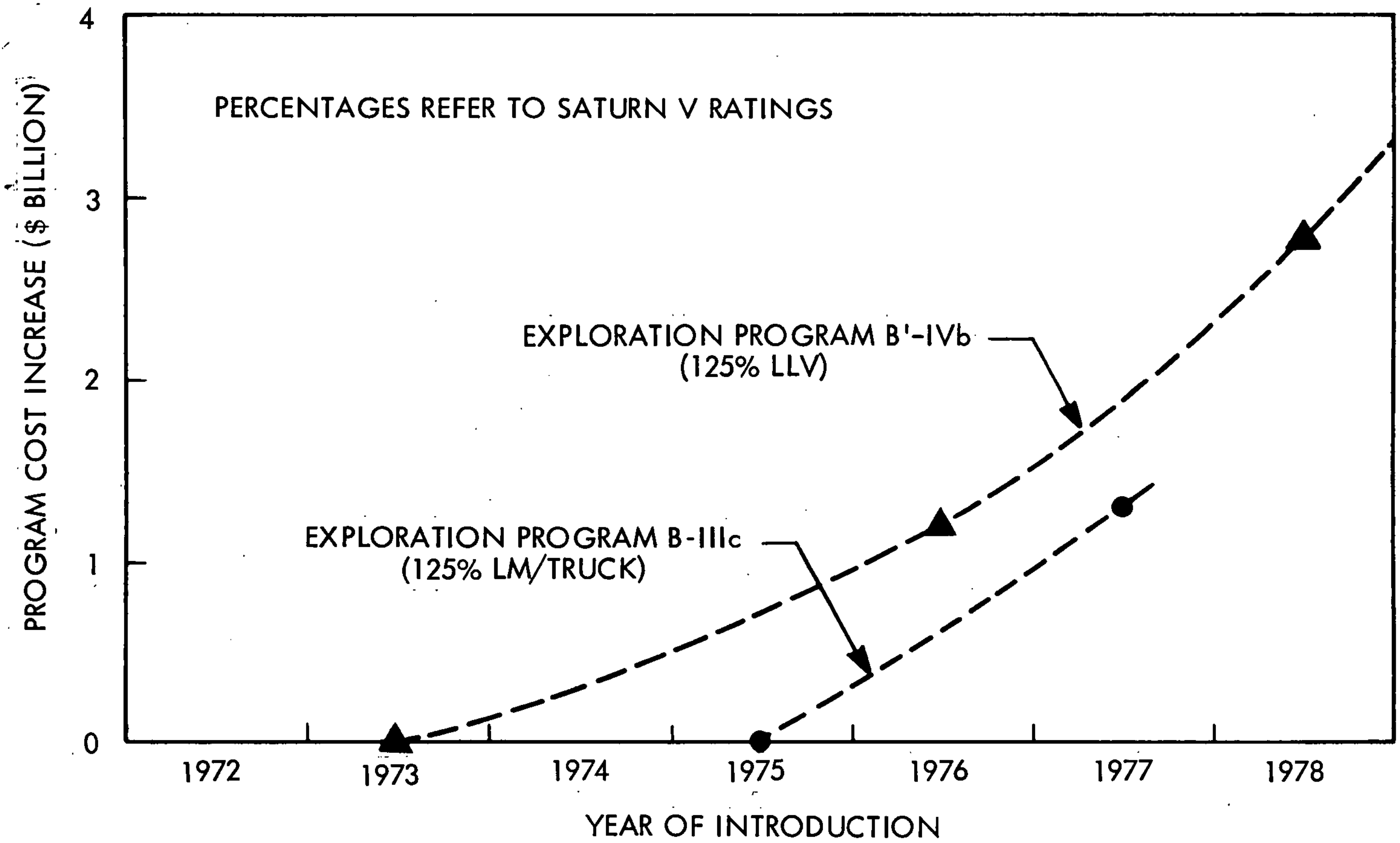


Fig. 4-5 Cost Penalty of Delay in Introduction of Higher Capability Systems

4.2.5 Funding Commitments

The planner may be specifically concerned about near-term commitments rather than total investment over a period of perhaps 15 years. In general, the funding rate falls within acceptable limits (1 to 2 billion dollars per year) since the launch rate is the main pacing item and this was similar for all programs. Any peaks in the funding rate curves can be removed by judicious planning but no detailed smoothing was warranted in this study. However, when uncertainties in the immediate post-Apollo philosophy exist, commitments to sizable R&D investments cause some concern. With the total program cost penalty in mind, it is interesting to examine the major commitments that would have to be made at decision point 2 for the three principal evolutions studied. These are shown in Table 4-3 for equipment evolution involving the 125% Saturn V and LM/Truck, 125% Saturn V and LLV, and 150% Saturn V and LLV. Introduction of the uprated systems into operational use is assumed to be 1975. The equipment item with the largest lead-time is the roving vehicle, for which the development funding would have to be committed in 1970. Decision point 2, then, precedes the introduction of the hardware into the program by about 5 years. The choice of Saturn V uprating may be delayed an additional 2 years. The actual spending of these R&D funds is spread over a time period up to and including the operational use of the uprated equipment. Peak funding rates and years of occurrence for the three evolutions are:

- 125% LM/Truck: 330 $M/yr 1974
- 125% LLV: 530 $M/yr 1973
- 150% LLV: 554 $M/yr 1973

4.3 FACTORS INFLUENCING DECISION POINT 3

By definition, decision point 3 is reached after the medium-capability systems have been introduced. One possibility concerns the discontinuation of lunar exploration or a considerable reduction in the level of scientific activity. It has been shown previously that the medium-capability systems function satisfactorily at scientific program C level so that the tapering-off of the exploration program becomes a matter of tailoring the endeavor to the requirements prevailing at that time. The most likely options involve continuing lunar exploration either at the medium-capability level or with increased

Table 4-3

MAJOR NONRECURRING FUNDING COMMITMENTS FOR LM/TRUCK AND LLV EVOLUTIONS ($M)

Equipment Evolution[a]	Fiscal Year		
	1970	1971	1972
IIIc (125% LM/Truck)[b]	LRV (21-day) 362	-	Saturn V 612 LM/Truck 99
IVb (125% LLV)	LRV (90-day) 423	LLV 623	Saturn V 612
VIe (150% LLV)	LRV (90-day) 423	LLV 623	Saturn V 675

(a) First operational use fiscal year 1975.
(b) Percentage refers to Saturn V rating.

capability systems. It is likely that the type of equipment used will be influenced by decisions yet to be made regarding manned planetary flight. Thus a number of exploration programs were generated that utilized various levels of Saturn V uprating. Although, for the purpose of this study, all R&D costs were attributed to the lunar program, some cost sharing of the selected Saturn V uprating with the planetary program might be possible.

4.3.1 Continued Use of Medium-Capability Hardware Systems

The performance of the medium-capability systems against scientific programs B and C have been discussed previously, and it was shown that the use of an LLV logistics delivery system, used with either the 100% or 125% Saturn V, results in relatively low-cost programs. Continued use of the medium-capability systems would eliminate possible problems that might be encountered in the development of new systems required for a step up to large capability; however, R&D commitments to a long stay-time shelter, associated power plant, and certain items of major scientific equipment would be required to maintain extended exploration at the medium-capability level.

4.3.2 Use of Large-Capability Hardware Systems

Exploration program costs for equipment evolutions that eventually make use of large capability systems are given in Table 4-4. For the scientific programs examined, no great differences in cost are evident, although the evolution using the 150% Saturn V and LLV (evolution VIe) again shows the most efficient performance. Reference to the program summaries of Appendix E shows that fairly large mass reserves are available in all these programs. This implies that even the scientific program A level-of-effort could be extended to fully utilize the capability of these evolutions. It is also noteworthy that the higher capability systems are capable of performing the larger science program for costs that are comparable with those required to perform the lower level science with the LM/Truck and 100% Saturn V combinations.

4.3.3 Influence of Crew Delivery Mode

A significant fact that emerged from the MIMOSA Program analyses is that the logistics delivery mode has a much greater effect on program cost than the personnel delivery mode. Thus, no distinct advantages of a particular personnel delivery mode could be identified. For the type of scientific program attempted, where a six-man level is required only towards the end of program A, the development of a six-man delivery system is not mandatory. In fact, a comparison of exploration programs A-IVb and A-VIa shows that the cost of developing the six-man systems more than offsets the reduction of launches required for base operation. If more extensive base activities are planned, then this trend would eventually be reversed. However, even for a six-man base, a three-man crew rotation offers distinct operational advantages, since it ensures carryover of experience at the base.

Direct-delivery systems are generally less costly than those using the LOR mode because the latter requires expensive CSM combinations. However, when the total program is considered, the increased logistics capabilities provided by the uprated Saturns (that are required for direct delivery) become the controlling factor. It seems

Table 4-4

EXPLORATION PROGRAM COSTS – LARGE CAPABILITY

Equipment Evolution	Major Items of Equipment Evolution (After S/AA)	Exploration Program Costs ($B)		
		Scientific Program A	Scientific Program B	Scientific Program C
Va	→ 100% LLV[a] → 175% LLV	25.77	16.95	
VIa	→ 125% LLV (3 LOR → 6 LOR)	24.61	17.71	
VIb	→ 125% LLV → 150% LLV	26.12	17.12	
VIc	→ 125% LLV → 175% LLV	25.59	17.27	
VId	→ 125% LLV → 200% LLV	25.63		
VIe	→ 150% LLV	23.20	14.97	11.50
IVb[b]	→ 125% LLV	23.86	16.43	10.97

(a) Percentage refers to Saturn V rating.
(b) Medium capability evolution given for comparison.

likely that operational considerations will be more influential in providing an answer to the LOR or direct crew delivery question. The requirements for maintaining a deactivated command module in orbit for times well in excess of 14 days are particularly stringent. From this point of view, the direct delivery mode is to be preferred.

4.3.4 Influence of Decision Point 3 on Decision Point 2

An important consideration at decision point 2 is that the hardware systems selected for continuation of lunar exploration must be flexible enough to accommodate a change of direction at decision point 3. From this point of view, the LLV logistics system is attractive since it is equally effective against the three widely different levels of science contemplated. Furthermore, the development experience can be economically utilized if the capability is uprated at decision point 3. A Saturn uprating in the 100 to 125 percent range is quite adequate and has been shown to be cost-effective when used in all three scientific programs. The selection of a large rover at decision point 2 would ensure that a common system is used throughout the exploration program as well as satisfy the traverse requirements at both the medium- and large-capability level.

4.4 PROGRAM COST SUMMARY BY TRANSPORTATION SYSTEM

The main effectiveness parameter used throughout the MIMOSA program analyses is the total program cost. The values of this parameter for all the programs generated are presented in Fig. 4-6 as a function of the scientific manhours performed. The latter are approximately constant for a given scientific program. It can be seen that the exploration program costs range from about 10 to 30 billion dollars for the programs examined. Accomplishment of the small scientific program (C) using small capability evolutions costs about the same as the accomplishment of the large scientific program (A) with the higher capability evolutions. Further, the more effective large- and medium-capability evolutions show the minimum program costs for each level of scientific effort. The curves shown in Fig. 4-6 join points that utilize the same transportation systems. A general trend is evident over the range of scientific manhours

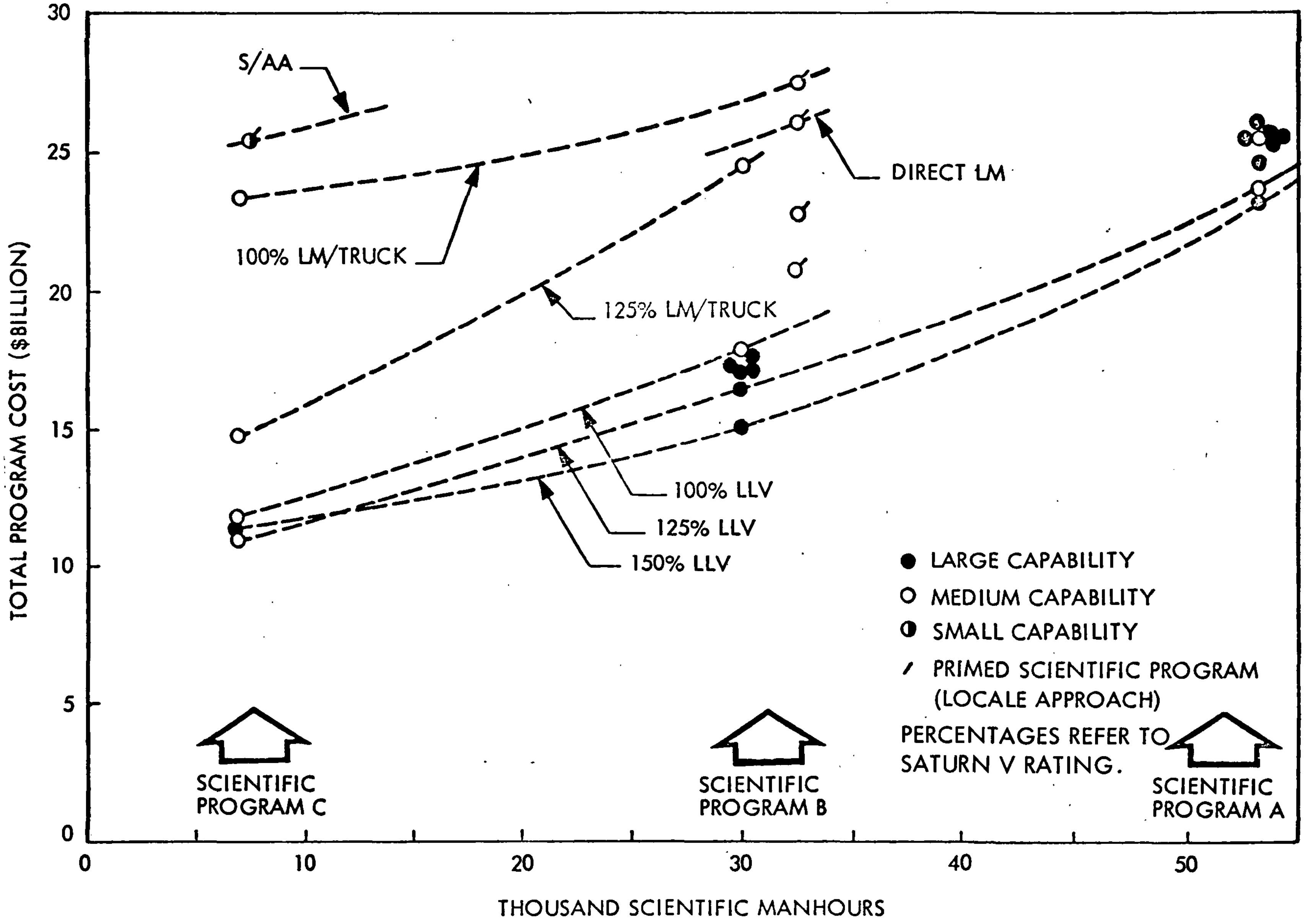


Fig. 4-6 Scientific Cost Effectiveness of Candidate Transportation Systems

constituting the three scientific levels. Reduced program costs are related to (1) the type of logistics delivery system and (2) the Saturn V uprating employed with that delivery system. The two most promising combinations are the 150% Saturn with LLV and the 125% Saturn with LLV.

4.5 INFLUENCE OF SCIENTIFIC PROGRAM

The influence of a change in the level of the scientific activity on three important exploration program parameters is shown in Fig. 4-7 for the equipment evolutions that gave the lowest total program costs when used against scientific programs A, B, and C. From a cost and schedule point of view, reduced scientific requirements result in lower total program costs and shorter program durations (for a fixed launch rate). The scientific manhours spent on the Moon are about the same up to 1980 for all scientific programs (approximately the same scientific return from each program). At this point, scientific program C is terminated and since the B-level science calls for base operations earlier than the A-level, the latter gives lower manhours up to about 1984 when the opening up of the six-man astronomy base results in the greatest rate of manhour accumulation of all three programs. The cost of a scientifc manhour is reduced, as the exploration program proceeds, for each scientific program. The early fluctuations arise from the use of manned orbiters, which represent an efficient mode of providing scientific manhours, followed by relatively heavy R&D investment for uprated systems. The displacement along the time axis of the curve corresponding to scientific program A (A-IVe) reflects the extended locale investigations and increased mass requirements of this scientific program and a somewhat later introduction date of the LLV systems. Programs A-VIe and B-VIe, which involve base operations, show a reduction in the cost per scientific manhour by a factor of 10 throughout the programs. The unit cost reduction is not so great for program C-IVb since no base operations are performed.

Another important influence exerted by the scientific programs is the high Earth-return mass requirement. For scientific programs A, B, and C, the requirements amount to 12,000, 6,000, and 3,000 kg, respectively. These masses include lunar material

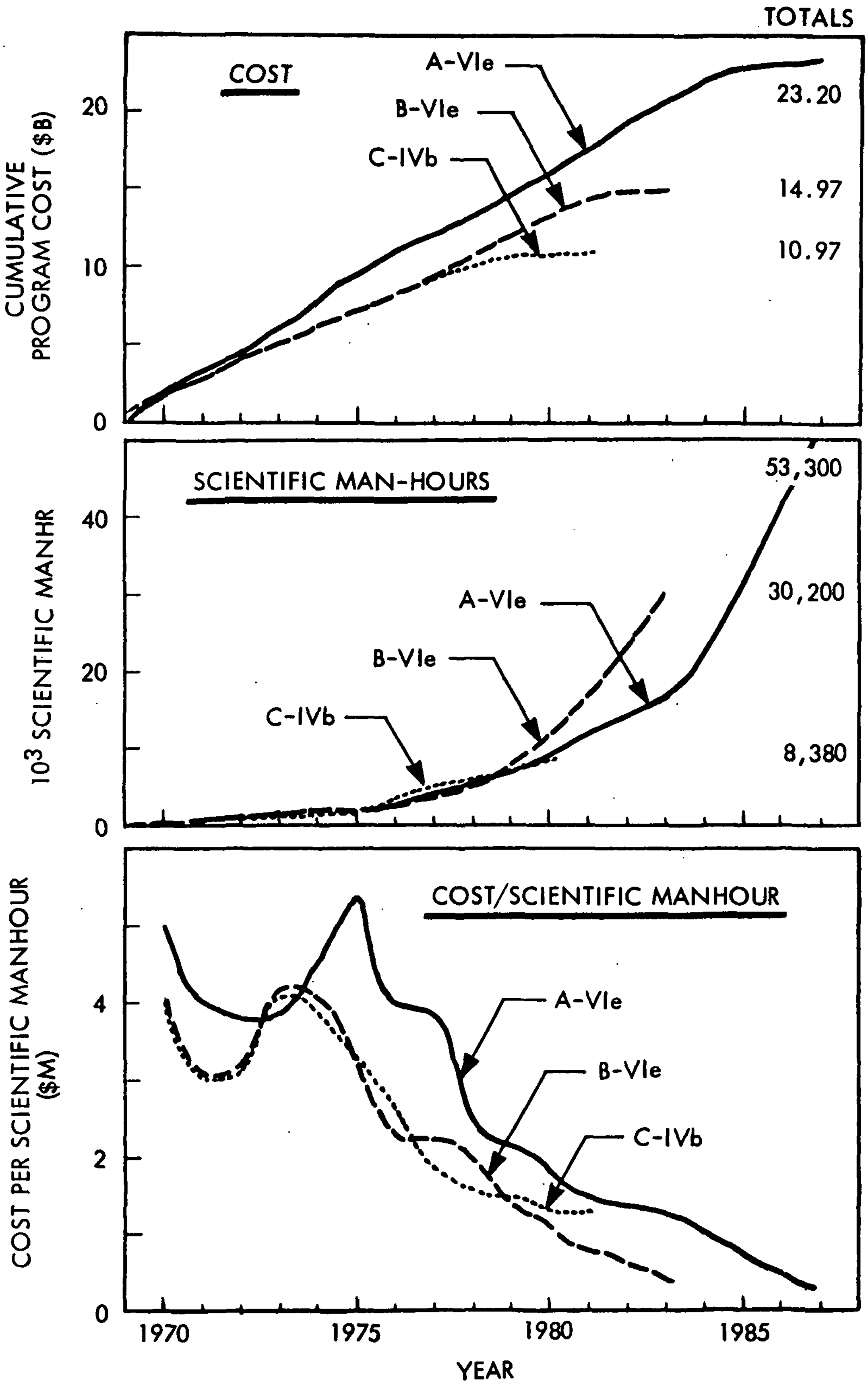


Fig. 4-7 Influence of Scientific Program on Exploration Program Parameters

samples, photographic film, and magnetic tapes and are required mainly for support of geological activities. In many instances, the mass-return requirements for the individual missions exceeded the surplus Earth-return capability of the personnel transportation system. For the purpose of this study, these discrepancies were ignored as it was felt that the actual Earth-return requirements had not been conclusively established. However, further study of this problem is required as large Earth-return mass requirements can significantly influence the performance requirements of the crew transportation system.

The large mass requirements for explosives associated with the active seismology experiments also give cause for concern. Explosive mass amounts to about 50 percent of the total scientific mass for each program. A reduction in this requirement would reduce the overall logistics requirements and would result in reduced exploration costs. The effect would be more noticeable for programs performing A-level science since these reflect the highest explosives requirement. However, this effect would not influence the general conclusions reached in this study. Again, further analysis is required of the scientific importance of active seismology, more effective explosive materials, and more efficient delivery of the explosives to the lunar surface.

4.6 CONCLUSIONS FROM PROGRAM ANALYSIS

The exploration programs generated during the MIMOSA study were derived from the use of particular sets of exploration equipments utilized in an evolutionary manner to perform specific scientific programs under a given set of ground rules. Bearing these assumptions in mind and the questions posed at the start of the analysis, the following major conclusions can be drawn.

4.6.1 Exploration Program Cost

- For the additional investment of an amount approximately equal to that already committed to the Apollo Program (20 billion dollars), a substantial lunar exploration program can be achieved. Such a program would provide answers in depth to basic scientific questions regarding the Moon and would involve the expenditure of about 55,000 scientific manhours on the Moon.

- The lower-cost exploration programs for each level of scientific program were as follows:

Scientific Program	Equipment Evolution	Approximate Expenditure (scientific manhr)	Cost ($B) Non-Recurring	Recurring	Total Exploration Program
A	S/AA → 150% Saturn V, LLV	55,000	4.4	18.8	23.2
B	S/AA → 150% Saturn V, LLV	30,000	4.3	10.7	15.0
C	S/AA → 125% Saturn V, LLV	7,000	2.7	8.3	11.0

- The nonrecurring part of the total exploration program cost amounts to about 15 percent for the less efficient equipment evolutions and about 20 percent for the more efficient evolutions. This represents a fairly low investment risk.

- Transporation system costs dominate the total exploration program cost. Typically, about 75 to 80 percent of the total program costs are attributable to the transportation systems, about 10 to 15 percent to the mission equipment, and about 5 percent to the scientific equipment.

4.6.2 Exploration Equipment Performance

- Continued use of the S/AA hardware is costly in terms of scientific return; only limited science (corresponding to the C level) can be accomplished. The step up to a higher system capability should be made as soon as possible. The decision for such a step up should be made in the period 1970 – 72.

- Generally, the use of equipment evolutions that involve a one-step increase in capability results in lower cost exploration programs.

- The choice of logistics delivery system exerts an important influence on the total exploration program cost; systems that utilize the LLV are the most cost effective.

- Equipment evolutions that utilize the 125% and 150% Saturn V in combination with an LLV (evolutions IVb and IVe) resulted in the lowest program costs for all three levels of scientific program. The LLV is a significant contributor to this efficiency and even when used with the 100% Saturn V, the resulting combination is more effective than the 125% Saturn V in combination with the LM/Truck.

- The inclusion of a roving vehicle with a range of 400 to 800 km in any equipment evolution is essential for the performance of scientific programs employing the path approach. A large shelter is not required until late in the program (approximately 1980).

4.6.3 Saturn Uprating

- Assuming the use of an LLV, the degree of Saturn V uprating does not strongly influence total program cost. Minimum uprating at decision point 2 is dictated by the requirement for three-man delivery to the lunar surface. Thus, an uprating in the range of 100 to 125 percent of the standard Saturn V capability is adequate.

- At decision point 3, a Saturn V uprating is not mandatory from a logistics requirement, but can be used effectively if provided from a source other thanthe lunar program.

4.6.4 Crew Delivery

- Three-man LOR crew delivery systems are quite adequate for the level of science postulated in the study. Operational limitations associated with the LOR mode might force the choice of a direct delivery system for the longer duration missions (stay times > 14 days).

4.6.5 Scientific Program Influence

- Selection of exploration equipment is insensitive to the size of the scientific program since the same equipment evolutions (those employing an LLV, a Saturn V rating in the range 100 to 150 percent, and a large rover) always gave the lowest total program cost for the three scientific levels that were examined.

- The size of the chosen scientific program is an important cost consideration. Some of the lower capability systems cannot complete the higher level scientific programs within a sensible time frame. For scientific programs A, B, and C, the exploration program costs for the most efficient equipment evolution (those with 125% LLV and 150% LLV) are in the approximate ratio 5:3:2.

- The higher capability systems studied possessed considerable mass "over-kill," and further tailoring of the scientific program to the equipment capability is desirable. Generally, manhour requirements are more difficult to satisfy than mass requirements.

- Earth return mass requirements, demanded by the geology experiments, are substantial and, if realistic, can impose stringent requirements on the personnel transportation system. Alternatively, subsidiary techniques for improving Earth return mass capability may be required.

Appendix A
THE SCIENTIFIC INVESTIGATION MATRIX

The scientific investigation matrix is an organized presentation of all scientific investigations conceived to be relevant to the basic questions defining the goals of lunar scientific programs. The investigations pertinent to each basic question are grouped according to major scientific disciplines.

The location of each investigation within the matrix is identified by a three-part code number. The first part corresponds to the number of the basic question. The second part specifies the major scientific discipline. The third part is the numerical order of the investigation within the group pertaining to a particular basic question and scientific discipline. The symbols (P) and (S), which follow the investigation code number, indicate whether the investigation is of primary or secondary importance to the question under consideration.

Page Intentionally Left Blank

NAS Question 1

Is the internal structure of the Moon radially symmetrical like the Earth, and if so is it differentiated? Does it have a core and crust?

1.1 Geodesy/Cartography

1.1.1 Establish a selenocentric coordinate system
- a. Navigational satellites for interaction with surface stations and traverses to produce three dimensional ground control by:
  1. Reflectors
  2. Emitters
  3. Relays
- b. Establish geodetic control station observatories
  1. Establish primary bench marks
  2. Measure deflection of the vertical
     (a). Establish a local and regional absolute gravity network
     (b). Astronomically determine zenith
- c. Establish lunar and navigational satellite ephemerii to determine fine characteristics of orbit and rotation
  1. Monitor astronomical observations from array of geodetic control stations
- d. Establish primary and secondary bench marks by surface triangulation surveys and interaction with navigational satellites

1.1.2 Establish a topographic map of the lunar surface
- a. Photograph the lunar surface using orbital satellites located by geodetic control array–(see 1.2.1.a.)
- b. Map the lunar surface using radio sounding orbital satellites located by geodetic control array
- c. Establish ground control–(see 1.1.1.d.)

1.1.3 Determine a reference figure representative of the Moon's center of mass
- a. Determine the lunar gravitational field from satellites
  1. Orbital satellites equipped with gravity gradiometer
  2. Navigational satellite ephemeral data–(see 1.1.1.c.)
- b. Determine the lunar gravitational field from surface stations
  1. *Absolute gravity base station network*
  2. Relative gravity from lunar traverses
  3. Elevation and location control–(see 1.1.1)
- c. Determine lunar tides–(see 1.1.4.a.)
- d. Astronomical observations–(see 1.1.1.b.)

1.1.4 Determine the gross elastic parameters of the moon
- a. Determine lunar tides
  1. Gravity method–(see 1.4.3.b.2)
  2. Strain network method–(see 2.4.2.b.)

1.1.5 Determine the mass and moment of inertia of the Moon–(see 1.1.1.,3)

1.1.6 Determine degree of isostatic compensation–(see 1.1.1., 3.)

1.1.7 Determine symmetry of density distribution of the Moon–(see 1.1.1., 3.)

1.2 Geology

1.2.1(S) Determine stratigraphic sequence of surface deposits and structure of exposed rocks
- a. Prepare geologic maps of surface from orbiters using the following remote-sensing techniques.
  1. X-ray gamma fluorescence
  2. Gamma-ray spectrometry
  3. Ultraviolet reflection and luminescence spectrometry
  4. Multispectral photography
  5. High resolution photography
  6. Infrared imagery
  7. Infrared spectrometry
  8. Microwave imagery
  9. Microwave spectrometry
  10. Radar imagery
  11. Radar spectrometry
  12. *Atomic absorption spectroscopy*
  13. Electromagnetic pulse probe
- b. Calibration of remote-sensing techniques on all geologic environments of the lunar surface by physical, chemical and geologic investigations.
  1. Pace and compass type geologic mapping
  2. Specimen collection
  3. Specimen examination and megascopic description
  4. Petrographic analysis–(see 1.3.1.b, c)
  5. Geochemical analysis–(see 1.3.1.b, c, d, e, f)
  6. Electromagnetic attenuation and reflectance coefficient at microwave and radar wavelengths
  7. Goniometric measurements of reflected sunlight
  8. Goniometric measurements of spectral emission and reflectance of infrared energy, simultaneously with temperature measurements at 1 meter depth and less
  9. Porosity measurements of surface material
  10. Density measurements of surface material
  11. Electrical conductivity and dielectric constant measurements of surface material

1.2.2(S) Establish stratigraphic succession in lunar craters and rills
- a. Measure geological section in walls and ejecta accumulations
- b. Specimen collection
- c. Specimen examination and megascopic description
- d. Petrographic analysis–(see 1.3.1.a, b)
- e. Geochemical analysis–(see 1.3.1.b, c, d, e, f)
- f. *Apply remote-sensing techniques as listed in (1.B.1.a.1) where walls are not accessible*

1.2.3(P) Determine petrologic variations in oldest rocks exposed on highlands and in maria basement rocks
- a. Drill core hole at least 300 meters deep
- b. Megascopic specimen examination and description
- c. Specimen collection
- d. Petrologic analysis–(see 1.3.1.a, b, c)
- e. Geochemical analysis–(see 1.3.1.b, c, d, e, f)

1.2.4(P) Determine composition of volcanic ejecta and plutonic xenoliths in volcanic ejecta and igneous rocks
- a. Pace and compass type geologic mapping
- b. Specimen collection
- c. Petrologic analysis–(see 1.3.1.b, c)
- d. Geochemical analysis–(see 1.3.2)

1.3 Geochemistry

1.3.1(P) Determine the state of compositional, structural, and age differentiation of the lunar crust
- a. Obtain appropriate samples–(see 1.2)

  Determine:
- b. Mineralogy
  1. Thin sections or loose grain polarizing microscope techniques
  2. X-ray diffraction
  3. Remote multispectral reconnaissance
- c. Texture
  1. Thin sections–petrographic microscope techniques
  2. Polished sections–reflected light techniques
  3. X-ray diffraction
- d. Elemental composition
  1. Wet analysis
  2. Activation analysis
  3. Electron probe
  4. Nuclear magnetic resonance
  5. X-ray fluorescence
  6. Emission spectroscopy
- e. Isotopic analysis-mass spectroscopy
- f. Age-isotope ratios-mass spectroscopy
  Uranium-thorium-lead isotopic ratios, A^{40}-K^{40}, Rb^{87}-Sr^{87} ratios, etc.

1.3.2(P) Evaluate with respect to genetic environment outcropping or shallowly buried xenoliths formed at depths beyond reach of the drill
- a. Obtain appropriate samples–(see 1.2.4.) (Helpful criteria-coarsely crystalline ±minerals of high density)
- b. Determine mineralogy–(see 1.3.1.b)
- c. Determine texture–(see 1.3.1.c)
- d. Determine elemental composition–(see 1.3.1.d)
- e. Determine isotopic composition–(see 1.3.1.e)
- f. Determine age–(see 1.3.1.f)

1.3.3(P) Determine and evaluate regional patterns of radiometric rock ages and
Evaluate relationship between age and composition and texture
- a. Use samples from 1.3.1
- b. Determine age of component minerals–(see 1.3.1.f)
- c. Determine mineralogy–(see 1.3.1.b)
- d. Determine elemental composition–(see 1.3.1.d)
- e. Determine isotopic composition–(see 1.3.1.e)

1.3.4(P) Obtain data on composition of exposed basement rocks
- a. Collect appropriate samples–(see 1.2.3)
- b. Determine mineralogy–(see 1.3.1.b)
- c. Determine texture–(see 1.3.1.c)
- d. Determine elemental composition–(see 1.3.1.d)
- e. Determine isotopic composition–(see 1.3.1.e)
- f. Determine radiometric age–(see 1.3.1.f)

1.4 Geophysics

1.4.1(P) Determine the near surface structure (0-5 km) of selected geologic terrains by surface traverses
- a. Seismology
  1. Active
     (a). Calibrate seismic methodology by tying into geologic sections obtained in craters, rills, scarps, and drill holes–(see 1.2.2,3)
     (b). Reflection seismic profiles
     (c). Refraction seismic profiles
- b. Gravity
  1. Measurement of relative gravity
- c. Magnetic
  1. Magnetic *measurements*
     (a). Total intensity
     (b). Vertical intensity
     (c). Horizontal intensity
     (d). Declination
     (e). Horizontal gradient
     (f). Vertical gradient
- d. Electrical methods
  1. Resistivity profiling
  2. Magnetotelluric measurements
  3. Electromagnetic induction
  4. *Equipotential method*
  5. Induced polarization
  6. Self potential
- e. Radioactivity
  1. Gamma ray emissivity studies
- f. Heat flow
  1. Monitor temperatures in 30 meter drill holes
  2. Measure thermal conductivities–(see 3.2.6)

1.4.2(P) Determine the structure of selected geologic terrains at intermediate depths (5-100 km)
- a. Seismology
  1. Passive
     (a). Monitor the three components of lunar seismicity
  2. Active
     (a). Deep refraction profiling
- b. Gravity
  1. Surface relative gravity measurements
  2. Lunar orbiter relative gravity measurements
  3. Surface network of absolute gravity measurements
- c. Magnetic
  1. Lunar orbiter total magnetic intensity measurements at one or more elevations
  2. Lunar orbiter total magnetic intensity gradient
- d. Electrical
  1. Magnetotelluric measurements
- e. Heat flow–(see 1.4.1.f)

1.4.3(P) Determine deep structure (100 km to the center of the Moon)
- a. Seismology
  1. See 1.4.2.a
- b. Gravity
  1. See 1.4.2.b.1, 2, 3)
  2. Monitor lunar gravitational tides
- c. Magnetic
  1. See 1.4.2.c)
  2. Monitor the lunar magnetic field at permanent stations recording three components
- d. Electrical
  1. Magnetotelluric measurements
- e. Heat flow–(see 1.4.1.f)

1.4.4(P) Determine the vertical deflection of gravity over the lunar surface
- a. Gravity
  1. Absolute gravity measurements
- b. Astronomic observations

1.4.5(P) Determine rock properties by <u>in situ</u> measurements in drill holes and from drill hole cores
- a. Drill hole geophysics–(see 4.4.1.a.1, a)
- b. Rock properties of cores–(see 4.4.1.a.1, b)

1.5 Particles and Fields

1.5.1 Obtain structure and variations in lunar magnetic field and solar wind to determine whether the lunar magnetic field is *intrinsic or due to solar wind accretion.*
- a. Gross lunar magnetic field and solar wind interaction from orbital measurement by simultaneous measurement of the vector magnetic field and solar wind flux.
  1. Magnetometer
  2. Plasma probe
- b. Lunar surface magnetic field and solar wind interaction by simultaneous measurement of the vector magnetic field and solar wind flux at emplaced sites on the lunar surface separated by 180° along the equator.
  1. Magnetometer
  2. Plasma probe

1.7 Astronomy

1.7.1 Determine lunar body motions with respect to inertial space
- a. Star field observations from lunar surface
  1. Star tracker at emplaced station
  2. Optical telescope observations of star fields

NAS Question 2

What is the Lunar Geometric Shape? How does the shape depart from fluid equilibrium? Is there a fundamental difference in morphology and history between sub-earth and the averted faces of the moon?

2.1 Geodesy/Cartography

2.1.1 See 1.1.1

2.1.2 See 1.1.2

2.1.3 See 1.1.3

2.1.4 Compare the moon's reference figure with the figure for fluid equilibrium
- a. Determine the reference figure–(see 1.1.3)
- b. *Determine the fluid equilibrium figure*
  1. Determine the depth density function based on lunar seismic data and surface density data–(see 1.4.2.a and 4.4.1.a.1.b.7.a)

2.2 Geology

2.2.1(P) Determine correlation of both rock type and structure with lunar geometric shape
- a. See 1.2.1, 1.2.2 and 1.2.3.

2.2.2(S) Establish presence and degree of vertical displacement along maria-highland contacts, scarps and lineaments
- a. Geologic mapping along and adjacent to maria-highland contacts, scarps and lineaments emphasizing structural features

2.3 Geochemistry

2.3.1(P) Evaluate relationship between distinctive rock series and regions anomalous with regard to the lunar figure of simple fluid equilibrium
- a. Collect appropriate samples–(see 2.2.1)
- b. Determine mineralogy–(see 1.3.1.b)
- c. Determine elemental composition–*(see 1.3.1.d)*
- d. Determine fluid equilibrium figure and actual figure of the moon–(see 2.1.1)

2.4 Geophysics

2.4.1(P) Determine the lunar reference spheroid, vertical deflection of gravity and isostatic deviations
- a. Gravity measurements
  1. Establish an absolute gravity network over the lunar surface
  2. *Establish a complete gravity network over the* lunar surface by measuring relative gravity over 1° x 1° (lat. x long.) areas (or 5° x 5°); the relative values being tied to the absolute network
  3. Lunar orbiter observations (polar orbit) used to determine gravitational field of the moon
  4. Monitor lunar tides
- b. Astronomic observations

2.4.2(S) Determine the stress-strain regime
- a. Seismology
  1. Monitor the three components of lunar seismicity
- b. Strain network studies
  1. Set up a lunar strain network based on radio or laser beam distance measurements and monitor the relative strain changes

2.5 Particles and Fields

2.5.1 See 1.5.1a and b.

2.5.2 Determine the nature of the lunar gravitational field.
- a. Gravity gradient measurements from lunar orbit
  1. Gravity gradiometer
- b. Lunar surface absolute gravity measurement
  1. Absolute gravimeter

2.7 Astronomy

2.7.1 See 1.7.1.a

Page Intentionally Left Blank

NAS Question 3

What is the present internal energy regime of the moon (heat flow, seismic activity, magnetic field)? Is there active vulcanism?

3.0 Lunar Atmospheres

3.0.1 Determine existence and detailed nature of the lunar atmosphere

- a. Determine total pressure
  1. Kreisman gauge
  2. Redhead gauge
- b. Determine neutral constituents
  1. Coincidence mass spectrometer
  2. Quadrupole mass spectrometer
  3. Double focusing magnetic mass spectrometer
  4. Hot cathode ion gauge
- c. Determine ion constituents
  1. Quadrupole mass spectrometer
  2. Double focusing magnetic mass spectrometer
  3. Hot cathode ion gauge
  4. Suprathermal ion gauge

3.1 Geodesy/Cartography

3.1.1 Provide base maps for necessary studies—(see 1.1.2)

3.1.2 Determine rotational energy of the moon—(see 1.1.1.c.)

3.2 Geology

3.2.1(P) Locate thermal anomalies from lunar orbiter data using remote-sensing techniques

- a. Lunar orbiter imaging
  1. Infrared imagery
  2. Microwave imagery

3.2.2(P) Investigate thermal anomalies for source and correlation with geologic and topographic features

- a. Same as 1.2.1

3.2.3(S) Monitor thermal anomalies for variations

- a. Same as 3.2.1 and 3.2.2.

3.2.4(P) Determine type, degree, and geographic extent and location of volcanic rock types and their alteration by recent volcanic activity

- a. Pace and compass type geologic mapping
- b. Measurement of geologic sections
- c. Specimen examination and megascopic description
- d. Specimen collection
- e. Petrographic analysis—(see 1.3.1.b, c)
- f. Geochemical analysis—(see 1.3.1.b, c, d, e, f)

3.2.5(P) Determine extent, nature, and age of physical and chemical alteration of rocks occurring within and adjacent to tectonic fractures

- a. Pace and compass type geologic mapping
- b. Specimen examination and megascopic description
- c. Specimen collection
- d. Petrographic analysis—(see 1.3.1. b, c)
- e. Geochemical analysis—(see 3.3.2)

3.2.6(P) Select areas for heat flow measurements and obtain samples for thermal conductivity measurements

- a. Map thermal anomalies
  1. Experiments same as 3.2.1.
- b. Drill core holes to 30 meters
  1. Specimen examination and megascopic description
  2. Specimen collection
  3. Petrographic analysis—(see 1.3.1.b, c)
  4. Geochemical analysis—(see 1.3.1.b, c, d, e, f)

3.2.7(P) Obtain samples of all rock types from surface and drill core for measurement of radioactive heat generation

- a. Pace and compass type geologic mapping
- b. Specimen examination and megascopic description
- c. Specimen collection
- d. Petrographic analysis—(see 1.3.1.b, c)
- e. Geochemical analysis—(see 1.3.1.b, c, d, e, f or 3.c.1)

3.2.8(S) Evaluate tectonic patterns

- a. See 1.2.1

3.3 Geochemistry

3.3.1(P) Estimate amount of heat generated by radioactive decay from successively deeper shells within the moon

- a. Collect appropriate surface and drill core samples—(see 3.2.7.)
- b. Determine amounts of radioactive species—(see 1.3.1.d)

3.3.2(S) Determine the amount of thermal and mechanical energy absorbed in endothermic mineral reactions

- a. Collect appropriate samples—(see 3.2.6.) (Examine samples from fault zones and at igneous contacts for evidence of thermal or dynamic metamorphisim compared with country rock.)
- b. Determine mineralogy—(see 1.3.1.b.1)
- c. Determine texture—(see 1.3.1.c.1)
- d. Determine elemental composition—(see 1.3.1.d)

3.3.3(S) Evaluate the mechanism of energy flow and storage by creation of metastable phases through physical transport

- a. Collect appropriate samples—(see 1.2.4)
- b. Evaluate metastable phases—(see 1.3.1.b, c, d, e, f)
- e. Evaluate country rock—(see 1.3.1.b, c, d, e, f)
- d. Calculate energy gradient

3.3.4(S) Evaluate the effect of diurnal temperature variations at the surface on the nature of synchronous volcanic products.

- a. Collect appropriate rock samples—(see 3.2.4.)
- b. Analyze samples—(see 1.3.1.b, c, d, e, f)

3.3.5(S) Evaluate relationship between remote sensing thermal data and geochemistry of associated rocks

- a. Collect appropriate samples—(see 3.2.2.)
- b. Analyze as 1.3.1.b, c, d, e, f

3.3.6(S) Determine thermal and stress history of lunar rocks

- a. Collect appropriate samples—(see 3.2.5.)

Estimate temperature of formation by:

- b. Mineralogy—(see 1.3.1.b)
- c. Texture—(see 1.3.1.c)
- d. Isotopic composition—(see 1.3.1.e)
- e. Gas-liquid inclusion geothermometry
  1. Petrographic microscope with hot stage
  2. Microscope and temperature-pressure regulation
  3. Decrepitation techniques

Estimate amount and direction of stress by:

- f. Petrofabric analysis
  1. Thin section petrographic microscope-universal stage
  2. Thin section petrographic microscope-photometer
  3. Polished section - thin section X-ray diffraction
- g. Measurement of intracrystalline strain
  1. Polarizing microscope-thin section
  2. X-ray diffraction
  3. Electron microscopy

3.4 Geophysics

3.4.1(P) Determine the internal mechanical energy

- a. Rotational energy
  1. Monitor astronomic measurements to determine rotational variations
- b. Vibrational energy
  1. Monitor the three components of lunar seismicity
  2. Monitor strain in areas of regional fracture
     - (a). Monitor bench mark array
     - (b). Strain transducers
     - (c). Photogrammetry
  3. Monitor lunar tides
     - (a). Gravimetric
     - (b). Strain network studies—(see 2.4.2.b)

3.4.2(P) Determine the internal thermal energy

- a. Heat flow measurements—(see 1.4.1.f)
- b. Lunar orbiter gamma ray emission studies
- c. Gamma ray emission ground surveys in areas of high relative radiation as determined from the orbiter survey

3.4.3(P) Determine the internal electric and magnetic energy

- a. Monitor magnetic field
  1. Monitor X, Y, Z components of the lunar magnetic field over a lunar network of stations
  2. Measure the lunar total magnetic field by lunar orbiter at regular intervals. Mapping of magnetic gradient in conjunction with this same experiment
- b. Monitor electromagnetic field
  1. Monitor magnetotelluric currents at a network of lunar stations
- c. Monitor electric field

3.5 Particles and Fields

3.5.1 See 1.5.1.a and b.

NAS Question 4

What is the average composition of rocks at the surface of the Moon and how does the composition vary from place to place? Are there volcanic rocks on the surface?

4.1 Geodesy/Cartography

4.1.1 Provide base maps for necessary studies—(see 1.1.2.)

4.2 Geology

4.2.1(S) See 1.2.1.

4.2.2(P) Determine composition of rocks beneath surficial deposits

- a. Drill core holes of 3, 30 and 300 meters depth in major geologic environments
  1. Specimen examination and megascopic description
  2. Specimen collection
  3. Petrologic analysis—(see 1.3.1.a, b, c)
  4. Geochemical analysis—(see 1.3.1.a, b, c, d, e, f)

4.3 Geochemistry

4.3.1(P) Determine composition of rocks on lunar surface

- a. Sample extensive surface net—(see 4.2.2.a.2)

Determine:

- b. Mineralogy—(see 1.3.1.b)
- c. Elemental composition—(see 1.3.1.d)
- d. Isotopic analysis—(see 1.3.1.e)
- e. Texture—(see 1.3.1.c)

4.4 Geophysics

4.4.1(P) Determine correlation between rock properties and rock composition

- a. Subsurface program
  1. Cored drill holes at various sites representative of all the major geological terrains—(see 4.2.2.)
     - (a). Drill hole geophysics
       - (1). Self potential
       - (2). Resistivity
       - (3). Induced polarization
       - (4). Electromagnetic
       - (5). Gamma-ray emissivity
       - (6). Temperature
       - (7). Thermal conductivity
       - (8). Magnetic field
       - (9). Magnetic susceptibility
       - (10). Sonic
       - (11). Caliper
       - (12). Dip meter
       - (13). Gravity
       - (14). Natural and induced radioactive logging techniques
       - (15). Sonic logging
     - (b). Measure cores for following rock properties
       - (1). Thermal
         - a. Conductivity
         - b. Diffusivity
         - c. Expansion
         - d. Radioactive isotopes—(see 1.3.1.e)
         - e. Specific heat
         - f. Emissivity
         - g. Radioactive age—(see 1.3.1.f)
       - (2). Elastic
         - a. Velocity P-wave
         - b. Velocity S-wave
         - c. Compressibility
       - (3). Inelastic
         - a. Q (attenuation mechanical)
         - b. Creep
         - c. Mechanical strength
       - (4). Electrical
         - a. Dielectric constant
         - b. Conductivity
         - c. Emissivity
         - d. Attenuation
         - e. Velocity
       - (5). Magnetic
         - a. Paleomagnetic measurements
         - b. Susceptibility
         - c. Curie point
         - d. B-H curve
       - (6). Optical
         - a. Albedo
         - b. Emissivity
       - (7). Miscellaneous
         - a. Density
         - b. Porosity
         - c. Permeability
       - (8). Petrographic analysis—(see 1.3.1.b, c, d)
- b. Surface program
  1. Specimen collection—(see 4.2.1.)
  2. Measurement of rock properties—(see 4.4.1.a.1.b)

4.4.2(P) Use the correlation between rock properties and rock composition in the interpretation of geophysical surveys over the lunar surface

- a. Seismic survey
  1. See 1.4.1.a.1
  2. Monitor the three components of lunar seismicity
- b. Gravity surveys
  1. Detailed relative gravity surveys at drill site areas and at selected areas of the lunar surface
  2. Lunar orbiter relative gravity
- c. Magnetic surveys
  1. Detailed magnetic surveys at the drill site and at selected areas of the lunar surface
     - (a). Total magnetic intensity
     - (b). Vertical magnetic intensity
     - (c). Horizontal magnetic intensity
  2. Lunar orbiter magnetic surveys
     - (a). Total magnetic intensity
     - (b). Total magnetic intensity gradient
- d. Electrical surveys
  1. Drill site surveys—(see 1.4.1.d)
  2. Surveys in adjacent areas—(see 1.4.1.d)
- e. Temperature surveys
  1. Near surface temperature measurements—(see 1.4.1.f)
- f. Radioactivity surveys
  1. Gamma-ray emissivity measurements at drill site and at selected locations
  2. Lunar orbiter gamma-ray emissivity surveys

4.5 Particles and Fields

4.5.1 Determine the nature of incident galactic cosmic rays.

- a. Determine spare radiation exposure effect on isotopic distribution of exposed materials.
  1. Collect samples for analysis in laboratory.

4.5.2 Determine the nature of the lunar cosmic ray albedo.

- a. Determine Hydrogen/Silicon ratios on lunar surface from neutron albedo.
  1. Orbital measurements of neutron flux from the lunar surface.

NAS Question 5

What are the principal processes responsible for the present relief of the lunar surface?

5.0 Lunar Atmospheres

5.0.1 See 3.0.1

5.1 Geodesy/Cartography

5.1.1 Provide base maps for necessary studies—(see 1.1.2.)

5.1.2 Provide photogrammatic base of same regions at selected intervals

5.1.3 Determine a reference figure representative of the Moon's center of mass—(see 1.1.3.)

5.2 Geology

5.2.1(P) See 1.2.1.

5.2.2(P) Study craters to determine impact or volcanic origin

- a. Establish criteria for differentiating between impact and volcanic origin of craters
  1. Select areally-limited recent craters of possible impact and volcanic origin from geological interpretation of maps prepared in 5.2.1 based upon criteria established by terrestrial measurements and experiments
  2. Prepare geologic maps of selected craters
     - (a). Plane table type geologic mapping
     - (b). Specimen examination and megascopic description
     - (c). Specimen collection
     - (d). Petrographic analysis—(see 5.3.1.)
     - (e). Geochemical analysis—(see 5.3.1.)
- b. Investigate representative craters using criteria established in 5.2.2.a.
  1. Plane table type geologic mapping
  2. Specimen examination and megascopic description
  3. Specimen collection
  4. Petrographic analysis—(see 5.3.1.)
  5. Geochemical analysis—(see 5.3.1.)

Page Intentionally Left Blank

5.2.3(P) Examine maria and highland to determine origin of surface features by internal and external processes

a. Select representative features from geological interpretation of maps prepared under 5.2.1 and topographic maps
b. Prepare geologic maps of selected areas
1. Plane table type geologic mapping
2. Specimen examination and description
3. Specimen collection
4. Petrographic analysis—(see 5.3.1.)
5. Geochemical analysis—(see 5.3.1.)

5.2.4(P) Determine environmental effects on lunar surface layers of varying rock type, physiography and age

a. Drill core hole to 3 meters
1. Measurement of geological section
2. Specimen examination and megascopic description
3. Specimen collection
4. Petrologic analysis—(see 5.3.1.b, c, d)
5. Geochemical analysis—(see 5.3.1 and 1.3.1.f)
b. Trenching to depth of one meter
1. Measurement of geological section
2. Specimen examination and description
3. Specimen collection
4. Petrographic analysis—(see 5.3.1.b, c, d)
5. Geochemical analysis—(see 5.3.1 and 1.3.1.f)
c. Environment exposure panel experiment—(see 5.2.5.b)

5.2.5(P) Determine effects of surface layer erosion and deposition caused by external and internal processes and force fields such as gravity and electrostatic fields

a. Geologic investigation of representative erosional and depositional features mapped in 5.2.1 and correlate with force fields and origin of surface features
1. Surface geologic mapping
(a). Plane table type geologic mapping
(b). Specimen examination and megascopic description
(c). Specimen collection
(d). Petrographic analysis—(see 5.3.1.b, c, d)
(e). Geochemical analysis—(see 5.3.1.)
2. Subsurface mapping
(a). Drill core hole to 30 meters depth
(b). Specimen examination and megascopic description
(c). Specimen collection
(d). Petrographic analysis—(see 5.3.1.b, c, d)
(e). Geochemical analysis—(see 5.3.1.)
b. Monitor environmental effects on standard panels of various rock types and minerals that are exposed to lunar environments
1. Environment exposure panel experiment
c. Monitor representative geologic terrains over extended period and record evidence of erosion and deposition.
1. Detailed topographic mapping
2. Establish bench marks with horizontal and vertical control
3. Plane table type mapping
4. Specimen collection
5. Petrographic analysis—(see 5.3.1.b, c, d)
6. Establish panels and collection containers to obtain samples of solids and gases in transport

5.3 Geochemistry

5.3.1(P) Evaluate relationship between physiographic or surface features and associated rocks

a. Take appropriate samples—(see 5.2.a.2.e)
Determine:
b. Mineralogy-petrology—(see 1.3.1.b, c)
c. Texture
1. Thin section petrofabric analysis-petrographic microscope plus universal stage
2. Measurement of intracrystalline strain patterns-oriented thin-section petrographic microscope
3. Thin section petrographic microscope technique
4. Polished sections-reflected light microscope
d. Elemental composition—(see 1.3.1.d)
e. Isotopic composition—(see 1.3.1.e)

5.4 Geophysics

5.4.1(S) Determine strain accumulation and release

a. Seismic measurements
1. Monitor lunar seismicity from a fixed array of stations (three component)
2. Shallow (0-5 km) penetration refraction surveys in selected areas to determine velocity variation with direction
b. Strain measurements
1. Triangulation networks set up in regions of stress release to monitor strains. Laser beam or radio wave distance measuring devices used at corners. Constant monitoring, recording device
2. Periodic photographic coverage of the lunar surface from satellite (i.e. 1 year period)
3. Monitor lunar tides

5.4.2(P) Determine the amount of volcanic and thermal activity

a. Locate thermal anomalies—(see 3.2.1.)
b. Heat flow measurements—(see 1.4.1.f)

5.4.3(S) Determine the degree of isostatic equilibrium

a. Gravity survey
1. Lunar orbiter relative gravity surveys over the entire lunar surface
2. Regional gravity surveys over the ground in selected areas of the lunar surface

5.4.4(P) Determine effects of surface layer erosion and deposition caused by external and internal processes and force fields

a. See 5.2.5.
b. Monitor environmental conditions
1. Surface and subsurface temperature
2. Surface vertical electrical potential field
3. Cosmic ray flux
4. Solar radiation flux
5. Atmospheric pressure
6. Meteorite and Micro-meteorite flux
a. Micro-meteorite detection
b. Monitor the three components of lunar seismicity-meteorite detection
7. Lunar tides
8. Lunar winds
a. Pressure sensors
1. Set up array of pressure monitoring stations over lunar surface
2. Set up an array of directional pressure sensitive monitoring devices
9. Gas density measurements conducted periodically at the monitoring stations
a. Optical refractive index
b. Acoustic properties
c. Mass Spectograph
d. Anerometers
10. Gas temperatures monitored from surface to tropopause

5.5 Particles and Fields

5.5.1 See 4.5.2a

5.5.2 Determine the nature of primary and secondary meteoroid flux.

a. Measure primary incident meteoroid flux from orbit with detector oriented away from lunar surface.
b. Determine lunar surface primary and secondary meteoroid flux.
1. Measure direct incident meteoroid flux
2. Measure ejecta from primary incident meteoroid flux

5.7 Astronomy

5.7.1 Determine the nature and extent of celestial bodies (comets, meteoroids and other media) contained in cislunar space

a. Photographic survey of the visible sky at a variety of wave lengths
1. 12-inch reflecting telescope
2. 40-inch reflecting telescope
b. Extended surface phenomena in Earth-Moon system
1. 12-inch reflecting telescope
2. 40-inch reflecting telescope

NAS Question 6

What is the present tectonic pattern on the moon and distribution of tectonic activity?

6.1 Geodesy/Cartography

6.1.1 Provide base maps for necessary studies—(see 1.1.2.)

6.2 Geology

6.2.1(P) See 1.2.1.

6.2.2(P) Establish tectonic patterns

a. Geological mapping
1. Identify and correlate areas and trends of similar surface features and characteristics; and groups of surface features such as lineaments, craters, rills, domes, etc., from maps prepared from 6.2.1.
2. Check interpretation and correlation of features identified in 6.2.2.a.1
a. Pace and compass type geologic mapping
b. Specimen examination and megascopic description
c. Measurement of geologic sections
d. Specimen collection
e. Petrographic analysis—(see 6.3.1.b, c, d)
f. Geochemical analysis—(see 6.3.1.b, c, d, e, f)

6.2.3(P) Determine tectonic events on relative geological time scale

a. Geological mapping
1. Establish relative age of features studied in 6.2.2.a.1. utilizing stratigraphic succession developed from geologic maps prepared in 6.2.1.
2. Check relative geologic age interpretation of features on the lunar surface
a. Pace and compass type geologic mapping
b. Specimen examination and megascopic description
c. Measurement of geologic sections
d. Specimen collection
e. Petrographic analysis—(see 1.3.1. b, c)
f. Geochemical analysis—(see 6.3.1.)

6.3 *Geochemistry*

6.3.1(S) Evaluate relationship between tectonic features and geochemical properties

a. Collect appropriate samples—(see 6.2.2.a.2, f)
b. Analyze rocks—(see 1.3.1.b, c, d, e, f)

6.3.2(P) Investigate existance of stable shield areas

a. Collect appropriate samples (criteria-area of consistently great radiometric age)—(see 6.2.2.a)
b. Determine mineralogy—(see 1.3.1.b)
c. Determine texture—(see 1.3.1.c)
d. Determine age—(see 1.3.1.f)

6.4 Geophysics

6.4.1(P) Determine the distribution of moonquake foci

a. Seismology
1. Establish a network of long period seismic observatories over the lunar surface to monitor lunar seismicity. Record displacements in X, Y, Z directions
2. Supplement the seismic observatories with remote short period "satellite" stations placed in active seismic zones. These instruments will radio the information to the observatory.

6.4.2(P) Determine the degree of isostatic equilibrium

a. Gravity survey—(see 5.4.3.)

6.4.3(P) Determine subsurface structure of tectonic provinces

a. Gravity—(see 1.4.1.b)
b. Magnetics—(see 1.4.1.c)
c. Seismology—(see 1.4.1.a)
d. Electrical methods—(see 1.4.1.d)

NAS Question 7

What are the dominant processes of erosion, transport, deposition of material on the lunar surface?

7.1 Geodesy/Cartography

7.1.1 Provide base maps for necessary studies—(see 1.1.2.)

7.1.2 Provide photogrammatic base of the same region at selected intervals

7.2 Geology

7.2.1(P) Investigate primary and secondary features of crater development

a. Establish degree of crushing, fracturing and alteration of rocks within and immediately adjacent to craters
1. Surface geological mapping
a. Pace and compass type geologic mapping
b. Specimen examination and description
c. Specimen collection
d. Petrographic analysis—(see 1.3.1.b, c, d)
e. Geochemical analysis—(see 1.3.1.b, c, d, e)
2. Subsurface geological mapping
a. Drill core hole to 30 meters
b. Specimen examination and description
c. Sample collection
d. Petrographic analysis—(see 1.3.1.b, c, d)
e. Geochemical analysis—(see 1.3.1.b, c, d, e)
b. Investigate gravitational slumping from crater and scarp walls
1. Plane table type geologic mapping
2. Specimen examination and megascopic description
3. Specimen collection
4. Petrographic analysis—(see 1.3.1.b, c, d)
c. Determine depositional features of crater rims, rays, and environs
1. Surface geologic mapping
a. Plane table type geologic mapping
b. Measurement of geologic sections
c. Specimen examination and megascopic description
d. Sample collection
e. Petrographic analysis—(see 1.3.1.b, c)
f. Geochemical analysis—(see 1.3.1.b, c, d, e)
2. Subsurface geological mapping
a. Drill core hole of 3 meter depth in ray material
b. Measurement of geologic section
c. *Specimen examination and megascopic description*
d. Specimen collection
e. Petrographic analysis—(see 1.3.1.b, c, d)
d. Study crater environs to determine erosional effects of impact ejecta
1. Surface geological mapping
a. Plane table type mapping
b. Measurement of geologic section
c. Specimen examination and megascopic description
d. Specimen collection
e. Petrographic analysis—(see 1.3.1.b, c, d)
f. Geochemical analysis—(see 1.3.1.b, c, d, e)
2. Subsurface geological mapping
a. Drill core hole to 30 meter depth in secondary craters
b. Measurement of geologic section
c. Specimen examination and description
d. Specimen collection
e. Petrographic analysis—(see 1.3.1.b, c, d)
f. Geochemical analysis—(see 1.3.1.b, c, d, e)

7.2.2(P) Investigate surficial highland material to study interprovince transport of material

a. Surface geological mapping
1. Pace and compass type geologic mapping
2. Specimen examination and megascopic description
3. Specimen collection
4. Petrographic analysis—(see 1.3.1.b, c, d)
5. Geochemical analysis—(see 1.3.1.b, c, d, e)
b. Subsurface geological mapping
1. Drill core hole to 300 meters
2. Specimen examination and megascopic description
3. Sample collection
4. Petrographic analysis—(see 1.3.1.b, c, d)
5. Geochemical analysis—(see 1.3.1.b, c, d, e)

7.2.3(P) Determine surface alteration and erosion effects and rates due to environmental conditions

a. Surface geological mapping of similar rock types of different relative geological ages
1. Pace and compass type mapping
2. Examination and megascopic description of surface formations
3. Specimen collection
4. Petrographic analysis—(see 1.3.1.b, c, d)
5. Geochemical analysis—(see 1.3.1.b, c, d, e)
b. Monitor environmental effects on standard panels of various rock types and minerals that are exposed to lunar environment
1. Environment exposure panel experiment
c. Monitor representative geologic terrains over extended period and record evidence of erosion and deposition
1. Detailed topographic mapping
2. Establish bench marks with horizontal and vertical control
3. Plane table type mapping
4. Specimen collection
5. Petrographic analysis—(see 1.3.1.b, c, d)
6. Geochemical analysis—(see 1.3.1.b, c, d, e)
7. Establish panels and collection containers for solid and gas phases in transport

7.3 Geochemistry

7.3.1(P) Evaluate the relative importance of transport and deposition of discrete particles as well as transport and precipitation of gas or colloidal particles
a. Collect appropriate samples—(see 7.2.3.c, 7)
b. Determine mineralogy—(see 1.3.1.b)
c. Determine texture—(see 1.3.1.c)
d. Measure flow properties of gases
1. See 8.4.1
2. Radioactive Tracer expts

7.3.2(P) Determine whether spalling yields significant and characteristic sediment

a. Collect appropriate samples—(see 7.2.3.b, c)
b. Determine mineralogy—(see 1.3.1.b)
c. Determine texture—(see 1.3.1.c)

7.3.3(P) *Determine whether meteoric impacts yield significant and* characteristic sediment

a. Collect appropriate samples—(see 7.2.1)
b. Analyze mineralogy—(see 1.3.1.b)
c. Analyze texture—(see 1.3.1.c)
d. Analyze elemental composition—(see 1.3.1.d)
e. Analyze isotopic composition—(see 1.3.1.c)

7.3.4(P) Determine whether explosive volcanic phenomena yield significant and characteristic sediment

a. Collect appropriate samples—(see 8.2.1.b, 3)
b. Determine mineralogy—(see 1.3.1.b)
c. Determine texture—(see 1.3.1.c)
d. Determine elemental composition—(see 1.3.1.d)
e. Determine isotopic composition—(see 1.3.1.e)

Page Intentionally Left Blank

7.3.5(P) Determine nature and rate of generation of volatile constituents from surface rocks

a. Collect appropriate samples—(see 7.2.3.b,c)
b. See 8.3.1,2,3

7.3.6(P) Determine conditions or processes that initiate recapture or precipitation of volatile constituents

a. Collect appropriate samples—(see 7.2.3.a.3)
b. Analyze solid samples for mineralogy—(see 1.3.1.b)
c. Analyze solid samples for texture—(see 1.3.1.c)
d. Analyze solid samples for elemental composition—(see 1.3.1.d)
e. Analyze solid samples for isotopic composition—(see 1.3.1.e)
f. Analyze gases by (1) mass spectroscopy (2) gas chromatography
g. *Measure associated physical parameters—(see 3.4.1.)*

7.4 Geophysics

7.4.1(P) Investigate primary cratering effects

a. Establish degree of crushing, fracturing, and alteration of rocks within and immediately adjacent to craters—(see 7.2.1.a)
1. Surface geophysical surveys—(see 7.2.1.a.1.)
(a) See 1.4.1.a,b,c,d,f
2. Subsurface geophysical measurements—(see 7.2.1.a.2)
(a) See 4.4.1.a.1.a

7.4.2(P) Monitor lunar environment

a. Rate of influx of meteorites and micro meteorites and their size distribution—(see 5.4.4.b)
b. Internally derived seismicity
1. Monitor three components of lunar seismicity

7.5 Particles and Fields

7.5.1 Determine the nature of the lunar electric field

a. Surface electric field from 0 to 10 meters
1. Measure vector electric field and evaluate its effect in *erosion processes.*
b. Surface electric field from 0 to 100 meters
c. Lunar electric field from 100 km to surface
1. Measure vector electric field by means of orbital sensors

7.5.2 See 4.5.1

a. Make simultaneous measurements of high energy particles and solar wind to evaluate the nature of galactic cosmic rays and Forbush decrease

7.5.3 Determine the nature of energetic solar particles

a. Make particle measurements over a wide evergy and flux range simultaneous with earth or lunar based measurements in solar optical astronomy

7.5.4 Same as 5.5.2 a and b

7.7 Astronomy

7.7.1 Determine nature of solar activity during particle influx

a. Observe solar flare activity with optical telescopes
b. Observe solar activity with radio telescopes

7.7.2 See 5.7.1. a and b

NAS Question 8

What volatile substances are present on or near the surface of the moon or in a transitory lunar atmosphere?

