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INTEGRATED MANNED INTERPLANETARY SPACECRAFT CONCEPT DEFINITION

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Volume V

D2-113544-5

Program Plans and Costs

The BOEING Company • Aerospace Group • Space Division • Seattle, Washington

NASA CR-66563

INTEGRATED MANNED INTERPLANETARY SPACECRAFT CONCEPT DEFINITION

FINAL REPORT

VOLUME V

PROGRAM PLANS AND COSTS

D2-113544-5

N68 19837

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
Hampton, Virginia

NASA CONTRACT NAS1-6774

January 1968

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AEROSPACE GROUP THE BOEING COMPANY SEATTLE, WASHINGTON

RECOMMENDED INTERPLANETARY MISSION SYSTEM

The recommended interplanetary mission system:

- Is flexible and versatile
- Can accomplish most of the available Mars and Venus missions
- Is highly tolerant to changes in environment, go-ahead dates, and funding.

It provides:

- Scientific and engineering data acquisition during all mission phases
- Analysis, evaluation, and transmission of data to Earth
- Return to Earth of Martian atmosphere and surface samples

The mission system is centered around the *space vehicle* which consists of the *space acceleration system* and the *spacecraft*.

The *space acceleration system* consists of five identical nuclear propulsion modules:

- Three in the Earth departure stage
- A single module in the planet deceleration stage
- A single module in the planet departure stage

Propellant is transferred between the stages, as necessary, to accommodate the variation in ΔV requirements for the different missions. This arrangement provides considerable discretionary payload capacity which may be used to increase the payload transported into the target planet orbit, the payload returning to the Earth, or both.

The *spacecraft* consists of:

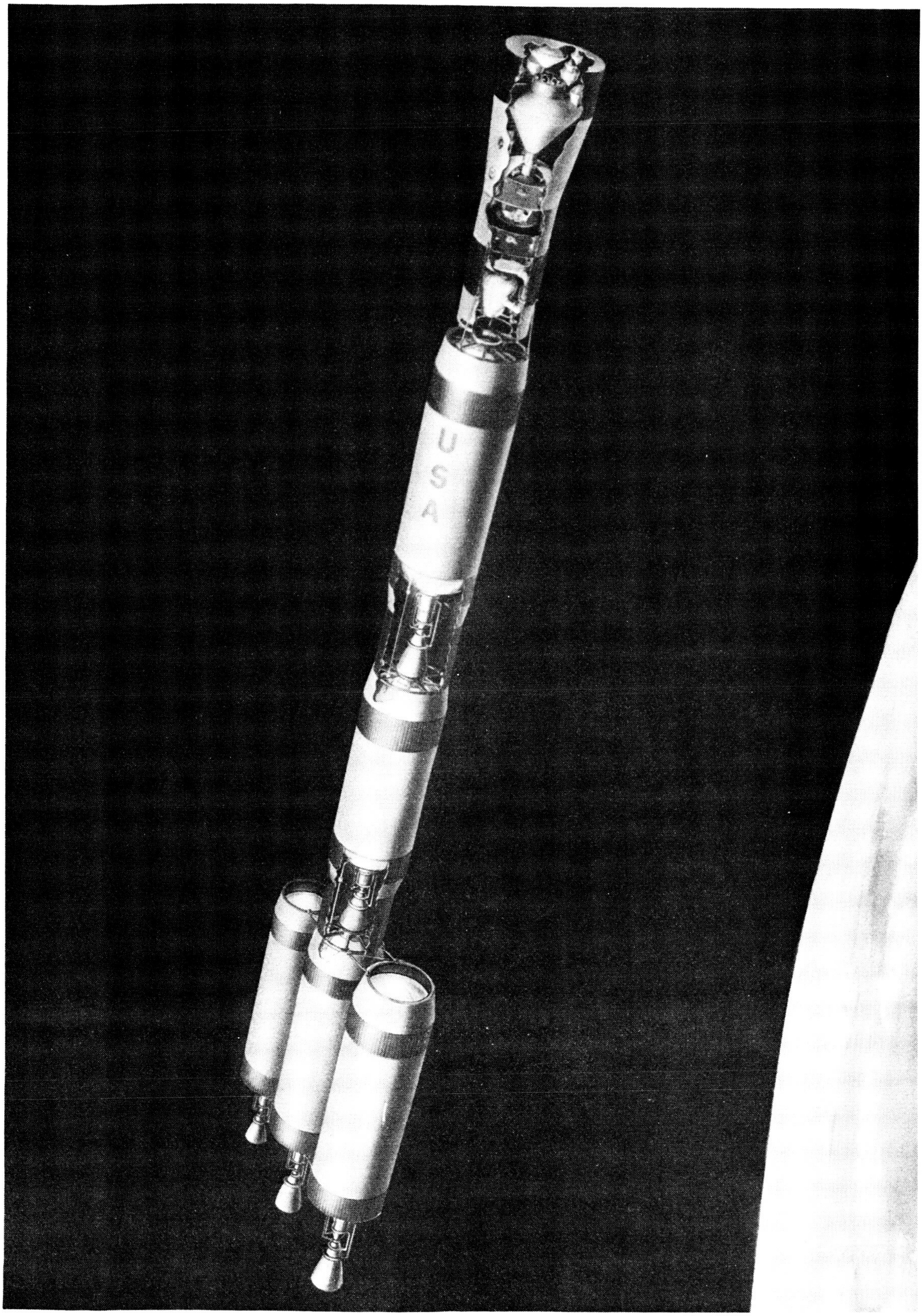
- A biconic Earth entry module capable of entry for the most severe missions
- An Apollo-shaped Mars excursion module capable of transporting three men to the Mars surface for a 30-day exploration and returning
- A mission module which provides the living accommodations, system control, and experiment laboratories for the six-man crew
- Experiment sensors and a planet probe module

The spacecraft and its systems have been designed to accomplish the most severe mission requirements. The meteoroid shielding, expendables, system spares, and mission-peculiar experiment hardware are off-loaded for missions with less stringent requirements.

The space vehicle is placed in Earth orbit by six launches of an uprated Saturn V launch vehicle which has four 156-inch solid rocket motors atttached to the first stage. Orbital assembly crew, supplies and mission crew transportation are accomplished with a six-man vehicle launched by a Saturn IB.

A new launch pad and associated facility modifications are necessary at Launch Complex 39 at Kennedy Space Center to accommodate:

- The weight and length of the uprated Saturn V
- The launch rate necessary for a reasonable Earth orbit assembly schedule
- The solid rocket motors used with the uprated Saturn V
- The requirement for hurricane protection at the launch pad.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ABSTRACT

Program plans and costs for the recommended interplanetary mission system include the program planning and cost conditions, the program schedules, the test program, the facilities plan, and program costs and funding. The first two reasonable missions are a 1983 Venus Short Mission, followed by a 1986 Mars Opposition Mission. Total program costs, including the two missions, are approximately $29 billion with the peak funding rate of $3.4 billion per year occurring in the 1976-1978 time period. Test plans are from early design development tests through qualification and end with a complete system flight demonstration in Earth orbit. Launch Complex 39 at Kennedy Space Center is used with modifications and additions.

FOREWORD

This study was performed by The Boeing Company for the National Aeronautics and Space Administration, Langley Research Center, under Contract NAS1-6774. The Integrated Manned Interplanetary Spacecraft Concept Definition Study was a 14-month effort to determine whether a variety of manned space missions to Mars and Venus could be accomplished with common flight hardware and to define that hardware and its mission requirements and capabilities. The investigation included analyses and trade studies associated with the entire mission system: the spacecraft; launch vehicle; ground, orbital, and flight systems; operations; utility; experiments; possible development schedules; and estimated costs.

The results discussed in this volume are based on extensive total system trades which can be found in the remaining volumes of this report. Attention is drawn to Volume II which has been especially prepared to serve as a handbook for planners of future manned planetary missions.

The final report is comprised of the following documents, in which the individual elements of the study are discussed as shown:

Volume	Title	Part	Report No.
I	Summary		D2-113544-1
II	System Assessment and Sensitivities		D2-113544-2
III	System Analysis	Part 1--Missions and Operations	D2-113544-3-1
		Part 2--Experiment Program	D2-113544-3-2
IV	System Definition		D2-113544-4
V	Program Plans and Costs		D2-113544-5
VI	Cost-Effective Subsystem Selection and Evolutionary Development		D2-113544-6

The accompanying matrix is a cross-reference of subjects in the various volumes.

● Primary Discussion

X Summary or Supplemental Discussion

	DOCUMENTATION						
STUDY AREAS	Volume I/D2-113544-1 Summary Report	Volume II/D2-113544-2 System Assessment and Sensitivities	Volume III/D2-113544-3 System Analysis		Volume IV/D2-113544-4 System Definition	Volume V/D2-113544-5 Program Plans and Cost	Volume VI/D2-113544-6 Cost Effective Subsystem Selection and Evolutionary Development
			Part 1 - Missions and Operations	Part 2 - Experiment Program			
MISSION ANALYSIS	X		●				
Trajectories and Orbits	X	X	●		X		
Mission and Crew Operations	X	X	●	●	X		
Mission Success and Crew Safety Analysis	X	X	●		X		
Environment	X	X	●				
Scientific Objectives	X	X		●			
Manned Experiment Program	X	X		●			
Experiment Payloads and Requirements	X	X		●			
DESIGN ANALYSIS	X				●		
Space Vehicle	X				●		
Spacecraft Systems	X				●		
Configurations	X	X			●		
Subsystems	X	X			●		
Redundancy and Maintenance	X				●		
Radiation Protection	X				●		
Meteoroid Protection	X				●		
Trades	X				●		
Experiment Accommodations	X				●		
Space Acceleration Systems	X				●		
Primary Propulsion--Nuclear	X	X			●		
Secondary Propulsion--Chemical	X	X			●		
System and Element Weights	X	X			●		
IMIEO Computer Program					●		
Earth Orbit Operations and Assembly Equip.	X	X			●		
Earth Launch Vehicles	X	X			●		
Facilities	X	X			●		
System Trades	X				●		
Space Acceleration--Earth Launch Vehicle	X				●		
Space Acceleration Commonality	X				●		
Space Vehicle--Artificial Gravity	X				●		
SYSTEM AND PROGRAM ASSESSMENT	X	●					
System Capability	X	●		●		X	
Design Sensitivities	X	●			X		
Program Sensitivities	X	●					
Adaptability to Other Space Programs	X	●					
Impact on Other Space Programs	X	●					
Technology Implications	X	●					
Future Sensitivity Studies	X	●					
Program Schedules and Plans	X	X				●	
Test Program	X	X				●	
Facilities Plan	X	X				●	
Program Cost	X	X				●	
Cost Effective Subsystems							●

ABBREVIATIONS

A.U.	Astronomical unit
bps	Bits per second
C/O	Checkout
CM	Command module (Apollo program)
CMG	Control moment gyro
CONJ	Conjunction
CSM	Command service module (Apollo program)
ΔV	Incremental velocity
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
$\oplus$	Earth
ECLS	Environmental control life support system
ECS	Environmental control system
EEM	Earth entry module
ELV	Earth launch vehicle
EMOS	Earth mean orbital speed
EVA	Extravehicular activity
FY	Fiscal year
fps	feet/sec
GSE	Ground support equipment
IBMC	Inbound midcourse correction
IMIEO	Initial mass in Earth orbit
IMISCD	Integrated Manned Interplanetary Spacecraft Concept Definition
I_{sp}	Specific impulse
IU	Instrument unit
KSC	Kennedy Space Center
λ'	Ratio of propellant weight to overall propulsion module weight
LC	Launch complex
LC-34 & -37	Launch complexes for Saturn IB
LC-39	Launch complex for Saturn V
LH_2	Liquid hydrogen
LO	Long
LO_2 or LOX	Liquid oxygen
LRC	Langley Research Center

ABBREVIATIONS (Continued)

LSS	Life support system
LUT	Launch umbilical tower
♂	Mars
MEM	Mars excursion module
MIMIEO	Minimum initial mass in Earth orbit
MM	Mission module
MODAP	Modified Apollo
MSC	Manned Spacecraft Center (Houston)
MSFC	Marshall Space Flight Center (Huntsville)
MTF	Mississippi Test Facility
NAC	Letters designate the type of acceleration systems
	First letter--Earth orbit depart
	Second--planetary deceleration
	Third--planet escape
	Example: NAC = Nuclear Earth depart/aerobraker deceleration at planet/chemical planet escape
OBMC	Outbound midcourse correction
OPP	Opposition
OT	Orbit trim
P/L	Payload
PM-1	Propulsion module, Earth orbit escape
PM-2	Propulsion module, planet braking
PM-3	Propulsion module, planet escape
RCS	Reaction control system
SA	Space acceleration
S/C	Spacecraft
S-IC	First stage of Saturn V
S-II	Second stage of Saturn V
SH	Short
SOA	State of art
SRM	Solid rocket motor
S/V	Space vehicle
SWBY	Swingby

ABBREVIATIONS (Continued)

T/M	Telemetry
TVC	Thrust vector control
VAB	Vehicle assembly building
♀	Venus
V_{HP}	Hyperbolic excess velocity

CONVERSION FACTORS

English to International Units

Physical Quantity	English Units	International Units	Multiply by
Acceleration	ft/sec^2	m/sec^2	3.048×10^{-1}
Area	ft^2	m^2	9.29×10^{-2}
	in^2	m^2	6.45×10^{-4}
Density	lb/ft^3	Kg/m^2	16.02
	lb/in^3	Kg/m^2	2.77×10^{4}
Energy	Btu	Joule	1.055×10^{3}
Force	lbf	Newton	4.448
Length	ft	m	3.048×10^{-1}
	n.mi.	m	1.852×10^{3}
Power	Btu/sec	watt	1.054×10^{3}
	Btu/min	watt	17.57
	Btu/hr	watt	2.93×10^{-1}
Pressure	Atmosphere	Newton/m^2	1.01×10^{3}
	lbf/in^2	Newton/m^2	6.89×10^{3}
	lbf/ft^2	Newton/m^2	47.88
Speed	ft/sec (fps)	m/sec	3.048×10^{-1}
Volume	in^3	m^3	1.64×10^{-5}
	ft^3	m^3	2.83×10^{-2}

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

1.0 INTRODUCTION

This volume includes the program plans and costs for the IMISCD program in five sections: introduction, including program planning and cost conditions; programs schedules and plans; test program; facilities plan; and program costs.