8.0 Lunar Atmospheres

8.0.1 See 3.0.1

8.1 Geodesy/Cartography

8.1.1 Provide base maps for necessary studies—(see 1.1.1.c)

8.2 Geology

8.2.1(P) Locate centers of volcanic activity and thermal anomalies

a. Lunar orbiter mapping
1. *Infra-red imagery*
2. Microwave imagery
b. Surface mapping of volcanic activity and positive thermal anomalies
1. Pace and compass type mapping of alteration zones due to volcanic emanations
2. Specimen examination and megascopic description of altered materials
3. Specimen collection
4. Petrographic analysis—(see 1.3.1.b,c)
5. Geochemical analysis—(see 1.3.1.b,c,d,e,f)
6. Gas collection—(see 8.3.1.,2.,3.)
c. Mapping of permanently shadowed areas which may serve as cold traps for volatiles
1. Surface geologic mapping
(a) *Specimen examination and description*
(b) Sample collection
(c) Petrographic analysis—(see 8.3.4.)
(d) Geochemical analysis—(see 8.3.4)

8.2.2(P) Determine volatile substance in surficial rocks

a. Drill core hole to depth of 3 meters
b. Specimen examination and megascopic description
c. Surface and core specimen collection
d. Petrographic analysis—(see 8.3.4)
e. Geochemical analysis—(see 8.3.4)

8.3 Geochemistry

8.3.1(P) Determine the nature and amount of gases produced by volcanic emanation and capture of cosmic volatiles—(see 8.2.1.b.6)

a. Collect appropriate samples
b. Gas analysis
1. Gas chromatograph
2. Mass spectrograph

8.3.2(P) Determine the nature and amount of gases produced by volatization upon meteoric impact and by low pressure unstressed sublimation from surface rocks

a. Collect appropriate samples—(see 8.2.1.b,c.1)
Determine for "leached" and unleached rocks:
b. Mineralogy—(see 1.3.1.b)
c. Texture—(see 1.3.1.c)
d. Elemental composition—(see 1.3.1.d)
e. Isotopic composition—(see 1.3.1.e)
Measure and analyze outward flux of volatiles from unstressed surface material by:
f. Gas chromatography
g. Mass spectroscopy

8.3.3(P) Evaluate the effect of winds, tides and incident radiation on separation or localization of volatile species

a. Take appropriate samples—(see 8.2.1.c.1.b)
b. Analyze volatiles
1. Gas chromatograph
2. Mass spectrograph
c. Obtain physical parameters—(see 8.4.1.)
1. Incident radiation—(see 3.4.1)
2. Gas flow movements—(see 8.4.1)

8.3.4(P) Determine composition of ices

a. Collect appropriate samples—(see 8.2.1.c.1.b)
b. Determine mineralogy
1. Thin section and loose grain-cold stage petrographic microscopic apparatus
2. X-ray diffraction
c. Determine texture
1. Megascopic examination
2. Thin section-cold stage petrographic microscope
3. Multispectral reconnaissance techniques
d. Determine elemental composition
1. Gas chromatrography
2. Mass spectroscopy
3. Activation analysis
e. Determine isotopic composition-mass spectroscopy

8.3.5(P) See 7.3.5. and 7.3.6

8.4 Geophysics

8.4.1(P) Measure lunar winds

a. See 5.4.4.b.8

8.5 Particles and Fields

8.5.1 Same as 1.5.1. a and b

NAS Question 9

Is there evidence for organic or proto-organic material on or near the lunar surface? Are living organisms present beneath the surface?

9.1 Geodesy-Cartography

9.1.1 Provide base maps for necessary studies—(see 1.1.2)

9.1.2 Provide photogrammatic base of the same region at selected intervals (See 5.1.2)

9.2 Geology

9.2.1(P) Determine presence of fossils of pre-existing life forms

a. Collection of surface materials
1. Megascopic examination
2. Microscopic examination—(see 1.3.1.b,c)
b. Subsurface materials obtained from core holes
1. Megascopic examination
2. Microscopic examination—(see 1.3.1.b,c)

9.3 Geochemistry

9.3.1(P) Determine presence of organic or proto-organic molecules in lunar rocks or atmosphere

a. Collect appropriate samples—(see 9.2.1)
b. Analyze surface and drill-core rock samples and rock voids
1. Chromatography
2. Bioassay with terrestrial microorganisms
3. Wet analysis for carbon, nitrogen, hydrogen
4. Instrumental analysis for carbon, nitrogen, hydrogen
c. Analyze atmospheric samples
1. Gas chromatography
2. Mass spectroscopy
3. Infrared spectroscopy, etc.

9.3.2(P) Determine presence of life supporting substances

a. Collect appropriate samples—(see 9.2.1.)
b. Analyze rock samples for oxygen, carbon, hydrogen, nitrogen
1. Wet analysis
2. Instrumental analysis
(a) *Activation analysis*
(b) Electron probe
(c) Infrared absorption
c. Analyze atmosphere for oxygen, carbon, hydrogen, and nitrogen
1. Gas chromatography
2. Mass spectroscopy

9.6 Biology

9.6.1 Determine presence of existing life forms on the lunar surface

a. Establish uncontaminated soil bank of surface materials—(see 9.2.1.a)
1. Perform chemical analysis, visual and microscopic examination of soil samples to detect presence of existing life forms
b. Note proximity of lunar surface infrared absorption lines to those of earth organic molecules
1. Lunar orbiter infrared imagery
c. Examine multispectral photos of lunar surface to detect evidence of life
1. Lunar orbiter multispectral photography

9.6.2 Determine presence of existing life forms beneath the lunar *surface*

a. Obtain subsurface materials from core holes (see 9.2.1.b)
1. See 9.6.1.a.1

NAS Question 10

What is the age of the moon? What is the range of age of the stratigraphic units on the lunar surface and what is the age of the oldest exposed material? Is primordial surface exposed?

10.0 Lunar Atmospheres

10.0.1 See 3.0.1

10.1 Geodesy/Cartography

10.1.1 Provide base maps for necessary studies—(see 1.1.2)

10.1.2 Provide photogrammatic base of the *same region* at selected intervals (See 5.1.2)

10.2 Geology

10.2.1(P) Correlate absolute ages with stratigraphic succession established in 10.2.1

a. Surface material
1. Collect *representative* indigenous samples *from* geologic terranes of all relative geologic ages as determined in 10.2.1 and measurement of geologic sections in craters, scarps and rill walls.
2. Petrographic analysis—(see 1.3.1.b,c)
b. Subsurface materials
1. Collect representative samples from drill hole cores
2. Petrographic analysis—(see 1.3.1.b,c)

10.3 Geochemistry

10.3.1(P) Determine the age of the moon

a. Collect appropriate samples—(see 10.2.2.a,1)
b. Necessary geochemical analysis preceding radiometric dating
1. Determine mineralogy—(see 1.3.1.b)
2. Determine texture—(see 1.3.1.c)
c. Perform radiometric dating - mass spectroscopy—(see 1.3.1.f)

10.3.2(S) Determine the longest and average duration of exposure of lunar surface to the space environment—(see 14.3.1)

10.3.3(P) Evaluate presence of ancient shield areas exposed on the moon—(see 6.3.2)

10.3.4(P) Correlate radiometric time scale with stratigraphic succession

a. Collect appropriate samples
b. Determine mineralogy—(see 1.3.1.b)
c. Determine texture—(see 1.3.1.c)
d. Determine radiometric age—(see 1.3.1.f)

10.4 Geophysics

10.4.1(S) Establish paleomagnetic absolute time scale

a. Correlate radioactive age dates with remanent magnetism
1. Radioactive age dates—(see 1.3.1.b,c,d,e,f)
2. Remanent magnetism measurements—(see 15.4.1)

10.5 Particles and Fields

10.5.1 Same as 7.5.2. a

10.5.2 Same as 7.5.3 a

10.7 Astronomy

10.7.1 See 7.7.1. a and b

NAS Question 11

What is the history of Dynamical Interaction between the Earth and Moon?

11.1 Geodesy/Cartography

11.1.1 See 1.1.2

11.2 Geology

11.2.1(P) Relate tectonic patterns and relative age of tectonic sequences to absolute age and lunar ephemeris throughout lunar history

a. Tectonic patterns and relative age of tectonic sequence
1. See 6.2.
b. Absolute ages of stratigraphic succession
1. See 10.2

11.2.2(S) Determine paleo-strain regime and correlate with physiographic province, *local* geology and latitude

a. Microscopic rock analysis
1. Sample collection of oriented specimens in various geologic terrains both in tectonicly active and stable areas
2. Petrologic analysis—(see 3.3.6)
b. Surface mapping
1. Pace and compass type mapping of parameters of *structural features* such as *faults, joints, cleavage,* folds, mineral lineation, etc. in rock outcrops
2. Regional tectonic patterns as determined in 6.2.2

11.2.3(P) Determine if secondary ejecta from earth has impacted lunar surface

a. Surface geological mapping
1. Collect and identify terrestrial material on basis of geological, chemical and physical properties pecular to earth and foreign to the moon—(see 11.3.1)

Page Intentionally Left Blank

11.3 Geochemistry

11.3.1(P) Determine nature and age of terrestrial debris on lunar surface

a. Collect appropriate samples–(see 11.2.3)
b. Determine mineralogy–(see 1.3.1.b)
c. Determine texture–(see 1.3.1.c)
d. Determine elemental composition–(see 1.3.1)
f. Determine radiometric age–(see 1.3.1.f)

11.3.2(P) Evaluate the effect of earth and solar tides on nature and rate of solid state diffusion

a. Collect appropriate samples–(see 11.2.2.a.1)
b. Determine mineralogy–(see 1.3.1.b)
c. Determine texture–(see 1.3.1.c)
d. Determine elemental composition–(see 1.3.1.d)
e. Determine isotopic composition–(see 1.3.1.e)
f. Determine radiometric age–(see 1.3.1.f)

11.4 Geophysics

11.4.1(P) Determine present dynamic interaction

a. Lunar tides
 1. Monitor lunar tides by gravitational method–(see 2.4.1.a.4)
 2. Monitor lunar tides by strain monitoring methods–(see 2.4.2.b)
 3. Atmosphere pressure variation measurement
b. Moon-Earth ephemeris
 1. Monitor Moon-Earth distance by radar, laser beam method utilizing station network
 2. Set up a network of astronomical observatories to determine more precisely the Moon ephemeris
 3. Lunar orbiter ephemeral data to augment studies of Moon eccentricity
c. Internal fluid motion determinations
 1. Monitor the lunar magnetic field
  (a) Permanent magnetic stations–(see 1.4.3.c.2)
  (b) Lunar orbiter mapping of magnetic field at repeated intervals–(see 1.4.2.c)
 2. Monitor lunar tides above (11.4.1.a) to substantiate a liquid core
 3. Substantiate the liquid core by monitoring lunar seismicity–(see 1.4.2.a.1)

11.4.2(P) Determine the departure of the moon from fluid equilibrium

a. Map the gravitatonal field of the moon–(see 1.4.2.b)

11.4.3(P) Determine past dynamic interaction

a. Paleomagnetic studies–(see 10.4.2.c)

11.5 Particles and Fields

11.5.1 Determine the interaction between the moon and the earth's magnetospheric tail.

a. Simultaneous measurements of the vector magnetic field and flux of radiation belt electrons and protons from lunar orbit and lunar surface. Surface measurements should be along the equator separated at 180°.

11.6 Biology

11.6.1 Determine the extent of earth originated contamination of the moon.

a. Evaluate sterilization capability of lunar environment.
 1. Expose earth organisms to the lunar environment and analyze the effects on the organisms
b. Evaluate the toxicity of lunar materials
 1. Obtain soil samples and rock from surface and cores (see 9.2.1.a and b)
  (a) Wet chemical analysis
c. Obtain samples from near previously landed probes and missions and analyze for biological contamination

11.7 Astronomy

11.7.1 See 1.7.1.a

11.7.2 Establish Moon-Earth distance

a. Determine distance by radar, laser beam method utilizing station network (see 11.4.1.b)

11.7.3 Determine Moon-Earth ephemeral data

a. Telescope observations of earth's motions
b. Set up a network of astronomical observatories to more precisely determine the lunar ephemeris

NAS Question 12

What is the thermal history of the moon? What has been the distribution of tectonic and volcanic activity with time?

12.0 Lunar Atmospheres

12.0.1 See 3.0.1

12.1 Geodesy-Cartography

12.1.1 Provide base maps for necessary studies–(see 1.1.2)

12.1.2 Provide photogrammatic base of the same region at selected intervals (see 5.1.2)

12.2 Geology

12.2.1(P) Obtain samples of rocks for measurement of thermal conductivity and radioactive heat production

a. Surface geologic mapping
 1. Collect specimens
b. Subsurface geologic mapping
 1. Collect specimens of cores

12.2.2(P) Determine distribution, intensity, and type of tectonic, magmatic, volcanic, and thermal metamorphic activity as a function of absolute age

a. See 6.2
b. See 10.2

12.3 Geochemistry

12.3.1(P) Collect and evaluate evidence for igneous differentiation

a. Collect appropriate samples
b. Determine mineralogy–(see 1.3.1.b)
c. Determine texture–(see 1.3.1.c)
d. Determine elemental composition–(see 1.3.1.d)
e. Determine isotopic composition–(see 1.3.1.e)

12.3.2(P) Determine variability of type and intensity of igenous and metamorphic activity through lunar history

a. Collect appropriate samples–(see 2.2.a.2.d)
b. Determine mineralogy–(see 1.3.1.b)
c. Determine elemental composition–(see 1.3.1.d)
d. Determine radiometric age–(see 1.3.1.f)

12.4 Geophysics

12.4.1(P) Determine the present thermal regime of the moon

a. Heat flow measurements–(see 1.4.1.f)

12.4.2(P) Determine the present tectonic pattern of the moon

a. Monitor lunar seismicity–(see 1.4.2.a.1)
b. Monitor lunar strains–(see 3.4.1.b.2)
c. Determine the isostatic anomaly pattern over the lunar surface to relate to tectonic patterns–(see 5.4.3)
d. Magnetic surveys–(see 1.4.1.c, 1.4.2.c, and 1.4.3.c)
e. Gravity surveys–(see 1.4.1.b, 1.4.2.b)

NAS Question 13

What has been the flux of solid objects striking the lunar surface in the past and how has it varied with time?

13.1 Geodesy-Cartography

13.1.1 Provide base maps for necessary studies–(see 1.1.2)

13.1.2 Provide photogrammatic base of the same region at selected intervals (see 5.1.2)

13.2 Geology

13.2.1(P) Establish criteria for differentiating primary from secondary impact craters

a. Select recent primary and secondary impact craters for study from maps prepared in 1.2.1
b. Prepare geologic maps of selected craters
 1. Plane table type geologic mapping
 2. Specimen examination and megascopic description
 3. Specimen collection
 4. Petrographic analysis–(see 1.3.1.b, c)
 5. Geochemical analysis–(see 1.3.1.b, c, d, e)

13.2.2(P) Establish criteria for determining age of craters

a. See 7.2.3
b. Prepare maps from lunar orbiter remote sensing data
 1. See 1.2.1
 2. Select criteria for relative dating of craters using such things as overlapping craters, flooding of crater floors by magma, depth to diameter ratio, etc.
c. Establish absolute age of physiographic provinces
 1. See 10.2.2

13.2.3(P) Determine history of meteoritic impacts on lunar surface

a. Sample lunar surface to determine the frequency and magnitude of meteor impacts during intervals of lunar history and relate to absolute ages
 1. Select sampling areas of all ages, latitudes and longitudes from geologic and topographic maps for counting number of and parameters of primary impact craters. Relate data to absolute age intervals–(see 10.2.2)
 2. Study representative sample of primary craters of all ages to determine variation in meteorite rock type as a function of age

(a) Perform surface geological mapping of craters
 (1) Pace and compass type mapping
 (2) Meteorite specimen collection
 (3) Petrographic analysis–(see 13.3.3.b, c)
 (4) Geochemical analysis–(see 13.3.3.b, c, d, e, f)
(b) Perform subsurface geological mapping
 (1) Drill core hole to 30 meters
 (2) Specimen examination and description
 (3) Specimen collection
 (4) Petrographic analysis–(see 13.3.3.b, c)
 (5) Geochemical analysis–(see 13.3.3.b, c, d, e, f)

13.3 Geochemistry

13.3.1(P) Determine age-frequency distribution of lunar impact craters

a. Collect appropriate samples–(see 10.2.2)
b. Determine mineralogy–(see 1.3.1.b)
c. Determine texture–(see 1.3.1.c)
d. Determine radiometric age–(see 1.3.1.f)

13.3.2(P) Evaluate relationship between crater size and age

a. Collect appropriate samples–(see 13.2.2)
b. Determine mineralogy–(see 1.3.1.b)
c. Determine texture–(see 1.3.1.c)
d. Determine radiometric age–(see 1.3.1.f)
e. Measure craters–(see 13.2.2.a.1)

13.3.3(P) Determine contrast between debris of direct cosmic origin from lunar material

a. Collect appropriate samples (see 13.2.1.b.2)
b. Determine mineralogy–(see 1.3.1.b)
c. Determine texture–(see 1.3.1.c)
d. Determine elemental composition–(see 1.3.1.d)
e. Determine isotopic composition–(see 1.3.1.e)
f. Determine radiometric age–(see 1.3.1.f)

13.4 Geophysics

13.4.1(P) Determine present solid object flux

a. See 5.4.4.b

13.4.2(P) Establish criteria for differentiating primary from secondary impact craters and for determining age of craters–(see 13.2.1, 2)

a. See 1.4.1

13.4.3(P) Determine history of meteorite impacts on lunar surface–(see 13.2.3.a.1)

a. See 1.4.1

13.4.4(P) Determine present flux of secondary impact and volcanic ejecta

a. Collection and analysis of incoming particles

13.5 Particles and Fields

13.5.1 Same as 5.5.2 a and b

13.7 Astronomy

13.7.1 See 5.7.1

NAS Question 14

What has been the flux of cosmic radiation and high energy solar radiation over the history of the moon?

14.1 Geodesy-Cartography

14.1.1(P) Provide base maps for necessary studies–(see 1.1.2)

14.2 Geology

14.2.1(P) Determine degradation and alteration of surface samples due to cosmic radiation and high energy solar radiation

a. Collect surface samples on open surface and in permanently shadowed areas from terrains representing all ages
 1. Specimen examination and description
 2. Specimen collection
 3. Petrographic analysis–(see 14.3.1.b, c)
 4. Geochemical analysis–(see 14.3.1.b, c)
b. Obtain subsurface samples from drill holes located to intersect buried rocks of various ages
 1. Drill core holes to 30 meters
 2. Specimen examination and description
 3. Specimen collection
 4. Petrographic analysis–(see 14.3.1.b, c)
 5. Geochemical analysis–(see 14.3.1.b, c)

14.3 Geochemistry

14.3.1(P) Determine the nature and rate of chemical, crystalline, and textural degradation of surficial rocks from solar and cosmic radiation and other environmental factors.

a. Collect appropriate samples–(see 14.2.1.a.2)
b. Analyze according to 1.3.1.b, c, d, e, f
c. Etch and examine microscopically, radiation trails

14.3.2(P) Subject fresh lunar material to artificially enhanced radiation levels–(see 5.2.5.b)

a. Collect appropriate samples–(see 5.2.5.b)
b. Analyze as 14.3.1

14.4 Geophysics

14.4.1(P) Determine the present radiation flux

a. Monitor cosmic radiation flux
b. Monitor high energy solar radiation flux
c. Monitor magnetic field–(see 1.3.3.c.2)

14.5 Particles and Fields

14.5.1 Same as 7.5.2.a

14.5.2 Same as 7.5.3.a

14.7 Astronomy

14.7.1 See 7.7.1.a and b

NAS Question 15

What past magnetic fields may be recorded in the rocks at the moon's surface?

15.1 Geodesy-Cartography

15.1.1(P) Provide base maps for necessary studies–(see 1.1.2)

15.2 Geology

15.2.1(P) Obtain rock samples for paleomagnetic measurements

a. Specimen collection from rocks of all ages and physiographic provinces
 1. Oriented specimen collection on surface
 2. Collection of oriented core from drill holes
 3. Petrological analysis–(see 15.3.1.b, c, d)
 4. Geochemical analysis–(see 15.3.1.b, c, d, e)

15.3 Geochemistry

15.3.1(P) Perform necessary geochemical analyses prior to paleomagnetic determinations

a. Collect appropriate samples–(see 15.2.1.a.1.2)
b. Determine mineralogy–(see 1.3.1.b)
c. Determine texture–(see 1.3.1.c)
d. Determine elemental composition–(see 1.3.1.d)
e. Determine radiometric age–(see 1.3.1.f)

15.4 Geophysics

15.4.1(P) Obtain rock samples for paleomagnetic measurements–(see 15.2.1)

a. Measure intensity and direction of remanent magnetism vector
b. Test for stability of remanent magnetism and repeat 15.4.1.a
c. Test for thermo-remanent magnetism
d. Measure magnetic properties of ferromagnetic minerals
 1. Separate ferromagnetic minerals
 2. Measure B-H curve
 3. Measure susceptibility
 4. Measure temperature dependence of the magnetic properties
e. Petrologic analysis of specimens–(see 15.3.1.b, c, d)
f. Measure radiometric age of specimens–(see 15.3.1.e)

15.4.2(P) Determine interaction of magnetic anomaly with regional magnetic variations to ascertain if source of anomaly is remanent magnetism

a. Monitor magnetic anomaly during moon-wide magnetic changes and correlate results with variations measured nearby, but off the magnetic anomaly

Question 16

What are the long-term effects of reduced gravity on various life forms, including man?

16.1 Geodesy/Cartography

16.1.1(S) Provide base maps for necessary studies–(see 1.1.2)

16.2 Geology

16.2.1(S) Determine presence of fossils of pre-existing life forms–(see 9.2.1)

16.3 Geochemistry

16.3.1(S) Determine presence of organic or proto-organic molecules in lunar rocks or atmosphere–(see 9.3.1)

16.4 Geophysics

16.4.1(P) Determine gravitational field–(see 2.4.1.a)

16.6 Biology

16.6.1 Determine the effects of lunar conditions on the behavior, rhythms, and genetics of plant life.

16.6.2 Determine the effects of lunar conditions on the behavior, rhythms, and genetics of animal life.

Page Intentionally Left Blank

16.6.3 Determine the effects of lunar conditions on the behavior, rhythms, and genetics of micro-organisms and algae strains.

16.8 Applied Sciences

16.8.1 Determine the effects of the lunar environment on man's psychological behavior.

16.8.2 Determine the physiological effects of the lunar environment on man.

Question 17

What lunar resources are available for exploitation?

17.0 Lunar Atmospheres

17.0.1 Determine the existence and detailed nature of the lunar atmosphere (see 3.0.1)

17.1 Geodesy/Cartography

17.1.1(P) Provide base maps for necessary studies–(see 1.1.2)

17.1.2(P) Establish a selenocentric coordinate system–(see 1.1.1)

17.1.3(P) Determine a reference figure for the moon–(see 1.1.3)

17.1.4(S) Provide photographic coverage at selected intervals–(see 5.1.2)

17.2 Geology

17.2.1(P) Determine stratigraphic sequence of surface deposits and structure of exposed rocks to locate mineral resources

- a. See 1.2.1
- b. Pace and compass type geologic mapping
- c. Specimen collection
- d. Specimen examination and megascopic description
- e. Petrographic analysis–(see 1.3.1.b, c)
- f. Geochemical analysis–(see 1.3.b, c, d, e)

17.2.2(P) Locate centers of volcanic activity and thermal anomalies to locate mineral resources

- a. See 8.2.1

17.2.3(P) Determine volatile substances in surficial rocks

- a. See 8.2.2

17.2.4(P) Determine composition of rocks beneath surficial deposits to locate mineral resources

- a. See 4.2.2

17.2.5(P) Investigate local minimum gravity anomalies to determine location, extent and configuration of subsurface voids

- a. Surface program
  1. Pace and compass type geologic mapping
  2. Specimen examination and megascopic description
  3. Plane table type geologic mapping of area immediately surrounding voids that are discovered
- b. Subsurface program
  1. Drill core hole 10 meters deep
  2. Megascopic specimen examination and description
  3. Specimen collection
  4. Petrologic analysis–(see 1.3.1.a, b, c, d, e)

17.3 Geochemistry

17.3.1(P) Locate and evaluate deposits of material that can be economically utilized for energy generation

- a. Prospect for chemical fuels–(see 17.2.1, 17.2.3, and 17.2.4)
  1. Collect appropriate samples
  2. Perform assays–(see 1.3.1.b, c, d, e)
- b. Prospect for nuclear fuels
  1. Collect appropriate samples
  2. Perform assays–(see 1.3.1.b, c, d, e)

17.3.2(P) Locate and evaluate substances for previously unknown physical or chemical properties

- a. Conduct mineralogic-petrographic reconnaissance–(see 17.2.1)
- b. Collect appropriate samples
- c. Perform geochemical analysis–(see 1.3.1.b, c, d, e)
- d. Measure physical properties–(see 4.4.1)

17.3.3(P) Determine presence of life supporting substances–(see 9.3.2)

17.3.4(P) Determine tenor and quality of metallic and non-metallic mineral deposits

- a. Collect appropriate samples–(see 17.2.1.b)
- b. Perform analyses–(see 1.3.1.b, c, d, e)

17.4 Geophysics

17.4.1(P) Determine the near surface structure (0-5 km) of selected geological terrains by surface traverses–(see 1.4.1)

17.4.2(P) Determine the lunar gravity and magnetic reference fields–(see 2.4.1 and 1.4.2.c)

17.4.3(P) Determine possible correlations between rock properties and rock composition–(see 4.4.1)

17.4.4(P) Use the correlations between rock properties and rock composition in the interpretation of geophysical surveys over the lunar surface–(see 4.4.2)

17.4.5(P) Locate and evaluate thermal anomalies as a source of energy–(see 1.4.1.f)

17.4.6(P) Locate and evaluate radioactivity anomalies as a source of energy

17.4.7(P) Monitor and evaluate electrostatic, electromagnetic fields as a source of energy–(see 3.4.4)

17.4.8(P) Monitor and evaluate solar and cosmic influx as a source of energy–(see 5.4.4.b)

17.4.9(P) Evaluate the electromagnetic propagation properties of the lunar atmosphere

- a. Conduct radio propagation experiments

17.4.10(P) Evaluate the propagation properties of the lunar subsurface–(see 1.4.1.a.1)

17.7 Astronomy

17.7.1 Evaluate the optical properties of the lunar atmosphere

17.8 Applied Sciences

17.8.1 Investigate the lunar soil engineering properties

17.8.2 Determine the lunar soil capability to support plant life

17.8.3 Evaluate the use of solar energy as a means of power

Question 18

What lunar environmental factors are most significant to the design of proposed lunar missions?

18.1 Geodesy/Cartography

18.1.1(S) Provide base maps for necessary studies–(see 1.1.1.2)

18.1.2(S) Provide photographic coverage at selected intervals–(see 5.1.2)

18.2 Geology

18.2.1(S) Locate centers of volcanic activity and thermal anomalies–(see 8.2.1.a, b)

18.2.2(P) Determine stratigraphic sequence of surface deposits and structure of exposed rocks–(see 1.2.1)

18.2.3(P) Correlate surface geology mapped in 18.2.2 with physical and engineering properties of surface materials

- a. Surface materials
  1. Determine physical properties of surface materials–(see 1.2.1)
  2. Determine engineering properties of surface materials
     - (a) Specimen collection–(see 1.2.1.b.2)
     - (b) Specimen examination and megascopic description–(see 1.2.1.b.3)
     - (c) Petrographic analysis–(see 1.3.1.b, c)
     - (d) Bearing strength measurements
     - (e) Shear strength measurements
     - (f) Penetration resistance measurements
     - (g) Internal properties measurements
     - (h) Dust adhesion
     - (i) Angle of repose
- b. Subsurface materials
  1. Drill core hole to 3 meters depth
  2. Determine physical properties of core samples–(see 18.2.3.a.1)
  3. Determine engineering properties of core samples
     - (a) Specimen collection
     - (b) Specimen examination and megascopic description
     - (c) Petrographic analysis–(see 1.3.1)
     - (d) Bearing strength measurements
     - (e) Shear strength measurements
     - (f) Internal properties measurements

18.2.4(P) Identify topographic features that will inhibit surface travel

- a. See 1.2.1
- b. Determine angle of repose of surface material

18.3 Geochemistry

18.3.1(P) Determine presence of life supporting substances–(see 9.3)

18.3.2(P) Analyze and evaluate lunar dusts and organic material to provide background data on potential dust-caused human allergic, pulmonary and other diseases

- a. Collect appropriate samples–(see 18.2.3.a.1)
- b. Perform analyses–(see 1.3.1.b, c, d, e)

18.4 Geophysics

18.4.1(P) Determine near surface structure–(see 1.4.1 and 4.4.1.2)

18.4.2(P) Determine degree of lunar seismicity and strain tides–(see 3.4.1.b and 5.4.1, and 6.4.1)

18.4.3(P) Determine degree of radioactivity–(see 3.4.3)

18.4.4(P) Determine degree of electromagnetic energy to evaluate radio noise–(see 3.4.4)

18.4.5(P) Determine the amount of volcanic and thermal activity on the lunar surface–(see 5.4.2)

18.4.6(P) Monitor environmental conditions–(see 5.4.4.b)

18.4.7(S) Measure lunar winds–(see 8.4.1)

18.4.8(P) Evaluate *the propagation properties of the lunar atmosphere–(see 17.4.9)*

18.5 Particles and Fields

18.5.1 Determine the intensity of solar and cosmic radiation

18.6 Biology

18.6.1 Determine the physiological effects of the lunar environment on man

18.8 Applied Sciences

18.8.1 Determine the engineering properties of the lunar crust

18.8.2 Determine the corrosive effect of the lunar environment

18.8.3 Determine surface alteration and erosion effects and rates due to environmental conditions

18.8.4 Investigate structural damage repair techniques in the lunar environment

Question 19

Are the basic postulates of general relativity valid?

19.1 Geodesy/Cartography

19.1.1(P) Provide base maps for necessary studies–(see 1.1.2)

19.1.2(P) Establish a selenocentric coordinate system–(see 1.1.1)

19.1.3(P) Determine a reference figure for the moon–(see 1.1.3)

19.1.4(P) Determine the bending of light rays toward celestial bodies

- a. Astronomical observations

19.4 Geophysics

19.4.1(P) Determine the bending of light rays toward celestial bodies–(see 19.1.4)

19.4.2(P) Determine increase in rate of physical processes on the moon compared with those on the earth

- a. Measure frequency shift of a laser beam on the earth and on the moon
- b. Measure variation in time of atomic clock on the earth and moon

19.4.3(P) Determine the presence of gravitational waves

19.4.4 Compare frequencies of ultra-high precision oscillators on moon and earth

19.7 Astronomy

19.7.1 Determine the amount of light bending due to the solar gravitational field for comparison with earth and theoretical determinations

19.7.2 Determine precession rate of perihelion of Mercury for comparison with earth theoretical determinations

19.7.3 Determine Einstein shift characteristics

Question 20

What is the total inventory of stars and interstellar matter in a representative volume of our galaxy?

20.1 Geodesy-Cartography

20.1.1(S) Provide base maps for necessary studies–(see 1.1.2)

20.1.2(P) Establish a selenocentric coordinate system–(see 1.1.1)

20.7 Astronomy

20.7.1 Determine representative region for detailed examination by sky brightness survey at selected wavelengths, visible, UV and IR

20.7.2 Determine content of representative galactic region by high resolution photometry at a variety of wavelengths, particularly those inaccessible from earth

Question 21

What processes account for the phenomena observed in the sun, e.g., sunspots, flares, plages, faculae and prominences?

21.1 Geodesy/Cartography

21.1.1(S) Provide base maps for necessary studies–(see 1.1.1.2)

21.3 Geochemistry

21.3.1(P) Determine effect of periodic and aperiodic solar phenomena on lunar material as a basis for establishment of sequence and type of solar activity from rock record–(see 14.3.1.2)

21.4 Geophysics

21.4.1(P) *Monitor effects of incoming electromagnetic radiation*

- a. Monitor magnetic field–(see 3.4.4.a.1)
- b. Monitor electromagnetic field–(see 3.4.4.b)
- c. Monitor electric field–(see 3.4.4.c)

21.4.2(P) Monitor solar radiation flux–(see 5.4.4.b.3, 4)

21.4.3(P) Monitor lunar winds–(see 8.4.1)

21.5 Particles and Fields

21.5.1 Determine the nature of incident energetic solar particles

21.5.2 Obtain the structure and variations in lunar magnetic field and solar wind

21.7 Astronomy

21.7.1 Determine changes in the solar spectrum from the center of the disk to the limb with high spectral resolution below 2000 angstroms

21.7.2 Determine the spectrum of the various types of active regions (such as plages, prominences, and coronal condensations) from 2000 argstroms into the soft X-ray region

21.7.3 Determine the extreme UV spectrum of flares and the change in spectrum with time

21.7.4 Provide spectroheliograms of the sun in a number of different wavelengths inaccessible from earth

21.7.5 Determine the nature and extent of white light corona

21.7.6 Determine solar emissions and burst phenomena at radio wavelengths during flare activity

Question 22

What are the structures, compositions and energy regimes of planetary atmospheres other than that of Earth?

22.1 Geodesy/Cartography

22.1.1(S) Provide base maps for necessary studies–(see 1.1.2)

22.3 Geochemistry

22.3.1 See 8.3

22.4 Geophysics

22.4.1(P) Monitor environmental conditions on the lunar surface–(see 5.4.4.b)

22.4.2(P) Measure lunar winds–(see 8.4.1)

22.7 Astronomy

22.7.1 Determine spectral distribution of planetary atmospheric gases for content of CO, CO_2, H_2O, SO_2, N_2, O_2, and H_2

22.7.2 Determine nature and extent of radio emission bursts from Jupiter and from other planets

Page Intentionally Left Blank

Question 23

What are the structures and compositions of comets?

23. 1 Geodesy/Cartography

23. 1. 1(S) Provide base maps for necessary studies—(see 1. 1. 1, 2)

23. 2 Geology

23. 2. 1(P) Collect meteorites derived from comets and investigate their craters

a. Specimen collection
b. Petrographic analysis
c. Geochemical analysis
d. Plane table type mapping
e. Drill 30 meter core hole

23. 3 Geochemistry

23. 3. 1(P) Measure and evaluate particulate and gaseous components of cometary tails in cis-lunar environment

a. Collect appropriate samples
b. Perform analyses—(see 8. 3 and 1. 3. 1. b, c, d, e, f)

23. 3. 2(P) Collect and analyze comet-derived meteors

a. Collect appropriate samples
b. Perform analyses—(see 1. 3. 1. b, c, d, e, f)

23. 4 Geophysics

23. 4. 1(P) Determine meteor flux

a. Monitor meteor flux—(see 5. 4. 4. b. 6)

23. 4. 2(P) Monitor perturbation of fields in cis-lunar environment during passage of comet

a. Monitor magnetic field—(see 3. 4. 4. a. 1)
b. Monitor electromagnetic field—(see 3. 4. 4. b)
c. Monitor electric field—(see 3. 4. 4. c)

23. 4. 3(S) Monitor lunar winds—(see 8. 4. 1.)

23. 7 Astronomy

23. 7. 1 Determine space density and size distribution of solid particles by high resolution photometry in various wavelength regions inaccessible from earth.

23. 7. 2 Determine the nature and extent of a solid nucleus by observation of occultation of stars in the visible and radio wavelength regions.

23. 7. 3 Determine spectral distribution of coma and tail gases for content of possible molecules of H_2, N_2, CO, NO, NH_3, H_2O, CH_2, CH_3, CH_4, and NH^+.

Question 24

What is the precise location of discrete X-ray sources and what is the distribution of faint X-ray sources?

24. 1 Geodesy/Cartography

24. 1. 1(S) Establish a selenocentric coordinate system—(see 1. 1. 1.)

24. 1. 2(S) Provide base maps for necessary studies—(see 1. 1. 2.)

24. 4 Geophysics

24. 4. 1(P) Determine the high energy radiation flux on the lunar surface

a. Monitor cosmic ray flux—(see 5. 4. 4. b. 3)
b. Monitor solar radiation flux—(see 5. 4. 4. b. 4)

24. 7 Astronomy

24. 7. 1 Monitor and record general background X-ray flux by wide field observation.

24. 7. 2 Map sky brightness distribution in X-ray region.

24. 7. 3 Determine upward and downward moving X-ray fluxes in 0. 1 to 10 angstrom and 0. 1 to 1000 angstrom bands.

24. 7. 4 Locate major X-ray discrete sources and measure fluxes by high resolution observation.

Question 25

What is the distribution of very long wavelength radio stars?

25. 1 Geodesy/Cartography

25. 1. 1(S) Establish a selenocentric coordinate system—(see 1. 1. 1.)

25. 1. 2(S) Provide base maps for necessary studies—(see 1. 1. 2)

25. 4 Geophysics

25. 4. 1(P) Determine electromagnetic incoming radiation

a. Monitor magnetic field—(see 3. 4. 4. a. 1)
b. Monitor electromagnetic field—(see 3. 4. 4. b)
c. Monitor electric field—(see 3. 4. 4. c)

25. 7 Astronomy

25. 7. 1 Determine non-directional background noise in the 300 KHZ to 20 MHZ frequency range.

25. 7. 2 Determine time dependent radio emissions from discrete sources in the frequency range of 300 KHZ to 20 MHZ.

25. 7. 3 Determine spatial distribution and intensity of sources in the 300 KHZ to 20 MHZ frequency range.

Page Intentionally Left Blank

Appendix B
MIMOSA EXPERIMENT LIST

The experiment list in the following pages comprises about 200 experiments that are used by MIMOSA in the formulation of lunar scientific programs. The experiments were selected from a catalog of about 350 lunar scientific experiments compiled by North American Aviation in a NASA-funded study entitled "Scientific Mission Support for Extended Lunar Exploration." The selection of experiments was governed by the scientific investigation matrix. Only those experiments were selected that could be identified as directly relevant to one or more of the investigations concerned with the 25 basic scientific questions. The experiments are listed in numerical order in accordance with the NAA code number.

NAA NO.	TITLE	REMARKS
01030159	Atmospheric Pressure	ALSEP- Redhead or Kriesman Gauge
01030260	Atmospheric Pressure	ESS-Redhead or Kriesman Gauge
01030464	Gas Chromatograph	Heavy Gas Identification
02030261	Electric Field	ESS-Electron Beam Deflection
02030263	Charged Dust	ALSEP-Charged Dust Spectrometer
02030362	Electric Field	Electron Beam Deflection
11010101	Selenodetic Astron	Star, Sun, Earth, and Satellite photos to establish selenocentric coord. system
12010202	Selenodetic Survey	Ground Control Pt. Surveying
12020606	Selenodetic Mapping	Topographic Mapping
13030303	Surface Gravity	Absolute Gravity
21010203	Fine Structure Def.	Ground Truth
21010204	Geologic Mapping	Staff and Automatic Tracking
21010309	Surface Sampling	Sampling Tools and Containers
21010412	Subsurface Mapping	Drill 10 Meter Hole and Log with TV and Geophysical Probes
21020307	Shallow Drilling	Drill and core 1 meter hole and log with periscope
21020308	Deep Drill - 300M	Drill and core 300 Meter hole and log with geophysical sonde and TV
21040101	Geologic Base Maps	Unmanned Orbiter

21040102	Surface Mapping	Manned Orbiter
21040205	Surface Photogeology	TV on Staff, LEM, or Rover
21040411	Visual Logging	TV or periscope logging of fine structure in bore hole (any depth)
24030310	Age Determination	Section measuring on exposed geologic column
24030413	Paleomagnetism	3 component fluxgate magnetometer in bore hole
32010101	Chem. Anal. by N. Activ.	Sample screening on mobile vehicle
32010107	Min. by X-Ray Diff.	Surveyor-type X-ray Diffractometer
32010108	Micr. Min.A Pet Study	Petrographic Microscope
32010111	Chem.Anal.by N Activ.	Sample Screening at base
32010113	Gamma Scattering	In Situ Density measurement using Gamma Ray Spectrometer
32010114	In Situ X-Ray Diff.	Screening of lunar surface formations along traverse
32010115	UV-Visible Spectra	In Situ reflectance spectra for ground truth
32010117	Orbital IR Spectra	IR reflectance and emissivity
32010301	Volatile Detn & Colln.	Distillation & Collection of Volatiles from solids
33010101	Gamma Ray Spectrom	In Situ elemental analysis along traverse route
34010402	Surf.M Spec.Gas Anal.	Location of gas emission source
34010403	Mass Spectrometry	Measuring of Gas Pressure Fluctuations

40010202	Seismic Velocity	Vertical velocity profile by borehole logging
40010303	Reflection Profile	Two buried geophones spaced at 100 ft. and 5 shots up to 2000 ft. from geophones
40010304	Refraction Profile	Two buried geophones and 5 shots out to several thousand feet
40010601	Seismic Velocity	Two geophones and small squib
40050324	Mag. Susceptibility	Air Core Transformer - In Situ
40050326	Mag. Susceptibility	Air Core Transformer - Bore Hole
40050338	Dielectric Constant	Cylindrical Capactor in Bore Hole
40060328	Self Potential	Bore Hole
40060330	Electrical Surveying	Self potential, induced polarization, and electrical resistivity of surface - four electrode Wenner Array at ESS site
40060332	Surface Resistivity	In Situ - Change in Q
40060334	Subsurface Resist	Bore Hole - Change in Q
40060431	Electrical Surveying	Self potential, induced polarization, and electrical resistivity of surface - four electrode Wenner Array on Molab
40060433	Surface Resistivity	Change in Q - Molab Boom
40060435	Resistivity Subsur	Change in Q - Molab Bore Holes
40060565	Radar Mapping	Orbiter
40070383	Spectral Reflectance	Ground Truth
40070569	Photography	UV, Black & White, Color, IR Imagery - Orbit
40080153	Meteoroid Detection	Meteorite Counter - Lem Site

40080252	Meteorite Detection	Meteorite Counter - ESS
40080570	Meteorite Detection	Meteorite Counter - Orbiter
40090055	Surface Hardness	Penetrometer - Probe
40090356	Surface Hardness	Record Drilling Rates
40110277	Neutron Spectra	ESS - Incident and Albedo Neutronflux and energy spectrum
40120378	Gamma Ray Spectra	Surface & Subsurface - Scintillation Detector
40120580	Gamma Ray Spectra	Orbiter - Detect Concentrated Deposits
40130371	Alpha Mass Spec	Identify light elements in crust
40130373	Radioactivity	Alpha, Beta, and Gamma Radiation
40130375	Neutron Activation	Surface Chemical Composition
40140357	Sample Collection	For Earth return
41010405	Seismic Reflection	12 geophones spaced 100 ft. - 1 shot
41010406	Seismic Profiling	Done in conjunction with 41010405
41010407	*Crust-Upper Mantle Surv.	Deep Seismic - Geophones & Small shots
41010408	*Crust-Upper Mantle Surv.	Deep Seismic - One 13 Kg. shot
41010409	*Crust-Upper Mantle Surv.	Deep Seismic - one 42 Kg. shot
41010410	*Crust-Upper Mantle Surv.	Deep Seismic - one 80 Kg. shot
41010411	*Crust-Upper Mantle Surv.	Deep Seismic - one 1300 Kg. shot
41010412	*Crust-Upper Mantle Surv.	Deep Seismic - one 2100 Kg. shot
41010413	*Crust-Upper Mantle Surv.	Deep Seismic - one 2500 Kg. shot

* = Experiments Defined For MIMOSA

41010414	*Crust-Upper Mantle Surv.	Deep Seismic - one 6000 Kg. shot
41020107	Seismic, Passive	ALSEP
41020208	Seismic, Passive	ESS
41020411	Seismic Array	ESS Array
41040281	Magneto - Telluric	Variations of electric field in lunar crust
41050322	Magnetism	Oriented sample collection for Earth analysis to detect remnant magnetism
41050341	E-M Pulse	Subsurface structure - chirping radar on small rover
41050423	Magnetism	Oriented sample collection for analysis in MOLAB to detect remnant magnetism
41060440	E-M Pulse	Subsurface structure - chirping radar on MOLAB
41090387	Subsurface Hardness	Penetrometer
42020784	Remote Seismic	Passive seismic - delivered by probe
44070047	Sur Temp Diffusivity	Variation in diffusivity at a point
44070050	Surface Emissivity	Contact sensor at a point
44070146	Thermal Blanket	ALSEP - Temp. Gradient Over blanket
44070148	Sub Sur Diffusivity	Bore Hole
44070182	Temperature Gradient	ALSEP - Heat Flow in Bore Hole
44070245	Temperature Gradient	ESS - Heat Flow in Bore Hole
44070343	Subsurface Temp.	Bore Hole Logging
44070444	Subsurface Temp. Log	Bore Hole Logging - MOLAB

44070449	Temp. Diffusivity	Bore Hole - MOLAB
44070786	Remote Temperature	Probes emplaced from orbit
45030112	Gravity - Absolute	ALSEP - Temporal variation
45030213	Gravity - Absolute	ESS - Temporal variation
45030314	Gravity Survey	Anomalies - LaCosta Romberg gravimeter
45030568	Gravity Gradient	Orbiter
46040117	Magnetic Field	ALSEP - Rubidium vapor
46040218	Magnetic Field	ESS - Rubidium vapor
46040219	Magnetic Field	ESS - 3 component fluxgate
46040320	Magnetic Survey	Anomalies - Proton Precession
46040567	Total Magnetic Field	Orbiter
46040616	Magnetic Field	Early Apollo - Field Detection
52020101	Solar Chg Par, Low E	Environment at surface - 0.1-0.5 Mev Low solar activity
52020102	Solar Chg Par, Low E	Environment at surface - 0.1-0.5 Mev Intermediate solar activity
52020103	Solar Chg Par, Low E	Environment at surface - 0.1-0.5 Mev High solar activity
52020201	Solar Chg Par, High E	Environment at surface - 0.5-1000 Mev Low solar activity
52020202	Solar Chg Par, High E	Environment at surface - 0.5-1000 Mev Intermediate solar activity
52020203	Solar Chg Par, High E	Environment at surface - 0.5-1000 Mev High solar activity
52020301	Charged Par Anisotpy	Orbiter
52020401	NUCL Radiation Envrn	Nuclear Environment at surface
52020402	Solar High E Electrons	Environment at surface Low solar activity
52020403	Solar High E Electrons	Environment at surface High solar activity

52030101	Galactic Nuclei	Environment at surface - 100 Mev - 100 Bev, low solar activity
52030102	Galactic Nuclei	Environment at surface - 100 Mev - 100 Bev intermediate solar activity
52030103	Galactic Nuclei	Environment at surface - 100 Mev - 100 Bev, high solar activity
52030201	Galactic Electrons	Environment at surface - 100 - 1000 Mev low solar activity
52030202	Galactic Electrons	Environment at surface - 100-1000 Mev intermediate solar activity
52030203	Galactic Electrons	Environment at surface - 100-1000 Mev high solar activity
53010101	Solar Wind Spectrum	Interaction with moon and geomagneto-sphere
53030101	Solar, Geomag Field	Interplanetary Field
53050103	Solar, Geomag Field	Interplanetary Field
55220101	Outer Corona Spectra	Outer Corona Structure
55220201	Flare UV Spectra - I	8 inch telescope
55220301	Granul Fine Structur	Photospheric Granulations
55220401	Sunspot Formation	Development of New Spots
55220601	Flare Ejecta, Accel	Solar Disk and Limb
55230101	UV Low Dispersion	4 positions on solar disk
55230102	UV High Dispersion	Determine chemical composition - 4 positions on solar disk.
55230201	Flare UV Spectra II	8 inch telescope
67010201	Biorhythms / Plant	Germinate and maintain higher plants under 28 day cycle
67010301	Gen. Effects / Plant	Effects of Trip from Earth to Moon

67020202	Biorhythms / Animal	Two generations of fruit flies, mice, daphnia and fowl.
67030303	Gen Effects / Micro	Effects on trip
68030401	Soil Bank	Lunar soil depot on lunar surface
68040102	Evid exist lift	Organic compound detection
72010308	Photg. Obs. (40)	Hi-resolution, 40 in telescope
72010309	Photg. Photom (40)	Wide-band, 40 in telescope
72010310	Photoel. Phot. (40)	Selected objects, 40 in telescope
72010311	Spectroscopy (40)	Low dispersion - faint stars & nebulae
72010312	High Disp. Spec (40)	Bright starts, nebulae, planets
72010313	Spectr. Scan (40)	Intensity of radiant energy of various objects
72010414	High Red. Photg (100)	Planets, nebulae, quasars, star clusters - 100 in telescope
72010415	High Disp. Spec (100)	Stars, planets, nebulae, comets
72010416	High Energy (100)	Chromosphere and corona of stars
72010417	Outer Envel. (100)	Stellar
72010418	Planet Like (100)	Planet-like companions of stars
72010419	Mag. and Color (100)	Photelectric index of stars
73020622	Spectral Char X-rays	X-ray radiation from Sun, stars, galaxies
73020623	Angular Pos. X-rays	Grazing incidence reflector
73020624	Dist. Int. Med. X-ray	Interstellar medium distribution
75010101	Non Dir. Radio Astr.	Antenna & radiometer - Jupiter decameter bursts and solar meter-wave bursts.

75010102	Dir. Radio Astr.	Interferometer with 2 800 meter elements each consisting of 12 in-line dipoles
75030101	Submilli. Radio Astr.	Steerable 100 foot dish.
80010101	Topgphy AES-LEM Site	Orbital photographic mapping
80010302	Eng. Prop Lunar Surf	Staff penetrometer
80010303	Eng. Prop. of Surf Sub	Shielding and construction support
80010305	Lunar Soil Shielding	Radiation shielding
80010321	Elec Param Surf Sub	Conductivity, permeability and dielectric constant
80010322	Lunar Strata E/M Pro	Subsurface RF propagation feasibility
80010401	Corrosion Test	Effect on lunar environment on test samples and operational equip.
80020101	Dist. Envrmt/Surface	Rate of dust collection on equipment and personnel - photos
80020302	Lunar RF Noise	10 HZ to 300 KHZ
80020401	Antenna Dust	Charged dust accumulation measurement
80020501	Lun Atm Contam - Rocket	Time-of-flight Mass spectrometer
80020502	Leakage Measurements	Vehicles, shelters, suits
80110101	Gas Reqts. for Drill	Monitor flow rate, volume, and drill bit temperature
80110401	Geolog. - Chem Samp Cas	Casset Evaluation
80120301	Explosv Energy Coupl	Small Scale Cratering study
80130101	Bio Contam Lunr Soil	Survivability of biological contaminants
80170101	Earth RFI BKGND Nois	Orbiter

80180101	Astronomy Feasible	Optical Test
80200401	Work Capability	Astronaut Limitations
80200601	Psychological Study	Effects of long term confinement on lunar based personnel
80201001	Cardiovascular Pheno	Effects of reduced gravity
80201101	Bone Demineralizatn	Effects of reduced gravity
80300104	Plant Grth Dev Repr	Determine abnormalities
80300201	Genetic Eff/Animals	Effects of trip from Earth to Moon
80320301	RF Grnd Wave Prpgtion	Propagation model confirmation
80320401	RF Subsurf propgtion	Path resistance and coupling effects
80340101	Dust Removal Technqs	Comparison of methods
80340301	Stat Xpos Eff on Mat	Effects of lunar environment on test samples of materials
80340302	Xpos Eff on Rad Mat	Radiator Material Comparison
80340401	Dynmic Test Machin El	Machine element behavior
80340402	Dynmic Test Thin Flm	Thin Film Bearing Test
80340403	Dynmic Test Ele Compt	Electrical component test
80341401	Elstmr- Polymer Degrd	Elastomer and polymer behavior
80350101	Efcts Long Boom Struc	Long antenna structures
80350201	Rpr Tech Majr Struc	Repair techniques for major structural damage
80360201	Dang Terrain Warning	Detect dangerous terrain
80370101	Vis Tech Astro Vis	Visual Techniques in land navigation astronaut vision

80370102	Vis Tech Land Recog	Visual techniques in land navigation-land recognition
80430301	Part Adhesn Mech Prc	Particle adhesion in mechanical processing
80450101	Dry Cement - Concrt App	Dry cement and concrete from lunar material
90010101	Hi Int Elec Beam Gen	Generation of high intensity electron beams for metal joining
90030101	Radiation Cryostat	Long term cryogenic storage
90040101	Atomic Species Life	Measure Decay rate
90050101	Lorentz Plsma Meas	Determine low frequency MHD Wave source and propagation mechanism
90050201	Crnr Rflr Laser Beam	Earth-Moon ranging and lunar libration study
99999948	Remote Seismometer	Same as 42020784 but provided with an RTG power supply
99999950	Stereophotography	Same as 80120501 except performed from a manned orbiter
99999951	Medium Depth Drill	100-meter core drill

Appendix C

CORRELATION OF NAA LUNAR SCIENTIFIC EXPERIMENTS WITH MIMOSA SCIENTIFIC INVESTIGATION MATRIX

The experiments appropriate to each investigation in the scientific investigation matrix are identified here. It will be noted that, in many instances, a particular experiment may relate to several investigations. The experiments are identified by the North American Aviation code number. In some instances in which an appropriate experiment is not identified in the NAA catalog, the experiment is called out by name or descriptive phrase.

Investigation No.	Experiment No.
1.1.1	12020606, 90050201
1.1.2	11010101, 12010202, 40060565, 80120501
1.1.3	11010101, 12010202, 12020606, 13030303, 45030112, 45030213, 45030314, 45030568
Ancillary-6 satellites (3 geodetic- 3 others) (seismometer must have period 1 minute or more)	
1.1.4	42020784, 45030112, 45030213
1.1.5	See 1.1.3
1.1.6	See 1.1.1, 1.1.3
1.1.7	See 1.1.1, 1.1.3, 42020784
1.2.1	21040101, 21040102, 21010203, 21010204, 21010309, 21040205, 24030310, 32010113, 40050439, 40060565, 40070383, 40070569, 40120580, 40140357
1.2.2	21010203, 21010204, 21010309, 21040205, 21040411, 24030310, 40140357
1.2.3	21020308
1.2.4	21010204, 21010309, 21040411, 24030310, 40140357
1.3.1	32010101, 32010107, 32010108, 32010111, 32010114, 33010101, 40110277, 40130371, 40130373, 40130375
1.3.2	See 1.2.4, See 1.3.1
1.3.3	See 1.3.1
1.3.4	See 1.2.1, 1.2.3, 1.3.1
1.4.1	21010412, 40060330, 40130373, 41010405, 41010406, 41010407, 41010408, 41010409, 41040281, 44070182, 44070245, 45030314, 46040320
1.4.2	21010412, 41010407, 41010408, 41010409, 41010410, 41010411, 41010412, 41010413, 41010414, 41020107, 41020208, 41040281, 44070182, 44070245, 45030112, 45030213, 45030314, 45030568, 46040320, 46040567
1.4.3	21010412, 41020107, 41020208, 41020411, 41040281, 44070182, 44070245, 45030112, 45030213, 45030314, 45030568
1.4.4	11010101, 13030303, 45030112, 45030213, 45030314, 45030568
1.4.5	See 4.4.1
1.5.1	46040117, 46040218, 46040219, 46040567, 52020101, 52020102, 52020103, 52020201, 52020202, 52020203, 52020301, 53010101, 53050101, 53050103
1.7.1	11010101, 72010308
2.1.1	See 1.1.1
2.1.2	See 1.1.2
2.1.3	See 1.1.3
2.1.4	See 1.1.3, See 1.4.2, See 1.4.3, 21010309, 32010113, 40140357
2.2.1	See 1.2.1, 1.2.2, 1.2.3, 1.1.3
2.2.2	21010203, 21010204, 21010309, 21040102, 21040225, 21040411, 24030310, 40070569, 40140357
2.3.1	See 2.2.1, See 1.3.1, See 2.1.1
2.4.1	12020606, 45030112, 45030213, 45030314, 45030568, Ancillary Satellites
2.4.2	41020107, 41020208, 41020411, Strain experiment
2.5.1	See 1.5.1
2.5.2	45030112, 45030213, 45030568
2.7.1	See 1.7.1
3.0.1	01030159, 01030260, 01030464, 34010402, 34010403
3.1.1	See 1.1.1, 1.1.2, 1.1.3
3.1.2	See 1.1.1
3.2.1	32010117, 44070566, 44070786
3.2.2	See 1.2.1
3.2.3	See 3.2.1, 3.2.2
3.2.4	See 1.2.1, 1.2.2, 1.2.4
3.2.5	See 1.2.2
3.2.6	See 3.2.1, 21010412
3.2.7	See 1.2.1
3.2.8	See 1.2.1
3.3.1	21010309, 21010412, 40120378, 40130373
3.3.2	See 3.3.6
3.3.3	See 1.2.4, 1.3.1
3.3.4	See 3.2.4, 1.3.1
3.3.5	See 3.2.2, See 1.3.1
3.3.6	3.2.4, 1.3.1
3.4.1	11010101, 41020107, 41020411, 41020708, 42020784, 45030112, 45030213, 72010308, Strain experiment
3.4.2	21010412, 32010117, 40120580, 40130373, 44070182, 44070245
3.4.3	02030261, 02030362, 24030413, 41040281, 46040219, 46040567
3.5.1	See 1.5.1
4.1.1	See 1.1.2
4.2.1	See 1.2.1
4.2.2	21020307, 21020308, 21010412
4.3.1	See 4.2.2, See 1.2.1, See 1.3.1
4.4.1	See 4.2.2, 21010309, 21040205, 24030413, 32010113, 40010601, 40050324, 40050326, 40050336, 40050338, 40060332, 40060334, 40070383, 40090055, 40090356, 40140357, 41050322, 41050423, 41090387, 44070047, 44070050, 44070449, 80010302, 80010303, 80010321, 80010322, 80120321
4.4.2	See 1.4.1, 40120580, 40130373, 40130474, 41020107, 41020108, 41020411, 45030114, 45030415, 45030568, 46040320, 46040421, 46040567
4.5.1	32010117, 52020301, 52020401, 52030101, 52030102, 52030103, 52030201, 52030203, 53020202, 73020622, 73020623, 73020624
4.5.2	See 4.5.1, 21010309, 32010113, 40120580, 40140357
5.0.1	See 3.0.1
5.1.1	See 1.1.2
5.1.2	21040111, 21040112, 40060565, 99999950
5.1.3	See 1.1.3
5.2.1	See 1.2.1
5.2.2	See 1.2.1, 1.2.2, See 3.2.4
5.2.3	See 1.2.1, 1.2.2
5.2.4	21020307, 80340301
5.2.5	See 1.2.1, 12010202, 21010412, 80340301
Traps for collection of solids and gases in transport	
5.3.1	See 1.2.1, See 1.3.1, 32010108
5.4.1	12020606, 21040101, 21040102, 40060565, 41010406, 41010407, 41010408, 41010409, 41020107, 41020208, 41020411, 45030112, 45030213
Strain network experiment	
5.4.2	See 3.2.1, See 1.4.1, 41020107, 41020108, 41020411
5.4.3	See 1.1.6
5.4.4	01030159, 01030260, 02030261, 02030362, 32010117, 40070444, 40080153, 40080252, 40080570, 44070343, 44070742, 44070786, 45030112, 52020101, 52020102, 52020103, 52020201, 52020202, 52020203, 52020401, 52020402, 52020403, 52030101, 52030102, 52030103, 52030201, 52030202, 52030203
5.5.1	See 4.5.2, 40080153, 40080252, 40080570
5.5.2	40080153, 40080252, 40080454, 40080570
5.7.1	72010308, 72010309, 72010310, 72010311, 72010312, 72010313, 72010404
6.1.1	See 1.1.2
6.2.1	See 1.2.1
6.2.2	See 1.2.1
6.2.3	See 1.2.1
6.3.1	See 1.2.1, 1.3.1
6.3.2	See 1.2.1, 1.3.1
6.4.1	41020107, 41020208, 41020411, 42020784
6.4.2	See 1.1.6
6.4.3	40060330, 40130373, 41010405, 41010406, 41010407, 41010408, 41010409, 41010410, 41010411, 41010412, 41010413, 41010414, 41020107, 41020208, 41020411, 41040281, 41050341, 42020784, 44070182, 44070245, 45030112, 45030314, 46040320
7.1.1	See 1.1.2
7.1.2	12020606, 21040101, 40060565, 99999950
7.2.1	See 1.2.2, 21010412, See 7.1.2, 21020317
7.2.2	See 1.2.1, 21020308, 21010203, 21010204
7.2.3	11010101, 12010202, 12020606, 21010230, 40060565, 80340301, 99999950
Traps for collecting solids and gases in transport	
7.3.1	See 7.2.3, See 1.3.1, 01030464, 32010301, 34010402, 34010403
7.3.2	See 7.2.3, 1.3.1
7.3.3	See 1.3.1, See 7.2.1
7.3.4	See 1.3.1, See 8.2.1
7.3.5	See 7.2.3, See 8.3.1, 8.3.2, 8.3.3
7.3.6	See 1.3.1, See 7.2.3, See 3.4.1, 01030464, 32010301, 34010402, 34010403
7.4.1	See 1.4.1, 21040411, 40010202, 40050326, 40050338, 40060328, 40060334, 44070343
7.4.2	See 5.5.2, 41010411, 41020107, 41020208, 42020784, 45030112, 45030213
7.5.1	02030261, 02030362
7.5.2	See 4.5.1
7.5.3	52020101, 52020102, 52020103, 52020201, 52020202, 52020203, 52020402, 52020403, 53010101, 55220601
7.5.4	See 5.5.2
7.7.1	55220101, 55220201, 55220301, 55220401, 55220601, 55230101, 55230102, 55230201
7.7.2	See 5.7.1
8.0.1	See 5.0.1
8.1.1	See 3.1.1
8.2.1	See 3.2.1, 3.2.2, 32010301

Page Intentionally Left Blank

Investigation No.	Experiment No.
8.2.2	32010301
8.3.1	01030159 01030260 01030464 32010301 34010402 34010403
8.3.2	See 8.3.1
8.3.3	See 8.3.1
8.3.4	21010309 21020307 32010101 32010113 32010114 32010115 32010301 33010101 34010402 34010403
8.3.5	See 7.3.5 7.3.6
8.4.1	01030159 01030260
8.5.1	See 1.5.1 53010101 53050101 53050103
9.1.1	See 2.1.2
9.1.2	See 7.1.2
9.2.1	68040102
9.3.1	68040101
9.3.2	32010111 32010301 40130475 68040101
9.6.1	68040102 68040101
9.6.2	68040102 68040101
10.0.1	See 3.0.1
10.1.1	See 2.1.2
10.1.2	See 7.1.2
10.2.1	See 1.2.1
10.2.2	See 10.2.1
10.3.1	21010309
10.3.2	See 14.3.1
10.3.3	See 6.3.2
10.3.4	See 1.2.1, 1.2.2, 10.3.1
10.4.1	See 15.4.1, 10.3.1
10.5.1	See 4.5.1
10.5.2	See 7.5.3
10.7.1	See 7.7.1
11.1.1	See 1.1.2
11.2.1	See 10.2.2
11.2.2	See 1.2.1
11.2.3	21010203 21010204 21010309
11.3.1	See 1.3.1
11.3.2	See 1.3.1
11.4.1	01030159 01030260 11010101 41020107 41020208 41020411 42020784 45030112 46040117 46040218 46040219 46040616 90050201 Strain monitoring
11.4.2	See 2.1.1
11.4.3	See 10.4.1
11.5.1	53050101 53050103
11.6.1	80130101
11.7.1	See 1.7.1
11.7.2	90050201
11.7.3	11010101
12.0.1	See 3.0.1
12.1.1	See 2.1.2
12.1.2	See 5.1.2
12.2.1	21010203 21010204 21010309 21010412 21020307 21020308
12.2.2	See 1.2.1
12.3.1	See 1.3.1 21010309
12.3.2	See 12.3.1
12.4.1	See 3.4.2
12.4.2	See 6.4.3
13.1.1	See 2.1.1
13.1.2	See 5.1.1
13.2.1	See 1.2.1, 1.2.2
13.2.2	See 1.2.1, 7.2.3
13.2.3	See 1.2.1, 7.2.3 21010412
13.3.1	See 1.3.1 21010309
13.3.2	See 1.3.1 21010309
13.3.3	See 1.3.1 21010309
13.4.1	See 7.4.2
13.4.2	See 1.4.1
13.4.3	See 1.4.1
13.4.4	40080153 40080252
13.5.1	See 7.5.4
13.7.1	See 5.7.1
14.1.1	See 2.1.2
14.2.1	See 21010309 21010412
14.3.1	See 14.2.1 1.3.1
14.3.2	See 5.2.3 21010309
14.4.1	46040117 46040218 46040219 46040616 52020101 52020102 52020103 52020201 52020202 52020203 52020401 52020402 52020403 52030101 52030102 52030103 52030201 52030202 52030203 73020622 73020623 73020624

Investigation No.	Experiment No.
14.51	See 4.5.1
14.5.2	See 7.5.3
14.7.1	See 7.7.1
15.1.1	See 2.1.2
15.2.1	41050322
15.3.1	See 1.3.1
15.4.1	See 15.2.1
15.4.2	46040117 46040219
16.1.1	See 2.1.2
16.2.1	See 9.2.1
16.3.1	See 9.3.1
16.4.1	See 2.4.1
16.6.1	67010201 67010301
16.6.2	67020202 80300201
16.6.3	67030303
16.8.1	80200601 80370102
16.8.2	See 16.8.1 80200401 80201001 80201101 80370102
17.0.1	See 3.0.1 See 2.1.2
17.1.1	See 1.1.2
17.1.2	See 1.1.1
17.1.3	See 1.1.3
17.1.4	See 5.1.2
17.2.1	See 1.2.1 See 4.2.2
17.2.2	See 3.2.1
17.2.3	See 8.2.2
17.2.4	See 4.2.2
17.2.5	21010203 21010204 21020307
17.3.1	See 17.2.1 17.2.3 17.2.4 1.3.1
17.3.2	See 17.2.1 1.3.1 4.4.1
17.3.3	See 9.3.2
17.3.4	See 17.2.1 1.3.1
17.4.1	See 1.4.1
17.4.2	See 2.4.1 41050423 46040117 46040218 46040219 46040616
17.4.3	See 4.4.1
17.4.4	See 4.4.2
17.4.5	See 3.2.1 3.2.2 3.2.3
17.4.6	40130373
17.4.7	See 3.4.4
17.4.8	See 4.5.1 7.5.3
17.4.9	80020302
17.4.10	80010321 80010322 80120301 80320301 80320401
17.7.1	80180101
17.8.1	80010302 80010305 40090055 40090356
17.8.2	67010201 80300102 80300103 80300104
17.8.3	90030201
18.1.1	2.1.1
18.1.2	7.1.1
18.2.1	See 8.2.1
18.2.2	See 1.2.1
18.2.3	See 1.2.1 02030263 40090055 40090356 80010302 80010303 80010305 80010321 80010322 80010401 80020101 80020302 80120301 80320301 80320401 80340301
18.2.4	See 1.2.1
18.3.1	See 9.3.2
18.3.2	21010309 See 1.3.1
18.4.1	See 1.4.1
18.4.2	41020107 41020208 41020411 42020784 45030112
18.4.3	40130373
18.4.4	80020302 See 5.4.4
18.4.5	See 5.4.2
18.4.6	See 5.4.4.2 01030159 01030260
18.4.7	See 8.4.1 80320301 80320401
18.4.8	See 17.4.9
18.5.1	See 14.4.1
18.6.1	See 16.8.2
18.8.1	80010302 80010303
18.8.2	80010401
18.8.3	80340301
18.8.4	80350201
19.1.1	See 1.1.2
19.1.2	See 1.1.1
19.1.3	See 1.1.3
19.1.4	72010308 72010309 72010310 72010414 72010415
19.4.1	See 19.1.4
19.4.2	Freq shift of laser on earth and on moon. Variation in time of atomic clock on earth and on moon.
19.4.3	Detect gravitational waves.
19.4.4	Compare frequencies of ultra-high precision oscillators on earth and moon.
19.7.1	72010308 72010309 72010310 72010414
19.7.2	72010308 72010414

Investigation No.	Experiment No.
19.7.3	See 19.7.2
20.1.1	See 1.1.2
20.1.2	See 1.1.1
20.7.1	72010308 72010309 72010310 72010311 72010312 72010313 72010414 72010415 72010416 72010417 72010418 72010419
20.7.2	72010308 72010309 72010310 72010414 72010415 72010416 72010419 73020622 73020623 73020624 75010102 75030101
21.1.1	See 1.1.1 See 1.1.2
21.3.1	See 14.3.1 See 14.3.2
21.4.1	See 3.4.4
21.4.2	See 5.4.4
21.4.3	See 8.4.1
21.5.1	See 7.5.3
21.5.2	See 3.5.1
21.7.1	55230101 55230102
21.7.2	55220301 55220401 55220601 55230201
21.7.3	55220201 55230201
21.7.4	Spectroheliograms of sun
21.7.5	55220101
21.7.6	75010101 75010102 75030101
22.1.1	See 1.1.1 See 1.1.2
22.3.1	See 8.3
22.4.1	See 5.4.4
22.4.2	See 8.4.1
22.7.1	72010311 72010415
22.7.2	75010101 75010102 75030101
23.1.1	See 1.1.1 See 1.1.2
23.2.1	40140357
23.3.1	See 1.3.1 See 8.3
23.3.2	See 1.3.1
23.4.1	See 5.4.4
23.4.2	See 3.4.4
23.4.3	See 8.4.1
23.7.1	72010309 72010310 72010414
23.7.2	72010308 72010414
23.7.3	72010415 72010311
24.1.1	See 1.1.1
24.1.2	See 1.1.2
24.4.1	See 5.4.4
24.7.1	73020622 73020624
24.7.2	73020622 73020623 73020624
24.7.3	73020623
24.7.4	73020623
25.1.1	See 1.1.1
25.1.2	See 1.1.2
25.4.1	See 3.4.4
25.7.1	75010101 75010102 75030101
25.7.2	See 25.7.1
25.7.3	See 25.7.1

Appendix D
DESCRIPTION OF LOCALES, PATHS, AND REGIONS

D.1 LOCALES

D.1.1 Locale 1 – Hyginus Rille

Hyginus Rille is about 1,000 km long with a northwest-southeast trend centered on Hyginus Crater (6°E, 8°N). It appears to be a tectonic feature that has controlled the location of volcanic activity. The slope of the surrounding area is toward the rille and appears to be covered with the residue of a volcanic extrusion. This suggests an epoch of lava emission and partial return to the lunar interior. Remanent magnetic fields may be retained in the lava flow. Hyginus Rille appears to be of the maar type, and may have ejected materials from great depth.