To develop the program plan and costs for a manned interplanetary program, a two-mission program example has been defined. This program example consists of a 1983 Venus short followed by a 1986 Mars opposition lander. Although missions beyond the first two have not been selected, a planning tool has been developed which can be used to select any mix of missions desired. This tool will provide the development costs, mission costs, and the fiscal funding requirements.

The total cost (development and recurring) for the first two missions is approximately 29 billion dollars. A five-mission program consisting of three to Venus and two to Mars would total approximately 37.0 billion dollars.

1.1 PROGRAM PLANNING AND COST CONDITIONS

During the course of this study it became necessary to define conditions that could have a major impact on program plans and schedules. Some of the conditions are assumptions necessitated by the uncertainties inherent in predicting future programs while others are a result of the rationale developed during the course of the study. The major conditions are listed below and detailed conditions particularly applicable to schedules, facilities, or cost results are discussed in those sections following.

1.1.1 MAJOR PROGRAM MILESTONES AND SCHEDULE CONDITIONS

1.1.1.1 Phased Project Planning (Figure 1.1-1)

Requirements imposed by phased project planning (PPP) have been considered. While it is understood that PPP is not a rigid process in which projects will always proceed from a specifically authorized Phase A through Phases B, C, and D, a reasonable time for each of the phases has been allowed. The cross-hatched portion of the schedule bars indicates time allowed for evaluation of previous results, submittal of proposals by industry, evaluation of industry proposals, and award of the next phase contract. It is further assumed that the present IMISCD study could be approximately equivalent to Phase A advance studies. Figure 1.1-1 illustrates the rationale for establishing the earliest phase D, which is January 1, 1972.

An exception to PPP for implementation of the total IMISCD program requirements is the Nerva II nuclear engine development. It is assumed throughout the study that the Nerva II engine would be under development prior to the 1972 go-ahead date. Volume II of this report will discuss sensitivities to items like a delay in the Nerva II engine development.

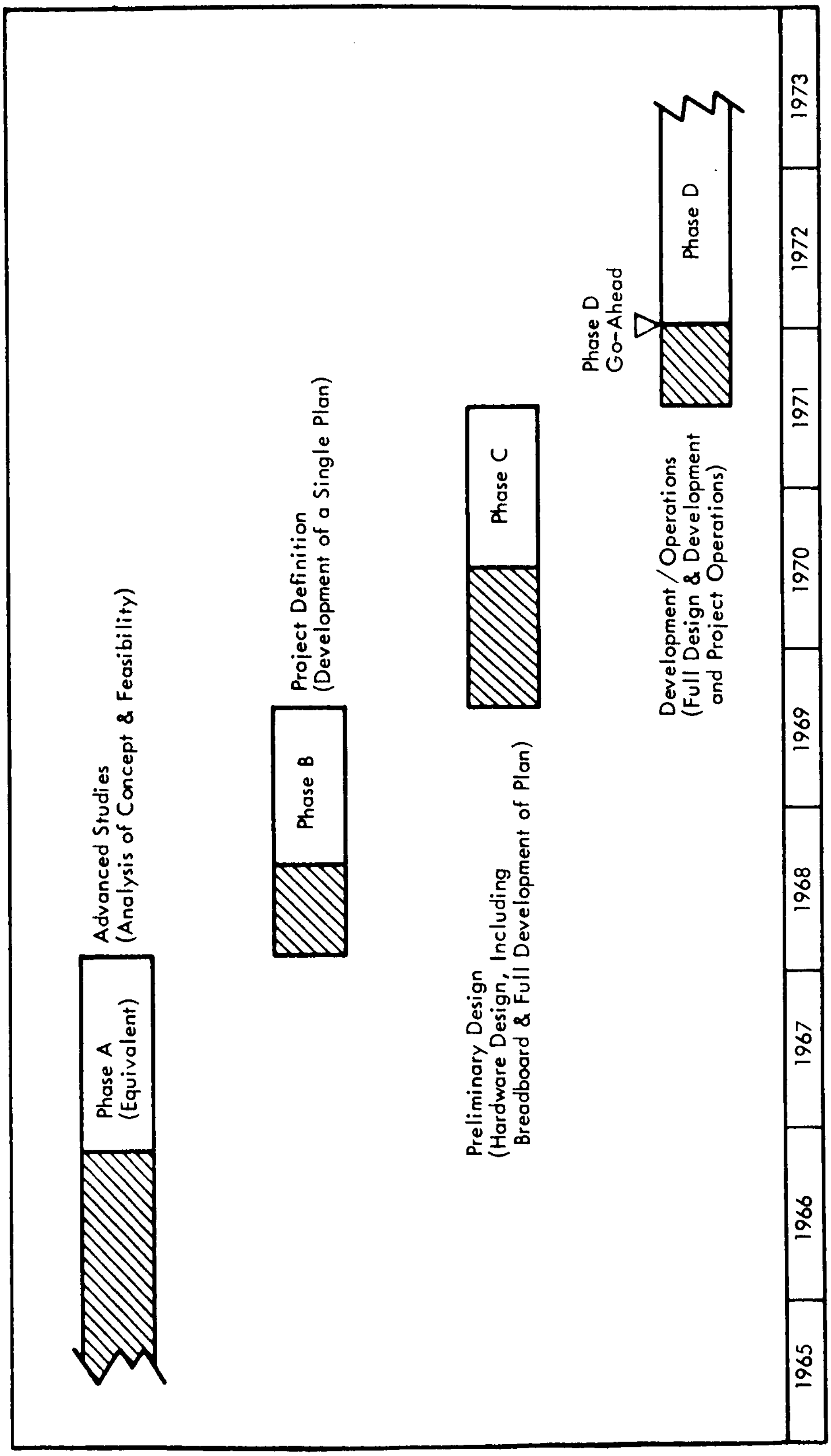

Figure 1.1-1: PHASED PROJECT PLANNING (PPP) FOR IMISCD

1.1.1.2 Planetary Environmental Data

It has been assumed that sufficient data concerning the Venus environment will be available by the contract go-ahead date, January 1972. It is further assumed that there will be an unmanned mission to Mars during the 1973 opportunity and that this unmanned mission will provide sufficient environmental data for design of the MEM and associated experiments. Sensitivities to schedule slides in the unmanned exploration program are also examined in Volume II of this report.

1.1.1.3 Total Program Schedule

The total program schedule will be developed to provide for a 1983 Venus short mission as the first planetary launch. Funding limits will not be allowed to pace the program schedule. Sensitivities to funding limits will be examined, however, and the results included in Volume II of this report.

1.2 MAJOR PROGRAM COST CONDITIONS

1.2.1 DEVELOPMENT COSTS

Development costs for all the major program elements will be included so that the total development cost to the nation can be appraised. Exceptions include those elements which have already been developed and are used in essentially their present configuration. These include the Saturn IB Earth launch vehicle and the Saturn V-INT 21 (two-stage Saturn V Earth launch vehicle).

1.2.2 COST EXCLUSIONS

Costs will be excluded for advanced research and technology and advanced development requirements, as well as NASA program management.

1.3 MAJOR STANDBY UNIT CONDITIONS

Extreme penalties to the program in costs, schedule delays, and prestige would occur if a mission launch opportunity were missed. The philosophy of providing standby units was adopted to ensure that mission opportunities, with their restricted launch windows, would be met. Schedules were made for processing standby units through launch operations: hardware quantity requirements and costs included standby units.

1.3.1 MISSION STANDBY UNITS

In addition to one standby launch and one standby ELV, which will be provided for each mission, fully assembled and tested standby units for each possible payload will also be provided.

1.3.2 DEMONSTRATION TEST STANDBY UNITS

Demonstration tests must be completed on schedule so that the subsequent mission can be on schedule. Standby units for demonstration tests will be provided and treated as for an actual mission.

1.3.3 UNUSED STANDBY UNITS

Unused standby units may be refurbished and used on a subsequent mission. Costs for refurbishment and storage would necessarily be included in the cost analysis.

1.3.4 ORBITAL DEVELOPMENT TESTS AND ORBITAL OUALIFICATION TESTS

Because of the high cost, standby units will not be provided for orbital development tests or orbital qualification tests. If a flight test unit fails, enough flexibility in the flight test program exists so that additional tests can be included in subsequent flight tests or in the demonstration test program. It may also be possible to refurbish one of the ground test units as a standby.

1.4 UTILIZATION OF KSC

1.4.1 MANNED PLANETARY MISSION PRIORITY

It was assumed that manned planetary missions would have first priority at KSC.

1.4.2 UNMANNED PLANETARY LAUNCHES

Unmanned planetary launches requiring Launch Complex 39 (LC-39) will be phased to prevent interference with manned planetary launches. This means that there will be no unmanned mission to Venus or Mars during the same opportunity that a manned mission is planned.

1.4.3 MANNED ORBITAL PROGRAM LAUNCHES OR MANNED LUNAR LAUNCHES

Manned orbital program launches, or manned lunar launches requiring LC-39, will be phased between the required planetary launches. Since the launch windows for either manned orbital or lunar programs are fairly flexible, these programs could be phased between the planetary program launches, and additional facilities would not have to be provided at KSC for them. The maximum period during which a manned orbital or lunar launch could not be scheduled would be approximately 4 months.

1.4.4 KSC GROUND ASSEMBLY AND CHECKOUT OF THE TOTAL SPACE VEHICLE

Ground assembly and checkout of the total space vehicle in its joined flight configuration is not required. Interfaces will be checked separately, and a thorough shakedown of all interfaces will have been conducted during the qualification test period.

1.5 MISCELLANEOUS MAJOR CONDITIONS

1.5.1 FLIGHT QUALIFICATION OF ELV's

Flight qualification tests of ELV's will always be conducted in conjunction with the flight qualification tests of one of its payloads. These payloads will be one of the nuclear propulsion modules.

1.5.2 LAUNCH OF THE ORBITAL ASSEMBLY AND CHECKOUT CREW AND/OR MISSION CREW

Because of the difficulties associated with man-rating ELV's, or spacecraft Earth launch configurations, it was concluded that all manned launches would be made with the logistics spacecraft which will, with its Saturn IB ELV, be man-rated.

1.5.3 PRECURSOR ORBITAL SPACE STATION

It was assumed that there would be no MORL or other major orbital space station as a precursor to the manned planetary mission. All subsystems will be developed, tested, and checked out during the IMISCD program. It is recognized that a precursor orbital space station may be desired, but it has been deleted from our program plans. It is assumed, however, that there will be some early orbital capability, that could be used for early experiment and for technological developments.

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2.0 PROGRAM PLANNING AND SCHEDULES

This program schedule section is arranged in a sequence from summaries to detailed backup schedules. The first summary highlights the flow times and milestones of two example program approaches. The two approaches are the basic and the alternate. The basic program example defines the 1983 short Venus capture mission as the first operational mission with the 1986 Mars opposition landing as a follow-on. The alternate defines the 1981 Venus short capture with the 1984 Mars opposition landing as a follow-on. The alternate backup lower level schedules deviate from the summary by separately scheduling both Venus and Mars as first missions. This deviation allows a program planner an option of selecting either the Venus capture or the Mars landing as the first operational mission. If Venus alternate is considered, the MEM can be incorporated as depicted on the summary schedule. If Mars alternate is considered, the MEM has been incorporated.