This is an area of great interest with regard to lunar thermal and tectonic history, and it may still be active. The proximity of tectonic activity to the sub-Earth point suggests a correlation with lunar tidal stresses that should be investigated. If it is an area of continuing tectonism, moonquakes should be frequent and useful for passive seismological study of the deep structure of the Moon.

This locale is appropriate to the study of questions concerning the interior structure of the Moon, present and past tectonic activity, present thermal activity, possible volatile emissions, and lunar magnetic history as recorded by remanent magnetic fields.

D.1.2 Locale 2 – Alphonsus

Alphonsus is an old crater located at the western edge of the central highlands (2°W, 14°S). Partial filling of the crater has formed a rough but essentially level floor with many features of interest, including maar-type craters and rilles strongly suggestive of volcanic origin. Hazy obscuration of portions of the crater floor as seen in photographs has been reported as indicative of gas emission. Spectra characteristic of emission from a gas have also been recorded.

The rim of Alphonsus is battered and the floor has a high density of craters compared with Mare Nubium immediately to the west. This implies a long history of development which makes it a favorable site for studying processes responsible for the present appearance of the Moon.

Ranger IX impacted in Alphonsus and provided excellent photographic coverage upon which to base plans for manned exploration of the area. The Ranger IX impact point also provides an opportunity to study a newly made crater in lunar material caused by an event of known mass, momentum, and energy.

It appears that extensive records of processes responsible for the present condition of the lunar surface may be found at Alphonsus. The composition of material ejected from maar craters may give evidence of subsurface differentiation. Gaseous emissions may indicate present thermal and chemical activity in the lunar interior.

D.1.3 Locale 3 – Capella M

This locale is located on the highland area bounded by Mare Tranquillitatis, Mare Fecunditatis, and Mare Nectaris at approximately 36° E and 4° S. It is a highland area typical of one of the two main lunar features, i.e., highlands and maria.

It has a rille system which roughly parallels other major lunar rille systems indicative of the present lunar tectonic pattern.

There will be ejecta contributions from each of the surrounding maria in connection with the formation of their basins. The preservation and extent of these ejecta blankets will be of interest in the investigation of lunar erosion, transport, and deposition processes as well as of lunar stratigraphic history.

There is also a problem arising from the unexplained filling of the long (200 km by 30 km) valley which trends northwest-southeast through this area. Both lava flow and deposition of material from the upland area have been offered as explanations.

D.1.4 Locale 4 — Hadley's Rille

Hadley's Rille is located at the foot of the northwest-facing steep wall of the Apennine Mountains and at the southeast edge of Palus Putredinis (3° E, 26° N). The rille heads in the hills and descends into Palus Putredinis. The rille itself is of interest in being a "lava ditch." It is believed that lava extruded at the "cobra head" and flowed down the rille. Investigation of this feature should be very productive of new information concerning volcanism and the thermal history of the Moon.

Of equal interest in this area is the scarp of the Apennines. Over 2,000 m of crustal section is exposed here. This scarp represents a major structural feature of the formation of the Imbrium basin. It is believed that slippage of major proportions occurred along this scarp. As a result, this area is of great interest in the investigation of the tectonism which accompanies basin formation.

D.1.5 Locale 5 — Dark Halo Craters Southeast of Copernicus

The dark halo craters locale is located 150 km southeast of Copernicus at 17°W, 16° N. This locale lies in an area of very low albedo that has been known as "dark Imbrian material." Photos taken at the Catalina Observatory show numerous dark halo craters to be present in this dark albedo area. These dark halo craters are believed to be of the maar type whose geysering action brings up rocks from depth. Because of the large number of these craters, it may be correspondingly more likely to find one where minerals are brought up from great depth. On Earth, this type of crater brings up minerals, in some instances, from the mantle. On the lunar surface this would be an unequalled opportunity to sample the deep crust.

In addition to being a "window" to the deeply buried crust, the dark halo craters offer an excellent example of volcanism for the study of internal heating, composition of the crust, and lunar radioactivity.

D.1.6 Locale 6 — Aristarchus

The Aristarchus locale is located on the highlands adjacent to the crater Aristarchus at 48°W, 25°N. This large upland area, located in the northern part of Oceanus Procellarum, is predominantly volcanic in origin. On it are many volcanic cones, volcanic flows, sinuous rilles, and craters exhibiting volcanic features. Aristarchus crater has recently been observed to be the location of red spots which are highly suggestive of continuing volcanic activity. Nearby is the head of the Schroters Valley, which continues north and west in a long sinuous pattern. This valley or rille is believed to be a "lava ditch," along which fluid lava descended until it reached the Ocean Procellarum surface to the west.

Investigation of this locale should yield information concerning volcanism, the thermal history of the Moon, the stratigraphy of the volcanic materials, and information about the nature and differentiation of the crust.

D.1.7 Locale 7 — Marius Hills

The Marius Hills locale is located in Oceanus Procellarum approximately 50 km west of the crater Marius in the Marius Hills at 53°W, 12°N. Volcanic domes, the mare surface of Oceanus Procellarum, and a variety of volcanic materials are available here for investigation.

Several types of domes have been observed in this area. One type is characterized by low slopes and upward convexity of shape. It appears to be similar to terrestrial basaltic shield volcanoes. Another type has steeper slopes, is concave upwards in shape, and appears to be similar to terrestrial acid or intermediate composition cones. A third type appears to consist of closely spaced volcanic vents.

The volcanic domes in this area differ from those in the Aristarchus area. It is believed that the volcanic complex here, since it is less densely cratered, is superimposed on the typical Oceanus Procellarum mare material.

The suggested difference of composition and form may be indicative of magmatic differentiation. Considerable information as to the nature of the processes of volcanism and crustal differentiation should be obtainable at this locale.

D.1.8 Locale 8 — Mare Humorum

The Mare Humorum locale is located on the western edge of Mare Humorum on a somewhat folded marginal bench at 43°W, 20°S. This marginal bench area is considerably more cratered than the central portion of Mare Humorum and would appear to be older. Also, it is at differing levels above the main Mare Humorum surface, which suggests that it had undergone folding prior to the deposition of the main portion of the mare. This locale represents, therefore, an area for the study of an earlier mare surface material, a period of folding, and an opportunity to investigate isostatic adjustment.

Mare Humorum is a basin considerably older than the Mare Orientale or Imbrium basins. Its surrounding rim has been battered and deformed. The age-dating of this rim in relation to the two nearby mare materials as well as its age relation to the other large basin rims will be of considerable interest.

D.1.9 Locale 9 — Menelaus Rilles

The Menelaus Rilles locale is located at the southern edge of Mare Serenitatis at 18°E, 17°N. The Menelaus Rilles are roughly parallel to the boundary of the mare and lie within a dark area of what is believed to be volcanic flows younger than the main body of Mare Serenitatis mare material. Many other similar dark volcanic areas occur on the lunar surface. Investigation of this area should reveal the nature of these other areas, as well as answer questions of the mechanism of rille formation, flow volcanism, mare material formation, and crustal differentiation. The thermal history of the Moon as one of multiple heating would be indicated if several distinct volcanic flows of different ages were found to exist here.

D.1.10 Locale 10 — Dome Field In Mare Tranquillitatis

The Dome Field locale is located near the north edge of Mare Tranquillitatis between Vitruvius G and Maraldi B at approximately 36°E, 14°N. The northern one-half of Mare Tranquillitatis has many domes on its surface. Many of these domes are large (10 km across) and many have pits or vents near their centers. It is believed that these domes are related to volcanism. At this locale, the domes are near the Mare Highlands boundary and a ridge system. The investigation of structure and origin of these domes will answer questions concerning volcanism, mare formation, and the structural controls that affect them.

D.1.11 Locale 11 — Tycho

The tycho locale is an excellent one for study of a very young, large-rayed crater and the mechanics of its formation.

Tycho is located at 43°S, 10°W in the highlands and excavates it to considerable depth. This presents the chance to study the highlands stratigraphy as exposed in the crater walls.

Tycho should be compared to Copernicus to see how the different country rock affects the cratering, structure, distribution of ejecta, ray pattern, and shock products.

The relative recency of Tycho is an advantage from the point of view of accessibility and good exposure.

D.1.12 Locale 12 — Mare Orientale

The Mare Orientale locale is located near the eastern edge of the young, unfilled Mare Orientale basin just beyond the west limb at approximately 94°W, 18°S. This large basin has a few very small areas of dark mare-like filling, as contrasted to the brimful condition of the Earth-side basins such as Mare Imbrium and Mare Humorum. This fresh, nearly empty basin presents an opportunity to study the mechanism of basin forming and filling. There should be an excellent exposure of the shock products, the lava filling sequence, and the overall structure resulting from an exceptionally large cratering event. Since the major lunar basins (Imbrium, Serenitatis, Tranquillitatis, Fecunditatis, Humorum, etc.,) cover a very large percentage of the Earth-side hemisphere of the Moon, the story of their origin and filling is of the first order of importance.

The Mare Orientale basin may provide exposure of several thousand meters of rock section within its steep inner crater walls. Since the basin appears to have been excavated from a highlands area, this exposed rock column would provide clues as to the differentiation of the lunar crust.

D.1.13 Locale 13 – Oceanus Procellarum

The Oceanus Procellarum locale is located in Oceanus Procellarum at 2°N, 43°W and about 100 km north of the Surveyor I landing site. This area is near the Luna 9 landing site, which is about 200 km to the west. In this area, which is typical of the relatively flat Oceanus, many of the Moon-wide experiments can be performed appropriate to mare surfaces which constitute more than 50 percent of the lunar Earth-side area. The absence of large features makes simpler the measurement of many physical properties such as gravity and magnetism. The flat terrain will permit wide ranging sampling and data gathering. Since the surface material at this locale is expected to be nearly uniform, infrequent sampling and wide ranging can replace frequent sampling and limited ranging.

Many of the surface measurements taken at this site will yield inferences as to the nature of the lunar interior. Gravity measurements, for example, can indicate the density variations and thus the probable characteristics of subsurface layers. Magnetic measurements will yield information as to the presence of iron-bearing beds which may occur in volcanic flow material of the type suspected to exist under much of the mare surface. Active and passive seismology will also provide a picture of the subsurface structure and differentiation.

D.1.14 Locale 14 — Sea of Moscow

The Sea of Moscow locale is located 130°W, 45°N on the edge of a filled mare basin. Such mares are rare on the lunar farside, and are of great interest for comparison with the numerous mares on the lunar nearside. This locale should be well suited to the study of differences in materials and processes occurring on the nearside and farside of the Moon and should indicate the degree of horizontal differentiation in the Moon.

D.1.15 Locale 15 — Farside

The Farside locale is at 180°W, 0°N, which is an arbitrary location intended to represent the farside. From farside photos, it appears to be a representative site essentially like the Nearside Highlands and definitely not a mare location. The apparent scarcity of farside maria is one of the very insistent lunar problems. At this locale, experiments requiring screening from Earth's influence may be conducted. Passive seismic investigations using natural shock waves as the energy source will be important at this locale. Information concerning the nature of mantle and core may be gained. Experiments to detect differences from the Earth-side will assume a prime role. One of these would be the difference in tidal action of the crust since this may have contributed to nearside crustal melting. The difference of meteoritic influx will also be of interest.

D.1.16 Locale 16 — South Pole

The South Pole locale is located in an area which is typically highlands in character and provides many sun-protected spots which are permanently shaded. These shaded areas are features such as caves, craters, deep rilles, and cracks which may give refuge as ices to any gases which had migrated over the surface. The ices would provide information relative to the history of the lunar atmosphere.

Ices would have considerable value as sources of water, air, and fuel.

The South Pole, being far removed from the large lunar basins, is relatively free from ejecta contributed by basin-forming processes. Thus, there is an opportunity to study the highlands in a relatively unblanketed state as well as to determine the extent of the thinning or disappearance of these blankets.

D.1.17 Locale 17 – Ranger VIII Landing Site

The Ranger VIII Landing Site is located 24.8°E, 2.6°N in the southwestern part of Mare Tranquillitatis, a mare whose slight spectral shift to the blue categorized it as a "blue" mare in contrast to the "red" mare photographed by Ranger VII.

It is a typical mare area whose structural simplicity makes the interpretation of geophysical data less ambiguous. The Ranger VIII photography furnishes a framework of geologic and topographic mapping for planning missions. The study of the Ranger VIII impact will contribute to the knowledge of impact mechanics.

D.1.18 Locale 18 – Straight Wall

Straight Wall, a long fault trending north-northwest, is located on the eastern edge of Mare Nubium at 22°S, 8°W. This is apparently a normal fault with the upthrown side on the east. The maximum relief of the scarp is about 400 m. The trend of the Straight Wall is roughly parallel to a strongly developed set of fractures in this general area. Because the Straight Wall is 120 km in length, it provides an opportunity to find some areas relatively free of slumping where the crustal section has been faulted up from depth, and it may be studied, the section thicknesses measured, and the primordial mare filling exposed to examination.

Because the Straight Wall fault is located in a mare area, it provides an opportunity to follow laterally, for great distances, exposed sections of rock which are likely to be of igneous origin and, therefore, probably widely deposited and clearly bedded. This would provide one of the few instances on the Moon where cohesive bedding may be traced laterally on the surface.

Although the slumped material, which will cover parts of the Straight Wall, will be somewhat of a handicap, it will, conversely, provide an unusual opportunity to study the nature of this category of transportation. There is also the advantage of knowing the origin of the slumped material from having measured the sections where they are exposed.

D.1.19 Locale 19 – Southeast Mare Serenitatis

The Southeast Mare Serenitatis locale is located at approximately 29°E, 22°N on the southeast margin of Mare Serenitatis and adjacent to the Highlands. This area is near the boundary of Mare Serenitatis and Mare Tranquillitatis. It contains the Littrow Rille system which is sub-parallel to the Serenitatis margin and lies in an area of very dark mare material. The rilles cut the mare and upland, although the dark material is restricted to the mare. A low scarp marks the edge of the dark material, and the rilles appear to consist of a string of craters. The flow material seems to be related to the rilles and appears to be younger than the Mare Serenitatis material. The mare material appears to be volcanic flow, and the older flows seem to have higher albedos than the younger flows. This locale is excellent for testing hypotheses concerning the manner of deposition of mare fill material.

D.1.20 Locale 20 – Southern Highlands

The Southern Highlands locale is located in the highland area near the boundary between the hummocky province and the pitted plain province at 27°E, 45°S. Since this may be the primordial lunar surface, for purposes of its investigation, it is advantageous to be as far removed as is practical from blanketing material derived from the formation of the large basins. This locale represents the highlands, one of the two major land forms of the lunar surface. It is highly cratered and the record of its evolution will probably be complicated. The story of the wasting from the higher elevations under the effects of shaking by moonquakes, particle bombardment, and thermal changes will be of great interest. The corollary movement to and accumulation in the low areas will also be investigated here.

D.1.21 Locale 21 — Grimaldi, Astronomical Location

The Astronomical Location is near the west limb in the southern part of Grimaldi at approximately 68°W, 7°S. Grimaldi, a crater 150 km in diameter, is filled with mare material. The site has been selected to furnish visibility of the southern celestial hemisphere as well as visibility of the planets. The limb location is intended to reduce Earth-shine interference. The flat surface of the floor of Grimaldi will furnish unimpeded telescopic viewing from the zenith to the horizon.

The site will have potential other than astronomical in that another mare material surface can be sampled and studied.

This locale provides the opportunity to examine the structure, age, composition, and origin of a very dark mare material which is connected to Oceanus Procellarum only by what appears to be narrow and shallow channels. Thus, the question is raised as to source of supply: Did the material rise from within the Moon or was it overflow from Oceanus Procellarum?

D.1.22 Locale 26 — Moltke B*

The Moltke B locale is at the southwest edge of Mare Tranquillitatis near a promontory of the Central Highlands. The crater is cut by a rille which branches near the center of the crater and cuts the east wall in two places. The rille extends for 40 km in a northwest-southeast direction and appears to be a part of the general pattern of rilles in the east and north-central area of the Moon.

This locale is a typical contrast area between mare and highland material. Erosional processes are indicated by slumping of highland material. Lunar domes are found about 12 km southeast of Moltke B. These are possibly of volcanic origin.

*There are no locales defined for 22, 23, 24, and 25.

This locale is a favorable place to obtain samples of materials representative of large areas of the Moon. The rilles and breaches in the crater rim permit study of the stratigraphy of exposed subsurface structures. Erosional and transport processes appear to have been active here. Exposed strata of different ages may show effects of various periods of radiation exposure. It is expected that rille and crater-wall samples will provide evidence of past magnetic fields.

D.1.23 Locale 27 — North Pole

The North Pole locale offers the same opportunities for the study of frozen volatile materials that are expected at the South Pole. However, the North Pole is much nearer to maria of major size than is the opposite pole, and it is possible that debris from the formation of giant basins may be lodged in permanently shaded crevasses in the north polar region. Therefore, the debris may have been preserved more nearly in the original state than that exposed to solar cycling elsewhere on the lunar surface.

D.1.24 Locale 28 — Mare Nubium

The Mare Nubium locale is located at the eastern edge of this relatively smooth dark mare at approximately 6°W, 15°S. It is of interest because of its proximity to the highlands and because of the contrast of the low density of cratering of its surface as related to the highly cratered surface of the floor of nearby Alphonsus.

The characteristics of a young mare surface will be studied, with emphasis here on suspected lava depressions and collapse features. Crater density and mare rock composition, as well as the potential of drained lava tubes and crevasses for use in housing and protecting personnel, may be explored.

D.1.25 Locale 29 — Copernicus

The Copernicus locale is within the crater Copernicus at 19°W, 9°N. Copernicus is a large, young crater, 90 km in diameter. It has been extensively studied because it is typical of rayed craters and has an extensive series of secondary or satellite craters. The crater floor and rim contain many features worthy of investigation, including central peaks, floor deposits, inner-wall exposure of a thick rock section, shock products, and impact-produced structures.

D.2 PATHS

D.2.1 Paths a and b – Mare Imbrium and Mare Imbrium to Mare Serenitatis

These paths together constitute a survey from the center of Mare Imbrium to the center of Mare Serenitatis. The purpose is to provide a geophysical cross section of these maria and the benches related to each. The boundary area between the maria is of special interest with regards to relationships of flows and ejecta material. The 900-km length will permit seismic exploration to a depth of approximately 200 km, thus giving data concerning differentiation, presence of a crust, and the nature of deep structural relationships. A 300-m core-drill hole along this path will provide information supplementary to the geophysical data. Surface and subsurface gelogical investiation along the path will also augment the understanding of these two large basins and their history.

Studies along these two paths should result in an understanding of the maria material, its composition and structure, and depth; and knowledge as to the shape of the underlying basin floors and of the benches at the margins of the maria along with the location and shape of slip planes at the inner edge of the benches.

D.2.2 Path c – Palus Putredinis to Mare Vaporum

The Palus Putredinis to Mare Vaporum path starts at Path b and extends south to Hyginus crater.

This path continues the overall study of the Imbrium basin. The emphasis here is on the Imbrian bench, its floor, and its relation to the steep inward facing scarp of the Apennine mountains. Involved are the large fault at the scarp and the volcanic rilles related to it. Opportunity is provided to study thick sections exposed on the scarp face.

Passage through a pass in the Apennine mountains seems feasible from examination of presently available lunar charts, and enables study of the gentle southeastern slope of the Apennine mountains. This slope is of great interest because of its structure induced by basin formation and involving the "Imbrian sculpture." Along this path lies the crater Canon which has excavated this slope to great depth. The south portion of the path involves the shallow basin filling the Mare Vaporum, small craters of various ages, mare surface structures, and the rille and crater chain systems. At the south end is the crater and rille of Hyginus which is of interest because of volcanism, exposure of considerable section, and possible bringing up from depth of xenoliths by volcanic geysering action.

D.2.3 Path d

The Mare Vaporum to Mare Tranquillitatis path extends from Hyginus crater east to a point (21°E, 7°N) in Tranquillitatis.

This segment crosses shallow mare filling, a considerable rille system (Ariadaeus), and explores the "shoreline" of Mare Tranquillitatis, as well as the rim of the large crater, Julius Caesar.

D.2.4 Path e

The Sinus Medii path extends from Hyginus crater south to the north rim of Ptolemaeus and follows the Sinus Medii shoreline of the highlands so that both can be explored. Several stratigraphic units important to deciphering lunar history are displayed here for exploration. A300-m core drill hole and geophysical work plus geological investigation work together to explore this subearth segment.

D.2.5 Path f

The Ptolemaeus to Alphonsus path extends from the north rim of Ptolemaeus to a point on the eastern floor of Alphonsus.

Originating on the north rim of Ptolemaeus, this traverse crosses Alphonsus to the east edge of its floor. Exploration of old highlands crater rims and floors with associated volcanic phenomena in this area are expected to furnish important data concerning the primordial lunar surface and early history.

D.2.6 Path g

The Central Highlands path extends from Alphonsus east to a point in the highlands (17°S, 9°E), and explores the highlands area geophysically and geologically. The main interest is in establishing early history, erosional processes, subsurface structure, age, and composition.

D.2.7 Path h

The Mare Nubium to Straight Wall path extends from Alphonsus through Mare Nubium and south along Straight Wall to locale 18 – westward 150 km to a point at 12°W, 15°S. It is of major interest to compare materials and conditions on the relatively recent Mare Nubium with older maria such as Mare Imbrium.

D.2.8 Path i

The Southern Highlands path is oriented east-west, centered at 45°S, 21°E. It tends from Janssen on the east to Maurolycus on the west.

This path explores the highlands area, which includes the typically hummocky eastern zone near Janssen and also the area to the west near Maurolycus which typically contains flat, pitted topography.

This area is far enough removed from the mare basins to be relatively free from ejecta contributions resulting from their formation. There will be considerable value in comparing the surface composition of this area with farside and mare margin areas.

D.2.9 Path j

In Programs A, B, and C, the Marius Hills path extends from Marius Hills to Aristarchus, and then northwest to Heredotus T.

Interest in this area is in its predominantly volcanic nature. A geophysical traverse across Oceanus Procellarum connects the Marius Hills volcanic field with the Aristarchus volcanic field. Investigations involving Schroters Valley as a long lava channel, Aristarchus crater as a site of recent red spots, and young volcanoes in addition to flows exhibiting distinctive coloration will be pursued here.

In Programs A', B', and C', the Marius Hills path extends from Marius Hills southeastward across Oceanus Procellarum. The main interest is in investigating their volcanic nature and origin.

D.2.10 Path k

The Northern Farside path starts at 150°E, 28°N and crosses the Sea of Moscow, one of the few maria to be found on the lunar farside. It is important to compare this feature with corresponding ones on the nearside so as to determine whether there are significant differences in structure and composition of the two sides of the Moon.

D.2.11 Path l

The Central Farside path extends north from 180°W, 0°N. The path covers an area typical of the remote farside. Investigation of the primordial surface of the Moon is the main objective.

D.2.12 Path m

Mare Orientale path crosses the Mare Oriental basin in an east-west direction, centered at 95°W, 18°S.

This path explores a part cross section of the unfilled basin. A small amount of mare filling appears in separated areas near the center and in the rim areas of the basin. The uncovered condition of this basin makes it attractive as a location to investigate the evolution of basin formation and filling.

D.2.13 Path n

The Copernicus path extends from Copernicus to the dark halo crater field of Locale 5. Investigation of this crater for data on the mechanics of impact, the nature of secondary impact, shock products, and structure will be important in clarifying the story of lunar processes of erosion, transport, and deposition, ray patterns, and the nature of crater formation in general.

D.2.14 Path o

The Mare Humorum path extends southwestward from rim of Gassendi to a point in the uplands at 52°W, 25°S.

Interest here is in the evidence of folding in a mare surface older than the one in the central Mare Humorum area. In addition, the rim of the basin will be traversed for study of basin history and products of its formation. This path will furnish information for the thermal and tectonic history of the Moon.

D.2.15 Path p

The Mare Smythii path extends in an east-west direction across Mare Smythii, centering at 100°E, 0°N.

This path explores the eastern limb area on the farside near the equator. The area appears to be typical mare, judging from recent orbiter photography. This locality for limb experiments also furnishes balanced regional coverage of the lunar surface. This limb path involves an area of investigation intermediate between nearside and farside for the study of focusing effects on radiation as well as on solid-body flux and magnetic effects.

D.2.16 Path q

The Mare Crisium path extends across the southeastern mare to the upland boundary. The direction is west-northwest to east-southeast and the location is centered at 63°E, 12°N.

This path permits exploration of the Auzout volcanic hills as well as the rim of the mare basin. The Crisium basin is of interest because it is a young basin among older basins in the eastern half of the Moon.

D.2.17 Path r

The Southeast Serenitatis path extends east-west across the mare uplands boundary at 30°E, 22°N.

This path traverses an area of young, dark flow material associated with the margin of Mare Serenitatis. Also of interest is the older bench material. Several indications of internal reheating will contribute to understanding lunar volcanism and thermal history.

D.2.18 Path s

The Capella M path extends in a northwest-southeast direction, centering at the crater Capella M (37°E, 4°S).

It covers a highland area which has been markedly deformed and subjected to volcanism as well as receiving material from the formation of the nearby Mare Tranquillitatis, Fecunditatis, and Nectaris. This path extends to Censorius C and Capella M, which are old, faulted, and deformed craters.

Information about volcanism, transportation, and tectonism will be available for investigation here, in addition to several important segments of the lunar stratigraphic column.

D.2.19 Path t

The North Pole path extends along the 10°W, 170°E meridians, centering at the north pole.

This path is intended to yield data for polar accumulation of gases in permanently shaded areas as well as to complete the balanced overall exploration of the Moon on a regional basis.

D.2.20 Path u

This South Pole path originates at south pole and extends northward along the 15°W meridian.

This path is intended to sample the gases which may have migrated to the poles and condensed as ice in the permanently shaded areas. In addition, the path investigates the geological and geophysical nature of highlands far removed from sources of ejecta or sediments contributed by formation of the large basins.

D.3 REGIONS

D.3.1 Region I — Palus Putredinis

This region presents the opportunity to investigate the bench and rim of a major lunar basin. It is believed by many lunar geologists that the major mare areas represent filled basins. These basins, probably of impact origin, range up to 1000 km in diameter and are surrounded beyond this by concentric ridges and valleys. The several basins (Imbrium, Serenitatis, Tranquillitatis, Nectaris, Humorum, Crisium) constitute about one half of the area of the Earth-side hemisphere. The bench, which extends from Archimedes to the foot of the Apennine Mountains, appears to be thinly covered by mare material. The area between the bench and the foot of the mountains is probably the location of a fault scarp. Within this zone arises Hadley's Rille, the "lava channel" which starts in a "cobra head" and descends to Palus Putredinis. This area contains several important volcanic and tectonic features. In addition, over 2000 m of lunar crust is exposed here in the steep inner face of the Apennine Mountains.

D.3.2 Region II — Copernicus

The Copernicus region is an excellent area for the study of an impact crater, its mechanics of formation and structure, the shock products, and the nature of the central peaks, rim, floor and rays, as well as satellite craters.

Copernicus is a young-rayed crater which has been studied extensively. Since it is believed that many lunar craters are of similar origin, a careful study of this crater will have application to other areas of the Moon.

The area of the region covers a strip from the center radially outward, to include the outer rim.

D.3.3 Region III — Southern Highlands

The Southern Highlands area of the lunar surface is important for several reasons. One reason is its apparent great age and the possibility that it is the primordial lunar surface. Another reason is its highly cratered surface with a resulting complex history of erosion and deposit. Being far removed from the influence of ejecta blanketing by basin-forming events will make this region somewhat simpler to study.

D.3.4 Region IV — Aristarchus

This region contains a wide variety of volcanic features such as volcanic cones and craters, lava channels, young cones and flows, and areas of present visible activity. Investigation here should answer questions concerning crustal composition, volcanic processes, and differentiation, and should clarify the thermal history of the Moon.

The crater Aristarchus and its recently observed red spots and the long rille of Schroters Valley are examples of objects of great interest in the study of lunar volcanic history. This area appears to be truly a volcanic province.

Appendix E
LUNAR EXPLORATION PROGRAM SUMMARIES

This Appendix presents summaries of 25 of the candidate lunar exploration programs that were generated during the initial planning phase of the study. These programs were generated using 13 equipment evolutions and 5 different scientific programs. Thus, these exploration programs represent a broad spectrum of approaches to post-Apollo lunar exploration. Each summary presents the following program data:

- General Description
- Cost and Schedule Summary
- Post-Apollo Mission Summary
- Equipment Usage and Cost Summary
- Scientific Program Operational Summary

The first 11 pages of this Appendix contain a brief review of the scientific programs together with a lunar reference map indicating the exploration pattern and locations to be visited in a particular program. Normally, these are given with each program summary but, for the purposes of this report, the scientific program descriptions are brought together at the front of this Appendix to avoid repetition. Following is an index of the exploration program summaries:

LUNAR SCIENTIFIC PROGRAM A

During its early and intermediate phases, Program A is essentially a plan for geoscientific exploration of the moon, with emphasis toward the end on establishment of major facilities for radio and optical astronomy. The total mass of scientific equipment is 153,000 kg; the masses of the geoscientific and astronomical equipment are about equal.

Program A uses the path approach for surface exploration of the moon, which involves 20 paths with a total path length of 8,500 km. In addition, there are missions to eight widely separated locales, each covering an exploration area of about 100 sq km.

The subsurface structure of the moon is probed to depths of 200 km by means of active seismic reflection and refraction techniques. Experiments in active seismology require detonations or surface impacts with energies ranging from the equivalent of 0.5 to 6,000 kg of TNT. The total amount of explosives used in Program A is equivalent to 156,000 kg of TNT. Core-drill samples from a depth of 300 m are acquired at five locales.

The astronomical facility comprises two types of radio telescopes, three optical telescopes, and one x-ray telescope. The radio telescopes operate at relatively low frequencies (0.3 to 1.0 MHz) that are not observable with earth-based radio telescopes and at relatively short wavelengths (in the millimeter and submillimeter ranges) that are troublesome to earth-based radio telescopes because of atmospheric interference. The apertures of the optical telescopes are 1 and 2.5 m, and they are designed primarily for operation at wavelengths in the far ultraviolet region, which is excluded from observation by earth-based telescopes because of atmospheric absorption. The x-ray telescope uses grazing-incidence double-reflection optics with an aperture diameter of 1 m and an angular resolution of 1 arcsec.

The total number of distinct scientific experiments, considering all scientific disciplines, is 198, and a total of 54,000 manhours is allocated for the performance of those experiments.

LUNAR SCIENTIFIC PROGRAM B

During its early and intermediate phases, Program B emphasizes geoscientific exploration of the moon. Toward the end of the Program, emphasis shifts to the establishment of major facilities for optical and radio astronomy but not to the degree of that in Program A. The total mass of scientific equipment delivered to the moon amounts to 80,000 kg, of which 44,000 kg is for geoscientific objectives and 32,000 kg is assigned to astronomy. The remainder is distributed over activities in physics, biology, and applied science.

Program B uses the path approach for surface exploration of the moon, which involves 11 paths with a total path length of 4,800 km. There are missions to seven widely separated locales, each covering an exploration area of 100 sq km.

Active seismic reflection and refraction techniques are used to probe the lunar subsurface structure to depths of 200 km. Explosive charges equivalent to 0.5 to 6,000 kg of TNT are used. The total amount of explosives used in Program B is equivalent to 94,000 kg of TNT. Core-drill samples from a depth of 300 m are acquired at three locales.

The astronomical facility comprises two types of radio telescopes, two optical telescopes, and one x-ray telescope. The radio telescopes operate at relatively low frequencies (0.3 to 1.0 MHz) that are below the range observable with earth-based radio telescopes and at relatively short wavelengths (in the millimeter and submillimeter ranges) that are troublesome to earth-based radio telescopes because of atmospheric interference. The apertures of the two optical telescopes are 1 and 2 m, and they are designed primarily for operation in the far ultraviolet region, which is excluded from observation by earth-based telescopes because of atmospheric absorption. The x-ray telescope uses grazing-incidence double-reflection optics with an aperture diameter of 1 m and an angular resolution of 1 arcsec.

Program B comprises 177 distinct scientific experiments, and a total of 30,000 manhours is allotted to the performance of those experiments.

LUNAR SCIENTIFIC PROGRAM B'

Program B' is the counterpart of Program B with regard to objectives and scope. The early and intermediate phases of Program B' emphasize geoscientific exploration of the moon, while the establishment of major facilities for radio and optical astronomy of less ambitious extent than in Program A is reserved for the end of the Program. The total mass of scientific equipment delivered to the moon is 73,000 kg, slightly more than half of which is assigned to lunar geoscientific activities; the bulk of the remainder is for astronomical purposes.

Program B' uses the locale approach in exploration of the lunar surface. Missions to 15 widely separated locales are required. Only three paths representing a total path length of 600 km are specified. However, extensive exploration of two regions covering a total area of 1,800 sq km is prescribed. Regional exploration involves locale and path-type missions in addition to those explicitly specified in the Program.

The locale approach uses active seismology much less extensively than does the path approach in probing the lunar subsurface structure simply because the path approach provides more favorable opportunities for the application of long-range seismic techniques. The largest explosive charges used in Program B' are equivalent to 2,500 kg of TNT, and the total amount of explosives is equivalent to 18,000 kg of TNT. Core-drill samples from a depth of 300 m are acquired at three locales.

The portion of Program B' concerning lunar-based astronomy is precisely equivalent to that of Program B. Two kinds of radio telescopes, two optical telescopes, and one x-ray telescope are established on the moon toward the end of the Program. The radio telescopes operate at frequencies below and above the range most accessible to earth-based radio telescopes. The apertures of the optical telescopes are 1 and 2 m, and they are designed primarily for operation in the far ultraviolet region, which is excluded from earth-based telescopes by atmospheric absorption. The x-ray telescope uses grazing-incidence double-reflecting optics with an aperture diameter of 1 m and an angular resolution of 1 arcsec.

Program B' comprises 165 distinct scientific experiments for which a total of 30,000 manhours has been allotted.

LUNAR SCIENTIFIC PROGRAM C

The effort of Program C is substantially devoted to lunar geoscientific goals throughout all phases of the Program. No attempt is made to establish major astronomical facilities in the manner undertaken in Programs A and B. The total mass of scientific equipment delivered to the moon is 31,000 kg, of which only 2,000 kg is assigned to objectives other than lunar geoscience.

Program C uses the path approach for surface exploration of the moon, which involves six paths with a total path length of 2,400 km. There are missions to six widely separated locales, each covering an exploration area of about 100 sq km.

Active seismic reflection and refraction techniques are used to probe the lunar subsurface structure to a depth of 200 km. Explosive charges equivalent to 0.5 to 6,000 kg of TNT are used. The total amount of explosives used in Program C is equivalent to 42,000 kg of TNT. Core-drill samples from a depth of 300 m are acquired at two locales.

The total number of distinct scientific experiments undertaken in Program C is 113, about half the number used in Program A. The distribution and replication of experiments are reduced in Program C to the minimum level estimated to be capable of yielding acceptable answers to the 15 basic questions about the moon proposed by the 1965 Conference of the Space Science Board at Woods Hole, Mass. A total of 7,000 manhours is allocated to the performance of the experiments.

LUNAR SCIENTIFIC PROGRAM C'

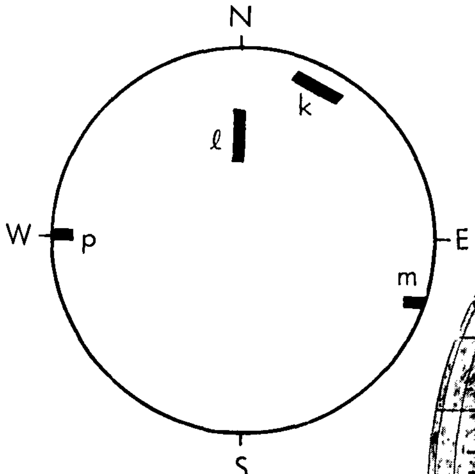
Program C' is the counterpart of Program C with regard to objectives and scope. The effort is substantially devoted to lunar geoscientific goals throughout all phases of the Program. No attempt is made to establish major astronomical facilities. The total mass of scientific equipment delivered to the moon is 29,000 kg, of which less than 10 percent is assigned to objectives other than lunar geoscience.

Program C' uses the locale approach for surface exploration of the moon, and involves 13 locales, one region, and two paths. The combined locale and regional explorations represent about 2,800 sq km, while the total path length is 200 km.

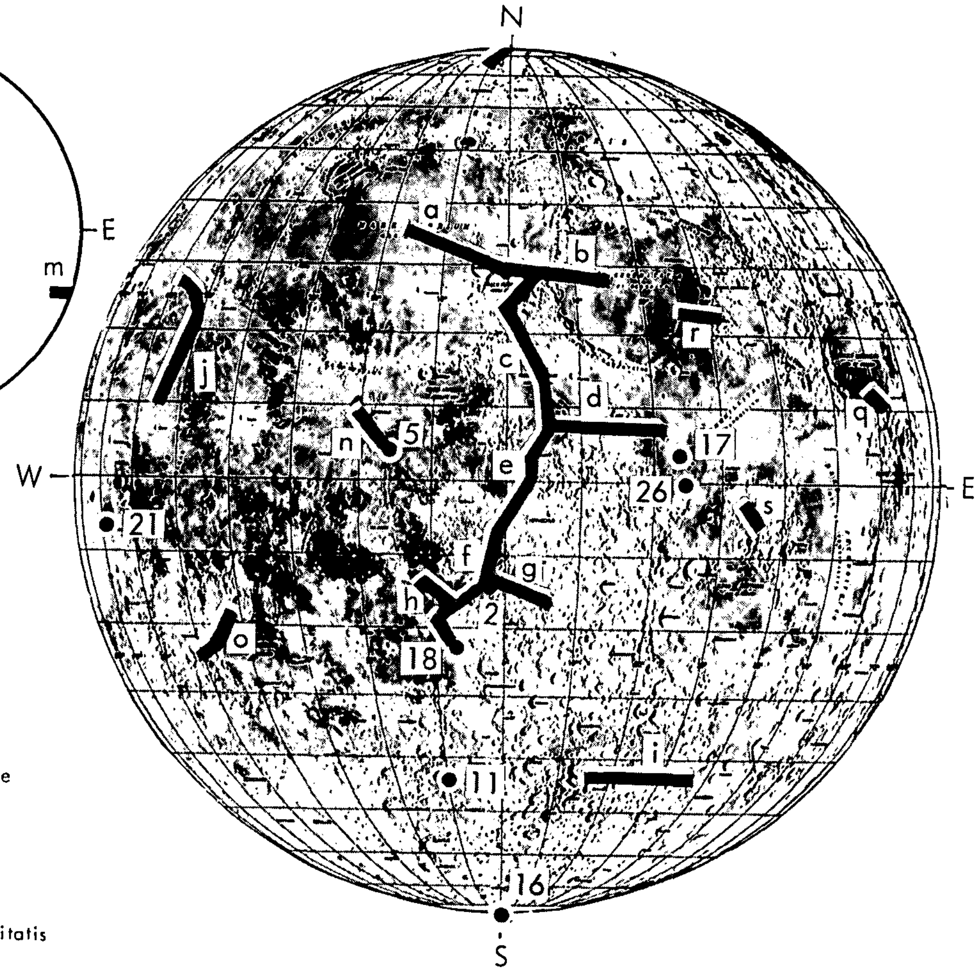
Active seismic techniques are used to a much more limited extent than in programs using the path approach. The total requirement for explosives in Program C' is equivalent to 2,900 kg of TNT, and the largest single shot involves an energy equivalent of 1,300 kg of TNT. Core-drill samples from a depth of 300 m are acquired at two locales.

There are 121 distinct experiments in Program C'. The scope of the scientific effort is estimated to be about the minimum level capable of yielding acceptable answers to the 15 basic questions about the moon proposed by the 1965 Conference of the Space Science Board at Woods Hole, Mass. A total of 9,000 manhours is allocated to the performance of scientific experiments.

LUNAR SURFACE EXPLORATION PATTERN
(Scientific Program A)



FARSIDE



Legend:

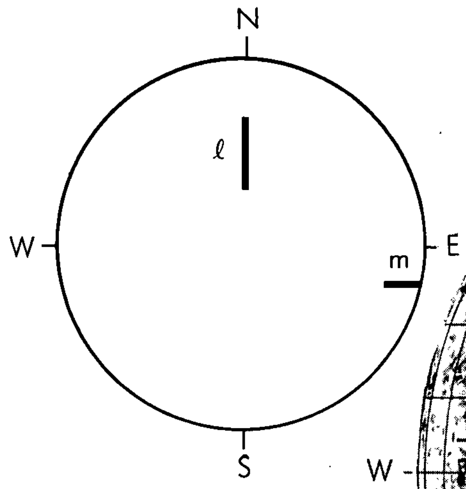
Locales

2 Alphonsus
5 Dark Halo Craters Southeast of Copernicus
11 Tycho
16 South Pole
17 Ranger VIII Landing Site
18 Straight Wall
21 Grimaldi, Astronomical Location
26 Moltke B

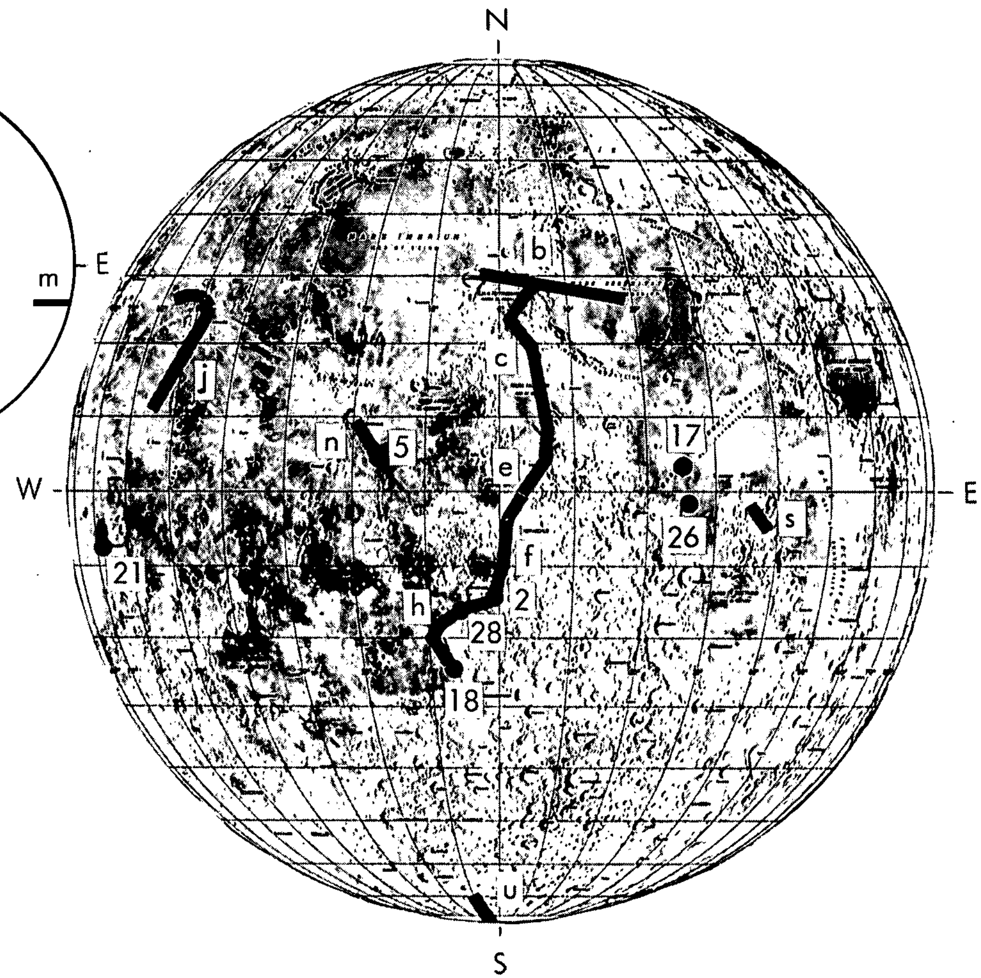
Paths

a Mare Imbrium
b Mare Imbrium – Mare Serenitatis
c Palus Putredinis – Mare Vaporum
d Mare Vaporum – Mare Tranquillitatis
e Sinus Medii
f Ptolemaeus – Alphonsus
g Central Highlands
h Mare Nubium – Straight Wall
i Southern Highlands
j Marius Hills – Aristarchus
k Northern Farside
ℓ Central Farside
m Mare Orientale
n Copernicus
o Mare Humorum
p Mare Smythii
q Mare Crisium
r Southeast Serenitatis
s Capella M
t North Pole

LUNAR SURFACE EXPLORATION PATTERN
(Scientific Program B)



FARSIDE



Legend:

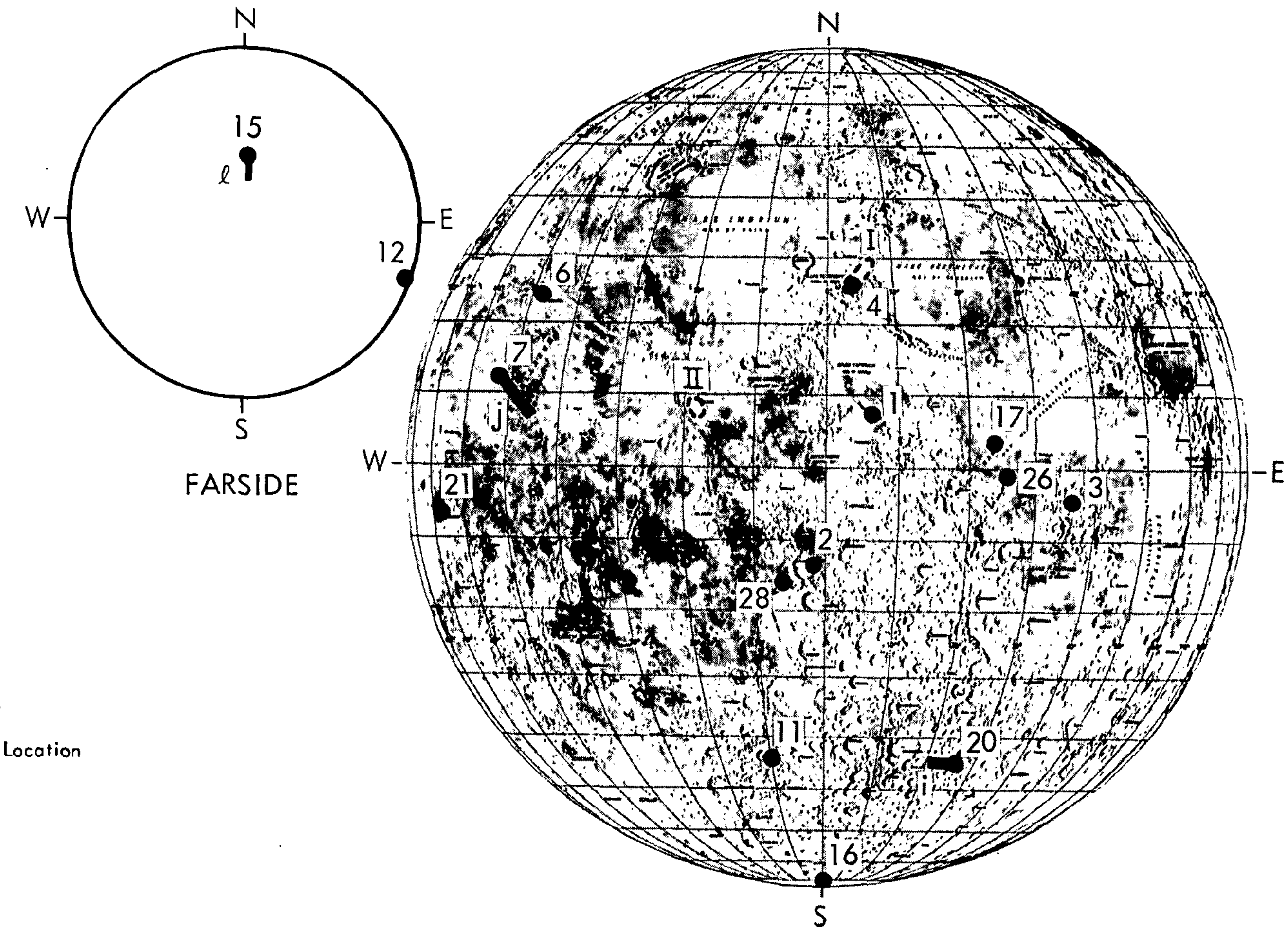
Locales

2 Alphonsus
5 Dark Halo Craters Southeast of Copernicus
17 Ranger VIII Landing Site
18 Straight Wall
21 Grimaldi, Astronomical Location
26 Moltke B
23 Mare Nubium

Paths

b Mare Imbrium – Mare Serenitatis
c Palus Putredinis – Mare Vaporum
e Sinus Medii
f Ptolemaeus – Alphonsus
h Mare Nubium – Straight Wall
j Marius Hills
ℓ Central Farside
m Mare Orientale
n Copernicus
s Capella M
u South Pole

LUNAR SURFACE EXPLORATION PATTERN
(Scientific Program B')



Legend:

Locales

1 Hyginus Rille
2 Alphonsus
3 Capella M
4 Hadley's Rille
6 Aristarchus
7 Marius Hills
11 Tycho
12 Mare Orientale
15 Farside
16 South Pole
17 Ranger VIII Landing Site
20 Southern Highlands
21 Grimaldi, Astronomical Location
26 Moltke B
28 Mare Nubium

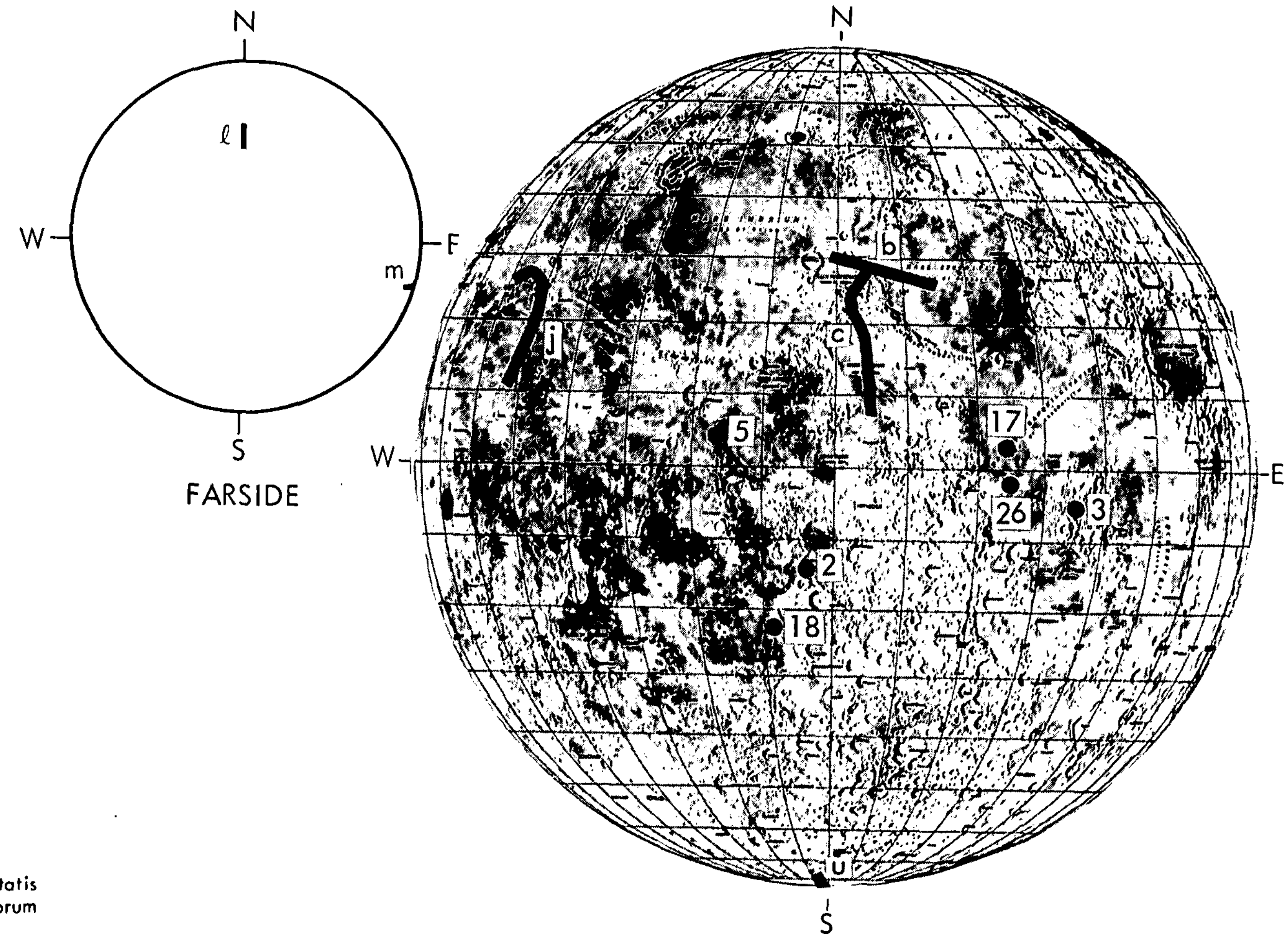
Paths

i Southern Highlands
j Marius Hills
ℓ Central Farside

Regions

I Palus Putredinis
II Copernicus

LUNAR SURFACE EXPLORATION PATTERN
(Scientific Program C)



Legend:

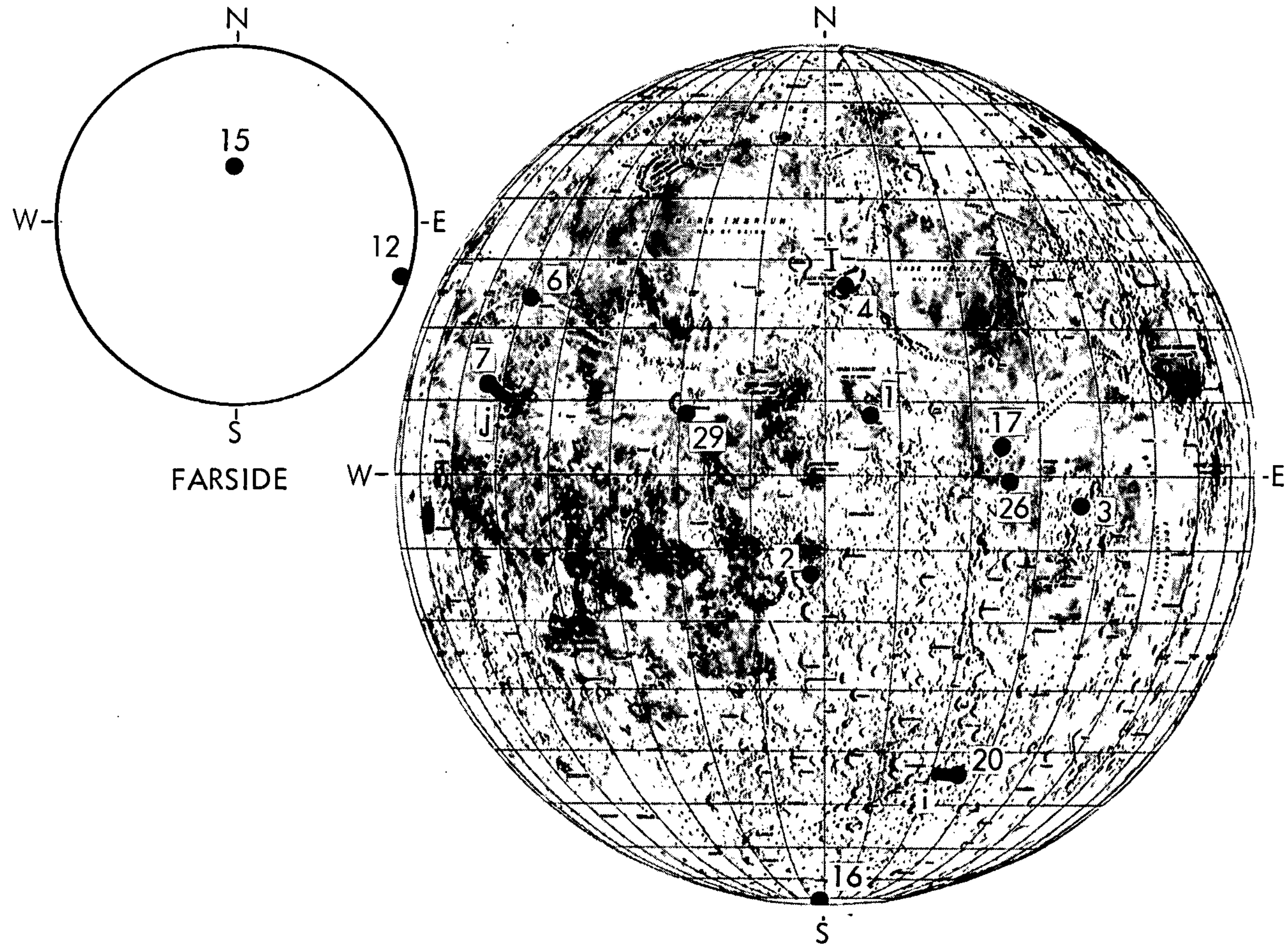
Locales

2 Alphonsus
3 Capella M
5 Dark Halo Craters Southeast of Copernicus
17 Ranger VIII Landing Site
18 Straight Wall
26 Moltke B

Paths

b Mare Imbrium – Mare Serenitatis
c Palus Putredinis – Mare Vaporum
j Marius Hills
ℓ Central Farside
m Mare Orientale
u South Pole

LUNAR SURFACE EXPLORATION PATTERN
(Scientific Program C')



Legend:

Locales

1 Hyginus Rille
2 Alphonsus
3 Capella M
4 Hadley's Rille
6 Aristarchus
7 Marius Hills
12 Mare Orientale
15 Farside
16 South Pole
17 Ranger VIII Landing Site
20 Southern Highlands
26 Moltke B
29 Copernicus

Paths

i Southern Highlands
j Marius Hills

Regions

I Palus Putredinis

SUMMARY OF LUNAR EXPLORATION PROGRAM A-IIIc

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the large scientific program (Scientific Program A) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step is to an uprated Saturn (125% Saturn V) and a lunar orbit rendezvous logistics LM/Truck. A third evolutionary step introduces the 125% Saturn V direct logistics landing vehicle (LLV) at the earliest practicable date.

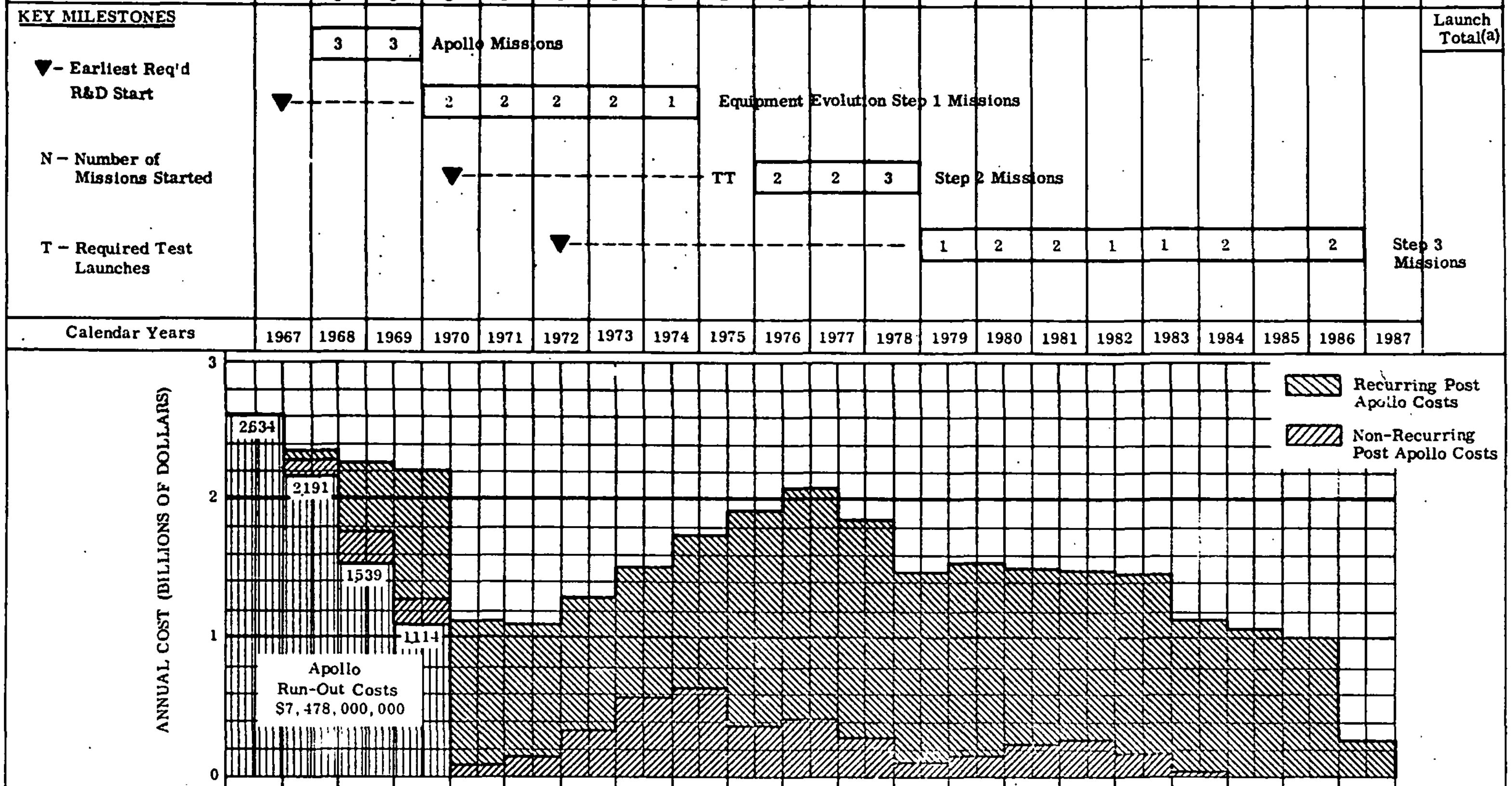
Eight locales are to be visited in the preferred order 17, 26, 11, 21, 16, 5, 2, and 18. Twenty different paths are to be explored in preferred order. Locale visits and path explorations can be freely intermixed.

Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. Annual funding available was assumed to be about 1 to 2 billion dollars. Transportation-system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

As developed within these constraints, exploration program A-IIIc introduces the 125% Saturn and the LM/Truck in 1967 and the LLV in 1979. The program is completed with a large astronomy mission to Grimaldi, beginning in late 1984 and requiring 17 launches. The total number of Saturn launches is 89, including 6 Apollo missions and 2 test launches for the Saturn uprating. The total post-Apollo cost is 25.5 billion dollars spread over a period of 20 years. The program indicates a cost of about 1.5 billion dollars for introduction of the 125% Saturn, the LM/Truck, and associated equipment. Funds must be committed in 1970. A further commitment of the order of 1 billion dollars for introduction of the LLV and related equipment must be made in about 1972.

COST AND SCHEDULE SUMMARY

LAUNCH RATE	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
		3	3	3	3	4	3	3	2	4	4	7	5	8	7	5	4	12		9		89



		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS		TOTAL (MILLIONS)	5	170	731	1090	1132	1125	1285	1564	1742	1865	2086	1828	1458	1542	1485	1482	1430	1150	1076	1008	236	25,490
	Non-Recur	R&D	5	92	233	134	63	149	310	560	612	362	395	256	85	151	221	265	177	20				4090
		C OF F		1	1		1	3	20	23	3	12	10	6	9	7								96
	Recurring	PROCUREMENT		77	486	862	865	786	796	766	988	1260	1397	1160	1062	1061	928	966	962	795	903	649	3	16,777
		OPERATIONS			11	94	203	187	159	215	139	231	284	406	302	323	336	251	291	335	173	359	233	4532

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

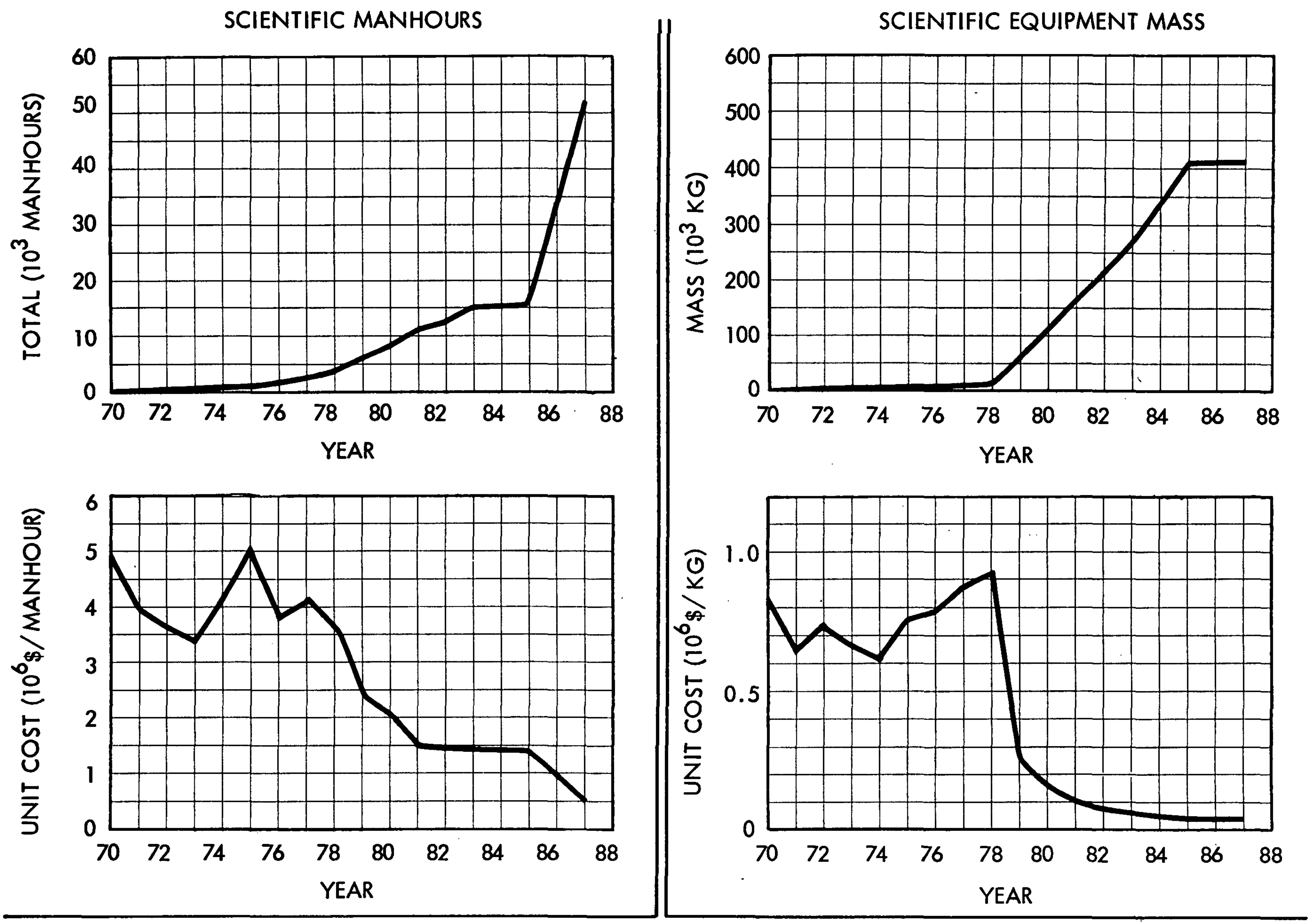
Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-02	1	–	9	636	212	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	15	729	180	4716	575	381	150
9	71A	Moltke B	402-10011-01	2	26	16	733	180	4719	575	378	150
10	71B	Orbiter 2	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
11	72A	Tycho	402-10011-03	2	11	16	780	197	4173	482	920	150
12	72B	Grimaldi, Astronomical Location	402-10011-03	2	21	16	747	190	4221	581	855	90
13	73B	Orbiter 3	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
14	73B	South Pole	402-10011-03	2	16	18	837	213	4165	458	973	150
15	74B	Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	3664	3674	–
16	76A	Capella M	503-10036-01	2	s	10	678	204	4592	623	2708	300
17	76B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-10036-01	2	n – 5	27	1937	809	5225	1235	2075	300
18	77A	Southeast Serenitatis	503-10036-01	2	r	10	667	199	4572	602	2728	300
19	77B	Mare Crisium	503-10036-01	2	q	9	647	189	4413	443	2887	300
20	78A	Mare Humorum	503-10036-01	2	o	15	1085	310	4607	637	2693	600
21	78A	North Pole	503-10036-01	2	t	9	647	189	4413	443	2887	300
22	78B	Mare Smythii	503-10016-01	3	p	27	1948	544	6936	593	7664	1200
23	79A	M Imbr, M Imbr to M Seren, N half P Putr to M Vapor	503-20191-01	5	a,b,N/2 c	105	7582	2372	62,608	52,452	2592	3900
24	80A	Central Farside	503-20201-01	4	ℓ	48	3470	1216	48,900	39,976	0	1200
25	80B	Marius Hills to Aristarchus	503-20222-01	4	j	41	2949	998	37,499	19,331	11,401	1200
26	81A	Ptol to Alphon, C High, M Nub to St Wall – Alphon. St Wall	503-20231-01	3	f,g,h – 2,18	65	4636	2192	26,822	8539	5778	2300
27	81B	*Mare Orientale*	503-20251-01	4	*m*	36	2600	1213	48,900	39,964	0	1200
28	82B	S half P Putr to M Vapor, M Vapor to M Tranq, Si Medii	503-20262-01	5	S/2c,d,e	73	5226	1695	61,949	52,845	3251	2400
29	83A	Southern Highlands	503-20251-01	4	i	36	2597	1211	49,148	39,950	0	1200
30	84A	Northern Farside	503-20222-01	4	k	34	2429	748	37,209	19,094	11,691	1200
31	84B	Grimaldi, Astronomical Location	406-20131-01	8	21	822	118,432	37,466	112,131	128,828	0	60
32	86A	Resupply Launches to Grimaldi, Astronomical Location	406-20131-02	1	21	0	0	0	0	0	0	0
32	86B	Resupply Launches to Grimaldi, Astronomical Location	406-20131-03	8	21	0	0	0	0	0	16,186	0
		Total				1493	164,128	53,266	562,538	417,181	81,722	18,650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/74B	13	2	–	–	2100	270	2370
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	72A	76A/86B	65	7	570	42	6630	1339	8581
	Subtotal					570	42	8730	1609	10,951
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/74B	13	2	–	–	1206	286	1492
1311-01/1321-02	CSM – LOR – Three-Man	–	76A/78B	8	1	–	–	740	175	915
1311-02/1321-04	CSM – LOR – Three-Man	73B	76A/86B	24	3	76	–	2148	513	2737
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/74B	6	1	32	–	348	89	469
1332-02/1342-01	LM Taxi – Three-Man	72B	76A/86B	24	3	246	–	1410	337	1993
1351-02	LM Truck	72A	76A/78B	8	1	99	–	179	74	352
1423-02/1433-02	Logistic Braking and Landing Stages	74B	79A/86B	33	4	599	24	685	126	1434
	Subtotal					1052	24	6716	1600	9392
	Mission Equipment									
2121-01	Orbit-Launched Probe	68B	70A/73B	7	1	58	–	26	2	86
2132-02	Surface-Launched Probe	75B	79A/84A	20	2	38	–	46	4	88
2222-02	Orbiter Rack	67B	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74B	6/7(a)	1	216	–	318	92	626
2322-08	Shelter – Three-Man	79B	84B/84B	2	1	360	–	112	16	488
2421-01	LSSM	67B	70B/73B	7	1	58	2	39	4	103
2423-01	LRV – Cabin – Three-Man	70A	76A/78B	7	1	360	2	130	10	502
2423-03	LRV – Three-Man – 90 Days	72B	79A/84B	9	1	421	2	200	15	638
2432-04	Trailer – Multipurpose	75B	78B/–	1	1	44	–	12	1	57
2433-04	Trailer – Large Multipurpose	76A	79A/84B	9	1	52	3	84	2	141
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2521-02	LFV – Return to Orbit	75A	79A/83A	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	78A	84B/–	1	1	136	20	28	–	184
	Subtotal					1854	29	1023	149	3055
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	75B	79A/83A	5	1	11	–	11	–	22
3223-01	15-m Radio Telescope	80B	84B/–	1	1	4	–	4	–	8
3224-02	Radio Telescope – Mills Cross	79A	84B/–	1	1	30	–	4	1	35
3231-01	X-Ray Telescope	77B	84B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	70A	74B/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78B	84B/–	1	1	152	–	25	1	178
3243-01	2.5-m Optical Telescope	77B	84B/	1	1	227	–	35	1	263
	Subtotal					492	–	96	5	593
	Total					3968	95	16,565	3363	23,991

(a)One 1351-03 used to deliver 1-m telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM A-IVb

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the large scientific program (Scientific Program A) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step is to an uprated Saturn (125% Saturn V) and a direct logistics landing vehicle (LLV), which are used for the remainder of the program.

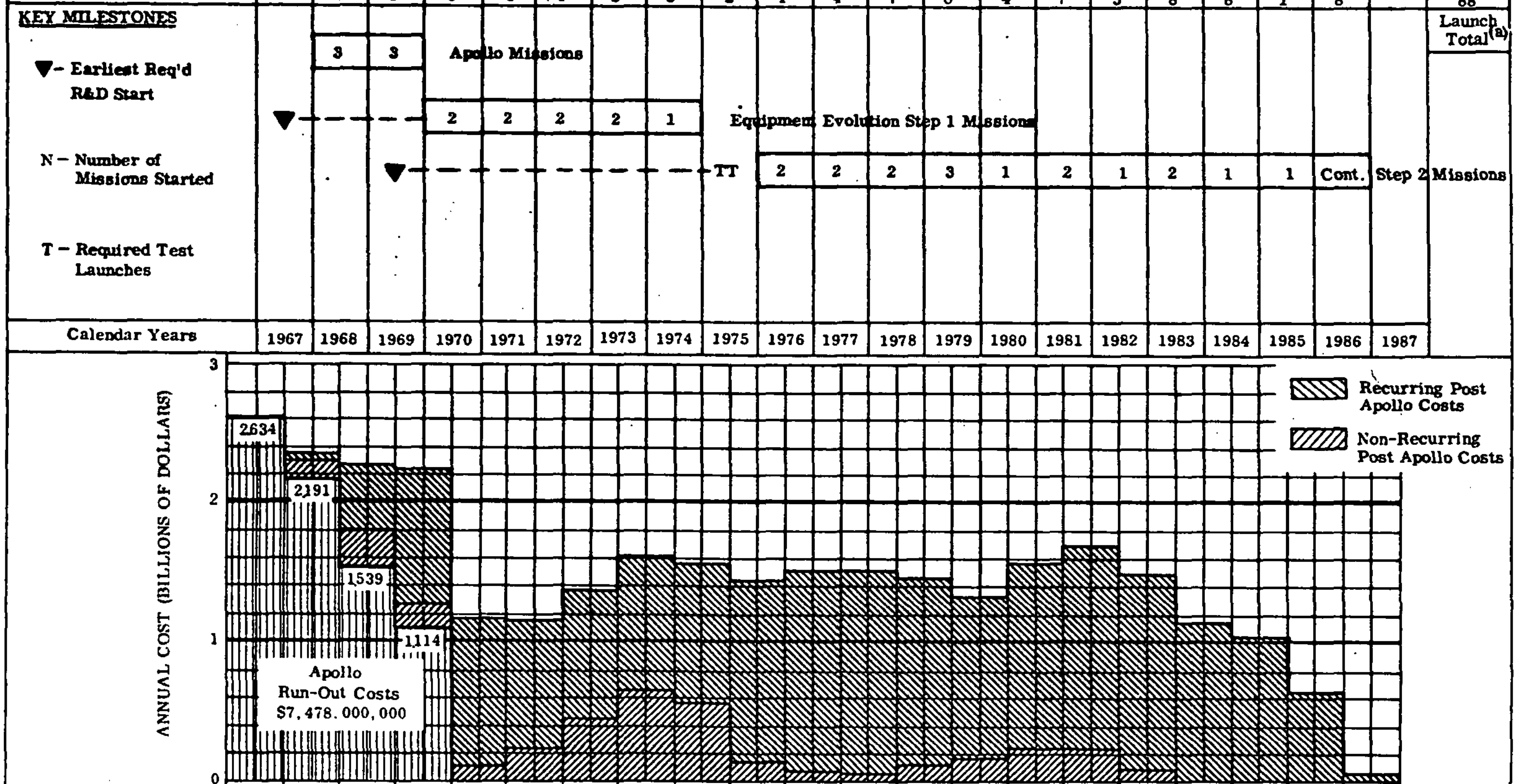
Eight locales are to be visited in the preferred order 17, 26, 11, 21, 16, 5, 2, and 18. Twenty different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. The annual program funding rate was to be about 1 to 2 billion dollars. Transportation-system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

As developed within these constraints, exploration program A-IVb introduces the 125% Saturn and the LLV in 1976. The program is completed with a large astronomy mission to Grimaldi, beginning in early 1984 and requiring 16 launches. The total number of Saturn launches is 88, including 6 Apollo missions and 2 test launches for the Saturn uprating. The total post-Apollo cost is 23.9 billion dollars spread over a period of about 20 years. The program indicates a nonrecurring cost of about 2 billion dollars for the introduction of the 125% Saturn, the LLV, and related equipment. Funds must be committed in 1969.

COST AND SCHEDULE SUMMARY

Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total[(a)]
LAUNCH RATE		3	3	3	3	4	3	3	2	4	4	7	8	4	7	5	8	8	1	8		88



		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS		TOTAL (MILLIONS)	5	170	730	1121	1183	1177	1388	1601	1583	1422	1506	1518	1446	1334	1587	1715	1474	1154	1075	627	43	23.859
	Non-Recur	R&D	5	92	233	165	113	199	406	624	575	164	65	45	108	184	258	240	84					3560
		C OF F		1	1		2	5	31	30		1	1	9	9	2								92
	Recurring	PROCUREMENT		77	485	862	865	786	792	730	871	1058	1209	1160	957	892	1066	1210	974	816	866	235		15.911
		OPERATIONS			11	94	203	187	159	217	137	199	231	304	372	256	263	265	416	338	209	392	43	4296

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

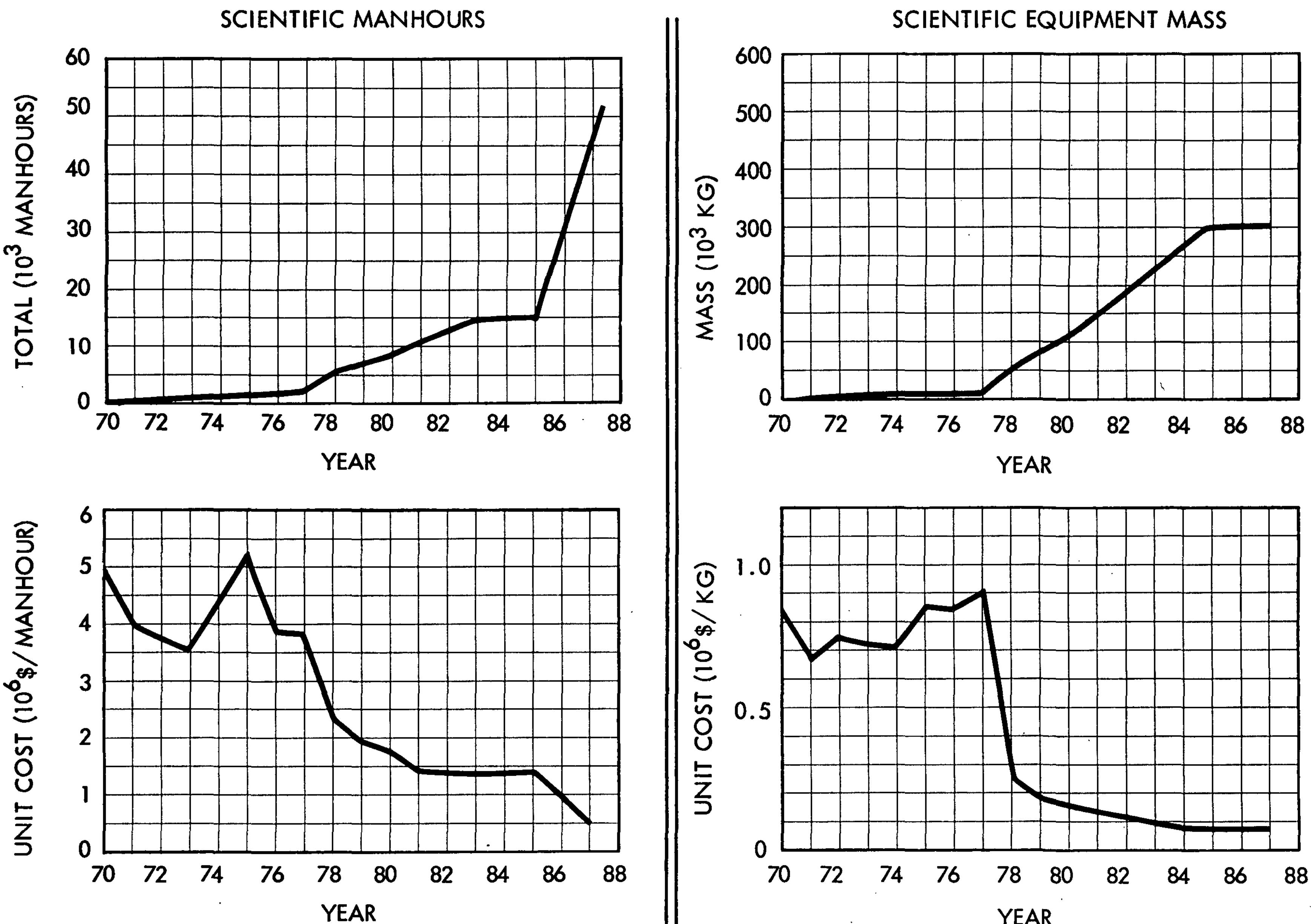
Mission No.	Mission Start	Mission Location (paths – locales)	Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
7	70A	Orbiter 1	303-10021-02	1	–	9	636	212	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	15	729	180	4716	575	381	150
9	71A	Moltke B	402-10011-01	2	26	16	733	180	4719	575	378	150
10	71B	Orbiter 2	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
11	72A	Tycho	402-10011-03	2	11	16	780	197	4173	482	920	150
12	72B	First Visit to Grimaldi, Astronomical Location	402-10011-03	2	21	16	747	190	4221	581	855	90
13	73B	Orbiter 3	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
14	73B	South Pole	402-10011-03	2	16	18	837	213	4165	458	973	150
15	74B	Second Visit to Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
16	76A	Capella M	503-20162-01	2	s	10	678	204	10,502	623	6798	300
17	76B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n – 5	27	1937	809	11,135	1235	5165	300
18	77A	Southeast Serenitatis	503-20162-01	2	r	10	661	199	10,482	602	5818	300
19	77B	Mare Crisium	503-20162-01	2	q	9	647	189	10,323	443	5977	300
20	78A	M Imbr, M Imbr to M Seren – N half P Putr to M Vapor	503-20191-01	5	a,b – N/2c	105	7582	2372	62,608	42,024	2592	3900
21	78B	Mare Humorum	503-20162-01	2	15	15	1085	310	10,517	637	5783	600
22	79A	North Pole	503-20162-01	2	t	9	647	189	10,323	443	5977	300
23	79A	Mare Smythii	503-20162-01	2	p	27	1948	544	10,493	593	5807	1200
24	79B	Central Farside	503-20201-01	4	ℓ	48	3470	1216	48,900	29,548	0	1200
25	80A	Marius Hills to Aristarchus	503-20222-01	4	j	41	2949	998	37,499	19,331	11,401	1200
26	81A	Ptol to Alphon, C High, M Nub to St Wall – Alphon, St Wall	503-20231-01	3	f,g,h – 2,18	65	4636	2192	26,822	8539	5778	2300
27	81B	Mare Orientale	503-20251-01	4	m	36	2600	1213	48,900	29,536	0	1200
28	82B	S half P Putr to M Vapor, M Vapor to M Tranq, Si Medii	503-20262-01	5	S/2c,d,e	73	5226	1695	61,949	42,417	3251	2400
29	83A	Southern Highlands	503-20251-01	4	i	36	2597	1211	49,148	29,522	0	1200
30	83B	Northern Farside	503-20222-01	4	k	34	2429	748	37,209	19,094	11,691	1200
31	84A	Third Visit to Grimaldi, Astronomical Location	406-20131-01	8	21	822	118,432	37,466	112,131	75,720	0	60
32	86A	Fourth Visit to Grimaldi, Astronomical Location	406-20131-02	8	21	0	0	0	0	0	16,186	0
		Total				1493	164,128	53,266	601,555	310,676	99,396	18,650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Vehicles									
1221-01	100% Saturn V	–	71A/74B	13	2	–	–	2100	270	2370
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	72A	76A/86A	64	7	570	42	6550	1321	8483
	Subtotal					570	42	8650	1591	10,853
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/74B	13	2	–	–	1231	288	1519
1311-02/1321-04	CSM – LOR – Three-Man	73B	76A/86A	24	3	76	–	884	513	1473
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/74B	6	1	32	–	348	85	465
1332-02/1342-01	LM Taxi – Three-Man	72B	76A/86A	24	3	246	–	1650	338	2234
1423-02/1433-02	LLV – 125% Saturn V	71B	76A/86A	40	4	599	24	797	150	1570
	Subtotal					953	24	4910	1374	7261
	Mission Equipment									
2121-01	Orbit-Launched Probe	68B	70A/73B	7	1	58	–	26	2	86
2132-02	Surface-Launched Probe	74B	78A/83B	20	2	38	–	46	4	88
2222-02	Orbiter Rack	67B	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74B	6/7[(a)]	1	217	–	318	92	627
2322-08	Shelter – Three-Man	79A	84A/84A	2	1	360	–	112	16	488
2421-01	LSSM	67B	70B/73B	7	1	58	2	39	4	103
2423-03	LRV – Three-Man – 90 Days	69B	76A/84A	16	2	421	2	347	27	797
2433-04	Trailer – Large Multipurpose	75A	78A/84A	9	1	52	3	84	2	141
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2521-02	LFV – Return To Orbit	74A	78A/83A	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	77B	84A/ –	1	1	136	20	28	0	184
	Subtotal					1451	27	1028	150	2656
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	74B	78A/83A	5	1	11	–	11	–	22
3223-01	15-m Radio Telescope	80A	84A/ –	1	1	4	–	4	–	8
3224-02	Radio Telescope – Mills Cross	78B	84A/–	1	1	30	–	4	1	35
3231-01	X-Ray Telescope	77A	84A/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	70A	74B/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78A	84A/–	1	1	152	–	25	1	178
3243-01	2.5-m Optical Telescope	77A	84A/–	1	1	227	–	35	1	263
	Subtotal					492	–	96	5	593
	Total					3466	93	14,684	3120	21,363

(a) One 1351-03 used to deliver telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM A-Va

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the large scientific program (Scientific Program A) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second step is to a direct logistics landing vehicle (LLV). A final evolutionary step introduces the 175% Saturn V at the earliest practicable date.

Eight locales are to be visited in the preferred order 17, 26, 11, 21, 16, 5, 2, and 18. Twenty different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. The target for annual program cost is about 1 to 2 billion dollars. Transportation-system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

As developed within these constraints, exploration program A-Va introduces the LLV in 1976 and the 175% Saturn in 1980. The program is completed with a large astronomy mission to Grimaldi, beginning in early 1984 and requiring 10 launches. The total number of Saturn launches is 76, including 6 Apollo missions and 2 test launches for the Saturn uprating. The total post-Apollo cost is 25.8 billion dollars spread over a period of about 18 years. The program indicates a cost of about 1.5 billion dollars for introduction of the LLV and associated equipment. Funds must be committed in 1969. A further commitment of the order of 3 billion dollars for introduction of the 175% Saturn and its related equipment must be made in about 1975.

COST AND SCHEDULE SUMMARY

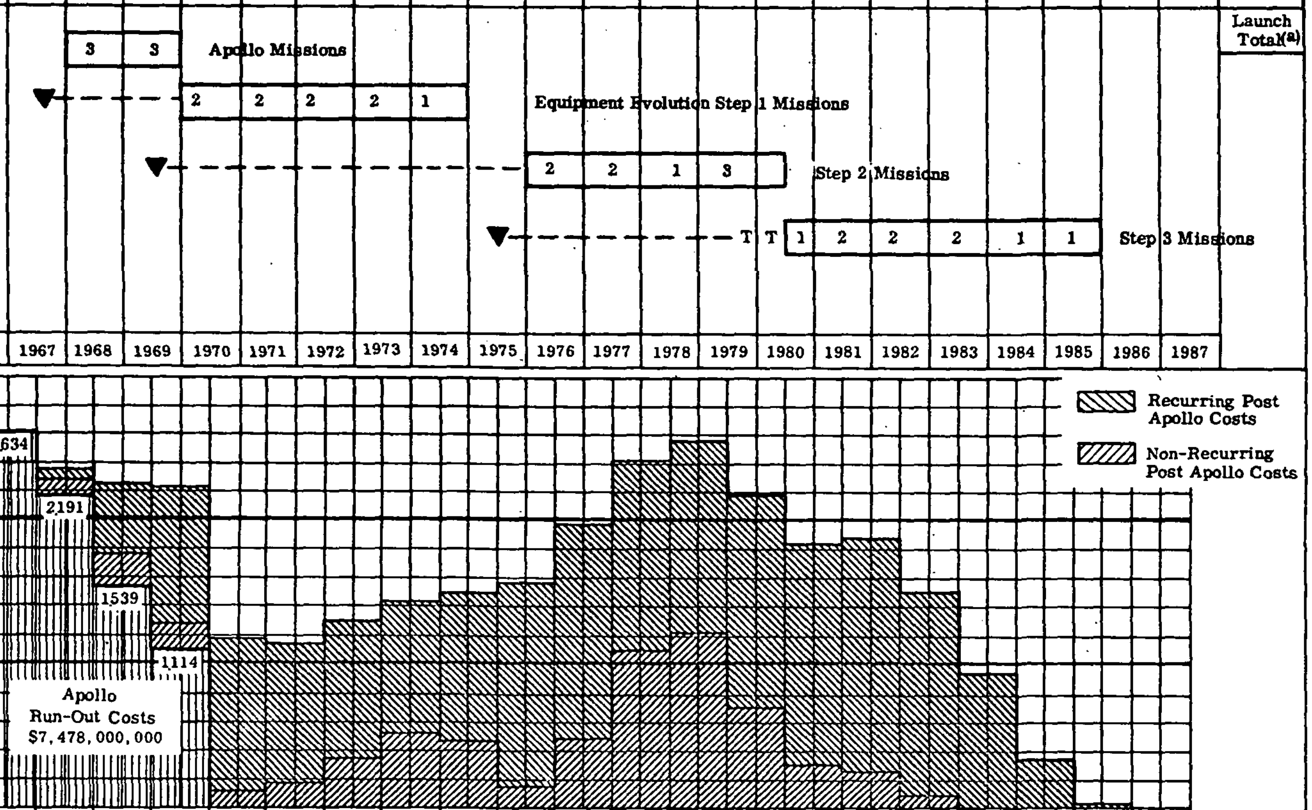
Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
LAUNCH RATE		3	3	3	3	4	3	3	0	4	4	7	7	4	5	7	6	6	4			76

KEY MILESTONES

▼ - Earliest Req'd R&D Start

N - Number of Missions Started

T - Required Test Launches



	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS	TOTAL (MILLIONS)	5	170	730	1121	1183	1165	1277	1409	1483	1552	1954	2416	2573	2198	1826	1876	1515	925	371	17		25.766
Non-Recur	R&D	5	92	233	165	113	186	328	475	446	168	423	967	1170	716	298	276	108					6169
Non-Recur	C OF F		1	1		2	6	16	14		5	51	120	39	2								257
Recurring	PROCUREMENT		77	485	862	865	786	774	703	905	1195	1248	1047	1104	1275	1259	1302	1081	623	144			15,735
Recurring	OPERATIONS			11	94	203	187	159	217	132	184	232	282	260	205	269	298	326	302	227	17		3605

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-02	1	–	9	636	212	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	15	729	180	4716	575	381	150
9	71A	Moltke B	402-10011-01	2	26	16	733	180	4719	575	378	150
10	71B	Orbiter 2	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
11	72A	Tycho	402-10011-03	2	11	16	780	197	4173	482	920	150
12	72B	First Visit to Grimaldi, Astronomical Location	402-10011-03	2	21	16	747	190	4221	581	855	90
13	73B	Orbiter 3	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
14	73B	South Pole	402-10011-03	2	16	18	837	213	4165	458	973	150
15	74B	Second Visit to Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
16	76A	Capella M	503-20161-01	2	s	10	678	204	10,502	623	1598	300
17	76B	Copernicus–Dark Halo Craters Southeast of Copernicus	503-20161-01	2	n–5	27	1937	809	11,135	1235	965	300
18	77A	Southeast Serenitatis	503-20161-01	2	r	10	661	199	10.482	602	1618	300
19	77B	Mare Crisium	503-20161-01	2	q	9	647	189	10,323	443	1777	300
20	78A	M Imbr, M Imbr to M Seren–N half Palus Putr to M Vapor	503-20171-01	7	a,b–N/2 c	105	7582	2372	62,608	42,024	9992	3900
21	79A	Mare Humorum	503-20161-01	2	o	15	1085	310	10.517	637	1583	600
22	79A	North Pole	503-20161-01	2	t	9	647	189	10.323	443	1777	300
23	79B	Mare Smythii	503-20161-01	2	p	27	1948	544	10.493	593	1607	1200
24	80B	Central Farside	503-30063-01	3	ℓ	48	3470	1216	49,578	29,548	1222	1200
25	81A	Marius Hills to Aristarchus	503-30094-01	3	j	41	2949	998	37,499	19.331	13,301	1200
26	81B	Ptol to Alphon. C High. M Nub to St Wall–Alphon St Wall	503-30083-01	2	f.g.h–2.18	65	4636	2192	25.400	8539	0	2300
27	82A	Mare Orientale	503-30103-01	3	m	36	2600	1213	48.762	29.536	2278	1200
28	82B	S half Palus Putr to M Vapor, M Vapor to M Tranq. Si Medii	503-30114-01	4	S/2 c.d.e	73	5226	1695	61.949	42.417	14,251	2400
29	83A	Southern Highlands	503-30103-01	3	i	36	2597	1211	48,748	29.522	2292	1200
30	83B	Northern Farside	503-30094-01	3	k	34	2429	748	37,209	19.094	14,734	1200
31	84A	Third Visit to Grimaldi, Astronomical Location	406-30161-01	6	21	822	118,432	37,466	118.051	75,720	8949	60
32	85A	Fourth Visit to Grimaldi, Astronomical Location	406-30161-02	4	21	0	0	0	0	0	0	0
		Total				1493	164,122	53,266	606.193	310.676	85,125	18,650

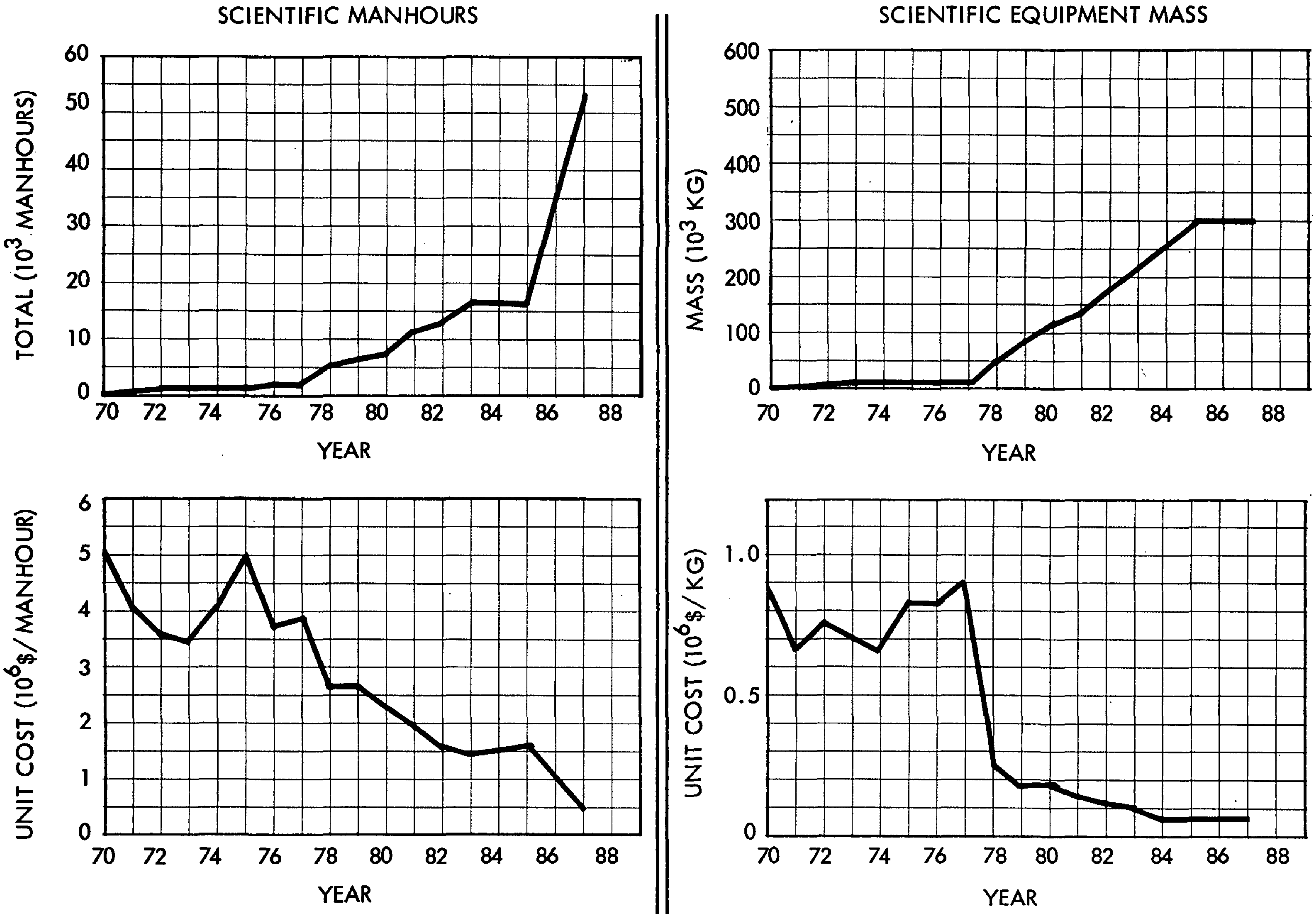
EQUIPMENT USAGE AND COST SUMMARY

ID No.	Name	R&D Start	First/ Last Use	Number Procured: Operations	Number Procured: Spares	Nonrecurring: R&D	Nonrecurring: C of F	Recurring: Procurement	Recurring: Operation	Total Cost
	Launch Systems									
1221-01	100% Saturn V	–	71A/79B	34	4	–	–	5067	684	5751
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1251-01	175% Saturn V	76B	80B/85A	31	4	818	135	4080	651	5684
	Subtotal					818	135	9147	1335	11,435
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/74B	13	2	–	–	1231	288	1519
1311-02/1321-02	CSM – LOR – Three-Man	73B	76A/79B	8	1	76	–	741	171	988
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/74B	6	1	32	–	348	89	469
1334-02/1342-01	LM Taxi – Three-Man	71B	76A/79B	8	1	411	12	507	113	1043
1412-02/1454-01	CSM Direct – Six-Man	76B	80B/85A	12	2	900	12	1500	274	2686
1421-02/1431-03	Personnel Braking and Landing Stages	75B	80B/85A	12	2	459	24	212	38	733
1423-01/1433-01	Logistic Braking and Landing Stages	71B	76A/79B	13	2	599	24	209	51	883
1423-04/1433-04	Logistic Braking and Landing Stages	76A	80B/84A	19	2	687	24	443	76	1230
	Subtotal					3164	96	5191	1100	9551
	Mission Equipment									
2121-01	Orbit-Launched Probe	68B	70A/73B	7	1	58	–	26	2	86
2132-02	Surface-Launched Probe	74B	78A/83B	20	2	38	–	46	4	88
2222-02	Orbiter Rack	67B	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74B	6/7[(a)]	1	217	–	318	92	627
2325-05	Shelter – Six-Man	79A	84A/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/73B	7	1	58	2	39	4	103
2423-03	LRV – Three-Man – 90 Days	69B	76A/84A	16	2	421	2	347	27	797
2433-04	Trailer – Large Multipurpose	75A	78A/84A	9	1	52	3	84	2	141
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2521-02	LFV – Return to Orbit	74A	78A/83A	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	77B	84A/–	1	1	136	20	28	–	184
	Subtotal					1575	27	1004	145	2751
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	74B	78A/83A	5	1	11	–	11	–	22
3223-01	15-m Radio Telescope	80A	84A/–	1	1	4	–	4	–	8
3224-02	Radio Telescope – Mills Cross	78B	84A/–	1	1	30	–	4	1	35
3231-01	X-Ray Telescope	77A	84A/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	70A	74B/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78A	84A/–	1	1	152	–	25	1	178
3243-01	2.5-m Optical Telescope	77A	84A/–	1	1	227	–	35	1	263
	Subtotal					492	–	96	5	593
	Total					6049	258	15.438	2585	24.330

Cost Summary in Millions of Dollars.

(a) One 1351-03 used to deliver 1-m telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM A-VIa

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the large scientific program (Scientific Program A) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second step is to an uprated Saturn (125% Saturn V) and a direct logistics landing vehicle (LLV). A final evolutionary step introduces a six-man shelter and the six-man lunar orbit rendezvous delivery mode.

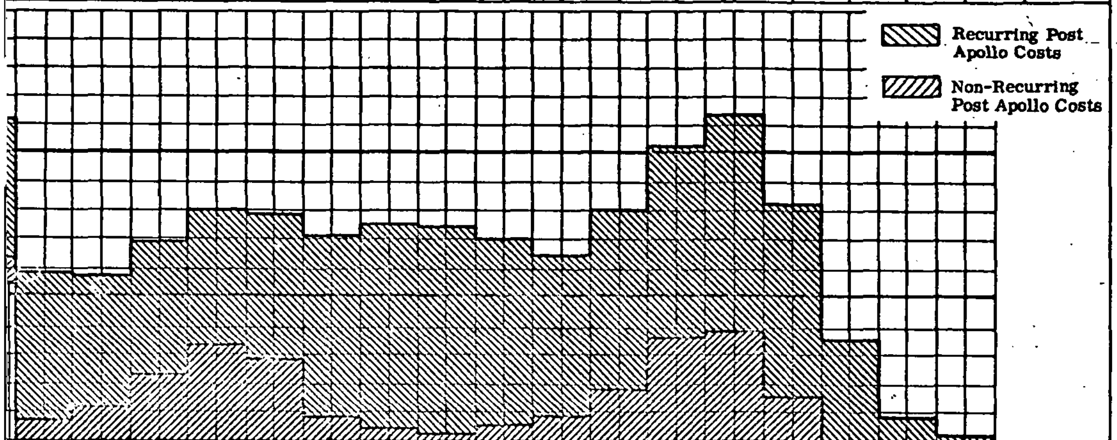
Eight locales are to be visited in the preferred order 17, 26, 11, 21, 16, 5, 2, and 18. Twenty different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. The target program funding rate is 1 to 2 billion dollars per year. Transportation-system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

As developed within these constraints, exploration program A-VIa introduces the 125% Saturn and the LLV in 1976 and the six-man mode in 1984. The program is completed with a large astronomy mission to Grimaldi, beginning in late 1984 and requiring 13 launches. The total number of Saturn launches is 84, including 6 Apollo missions and 2 test launches for the Saturn uprating. Total post-Apollo cost is 24.6 billion dollars spread over a period of about 20 years. The program indicates a cost of about 2 billion dollars for development of the 125% Saturn and the LLV. Funds must be committed in 1969. A further commitment of the order of 2.5 billion dollars for development of the six-man command service module, shelter, and major scientific equipment must be made in about 1977.

COST AND SCHEDULE SUMMARY

1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total[a]
3	3	4	3	3	2	4	4	7	8	4	7	5	9	8	8			84
Apollo Missions																		
2	2	2	2	1	Equipment Evolution Step 1 Missions													
					TT	2	2	2	3	1	2	1	2	Step 2 Missions				
							▼							1	1	Step 3 Missions		



	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
[illegible]	[illegible]	1183	1177	1388	1601	1583	1422	1500	1488	1410	1309	1616	2065	2291	1640	735	161	19	24,614
[illegible]	[illegible]	113	199	406	624	575	164	59	20	72	157	365	717	795	320	2			5083
[illegible]		2	5	31	30		1	1	4	9	8	4	5	2					104
[illegible]	[illegible]	865	786	792	730	871	1058	1209	1160	957	888	984	1078	1153	1013	427			15,394
[illegible]	[illegible]	203	187	159	217	137	199	231	304	372	256	263	265	341	307	306	161	19	4032

POST-APOLLO MISSION SUMMARY

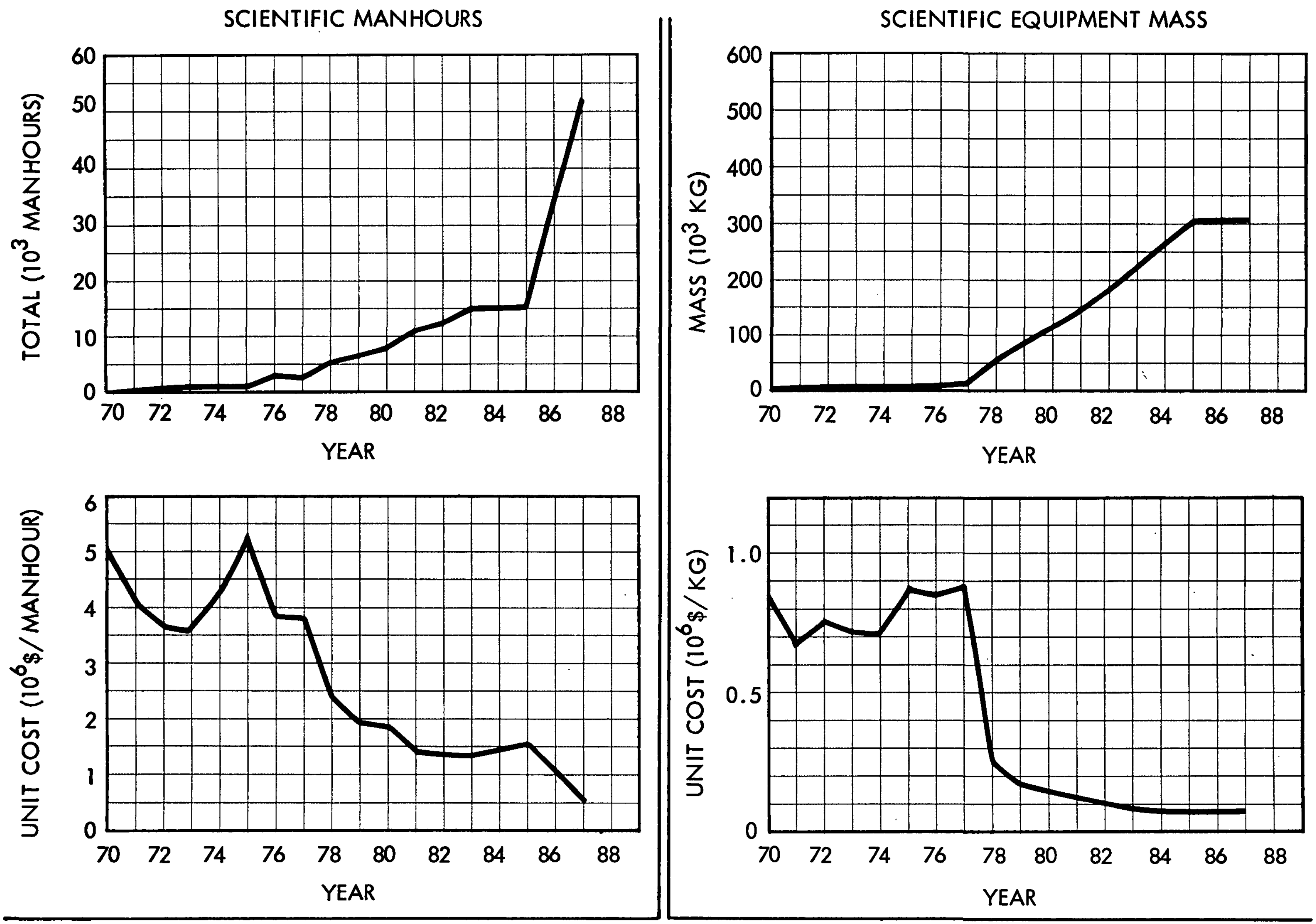
Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-02	1	–	9	636	212	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	15	729	180	4716	575	381	150
9	71A	Moltke B	402-10011-01	2	26	16	733	180	4719	575	378	150
10	71B	Orbiter 2	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
11	72A	Tycho	402-10011-03	2	11	16	780	197	4173	482	920	150
12	72B	First Visit to Grimaldi, Astronomical Location	402-10011-03	2	21	16	747	190	4221	581	855	90
13	73B	Orbiter 3	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
14	73B	South Pole	402-10011-03	2	16	18	837	213	4165	458	973	150
15	74B	Second Visit to Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
16	76A	Capella M	503-20162-01	2	s	10	678	204	10,502	623	6798	300
17	76B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n – 5	27	1937	809	11,135	1235	5165	300
18	77A	Southeast Serenitatis	503-20162-01	2	r	10	661	199	10,482	602	5818	300
19	77B	Mare Crisium	503-20162-01	2	q	9	647	189	10,323	443	5977	300
20	78A	M Imbr, M Imbr to M Seren – N half P Putr to M Vapor	503-20191-01	5	a,b, –N/2c	105	7582	2372	62,608	42,024	2592	3900
21	78B	Mare Humorum	503-20162-01	2	o	15	1085	310	10,517	637	5783	600
22	79A	North Pole	503-20162-01	2	t	9	647	189	10,323	443	5977	300
23	79A	Mare Smythii	503-20162-01	2	p	27	1948	544	10,439	593	5807	1200
24	79B	Central Farside	503-20201-01	4	ℓ	48	3470	1216	48,900	29,548	19,316	1200
25	80A	Marius Hills to Aristarchus	503-20222-01	4	j	41	2949	998	37,499	19,331	11,401	1200
26	81A	Ptol to Alphon, C High, M Nub to St Wall – Alphon, St Wall	503-20231-01	3	f,g,h – 2,18	65	4636	2192	26,822	8539	5778	2300
27	81B	Mare Orientale	503-20251-01	4	m	36	2600	1213	48,900	29,536	19,710	1200
28	82B	S half P Putr to M Vapor, M Vapor to M Tranq, Si Medii	503-20262-01	5	S/2c,d,e	73	5226	1695	61,949	42,417	3251	2400
29	83A	Southern Highlands	503-20251-01	4	i	36	2597	1211	49,148	29,522	0	1200
30	83B	Northern Farside	503-20222-01	4	k	34	2429	748	37,209	19,094	11,691	1200
31	84B	Third Visit to Grimaldi, Astronomical Location	406-20111-01	8	21	822	118432	37,466	112,131	75,720	0	60
32	85B	Fourth Visit to Grimaldi, Astronomical Location	406-20111-02	5	21	0	0	0	0	0	16,186	0
		Total				1493	171,583	53,266	601,501	310,676	138,431	18,650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	<u>Launch Systems</u>									
1221-01	100% Saturn V	–	71A/74B	13	2	–	–	2100	270	2370
1221-03	100% Saturn V (Apollo Funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	72A	76A/85B	60	6	570	42	6147	1228	7987
	Subtotal					570	42	8247	1498	10,357
	<u>Flight Systems</u>									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/74B	13	2	–	–	1231	288	1519
1311-02/1321-04	CSM – LOR – Three-Man	73B	76A/83B	15	2	76	–	1377	323	1776
1312-02/1322-01	CSM – LOR – Six-Man	80B	84B/85B	5	1	889	–	739	119	1747
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/74B	6	1	31	–	348	89	468
1332-02/1342-01	LM Taxi – Three-Man	72B	76A/83B	15	2	246	–	919	213	1378
1335-01/1343-01	LM Taxi – Six-Man	80A	84B/85B	5	1	464	12	436	78	990
1423-02/1433-02	Logistic Braking and Landing Stages	71B	76A/85B	40	4	599	24	798	150	1571
	Subtotal					2305	36	5848	1260	9449
	<u>Mission Equipment</u>									
2121-01	Orbit-Launched Probe	68B	70A/71B	7	1	58	–	26	2	86
2132-02	Surface-Launched Probe	74B	78A/83B	20	2	38	–	46	4	88
2222-02	Orbiter Rack	67B	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74B	6/7[a]	1	217	–	318	92	627
2325-05	Shelter – Six-Man	79B	84B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/73B	7	1	58	2	39	4	103
2423-03	LRV – Three-Man – 90 Days	69B	76A/84B	16	2	421	2	347	27	797
2433-04	Trailer – Large Multipurpose	75A	78A/84B	9	1	52	3	84	2	141
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2521-02	LFV – Return to Orbit	74A	78A/83A	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	78A	84B/–	1	1	136	20	28	–	184
	Subtotal					1575	27	1004	145	2751
	<u>Major Scientific Equipment</u>									
3213-02	300-m Drill – Fuel Cell	74B	78A/83A	5	1	11	–	11	–	22
3223-01	15-m Radio Telescope	80B	84B/–	1	1	4	–	4	–	8
3224-02	Radio Telescope – Mills Cross	79A	84B/–	1	1	30	–	4	1	35
3231-01	X-Ray Telescope	77B	84B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	70A	74B/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78B	84B/–	1	1	152	–	25	1	178
3243-01	2.5-m Optical Telescope	77B	84B/–	1	1	227	–	35	1	263
	Subtotal					492	–	96	5	593
	Total					4942	105	15,195	2908	23,150

(a) One 1351-03 used to deliver 1-m telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM A-VIb

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the large scientific program (Scientific Program A) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step introduces an uprated Saturn (125% Saturn V) and a direct logistics landing vehicle (LLV). The final step is to introduce the 150% Saturn V at the earliest practicable date.

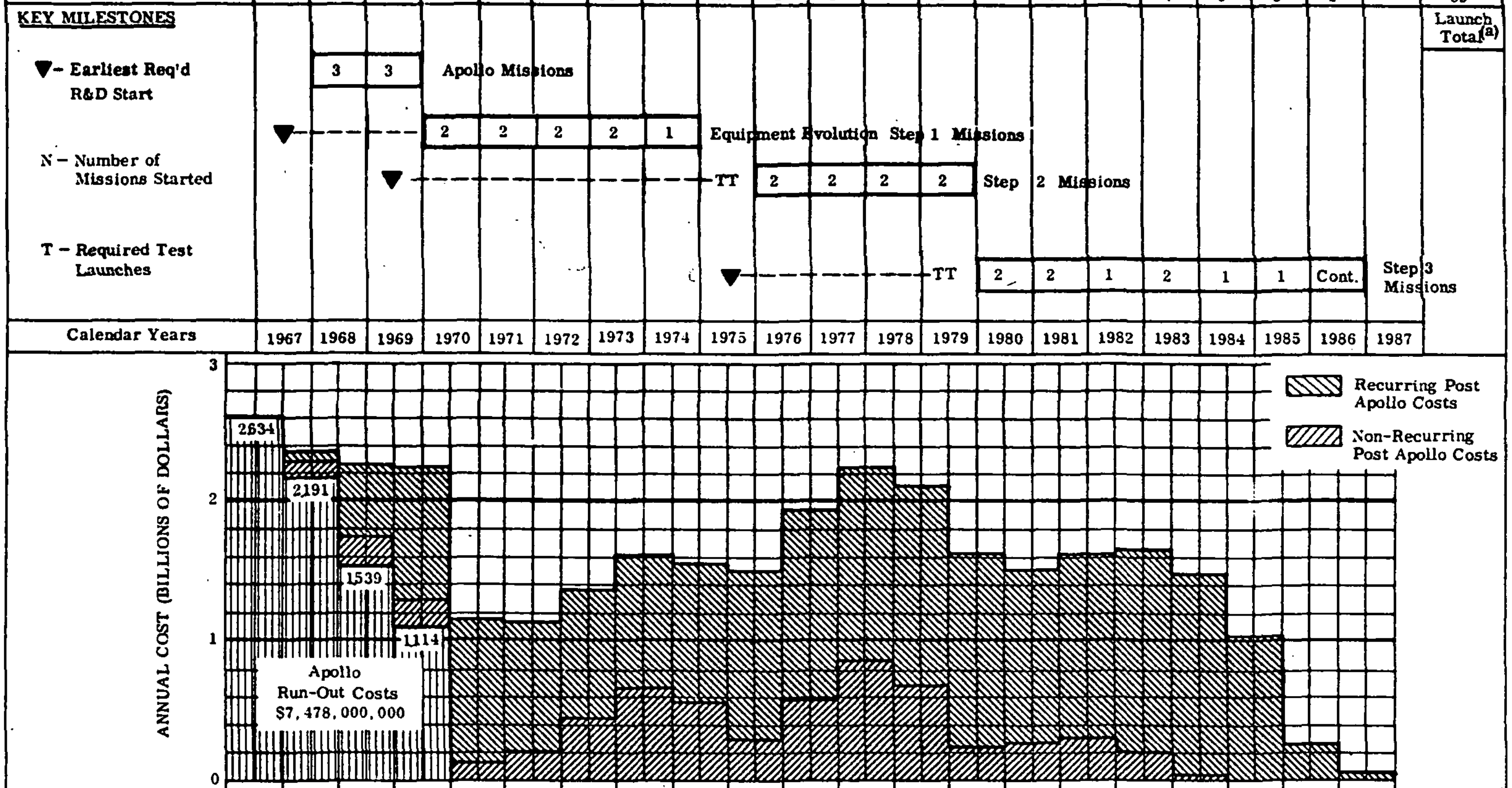
Eight locales are to be visited in the preferred order 17, 26, 11, 21, 16, 5, 2, and 18. Twenty different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. The target for annual spending is 1 to 2 billion dollars. Transportation-system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

As developed with these constraints, exploration program A-VIb introduces the 125% Saturn and the LLV in 1976 and the 150% Saturn in 1980. The program is completed with a large astronomy mission to Grimaldi, beginning in late 1984 and requiring 17 launches. The total number of Saturn launches is 89, including 6 Apollo missions and 4 test launches (2 each for the 2 Saturn upratings). The total post-Apollo cost is 26.1 billion dollars spread over a period of about 20 years. The program indicates a cost of about 2 billion dollars for introduction of the 125% Saturn, the LLV, and associated hardware systems. Funds must be committed in 1969. A further commitment of the order of 2 billion dollars for introducing the 150% Saturn and related equipment must be made in about 1976.

COST AND SCHEDULE SUMMARY

Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
LAUNCH RATE		3	3	3	3	4	3	3	2	4	4	7	8	7	7	4	7	8	8	1		89



POST APOLLO COSTS	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
	TOTAL (MILLIONS)	5	170	730	1121	1183	1177	1387	1601	1590	1524	1977	2261	2125	1617	1526	1617	1662	1494	1028	286	38	26,119
Non-Recur	R&D	5	92	233	165	113	199	406	624	581	279	527	790	652	238	264	303	208	28				5707
Non-Recur	C OF F		1	1		2	5	31	30	1	16	68	62	9	7								233
Recurring	PROCUREMENT		77	485	862	865	786	791	730	871	1030	1151	1113	1186	1091	986	1067	1167	1204	642	15		16,119
Recurring	OPERATIONS			11	94	203	187	159	217	137	199	231	296	278	281	276	247	287	262	386	271	38	4060

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

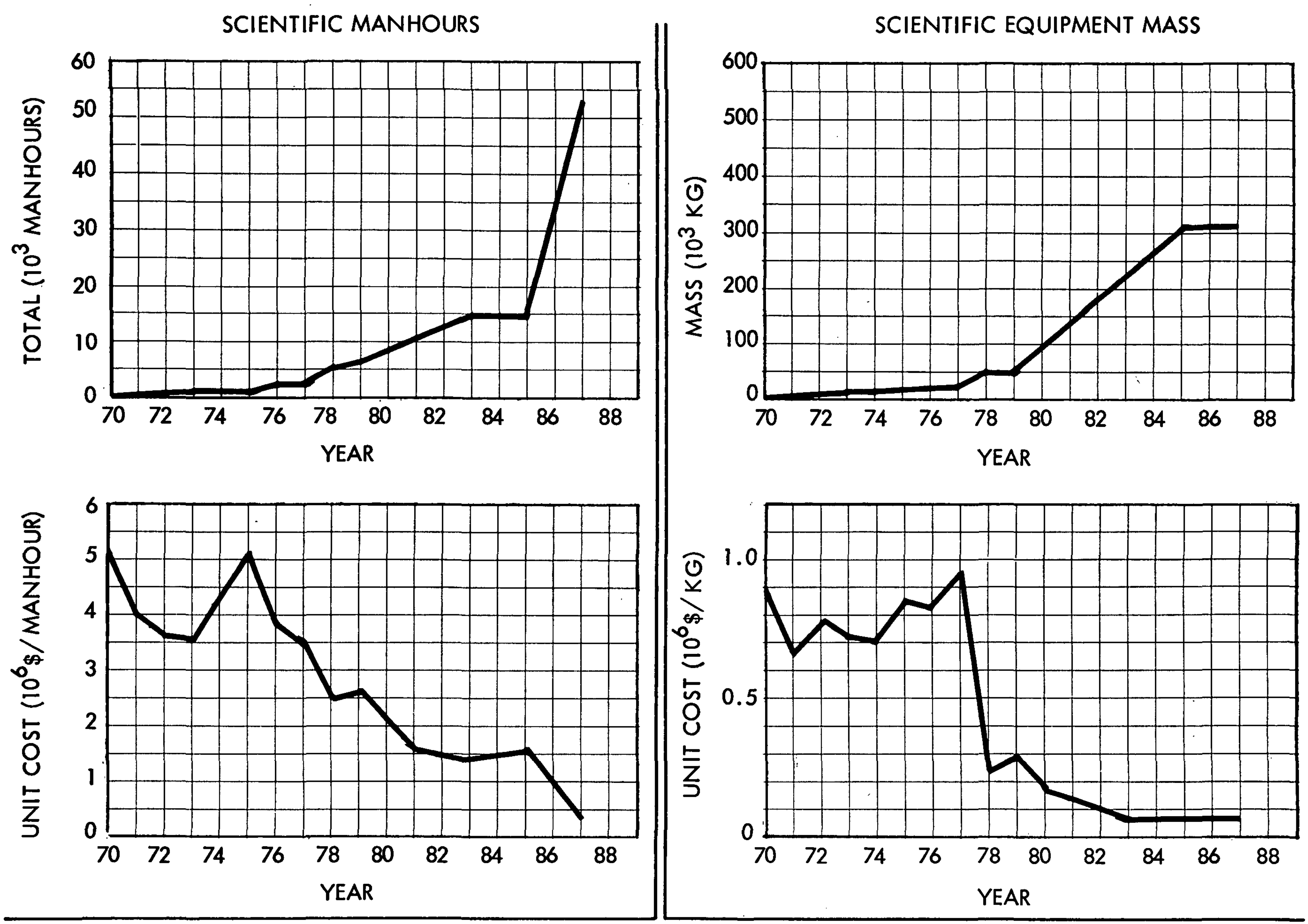
No.	Start	Mission Location (paths – locales)	Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
7	70A	Orbiter 1	303-10021-02	1	–	9	636	212	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	15	729	180	4716	575	381	150
9	71A	Moltke B	402-10011-01	2	26	16	733	180	4719	575	378	150
10	71B	Orbiter 2	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
11	72A	Tycho	402-10011-03	2	11	16	780	197	4173	482	920	150
12	72B	First Visit to Grimaldi, Astronomical Location	402-10011-03	2	21	16	747	190	4221	581	855	90
13	73B	Orbiter 3	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
14	73B	South Pole	402-10011-03	2	16	18	837	213	4165	458	973	150
15	74B	Second Visit to Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
16	76A	Capella M	503-20162-01	2	s	10	678	204	10,502	623	6798	300
17	76B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n – 5	27	1937	809	11,135	1235	5165	300
18	77A	Southeast Serenitatis	503-20162-01	2	r	10	667	199	10,482	602	5818	300
19	77B	Mare Crisium	503-20162-01	2	q	9	647	189	10,323	443	5977	300
20	78A	M Imbr, M Imbr to M Seren – N half P Putr to M Vapor	503-20191-01	5	a,b, –N/2 c	105	7582	2372	62,608	42,024	2592	3900
21	78B	Mare Humorum	503-20162-01	2	o	15	1085	310	10,517	637	5783	600
22	79A	North Pole	503-20162-01	2	t	9	647	189	10,323	443	5977	300
23	79A	Mare Smythii	503-20162-01	2	p	27	1948	544	10,493	593	5807	1200
24	80A	Central Farside	503-30071-01	4	ℓ	48	3470	1216	49,578	29,548	12,822	1200
25	80B	Marius Hills to Aristarchus	503-30091-01	3	j	41	2949	998	37,499	19,331	4101	1200
26	81A	Ptol to Alphon, C High, M Nub to St Wall – Alphon, St Wall	503-30091-01	3	f,g,h – 2,18	65	4636	2192	26,822	8539	14,778	2300
27	81B	Mare Orientale	503-30111-01	4	m	36	2600	1213	49,162	29,536	13,238	1200
28	82B	S half P Putr to M Vapor, M Vapor to M Tranq, Si Medii	503-30111-01	4	S/2 c,d,e	73	5226	1695	61,949	42,417	451	2400
29	83A	Southern Highlands	503-30111-01	4	i	36	2597	1211	49,148	29,522	13,252	1200
30	83B	Northern Farside	503-30091-01	3	k	34	2429	748	37,209	19,094	4391	1200
31	84B	Third Visit to Grimaldi, Astronomical Location	406-30181-01	8	21	822	118,432	37,466	118,801	75,720	5999	60
32	85B	Fourth Visit to Grimaldi, Astronomical Location	406-30181-02	8	21	0	0	0	0	0	20,800	0
32	86A	Fifth Visit to Grimaldi, Astronomical Location	406-30181-03	1								
		Total				1493	164,128	53,266	609,165	310,676	140,930	18,650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Vehicles									
1221-01	100% Saturn V	–	71A/74B	13	2	–	–	2100	270	2370
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	72A	76A/79A	19	2	570	42	2294	391	3297
1241-01	150% Saturn V	76A	80A/86A	42	5	595	80	4952	874	6501
	Subtotal					1165	122	9346	1535	12.168
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/74B	13	2	–	–	1231	288	1519
1311-02/1321-04	CSM – LOR – Three-Man	73B	76A/79A	8	1	76	–	741	172	989
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/74B	6	1	32	–	348	85	465
1332-02/1342-01	LM Taxi – Three-Man	72B	76A/79A	8	1	246	–	509	113	868
1411-02/1453-01	CSM – Direct – Three-Man	77A	80A/85B	17	2	352	12	1566	361	2291
1421-01/1431-01	Personnel Braking and Landing Stages	75A	80A/85B	17	2	459	24	276	51	810
1423-02/1433-02	LLV – 125% Saturn V	71B	76A/79A	11	2	599	24	273	44	940
1423-03/1433-03	LLV – 150% Saturn V	75B	80A/86A	25	3	599	24	533	95	1251
	Subtotal					2363	84	5477	1209	9133
	Mission Equipment									
2121-01	Orbit-Launched Probe	68B	70A/73B	7	1	58	–	26	2	86
2132-02	Surface-Launched Probe	74B	78A/83B	20	2	38	–	46	4	88
2222-02	Orbiter Rack	67B	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74B	6/7(a)	1	217	–	318	92	627
2325-05	Shelter – Six-Man	79B	84B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/73B	7	1	58	2	39	4	103
2423-03	LRV – Three-Man – 90 Days	69B	76A/84B	16	2	421	2	347	27	797
2433-04	Trailer – Large Multipurpose	75A	78A/84B	9	1	52	3	84	2	141
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2521-02	LFV – Return to Orbit	74A	78A/83A	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	78A	84B/–	1	1	136	20	28	–	184
	Subtotal					1575	27	1004	145	2751
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	74B	78A/83A	5	1	11	–	11	–	22
3223-01	15-m Parabolic Radio Telescope	80B	84B/–	1	1	4	–	4	–	8
3224-02	Radio Telescope – Mills Cross	79A	84B/–	1	1	30	–	4	1	35
3231-01	X-Ray Telescope	77B	84B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	70A	74B/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78B	84B/–	1	1	152	–	25	1	178
3243-01	2.5-m Optical Telescope	77B	84B/–	1	1	227	–	35	1	263
	Subtotal					492	–	96	5	593
	Total					5595	233	15,923	2894	24.645

(a) One 1351-03 used to deliver 1-m telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM A-VIc

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the large scientific program (Scientific Program A) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step involves an uprated Saturn (125% Saturn V) and a direct logistics landing vehicle (LLV). Introduction of the 175% Saturn V, as soon as practical represents a third evolutionary step in hardware capability.

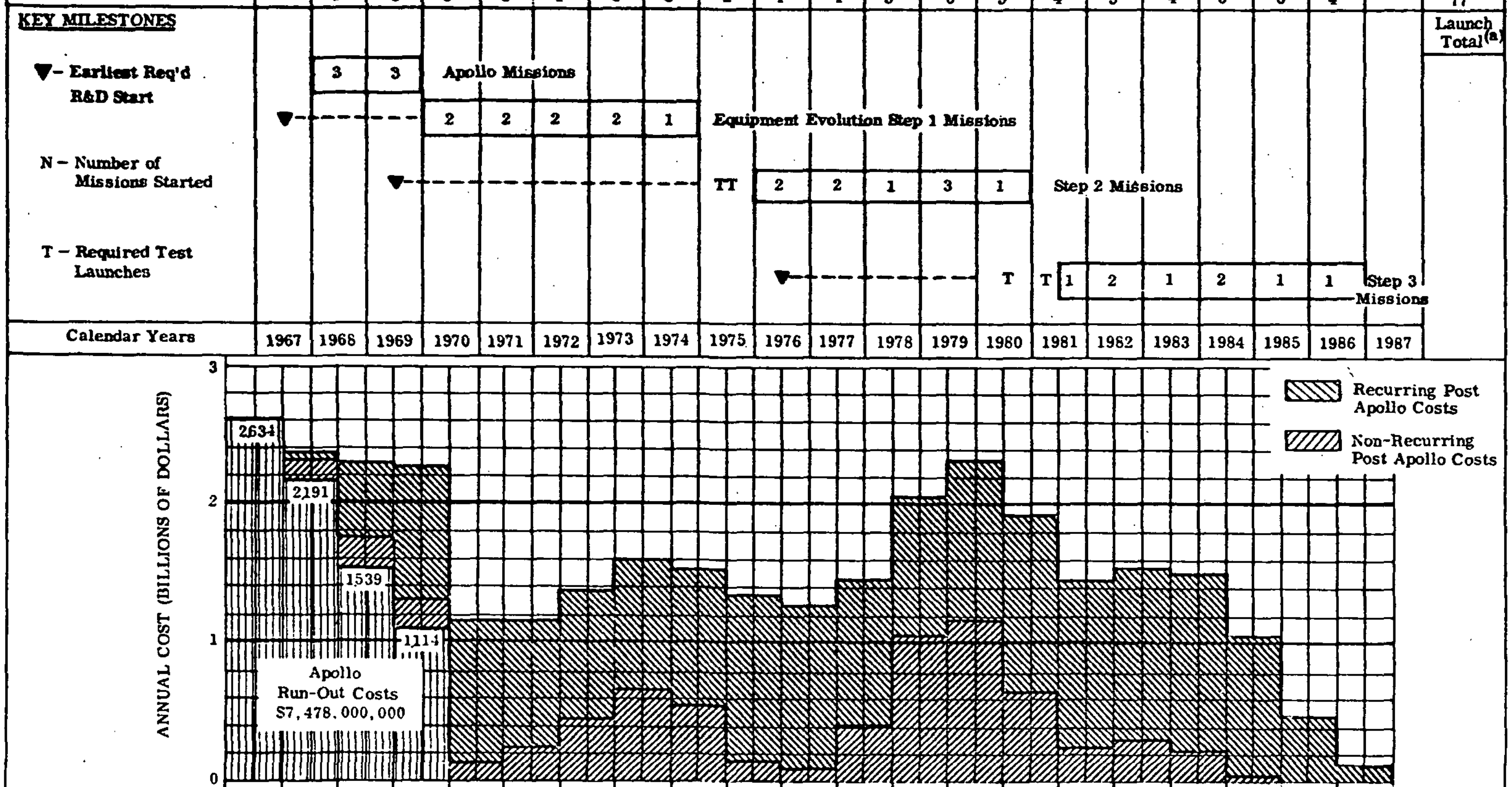
Eight locales are to be visited in the preferred order 17, 26, 11, 21, 16, 5, 2, and 18. Twenty different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. No rigid cost constraints were specified but the funding target was set at 1 to 2 billion dollars per year. Transportation-system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

As developed within these constraints, exploration program A-VIc introduces the 125% Saturn and the LLV in 1976 and the 175% Saturn in 1981. The program is completed with a large astronomy mission to Grimaldi, beginning in late 1985, and requiring 10 launches. The total number of Saturn launches is 77, including 6 Apollo missions and 4 test launches (2 each for the 2 Saturn upratings). The total post-Apollo cost is 25.6 billion dollars spread over a period of about 20 years. The program indicates a cost of about 2 billion dollars for the introduction of the 125% Saturn, the LLV, and associated equipment. Funds must be committed in 1969. A further commitment of the order of 3 billion dollars for introduction of the 175% Saturn and its related equipment must be made in about 1976.