The major conditions used to guide this program planning and schedules portion are given below.

1) Phase D program go-ahead is January, 1972, or later.

2) Assumed that sufficient data concerning the Venus environment will be available by January, 1972;

3) It is assumed that there will be an unmanned mission to Mars during 1973 opportunity, which will provide sufficient environmental data for design of the MEM and the experiments;

4) Standby payloads for backup are not planned for the orbital hardware qualification tests because:

    - Each payload test can be revised to include more or less test requirements,
    - Previous assigned tests can be transferred to succeeding tests,
    - Abort payloads and test can be reproduced by refurbishing ground test units.

5) The orbital demonstration and each operational mission payload is augmented by a payload standby, consisting of one spacecraft, one PM-1, and one PM augmenting both PM-2 and PM-3.

6) The orbital demonstration and each operational mission will have one ELV off-pad standby, while for each operational mission seven ELV's are required (six for the operational launches and one as an off-pad standby).

7) Manned planetary missions will have top priority at KSC because of launch window requirements;

8) Ground assembly and checkout of the total space vehicle in its joined flight configuration is not planned, but each interface will be checked separately during the qualification test period;

9) The SAT V-25(S)U ELV is not manrated, but other manrated launch vehicles will be used for manned launches;

10) Logistics spacecraft will be used to launch the orbital assembly and checkout crew or the mission crew.

The 1972 Phase D contract go-ahead complies with NASA PPP. Before selecting Phase D go-ahead date, reasonable time allowance has been allocated to accomplish Phases B and C. Time was not allocated for a complete Phase A because this study is roughly equivalent to that phase.

2.1 SUMMARY PROGRAM SCHEDULES

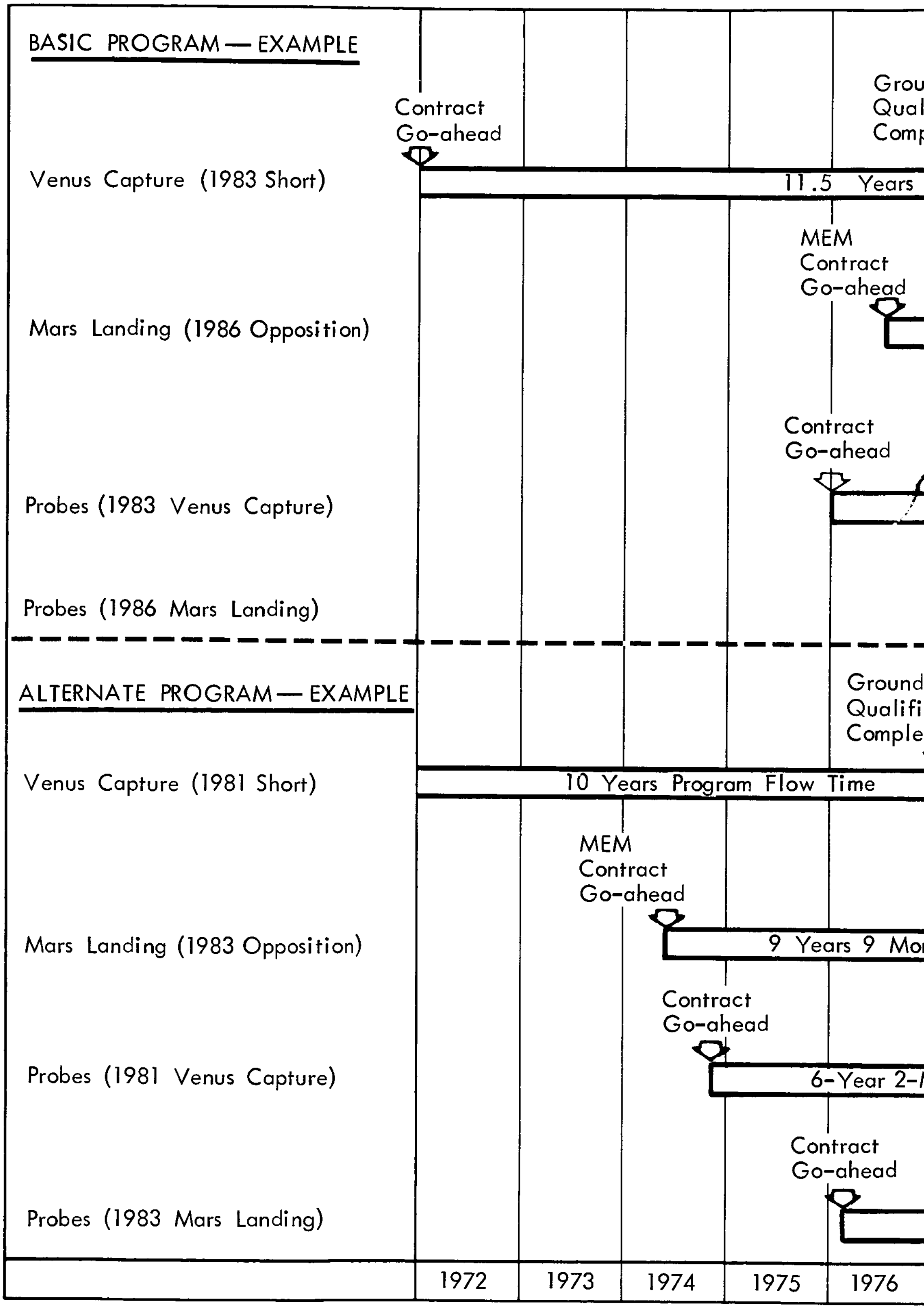
The summary program schedule (Figure 2.1-1) depicts two program examples, the basic and the alternate. Of the two programs, the basic is more realistic than the alternate in both flow time and program risks. The basic program flow time, from go-ahead to the launching of both Venus capture and Mars landing missions, extends over a period of about 14.5 years, while the alternate is about 12 years. The 2.5-year reduction increases the program risk by concurrent development and qualification testing.

2.1.1 BASIC PROGRAM EXAMPLE SUMMARY

From go-ahead to the first Venus capture 1983 mission the flow time is approximately 11.5 years. The major development over these years are the MM, EEM, and the PM's. The major program phases during the 11.5 years are the ground qualifications, orbital hardware qualification, and the space vehicle and orbital demonstration. Each of the three phase completions are designated as milestones on the summary schedule.

From MEM go-ahead, the Mars landing 1986 follow-on mission is approximately 9.75 years. The Venus mission hardware development will have been completed; therefore, the only remaining major development will be the MEM. For the MEM development, the engineering aids and test hardware used in the development of the Venus program are transferred to the Mars mission program.

The soft lander was selected to represent the probes/experiment equipment. The selection was based on two criteria: the soft lander flow time is probably the longest of all the probes; and the subsystems are considered the most complex. The soft lander development flow time is 6 years and 2 months. Since both missions require the soft lander, this flow time is applied to both the basic and alternate programs. The required contract go-ahead is early 1976 followed by probe integration with Venus mission hardware in early 1979.



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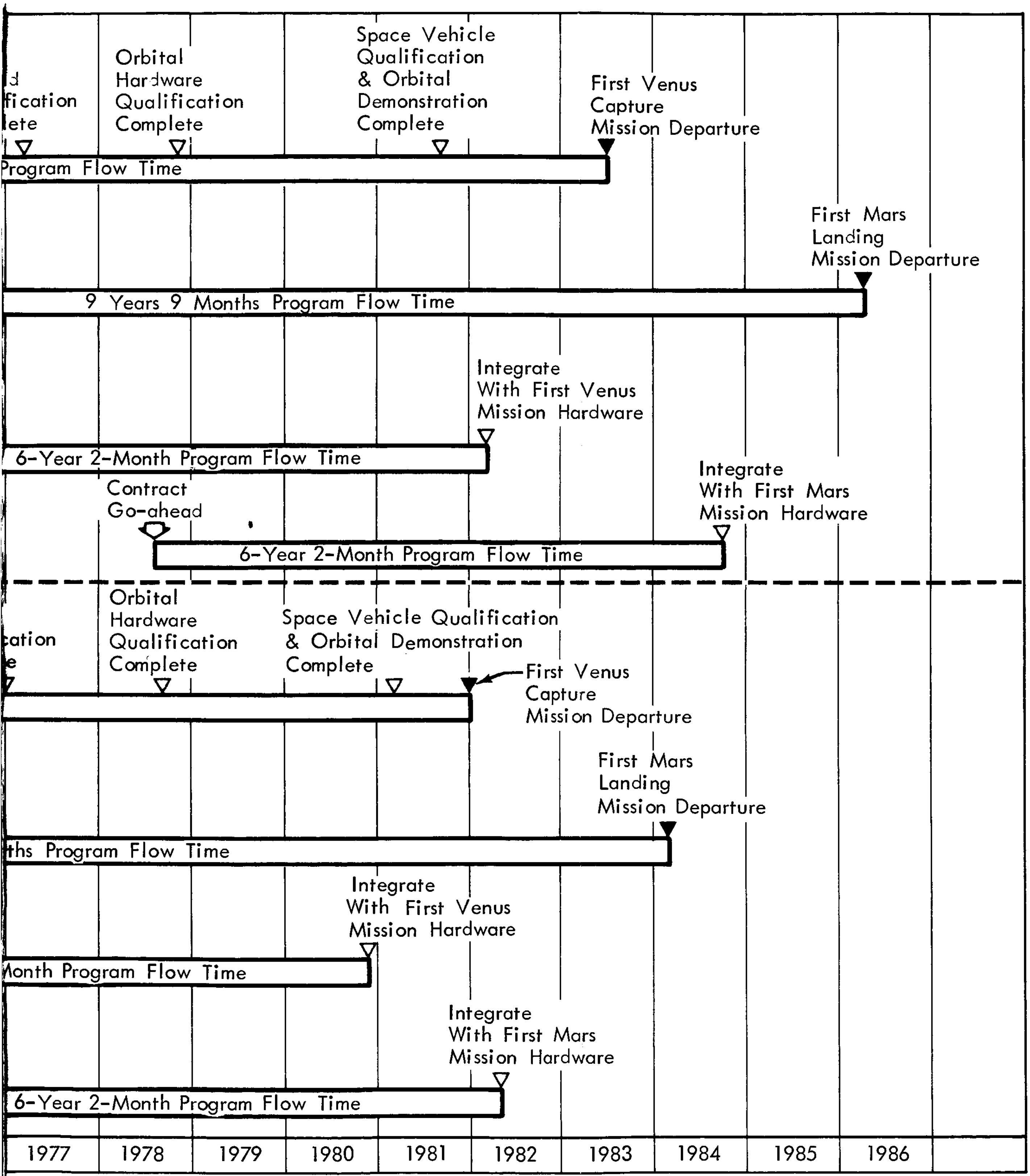


Figure 2.1-1: SUMMARY PROGRAM SCHEDULES

2.1.2 ALTERNATE PROGRAM EXAMPLE SUMMARY

The alternate program planning criteria are identical to the basic program except for the Venus and Mars mission dates and subsequent overall flow time for each of the missions. The Venus 1981 capture mission program flow time is 10 years from contract go-ahead, which is about 1.5 years shorter than the basic program Venus capture mission. From an overall program viewpoint, the 1.5 years is insignificant; however, the testing impact of the revised program is significant.

The 1.5-year reduction primarily impacts the normal development feedback cycle. With this reduced, an exceptional amount of success on each system and subsystem must be anticipated throughout the development cycle to meet overall program schedules.

The Mars landing follow-on mission flow time is identical to the basic program. The exception is that the MEM and the Mars probes contract go-aheads are required relatively earlier than for the basic program.

2.2 BASIC PROGRAM PLAN AND SCHEDULES

The second level schedule summary of the basic program is the "Venus Capture Program Schedule," Figure 2.2-1. This schedule depicts the overall program by phases, flow time, flow time sequence, hardware and function designations, and the planning criteria. The planning criteria are the estimated flow times and the sequence and phasing of the functions.

Following the second level summary schedule, the order of program planning and schedule presentations is:

- Individual program phases and their details,
- Individual module schedules,
- MEM phasing details for Mars landing follow-on mission,
- Probes phasing details supporting the program.

2.2.1 VENUS CAPTURE PROGRAM SCHEDULE

This schedule (Figure 2.2-1) shows in detail the four phases of the Venus capture mission program. The four phases are the ground qualification and development flight test, orbital hardware qualification, space vehicle qualification and demonstration, and the operational program.

2.2.1.1 Ground Qualification and Development Flight Test Program

The ground qualification and development flight test program phase covers approximately 5 years. The schedule for this program phase is discussed in Section 2.2.2. The development models for ground qualification program are the thermal, structural, dynamic, and the physical interface. The primary objective of this phase is to ground qualify the subsystems at a subsystem level and then at a system level. Development flight test models are for the EEM, PM, and MEM.

The thermal model and thermal test results pace the early part of the program because of critical constraints on material selection and early design efforts. This pacing aspect resulted in two thermal testing phases. Phase I, started during the early program period, will confirm the thermal analysis and concept prior to initial designs. The thermal models for this phase will consist primarily of simulated articles conforming to the modules mass and profile. Phase II thermal models will consist primarily of engineering models during the early stages and eventually prototype hardware during the later stages. This phase will verify the detail design of the spacecraft. The thermal models include the MM, EEM, and one PM because the PM's are of common design.

Structural Model--The structural test models will be of flight configuration. The models are full-scale and include the MM, EEM, and PM's. The engines for the propulsion modules will be simulated. The testing will proceed from module to spacecraft level. Module testing will be accomplished at the contractors' facilities; then, upon completion, the modules will be shipped to existing NASA facilities where the contractor will continue the testing at a spacecraft level. Major additions and modifications of MSFC test facilities must be made to support this program.

Dynamic Model--The dynamic test model will be of flight configuration. The propulsion module engine will be simulated. Dynamic testing will start from components to module level using mass simulated components, engineering models, and, if required, prototype equipment. Module level testing is at the contractors' facilities and testing above module level will be at the NASA facilities with the contractor conducting the tests.

Physical Interface Model--During the early part of the program, the interface model will extensively use dimensional models of subsystem equipment. As the program progresses, equipment updating will eventually be to prototype equipment. The structures of the MM, EEM, and PM models will be prototype design, but the material and weight may not be to prototype specifications. The use of this model is for subsystems continuity and positioning solutions for both inter- and intra-module interface before the ground qualification is completed. The interfacing of the spacecraft to the ground support equipment will also be accomplished through this model. During development, engineering changes are incorporated into the model to optimize placement, continuity, and interface. During the later stages of development and throughout the program, this model will remain as a ground checkout unit.

Subsystem and System Qualification--The subsystem and system qualifications are the major objectives of this phase. Initially, qualification will be at the subsystem level, progressing to the system level. The component qualification and subsystem qualification, with simulation interface, will be accomplished by the vendors or major subcontractors. The contractor will qualify the subsystem and system with flight equipment interface. The ground qualification test completion constrains the next phase, which requires that ground qualification be complete prior to orbital qualification.

2.2.1.2 Orbital Hardware Qualification Program

The orbital hardware qualification program occurs after the ground qualification and before the space vehicle qualification and demonstration phases. The objective of this phase is to flight qualify the module configurations in both manned and unmanned modes. During this phase, minimum attempt is made to integrate the modules into a space vehicle configuration. This phase will verify the design by simulated and actual rendezvous, docking, separation, guidance and control, heat transfer, reentry, and other space tests.

The major role of the manned logistic vehicle during the period of orbital tests will be to perform orbital operations relating to manned requirements for the conduct of various tests. Astronauts will be launched on manrated vehicles, housed in the MM and logistics space vehicles, and transferred to the test specimen in space to conduct the tests.

EEM--The EEM orbital testing will begin with a boilerplate. The boilerplate will verify the guidance and control, heat transfer capabilities, terminal maneuvers, and landing impact effects. Following the boilerplate flight, an unmanned EEM flight test will repeat the tests. This test will also qualify the reentry requirement of 65,000 fps using the S-IVB as a space propulsion system. Finally, manned flights will qualify man/module functions and capability.

MM--After the MM launch, the MM orbital checkout will be accomplished by the logistic spacecraft. Remote checkout of the MM will be completed before personnel transfer is made from the logistic spacecraft. The objective of this MM orbital test is to conduct mission control capability. During and after completing the test objectives, the module will remain in space for future experiments and to support other orbital tests.

PM's--After ground qualification, this phase will space qualify the PM's. The tests will be for short space soak and firing followed by extended space soak and firing. The PM tests will include the PM-OBMC and PM-OT propulsion systems. Each of the two propulsion systems will undergo appropriate space soak and intermittent firing.

2.2.1.3 Space Vehicle Qualification and Orbital Demonstration Program

This phase follows the orbital hardware qualification phase and must be accomplished on schedule. Changes required by the testing results received from this phase will be incorporated into the operational program. Schedule slides in this phase will directly jeopardize the mission launch date. The system integration lab (SIL) functional checkout will be accomplished with the functional integration model. The first portion of orbital testing is for spacecraft qualification. Spacecraft qualification will be accomplished with the aid of the MM that remained in orbit from the orbital hardware qualification program and the space logistics vehicle and personnel. Following qualification, the orbital demonstration will occur. Life-environment tests for the spacecraft will be accomplished both during the qualification and orbital demonstration. The total testing lasts 18 months.

2.2.1.4 Operational Program

The operational program is for two example missions. Final operational engineering design is incorporated into this phase from the previous phase test results. Building block space assembly technique has been incorporated in the schedule time. Six SAT V-25(S)U flights are required to put the space vehicle systems in Earth orbit. Launch preparation and orbital operations flow time is 8.5 months, of which 4.75 months are for orbital operations.

2.2.2 GROUND QUALIFICATION AND DEVELOPMENT FLIGHT TEST PROGRAM SCHEDULE

The ground qualification hardware phasing program (Figure 2.2-2) is a detailed breakdown of the same phase depicted on Figure 2.2-1. The details on this schedule cover both programs, Venus 1983 and Mars 1986 missions, of the basic program example. Models in this and the succeeding phases consist of the entire spacecraft--the MM, EEM, and the PM's. The elements of the schedule details are flow times, hardware nomenclature and hardware accountability, and launch vehicles.

The EEM and MEM scale model Earth reentry tests are to verify heat shielding and the models will be launched by Atlas-Agena vehicles. The MEM scale model test is during the Mars mission ground qualification phase. The other launch vehicle used for EEM suborbital tests is the Saturn IB. This test is to evaluate reentry, terminal maneuver, and landing impact characteristics. There are two thermal test models, one for each of the Phase I and Phase II thermal tests. Phase I will utilize primarily mass simulation to verify the analysis and concept while Phase II will utilize engineering model and prototype subsystems to verify design. The test duration for both phases is 4 years. The structural model testing will procced from the module level to the spacecraft level. One of each module configuration will be sufficient for both levels of testing. The structural tests duration is approximately 2 years.

The dynamic test models and test approach are identical to the structural model and test approach, but have different objectives. Upon completion of the module level tests, the NASA facilities are utilized for both the dynamic and structural spacecraft level tests. Conduct of the test is the contractor's responsibility. The spacecraft level testing at MSFC will require major test equipment additions and modification.

The interface module structural configuration is of prototype design but not necessarily built with flight material. During the early stage of this phase the physical interface model subsystems will be simulated. Initially, it will be used primarily as a design aid. As the program progresses, prototype hardware will be incorporated to establish the internal configuration and GSE interface. The subsystem ground qualification test for the Venus 1983 mission, Milestones 8 and 9, consists of two complete module subsystems. One of the subsystems will be to qualify at the subsystem level and the other for qualification at the system level.

GROUND QUALIFICATION PROGRAM	Mfg Thermal Model Thermal Test Mfg Structural Test Model Module Struct Test Spacecraft Struct Tests Mfg Dynamic Test Model Module Dynamic Test Spacecraft Dynamic Test Physical Interface Model Mfg & Test Interface Test Ground Qual Hdwe Mfg & Test Subsystem Qual Test (Ground) Spacecraft System Qual Test (Ground)	△ Contract Go-Ahead
ORBITAL HARDWARE QUALIFICATION PROGRAM	PM's Mfg & Test MM Mfg & Test EEM Mfg & Test Acceptance Test SIL (System Integration Lab) EEM Mfg & Test Unmanned Suborbital EEM Boiler Plate Mfg & Test Launch Operations Module & PM Orbital Qual	
SPACE VEHICLE QUALIFICATION & DEMONSTRATION PROGRAM	Flt Simulation Model Mfg & Test Flt Simulation Test Sustain Flt Simulation Test Probe Mfg & Test Mfg & Test Functional Integration Model (EEM & MM) System Integration Lab Functional Checkout PM's Mfg & Tests Spacecraft Mfg & Test Acceptance Tests (SIL) Complex 39 & Orbital Operations Space Vehicle Orbital Qual Tests Space Vehicle Orbital Flt Demonstration Tests	
OPERATIONAL PROGRAM	Design Improvement & Test Allowance Probes Mfg & Tests EEM Mfg & Tests Critical Experiments MM Mfg & Tests PM's Mfg & Tests Acceptance Tests (SIL) Complex 39 & Orbital Opns	
		197

FOLDOUT FRAME 1

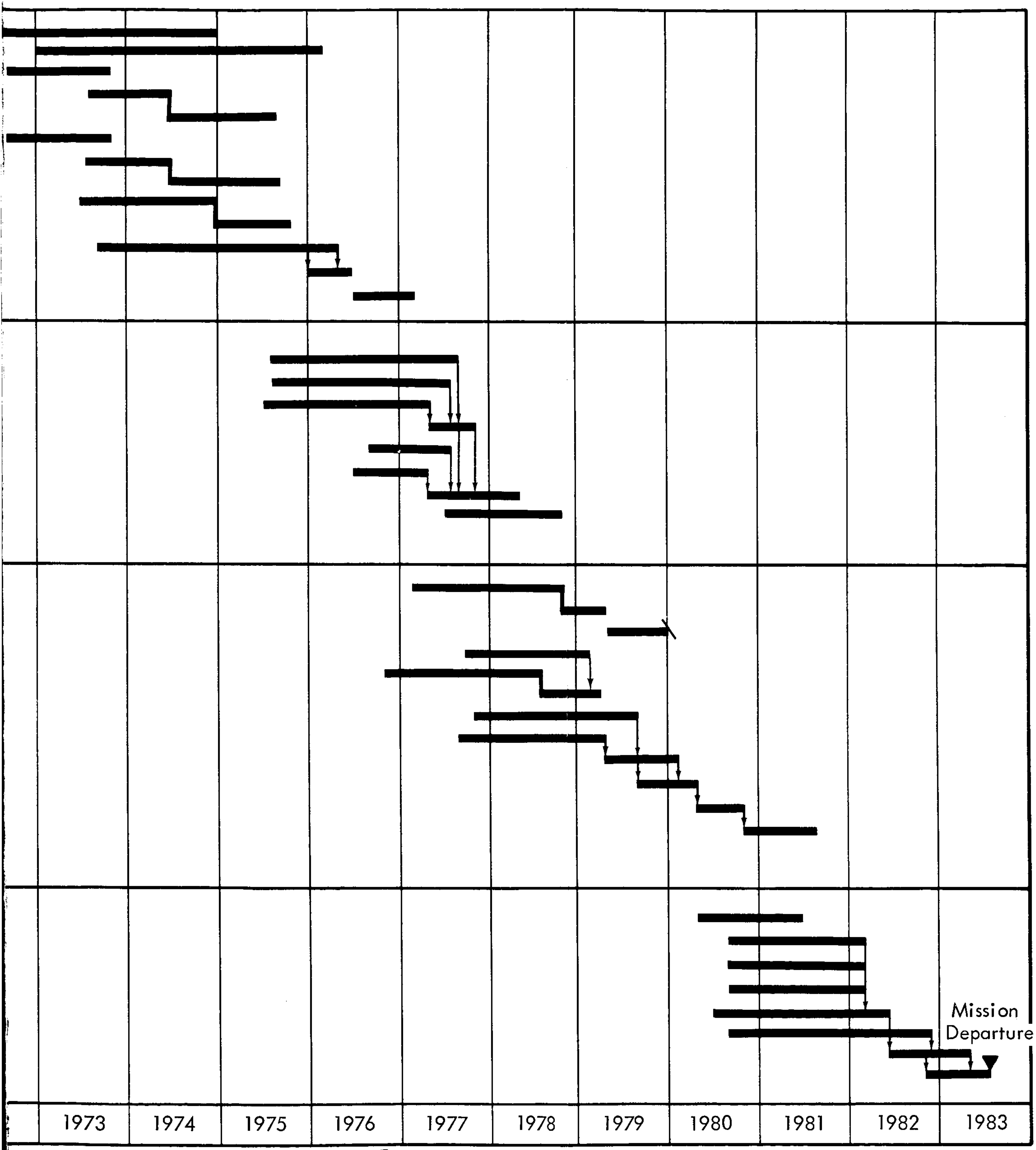
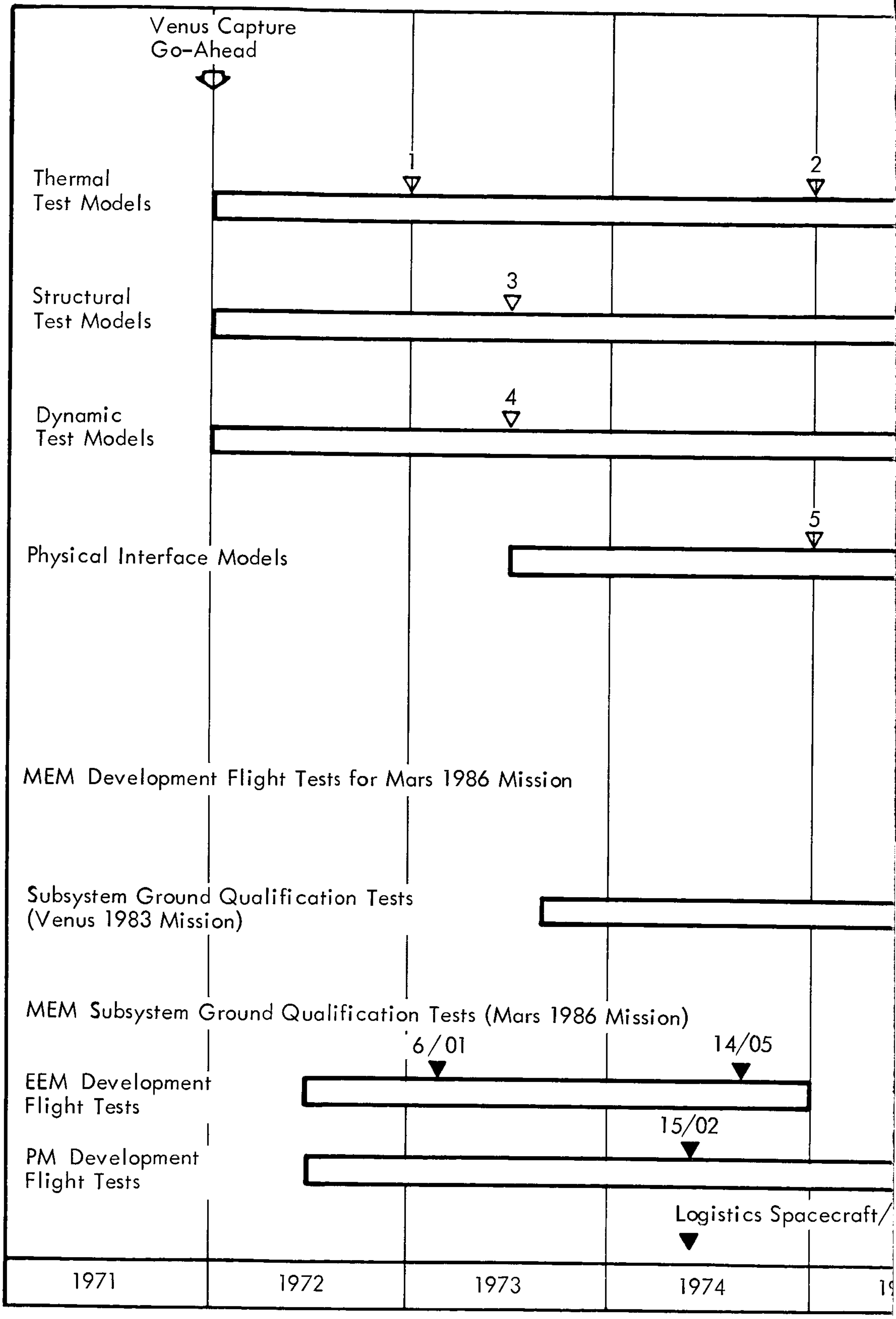