COST AND SCHEDULE SUMMARY

Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total[a]
LAUNCH RATE		3	3	3	3	4	3	3	2	4	4	5	6	5	4	5	4	6	6	4		77



POST APOLLO COSTS

Fiscal Years		1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
TOTAL (MILLIONS)		5	170	730	1121	1183	1177	1387	1601	1572	1340	1272	1456	2071	2333	1941	1460	1582	1514	1060	488	125	25,588
Non-Recur	R&D	5	92	233	165	113	199	406	624	575	164	91	358	942	1137	658	265	303	208	28			6,566
Non-Recur	C OF F		1	1		2	5	31	30		1	5	50	115	39	7							287
Recurring	PROCUREMENT		77	485	862	865	786	791	730	860	976	952	799	781	992	1064	970	1064	1053	760	300	70	15,237
Recurring	OPERATIONS			11	94	203	187	159	217	187	199	224	249	233	165	212	225	215	253	272	188	55	3,498

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

No.	Start	Mission: Location (paths – locales)	Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
7	70A	Orbiter 1	303-10021-02	1	–	27	1908	636	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	15	729	180	4716	575	381	150
9	71A	Moltke B	402-10011-01	2	26	16	733	180	4719	575	378	150
10	71B	Orbiter 2	303-10022-02	1	–	27	1908	636	5031	1777	(10,382)	–
11	72A	Tycho	402-10011-03	2	11	16	780	197	4173	482	920	150
12	72B	First Visit to Grimaldi, Astronomical Location	402-10011-03	2	21	16	747	190	4221	581	855	90
13	73B	Orbiter 3	303-10022-02	1	–	27	1908	636	5031	1777	(10,382)	–
14	73B	*South Pole*	402-10011-03	2	16	18	837	213	4165	458	973	150
15	74B	Second Visit to Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
16	76A	Capella M	503-20162-01	2	s	10	678	204	10,502	623	6798	300
17	76B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n–5	27	1937	809	11,135	1235	5165	300
18	77A	Southeast Serenitatis	503-20162-01	2	r	10	667	199	20,964	602	5818	300
19	77B	Mare Crisium	503-20162-01	2	q	9	647	189	10,323	443	5977	300
20	78A	M Imbr, M Imbr to M Seren, P Putr to M Vapor	503-20191-01	5	a,b,c	105	7582	2372	62,608	42,024	2592	3900
21	79A	Mare Humorum	503-20162-01	2	o	15	1085	310	10,517	637	5783	600
22	79A	North Pole	503-20162-01	2	t	9	647	189	10,323	443	5977	300
23	79B	Mare Smythii	503-20162-01	2	p	27	1948	544	10,493	593	5807	1200
24	80B	Central Farside	503-20201-01	4	ℓ	48	3470	1216	48,900	29,548	0	1200
25	81B	Marius Hills to Aristarchus	503-30094-01	3	j	41	2949	998	37,499	19,331	13,301	1200
26	82A	Ptol to Alphon,C High,M Nub to St Wall – Alphon, St Wall	503-30083-01	2	f,g,h–2,18	65	4636	2192	25,400	8539	0	2300
27	82B	Mare Orientale	503-30103-01	3	m	36	2600	1213	48,762	29,536	2278	1200
28	83B	P Putr to M Vapor, M Vapor to M Tranq, Si Medii	503-30114-01	4	c,d,e	73	5226	1695	61,949	42,417	14,251	2400
29	84A	Southern Highlands	503-30103-01	3	i	36	2597	1211	48,748	29,522	2292	1200
30	84B	Northern Farside	503-30094-01	3	k	34	2429	748	37,209	19,094	14,734	1200
31	85B	Third Visit to Grimaldi, Astronomical Location	406-30161-01	6	21	822	118,433	37,466	118,051	75,720	8949	60
32	86B	Fourth Visit to Grimaldi, Astronomical Location	406-30161-02	4	21	0	0	0	0	0	0	0
		Total				1547	167,944	54,538	605,515	310,676	106,905	18,650

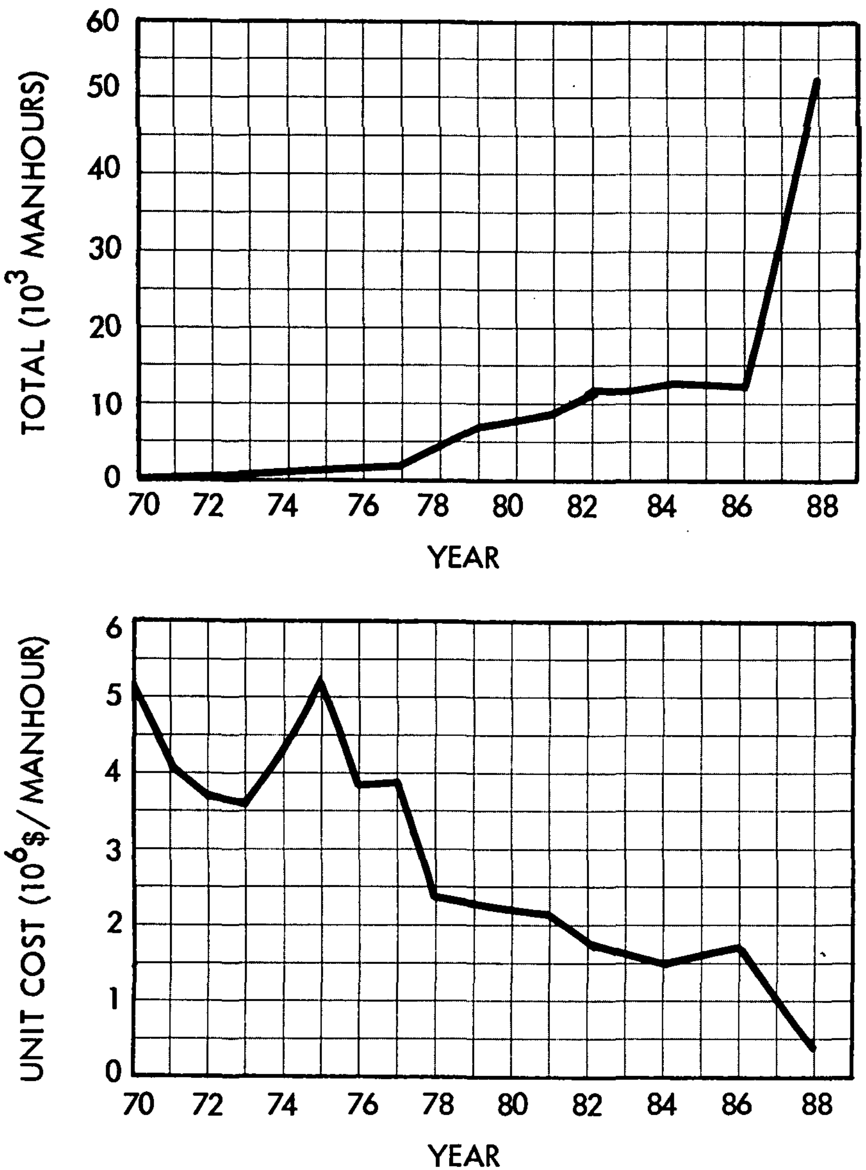
EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Vehicles									
1221-01	100% Saturn V	–	71A/74B	13	2	–	–	2100	270	2370
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	72A	76A/79B	23	3	570	42	2760	484	3856
1251-01	175% Saturn V	77A	80A/86A	28	3	818	135	3799	548	5300
	Subtotals					1388	177	8659	1302	11,526
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/74B	13	2	–	–	1231	288	1519
1311-02/1321-04	CSM – LOR – Three-Man	73B	76A/79B	9	1	76	–	821	190	1087
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/74B	6	1	32	–	348	85	465
1332-02/1342-01	LM Taxi – Three-Man	72B	76A/79B	9	1	246	–	561	125	932
1412-02/1454-01	CSM – Direct – Six-Man	77B	81A/86A	11	2	900	12	1070	172	2154
1421-02/1431-03	Personnel Braking and Landing Stages	76B	81A/86A	11	2	459	24	221	31	735
1423-02/1433-02	LLV – 125% Saturn V	71B	76A/79B	14	2	599	24	328	55	1006
1423-04/1433-04	LLV – 175% Saturn V	76B	80A/85A	17	2	687	24	405	69	1185
	Subtotal					2999	84	4985	1015	9083
	Mission Equipment									
2121-01	Orbit-Launched Probe	68B	70A/73B	7	1	58	–	26	2	86
2132-02	Surface-Launched Probe	74B	78A/84B	20	2	38	–	46	4	88
2222-02	Orbiter Rack	67B	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74B	6/7[(a)]	1	217	–	318	92	627
2325-05	Shelter – Six-Man	80A	85A/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/73B	7	1	58	2	39	4	103
2423-03	LRV – Three-Man – 90 Days	69B	76A/85A	16	2	421	2	347	27	797
2433-04	Trailer – Large Multipurpose	75A	78A/85A	9	1	52	3	84	2	141
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2521-02	LFV – Return to Orbit	74A	78A/84B	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	78B	85A/–	1	1	136	20	28	–	184
	Subtotal					1575	27	1004	145	2751
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	74B	78A/84B	5	1	11	–	11	–	22
3223-01	15-m Parabolic Radio Telescope	81A	85A/–	1	1	4	–	4	–	8
3224-02	Radio Telescope – Mills Cross	79B	85A/–	1	1	30	–	4	1	35
3231-01	X-Ray Telescope	78A	85A/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	70A	74B/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	79A	85A/–	1	1	152	–	25	1	178
3243-01	2.5-m Optical Telescope	78A	85A/–	1	1	227	–	35	1	263
	Subtotal					492	–	96	5	593
	Total					6454	288	14,744	2467	23,953

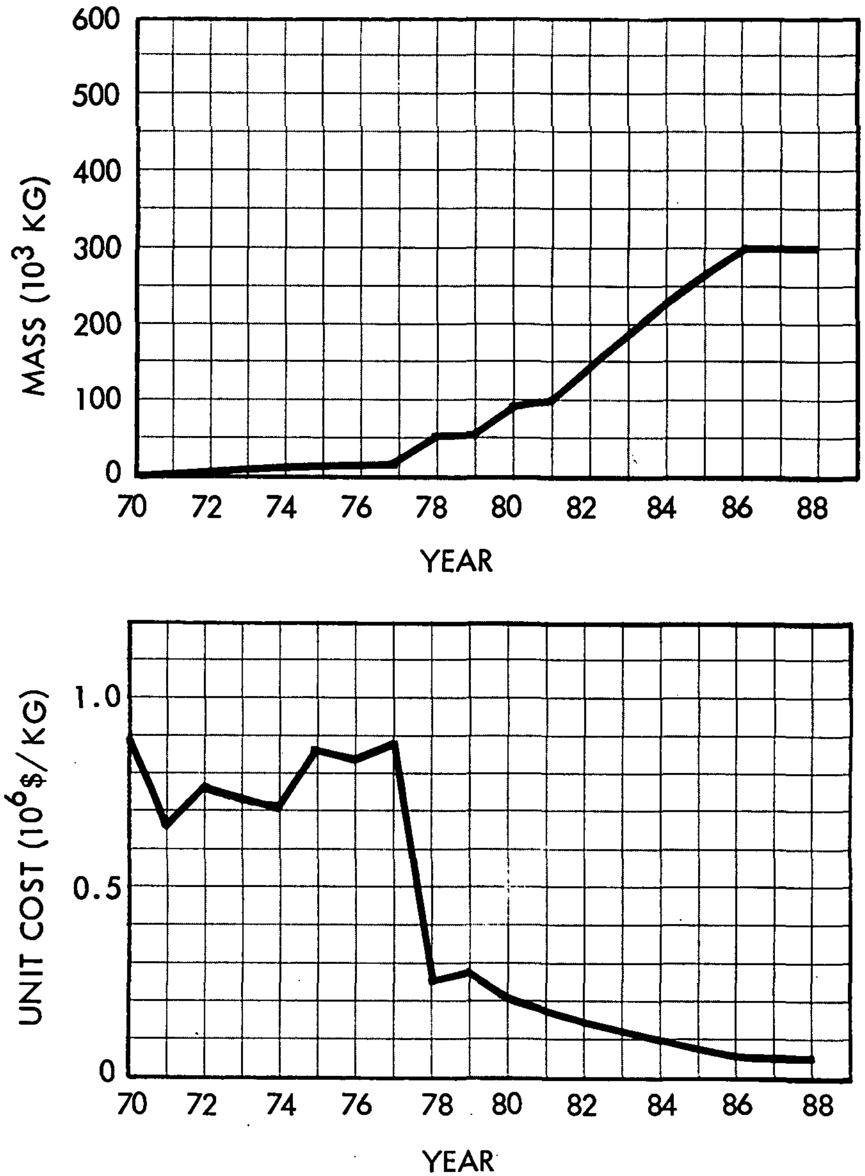
(a) One 1351-03 used to deliver 1-m optical telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY

SCIENTIFIC MANHOURS



SCIENTIFIC EQUIPMENT MASS



SUMMARY OF LUNAR EXPLORATION PROGRAM A-VId

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the large scientific program (Scientific Program A) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. A second evolutionary step introduces an uprated Saturn (125% Saturn V) and a direct logistics landing vehicle (LLV). The final step is to introduce the 200% Saturn V at the earliest practicable date.

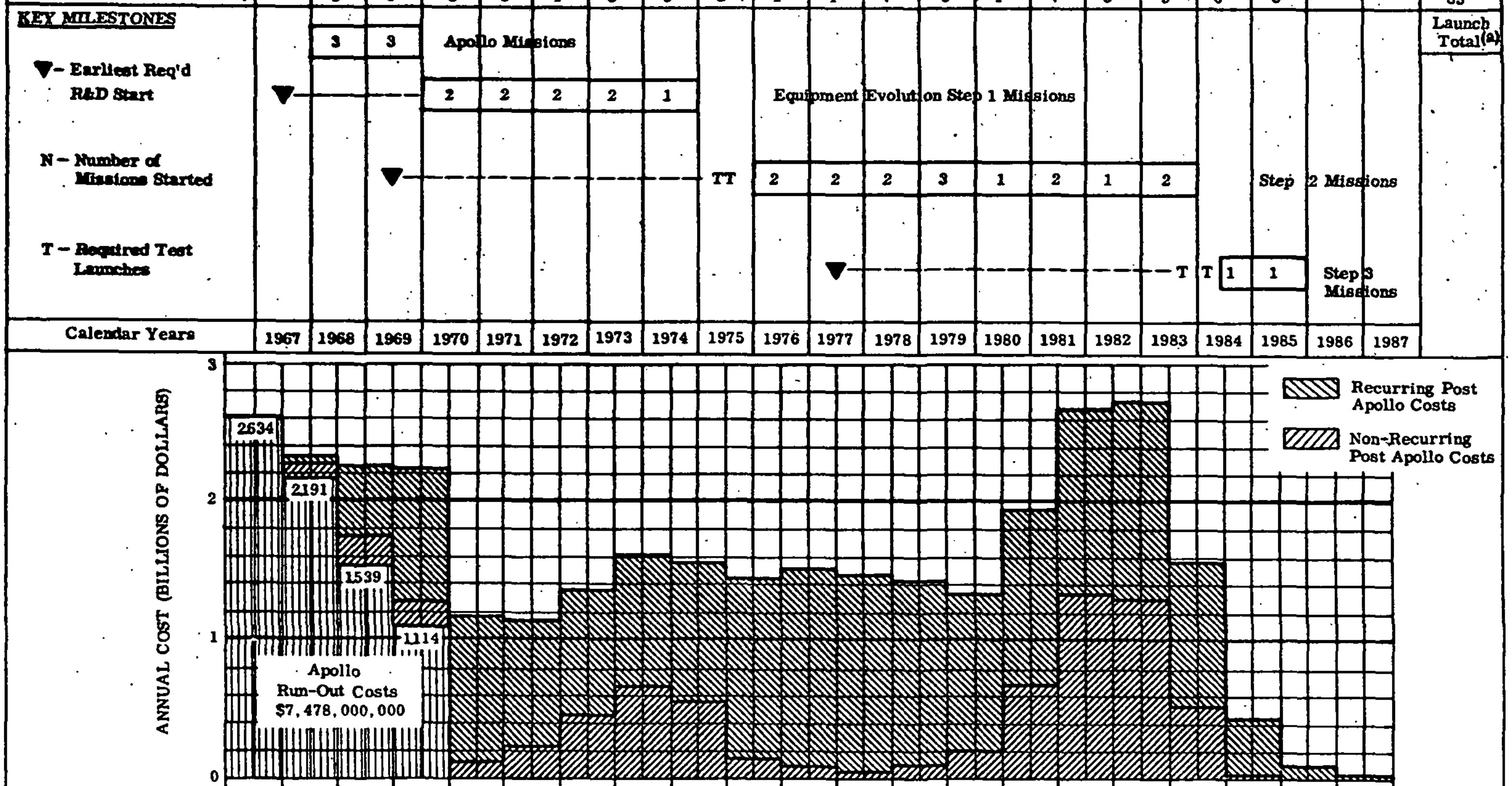
Eight locales are to be visited in the preferred order 17, 26, 11, 21, 16, 5, 2, and 18. Twenty different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. The target funding rate is 1 to 2 billion dollars per year. Transportation system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

As developed within these constraints, exploration program A-VId introduces the 125% Saturn and the LLV in 1976 and the 200% Saturn in 1984. The program is completed with a large astronomy mission to Grimaldi, beginning in late 1984 and requiring 10 launches. The total number of Saturn launches is 83, including 6 Apollo missions and 4 test launches (2 each for the 2 Saturn upratings). The total post-Apollo cost is 25.6 billion dollars spread over a period of about 18 years. The program indicates a cost of about 2 billion dollars for introducing the 125% Saturn, the LLV, and associated hardware systems. Funds must be committed in 1969. A further commitment of the order of 3 billion dollars for introduction of the 200% Saturn and related systems must be made in about 1977.

COST AND SCHEDULE SUMMARY

LAUNCH RATE	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total[(a)]
		3	3	3	3	4	3	3	2	4	4	7	8	4	7	5	9	6	5			83



POST APOLLO COSTS	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
	TOTAL (MILLIONS)	5	170	730	1121	1183	1177	1387	1601	1583	1422	1501	1488	1410	1342	1934	2698	2747	1581	450	90	15	25,635
Non-Recur	R&D	5	92	233	165	113	199	406	624	575	164	59	20	72	187	628	1216	1258	537	3			6556
Non-Recur	C OF F		1	1		2	5	31	30		1	2	4	9	11	49	110	30					286
Recurring	PROCUREMENT		77	485	862	865	786	791	730	871	1058	1209	1160	957	888	994	1107	1118	792	246			14,996
Recurring	OPERATIONS			11	94	203	187	159	217	137	199	231	304	372	256	263	265	341	252	201	90	15	3797

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

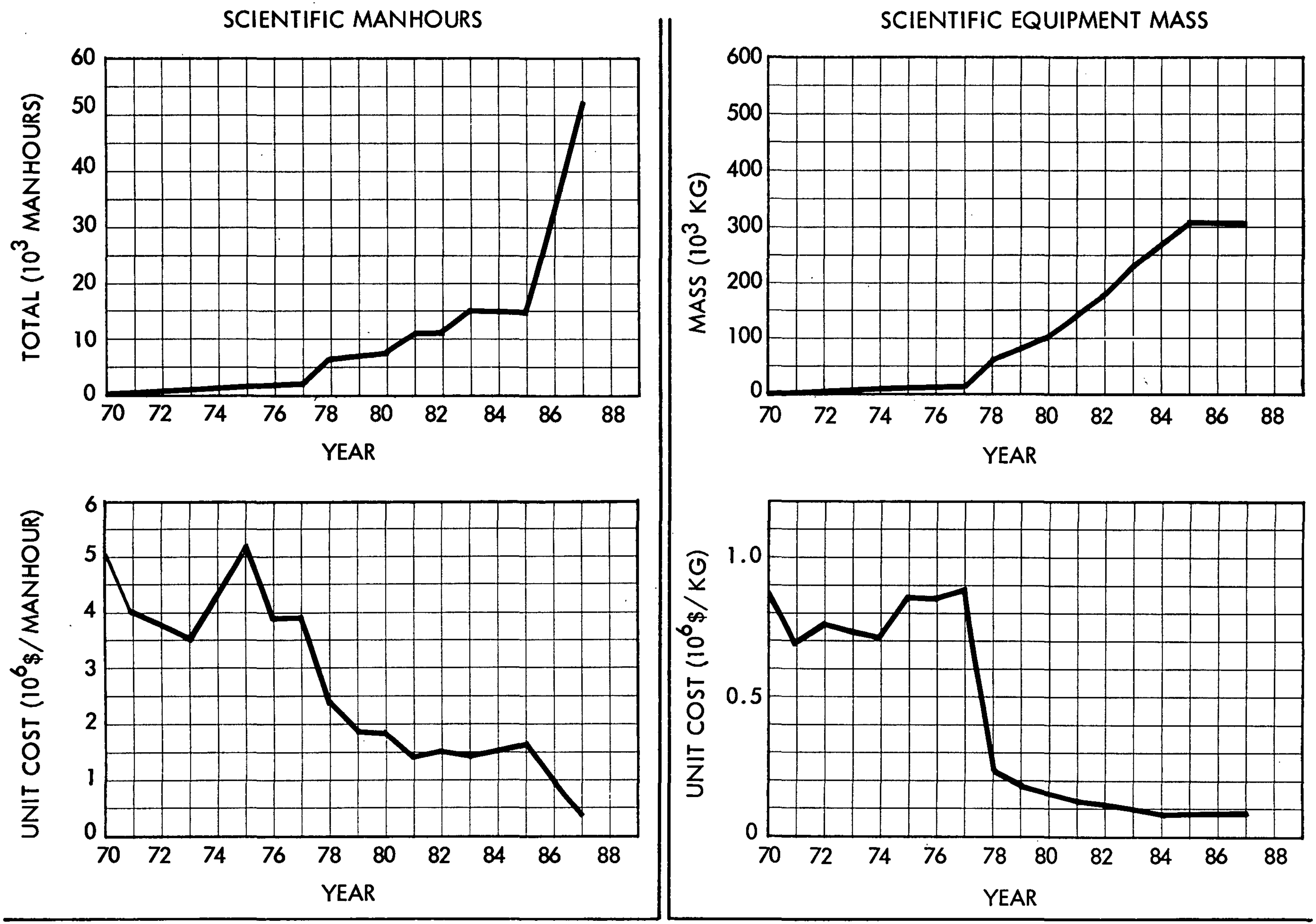
Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-02	1	–	9	636	212	[illegible]	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	15	729	180	4716	575	381	150
9	71A	Moltke B	402-10011-01	2	26	16	733	180	4719	575	378	150
10	71B	Orbiter 2	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
11	72A	Tycho	402-10011-03	2	11	16	780	197	4173	482	920	150
12	72B	First Visit to Grimaldi, Astronomical Location	402-10011-03	2	21	16	747	190	4221	581	855	90
13	73B	Orbiter 3	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
14	73B	South Pole	402-10011-03	2	16	18	837	213	4165	458	973	150
15	74B	Second Visit to Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
16	76A	Capella M	503-20162-01	2	s	10	678	204	10,502	623	6798	300
17	76B	Copernicus–Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n – 5	27	1937	809	11,135	1235	5165	300
18	77A	Southeast Serenitatis	503-20162-01	2	r	10	661	199	10,482	602	5818	300
19	77B	Mare Crisium	503-20162-01	2	q	9	647	189	10,323	443	5977	300
20	78A	M Imbr, M Imbr to M Seren–N half Palus Putr to M Vapor	503-20191-01	5	a, b–N/2 c	105	7582	2372	62.608	42,024	2592	3900
21	78B	Mare Humorum	503-20162-01	2	o	15	1085	310	10,517	637	5783	600
22	79A	North Pole	503-20162-01	2	t	9	647	189	10,323	443	5977	300
23	79A	Mare Smythii	503-20162-01	2	p	27	1948	544	10,493	593	5867	1200
24	79B	Central Farside	503-20201-01	4	ℓ	48	3470	1216	48,900	29,548	0	1200
25	80A	Marius Hills to Aristarchus	503-20222-01	4	j	41	2949	998	37,499	19,331	11,401	1200
26	81A	Ptol to Alphon, C High, M Nub to St Wall–Alphon, St Wall	503-20231-01	3	f, g, h–2.16	65	4636	2192	26,822	8537	5778	2300
27	81B	Mare Orientale	503-20251-01	4	m	36	2600	1213	48,900	29.536	0	1200
28	82B	S half Palus Putr to M Vapor, M Vapor to M Tranq, Si Medii	503-20262-01	5	S/2 c, d, e	73	5226	1695	61,949	42,417	3251	2400
29	83A	Southern Highlands	503-20251-01	4	i	36	2597	1211	49,148	29,522	0	1200
30	83B	Northern Farside	503-20222-01	4	k	34	2429	748	37,209	19,094	11,691	1200
31	84B	Third Visit to Grimaldi, Astronomical Location	406-30171-01	5	21	822	118,43	37,466	118,072	75,720	0	60
32	85B	Fourth Visit to Grimaldi, Astronomical Location	406-30171-02	5	21	0	0	0	0	0	30,550	0
		Total				1493	164,12	53,266	607,496	310,676	113,769	18,650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Vehicles									
1221-01	100% Saturn V	–	71A/74B	13	2	–	–	2100	270	2370
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	72A	76A/83B	47	5	570	42	5013	967	6592
1261-01	200% Saturn V	80B	84B/85B	10	1	865	135	1520	205	2725
	Subtotal					1435	177	8633	1442	11,687
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/74B	13	2	–	–	1231	288	1519
1311-02/1321-04	CSM – LOR – Three-Man	73B	76A/83B	15	2	76	–	1377	323	1776
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/74B	6	1	32	–	348	85	425
1332-02/1342-01	LM Taxi – Three-Man	72B	76A/83B	15	2	246	–	919	213	1378
1412-02/1452-01	CSM – Direct – Six-Man	80B	84B/–	1	1	830	10	254	39	1133
1421-03/1431-04	Personnel Braking and Landing Stages	79B	84B/–	1	1	459	24	37	5	525
1423-02/1433-02	LLV – 125% Saturn V	71B	76A/83B	32	4	599	24	669	122	1414
1423-05/1433-05	LLV – 200% Saturn V	80A	84B/85B	9	1	687	24	230	36	977
	Subtotal					2929	82	5065	1111	9187
	Mission Equipment									
2121-01	Orbit-Launched Probe	68B	70A/73B	7	1	58	–	26	2	86
2132-02	Surface-Launched Probe	74B	78A/83B	20	2	38	–	46	4	88
2222-02	Orbiter Rack	67B	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74B	6/7[(a)]	1	217	–	318	92	627
2325-05	Shelter – Six-Man	79B	84B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/73B	7	1	58	2	39	4	103
2423-03	LRV – Three-Man – 90 Days	69B	76A/84B	16	2	421	2	347	27	797
2433-04	Trailer – Large Multipurpose	75A	78A/84B	9	1	52	3	84	2	141
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2521-02	LFV – Return to Orbit	74A	78A/83A	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	78A	84B/–	1	1	136	20	28	–	184
	Subtotal					1575	27	1004	145	2751
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	74B	78A/83A	5	1	11	–	11	–	22
3223-01	15-m Parabolic Radio Telescope	80B	84B/–	1	1	4	–	4	–	8
3224-02	Radio Telescope – Mills Cross	79A	84B/–	1	1	30	–	4	1	35
3231-01	X-Ray Telescope	77B	84B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	70A	74B/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78B	84B/–	1	1	152	–	25	1	178
3243-01	2.5-m Optical Telescope	77B	84B/–	1	1	227	–	35	1	263
	Subtotal					492	–	96	5	593
	Total					6431	286	14,798	2704	24,218

(a) One 1351-03 used to deliver 1-m optical telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM A-VIe

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the large scientific program (Scientific Program A) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. A further evolutionary step introduces an uprated Saturn (150% Saturn V) and a direct logistics landing vehicle (LLV).

Eight locales are to be visited in the preferred order 17, 26, 11, 21, 16, 5, 2, and 18. Twenty different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Annual program costs are intended to be about 1 to 2 billion dollars. Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. Transportation system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

As developed within these constraints, exploration program A-VIe introduces the 150% Saturn and the LLV in 1976. The program is completed with a large astronomy mission to Grimaldi, beginning in late 1984 and requiring 17 launches. The total number of Saturn launches is 84, including 6 Apollo missions and 2 test launches for the Saturn uprating. The total post-Apollo cost is 23.2 billion dollars spread over a period of about 19 years. The program indicates a cost of about 2 billion dollars for introduction of the 150% Saturn, the LLV,and related systems. Funds must be committed in 1969.

COST AND SCHEDULE SUMMARY

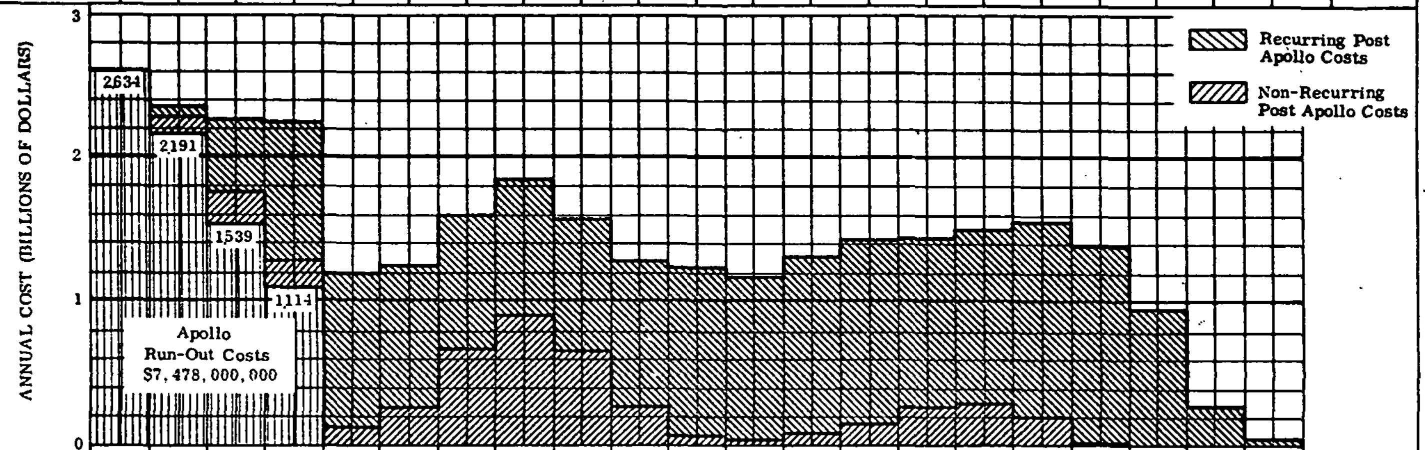
Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
LAUNCH RATE		3	3	3	3	4	3	3	2	4	4	6	4	7	7	4	7	8	8	1		84
Apollo Missions		3	3																			
Equipment Evolution Step 1 Missions	▼			2	2	2	2	1														
Step 2 Missions			▼						T T	2	2	2	2	2	2	1	2	1	1	1		

KEY MILESTONES

▼ – Earliest Req'd R&D Start

N – Number of Missions Started

T – Required Test Launches



		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS		TOTAL (MILLIONS)	5	170	730	1121	1191	1234	1594	1831	1588	1283	1234	1186	1337	1442	1460	1528	1587	1400	962	279	38	23,200
	Non-Recur	R&D	5	92	233	165	120	246	571	841	633	164	59	20	72	155	264	303	208	28				4179
		C OF F		1	1		3	15	67	58		1	1	4	9	7								167
	Recurring	PROCUREMENT		77	485	862	865	786	797	715	821	942	966	921	1034	982	902	983	1093	1103	588	15		14,937
		OPERATIONS			11	94	203	187	159	217	134	176	208	241	222	298	294	242	286	269	374	264	38	3917

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

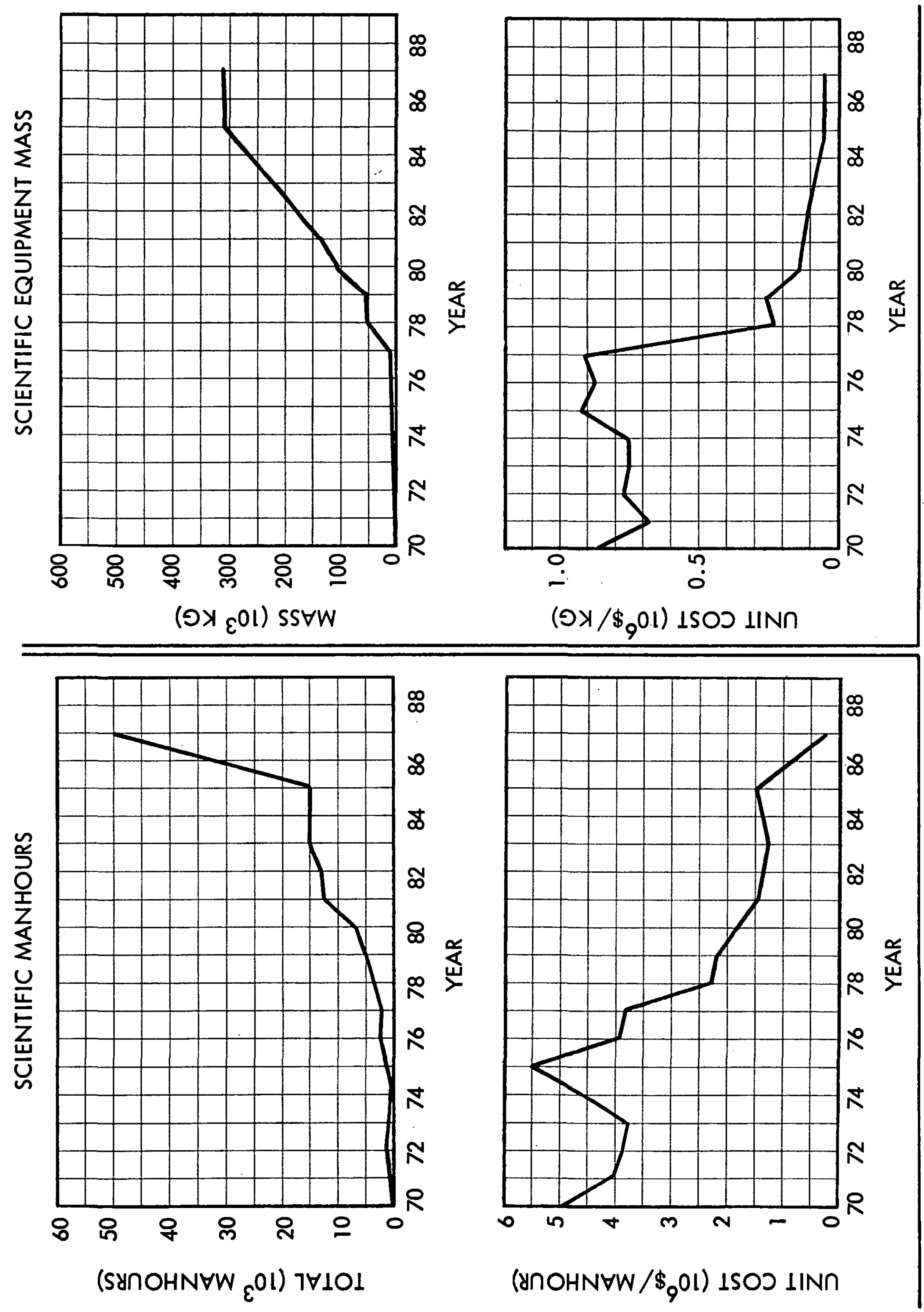
Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-02	1	–	9	636	212	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	15	729	180	4716	575	381	150
9	71A	Moltke B	402-10011-01	2	26	16	733	180	4719	575	378	150
10	71B	Orbiter 2	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
11	72A	Tycho	402-10011-03	2	11	16	780	197	4173	482	920	150
12	72B	First Visit to Grimaldi, Astronomical Location	402-10011-03	2	21	16	747	190	4221	581	855	90
13	73B	Orbiter 3	303-10022-02	1	–	9	636	212	5031	1777	(10,382)	–
14	73B	South Pole	402-10011-03	2	16	18	837	213	4165	458	973	150
15	74B	Second Visit to Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
16	76A	Capella M	503-30041-01	2	s	10	678	204	10,502	623	10,298	300
17	76B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-30041-01	2	n – 5	27	1937	809	11,135	1235	9665	300
18	77A	Southeast Serenitatis	503-30041-01	2	r	10	661	199	10,482	602	10,318	300
19	77B	Mare Crisium	503-30041-01	2	q	9	647	189	10,323	443	10,477	300
20	78A	M Imbr,M Imbr to M Seren – N half P Putr to M Vapor	503-30051-01	4	a,b–N/2 c	105	7582	2372	62,708	42,024	0	3900
21	78B	Mare Humorum	503-30041-01	2	0	15	1085	310	10,517	637	10,283	600
22	79A	North Pole	503-30041-01	2	t	9	647	189	10,323	443	10,477	300
23	79B	Mare Smythii	503-30041-01	2	p	27	1948	544	10,493	593	10,307	1200
24	80A	Central Farside	503-30071-01	4	ℓ	48	3470	1216	49,578	29,548	12,822	1200
25	80B	Marius Hills to Aristarchus	503-30091-01	3	j	41	2949	998	37,499	19,331	4101	1200
26	81A	Ptol to Alphon,C High,M Nub to St Wall – Alphon,St Wall	503-30091-01	3	f,g,h–2,18	65	4636	2192	26,822	8539	14,778	2300
27	81B	Mare Orientale	503-30111-01	4	m	36	2600	1213	49,162	29,536	13,238	1200
28	82B	S half P Putr to M Vapor,M Vapor to M Tranq,Si Medii	503-30111-01	4	S/2c,d,e	73	5226	1695	61,949	42,417	451	2400
29	83A	Southern Highlands	503-30111-01	4	i	36	2597	1211	49,148	29,522	13,252	1200
30	83B	Northern Farside	503-30091-01	3	k	34	2429	748	37,209	19,094	4391	1200
31	84B	Third Visit to Grimaldi, Astronomical Location	406-30181-01	8	21	822	118,432	37,466	118,801	75,720	5999	60
32	85B	Fourth Visit to Grimaldi, Astronomical Location	406-30181-02	8	21	0	0	0	0	0	20,800	0
33	86A	Fifth Visit to Grimaldi, Astronomical Location	406-30181-03	1	21	0	0	0	0	0	0	0
		Total				1493	164,122	53,266	609,265	310,676	1[illegible]5,847	18,650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/74B	13	2	–	–	2100	270	2370
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1241-01	150% Saturn V	72A	76A/86A	60	6	595	80	6605	1228	8508
	Subtotal					595	80	8705	1498	10,878
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/74B	13	2	–	–	1231	288	1519
1331-01/1341-01	LM Taxi – Two Man	67B	70B/74B	6	1	32	–	348	85	465
1411-02/1453-01	CSM – Direct – Three-Man	72A	76A/85B	25	3	352	12	2260	532	3156
1421-01/1431-01	Personnel Braking and Landing Stages	71A	76A/85B	25	3	459	24	388	76	947
1423-03/1433-03	Logistic Braking and Landing Stages	71B	76A/86A	35	4	599	24	713	133	1469
	Subtotal					1442	60	4940	1114	7556
	Mission Equipment									
2121-01	Orbit-Launched Probe	68B	70A/73B	7	1	58	–	26	2	86
2132-02	Surface-Launched Probe	74B	78A/83B	20	2	38	–	46	4	88
2222-02	Orbiter Rack	67B	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74A	6/7[(a)]	1	217	–	318	92	627
2325-05	Shelter – Six-Man	79B	84B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/73B	7	1	58	2	39	4	103
2423-03	LRV – Three-Man – 90 Days	69B	76A/84B	16	2	421	2	347	27	797
2433-04	Trailer – Large Multipurpose	75A	78A/84B	9	1	52	3	84	2	141
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2521-02	LFV – Return To Orbit	74A	78A/83A	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	78A	84B/–	1	1	136	20	28	–	184
	Subtotal					1575	27	1004	145	2751
	Major Scienific Equipment									
3213-02	300-m Drill – Fuel Cell	74B	78A/83A	5	1	11	–	11	–	22
3223-01	15-m Radio Telescope	80B	84B/–	1	1	4	–	4	–	8
3224-02	Radio Telescope – Mills Cross	79A	84B/–	1	1	30	–	4	1	35
3231-01	X-Ray Telescope	77B	84B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	70A	74B/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78B	84B/–	1	1	152	–	25	1	178
3243-01	2.5-m Optical Telescope	77B	84B/–	1	1	227	–	35	1	263
	Subtotal					492	–	96	5	593
	Total					4104	167	14,745	2762	21,778

(a) One 1351-03 used to deliver 1-m telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM B-IIIc

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium-sized scientific program (Scientific Program B) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step introduces an uprated Saturn (125% Saturn V) and an uprated LM/Truck. A final step introduces a direct logistics landing vehicle (LLV).

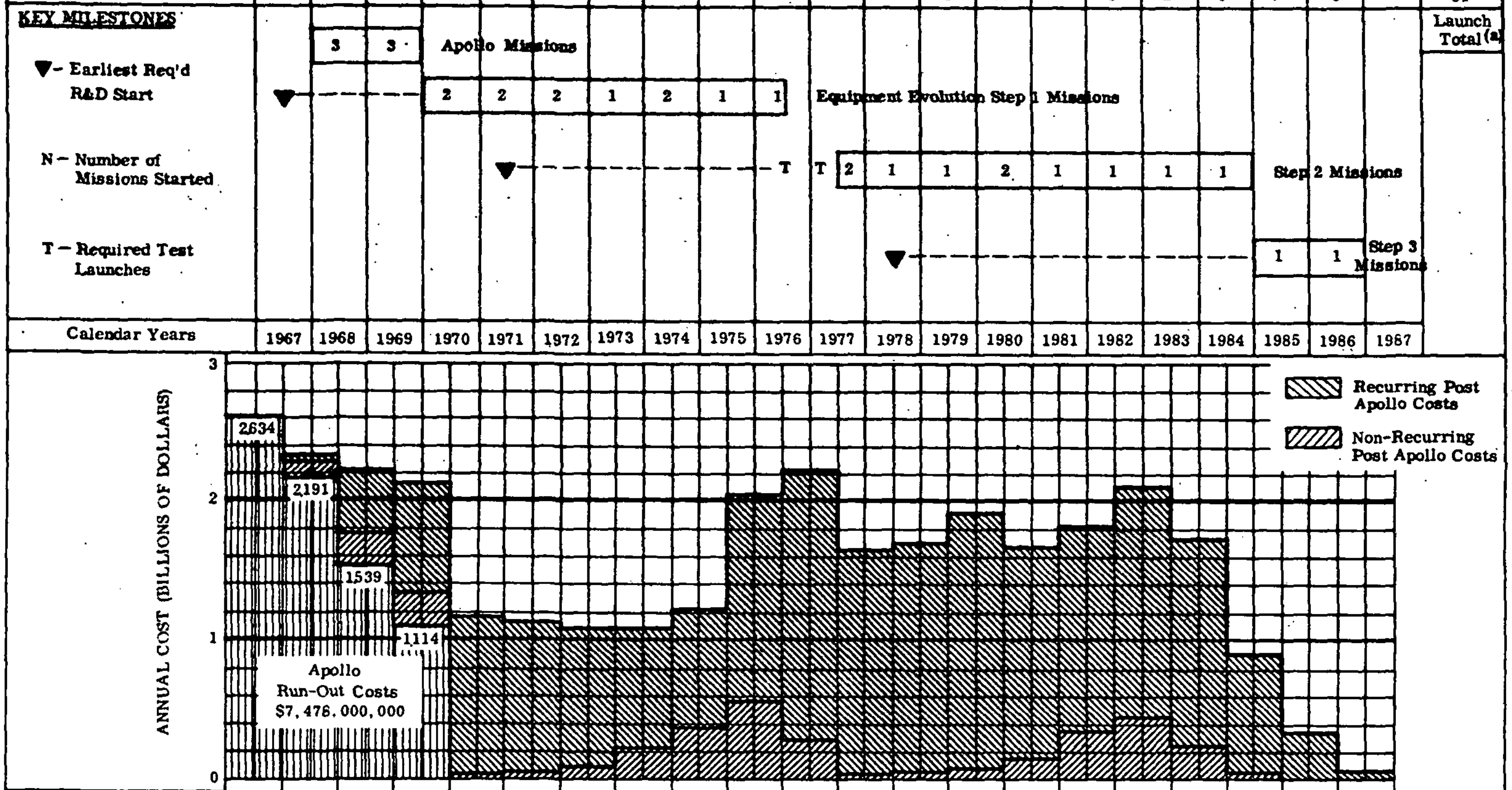
Seven locales are to be visited in the preferred order 17, 26, 21, 5, 2, 18, and 28. Eleven different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Annual program costs are aimed at 1 to 2 billion dollars. Nominal launch rates are three or four per year through 1975, four per year through 1977, and six to eight per year thereafter. The first two post-Apollo mission transportation systems are included in the Apollo run-out costs.

As developed within these constraints, exploration program B-IIIc introduces the 125% Saturn and the uprated LM/Truck in 1977 and the LLV in 1985. The program is completed with a large astronomy mission to Grimaldi, beginning in early 1985 and requiring 12 launches. The total number of Saturn launches is 84, including 6 Apollo missions and 2 test launches (for the Saturn uprating). The total post-Apollo cost is 25.9 billion dollars spread over a period of about 18 years. The program indicates a cost of about 0.6 billion dollars for development of the uprated LM/Truck and an additional 0.6 billion dollars for development of the LLV. Development funding for the uprated Saturn V is 0.6 billion dollars. Funding for development of the various upratings should be committed as follows: Saturn V, 1973; uprated LM/Truck, 1973; and LLV, 1980.

COST AND SCHEDULE SUMMARY

LAUNCH RATE	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total (a)
		3	3	3	3	5	2	3	2	3	5	7	4	10	7	5	2	5	7	5		84



POST APOLLO COSTS	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
	TOTAL (MILLIONS)	5	168	707	1085	1173	1131	1098	1120	1240	2015	2205	1667	1733	1959	1704	1816	2095	1753	915	343	42	25,974
Non-Recur	R&D	5	90	205	101	9	37	86	193	366	554	296	10	13	53	168	371	456	251	13			3277
Non-Recur	C OF F		1	1				2	9	24	9			9	9	5	12	9					90
Recurring	PROCUREMENT		77	490	892	953	860	840	702	690	1356	1635	1178	1429	1476	1108	1055	1272	1068	562	112		17,755
Recurring	OPERATIONS			11	92	211	234	170	216	160	96	274	479	282	421	423	378	358	434	340	231	42	4852

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

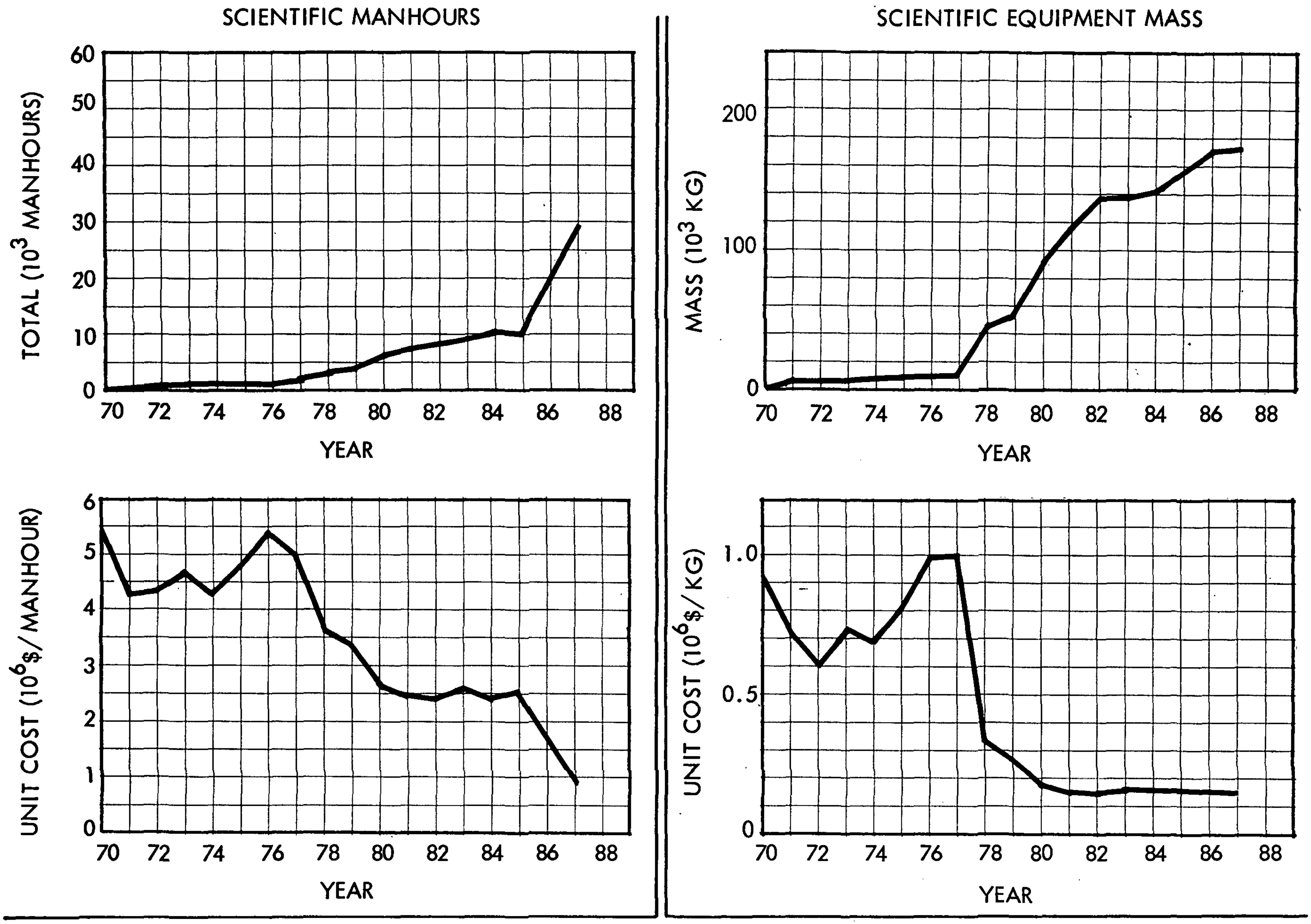
Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	*Location (paths – locales)*										
7	70A	*Apollo 7*	303-10021-01	1	–	9	636	212	3779	1737	(12,493)	0
8	70B	AAP Ranger VIII Landing Site	402-10012-01	2	17	14	649	157	4476	420	582	150
9	71A	AAP Moltke B	402-10011-01	2	26	14	653	157	4438	420	580	150
10	71B	AAP Orbiter	303-10022-01	1	–	9	636	212	3779	1737	(12,576)	0
11	72A	Grimaldi, Astronomical Location	402-10011-01	2	21	13	603	142	4365	345	673	150
12	72B	Grimaldi, Astronomical Location	402-10081-01	3	21	17	795	100	5432	2257	3812	0
13	73B	Dark Halo Craters Southeast of Copernicus	402-10011-01	2	5	14	684	166	4503	440	535	150
14	74A	AAP Orbiter	303-10022-01	1	–	9	636	212	3779	1737	(12,576)	0
15	74B	Dark Halo Craters Southeast of Copernicus	402-10011-01	2	5	12	588	138	4181	181	752	150
16	75A	Straight Wall	402-10011-01	2	18	13	631	150	4159	129	879	150
17	76A	Straight Wall	402-10011-01	2	18	14	655	157	4428	361	610	150
18	77B	Capella M	503-10026-02	2	s	13	907	271	7033	882	995	330
19	77B	Copernicus	503-10026-02	2	n	14	1030	330	7141	990	995	330
20	78A	Mare Imbrium to Mare Serenitatis	503-10026-03	7	b	57	4117	1302	38.680	29.602	4965	1650
21	79A	Southern Highlands	503-10026-05	4	i	40	2913	800	22.781	13.111	1157	1650
22	80A	Southern Highlands	503-10026-04	3	i	32	2268	768	13.490	6598	798	1100
23	80B	Central Farside	503-10026-03	7	ℓ	58	4138	1281	38.580	29.499	5065	1760
24	81B	South Pole	503-10026-03	7	u	51	3896	1148	38.335	29.337	6598	1760
25	82B	Marius Hills to Aristarchus	503-10026-06	5	j	42	3048	820	26.858	18.977	2571	1760
26	83B	Mare Orientale	503-10026-02	2	m	15	1054	341	7354	1214	0	330
27	84A	Mare Nubium to Straight Wall. Ptol to Alphon, Si Medii	503-10041-01	5	h.f.e	57	4122	1136	16.904	1742	3647	2310
28	85A	Grimaldi. Astronomical Location	403-20301-01	7	21	142	10.244	467	59,999	29,602	4343	240
29	86A	Grimaldi. Astronomical Location	403-20311-01	5	21	536	38.555	18.324	31.342	2270	1255	100
		Total				1195	83.458	28.791	348.816	173.588	40.812	14.370

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/76A	17	2	–	–	2644	342	2986
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	73B	77B/86A	56	6	570	42	5825	1153	7590
	Subtotal					570	42	8469	1495	10,576
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/76A	17	2	–	–	1576	360	1936
1311-01/1321-02	CSM – LOR – Three-Man	–	77B/84A	33	4	–	–	2847	700	3547
1311-02/1321-04	CSM – LOR – Three-Man	75A	77B/86A	17	2	76	–	1532	365	1973
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/76A	8	1	32	–	446	109	587
1332-02/1342-01	LM Taxi – Three-Man	74A	77B/86A	17	2	246	–	1018	238	1502
1351-02	Logistic Descent Stage – LOR	73B	77B/84A	33	4	99	–	691	303	1093
1423-02/1433-02	Logistic Braking and Landing Stages	80B	85A/86A	6	1	599	24	158	24	805
	Subtotal					1052	24	8268	2099	11,443
	Mission Equipment									
2132-02	Surface Probe	75A	78A/82A	10	1	38	–	24	2	64
2222-02	Orbiter Rack	68A	70A/74A	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/76A	8/9[a]	1	217	–	401	116	734
2322-08	Shelter – Three-Man	80A	85A/–	1	1	360	–	76	10	446
2421-01	LSSM	67B	70B/76A	8	1	58	2	44	5	109
2423-01	LRV – Cabin – Three-Man	71B	77B/86A	13	2	360	2	238	18	618
2432-04	Trailer – Multipurpose	74B	77B/85A	12	2	44	–	70	3	117
2512-03	LFV – Two-Man Exploration	67B	70B/76A	7	1	48	–	20	2	70
2721-02	Nuclear Power Supply – 20 kw	78B	85A/–	1	1	136	20	28	–	184
	Subtotal					1262	24	901	156	2343
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	75A	78A/81B	3	1	11	–	7	–	18
3224-01	Radio Telescope – Mills Cross	79B	85A/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	78B	85A/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	68A	72B/85A	2	1	29	–	17	2	48
3242-04	2-m Optical Telescope	79B	85A/–	1	1	152	–	25	1	178
	Subtotal					261	–	63	5	329
	Total					3145	90	17,701	3755	24,691

(a) One 1351-03 used to deliver 1-m telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM B-IVa

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium-sized scientific program (Scientific Program B) using the "path approach." Evolution of transportation systems beyond S/AA will provide a direct logistics landing vehicle and a three-man personnel delivery system with a lunar orbit rendezvous, as used with non-uprated Saturn V launch vehicles.

The target for annual program costs is about 1 to 2 billion dollars. Nominal launch rates are limited to four per year through 1975 and six to eight per year thereafter.

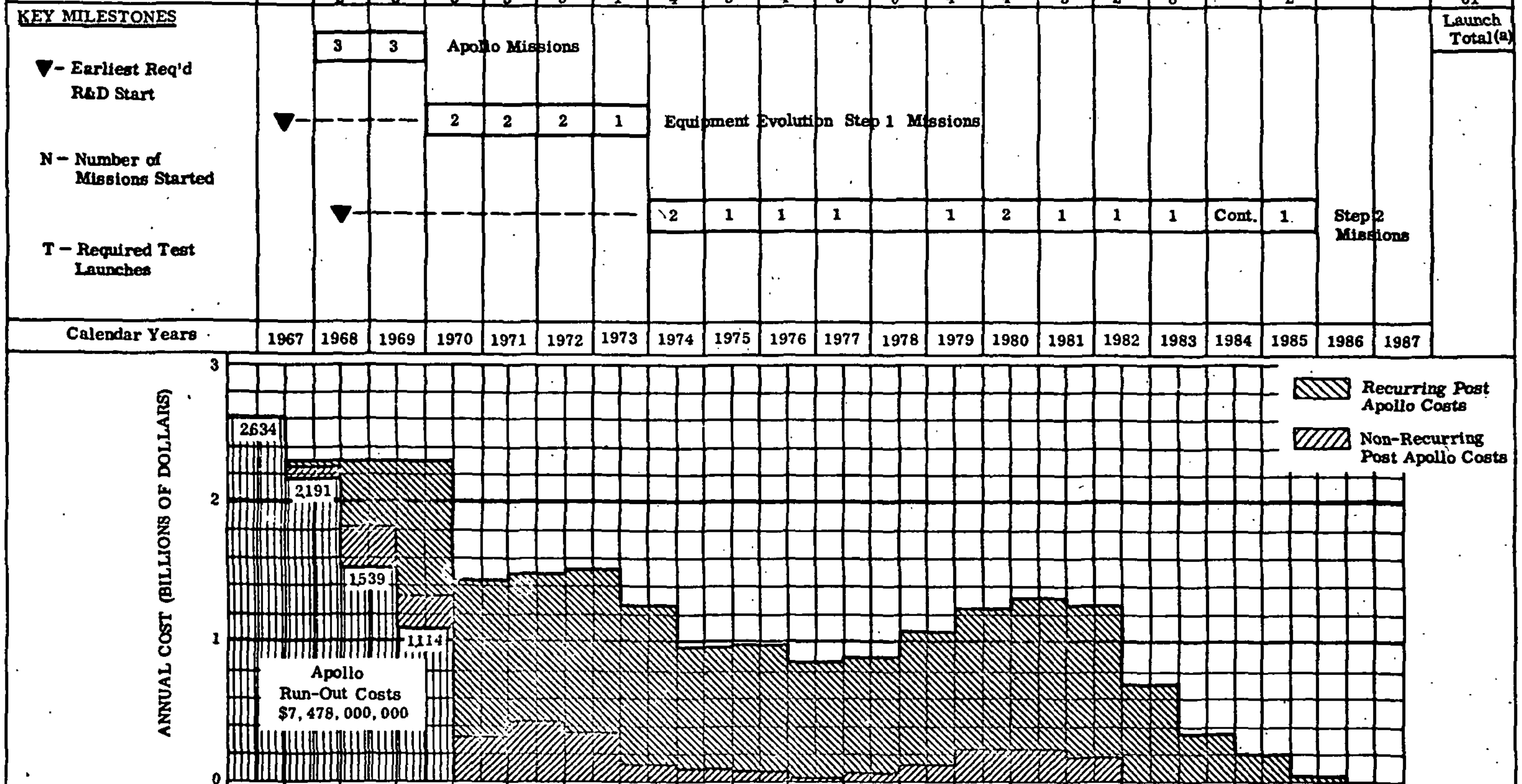
Exploration of the 7 locales and 11 paths is to begin in 1970, following the 6 Apollo missions. Seven missions are to be accomplished with S/AA hardware. The remaining missions employ a large, three-man roving vehicle as the basic mission equipment until the final astronomical mission beginning in 1983, which uses a long-term, three-man shelter. Major scientific equipment used on this program includes a 300-m drill, large x-ray and radio telescopes, and 1- and 2-m optical telescopes. Extensive seismic surveys will require that 90,000 kg of equivalent TNT explosives be delivered to the lunar surface.

Total post-Apollo cost of this program is 17.8 billion dollars spread over a period of about 17 years. A total of 61 Saturn launches is required, including 6 Apollo launches. The post-S/AA hardware will be introduced operationally in 1974, requiring a commitment in 1968 of 2 billion dollars for development.

COST AND SCHEDULE SUMMARY

LAUNCH RATE																					
Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Launch Rate		3	3	3	3	5	1	4	5	4	5	0	4	4	5	2	8		2		

Launch Total(a): 61



POST APOLLO COSTS	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
	TOTAL (MILLIONS)	5	185	784	1239	1441	1498	1514	1258	990	996	848	678	1091	1234	1335	1256	708	364	200	14	0	17,838
Non-Recur	R&D	5	107	283	259	296	411	376	113	103	86	14	53	124	211	219	99						2759
Non-Recur	C OF F		1	2	4	12	9	1	1			9	9	2									50
Recurring	PROCUREMENT		77	489	884	923	843	988	900	678	761	634	677	787	829	917	974	407	281	77			12,126
Recurring	OPERATIONS			10	92	210	235	149	244	209	149	191	139	178	194	199	183	301	83	123	14		2903

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

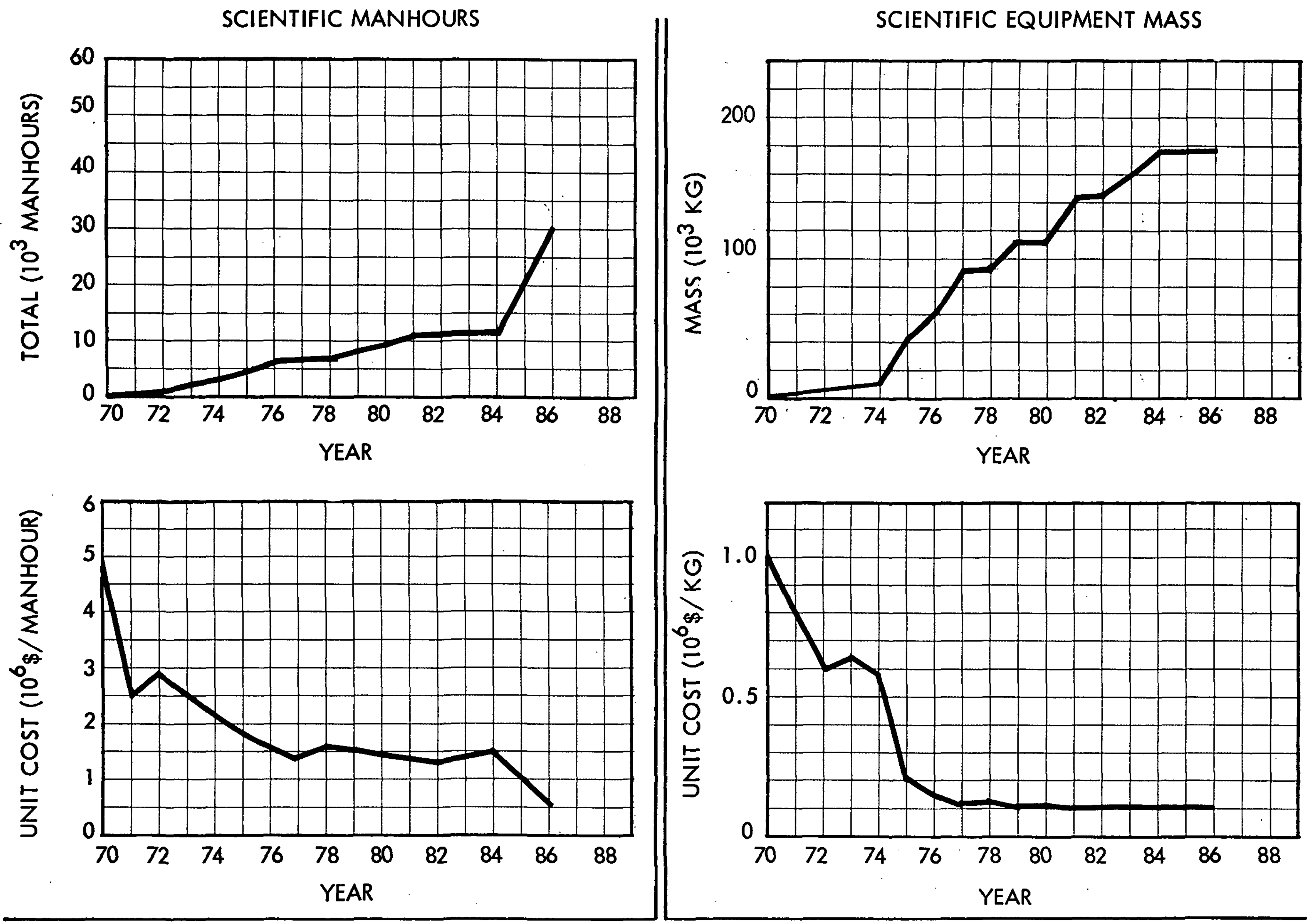
Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	2837	1737	(12,576)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	655	158	4287	430	624	150
9	71A	Moltke B	402-10011-01	2	26	15	731	180	4344	430	567	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	861	2877	1777	(12,536)	–
11	72A	Grimaldi, Astronomical Location	402-10011-01	2	21	16	762	192	4484	540	427	0
12	72B	Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	3664	2674	0
13	73B	Orbiter 3	303-10022-01	1	–	12	861	861	2877	1777	(12,356)	–
14	74A	Capella M	503-20371-01	2	s	13	905	298	10,952	952	1148	350
15	74B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20371-01	2	n – 5	26	1825	695	12,100	2250	0	500
16	75A	Mare Imbrium to Mare Serenitatis	503-20351-01	5	b	64	4596	1294	44,332	29,614	4068	2300
17	76B	Palus Putredinis to Mare Vaporum	503-20361-01	4	c	68	4884	1223	31,594	19,236	4706	2700
18	77B	Central Farside	503-20351-01	5	ℓ	65	4674	1242	44,386	29,640	4014	2600
19	79A	Marius Hills to Aristarchus	503-20361-01	4	j	53	3811	978	30,075	19,182	5225	2200
20	80A	Mare Orientale	503-20371-01	2	m	13	951	320	11,102	1102	998	350
21	80B	M Nub to St Wall – St Wall, Mare Nubium	503-20371-01	2	h – 18,28	46	3281	1125	12,100	2108	0	1400
22	81A	South Pole	503-20351-01	5	u	63	4486	1272	44,633	29,464	3767	2200
23	82B	Ptolemaeus to Alphon, Sinus Medii – Alphonsus	503-20371-01	2	f, e – 2	50	3590	1198	12,050	1958	50	1650
24	83A	Grimaldi, Astronomical Location	403-20331-01	8	21	762	55,137	18,975	88,313	31,943	8487	150
25	85A	Grimaldi, Astronomical Location	MSN-EXT-02	2	21	–	–	–	–	–	–	–
		Total				1322	93,737	31,274	369,718	177,804	37,755	16,700

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/85A	52	6	–	–	7491	1044	8535
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
	Subtotal							7491	1044	8535
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/73B	9	1	–	–	820	195	1015
1311-01/1321-03	CSM – LOR – Three-Man	71B	74A/85A	14	2	48	–	1267	301	1616
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/72B	4	1	32	–	251	61	344
1332-01/1342-01	LM Taxi – Three-Man	70B	74A/85A	14	2	234	–	842	197	1273
1423-01/1433-01	Logistic Braking and Landing Stages	69B	74A/83A	29	3	599	24	600	109	1332
	Subtotal					913	24	3780	863	5580
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/72B	4/5[a]	1	111	–	105	18	234
2322-08	Shelter – Three-Man	78A	83A/–	1	1	360	–	76	10	446
2421-01	LSSM	67B	70B/72A	3	1	58	2	21	2	83
2423-03	LRV – Three-Man – 90 Days	68A	74A/83A	11	2	421	2	256	20	699
2436-02	Trailer – Multipurpose	72A	75A/83A	6	1	275	3	24	1	303
2512-03	LFV – Two-Man Exploration	67B	70B/71A	3	1	48	–	10	1	59
2721-02	Nuclear Power Supply – 20 kw	76B	83A/–	1	1	136	20	28	–	184
	Subtotal					1410	27	520	52	2009
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	71B	75A/81A	3	1	11	–	7	–	18
3224-01	Radio Telescope – Mills Cross	77B	83A/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	76B	83A/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	68A	72B/83A	2	1	29	–	17	2	48
3242-04	2-m Optical Telescope	77B	83A/–	1	1	152	–	25	1	178
	Subtotal					261	–	63	5	329
	Total					2584	51	11,854	1964	16,453

(a) One 1351-03 used to deliver 1-m telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM B-IVb

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish a medium-sized scientific program (Scientific Program B) using the "path approach." Evolution of transportation systems beyond S/AA will result in an uprating to 125% for Saturn V launch vehicles, a direct lunar logistic vehicle, and a three-man personnel delivery system using lunar orbit rendezvous.