Figure 2.2-1: VENUS CAPTURE PROGRAM SCHEDULE EXAMPLE


Venus Capture Go-Ahead
Thermal Test Models
1
2
Structural Test Models
3
Dynamic Test Models
4
Physical Interface Models
5
MEM Development Flight Tests for Mars 1986 Mission
Subsystem Ground Qualification Tests (Venus 1983 Mission)
MEM Subsystem Ground Qualification Tests (Mars 1986 Mission)
6/01
14/05
EEM Development Flight Tests
15/02
PM Development Flight Tests
Logistics Spacecraft/
1971
1972
1973
1974

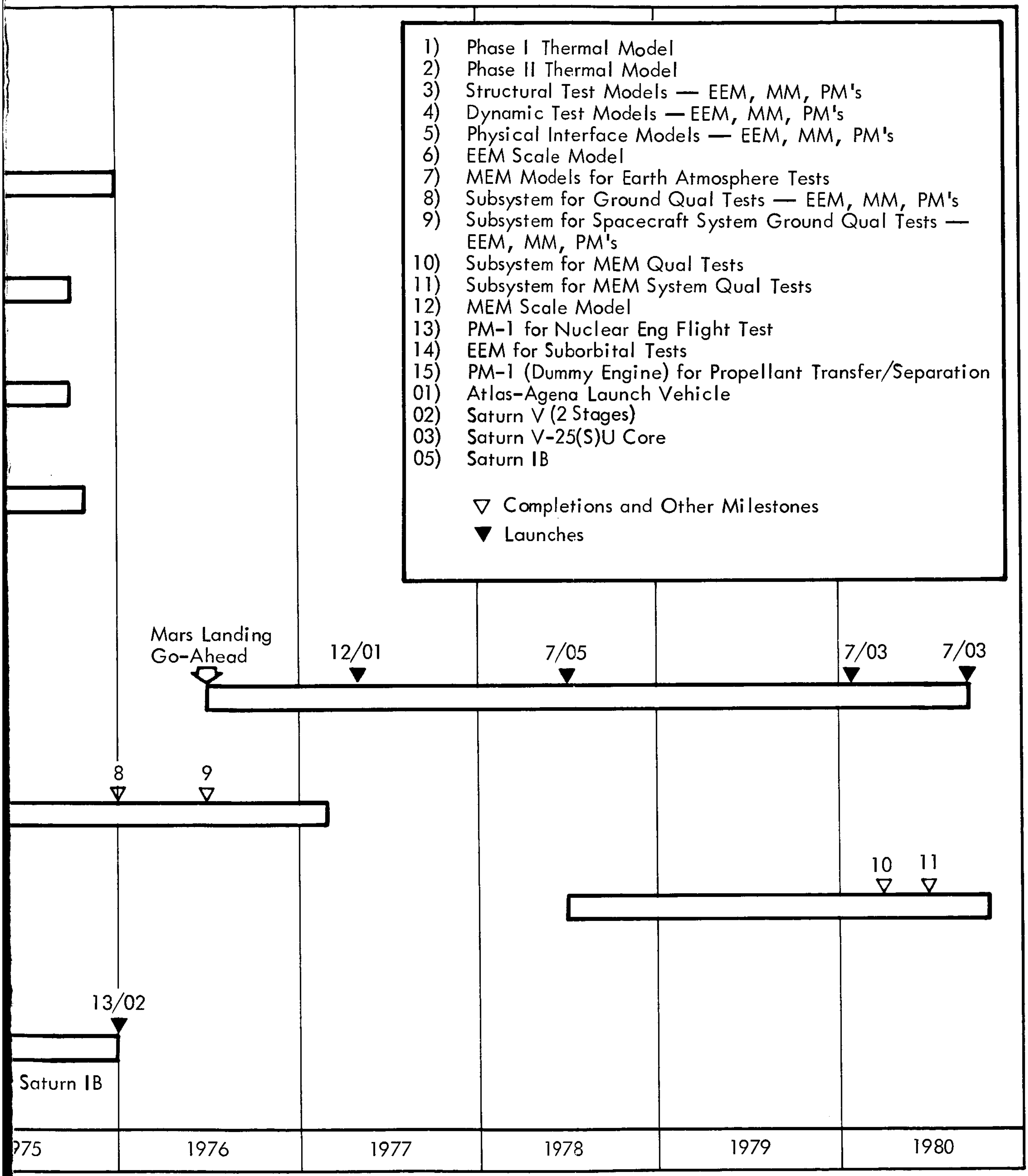


Figure 2.2-2: GROUND QUALIFICATION AND DEVELOPMENT FLIGHT TEST PROGRAM PHASING — VENUS 1983 CAPTURE AND MARS 1986 LANDING

Redundant or dual usage of subsystems is not expected at the time of this study. Subsystem degradation and the degree of testing strains will not permit dual usage.

Early design development flight tests are included for PM's. Two tests are planned: the first will be with a dummy engine for development of propellant transfer and stage separation techniques, and the second for the first flight test firing of a nuclear engine.

Mars landing mission contract go-ahead is mid-1976. The ground qualification requires three major articles. Two are the MEM structural test articles and one is a dynamic test article. Milestone 7 for three Earth atmospheric tests of the MEM include propulsion ascent and descent tests. One logistics spacecraft is launched to support the suborbital tests and to prepare the ground work for orbital qualification.

2.2.3 FLIGHT QUALIFICATION HARDWARE AND ORBITAL QUALIFICATION/DEMONSTRATION

Figure 2.2-3 depicts the scheduling details of orbital qualification for two phases covering the Venus 1983 and Mars 1986 mission follow-on. The two phases are the orbital hardware qualification program and the space vehicle qualification and orbital demonstration program. The first phase is composed mainly of individual module flight tests. The next phase is an all up manned space vehicle qualification followed by orbital demonstration. Details of the test objectives are listed in the test plan, Section 3.0.

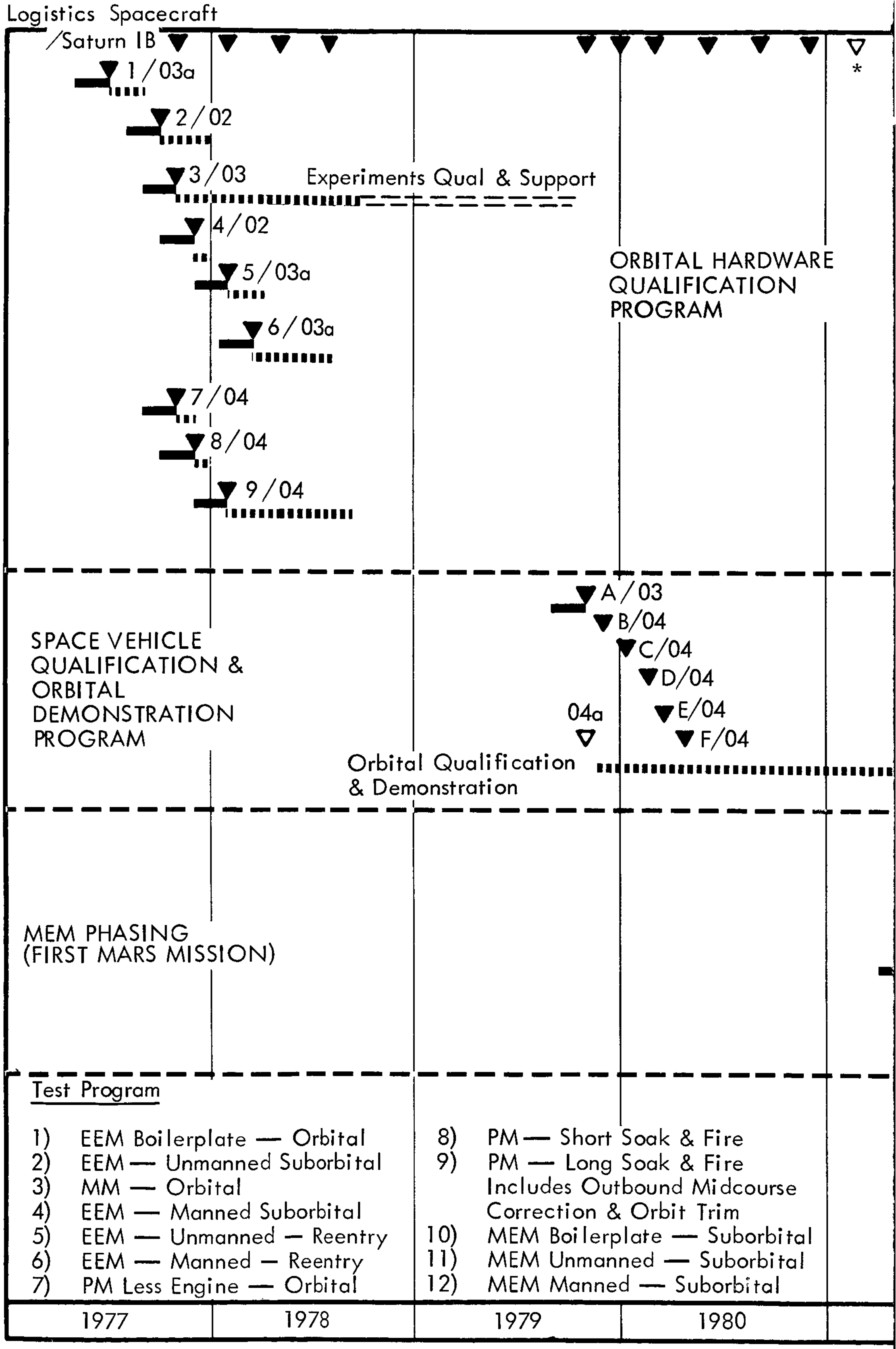
The quantities and types of launches required for these phases are two Saturn IB launches, six Sat V-25(S)U-Core launches, three SAT V-25(S)U-Core + SIVB launches, and nine SAT V-25(S)U launches.

The launches are module launches with logistics spacecraft support for required man-module interface. There are 12 logistics spacecraft launches to support the two phases. The following ground rules were adapted for the space logistics support:

1) All men will be launched from Earth in a man-rated logistics vehicle;
2) The module is launched in an assembled configuration;
3) Checkout before and after personnel boarding can be accomplished by the logistics vehicle and personnel.

The space vehicle qualification and orbital demonstration launch operations, A through F, will be supported by standby backup units. The standby units are one complete spacecraft, one PM for PM-2 or -3, one PM-1, and one off-pad SAT V-25(S)U ELV.

Orbital Hardware Qualification--During the orbital hardware qualification, dual usage will be made of the mission module and the PM test firing. The mission module test objective for this phase is to establish mission control capabilities. After successfully completing the test objective and supporting other orbital tests, the mission module will remain in


Logistics Spacecraft /Saturn IB
*
1/03a
2/02
3/03
Experiments Qual & Support
4/02
5/03a
6/03a
7/04
8/04
9/04
ORBITAL HARDWARE QUALIFICATION PROGRAM
A/03
B/04
C/04
D/04
E/04
F/04
04a
SPACE VEHICLE QUALIFICATION & ORBITAL DEMONSTRATION PROGRAM
Orbital Qualification & Demonstration
MEM PHASING (FIRST MARS MISSION)
Test Program
1) EEM Boilerplate — Orbital
2) EEM — Unmanned Suborbital
3) MM — Orbital
4) EEM — Manned Suborbital
5) EEM — Unmanned — Reentry
6) EEM — Manned — Reentry
7) PM Less Engine — Orbital
8) PM — Short Soak & Fire
9) PM — Long Soak & Fire Includes Outbound Midcourse Correction & Orbit Trim
10) MEM Boilerplate — Suborbital
11) MEM Unmanned — Suborbital
12) MEM Manned — Suborbital
1977
1978
1979
1980

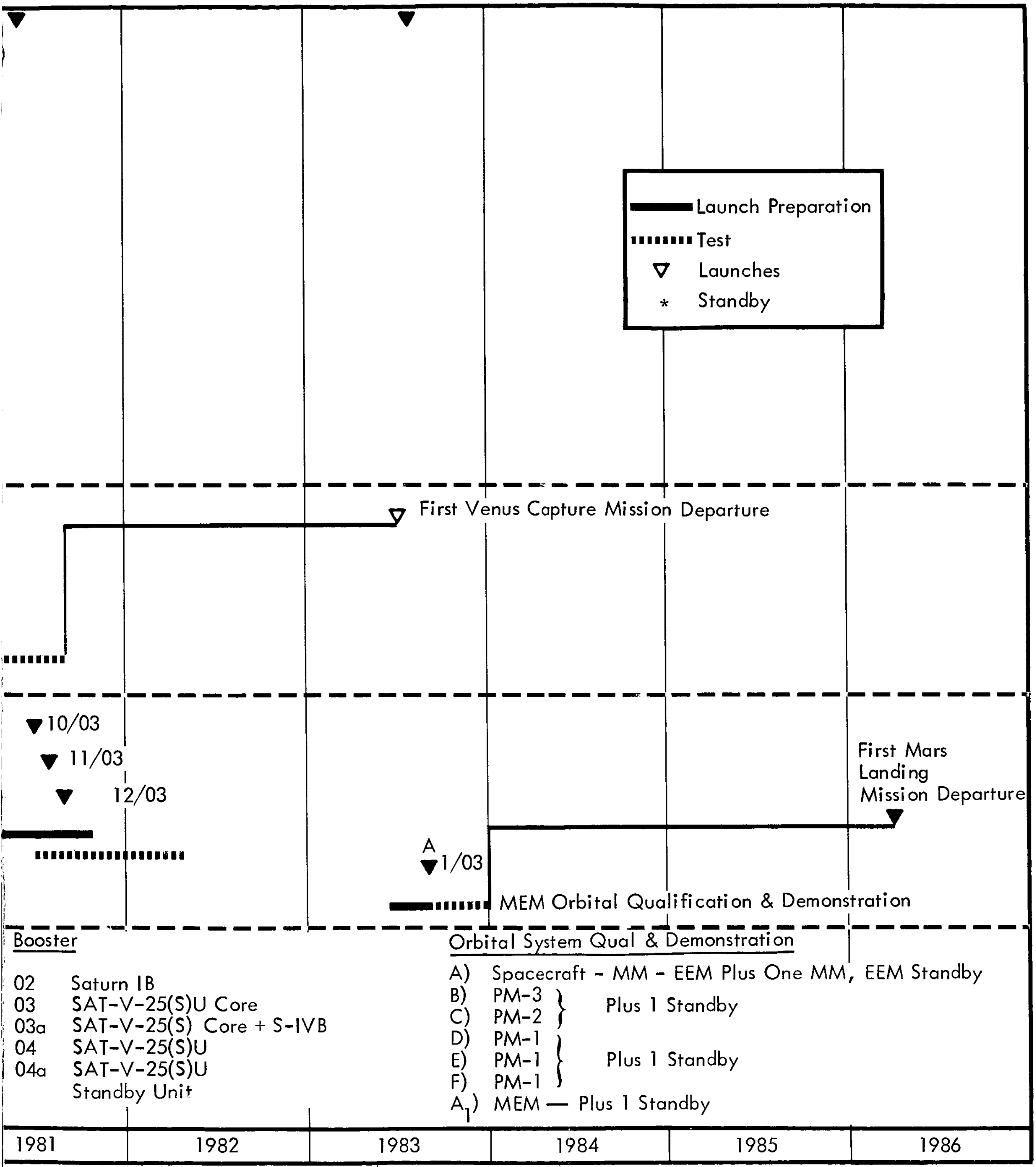


Figure 2.2-3: FLIGHT QUALIFICATION HARDWARE PROGRAM PHASING — VENUS 1983 CAPTURE AND MARS 1986 LANDING

orbit for extended space experiments and support. When the follow-on Mars mission imposes requirements for an orbiting mission module, the same mission module that has remained in orbit is used. The three PM's, after specified space soaks, could include experiments for deep space probes by carrying such experiments on deep-space oriented flights.

This phase uses four types of launch vehicles, Saturn IB, Sat V-25(S)U-Core, Sat V-25(S)U-Core + SIVB, and Sat V-25(S)U. The launch complexes to be used are 34, 37 for Saturn IB, and 39 for the balance. Adequate flow time is scheduled after test completions for the engineering/manufacturing functions necessary to process improvements into the following phase.

Orbital Qualification and Demonstration--Six launches are required for the orbital qualification and demonstration program, one launch for the MM and the EEM or the spacecraft, and five launches for the PM's. All of the launches will be made from Complex 39 and the scheduling allows for adequate standby processing time. The spacecraft and propulsion modules, launched separately, will be assembled in space and qualified over a period of approximately 6 months before orbital demonstration of 10 months.

2.2.4 OPERATIONAL PROGRAM PHASING

The operational program phasing follows the orbital qualification and demonstration phase. The timing of this phase allows for data transfer and completing design improvements during the after the orbital qualification tests. Figure 2.2-4, operational program phasing, depicts:

1) When the hardware is required after manufacturing and testing;
2) Flow times required for manufacture, test, and launch;
3) How many hardware modules and launch vehicles are required for the Venus and Mars missions;
4) How much logistics spacecraft support is required for the two missions.

Complex 39 will be used for the launching of Sat V-25(S)U core and Sat V-25(S)U. The launches will be by modules and each mission requires six; one for the spacecraft, which includes the MM and the EEM, and the remaining five launches for PM-3, PM-2, and the three PM-1's. The Earth launch vehicles for the Venus and Mars missions are ten Saturn V-25(S)U, and two Sat V-25(S)U cores. The "Earth Launch and Assembly Sequence," Volume IV, depicts the operational sequence and Figure 2.4-1 gives a more detailed accounting of the launch scheduling.

2.2.5 MODULE SCHEDULES

The three schedules, Figures 2.2-5 through 2.2-7, show the MM, EEM, and PM modules, provide a manufacturing and test completion demand date, and designate the modules by number and nomenclature. The total

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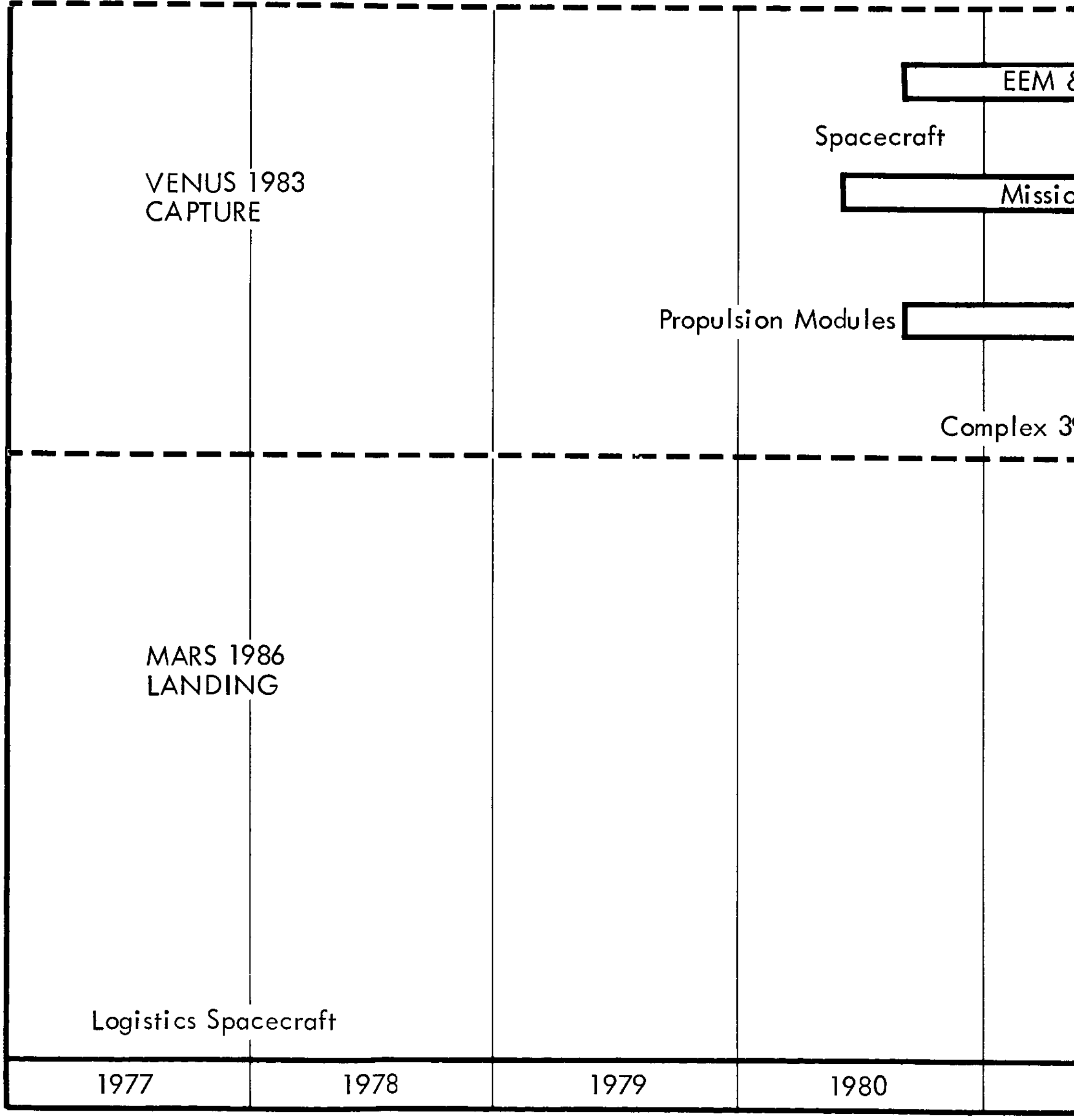
A) Operational EEM, MEM, & Probes Mfg Complete
B) Oper MM Integrated & Tested with EEM, MEM, & Probes
C) PM - Outbound Midcourse Correction
D) PM - Orbit Trim
E) PM-3
F) PM-2
G) PM-1
H) PM-1
I) PM-1
J) Spacecraft-Launch with Saturn V-25(S)U Core
K) PM-3 Launch with Saturn V-25(S)U
L) PM-2 Launch with Saturn V-25(S)U
M) PM-1 Launch with Saturn V-25(S)U
N) PM-1 Launch with Saturn V-25(S)U
O) PM-1 Launch with Saturn V-25(S)U