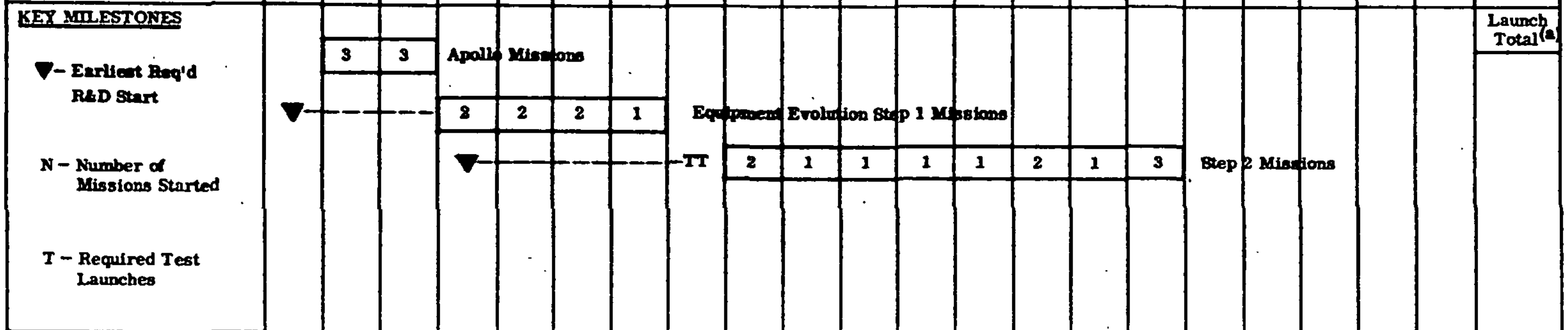
Annual costs are targeted at 1 to 2 billion dollars. Launch rates are four per year through 1975 and six to eight per year thereafter.

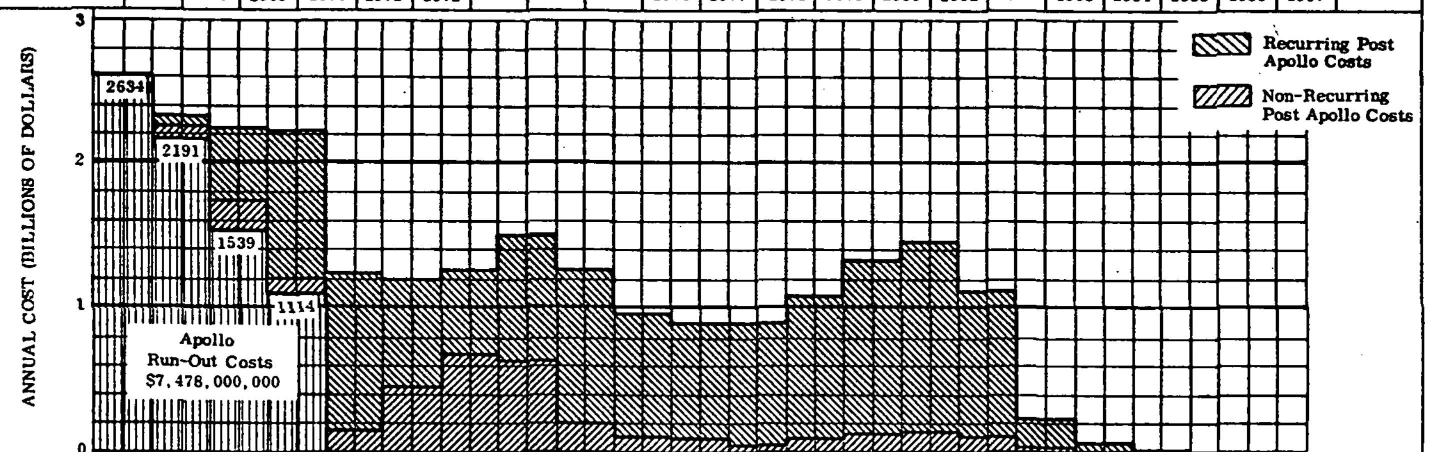
Exploration of the 7 locales and 11 paths begins in 1970, following the 6 Apollo missions. Seven missions are accomplished using S/AA hardware. The remaining missions employ a large, three-man roving vehicle as the basic mission equipment until the final astronomical mission in 1982, which uses a long-term, three-man shelter. Major scientific equipment used on this program includes a 300-m drill, large x-ray and radio telescopes, and 1- or 2-m optical telescopes. Extensive seismic surveys require that 90,000 kg of equivalent TNT explosives be delivered to the lunar surface.

The total post-Apollo cost of the program is 16.4 billion dollars spread over a period of 13 years. A total of 57 Saturn launches is required, including 2 test launches. The post-S/AA hardware is introduced operationally in 1975, requiring a commitment of 2 billion dollars by 1968.

COST AND SCHEDULE SUMMARY

LAUNCH RATE																						
Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
Launch Rate		3	3	3	3	5	1	2	4	4	3	4	3	4	4	11						57





Post Apollo Costs	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
	TOTAL (MILLIONS)	5	167	708	1097	1227	1198	1261	1512	1280	965	898	898	1070	1332	1445	1115	216	35	4			16,433
Non-Recur	R&D	5	90	206	121	161	427	668	621	197	114	142	145	232	194	73	10						3406
Non-Recur	C OF F		1	1		6	32	30	1	1	9	9	2										92
Recurring	PROCUREMENT		76	490	884	849	504	452	819	866	633	574	571	694	935	1171	751	4					10,273
Recurring	OPERATIONS			11	92	211	235	111	71	216	209	173	180	144	203	201	354	212	35	4			2662

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

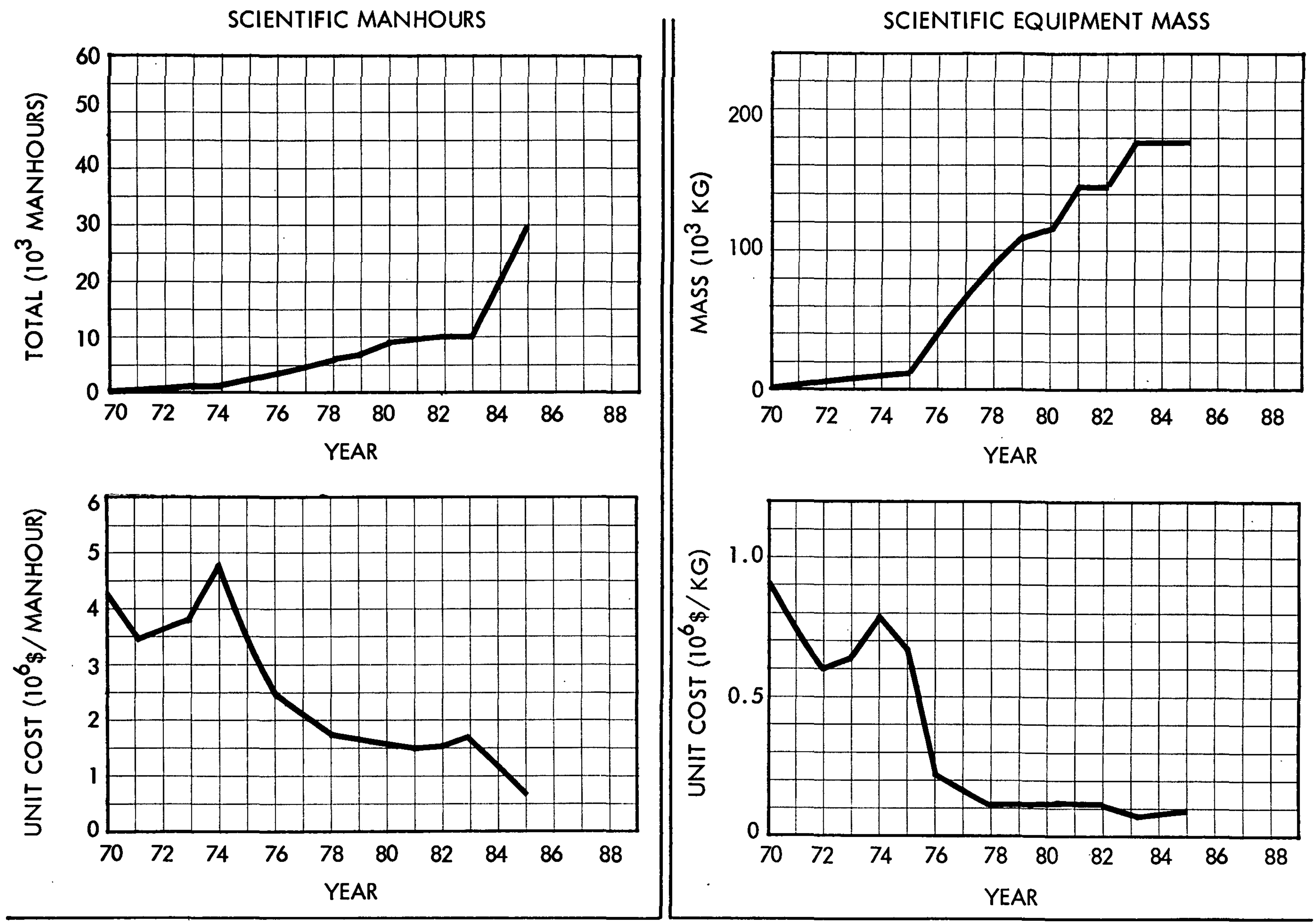
Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	2837	1737	(12,576)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	655	158	4287	430	624	150
9	71A	Moltke B	402-10011-01	2	26	15	731	180	4344	430	567	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
11	72A	Grimaldi, Astronomical Location	402-10011-01	2	21	16	762	192	4484	540	427	90
12	72B	Grimaldi, Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
13	73B	Orbiter 3	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
14	75A	Southeast Serenitatis	503-20162-01	2	r	13	905	298	10,832	952	5468	350
15	75B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n – 5	26	1825	695	12,150	2250	4150	500
16	76A	Mare Imbrium to Mare Serenitatis	503-20321-01	4	b	64	4596	1294	43,732	29,614	5168	2300
17	77A	Palus Putredinis to Mare Vaporum	503-20311-01	3	c	68	4884	1223	31,492	19,236	1108	2700
18	78A	Central Farside	503-20321-01	4	ℓ	65	4674	1242	43,615	29,640	5285	2600
19	79A	Marius Hills to Aristarchus	503-20311-01	3	j	53	3811	978	31,375	19,182	1225	2200
20	80A	Mare Orientale	503-20162-01	2	m	13	951	320	10,982	1102	5318	350
21	80B	M Nub to St Wall – Straight Wall, Mare Nubium	503-20162-01	2	h – 18,28	46	3281	1125	8143	2180	4157	1400
22	81A	South Pole	503-20321-01	4	u	63	4488	1272	43,472	29,464	5428	2200
23	82A	Ptolemaeus to Alphonsus, Sinus Medii – Alphonsus	503-20162-01	2	f,e – 2	50	3590	1198	7930	1958	4370	1650
24	82B	Grimaldi, Astronomical Location	503-20301-01	8	21	762	55,137	18,975	77,983	31,843	3517	150
25	82B	Grimaldi, Astronomical Location	MSN-EXT-04	1	21	–	–	–	–	–	–	–
		Total				1322	93,737	30,126	349,787	176,519	50,486	16,790

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/73B	9	1	–	–	1419	180	1599
1221-03	100% Saturn V (Apollo funded)	–	66A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	71A	75A/82B	37	4	570	42	4098	765	5475
	Subtotal					570	42	5517	945	7074
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/73B	9	1	–	–	827	192	1019
1311-02/1321-04	CSM – LOR – Three-Man	72B	75A/82B	15	2	76	–	1381	326	1783
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/72B	4	1	32	–	251	61	344
1332-02/1342-01	LM Taxi – Three-Man	71B	75A/82B	15	2	246	–	924	214	1384
1423-02/1433-02	Logistic Braking and Landing Stages	70B	75A/82B	22	3	599	24	486	85	1194
	Subtotal					953	24	3869	878	5724
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/72B	4/5[a]	1	217	–	235	68	520
2322-08	Shelter – Three-Man	77B	82B/ –	1	1	360	–	76	10	446
2421-01	LSSM	67B	70B/82B	4	1	58	2	26	3	89
2423-03	LRV – Three-Man – 90 Days	70A	75A/82B	11	2	421	2	254	20	697
2436-02	Trailer – Multipurpose	73A	76A/82B	6	1	275	3	24	1	303
2512-03	LFV – Two-Man Exploration	67B	70B/72A	3	1	48	–	10	1	59
2721-02	Nuclear Power Supply – 20 kw	76A	82B/ –	1	1	136	–	76	10	222
	Subtotal					1516	7	701	113	2337
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	72B	76A/81A	3	1	11	–	7	–	18
3224-01	Radio Telescope – Mills Cross	77A	82B/ –	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	76A	82B/ –	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	68A	72B/82B	2	1	29	–	17	2	48
3242-04	2-m Optical Telescope	77A	82B/ –	1	1	152	–	25	1	178
	Subtotal					261	–	63	5	329
	Total					3300	73	10,150	1941	15,464

(a) One 1351-03 used to deliver 1-m telescope.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM B-Va

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium-sized scientific program (Scientific Program B) using the "path approach." Evolution of transportation systems beyond S/AA starts with use of a direct logistics landing vehicle (LLV) and a three-man personnel delivery system on the standard non-uprated Saturn V, and then progresses through an uprating to the 175% Saturn V, a large LLV, and six-man direct-delivery systems.

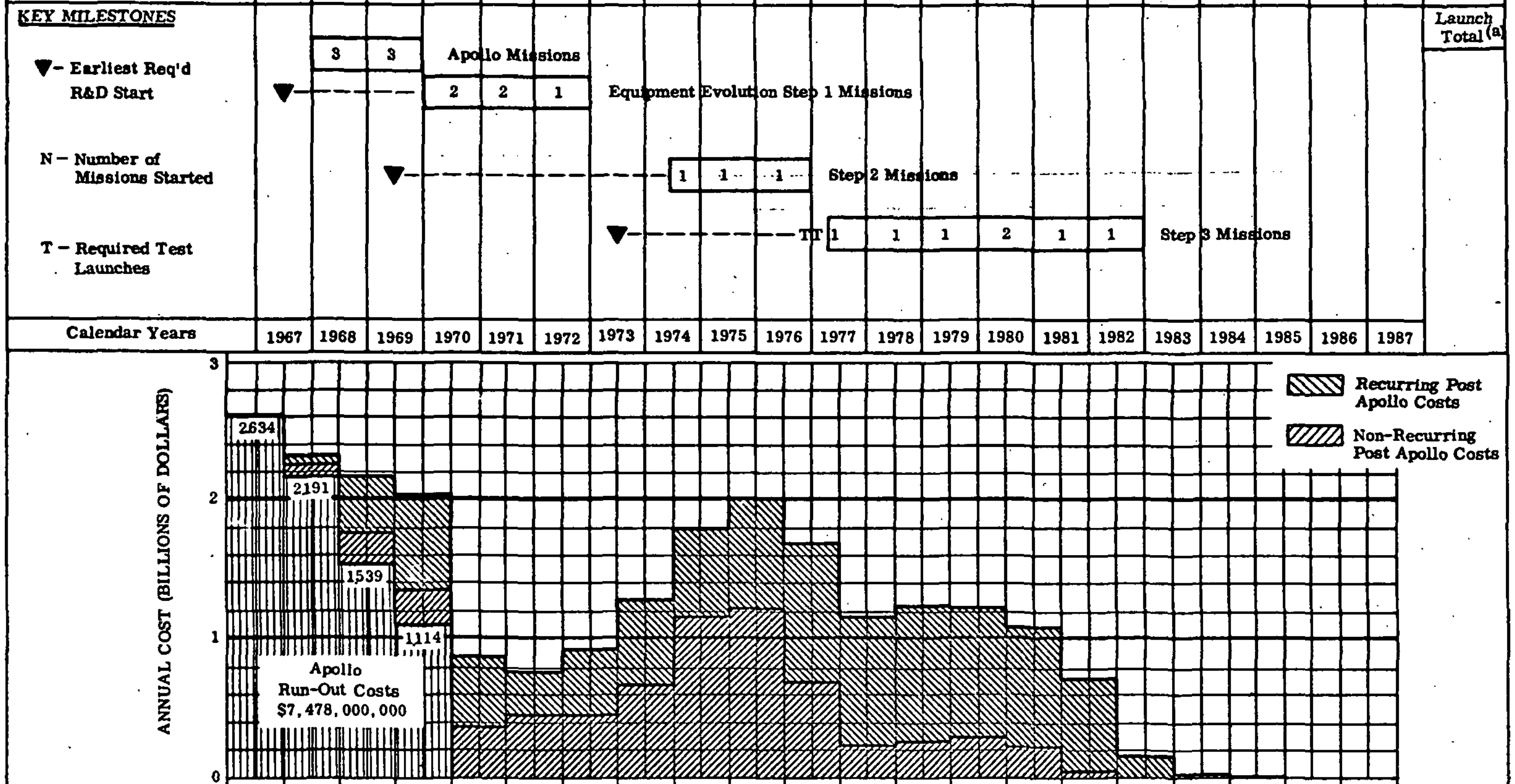
Nominal annual program costs are 1 to 2 billion dollars. Launch rates are limited to four per year through 1975 and six to eight per year thereafter.

Exploration of the 7 locales and 11 paths is to begin in 1970, following the 6 Apollo missions. Seven missions are to be accomplished using S/AA hardware. The remaining missions employ a large, three-man roving vehicle as the basic mission equipment until the final astronomical mission in 1982, which uses a long-term, six-man shelter. Major scientific equipment used on this program includes a 300-m drill, large x-ray and radio telescopes, and 1- and 2-m optical telescopes. Extensive seismic surveys require that 90,000 kg of equivalent TNT explosives be delivered to the lunar surface.

The total post-Apollo cost of the program is 16.9 billion dollars spread over a period of about 15 years. A total of 44 Saturn launches is required, including 2 test launches. The first step in the evolution of post-S/AA hardware is introduced operationally in 1974, requiring a commitment of 1.5 billion dollars by 1969. The second step is employed in 1977; its development cost is 3 billion dollars starting in 1972.

COST AND SCHEDULE SUMMARY

Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total (a)
LAUNCH RATE		3	3	3	3	1		2	2	3	4	2	3	7	2	6						44



	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS	TOTAL (MILLIONS)	5	167	659	937	877	782	929	1289	1798	2023	1723	1191	1249	1247	1105	755	170	30	11			16,947
Non-Recur	R&D	5	89	213	238	357	432	443	633	1066	1185	715	213	265	299	223	52	6					6434
Non-Recur	C OF F		1	2	8	20	7	6	51	112	32	5	9	7	2	1							263
Recurring	PROCUREMENT		77	433	599	325	279	433	519	495	705	857	796	783	711	720	466	8					8206
Recurring	OPERATIONS			11	92	175	64	47	86	125	101	146	173	194	235	161	237	156	30	11			2044

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

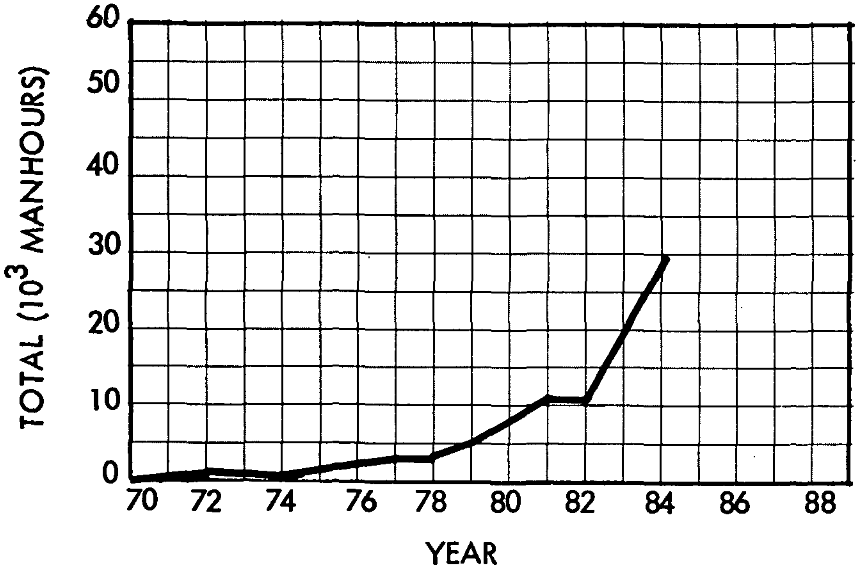
Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths - locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	2837	1737	(12,576)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	655	158	4287	430	624	150
9	71A	Moltke B	402-10011-01	2	26	15	731	180	4344	430	567	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
11	72B	Orbiter 3	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
12	74B	Capella M	503-20161-01	2	s	13	905	298	10,932	952	1168	350
13	75B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20161-01	2	n – 5	26	1825	695	12,050	2250	50	500
14	76B	Mare Orientale	503-20161-01	2	m	13	951	320	10,982	1102	1118	350
15	77B	Marius Hills to Aristarchus	503-30132-01	3	j	53	3811	978	31,075	19,182	19,725	2200
16	78B	Grimaldi, Astronomical Location	503-30202-01	2	21	10	258	366	14,310	2968	1990	150
17	79A	Central Farside	503-30142-01	3	ℓ	65	4674	1242	43,215	29,640	7585	2600
18	80A	South Pole	503-30142-01	3	u	63	4488	1272	43,072	29,464	7728	2200
19	80B	M Imbr to M Seren, P Putr to M Vapor	503-30191-01	4	b,c	126	9031	2517	53,711	47,728	12,689	4700
20	81B	Si Medii, Ptol to Alphon, M Nub to St Wall	503-30171-01	2	e,f,h	97	6942	2320	20,770	2509	4630	3200
21	82B	Grimaldi, Astronomical Location	406-30191-02	6	21	448	64,534	18,975	66,900	31,843	12,300	150
Total						979	101,388	30,182	324,239	173,789	70,174	16,700

EQUIPMENT USAGE AND COST SUMMARY

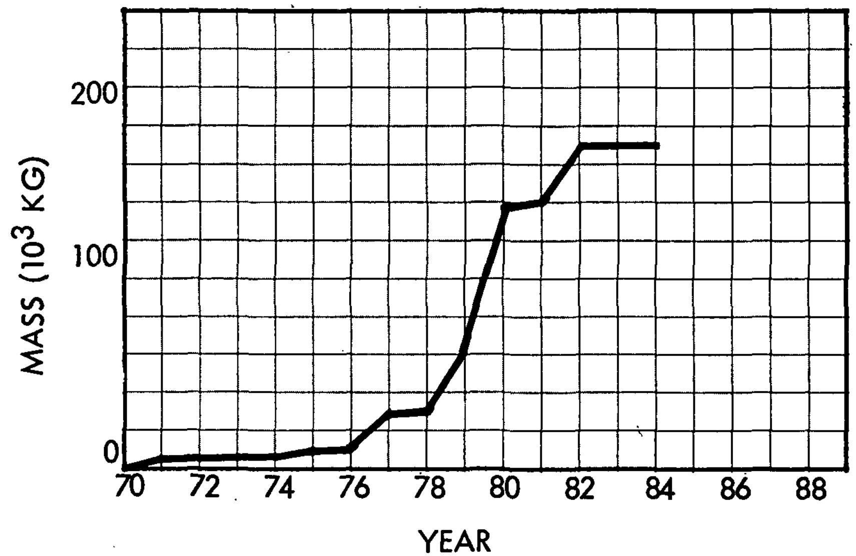
Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/76B	10	1	–	–	1555	198	1753
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1251-01	175% Saturn V	73B	77B/82B	23	3	818	135	3160	484	4597
	Subtotal					818	135	4715	682	6350
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/72B	4	1	–	–	418	96	514
1311-02/1321-03	CSM – LOR – Three-Man	72A	74B/76B	3	1	76	–	332	76	484
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/71A	2	1	32	–	152	36	220
1334-02/1342-01	LM Taxi – Three-Man	71A	74B/76B	3	1	413	12	234	50	709
1412-02/1454-01	CSM – Direct – Six-Man	73B	77B/80B	8	1	899	12	1019	176	2106
1421-02/1431-03	Personnel Braking and Landing Stages	72B	77B/80B	8	1	459	24	144	24	651
1423-01/1433-01	Logistic Braking and Landing Stages	69A	74B/76B	3	1	599	24	94	14	731
1423-04/1433-04	Logistic Braking and Landing Stages	73A	77B/82B	15	2	687	24	368	61	1140
	Subtotal					3165	96	2761	533	6555
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/72B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/71A	2	1	111	–	63	11	185
2325-05	Shelter – Six-Man	77B	82B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/71A	2	1	58	2	16	2	78
2423-01	LRV – Cabin – Three-Man	73A	79A/80A	2	1	360	2	50	4	416
2423-03	LRV – Three-Man – 90 Days	69B	74B/81B	8	1	421	2	181	14	618
2433-04	Trailer – Large Multipurpose	78B	81B/–	1	1	52	3	18	1	74
2436-02	Trailer – Multipurpose	74B	77B/82B	7	1	275	3	27	1	306
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2721-02	Nuclear Power Supply – 20 kw	77A	82B/–	1	1	136	20	28	–	184
	Subtotal					1946	32	479	45	2502
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	75B	79A/80B	3	1	11	–	7	–	18
3224-01	Radio Telescope – Mills Cross	77A	82B/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	76A	82B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	74A	78B/83B	2	1	29	–	17	2	48
3242-04	2-m Optical Telescope	77A	82B/–	1	1	152	–	25	1	178
	Subtotal					261	–	63	5	329
	Total					6190	263	8018	1265	15,736

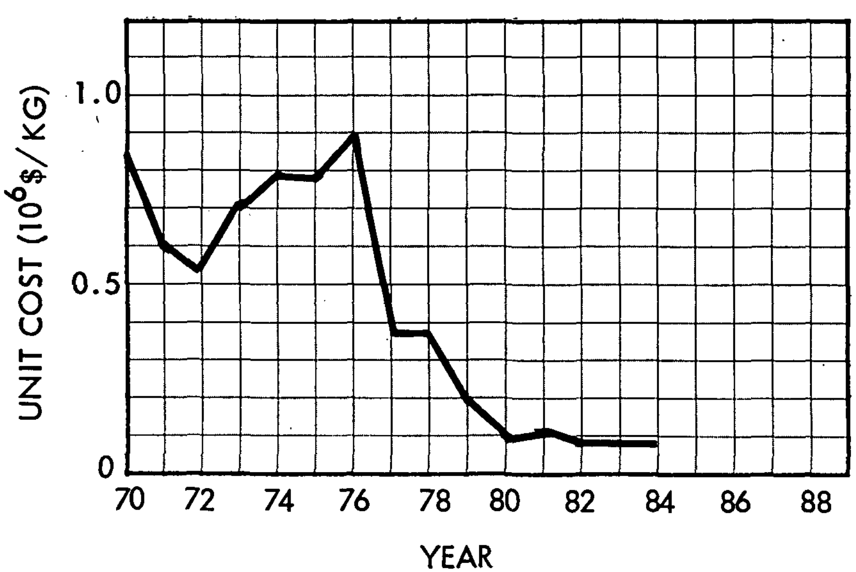
SCIENTIFIC PROGRAM OPERATIONAL SUMMARY

SCIENTIFIC MANHOURS



SCIENTIFIC EQUIPMENT MASS





SUMMARY OF LUNAR EXPLORATION PROGRAM B-VIa

GENERAL DESCRIPTION

This lunar exploration program was designed to accomplish the medium-sized scientific program (Scientific Program B) using the "path approach." Evolution of post-S/AA transportation systems will result in an uprating to 125% for Saturn V launch vehicles, a direct lunar logistics vehicle, a three-man personnel delivery system using lunar orbit rendezvous (LOR), followed by a six-man LOR delivery system.

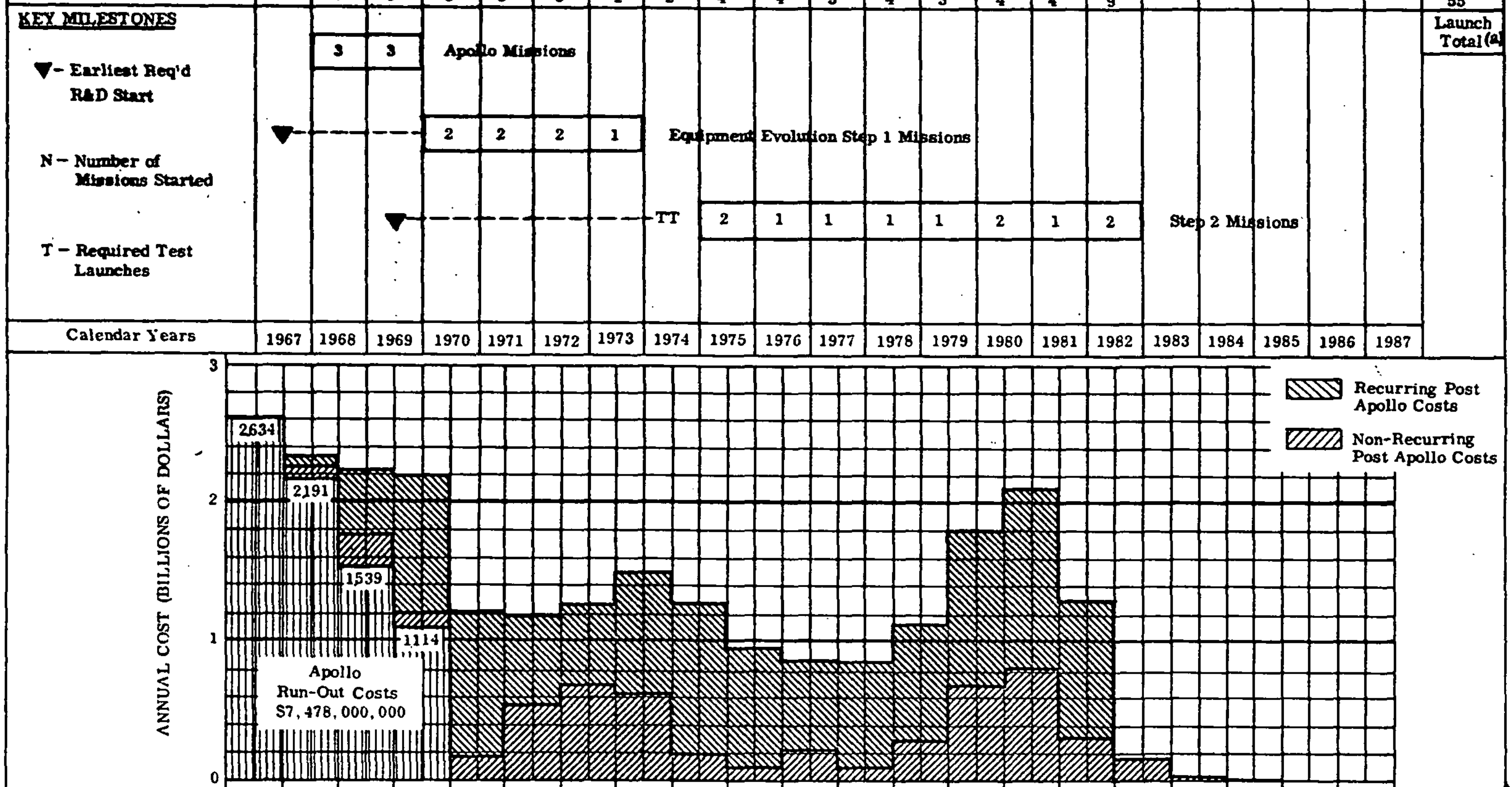
The target for annual program costs is 1 to 2 billion dollars. Launch rates are limited to four per year through 1975 and six to eight per year thereafter. Transportation system costs for the first two post-Apollo missions are included in the Apollo run-out costs.

Exploration of the 7 locales and 11 paths begins in 1970, following the 6 Apollo missions. Seven missions are accomplished using S/AA hardware. The remaining missions employ a large, three-man roving vehicle as the basic mission equipment until the final astronomical mission in 1982, which uses a long-term, six-man shelter. Major scientific equipment used on this program includes a 300-m drill, a large x-ray and radio telescopes, and 1- and 2-m optical telescopes.

The total post-Apollo cost of the program is 17.7 billion dollars spread over a period of 15 years. A total of 55 Saturn launches is required, including 2 test launches. The post-S/AA hardware is introduced operationally in 1975, requiring a commitment of 2 billion dollars by 1969.

COST AND SCHEDULE SUMMARY

LAUNCH RATE	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
		3	3	3	3	5	1	2	4	4	3	4	3	4	4	9						55



POST APOLLO COSTS	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
	TOTAL (MILLIONS)	4	167	707	1097	1227	1198	1261	1512	1281	954	869	855	1139	1804	2113	1311	176	29	3			17,707
Non-Recur	R&D	4	89	206	121	161	427	668	622	197	107	113	96	311	697	821	337	2					4979
Non-Recur	C OF F		1	1		6	32	30	1	2	5	9	8	4	5	4							108
Recurring	PROCUREMENT		77	489	884	849	504	452	819	666	633	574	571	680	899	1090	678	2					10,067
Recurring	OPERATIONS			11	92	211	235	111	70	216	209	173	180	144	203	198	296	172	29	3			2553

(a) Includes six Apollo launches.

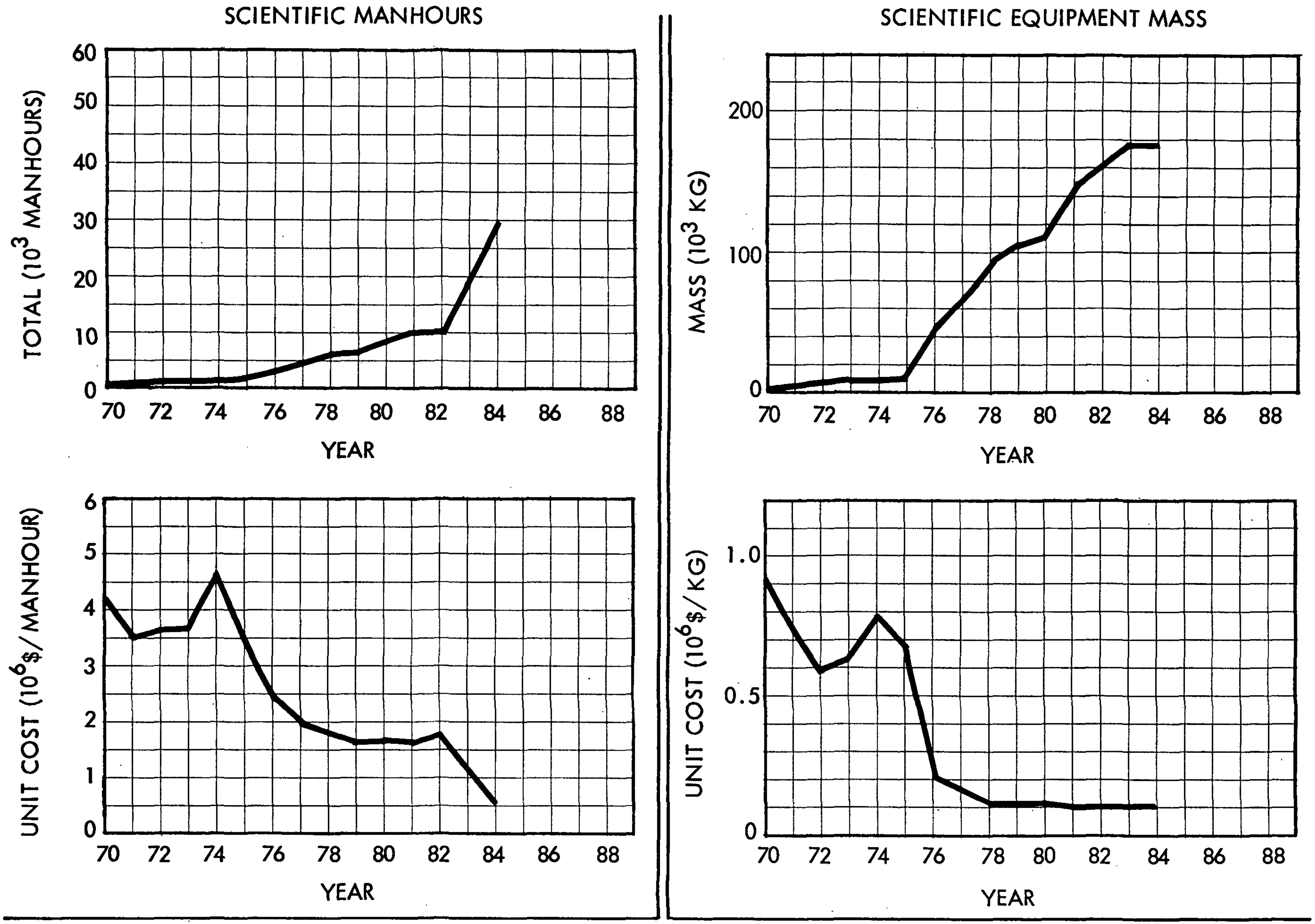
POST-APOLLO MISSION SUMMARY

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	2837	1737	(12,576)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	655	158	4287	430	624	150
9	71A	Moltke B	402-10011-01	2	26	15	731	180	4344	430	567	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
11	72A	Grimaldi. Astronomical Location	402-10011-01	2	21	16	762	192	4484	540	427	90
12	72B	Grimaldi. Astronomical Location	402-10081-01	3	21	18	864	115	6375	2407	3674	–
13	73B	Orbiter 3	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
14	75A	Capella M	503-20162-01	2	s	13	905	298	10.832	952	5468	350
15	75B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n–5	26	1825	695	12.150	2250	4150	500
16	76A	Mare Imbrium to Mare Serenitatis	503-20321-01	4	b	64	4596	1294	43.732	29,614	5168	2300
17	77A	Palus Putredinis to Mare Vaporum	503-20311-01	3	c	68	4884	1223	31,492	19,236	1108	2700
18	78A	Central Farside	503-20321-01	4	ℓ	65	4674	1242	43,615	29,640	5285	2600
19	79A	Marius Hills to Aristarchus	503-20311-01	3	j	53	3811	978	31,375	19.182	1225	2200
20	80A	Mare Orientale	503-20162-01	2	m	13	951	320	10,982	1102	5318	350
21	80B	Mare Nubium to Straight Wall – Mare Nubium.Straight Wall	503-20162-01	2	h–28, 18	46	3281	1125	8143	2180	4157	1400
22	81A	South Pole	503-20321-01	4	u	63	4488	1272	43,472	29,464	5428	2200
23	82A	Ptolemaeus to Alphonsus, Sinus Medii – Alphonsus	503-20162-01	2	f, e – 2	50	3590	1198	7930	1958	4370	1650
24	82B	Grimaldi. Astronomical Location	406-20141-02	7	21	448	64,534	18,975	64.508	31,843	692	150
		Total				1008	103,134	30.126	336.312	176.519	47.661	16.790

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/73B	9	1	–	–	1419	180	1599
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	71A	75A/82B	35	4	570	42	3911	725	5248
	Subtotal					570	42	5330	905	6847
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/73B	9	1	–	–	827	192	1019
1311-02/1321-04	CSM – LOR – Three-Man	72B	75A/82A	10	1	76	–	901	209	1186
1312-02/1322-01	CSM – LOR – Six-Man	78B	82B/82B	3	1	889	–	511	80	1480
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/72B	4	1	32	–	251	61	344
1332-02/1342-02	LM Taxi – Three-Man	71B	75A/82A	10	1	246	–	612	138	996
1335-01/1343-01	LM Taxi – Six-Man	78A	82B/82B	3	1	464	12	301	52	829
1423-02/1433-02	Logistic Braking and Landing Stages	70B	75A/82B	22	3	599	24	486	85	1194
	Subtotal					2306	36	3889	817	7048
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/72B	4	1	217	–	235	68	520
2325-05	Shelter – Six-Man	77B	82B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/82B	4	1	58	2	26	3	89
2423-03	LRV – Three-Man – 90 Days	69A	75A/82A	10	1	421	2	219	17	659
2433-03	Trailer – Large Multipurpose	79B	82B/–	1	1	52	2	18	1	73
2436-02	Trailer – Multipurpose	73A	76A/81A	5	1	275	3	20	1	299
2512-03	LFV – Two-Man Exploration	67B	70B/72A	3	1	48	–	10	1	59
2721-02	Nuclear Power Supply – 20 kw	76A	82B/–	1	1	136	20	28	–	184
	Subtotal					1692	29	644	102	2467
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	72B	76A/81A	3	1	11	–	7	–	18
3224-01	Radio Telescope – Mills Cross	77A	82B/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	76A	82B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	68A	72B/82B	2	1	29	–	17	2	48
3242-04	2-m Optical Telescope	77A	82B/–	1	1	152	–	25	1	178
	Subtotal					261	–	63	5	329
	Total					4829	107	9926	1829	16,691

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM B-VIb

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium-sized scientific program (Scientific Program B) using the "path approach." Transportation-system evolution (post-S/AA) will provide an initial uprating to 125% Saturn V launch vehicles, a direct logistic landing vehicle (LLV), and three-man personnel delivery systems using lunar orbit rendezvous (LOR). A later uprating to 150% Saturn V launch vehicles will employ a large LLV and three-man direct-delivery systems.

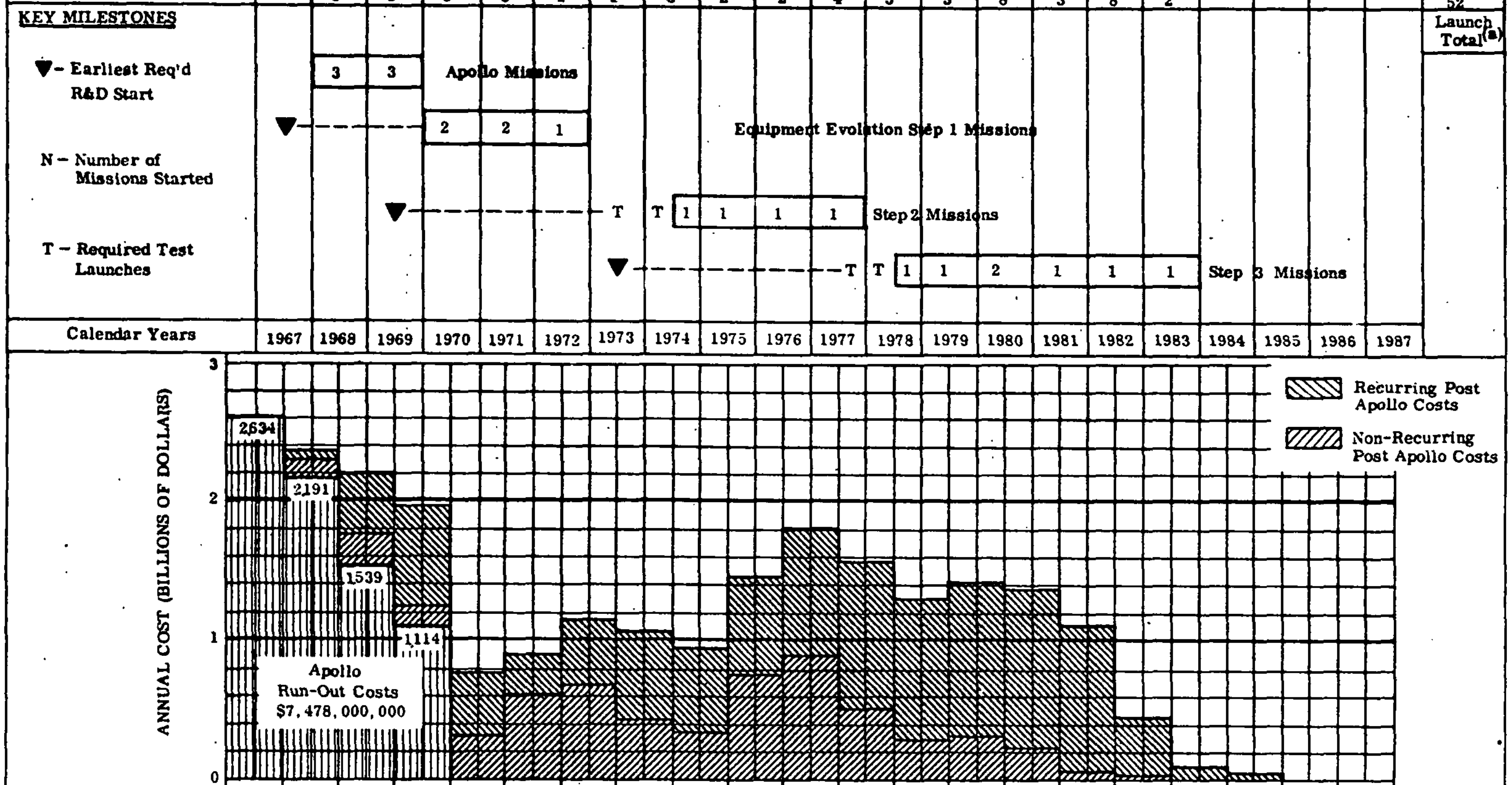
Annual program costs are aimed at 1 to 2 billion dollars. Launch rates are limited to four per year through 1975 and six to eight per year thereafter.

Exploration of the 7 locales and 11 paths will begin in 1970, following the 6 Apollo missions. Five missions are accomplished using S/AA hardware. The remaining missions employ a large, three-man roving vehicle as the basic mission equipment until the final astronomical mission in 1982, which uses a long-term, six-man shelter. *Major scientific equipment used on this program includes* a 300-m drill, large x-ray and radio telescopes, and 1- and 2-m optical telescopes. Extensive active seismic surveys include 90,000 kg of equivalent TNT explosives to be delivered to the lunar surface.

The total post-Apollo cost of this program is 17.1 billion dollars spread over a period of about 16 years. A total of 52 Saturn launches is required, including 6 Apollo missions and 4 test launches. The evolutionary step following S/AA hardware – 125% Saturn V, LLV, three-man LOR, and large lunar roving vehicle – is introduced operationally in 1974, requiring a commitment of 2 billion dollars by 1969. The final step is employed in 1978; its development cost is 3 billion dollars, and it begins in 1973.

COST AND SCHEDULE SUMMARY

Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
LAUNCH RATE		3	3	3	3	1	1	3	2	2	4	3	3	8	3	8	2					52



POST APOLLO COSTS	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
	TOTAL (MILLIONS)	5	167	646	829	787	891	1151	1051	946	1449	1818	1573	1318	1424	1377	1112	446	111	18			17,119
Non-Recur	R&D	5	89	201	146	294	565	680	398	320	690	872	506	266	299	223	52	6					5612
Non-Recur	C OF F		1	1	1	18	38	11	4	40	77	26	9	7	2	1							236
Recurring	PROCUREMENT		77	433	590	300	224	425	560	462	582	797	879	848	893	947	751	185	1				8954
Recurring	OPERATIONS			11	92	175	64	35	89	124	100	123	179	197	230	206	309	255	110	18			2317

(a) Includes six Apollo launches.

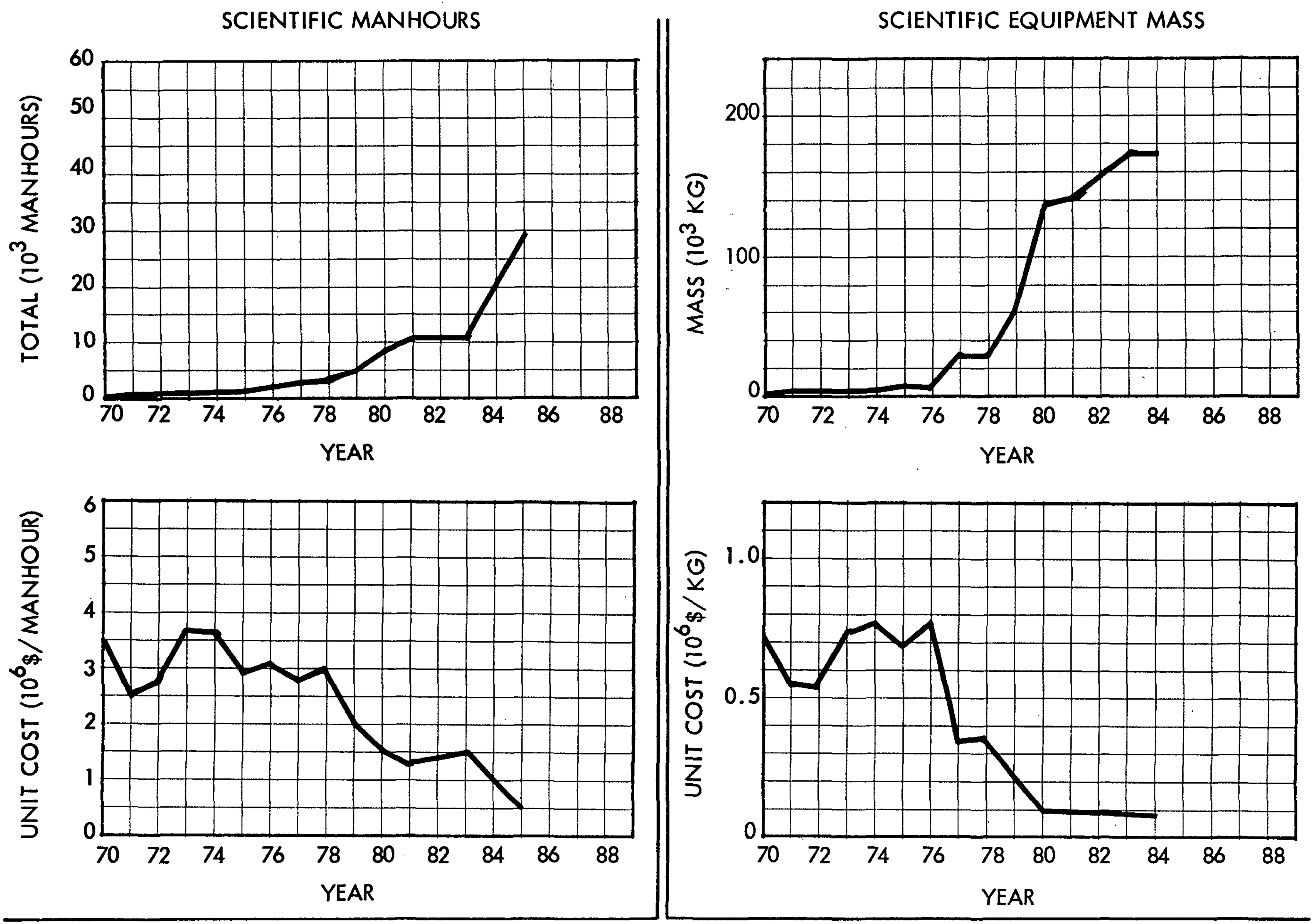
POST-APOLLO MISSION SUMMARY

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	2837	1737	(12,576)	–
8	70B	Ranger VIII Landing Site	403-10012-01	2	17	14	655	158	4287	430	624	150
9	71A	Moltke B	402-10011-01	2	26	15	731	180	4344	430	567	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
11	72B	Orbiter 3	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
12	74B	Capella M	503-20162-01	2	s	13	905	298	10,832	952	5468	350
13	75B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n–5	26	1825	695	12,150	2250	4150	500
14	76B	Mare Orientale	503-20162-01	2	m	13	951	320	10,982	1102	5318	350
15	77B	Marius Hills to Aristarchus	503-20311-01	3	j	53	3811	978	31,375	19,182	1225	2200
16	78B	Grimaldi, Astronomical Location	503-30201-01	2	21	10	258	366	14,310	2968	1990	150
17	79A	Central Farside	503-30141-01	3	l	65	4674	1242	42,271	29,640	0	2600
18	80A	South Pole	503-30141-01	3	u	63	4488	1272	42,233	29,464	0	2200
19	80B	M Imbr to M Seren, Palus Putr to M Vaporum	503-30181-01	5	b,c	126	9031	2517	70,288	47,728	12,912	4700
20	81B	Sinus Medii, Ptol to Alphon, M Nubium to St Wall	503-30161-01	3	e,f,h	97	6942	2320	20,770	2509	20,830	3200
21	82B	Grimaldi, Astronomical Location	406-30181-01	8	21	448	64,534	18,975	68,500	31,843	14,700	150
22	83B	Grimaldi, Astronomical Location	MSN-EXT-01	2	21	–	–	–	–	–	–	–
		Total				979	101,388	30,182	340,933	173,789	67,784	16,700

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/72B	4	1	–	–	713	90	803
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	70B	74B/77B	9	1	570	42	1202	186	2000
1241-01	150% Saturn V	74B	78B/83B	26	3	595	80	3274	539	4488
	Subtotal					1165	122	5189	815	7291
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/72B	4	1	–	–	417	96	513
1311-02/1321-04	CSM – LOR – Three-Man	72A	74B/77B	4	1	76	–	414	95	585
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/71A	2	1	31	–	152	36	219
1332-02/1342-01	LM Taxi – Three-Man	71A	74B/77B	4	1	246	–	291	63	600
1411-02/1453-01	CSM – Direct – Three-Man	74B	78B/83B	11	2	352	12	1093	247	1704
1421-01/1431-01	Personnel Braking and Landing Stage	73B	78B/83B	11	2	459	24	197	35	715
1423-02/1433-02	Logistic Braking and Landing Stage	70A	74B/77B	5	1	599	24	137	20	780
1423-03/1433-03	Logistic Braking and Landing Stage	74A	78B/82B	15	2	599	24	344	58	1025
	Subtotal					2362	84	3045	650	6141
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/72B	3	–	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/71A	2	1	111	–	63	11	185
2325-05	Shelter – Six-Man	77B	82B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/71A	2	1	58	2	16	2	78
2423-03	LRV – Three-Man – 90 Days	69B	74B/81B	10	1	421	2	219	16	658
2433-04	Trailer – Large Multipurpose	78B	81B/–	1	1	52	3	18	–	73
2436-02	Trailer – Multipurpose	74B	77B/82B	7	1	275	2	27	1	305
2512-03	LFV – Two-Man	67B	70B/71A	2	1	48	–	8	1	57
2721-02	Nuclear Power Supply – 20 kw	77A	82B/–	1	1	136	20	28	–	184
	Subtotal					1586	29	467	42	2124
	Major Scientific Equipment									
3213-02	300-m Drill with Fuel Cells	75B	79A/80B	3	1	11	–	7	–	18
3224-01	Radio Telescope – Mills Cross	77B	82B/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	76A	82B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	74A	78B/83B	2	1	29	–	17	2	48
3242-04	2-m Optical Telescope	77A	82B/–	1	1	152	–	25	1	178
	Subtotal					261	–	63	5	329
	Total					5374	235	8764	1512	15.885

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROBLEM B-VIc

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium-sized scientific program (Scientific Program B) using the "path approach." Evolution of post-S/AA transportation systems will provide an initial uprating to 125% for Saturn V launch vehicles, a direct lunar logistics vehicle (LLV), and a three-man personnel delivery system using lunar orbit rendezvous. A later uprating to 175% of Saturn V employs an LLV plus six-man direct-delivery systems.

Cost goals were set at 1 to 2 billion dollars per year. Nominal launch rates are four per year through 1975 and six to eight per year thereafter.

Exploration of the 7 locales and 11 paths begins in 1970, following the 6 Apollo missions. Five missions are accomplished using S/AA hardware. The remaining missions employ a large, three-man roving vehicle as the basic mission equipment until the final astronomical mission in 1982, which uses a long-term, six-man shelter. Major scientific equipment used on this program includes a 300-m drill, large x-ray and radio telescopes, and 1- and 2-m optical telescopes. Extensive active seismic surveys require 90,000 kg of equivalent TNT explosives on the lunar surface.

The total post-Apollo cost of this program is 17.3 billion dollars spread over a period of 15 years. A total of 46 Saturn launches is required, including 4 test launches. The first step in the evolution of post-S/AA hardware is introduced operationally in 1974, requiring a commitment of 2 billion dollars by 1967. The second step is used in 1978; its development cost is 3 billion dollars, starting in 1973.

COST AND SCHEDULE SUMMARY

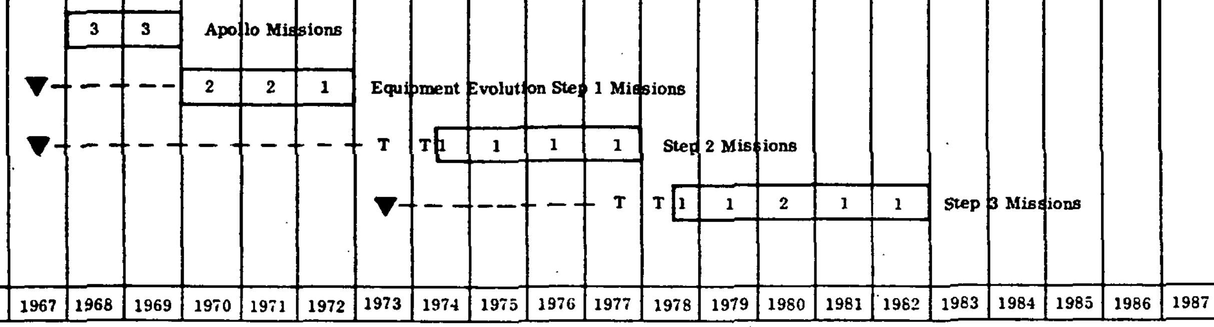
LAUNCH RATE	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
		3	3	3	3	1	1	3	2	2	4	3	3	7	2	6						46

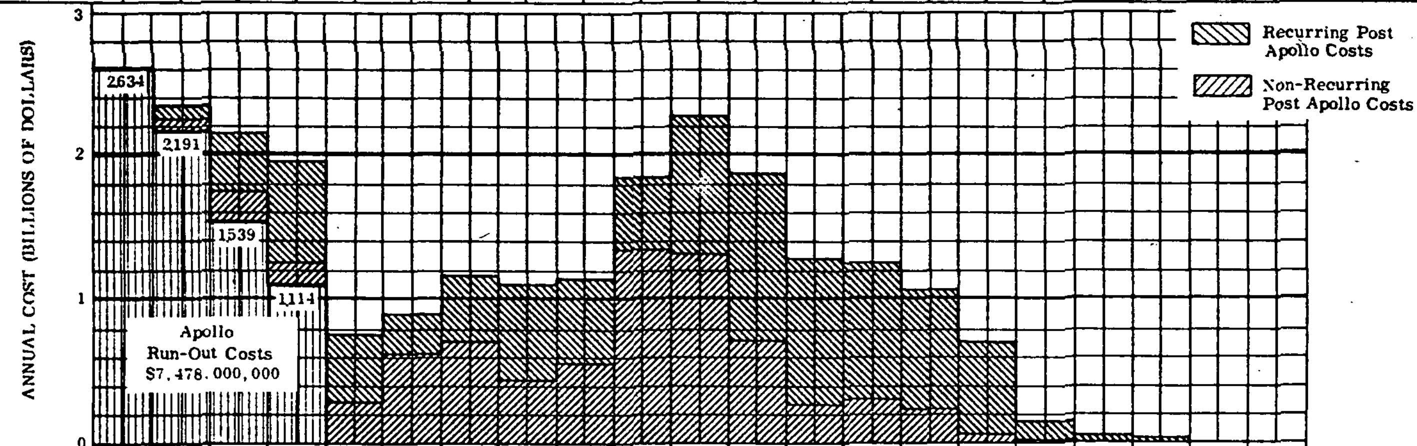
KEY MILESTONES

▼ – Earliest Req'd R&D Start

N – Number of Missions Started

T – Required Test Launches





	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS	TOTAL (MILLIONS)	5	167	646	829	787	891	1166	1108	1138	1856	2303	1859	1285	1242	1056	729	165	30	10			17.274
Non-Recur	R&D	5	89	201	146	294	565	695	454	500	1043	1277	715	266	299	223	52	6					6830
Non-Recur	C OF F		1	1	1	18	38	11	5	51	113	35	9	7	2	1							293
Recurring	PROCUREMENT		77	433	590	300	224	425	560	464	600	868	955	811	721	679	451	8					8166
Recurring	OPERATIONS			11	92	175	64	35	89	123	100	123	180	201	220	155	226	151	30	10			1985

(a) Includes six Apollo launches.

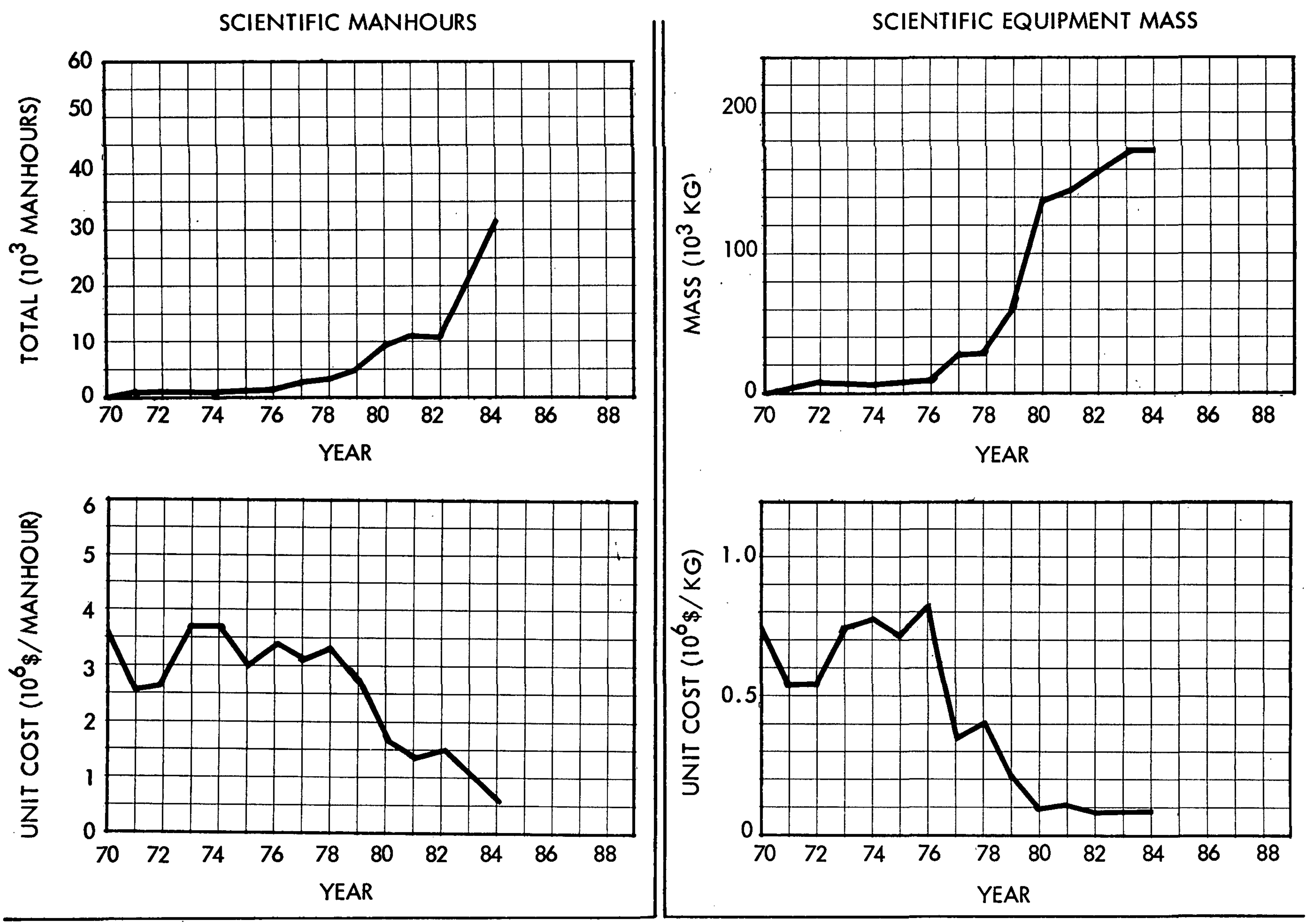
POST-APOLLO MISSION SUMMARY

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	2837	1737	(12,576)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	655	158	4287	430	624	150
9	71A	Moltke B	402-10011-01	2	26	15	731	180	4344	430	567	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
11	72B	Orbiter 3	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
12	74B	Capella M	503-20162-01	2	s	13	905	298	10,832	952	5468	350
13	75B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-20162-01	2	n – 5	26	1825	695	12,150	2250	4150	500
14	76B	Mare Orientale	503-20162-01	2	m	13	951	320	10,982	1102	5318	350
15	77B	Marius Hills to Aristarchus	503-20311-01	3	j	53	3811	978	31,375	19,182	1225	2200
16	78B	Grimaldi, Astronomical Location	503-30202-01	2	21	10	258	366	14,310	2968	1990	150
17	79A	Central Farside	503-30142-01	3	ℓ	65	4674	1242	43,215	29,640	7585	2600
18	80A	South Pole	503-30142-01	3	u	63	4488	1272	43,072	29,464	7728	2200
19	80B	M Imbr to M Seren, P Putr to M Vaporum	503-30191-01	4	b,c	126	9031	2517	53,711	47,728	12,689	4700
20	81B	Si Medii, Ptol to Alphon, M Nubium to St Wall	503-30171-01	2	e,f,h	97	6942	2320	20,770	2509	4630	3200
21	82B	Grimaldi, Astronomical Location	406-30191-02	6	21	448	64,534	18,975	66,900	31,843	12,300	150
		Total				979	101,388	30,182	324,539	173,789	64,274	16,700

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/72B	4	1	–	–	713	90	803
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	70B	74B/77B	9	1	570	42	1202	186	2000
1251-01	175% Saturn V	74B	78B/82B	20	2	818	135	2735	409	4097
	Subtotal					1388	177	4650	685	6900
	Flight Systems									
1311-01/1321-01	CM – LOR – Three-Man	–	71A/72B	4	1	–	–	418	96	514
1311-02/1321-04	CM – LOR – Three-Man	72A	74B/77B	4	1	76	–	415	95	586
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/71A	2	1	32	–	152	36	220
1332-02/1342-01	LM Taxi – Three-Man	71A	74B/77B	4	1	246	–	292	63	601
1412-02/1454-01	CSM – Direct – Six-Man	74B	78B/82B	7	1	900	12	921	157	1990
1421-02/1431-03	Personnel Braking and Landing Stages	73B	78B/82B	7	1	459	24	129	21	633
1423-02/1433-02	Logistic Braking and Landing Stages	70A	74B/77B	5	1	599	24	137	20	780
1423-04/1433-04	Logistic Braking and Landing Stages	74A	78B/82B	13	2	687	24	330	54	1095
	Subtotal					2999	84	2794	542	6419
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/72B	3	1	.1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/71A	2	1	216	–	129	36	381
2325-05	Personnel Shelter – Six-Man	77B	82B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/71A	2	1	58	2	16	2	78
2423-01	LRV – Three-Man	73A	79A/80A	2	1	360	2	50	4	416
2423-03	LRV – Three-Man – 90 Days	69B	74B/81B	8	1	421	2	181	14	618
2433-04	Trailer – Large Multipurpose	78B	81B/–	1	1	52	3	18	–	73
2436-02	Trailer – Multipurpose	74B	77B/82B	7	1	275	3	27	1	306
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2721-02	20-kw Reactor	77A	82B/–	1	–	136	20	28	–	184
	Subtotal					2051	32	545	69	2697
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cells	75B	79A/80B	3	–	11	–	7	–	18
3224-01	Radio Telescope – Mills Cross	77A	82B/–	1	–	30	–	8	1	39
3231-01	X-Ray Telescope	76A	82B/–	1	–	39	–	6	1	46
3242-01	1-m Optical Telescope	74A	78B/83B	2	–	29	–	17	2	48
3242-04	2-m Optical Telescope	77A	82B/–	1	–	152	–	25	1	178
	Subtotal					261	–	63	5	329
	Total					6699	293	8052	1301	16,345

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM B-VIe

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium scientific program (Scientific Program B) using the "path approach." Evolution of post-S/AA transportation systems will result in an uprating to 150% Saturn V launch vehicles, a direct logistics landing vehicle, and three-man personnel delivery using lunar orbit rendezvous.