1) Op
2) Op
3) PM
4) PM
5) PM
6) PM
7) PM
8) PM
9) PM
10) Sp
11) PM
12) PM
13) PM
14) PM
15) PM



FOLDOUT FRAME 1

erational EEM & Probes Mfg Complete
er MM Integrated & Tested with EEM & Probes
- Outbound Midcourse Correction
- Orbit Trim
-3
-2
-1
-1
-1
icecraft Launch with Saturn V-25(S)U Core
-3 Launch with Saturn V-25(S)U
-2 Launch with Saturn V-25(S)U
-1 Launch with Saturn V-25(S)U
-1 Launch with Saturn V-25(S)U
-1 Launch with Saturn V-25(S)U

1s, 2s, etc.	Complete module for standbys — if not used, transferred to Mars mission as spare
LS	ELV off-pad unit for standby
▽	Completions and other milestones
▼	Launches
*	Standby

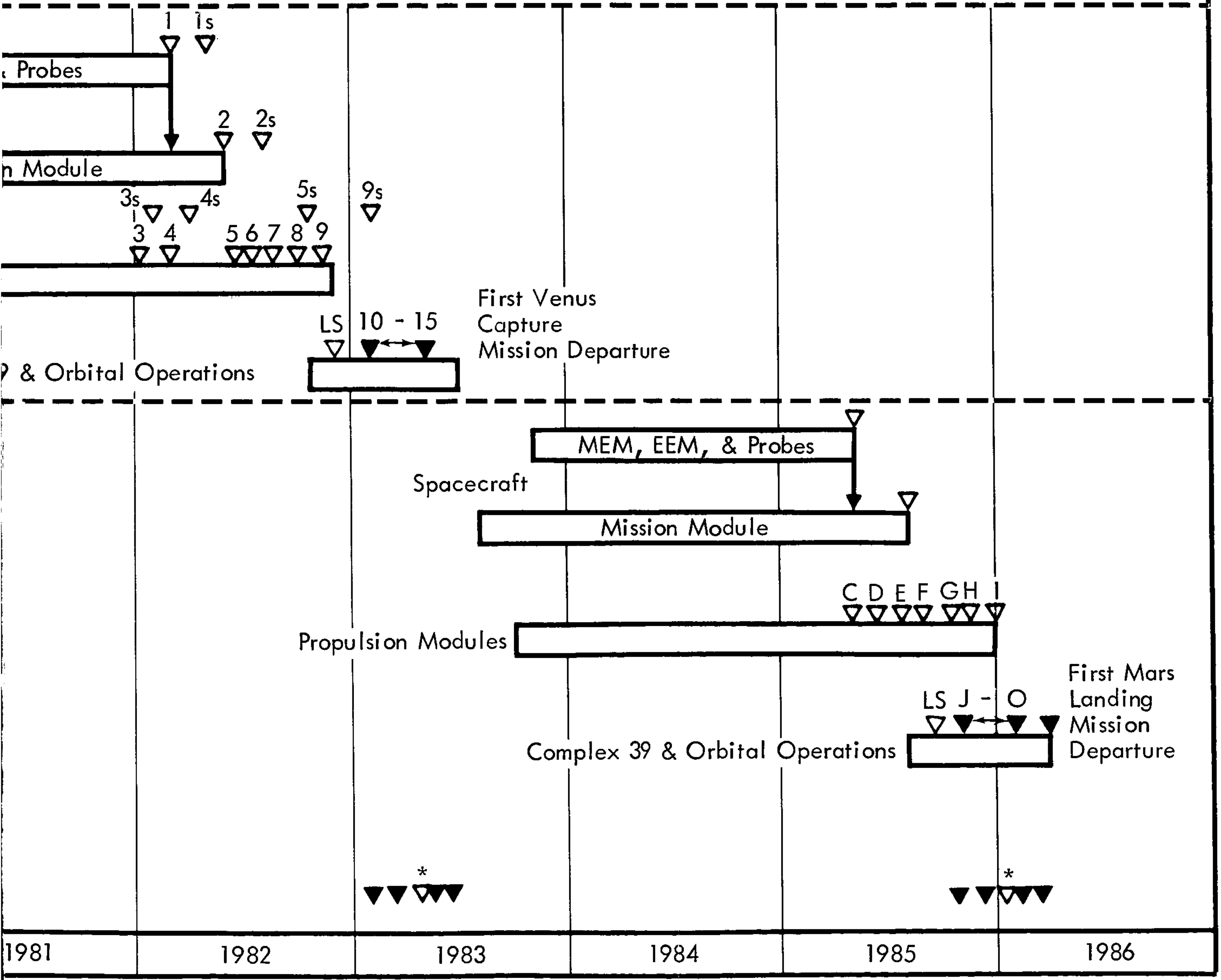
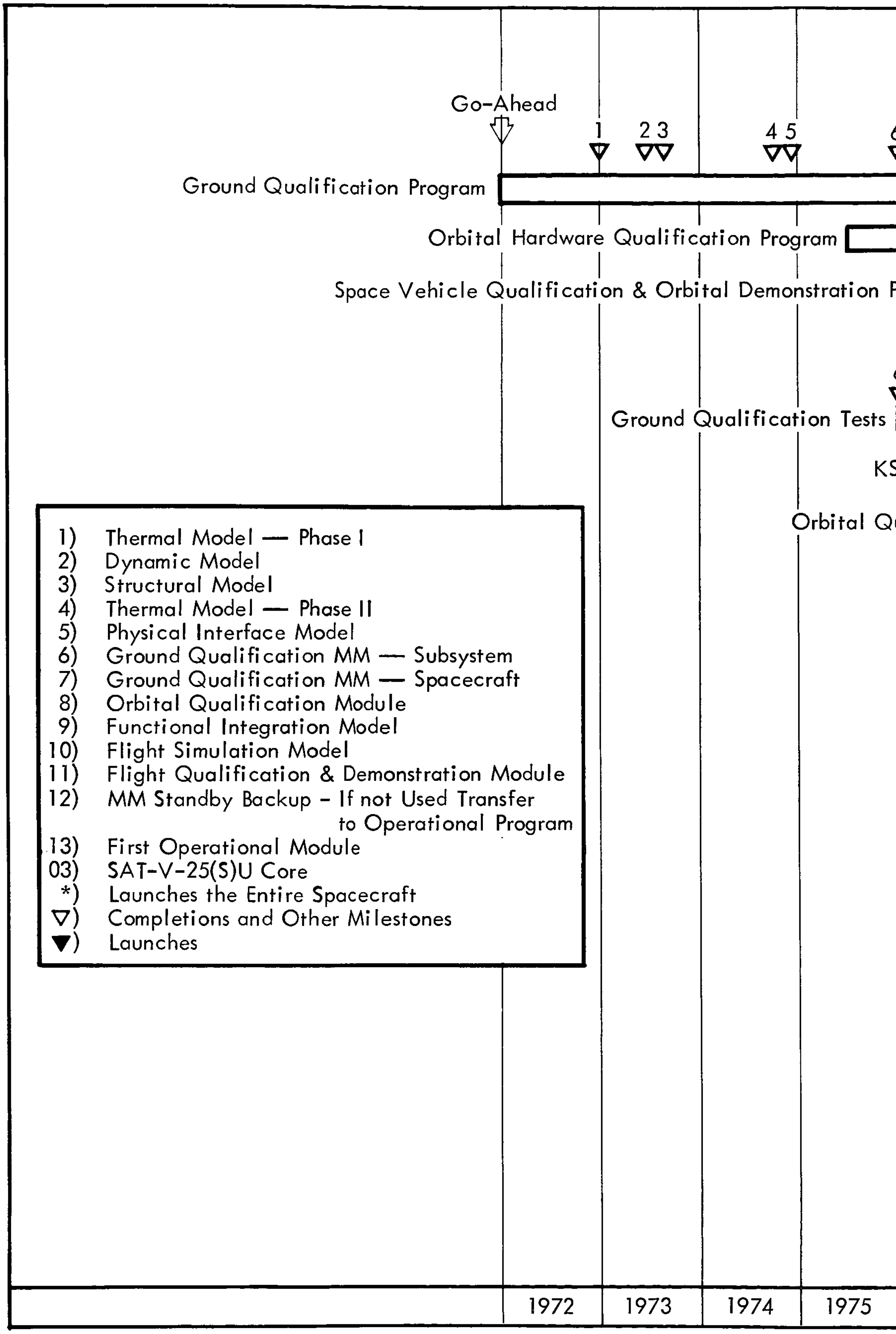


Figure 2.2-4: OPERATIONAL PROGRAM PHASING — VENUS 1983 CAPTURE & MARS 1986 LANDING


Go-Ahead
1
2 3
4 5
Ground Qualification Program
Orbital Hardware Qualification Program
Space Vehicle Qualification & Orbital Demonstration P
Ground Qualification Tests
KS
Orbital Q
1) Thermal Model — Phase I
2) Dynamic Model
3) Structural Model
4) Thermal Model — Phase II
5) Physical Interface Model
6) Ground Qualification MM — Subsystem
7) Ground Qualification MM — Spacecraft
8) Orbital Qualification Module
9) Functional Integration Model
10) Flight Simulation Model
11) Flight Qualification & Demonstration Module
12) MM Standby Backup - If not Used Transfer to Operational Program
13) First Operational Module
03) SAT-V-25(S)U Core
*) Launches the Entire Spacecraft
▽) Completions and Other Milestones
▼) Launches
1972
1973
1974
1975