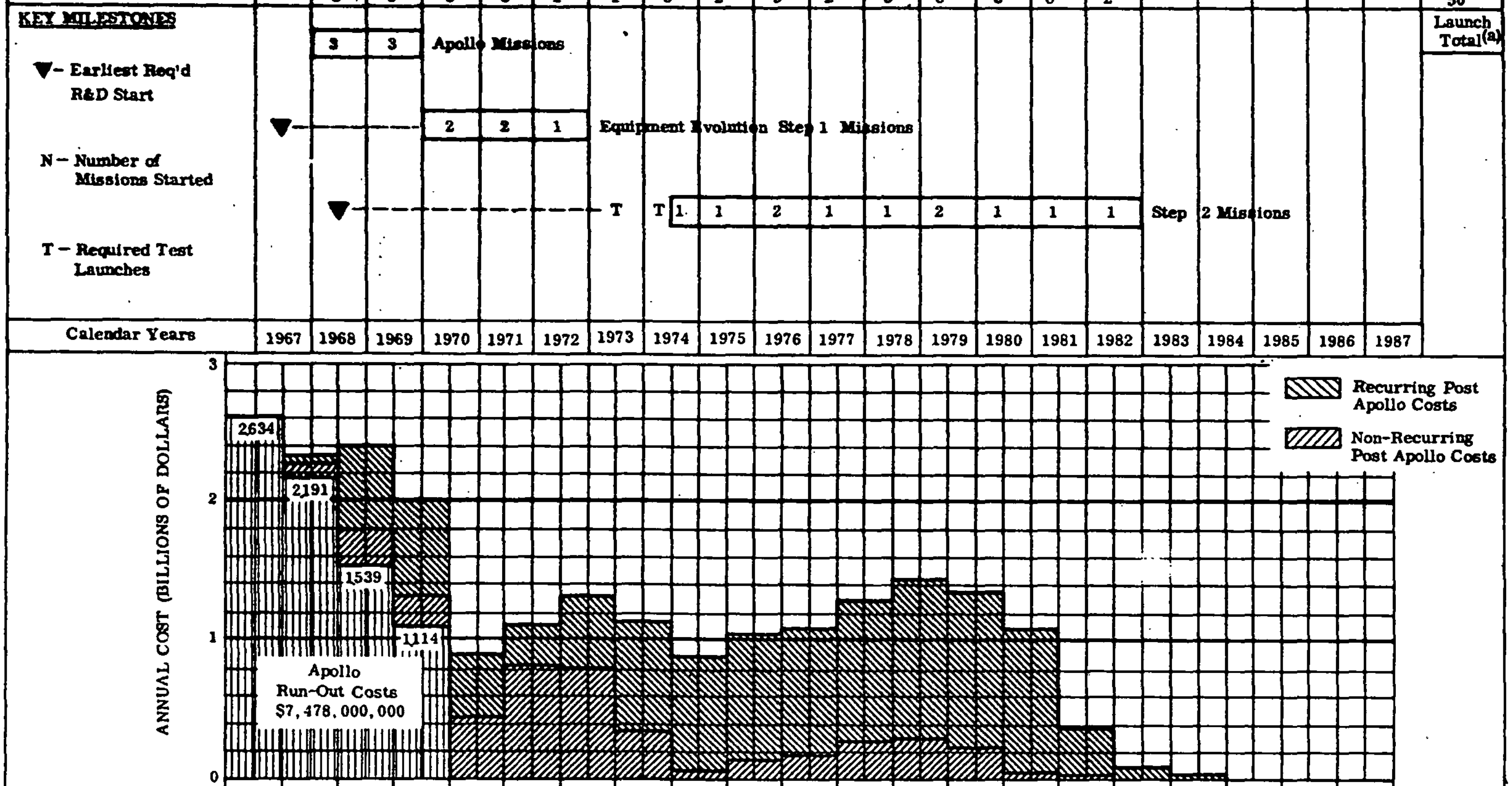
Annual program costs are intended to be 1 to 2 billion dollars. Launch rates are limited to four per year through 1975 and six to eight per year thereafter.

Exploration of the 7 locales and 11 paths is to begin in 1970, following the 6 Apollo missions. Five missions are accomplished using S/AA hardware. The remaining missions employ a large, three-man roving vehicle as the basic mission equipment until the final astronomical mission in 1981, which uses a long-term, six-man shelter. Major scientific equipment used on this program includes a 300-m drill, large x-ray and radio telescopes, and 1- and 2-m optical telescopes. Extensive seismic surveys require that 90,000 kg of equivalent TNT explosives be delivered to the lunar surface.

The total post-Apollo cost of the program is 15 billion dollars spread over a period of 14 years. A total of 50 Saturn launches is required, including 2 test launches. The post-S/AA hardware is introduced operationally in 1974, requiring a commitment of 2.9 billion dollars by 1967.

COST AND SCHEDULE SUMMARY

LAUNCH RATE	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
Calendar Years		3	3	3	3	1	1	3	2	5	2	3	8	3	8	2						50



		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS		TOTAL (MILLIONS)	5	167	692	911	918	1106	1322	1132	878	1039	1103	1293	1429	1370	1089	399	99	18				14,970
	Non-Recur	R&D	5	89	247	224	401	747	796	368	38	144	178	265	299	223	52	6						4082
		C OF F		1	1	5	40	75	21		2	5	9	7	2	1								169
	Recurring	PROCUREMENT		77	433	590	302	220	473	681	689	697	716	790	855	930	718	139						8310
		OPERATIONS			11	92	175	64	32	83	149	193	200	231	273	216	319	254	99	18				2409

(a) Includes six Apollo launches.

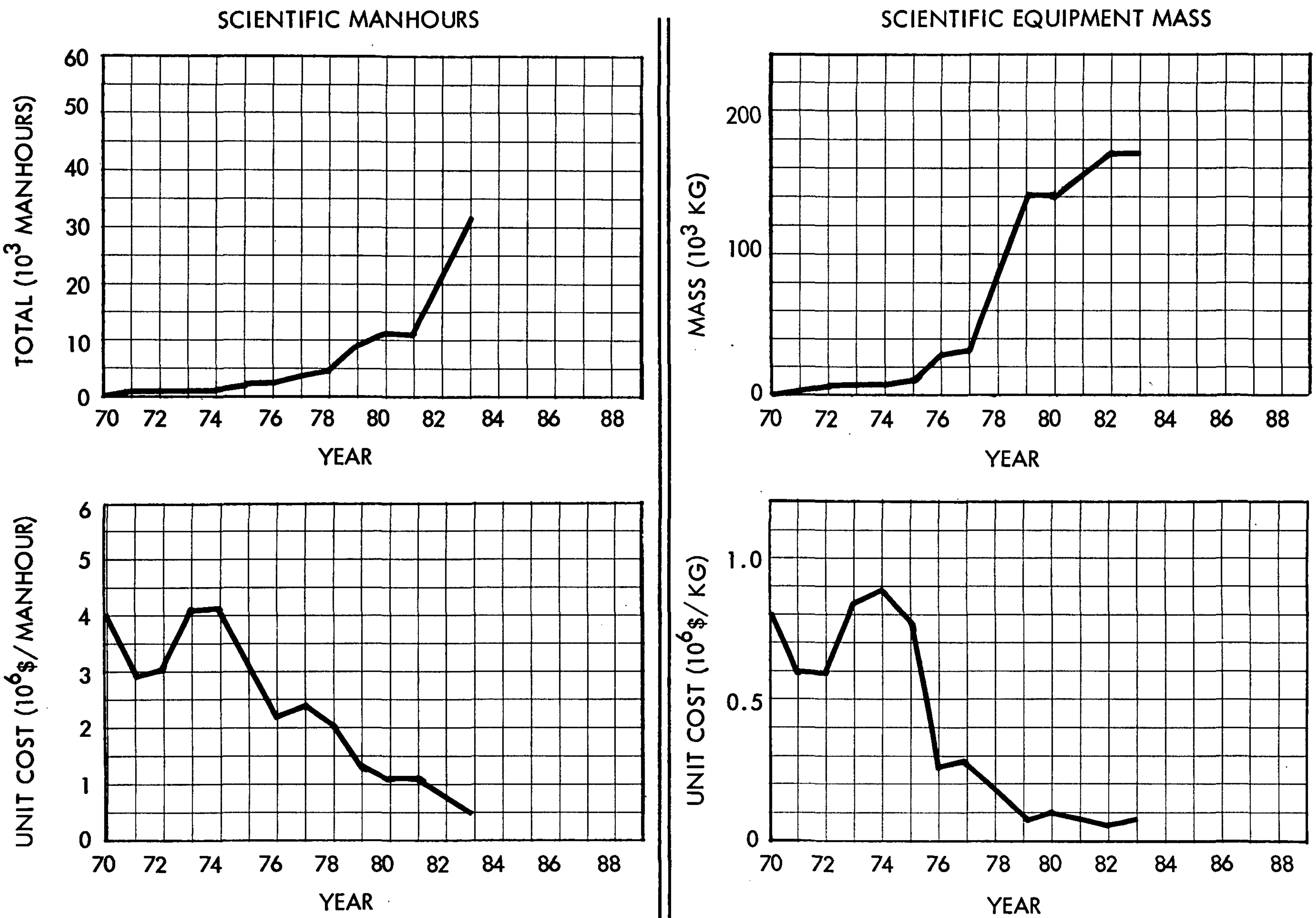
POST-APOLLO MISSION SUMMARY

No.	Start	Mission Location (paths – locales)	Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
7	70A	Orbiter 1	402-10021-01	1	–	12	861	287	2837	1737	(12,576)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	655	158	4287	430	624	150
9	71A	Moltke B	402-10011-01	2	26	15	731	180	4344	430	567	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
11	72B	Orbiter 3	303-10022-01	1	–	12	861	287	2877	1777	(12,536)	–
12	74B	Capella M	503-30151-01	2	s	13	905	298	10,952	952	9848	350
13	75B	Copernicus – Dark Halo Craters Southeast of Copernicus	503-30151-01	2	n – 5	26	1825	695	12,270	2250	8530	500
14	76A	Mare Orientale	503-30151-01	2	m	13	951	320	11,102	1102	9698	350
15	76B	Marius Hills to Aristarchus	503-30131-01	3	j	53	3811	978	31,075	19,182	10,525	2200
16	77B	Grimaldi, Astronomical Location	503-30201-01	2	21	10	258	366	14,310	2968	1990	150
17	78A	Central Farside	503-30141-01	3	ℓ	65	4674	1242	42,271	29,640	0	2600
18	79A	South Pole	503-30141-01	3	u	63	4488	1272	42,233	29,464	0	2200
19	79B	M Imbr to M Seren, P Putr to M Vapor	503-30181-01	5	b,c	126	9031	2517	70,288	47,728	12,912	4700
20	80B	Si Medii, Ptol to Alphon, M Nub to St Wall	503-30161-01	3	e,f,h	97	6942	2320	20,770	2509	20,830	3200
21	81B	Grimaldi, Astronomical Location	406-30181-01	8	21	448	54,534	18,975	68,500	31,843	14,700	150
22	82B	Grimaldi, Astronomical Location	MSN-EXT-01	2	21	–	–	–	–	–	–	–
		Total				979	101,388	30,182	340,993	173,789	90,274	16,700

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/72B	4	1	–	–	713	90	803
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
1241-01	150% Saturn V	70B	74B/82B	35	4	595	80	4222	725	5622
	Subtotal			48	6	595	80	4935	815	6425
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/72B	4	1	–	–	418	96	514
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/71A	2	1	32	–	152	36	220
1411-02/1453-01	CSM – Direct – Three-Man	70B	74B/82B	15	2	352	12	1410	323	2097
1421-01/1431-01	Personnel Braking and Landing Stages	69B	74B/82B	15	2	459	24	250	46	779
1423-03/1433-03	Logistic Braking and Landing Stages	70A	74B/81B	20	2	599	24	432	75	1130
	Subtotal			56	8	1442	60	2662	576	4740
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/72B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/71A	2	1	216	–	129	36	381
2325-05	Shelter – Six-Man	76B	81B/–	1	1	484	–	88	11	583
2421-01	LSSM	67B	70B/71A	2	1	58	2	16	2	78
2423-03	LRV – Three-Man – 90 Days	68B	74B/81B	10	1	421	2	219	16	658
2433-04	Trailer – Large Multipurpose	77B	80B/–	1	1	52	3	18	–	73
2436-02	Trailer – Multipurpose	73B	76B/81B	7	1	275	2	27	1	305
2512-03	LFV – Two-Man Exploration	67B	70B/71A	2	1	48	–	8	1	57
2721-02	Nuclear Power Supply – 20 kw	76A	81B/–	1	1	136	20	27	–	183
	Subtotal			29	9	1691	29	532	67	2319
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	74B	78A/79B	3	1	11	–	7	–	18
3224-01	Radio Telescope – Mills Cross	76A	81B/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	75A	81B/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	73A	77B/82B	2	1	29	–	17	2	48
3242-04	2-m Optical Telescope	76A	81B/–	1	1	152	–	24	1	177
	Subtotal			8	5	261	–	62	5	328
	Total					3989	169	8191	1463	13,812

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM B'-IIb

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium scientific program (Scientific Program B') using the "locale approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. A later evolutionary step introduces a direct logistics LM/Truck.

Fifteen locales are to be visited in the preferred order 17, 26, 2, 11, 28, 21, 15, 1, 4, 7, 6, 20, 3, 16, and 12. Three different paths are to be explored in a preferred order. Two regions are to be explored. Locales, paths, and regions can be mingled in almost any order desired.

The annual funding rate available was assumed to be 1 to 2 billion dollars. The launch rate is four per year.

As developed within these constraints, exploration program B'-IIb introduces the direct LM/Truck in 1974. The program is completed with a large astronomy mission to Grimaldi, beginning in early 1984 and requiring 15 launches. The total number of Saturn launches is 84, including 6 Apollo missions. The total post-Apollo cost is 26.1 billion dollars spread over a period of about 18 years. The program indicates a cost of about 1 billion dollars for the introduction of the direct LM/Truck and associated hardware systems. Funds must be committed in 1968.

COST AND SCHEDULE SUMMARY

LAUNCH RATE	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	84 Launch Total(a)
		3	3	4	5	4	2	3	2	3	4	6	6	7	6	5	6	7	8			84
KEY MILESTONES																						
Apollo Missions		3	3																			
Equipment Evolution Step 1 Missions	▼			3	3	2	1															
Step 2 Missions		▼						1	1	1	2	3	2	2	2	2	3	1	1			
Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	

▼ – Earliest Req'd R&D Start

N – Number of Missions Started

T – Required Test Launches

POST APOLLO COSTS	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
	TOTAL (MILLIONS)	39	371	963	1389	1473	1490	1432	998	1071	1243	1583	1922	2026	1945	1945	2057	2006	1427	616	56	20	26,072
Non-Recur	R&D	22	162	229	136	183	346	429	171	112	46	61	137	198	179	219	234	103					2967
Non-Recur	C OF F		2	1	4	4	5						9	9	3								37
Recurring	PROCUREMENT	17	207	706	1097	1029	908	808	624	838	1012	1332	1473	1456	1395	1368	1506	1551	1033	239			18,599
Recurring	OPERATIONS			27	152	257	231	195	203	121	185	190	303	363	368	358	317	352	394	377	56	20	4469

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

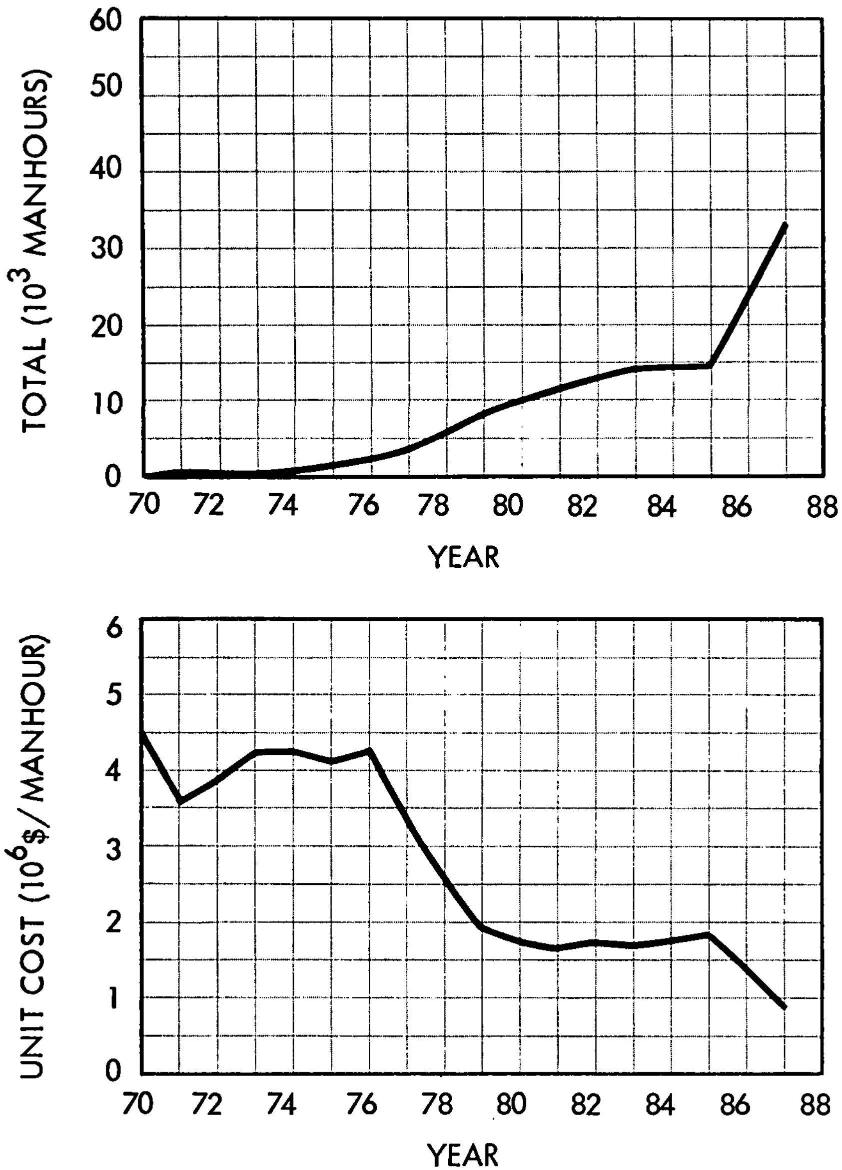
No.	Start	Mission: Location (paths – locales)	Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
7	70A	Orbiter 1	303-10021-01	1	–	9	645	215	3790	1748	(11,623)	0
8	70A	Ranger VIII Landing Site	402-10012-01	2	17	14	665	181	4410	430	690	150
9	70B	Orbiter 2	303-10022-01	1	–	9	645	215	3770	1728	(11,643)	0
10	71A	Moltke B	402-10011-01	2	26	16	740	182	4450	470	640	150
11	71B	Orbiter 3	303-10022-01	1	–	9	645	215	3770	1728	(11,643)	0
12	71B	Alphonsus	402-10011-03	2	2	14	677	173	4291	647	797	30
13	72A	Alphonsus	402-10011-03	2	2	13	642	163	3862	265	1276	30
14	72B	Tycho	402-10011-03	2	11	13	625	157	4248	655	836	60
15	73B	Alphonsus	402-10011-03	2	2	15	714	181	3885	260	1253	90
16	74A	Marius Hills to Aristarchus	503-20075-01	3	1	12	799	208	12,452	6139	5798	400
17	75B	Tycho	503-20081-01	2	11	14	873	349	4511	531	4389	90
18	76A	Central Farside	503-20075-01	3	1	12	836	208	12,452	6139	5798	460
19	77A	Mare Nubium	403-20023-01	2	28	24	1725	538	5946	1185	3107	150
20	77B	Grimaldi, Astronomical Location	403-20023-01	2	21	28	2004	631	6202	1294	2833	150
21	78A	Farside	403-20023-01	2	15	25	1808	566	5860	1086	3040	150
22	78B	Hyginus Rille	403-20023-01	2	1	26	1897	595	5943	1098	2957	150
23	78B	Hadley's Rille	403-20023-01	2	4	26	1839	576	5883	1081	3016	150
24	79A	Copernicus	503-20075-02	3	II	41	2963	1258	9661	972	8139	250
25	79B	Palus Putredinis	503-20075-02	3	I	48	3465	1484	10,067	955	5017	300
26	80A	Palus Putredinis	503-20075-02	3	I	42	2987	1255	9654	976	8146	300
27	80B	Marius Hills	403-20241-03	4	7	45	3210	958	21,076	8184	5624	150
28	81A	Aristarchus	403-20023-01	2	6	26	1854	581	5979	1139	2921	150
29	81B	Southern Highlands	403-20241-03	4	20	46	3297	987	21,131	8206	5569	150
30	82A	Southern Highlands	503-20075-01	3	1	12	836	208	12,452	6139	5798	460
31	82B	Capella M	403-20023-01	2	3	28	2011	633	6055	1154	2845	150
32	83A	South Pole	403-20023-01	2	16	30	2142	512	6085	1168	2785	150
33	83A	Grimaldi, Astronomical Location	403-20023-01	2	21	10	705	111	6372	1825	2528	0
34	83B	Mare Orientale	403-20023-01	2	12	30	2154	681	6790	1894	2110	150
35	84A	Grimaldi, Astronomical Location	403-20321-01	7	21	143	10,244	467	50,118	29,502	642	240
36	85A	Grimaldi, Astronomical Location	403-20321-02	8	21	536	38,556	18,424	17,028	2270	14,163	100
		Total				1316	92,194	32,912	278,133	90,868	102,717	4660

EQUIPMENT USAGE AND COST SUMMARY

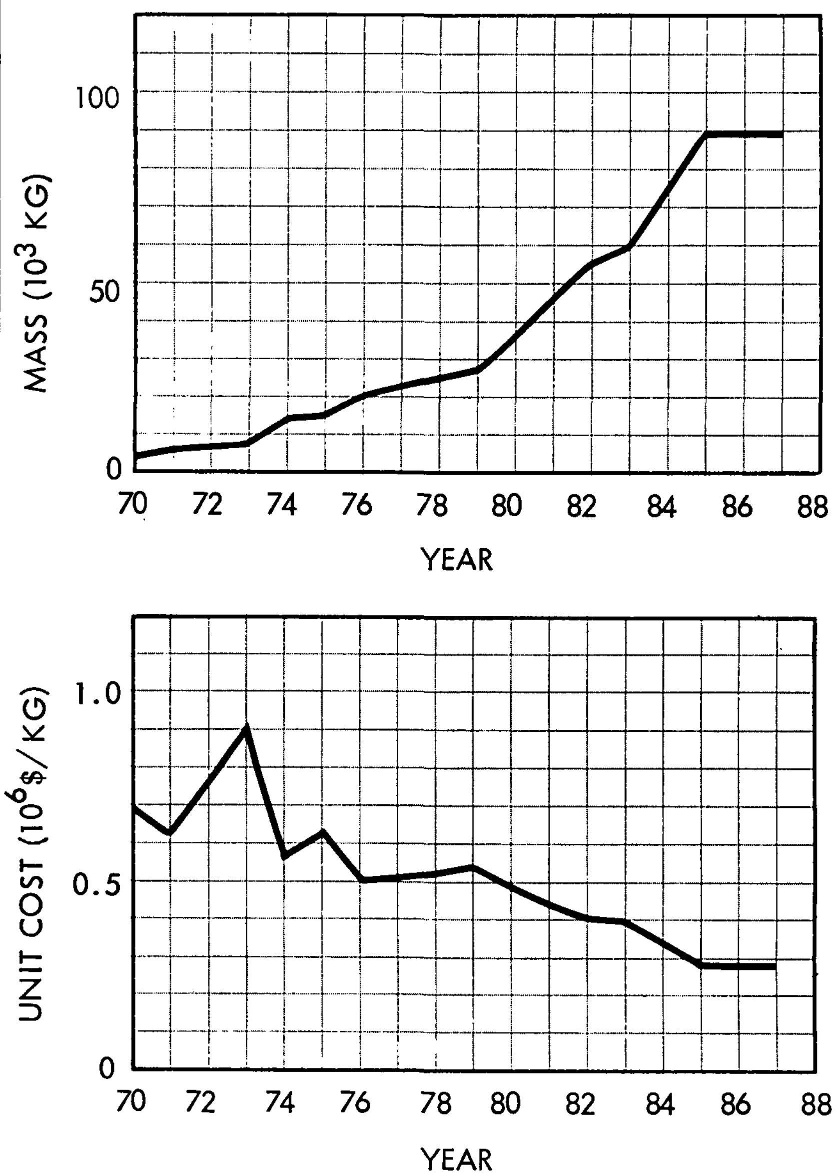
Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	70B/85A	75	8	–	–	10,403	1494	11,897
1221-03	100% Saturn V (Apollo funded)	–	68A/70A	8	1	–	–	–	–	–
	Subtotal					–	–	10,403	1494	11,897
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	70B/75B	13	2	–	–	1210	284	1494
1311-02/1321-03	CSM – LOR – Three-Man	71B	74A/85A	24	3	76	–	2168	517	2761
1331-01/1341-01	LM Taxi – Two-Man	67A	70A/73B	6	1	32	–	348	85	465
1332-01/1342-01	LM Taxi – Three-Man	72A	75B/75B	1	1	117	–	44	7	168
1334-02/1342-01	LM Taxi – Three-Man	69B	74A/85A	24	3	411	12	1437	347	2207
1422-01/1432-01	Logistic Braking and Landing Stages	70A	74A/85A	38	4	158	–	1640	508	2306
	Subtotal					794	12	6847	1748	9401
	Mission Equipment									
2202-02	Orbiter Rack	68A	70A/71B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67A	70A/71B	6	1	216	–	297	84	597
2322-01	Shelter – Three-Man	72B	77A/83B	10	1	171	–	231	41	443
2322-02	Shelter – Three-Man	76B	80B/81B	2	1	317	–	110	15	442
2322-08	Shelter – Three-Man	79A	84A/–	1	1	360	–	76	10	446
2421-01	LSSM	67A	70A/83B	18	2	58	2	85	10	155
2423-01	LRV – Cabin – Three-Man	68A	74A/84A	8	1	360	2	146	11	519
2432-04	Trailer – Multipurpose	71A	74A/84A	7	1	44	–	43	2	89
2512-03	LFV – Two-Man Exploration	67A	70A/83B	12	2	48	–	33	3	84
2521-02	LFV – Return to Orbit	75A	79A/80A	3	1	62	–	13	1	76
2721-01	Nuclear Power Supply – 20 kw	77B	84A/85A	2	1	136	20	42	–	198
	Subtotal					1773	24	1076	177	3050
	Major Scientific Equipment									
3213-01	300-m Drill – Fuel Cell	78B	80B/81B	2	1	4	–	3	–	7
3224-01	Radio Telescope – Mills Cross	78B	84A/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	77B	84A/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	79B	84A/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78B	84A/–	1	1	152	–	25	1	178
	Subtotal					254	–	53	4	311
	Total					2821	36	18,379	3423	24,659

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY

SCIENTIFIC MANHOURS



SCIENTIFIC EQUIPMENT MASS



SUMMARY OF LUNAR EXPLORATION PROGRAM B'-IIIa

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium scientific program (Scientific Program B') using the "locale approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step introduces the lunar orbit rendezvous LM/Truck. A final major step introduces the direct LM/Truck at the earliest practicable date.

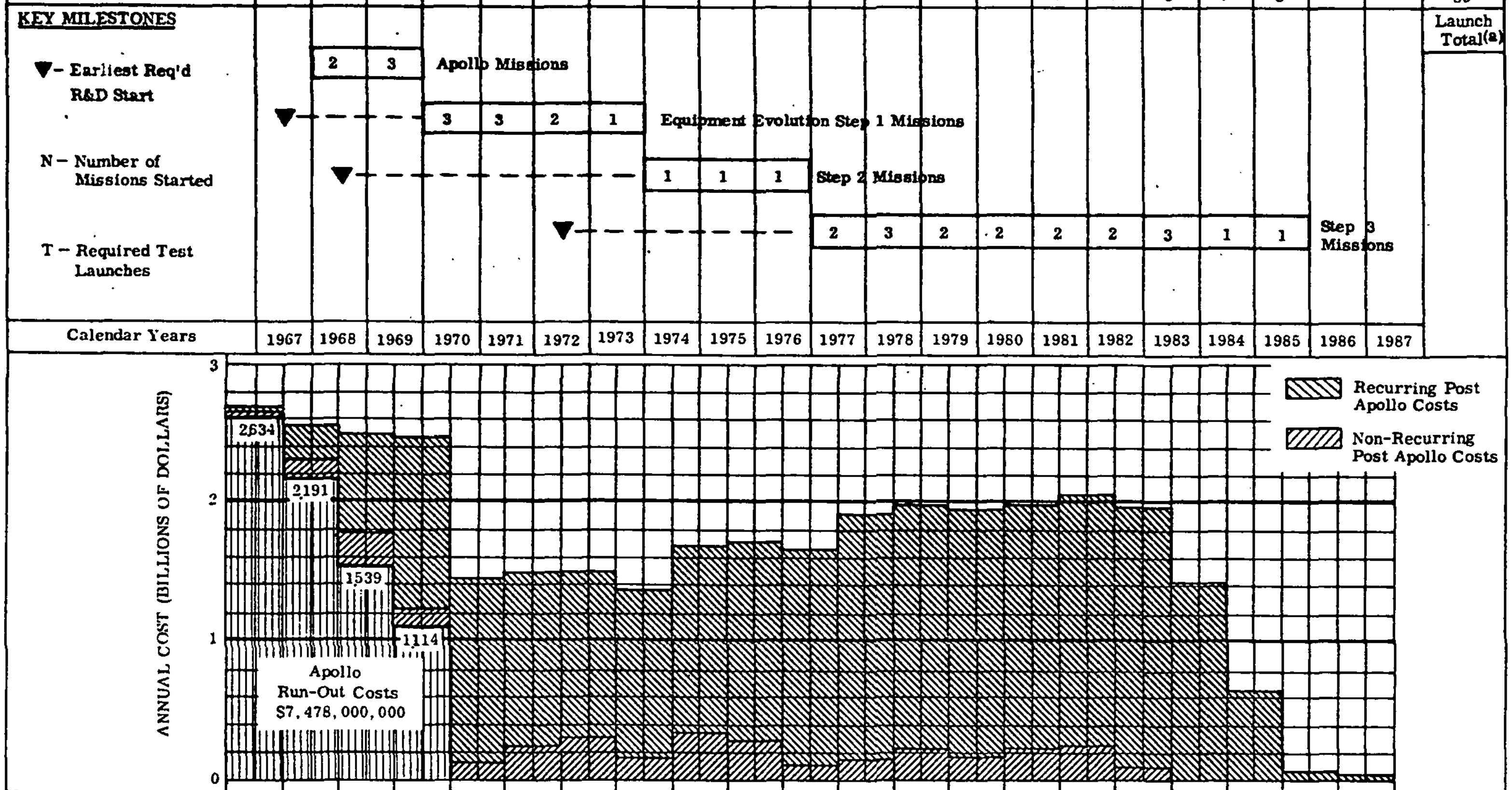
Fifteen locales are to be visited in the preferred order 17, 26, 2, 11, 28, 21, 15, 1, 4, 7, 6, 20, 3, 16, and 12. Three different paths are to be explored in a preferred order. Two regions are to be explored. Locales, paths, and regions can be mingled in almost any order desired.

Program funding rates are aimed at 1 to 2 billion dollars per year. The launch rate is four per year.

As developed within these constraints, exploration program B'-IIIa introduces the LM/Truck in 1974 and the direct LM/Truck in 1977. The program is completed with a large astronomy mission to Grimaldi, beginning in early 1984 and requiring 15 launches. The total number of Saturn launches is 86, including 6 Apollo missions. The total post-Apollo cost is 27.5 billion dollars spread over a period of about 18 years. The program indicates a cost of about 0.5 billion dollars for introduction of the LM/Truck and related equipment. Funds must be committed in 1968. A further commitment of the order of 0.7 billion dollars for the development of the direct LM/Truck and associated hardware must be made in about 1972.

COST AND SCHEDULE SUMMARY

LAUNCH RATE		2	3	4	5	4	2	4	3	4	4	6	6	7	6	5	6	7	8			86 Launch Total(a)



	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS	TOTAL (MILLIONS)	39	371	963	1374	1431	1464	1480	1359	1661	1679	1642	1922	1998	1946	1984	2064	1975	1414	627	56	20	27,469
Non-Recur	R&D	22	162	229	124	125	228	254	166	308	286	101	137	198	179	219	234	103					3075
Non-Recur	C OF F		2	1	1			3	4	5			9	9	3								37
Recurring	PROCUREMENT	17	207	706	1097	1049	1005	1011	938	1160	1093	[illegible]	1471	1431	1399	1415	1498	1515	1034	243			19,631
Recurring	OPERATIONS			27	152	257	231	212	251	188	300	199	305	360	365	350	332	357	380	384	56	20	4726

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

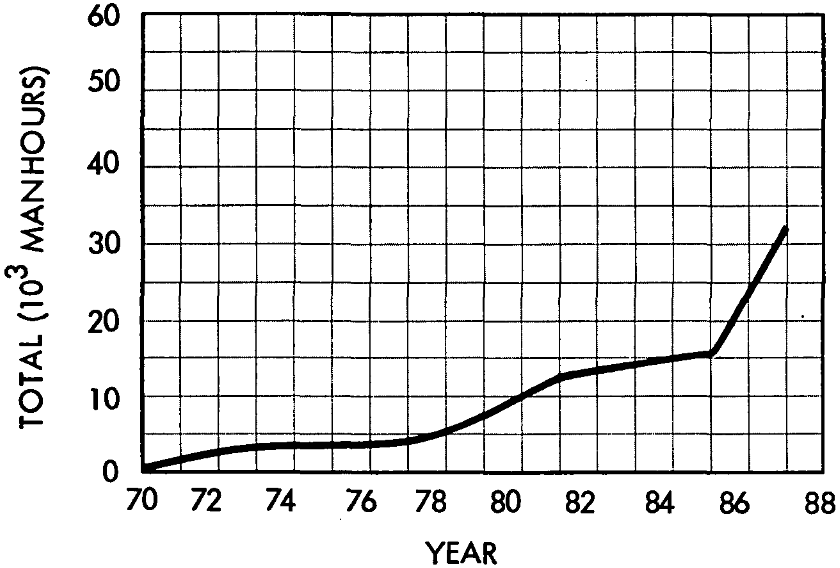
No.	Start	Location (paths – locales)	Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
7	70A	Orbiter 1	303-10021-01	1	–	9	645	215	3790	1748	(11,623)	–
8	70A	Ranger VIII Landing Site	402-10012-01	2	17	14	655	158	4410	430	690	150
9	70B	Orbiter 2	303-10022-01	1	–	9	645	215	3770	1728	(11,643)	–
10	71A	Moltke B	402-10011-01	2	26	16	731	180	4450	430	640	150
11	71B	Orbiter 3	303-10022-01	1	–	9	645	215	3770	1728	(11,643)	–
12	71B	Alphonsus 1	402-10011-03	2	2	14	676	173	4291	647	747	30
13	72A	Alphonsus 2	402-10011-03	2	2	13	642	163	3862	265	1267	30
14	72B	Tycho 1	402-10011-03	2	11	13	625	156	4248	655	836	60
15	73B	Alphonsus 3	402-10011-03	2	2	15	714	181	3885	259	1253	90
16	74A	Marius Hills to Aristarchus	503-10021-02	4	j	12	823	208	12,452	6138	148	400
17	75B	Tycho 2	503-10021-01	3	11	14	964	348	6854	530	1546	90
18	76A	Central Farside	503-10021-02	4	f	12	861	208	12,452	6138	148	460
19	77A	Mare Nubium	403-20023-01	2	28	24	1725	538	5946	1184	3107	150
20	77B	Grimaldi, Astronomical Location 1	403-20023-01	2	21	28	2004	631	6202	1293	2833	150
21	78A	Farside	403-20023-01	2	15	25	1808	565	5860	1085	3040	150
22	78B	Hyginus Rille	403-20023-01	2	1	26	1897	595	5943	1097	2957	150
23	78B	Hadley's Rille	403-20023-01	2	4	26	1838	575	5883	1081	3016	150
24	79A	Copernicus	503-20075-02	3	II	41	989	1258	9661	972	8139	250
25	79B	Palus Putredinis 1	503-20075-02	3	I	48	3465	1484	10,067	954	5017	300
26	80A	Palus Putredinis 2	503-20075-02	3	I	42	2986	1254	9654	976	8146	300
27	80B	Marius Hills	403-20241-03	4	7	45	3209	957	21,076	8184	5624	150
28	81A	Aristarchus	403-20023-01	2	6	26	1853	581	5979	1139	2921	150
29	81B	Southern Highlands	403-20241-03	4	20	46	3297	986	21,131	8206	5569	150
30	82A	Southern Highlands	503-20075-01	3	i	12	836	207	12,452	6138	5798	460
31	82B	Capella M	403-20023-01	2	3	28	2011	633	6055	1154	2845	150
32	83A	South Pole	403-20023-01	2	16	30	2142	512	6085	1167	2785	150
33	83A	Grimaldi, Astronomical Location 2	403-20023-01	2	21	10	705	111	6372	1825	2528	–
34	83B	Mare Orientale	403-20023-01	2	12	30	2154	681	6790	1894	2110	150
35	84A	Grimaldi, Astronomical Location 3	403-20321-01	7	21	143	10,244	467	50,118	29,602	642	240
36	85A	Grimaldi, Astronomical Location 4	403-20321-02	8	21	536	38,556	18,424	17,028	2270	14,163	100
		Total				1316	61,572	33,657	280,536	90,918	88,515	4660

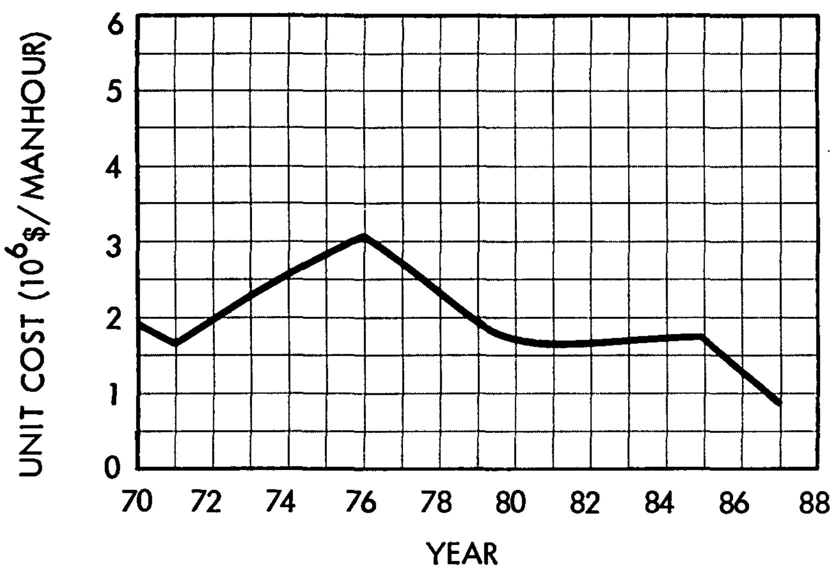
EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	70B/85A	78	8	–	–	10,746	1548	12,294
1221-03	100% Saturn V (Apollo funded)	–	68A/70A	8	1	–	–	–	–	–
	Subtotal					–	–	10,746	1548	12,294
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	70B/76A	20	3	–	–	1645	388	2033
1311-01/1321-03	CSM – LOR – Three-Man	71B	74A/85A	3	3	28	–	240	57	325
1311-02/1321-03	CSM – LOR – Three-Man	74B	77A/85A	22	5	48	–	1785	418	2250
1331-01/1341-01	Personnel Braking and Landing Stgs – Two-Man	67A	70A/73B	6	2	143	–	350	73	566
1332-01/1342-01	Personnel Braking and Lndg Stgs – Three-Man	70B	74A/76A	3	1	117	6	192	40	355
1334-02/1342-01	Personnel Braking and Lndg Stgs – Three-Man	72B	77A/85A	22	6	300	6	1294	326	1926
1351-01	Logistic Descent Stage – LOR	70A	74A/76A	8	1	97	–	180	74	351
1422-01/1432-01	Logistic Braking and Landing Stages	73A	77A/85A	33	4	158	–	1456	448	2062
	Subtotal					891	12	7142	1824	9868
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/71B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67A	70A/73B	6	1	217	–	297	84	598
2322-01	Shelter – Three-Man	72B	77A/83B	10	1	171	–	231	41	443
2322-02	Shelter – Three-Man	76B	80B/81B	2	1	317	–	110	15	442
2322-08	Shelter – Three-Man	79A	84A/–	1	1	360	–	76	10	446
2421-01	LSSM	67A	70A/83B	18	2	58	2	85	10	155
2423-01	LRV – Three-Man	68A	74A/84A	8	1	360	2	146	11	519
2432-04	Trailer – Multipurpose	68A	74A/84A	8	1	44	–	47	2	93
2512-03	LFV – Two-Man	67A	70A/83B	12	2	48	–	33	3	84
2521-02	LFV – Return to Orbit	75A	79A/80A	3	1	62	–	13	1	76
2721-01	Nuclear Power Supply – 20 kw	77B	84A/85A	2	1	136	20	42	–	198
	Subtotal					1774	24	1080	177	3055
	Major Scientific Equipment									
3213-01	300-m Drill – Fuel Cell	78B	80B/81B	2	1	4	–	3	–	7
3224-01	Radio Telescope – Mills Cross	78B	84A/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	77B	84A/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	79B	84A/–	1	1	29	–	11	1	41
3242-04	2-m Optical Telescope	78B	84A/–	1	1	152	–	25	1	178
	Subtotal					254	–	53	4	311
	Total					2919	36	19,021	3553	25,528

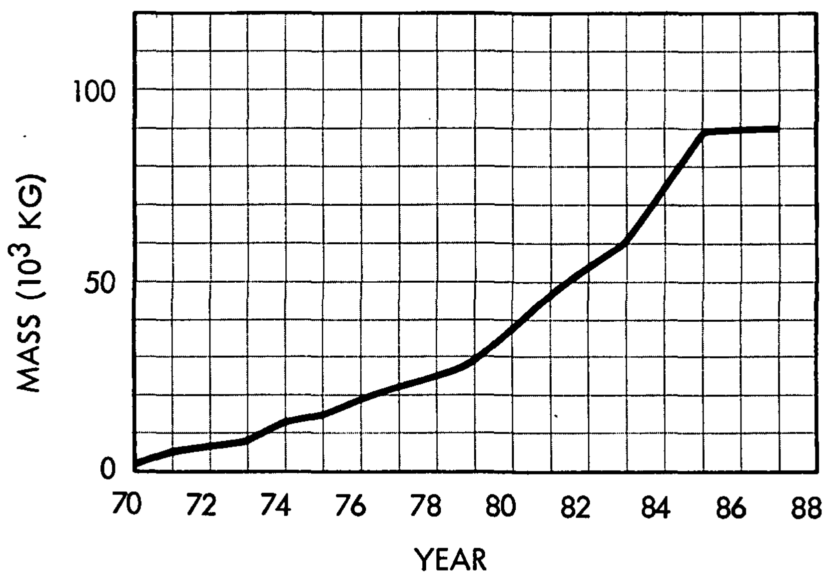
SCIENTIFIC PROGRAM OPERATIONAL SUMMARY

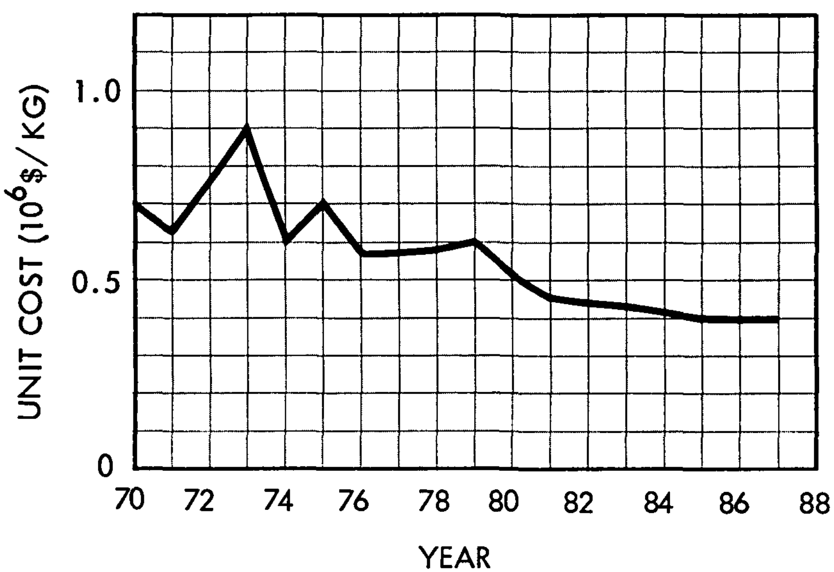
SCIENTIFIC MANHOURS





SCIENTIFIC EQUIPMENT MASS





SUMMARY OF LUNAR EXPLORATION PROGRAM B'-IIIc

GENERAL DESCRIPTION

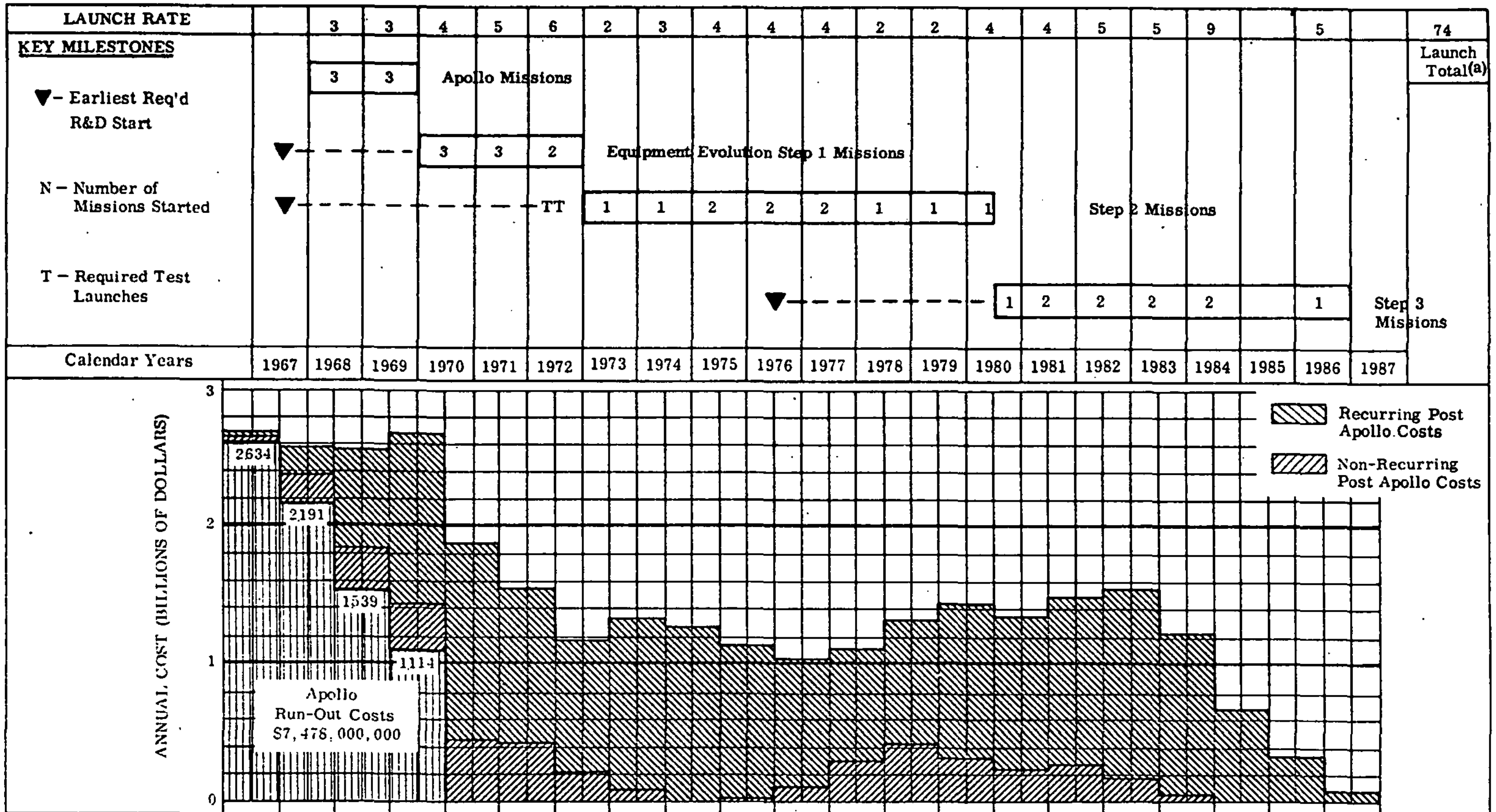
This lunar exploration program is designed to accomplish a medium-sized scientific program (Scientific Program B') using the "locale approach." The first step beyond Apollo uses S/AA-type hardware. Further evolution of transportation systems will result in an uprating to 125% Saturn V launch vehicles, an LM truck logistics landing system, and a three-man personnel delivery system using lunar orbit rendezvous. A third evolutionary step will provide a direct lunar logistics vehicle (LLV) for use with the 125% Saturn launch vehicle.

Cost goals for the program are set at 1 to 2 billion dollars per year. Launch rates are four per year through 1975 and six to eight per year thereafter.

Exploration of the 15 locales, 3 paths, and 2 regions begins in 1970, following the 6 Apollo missions. Eight missions are accomplished using S/AA hardware. The remaining missions employ a three-man roving vehicle as the basic mission equipment until the final astronomical mission in 1984, which uses a three-man shelter. Major scientific equipment used on this program includes a 300-m drill, large x-ray and radio telescopes, and 1- and 2-m optical telescopes.

The total post-Apollo cost of this program is 22.8 billion dollars spread over a period of 19 years. A total of 74 Saturn launches is required, including 6 Apollo launches and 2 test launches. The uprated Saturn, LM/Truck, and three-man delivery system become operational in 1973, requiring a commitment of 1.5 billion dollars by 1967. The direct LLV and related systems are first used in 1980 and require a commitment of 1.1 billion dollars for development, starting in 1976.

COST AND SCHEDULE SUMMARY



		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS		TOTAL (MILLIONS)	54	412	1042	1570	1846	1555	1191	1289	1256	1142	1023	1080	1323	1415	1355	1475	1555	1206	672	346	33	22,840
	Non-Recur	R&D	37	202	306	264	427	441	204	91	3	12	122	288	394	325	226	245	184	32				3803
		C OF F		3	3	19	21					1	7	18	11	7								90
	Recurring	PROCUREMENT	.17	207	706	1135	1141	840	798	1041	979	861	643	590	769	876	901	982	1134	826	435	120		15,001
		OPERATIONS			27	152	257	274	189	157	274	268	251	184	149	207	228	248	237	348	237	226	33	3946

(a) Includes six Apollo launches.

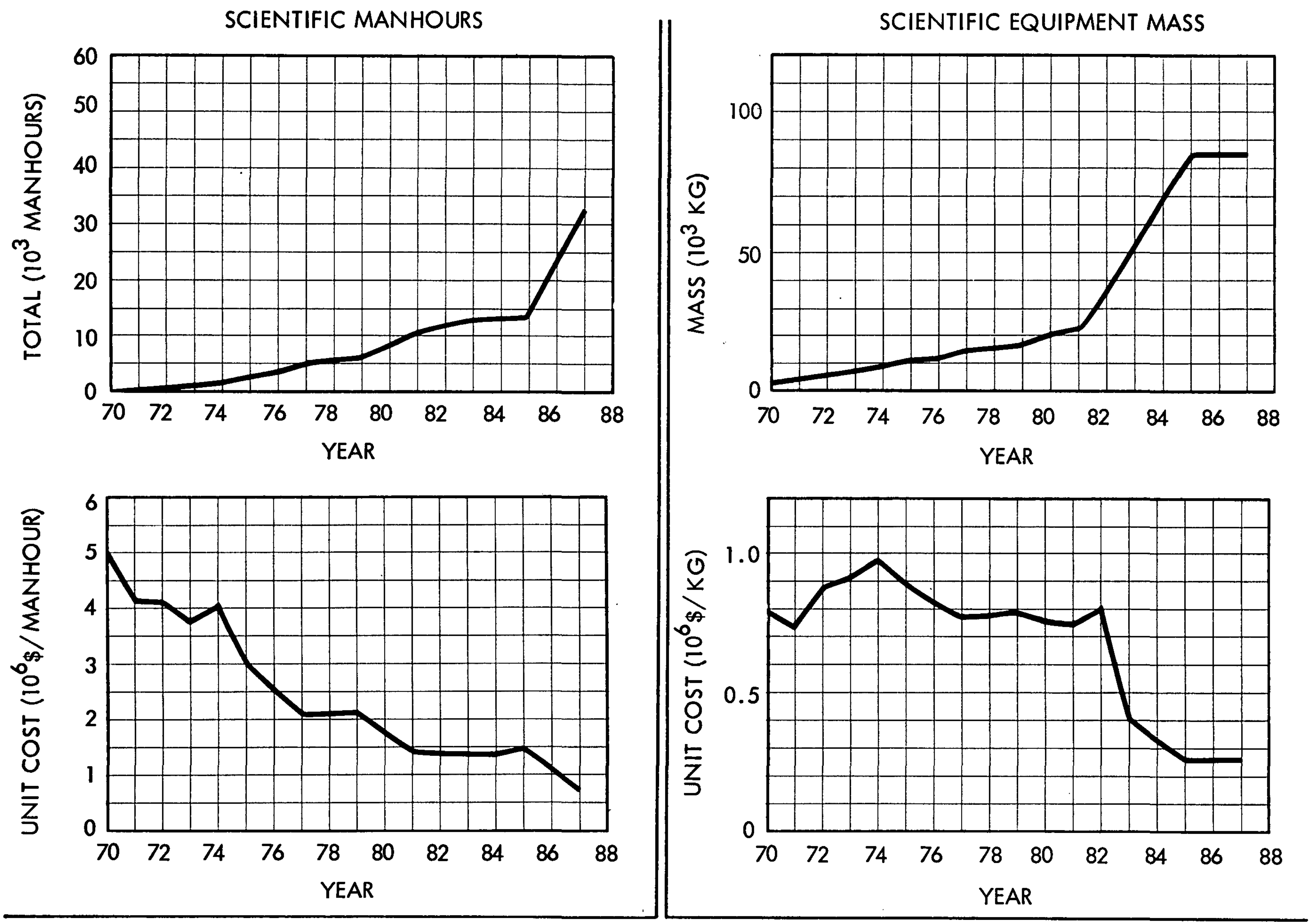
POST-APOLLO MISSION SUMMARY

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	10	663	221	4183	1750	(11,230)	–
8	70A	Ranger VIII Landing Site	402-10012-01	2	17	14	655	181	4619	430	472	150
9	70B	Orbiter 2	303-10022-01	1	–	10	663	221	4183	1730	(11,230)	–
10	71A	Moltke B	402-10011-01	2	26	16	740	182	4487	470	596	150
11	71B	Orbiter 3	303-10022-01	1	–	10	663	221	4183	1730	(11,230)	–
12	71B	Alphonsus	402-10011-03	2	2	13	627	158	4240	640	850	30
13	72A	Alphonsus	402-10011-03	2	2	14	642	163	3862	270	1276	30
14	72B	Alphonsus	402-10011-03	2	2	15	714	181	3885	260	1253	90
15	73A	Tycho	503-10035-02	2	11	30	2179	511	5224	1220	2076	150
16	74B	Marius Hills to Aristarchus	503-10015-01	3	1	12	860	205	12,457	610	2189	400
17	75A	Grimaldi, Astronomical Location	503-10035-02	2	21	21	1473	631	5472	1290	1828	150
18	75B	Farside	503-10035-02	2	15	19	1336	565	5110	1090	2190	150
19	76A	Hyginus Rille	503-10035-02	2	1	20	1398	595	5208	1100	2193	150
20	76B	Mare Nubium	503-10035-02	2	28	18	1262	525	5194	1250	2046	150
21	77A	Hadley's Rille	503-10035-02	2	4	19	1358	575	5142	1080	2158	150
22	77B	Aristarchus	503-10035-02	2	6	20	1399	596	5267	1140	2033	150
23	78A	Capella M	503-10035-02	2	3	21	1477	633	5318	1150	2082	150
24	79A	South Pole	503-10035-02	2	16	18	1237	517	5212	1200	2088	150
25	80A	Mare Orientale	503-10035-02	2	12	22	1577	683	5989	1890	1311	150
26	80B	Copernicus	503-20141-02	2	II	42	2983	1467	8488	970	7812	250
27	81A	Palus Putredinis	503-20141-02	2	I	49	3486	1484	8930	950	7370	300
28	81B	Palus Putredinis	503-20141-02	2	I	42	3007	1254	8483	980	7817	300
29	82A	Southern Highlands	403-20261-02	3	20	46	3282	987	26,417	8208	6183	150
30	82B	Southern Highlands	503-20141-01	2	i	14	950	218	13,403	6210	2893	460
31	83A	Central Farside	503-20141-01	2	i	13	929	208	13,365	6170	2935	460
32	83B	Marius Hills	403-20261-02	3	7	45	3194	956	26,348	8276	6252	150
33	84A	Grimaldi, Astronomical Location	403-20251-01	2	21	14	962	111	12,175	3082	4125	–
34	84B	Grimaldi, Astronomical Location	403-20301-01	7	21	142	10,244	467	59,999	29,602	4343	240
35	86A	Grimaldi, Astronomical Location	403-20311-01	5	21	536	38,555	18,324	31,342	2270	1255	100
		Total				1265	87,604	33,042	308,185	87,020	77,626	4760

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	70B/72B	10	1	–	–	1555	198	1753
1221-03	100% Saturn V (Apollo funded)	–	68A/70A	9	1	–	–	–	–	–
1231-01	125% Saturn V	69A	73A/86A	53	6	570	42	5583	1097	7292
	Subtotal					570	42	7138	1295	9045
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	70B/72B	10	1	–	–	896	215	1111
1311-01/1321-02	CSM – LOR – Three-Man	–	73A/80A	22	3	–	–	1975	476	2451
1311-02/1321-04	CSM – LOR – Three-Man	72A	74B/86A	15	2	78	–	1377	323	1778
1331-01/1341-01	LM Taxi – Two-Man	67A	70A/72B	5	1	32	–	299	73	404
1332-01/1342-01	LM Taxi – Three-Man	69B	73A/80A	10	1	234	–	584	137	955
1332-02/1342-01	LM Taxi – Three-Man	71A	74B/86B	15	2	129	–	887	201	1217
1351-02	LM Truck	69A	73A/80A	12	2	99	–	275	115	489
1423-02/1433-02	Logistic Braking and Landing Stages	76A	80B/86A	16	2	599	24	238	38	899
	Subtotal					1171	24	6531	1578	9304
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/71B	3	1	1	–	–	–	1
1351-03/2321-01	LM Shelter – Two-Man	67A	70A/72B	5	1	216	–	256	72	544
2322-02	Shelter – Three-Man	77B	82A/84A	3	1	317	–	144	20	481
2322-08	Shelter – Three-Man (nuclear powered)	79B	84B/84B	1	1	360	–	76	10	446
2421-01	LSSM	67A	70A/84B	12	2	58	2	63	7	130
2423-01	LRV – Three-Man	67A	73A/86A	18	2	360	2	314	24	700
2432-04	Trailer – Multipurpose	71B	74B/84B	7	1	44	–	43	2	89
2512-03	LFV – Two-Man Exploration	67A	70A/71A	2	1	48	–	8	1	57
2513-02	LFV – Three-Man Exploration	76B	80B/83A	5	1	64	–	19	2	85
2521-02	LFV – Return to Orbit	76B	80B/82A	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	78A	84B/84B	1	1	136	20	28	–	184
	Subtotal					1666	24	971	140	2801
	Major Scientific Equipment									
3213-01	300-m Drill – Fuel Cell	80B	82A/83B	2	1	4	–	3	–	7
3224-01	Radio Telescope – Mills Cross	79A	84B/84B	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	78A	84B/84B	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	80A	84B/84B	2	1	28	–	17	2	47
3242-04	2-m Optical Telescope	79A	84B/84B	1	1	152	–	25	1	178
	Subtotal					253	–	59	5	317
	Total					3660	90	14,699	3018	21,467

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM B'-IVb

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the medium scientific program (Scientific Program B') using the "locale approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second step introduces an uprated Saturn (125% Saturn V) and a direct logistics landing vehicle (LLV).

Fifteen locales are to be visited in the preferred order 17, 26, 2, 11, 28, 21, 15, 1, 4, 7, 6, 20, 3, 16, and 12. Three different paths are to be explored in a preferred order. Two regions are to be explored. Locales, paths, and regions can be mingled in almost any order desired.

Cost goals are set at 1 to 2 billion dollars per year. The launch rate is four per year.

As developed within these constraints, exploration program B'-IVb introduces the 125% Saturn and the LLV in 1973. The program is completed with a medium astronomy mission to Grimaldi, beginning in early 1983 and requiring 12 launches. The total number of Saturn launches is 73, including 6 Apollo missions and 2 test launches (for the Saturn uprating). The total post-Apollo cost is 20.8 billion dollars spread over a period of about 18 years. The program indicates a cost of about 1.5 billion dollars for introduction of the 125% Saturn, the LLV, and associated systems. Development funds must be committed in 1967.

COST AND SCHEDULE SUMMARY

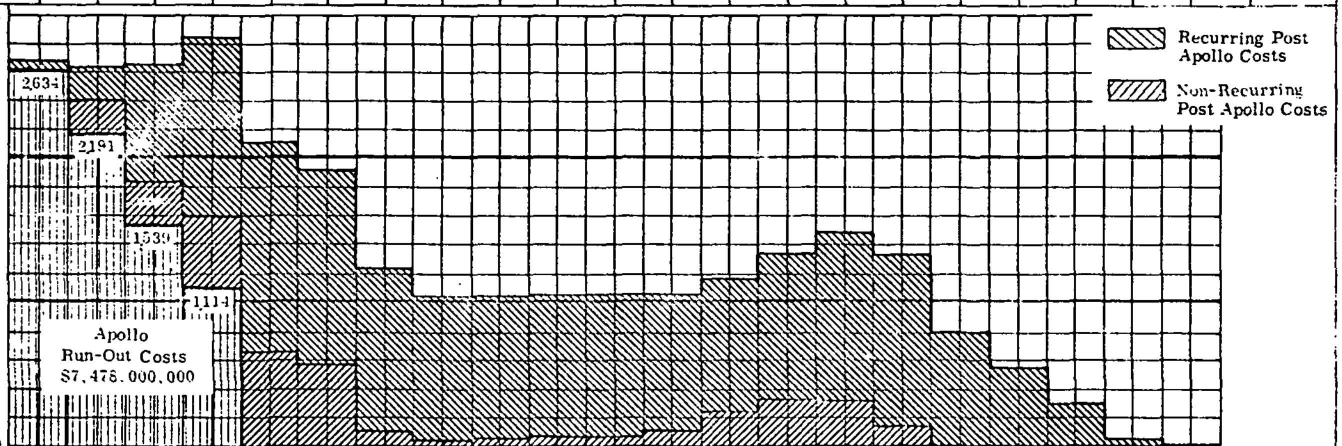
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
LAUNCH RATE		3	3	4	5	6	4	4	4	4	4	3	4	5	4	4	7		5			73
Apollo Missions		3	3																			
Equipment Evolution Step 1 Missions		▼		3	3	2																
Step 2 Missions		▼				TT	2	2	2	2	2	1	2	2	2	2	1		1			

KEY MILESTONES

▼ – Earliest Req'd R&D Start

N – Number of Missions Started

T – Required Test Launches



	Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS	TOTAL (MILLIONS)	58	434	1092	1735	2096	1897	1215	1036	1036	1050	1031	1025	1193	1353	1520	1346	796	539	328	29	3	20,812
Non-Recur	R&D	41	224	354	407	617	564	84	13	30	46	39	110	238	314	312	153						3546
Non-Recur	C OF F		3	6	31	30						9	10	3									92
Recurring	PROCUREMENT	17	207	706	1145	1192	1064	877	814	785	789	759	689	773	796	986	930	471	430	118			13,548
Recurring	OPERATIONS			26	152	257	269	254	209	221	215	224	216	179	243	222	263	325	109	210	29	3	3626

(a) Includes six Apollo launches.

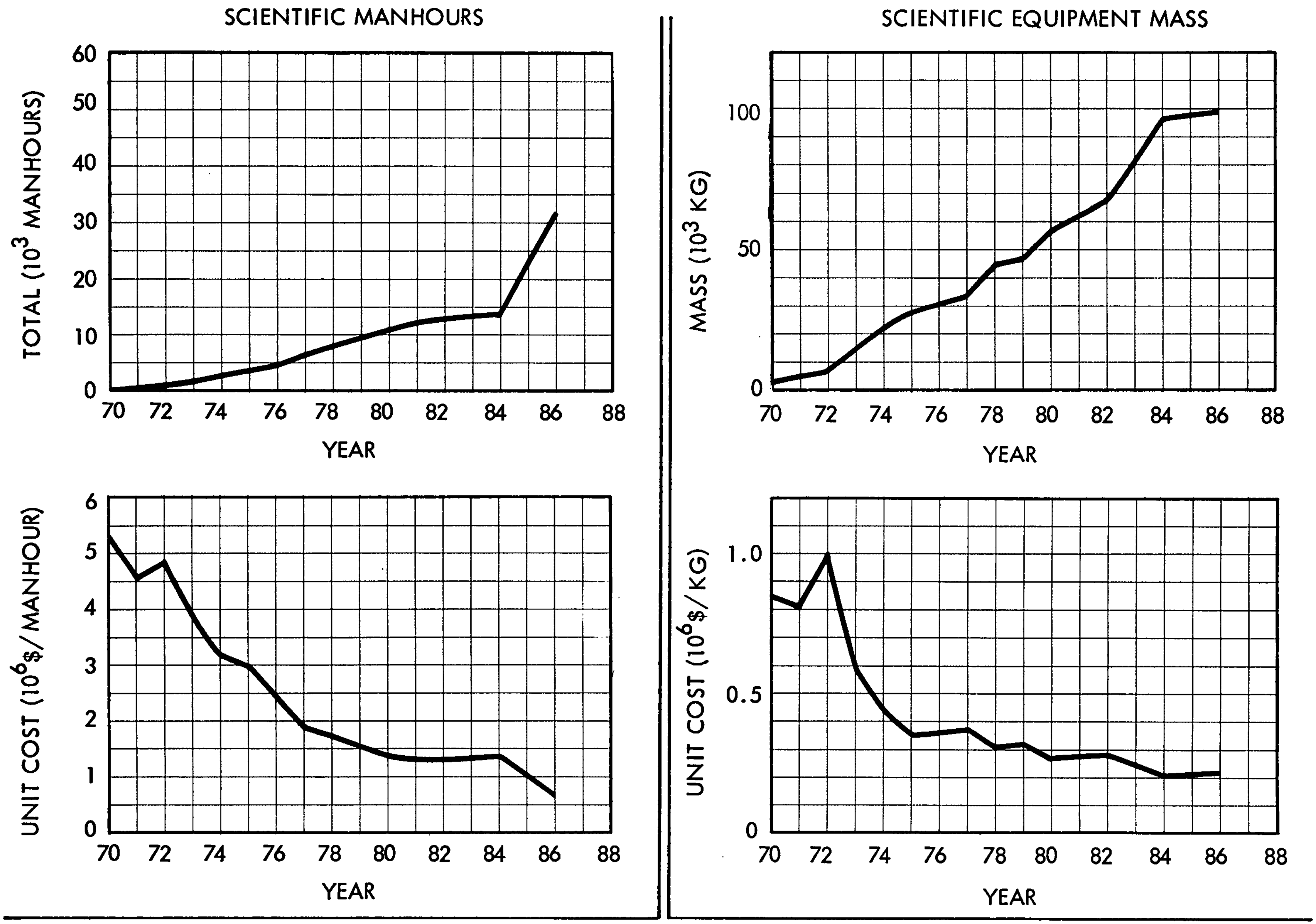
POST-APOLLO MISSION SUMMARY

No.	Start	Mission: Location (paths – locales)	Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
7	70A	Orbiter 1	303-10021-01	1	–	10	663	221	3690	1750	(12,570)	–
8	70A	Ranger VIII Landing Site	402-10012-01	2	17	14	665	181	4410	430	690	150
9	70B	Orbiter 2	303-10022-01	1	–	10	663	221	3690	1730	(12,590)	–
10	71A	Moltke B	402-10011-01	2	26	16	740	182	4450	470	640	150
11	71B	Orbiter 3	303-10022-01	1	–	10	663	221	3670	1730	(12,590)	–
12	71B	Alphonsus 1	402-10011-03	2	2	13	627	158	4380	640	990	30
13	72A	Alphonsus 2	402-10011-03	2	2	14	642	163	4010	270	1360	30
14	72B	Alphonsus 3	402-10011-03	2	2	15	714	181	4000	260	1370	90
15	73A	Tycho	503-20126-01	2	11	17	1231	511	7629	1224	8571	150
16	73B	Marius Hills to Aristarchus	503-20126-01	2	j	12	815	206	12,520	6134	4450	500
17	74A	Mare Nubium	503-20126-01	2	28	18	1262	520	7652	1247	8857	150
18	74B	Southern Highlands	503-20126-01	2	i	12	815	206	12,520	6134	4450	500
19	75A	Grimaldi, Astronomical Location	503-20126-01	2	21	12	875	340	7371	986	9361	150
20	75B	Central Farside	503-20126-01	2	ℓ	12	815	206	12,520	6134	9450	500
21	76A	Farside	503-20126-01	2	15	20	1439	611	7499	1084	9113	150
22	76B	Hyginus Rille	503-20126-01	2	1	21	525	621	7592	1177	8608	150
23	77A	Hadley's Rille	503-20126-01	2	4	20	1426	604	7494	1089	8706	150
24	77B	Palus Putredinis	503-20126-02	2	I	47	3355	1484	8067	939	8151	300
25	78A	Marius Hills	503-20152-01	3	7	31	2191	943	20,090	11,624	12,510	150
26	79A	Palus Putredinis	503-20126-02	2	I	38	2690	1165	9056	976	7244	300
27	79B	Aristarchus	503-20126-01	2	6	19	1351	568	7629	1224	8571	150
28	80A	Southern Highlands	503-20152-01	3	20	30	2110	905	19,523	11,550	13,077	150
29	80B	Copernicus	503-20126-02	2	II	36	2590	1132	8918	957	7382	250
30	81A	Capella M	503-20126-01	2	3	20	1409	606	7600	1195	8600	150
31	81B	South Pole	503-20126-01	2	16	16	1164	478	7556	1150	8644	150
32	82A	Grimaldi, Astronomical Location	503-20126-03	2	21	21	1508	635	10,398	3943	5902	150
33	82B	Mare Orientale	503-20126-01	2	12	18	1248	519	7494	1088	8826	150
34	83A	Grimaldi.Astronomical Location 2A	403-20301-01	7	21	143	10,244	467	59,999	29,602	4343	240
35	85A	Grimaldi.Astronomical Location 2B	403-20311-01	5	21	536	38,556	18,424	31,342	2270	1255	100
		Total				1201	82,996	32,679	312,769	99,007	171,120	5090

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	70B/72B	10	1	–	–	1555	198	1753
1221-03	100% Saturn V (Apollo funded)	–	68A/70A	9	1	–	–	–	–	–
1231-01	125% Saturn V	69A	73A/85A	52	6	570	42	5502	1078	7192
	Subtotal					570	42	7057	1276	8945
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	70B/72B	10	1	–	–	908	211	1119
1311-02/1321-04	CSM – LOR – Three-Man	70B	73A/85A	25	3	76	–	2225	532	2833
1331-01/1341-01	LM Taxi – Two-Man	67A	70A/72B	5	1	32	–	300	73	405
1332-02/1342-01	LM Taxi – Three-Man	69B	73A/85A	25	3	246	–	1457	350	2053
1423-02/1433-02	Logistic Braking and Landing Stages	68B	73A/85A	27	3	599	24	570	102	1295
	Subtotal					953	24	5460	1268	7705
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/71B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67A	70A/72B	5	1	217	–	256	72	545
2322-08	Shelter – Three-Man	78A	83A/–	1	1	360	–	76	10	446
2421-01	LSSM	67A	70A/72B	6	1	58	2	35	4	99
2423-01	LRV – Cabin – Three-Man	77A	83A/85A	2	1	360	2	50	4	416
2423-02	LRV – Cabin – Three-Man	67A	73A/82B	19	2	387	2	340	27	756
2432-04	Trailer – Multipurpose	80A	83A/–	1	1	44	–	12	1	57
2512-03	LFV – Two-Man Exploration	67A	70A/70A	2	1	48	–	8	1	57
2521-02	LFV – Return to Orbit	73B	77B/80B	5	1	62	–	20	2	84
2721-02	Nuclear Power Supply – 20 kw	76B	83A/–	1	1	136	20	28	–	184
	Subtotal					1673	26	825	121	2645
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	74B	78A/80A	2	1	11	–	6	–	17
3224-01	Radio Telescope – Mills Cross	77B	83A/–	1	1	30	–	8	1	39
3231-01	X-Ray Telescope	76B	83A/–	1	1	39	–	6	1	46
3242-01	1-m Optical Telescope	77B	82A/83A	2	1	29	–	17	2	48
3242-04	2-m Optical Telescope	77B	83A/–	1	1	152	–	25	1	178
	Subtotal					261	–	62	5	328
	Total					3457	92	13,405	2670	19,624

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM C-IIa

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the small scientific program (Scientific Program C) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. A second evolutionary step introduces the LM/Truck. No uprating of the Saturn V is permitted.

Six locales are to be visited in the preferred order 17, 26, 2, 5, 18, and 3. Six different paths are to be explored in a preferred order. Locale visits and path explorations can be freely intermixed.

Cost goals are set at 1 to 2 billion dollars per year. Launch rates are limited to three or four per year through 1975, four per year through 1977, and six to eight per year thereafter.

As developed within these constraints, exploration program C-IIa introduces the LM/Truck in 1975. The only major scientific equipment used is a 300-m drill; however, approximately 42,000 kg of explosives are delivered for seismic experiments. The total number of Saturn launches is 76, including 6 Apollo missions. The total post-Apollo cost is 23.4 billion dollars spread over a period of about 18 years. The major R&D costs of this program are 0.34 billion dollars and 0.16 billion dollars for the two-man roving vehicle and two-man shelter, respectively.

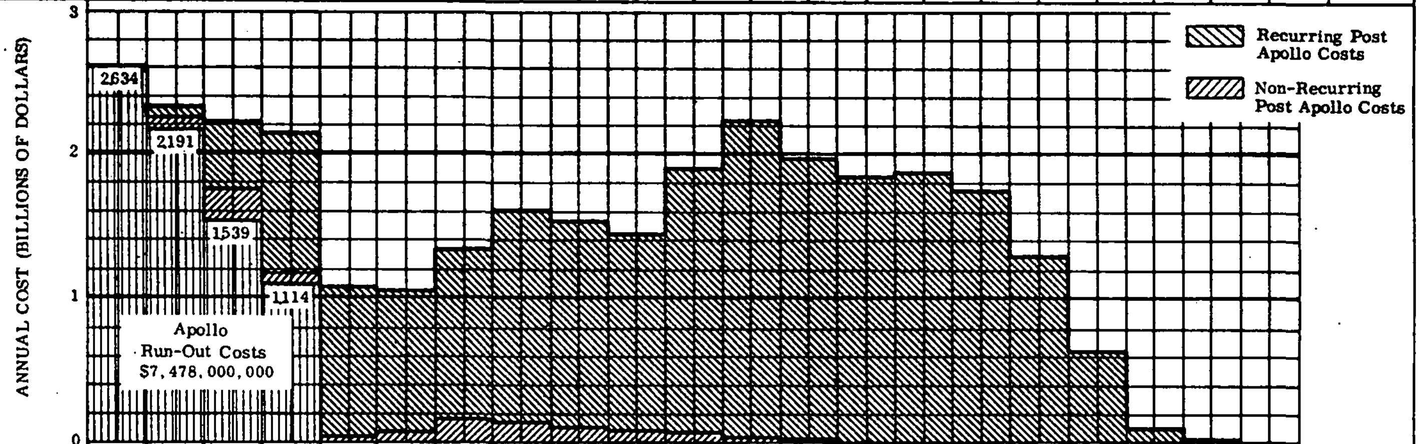
COST AND SCHEDULE SUMMARY

Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	
LAUNCH RATE		3	3	3	3	4	3	2	4	5	2	8	6	8	4	7	4	7				76 Launch Total[a]
KEY MILESTONES: Apollo Missions		3	3																			
Equipment Evolution Step 1 Missions (N)	▼			2	2	2	2	1														
Step 2 Missions (T)				▼					2	1	1	2	2	2	1	2	1	2				

▼ – Earliest Req'd R&D Start

N – Number of Missions Started

T – Required Test Launches



Fiscal Years		1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS	TOTAL (MILLIONS)	2	164	691	1034	1062	1054	1343	1606	1513	1428	1913	2203	1980	1828	1852	1757	1275	623	81	4		23,413
Non-Recur	R&D	2	86	198	88	9	66	178	148	117	107	82	20	3									1104
Non-Recur	C OF F		1	1				1	2														5
Recurring	PROCUREMENT		77	481	854	850	802	1013	1256	1095	1031	1660	1734	1535	1410	1535	1298	939	309	3			17,882
Recurring	OPERATIONS			11	92	203	186	151	200	301	290	171	449	442	418	317	459	336	314	78	4		4422

(a) Includes six Apollo launches.

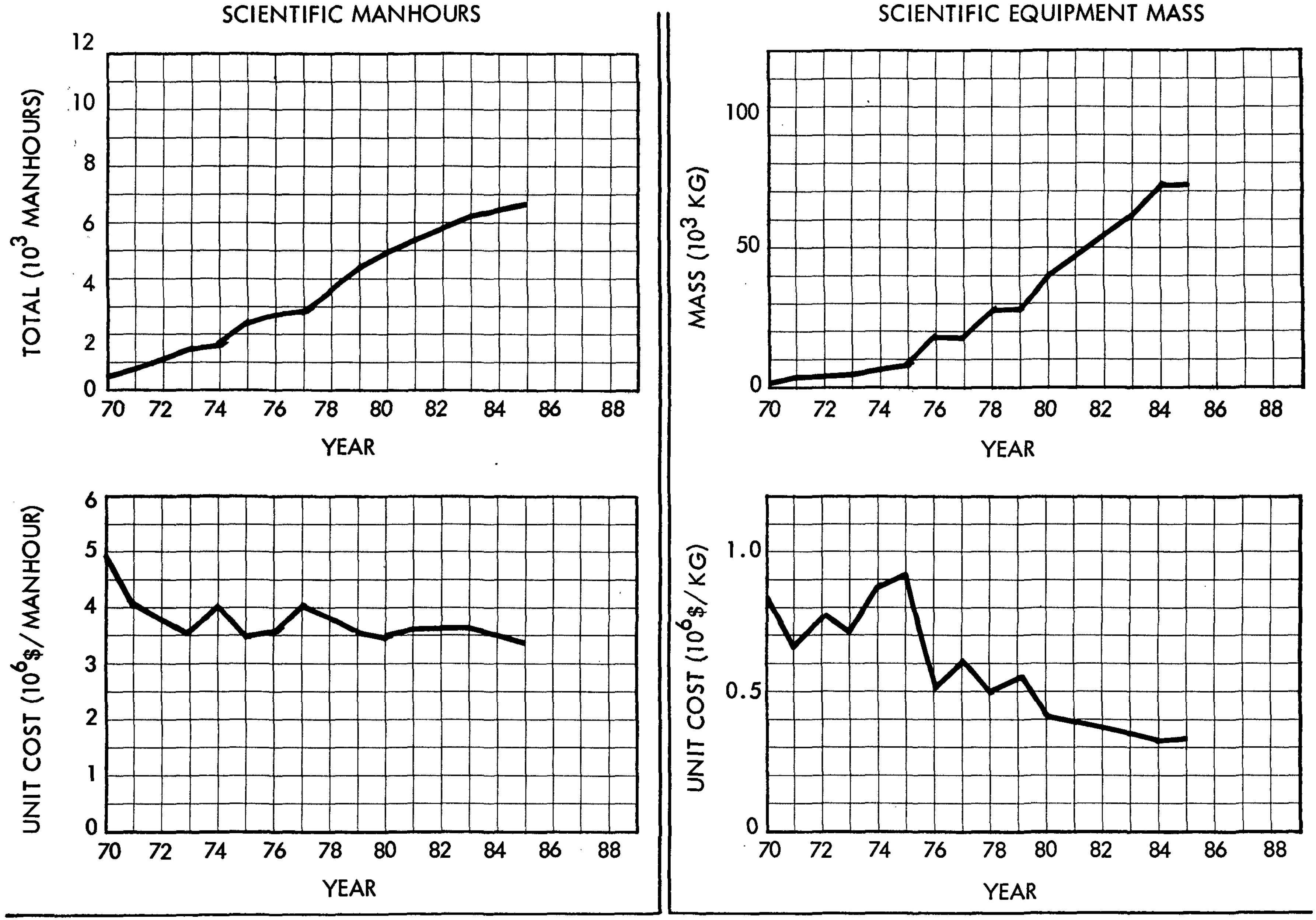
POST-APOLLO MISSION SUMMARY

No.	Start	Mission: Location (paths – locales)	Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
7	70A	Orbiter 1	303-10021-01	1	–	9	636	212	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	649	157	4619	472	491	150
9	71A	Moltke B	402-10011-01	2	26	12	593	139	4487	421	596	150
10	71B	Orbiter 2	303-10022-01	1	–	9	636	212	4183	1737	(11,230)	–
11	72A	Ranger VIII Landing Site	402-10011-01	2	17	14	654	157	4949	435	534	150
12	72B	Moltke B	402-10011-01	2	26	14	662	160	4521	392	562	150
13	73B	Orbiter 3	303-10022-01	1	–	9	636	212	4183	1737	(11,230)	–
14	73B	Alphonsus	402-10011-01	2	2	20	951	244	4804	462	279	150
15	74B	Alphonsus	402-10011-01	2	2	19	926	236	4819	611	269	150
16	75A	Dark Halo Craters Southeast of Copernicus	402-10041-01	2	5	26	1246	344	4716	636	372	150
17	75B	Straight Wall	402-10041-01	2	18	23	1099	300	4618	571	470	150
18	76A	Straight Wall	402-10041-02	5	18	38	1838	383	15,667	10,428	1323	150
19	77B	Capella M	402-10041-01	2	3	14	683	175	3818	26	549	150
20	78A	Marius Hills to Aristarchus	502-10021-02	4	j	22	1054	362	12,960	4438	0	400
21	78B	Marius Hills to Aristarchus	502-10021-05	3	j	23	1096	332	8966	3320	3861	600
22	79A	Point at South End of Marius Hills to Aristarchus	502-10011-01	3	j	23	1102	491	6579	859	1998	440
23	79B	Point at South End of Palus Putredinis to Mare Vaporum	502-10011-01	3	c	21	985	354	6054	376	2523	960
24	80A	Point at East End of M Imbr to M Seren	502-10021-02	4	b	20	951	294	11,744	6430	1193	500
25	80B	Point at Middle of M Imbr to M Seren	502-10021-02	4	b	18	841	302	12,116	6823	811	200
26	81B	Point at Middle of M Imbr to M Seren	502-10021-05	4	b	22	1058	345	10,656	6887	353	500
27	82A	Mare Imbrium to Mare Serenitatis	502-10021-05	4	b	18	884	282	10,529	6500	760	400
28	82B	Mare Imbrium to Mare Serenitatis	502-10011-01	3	b	11	514	235	6099	443	2477	300
29	83A	Mare Imbrium to Mare Serenitatis	502-10021-05	4	b	18	884	282	10,268	6500	741	400
30	84A	Palus Putredinis to Mare Vaporum	402-10041-02	5	c	38	1838	383	15,781	10,428	2227	150
31	84B	Palus Putredinis to Mare Vaporum	402-10041-01	2	c	15	736	191	4268	466	0	150
		Total				470	23.152	6784	185.587	73,135	22,389	6500

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/84B	67	7	–	–	9361	1332	10.693
1221-03	100% Saturn V (Apollo funded)	–	68A/70B	9	1	–	–	–	–	–
	Subtotal					–	–	9361	1332	10.693
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/84B	67	7	–	–	5625	1421	7046
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/84B	22	3	32	–	1187	303	1522
1351-01	LM Truck	71A	75A/84A	39	4	99	–	795	353	1247
	Subtotal					131	–	7607	2077	9815
	Mission Equipment									
2132-02	Surface-Launched Probe	76A	78B/83A	8	1	38	–	20	2	60
2222-02	Orbiter Rack	68A	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/74B	6	1	217	–	297	84	598
2321-02	Shelter – Two-Man	70B	75A/84B	6	1	165	–	143	25	333
2421-01	LSSM	67B	70B/84B	12	2	58	2	63	7	130
2422-01	LRV – Cabin – Two-Man	72B	78A/83A	10	1	344	2	155	12	513
2432-02	Trailer – Multipurpose	75A	78A/83A	10	1	44	–	57	2	103
2512-03	LFV – Two-Man Exploration	67B	70B/82B	9	1	48	–	25	2	75
	Subtotal					915	4	760	134	1813
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	73A	76A/84A	2	1	11	–	6	–	17
	Subtotal					11	–	6	–	17
	Total					1057	4	17,734	3543	22,338

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM C-IVa

GENERAL DESCRIPTION

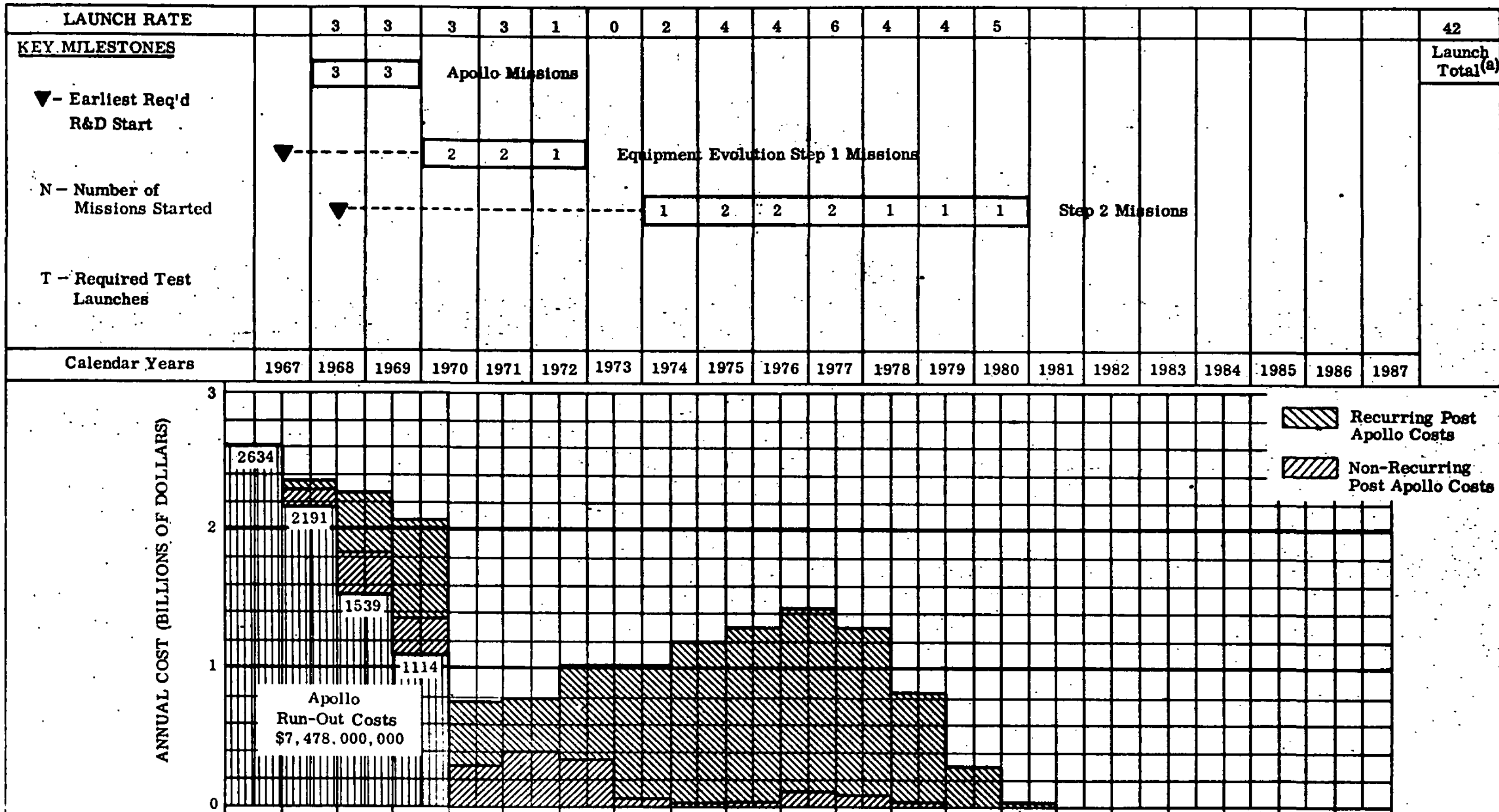
This lunar exploration program is designed to accomplish the small scientific program (Scientific Program C) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step will provide a direct logistics landing vehicle (LLV), an extended stay-time personnel delivery command service module and a long-range, three-man lunar roving vehicle (LRV) which provides living quarters for the crew on the lunar surface. No Saturn V uprating is required.

Six locales are to be visited and six paths are to be explored. The more demanding missions, in terms of stay time and mass delivery requirements, were scheduled later in the program. The only major scientific equipment used is the 300-m drill.

Launch rates were limited to four per year through 1977 and six per year thereafter. No rigid cost constraints were imposed on this program. Transportation system costs for the first two post-Apollo missions are considered to be Apollo run-out costs and not included as part of this program cost.

Exploration program C-IVa introduces the post-S/AA hardware, including the LLV, in 1974. The total number of operational Saturn V launches is 42, including six Apollo missions. The total post-Apollo cost is 11.8 billion dollars spread over a period of 13 years. The major R&D costs of the program are 0.4 billion dollars for the three-man LRV (to be committed in 1968) and 0.6 billion dollars for the LLV (to be committed in 1970).

COST AND SCHEDULE SUMMARY



		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS		TOTAL (MILLIONS)	1	182	722	931	783	795	1009	1008	1202	1296	1427	1300	832	289	24	4						11,805
	Non-Recur	R&D	1	104	276	245	280	398	344	41	13	24	115	95	39									1975
		C OF F		1	2	4	12	9			1	2	1											32
	Recurring	PROCUREMENT		77	433	590	316	325	605	850	1010	1034	1062	944	538	125								7909
		OPERATIONS			11	92	175	63	60	117	178	236	249	261	255	164	24	4						1889

(a) Includes six Apollo launches.

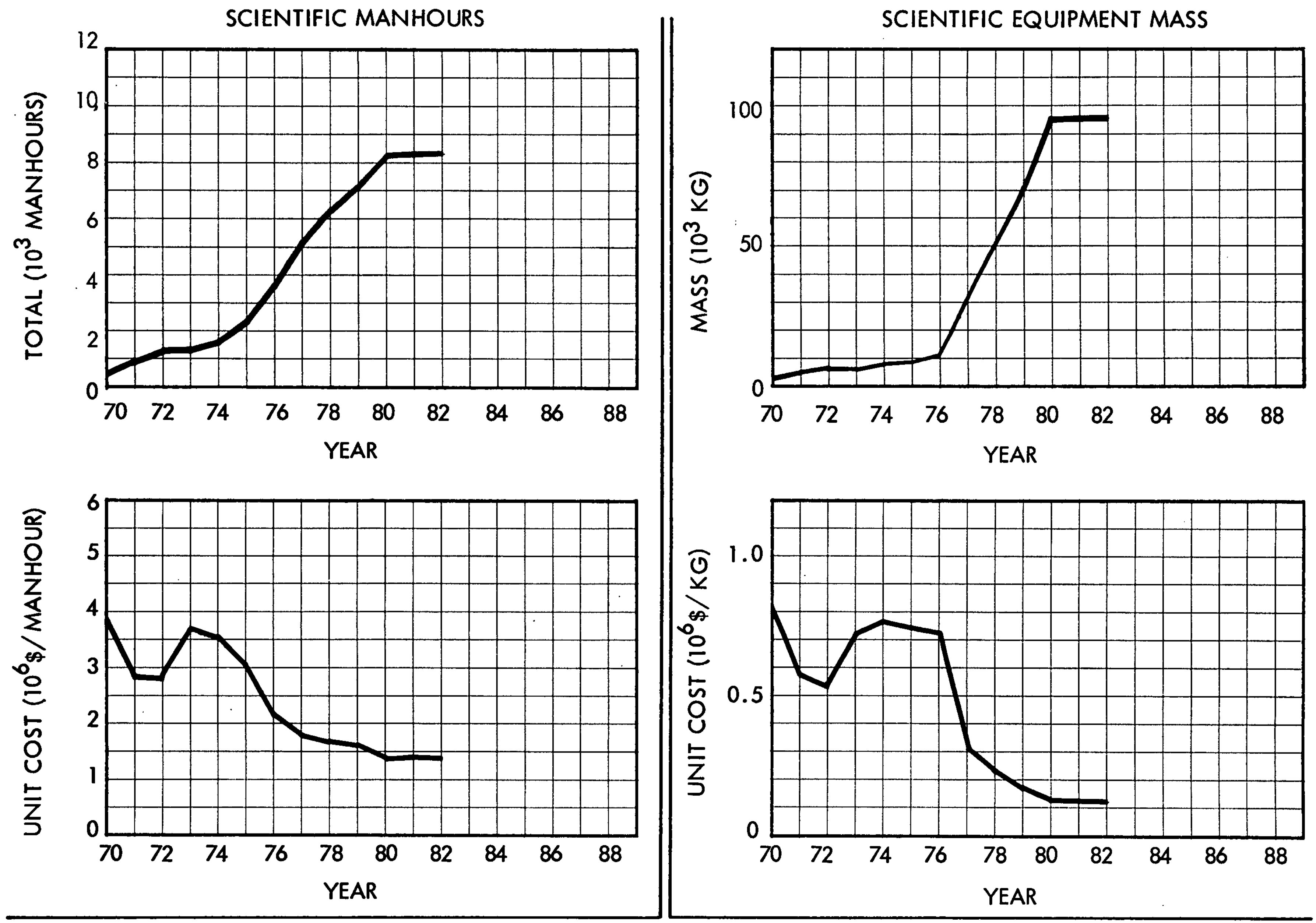
POST-APOLLO MISSION SUMMARY

Mission			Mock Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	303-10012-01	2	17	14	655	178	4368	488	630	150
9	71A	Moltke B	402-10011-01	2	26	15	731	179	4464	520	598	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	4223	1777	(10,382)	–
11	72B	Orbiter 3	303-10022-01	1	–	12	861	287	4223	1777	(10,383)	–
12	74A	Capella M	503-20371-01	2	3	13	936	331	10,236	806	1294	150
13	75A	Dark Halo Craters Southeast of Copernicus	503-20371-01	2	5	13	936	321	10,192	762	1338	150
14	75B	Mare Orientale	503-20371-01	2	m	14	1008	320	10,532	1102	998	350
15	76A	Palus Putredinis to Mare Vaporum	503-20371-01	2	c	55	3960	1064	10,652	1122	978	1800
16	76B	Alphonsus	503-20371-01	2	2	17	1224	412	10,253	823	1237	150
17	77A	Straight Wall	503-20371-01	2	18	17	1224	408	10,255	825	1235	150
18	77B	Marius Hills to Aristarchus	503-20361-01	4	j	53	3811	976	31,075	19,275	5225	2200
19	78B	South Pole	503-20391-01	4	u	54	3888	1271	31,072	19,272	5228	1150
20	79A	Central Farside	503-20361-01	4	ℓ	38	2736	745	31,215	19,415	5085	1150
21	80A	Mare Imbrium to Mare Serenitatis	503-20351-01	5	b	62	4464	1310	38,072	25,432	10,328	2100
		Total				401	28,156	8376	21,505	95,133	34,174	9650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/80A	33	4	–	–	4942	666	5608
1221-03	100% Staurn V (Apollo Funded)	–	68A/70B	9	1	–	–	–	–	–
	Subtotal					–	–	4942	666	5608
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	70A/72B	4	1	–	–	418	96	514
1311-01/1321-03	CSM – LOR – Three-Man	71B	74A/80A	10	2	48	–	953	223	1224
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/71A	2	1	32	–	152	37	221
1332-01/1342-01	LM Taxi – Three-Man	70B	74A/80A	10	1	234	–	593	135	962
1423-01/1433-01	Logistic Braking and Landing Stages	70B	74A/80A	19	2	599	24	414	71	1108
	Subtotal					913	24	2530	562	4029
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/72B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/71A	2	1	216	–	129	36	381
2421-01	LSSM	67B	70B/71A	2	1	58	2	16	1	77
2423-03	LRV – Cabin – Three-Man	68A	74A/80A	10	1	421	2	219	17	659
2436-02	Trailer – Cargo	74B	77A/80A	4	1	275	2	17	1	295
2512-03	LFV – Exploration – Two-Man	67B	70B/71A	2	1	48	–	8	1	57
	Subtotal					1019	6	389	56	1470
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	74A	77B/80A	2	1	11	–	6	–	17
	Subtotal					11	–	6	–	17
	Total					1943	30	7867	1284	11,124

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM C-IVb

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the small scientific program (Scientific Program C) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step will employ an uprated Saturn V (125% Saturn V), a direct logistics landing vehicle (LLV), extended stay-time personnel delivery command service module, and a long-range, three-man lunar roving vehicle (LRV) which provides living quarters for the crew on the lunar surface.

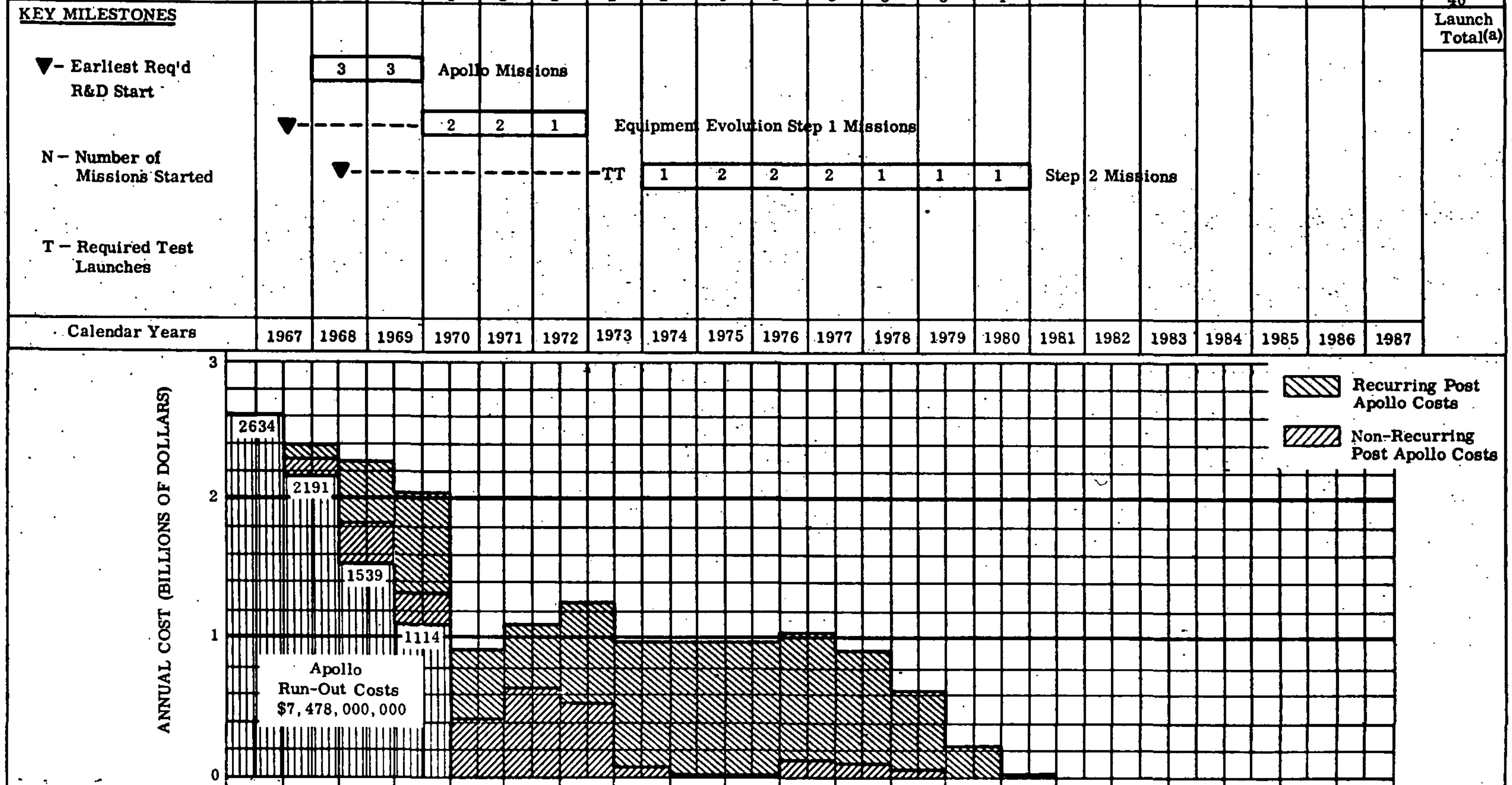
Six locales are to be visited and six paths are to be explored. The more demanding ones in terms of stay time and mass delivery requirements were scheduled later in the program. The only major scientific equipment used is the 300-m drill.

Launch rates were limited to four per year through 1977 and six per year thereafter. No rigid cost constraints were imposed on this program. Transportation system costs for the first two post-Apollo missions are considered to be Apollo run-out costs, and are not included as part of this program's cost.

Exploration program C-IVb introduces the post-S/AA hardware, including the Saturn V uprating, in 1974. The total number of operational Saturn V launches is 40, including 2 test launches and 6 Apollo missions. The total post-Apollo cost is 11 billion dollars spread over a period of 12 years. The major R&D costs of the program are 1.2 billion dollars for the Saturn V uprating and LLV (to be committed in 1970) and 0.4 billion dollars for the three-man LRV (to be committed in 1968).

COST AND SCHEDULE SUMMARY

LAUNCH RATE	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Launch Total(a)
		3	3	3	3	1	2	2	4	4	5	3	3	4								40



		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS		TOTAL (MILLIONS)	1	210	750	958	929	1107	1242	988	992	990	1033	917	622	220	15							10,974
	Non-Recur	R&D	1	132	303	271	390	611	541	83	11	22	119	97	39									2620
		C OF F		1	3	5	31	30			1	2	1											74
	Recurring	PROCUREMENT		77	433	590	333	400	632	757	821	765	703	634	358	80								6583
		OPERATIONS			11	92	175	66	69	148	159	201	210	186	225	140	15							1697

(a) Includes six Apollo launches.

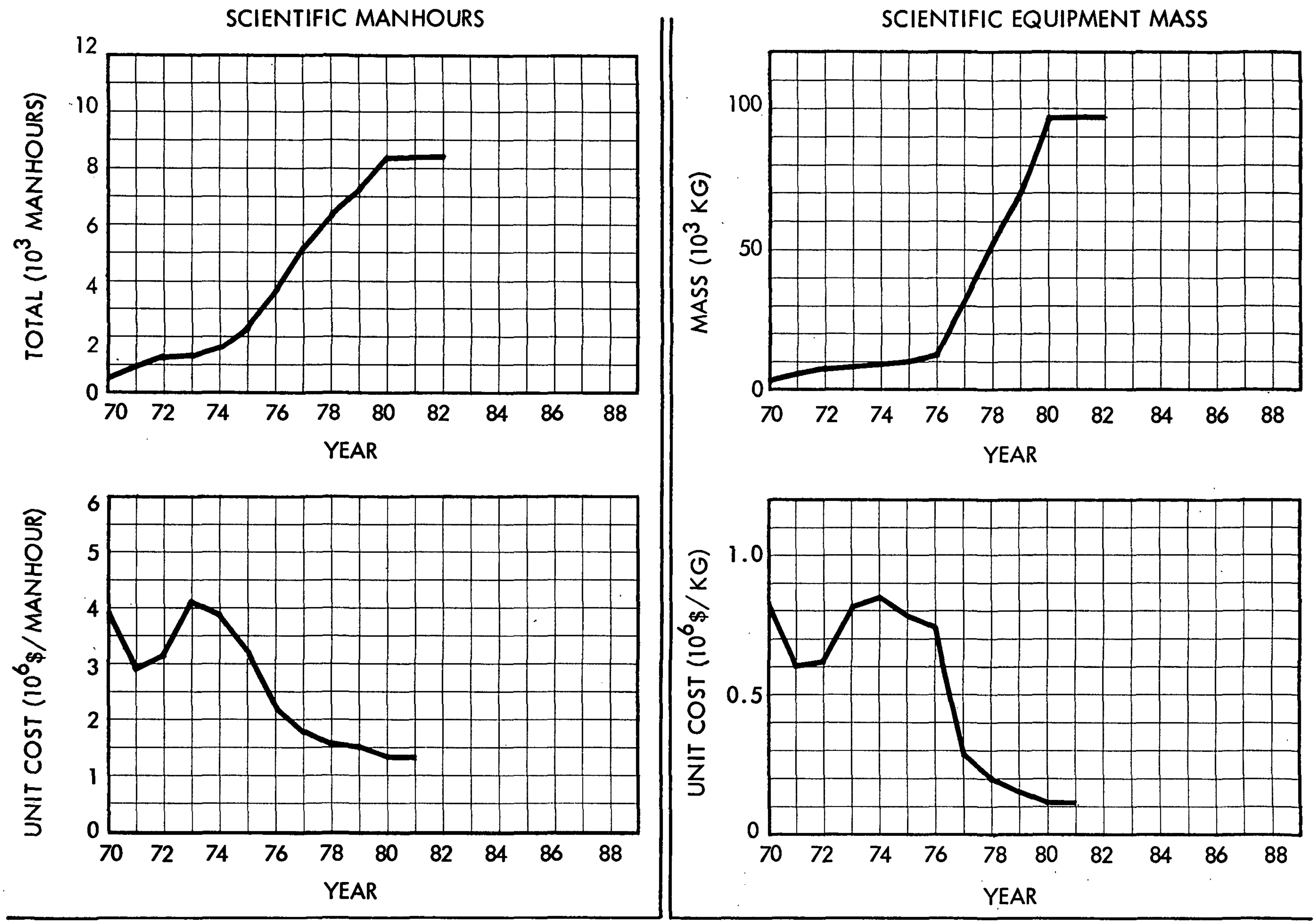
POST-APOLLO MISSION SUMMARY

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	655	178	4368	488	630	150
9	71A	Moltke B	402-10011-01	2	26	15	731	179	4464	520	598	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	4223	1777	(10,382)	–
11	72B	Orbiter 3	303-10022-01	1	–	12	861	287	4223	1777	(10,382)	–
12	74A	Capella M	503-20162-01	2	3	13	936	331	10,236	806	5494	150
13	75A	Dark Halo Craters Southeast of Copernicus	503-20162-01	2	5	13	936	321	10,192	762	5538	150
14	75B	Mare Orientale	503-20162-01	2	m	14	1008	320	10,532	1102	5198	350
15	76A	Palus Putredinis to Mare Vaporum	503-20162-01	2	c	55	3960	1064	10,652	1122	5178	1800
16	76B	Alphonsus	503-20162-01	2	2	17	1224	412	10,253	823	5437	150
17	77A	Straight Wall	503-20162-01	2	18	17	1224	408	10,255	825	5435	150
18	77B	Marius Hills to Aristarchus	503-20311-01	3	j	53	3811	976	31,075	19,275	1525	2200
19	78B	South Pole	503-20381-01	3	u	54	3888	1271	31,072	19,272	1528	1150
20	79A	Central Farside	503-20311-01	3	ℓ	38	2736	745	31,215	19,415	1385	1150
21	80A	Mare Imbrium to Mare Serenitatis	503-20321-01	4	b	62	4464	1310	38,072	25,432	10,828	2100
		Total				401	28,156	8376	214,895	95,133	48,774	9650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	71A/74A	4	1	–	–	713	90	803
1221-03	100% Saturn V (Apollo Funded)	–	68A/70B	9	1	–	–	–	–	–
1231-01	125% Saturn V	70A	74A/80A	25	3	570	42	2940	521	4073
	Subtotal					570	42	3653	611	4876
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	71A/72B	4	1	–	–	418	96	514
1311-02/1321-04	CSM – LOR – Three-Man	71B	74A/80A	10	1	76	–	900	209	1185
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/71A	2	1	32	–	152	37	221
1332-02/1342-01	LM Taxi – Three-Man	70B	74A/80A	10	1	246	–	612	137	995
1423-02/1433-02	Logistic Braking and Landing Stages	69B	74A/80A	15	2	599	24	346	58	1027
	Subtotal					953	24	2428	537	3942
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/72B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	68A	70B/71A	2	1	216	–	129	36	381
2421-01	LSSM	67B	70B/71A	2	1	58	2	16	1	77
2423-03	LRV – Three-Man	68B	74A/80A	10	1	421	2	219	17	659
2436-02	Trailer – Cargo	74B	77A/80A	4	1	275	2	17	1	295
2512-03	LFV – Exploration – Three-Man	67B	70B/71A	2	1	48	–	8	1	57
	Subtotal					1019	6	389	56	1470
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	75A	78B/80A	2	1	11	–	6	–	17
	Subtotal					11	–	6	–	17
	Total					2553	72	6476	1204	10,305

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM C-VIe

GENERAL DESCRIPTION

This lunar exploration program is designed to accomplish the small scientific program (Scientific Program C) using the "path approach." The first evolutionary hardware step beyond Apollo uses S/AA-type hardware. The second evolutionary step will employ an uprated Saturn V (150% Saturn V), a direct logistics landing vehicle (LLV), a direct three-man delivery system, and a long-range, three-man lunar roving vehicle (LRV) which provides living quarters for the crew on the lunar surface.

Six locales are to be visited and six paths are to be explored. The more demanding ones in terms of stay time and mass delivery requirements were scheduled later in the program. The only major scientific equipment used is the 300-m drill.

Launch rates were limited to four per year through 1977 and six per year thereafter. No rigid cost constraints were imposed on this program. Transportation system costs for the first two post-Apollo missions are considered to be Apollo run-out costs and are not included as part of this program's cost.

Exploration program C-IVe introduces the post-S/AA hardware, including the Saturn V uprating, in 1974. The total number of operational Saturn V launches is 39, including 2 test launches and 6 Apollo missions. The total post-Apollo cost is 11.5 billion dollars spread over a period of 14 years. The major R&D costs of the program are 1.8 billion dollars for the Saturn V uprating, LLV, and direct personnel delivery system (committed in 1970) and 0.4 billion dollars for the three-man LRV (to be committed in 1968).

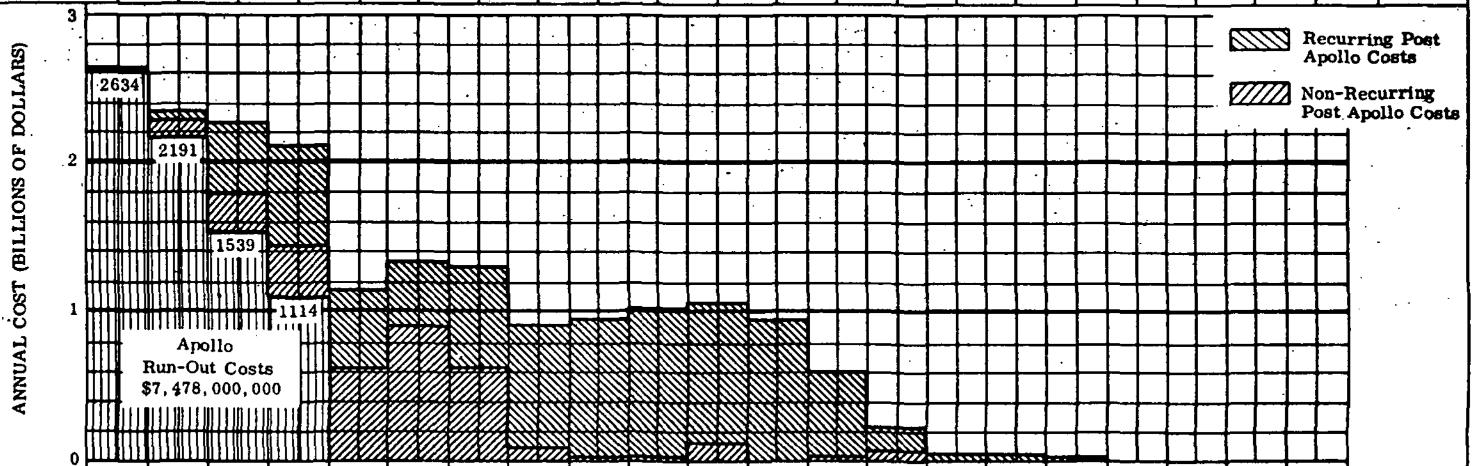
COST AND SCHEDULE SUMMARY

Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	
LAUNCH RATE		3	3	3	3	1	2	2	4	4	5	3	3	3								39 Launch Total(a)
KEY MILESTONES: Apollo Missions		3	3																			
Equipment Evolution Step 1 Missions		▼		2	2	1																
Step 2 Missions		▼					TT	1	2	2	2	1	1	1								

▼ – Earliest Req'd R&D Start

N – Number of Missions Started

T – Required Test Launches



		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
POST APOLLO COSTS		TOTAL (MILLIONS)	1	182	729	1014	1150	1333	1300	928	957	1001	1050	923	604	218	55	43	17					11,505
	Non-Recur	R&D	1	104	282	316	570	843	625	83	11	22	119	97	39									3112
		C OF F		1	3	16	67	58			1	2	1											149
	Recurring	PROCUREMENT		77	433	590	338	369	610	718	786	751	673	587	300	64								6290
		OPERATIONS			11	92	175	63	65	127	159	226	257	245	265	154	55	43	17					1954

(a) Includes six Apollo launches.

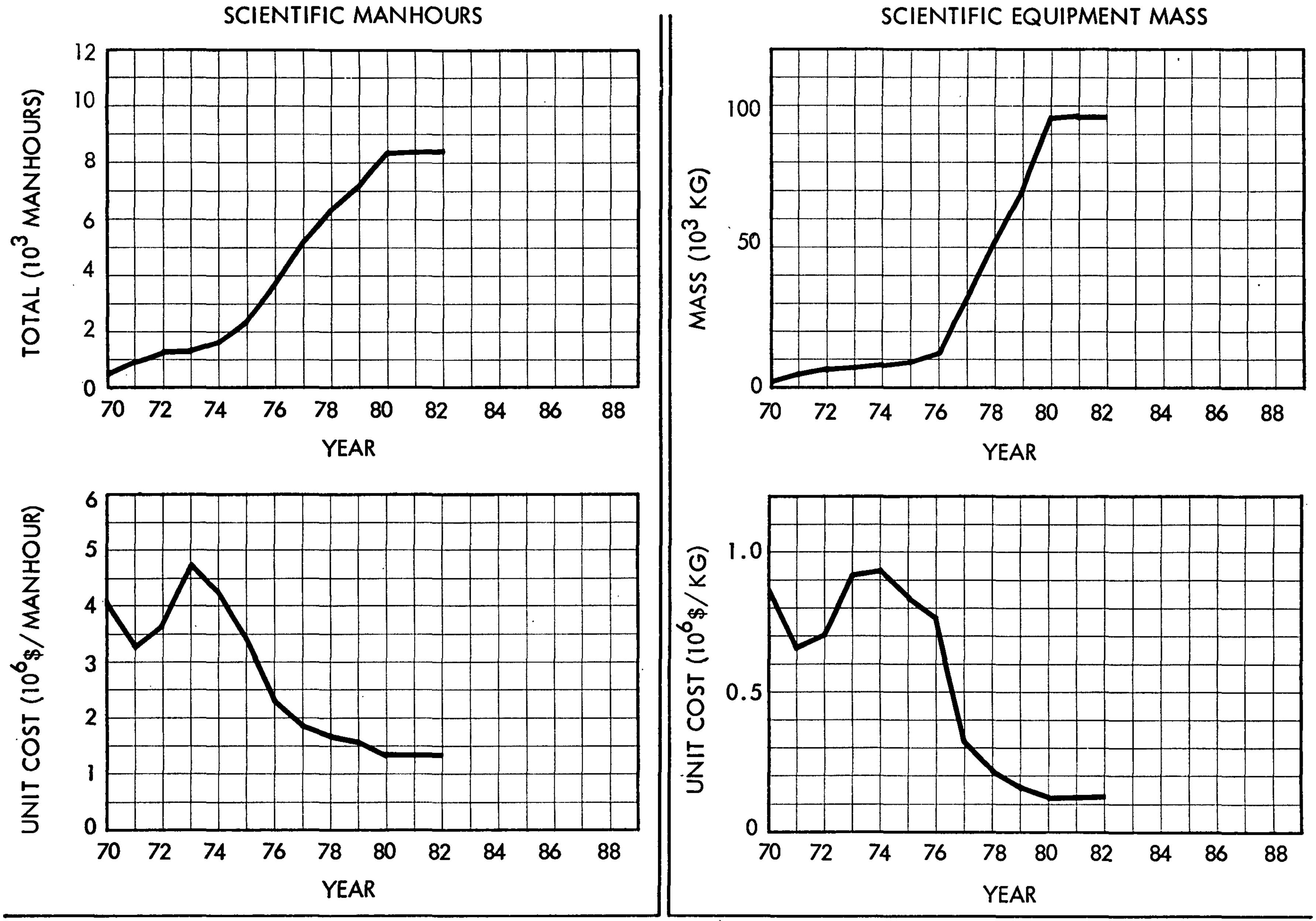
POST-APOLLO MISSION SUMMARY

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	12	861	287	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10012-01	2	17	14	655	178	4368	488	630	150
9	71A	Moltke B	402-10011-01	2	26	15	731	179	4464	520	598	150
10	71B	Orbiter 2	303-10022-01	1	–	12	861	287	4223	1777	(10,382)	–
11	72B	Orbiter 3	303-10022-01	1	–	12	861	287	4223	1777	(10,383)	–
12	74A	Capella M	503-30151-01	2	3	13	936	331	10,236	806	9994	150
13	75A	Dark Halo Craters Southeast of Copernicus	503-30151-01	2	5	13	936	321	10,192	762	10,338	150
14	75B	Mare Orientale	503-30151-01	2	m	14	1008	320	10,532	1102	9698	350
15	76A	Palus Putredinis to Mare Vaporum	503-30151-01	2	c	55	3960	1064	10,652	1122	9678	1800
16	76B	Alphonsus	503-30151-01	2	2	17	1224	412	10,253	823	9937	150
17	77A	Straight Wall	503-30151-01	2	18	17	1224	408	10,255	825	9935	160
18	77B	Marius Hills to Aristarchus	503-30131-01	3	j	53	3811	976	31,075	19,275	9725	2200
19	78B	South Pole	503-30141-01	3	u	54	3888	1271	31,072	19,272	9728	1150
20	79A	Central Farside	503-30131-01	3	ℓ	38	2736	745	31,215	19,415	9585	1150
21	80A	Mare Imbrium to Mare Serenitatis	503-30141-01	3	b	62	4464	1310	38,072	25,432	2728	2100
		Total				401	28,156	8376	214,895	95,133	92,574	9650

EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn	—	71A/74A	4	1	—	—	713	90	803
1221-03	100% Saturn (Apollo Funded)	—	68A/70B	9	1	—	—	—	—	—
1241-01	150% Saturn	70A	74A/80A	24	3	595	80	3079	502	4256
	Subtotal					595	80	3792	592	5059
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	—	71A/72B	4	1	—	—	418	96	514
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/71A	2	1	32	—	152	37	221
1411-02/1453-01	CSM – Direct – Three-Man	70A	74A/80A	10	1	352	12	933	209	1506
1421-01/1431-01	Personnel Braking and Landing Stages	69A	74A/80A	10	1	459	24	170	30	683
1423-03/1433-03	Logistic Braking and Landing Stages	—	74A/80A	14	2	317	12	376	63	768
	Subtotal					1160	48	2049	435	3692
	Mission Equipment									
2222-02	Orbiter Rack	68A	70A/72B	3	1	1	—	—	—	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/71A	2	1	216	—	129	36	381
2421-01	LSSM	67B	70B/71A	2	1	58	2	16	1	77
2423-03	LRV – Three-Man	68A	74A/80A	10	1	421	2	219	17	659
2436-02	Trailer – Cargo	74B	77B/80A	4	1	275	2	17	1	295
2512-03	LFV – Exploration – Two-Man	67B	70B/71A	2	1	48	—	8	1	57
	Subtotal					1019	6	389	56	1470
	Major Scientific Equipment									
3213-02	300-m Drill With Fuel Cell	75A	78B/80A	2	1	11	—	6	—	17
	Subtotal					11	—	6	—	17
	Total					2785	134	6236	1083	10,238

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY



SUMMARY OF LUNAR EXPLORATION PROGRAM C'-Ia

GENERAL DESCRIPTION

The objective of this lunar exploration program is to accomplish as much as possible of the minimal scientific program (Scientific Program C') with the "locale approach." S/AA-type hardware is to be used for the entire post-Apollo program. This hardware includes a logistics LM, which is a stripped version of the LM shelter. The physical constraints of this system prevent transporting a lunar roving vehicle having an enclosed cabin; therefore, only the locale and region experiments of Program C' are to be undertaken.

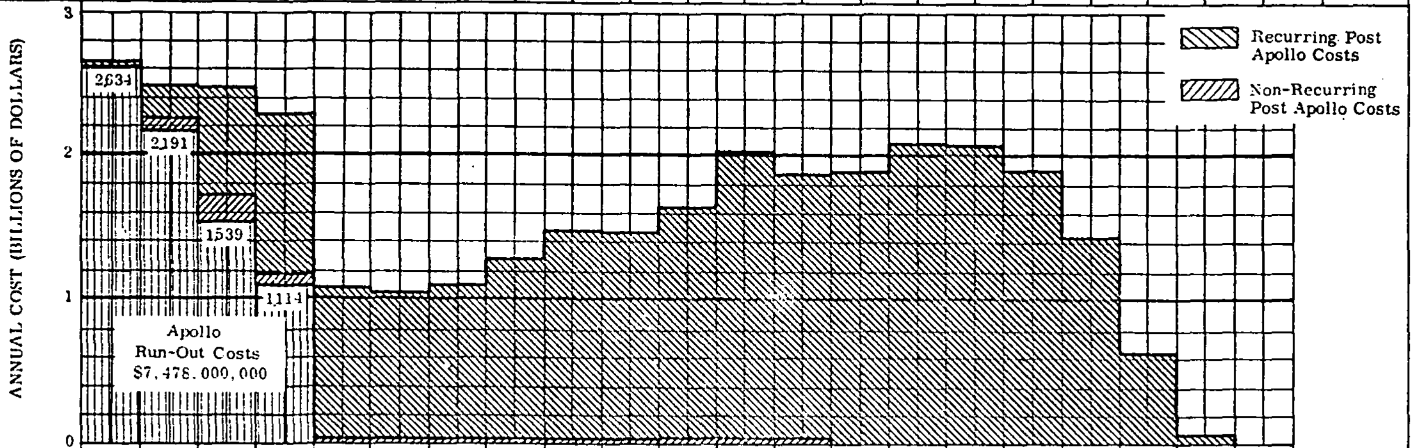
Thirteen locales are to be visited in the preferred order 17, 26, 29, 2, 15, 1, 4, 7, 6, 20, 3, 16, and 12. One region, Palus Putredinus, is to be explored by visiting 7 locales within its boundaries.

Cost goals are set at 1 to 2 billion dollars per year. Launch rates are three per year through 1975, four per year through 1977, and six per year thereafter.

With these objectives and constraints, all of the experiments specified for the locales and the one region of Scientific Program C' are to be completed by the end of 1985. Forty-two missions with a total of 81 Saturn V launches, including 6 Apollo missions, are required. In this program, the requirements of Scientific Program C' were fulfilled except that the two paths (each 100 km in length) could not be performed due to the roving limitation of the local scientific survey module. The total post-Apollo cost is 25.4 billion dollars spread over a period of about 18 years.

COST AND SCHEDULE SUMMARY

Calendar Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	
LAUNCH RATE		3	3	3	3	4	3	2	4	7		6	9	4	6	6	6	6	6			81 Launch Total(a)
KEY MILESTONES — Apollo Missions		3	3																			
▼ Earliest Req'd R&D Start / N - Number of Missions Started	▼			2	2	2	2	1	2	2	Cont.	3	3	2	3	3	3	3	3			Equipment Evolution Step 1 Missions
T - Required Test Launches																						



POST APOLLO COSTS		Fiscal Years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTALS
		TOTAL (MILLIONS)	26	296	931	1178	1066	1029	1098	1297	1471	1450	1634	2003	1885	1893	2083	2064	1900	1433	631	65		25,433
	Non-Recur	R&D	1	101	206	59	4	4	4	5	4	6	10	20	12									436
	Non-Recur	C OF F		1	1																			2
	Recurring	PROCUREMENT	25	194	711	967	848	839	921	1104	1230	1109	1420	1627	1445	1569	1671	1634	1467	1048	303	6		20,138
	Recurring	OPERATIONS			13	152	214	186	173	188	237	335	204	356	428	324	412	430	433	385	328	59		4857

(a) Includes six Apollo launches.

POST-APOLLO MISSION SUMMARY

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths – locales)										
7	70A	Orbiter 1	303-10021-01	1	–	9	636	212	4183	1737	(11,230)	–
8	70B	Ranger VIII Landing Site	402-10011-01	2	17	15	700	170	4716	624	289	150
9	71A	Moltke B	402-10011-01	2	26	15	702	171	4719	767	143	150
10	71B	Orbiter 2	303-10022-01	1	–	9	636	212	5031	1777	(10,382)	–
11	72A	Alphonsus	402-10011-01	2	2	15	685	166	4379	257	709	150
12	72B	Copernicus	402-10011-01	2	29	15	702	171	4562	425	426	150
13	73B	Orbiter 3	303-10022-01	1	–	9	636	212	5031	1777	(10,382)	–
14	73B	Hyginus Rille	402-10011-01	2	1	15	687	167	4282	142	806	150
15	74B	Hadley's Rille	402-10011-01	2	4	15	685	166	4220	79	868	150
16	75A	Hadley's Rille	402-10011-03	2	4	21	975	254	4551	664	537	150
17	75B	Farside	402-10011-01	2	15	19	893	227	4718	429	370	150
18	76A	Farside	402-10011-03	2	15	20	965	251	4510	662	268	150
19	76B	Marius Hills	402-10011-06	5	7	39	1893	383	16,397	10,428	1129	150
20	78A	Marius Hills	402-10011-03	2	7	2	105	0	3471	0	1582	150
21	78A	Marius Hills	402-10011-01	2	7	9	412	86	4048	28	1040	150
22	78A	Marius Hills	402-10011-01	2	7	20	937	240	4549	240	539	150
23	79A	Marius Hills	402-10011-01	2	7	21	1003	259	4619	257	469	150
24	79A	Aristarchus	402-10011-07	2	6	21	1005	260	4615	389	438	150
25	79B	Southern Highlands	402-10011-06	5	20	39	1893	383	16,097	10,428	1129	150
26	80B	Southern Highlands	402-10011-03	2	20	2	105	0	3471	0	1582	150
27	80B	Southern Highlands	402-10011-01	2	20	9	412	86	4048	28	1068	150
28	81A	Southern Highlands	402-10011-01	2	20	20	974	250	5198	794	0	150
29	81B	Southern Highlands	402-10011-07	2	20	21	995	258	4461	712	152	150
30	81B	Capella M	402-10011-01	2	3	21	1003	259	5140	732	0	150
31	82A	Capella M	402-10011-07	2	3	20	976	252	3978	259	635	150

(Continued on next page)

(CONT.)

Mission			Mode Identification Number	Number of Launches	Map Reference	Stay Time (days)	Total Man-hours	Scientific Man-hours	Total Cargo (kg)	Scientific Equipment (kg)	Mass Reserve (kg)	Total Traverse (km)
No.	Start	Location (paths - locales)										
32	82B	South Pole	402-10011-01	2	16	20	980	252	4722	391	366	150
33	82B	South Pole	402-10011-03	2	16	20	959	249	4513	670	540	150
34	83A	Mare Orientale	402-10011-01	2	12	20	977	251	4826	460	262	150
35	83A	Mare Orientale	402-10011-07	2	12	20	973	251	3976	257	637	150
36	83B	Palus Putredinis	402-10011-03	2	I	18	848	216	4645	886	443	150
37	84A	Palus Putredinis	402-10011-01	2	I	16	784	195	4748	529	340	150
38	84A	Palus Putredinis	402-10011-01	2	I	18	843	212	4786	542	302	150
39	84B	Palus Putredinis	402-10011-01	2	I	16	762	188	4708	517	380	150
40	85A	Palus Putredinis	402-10011-01	2	I	18	859	217	4819	533	269	150
41	85A	Palus Putredinis	402-10011-01	2	I	16	746	184	4716	525	372	150
42	85B	Palus Putredinis	402-10011-03	2	I	17	802	203	4618	892	476	150
		Total				620	30,148	7513	186,071	39,837	18,566	4950

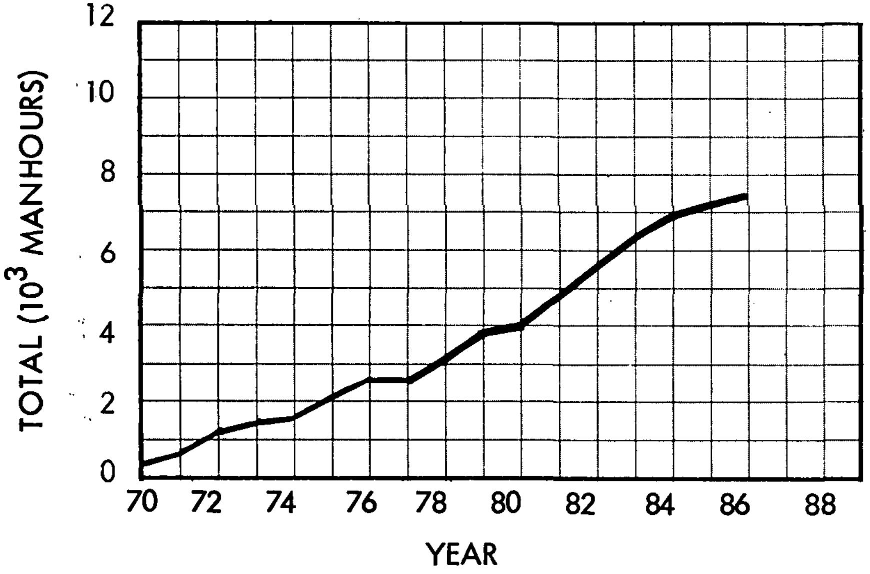
EQUIPMENT USAGE AND COST SUMMARY

Equipment Identification		R&D Start	First/ Last Use	Number Procured		Cost Summary (Millions of Dollars)				
						Nonrecurring		Recurring		Total Cost
ID No.	Name			Operations	Spares	R&D	C of F	Procurement	Operation	
	Launch Systems									
1221-01	100% Saturn V	–	70B/85B	74	8	–	–	10,288	1476	11,764
1221-03	100% Saturn V (Apollo funded)	–	68B/70A	7	1	–	–	–	–	–
	Subtotal					–	–	10,228	1476	11,764
	Flight Systems									
1311-01/1321-01	CSM – LOR – Three-Man	–	70B/85B	74	8	–	–	6185	1574	7759
1331-01/1341-01	LM Taxi – Two-Man	67B	70B/85B	33	4	32	–	1714	448	2194
	Subtotal					32	–	7899	2022	9953
	Mission Equipment									
2132-02	Surface-Launched Probe	76B	79A/83A	8	1	38	–	20	2	60
2222-02	Orbiter Rack	68A	70A/73B	3	1	1	–	–	–	1
2321-01/1351-03	LM Shelter – Two-Man	67B	70B/85B	33/39[(a)]	4	216	–	1577	494	2287
2421-01	LSSM	67B	70B/85B	33	4	58	2	144	19	223
2512-03	LFV – Two-Man Exploration	67B	70B/84B	22	3	48	–	55	5	108
	Subtotal					361	2	1796	520	2679
	Major Scientific Equipment									
3213-02	300-m Drill – Fuel Cell	74A	76B/79B	2	1	11	–	6	–	17
	Subtotal					11	–	6	–	17
	Total					404	2	19,989	4018	24,413

(a) Six 1351-03 logistic descent stages used without shelter.

SCIENTIFIC PROGRAM OPERATIONAL SUMMARY

SCIENTIFIC MANHOURS



SCIENTIFIC EQUIPMENT MASS