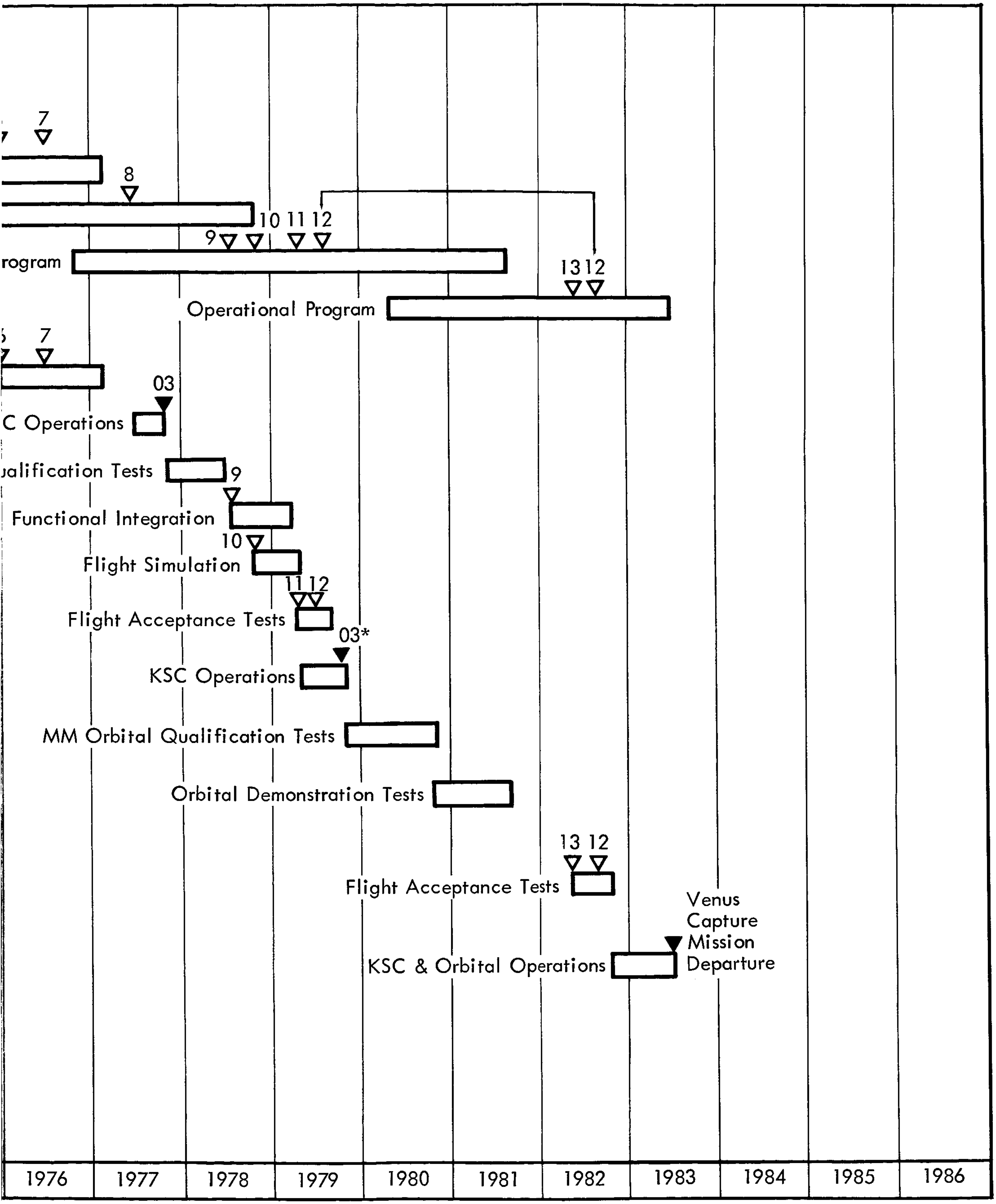
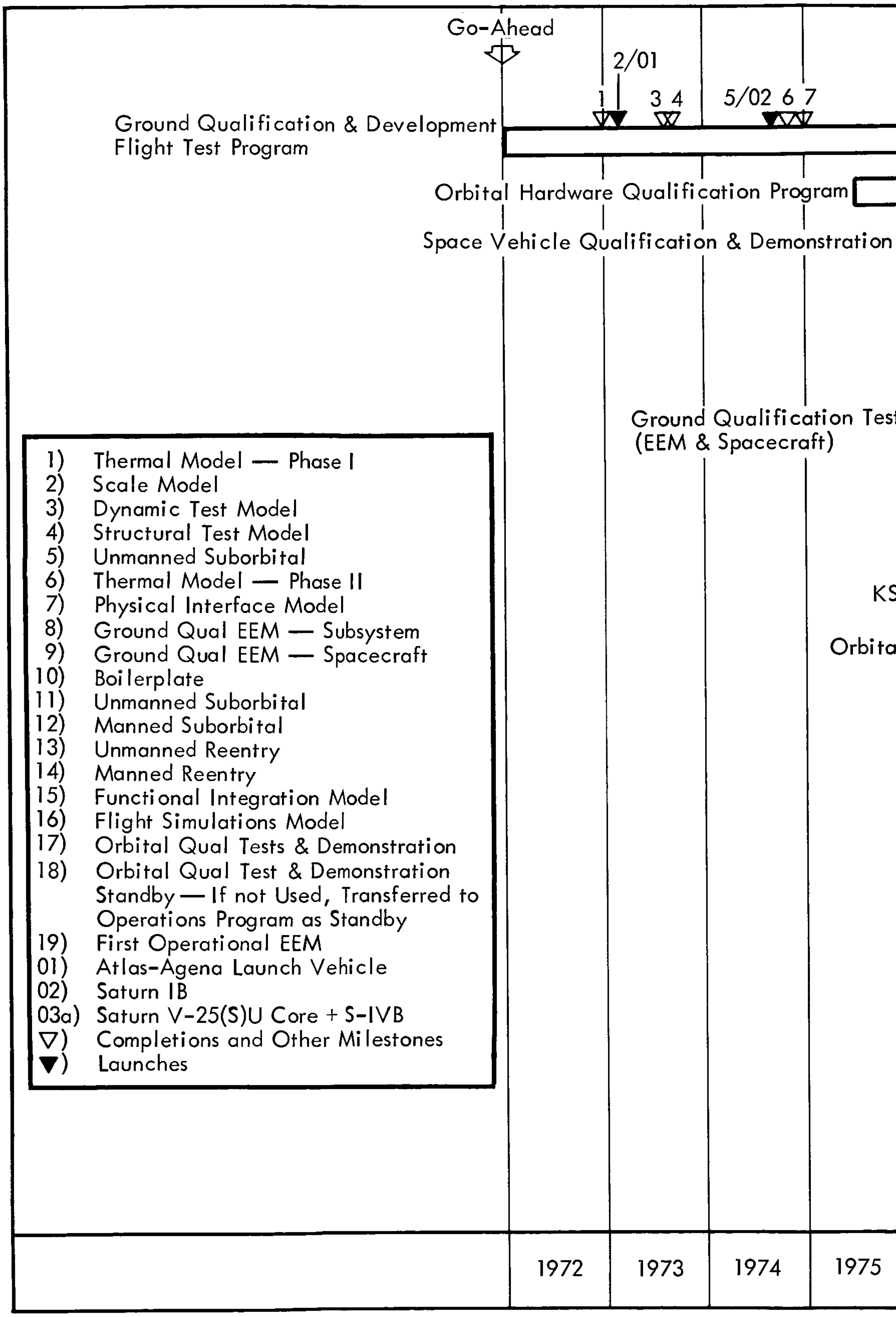


Figure 2.2-5: MISSION MODULE SCHEDULE



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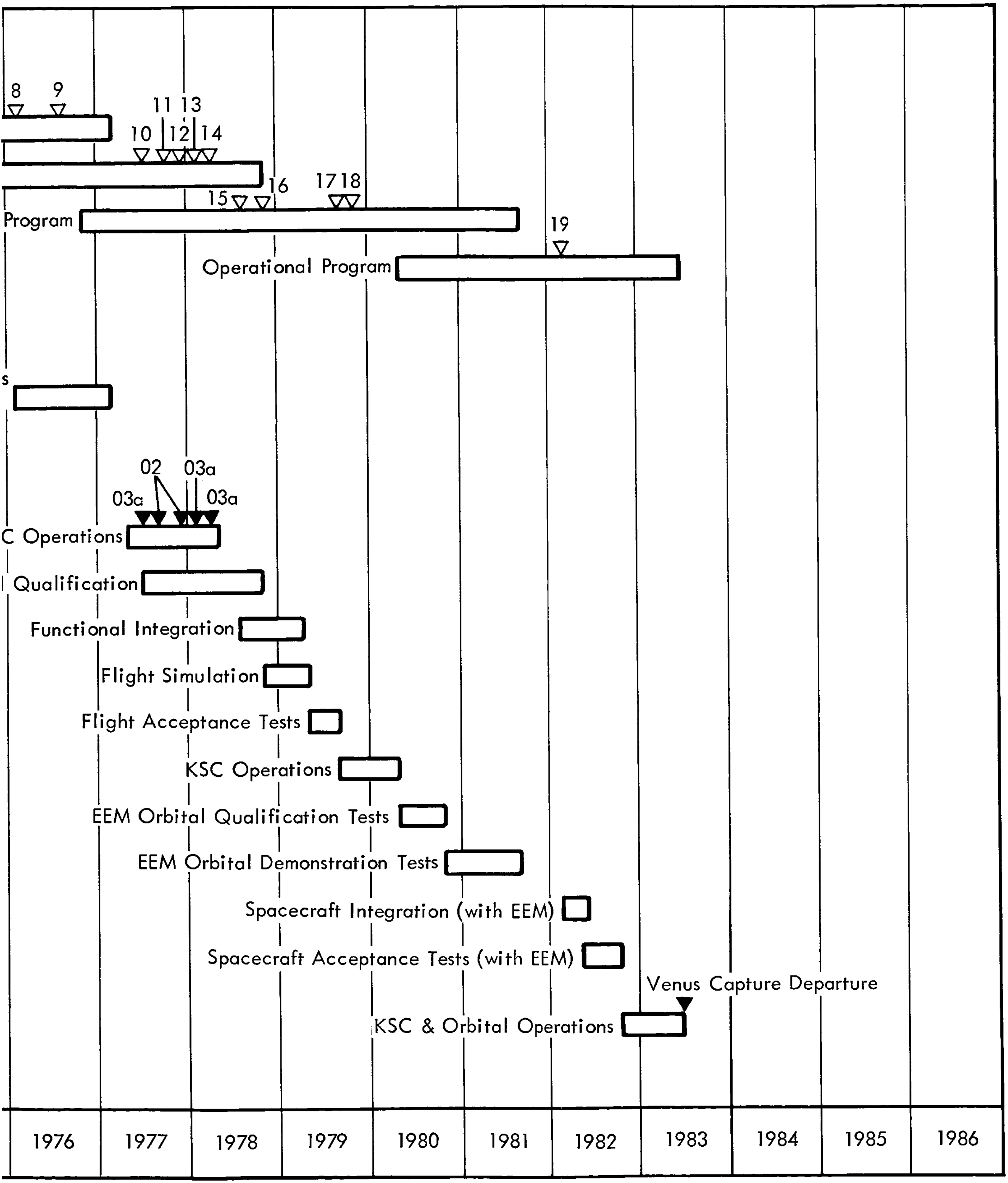
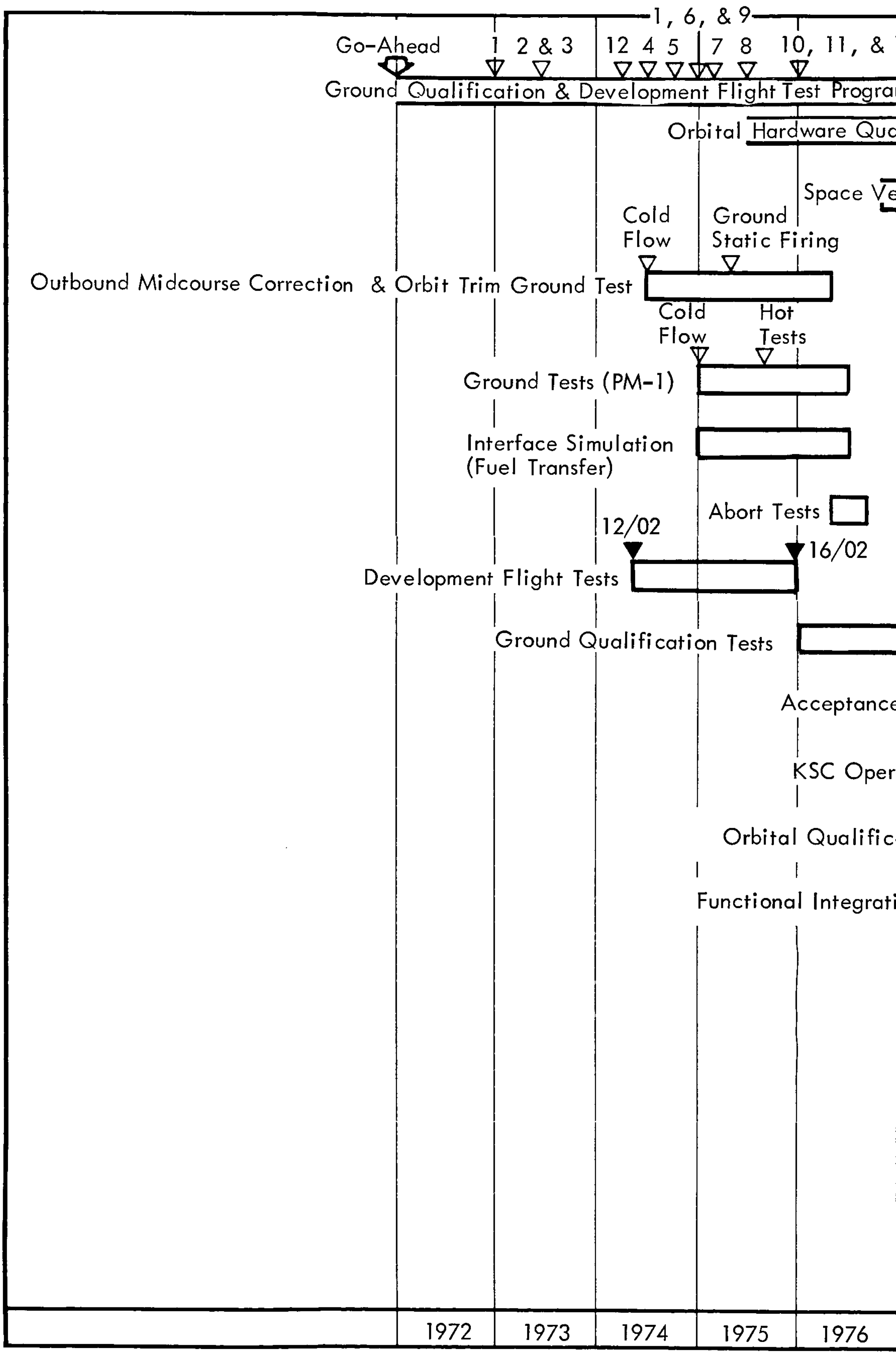


Figure 2.2-6: EARTH ENTRY MODULE SCHEDULE



FOLDOUT FRAME 1

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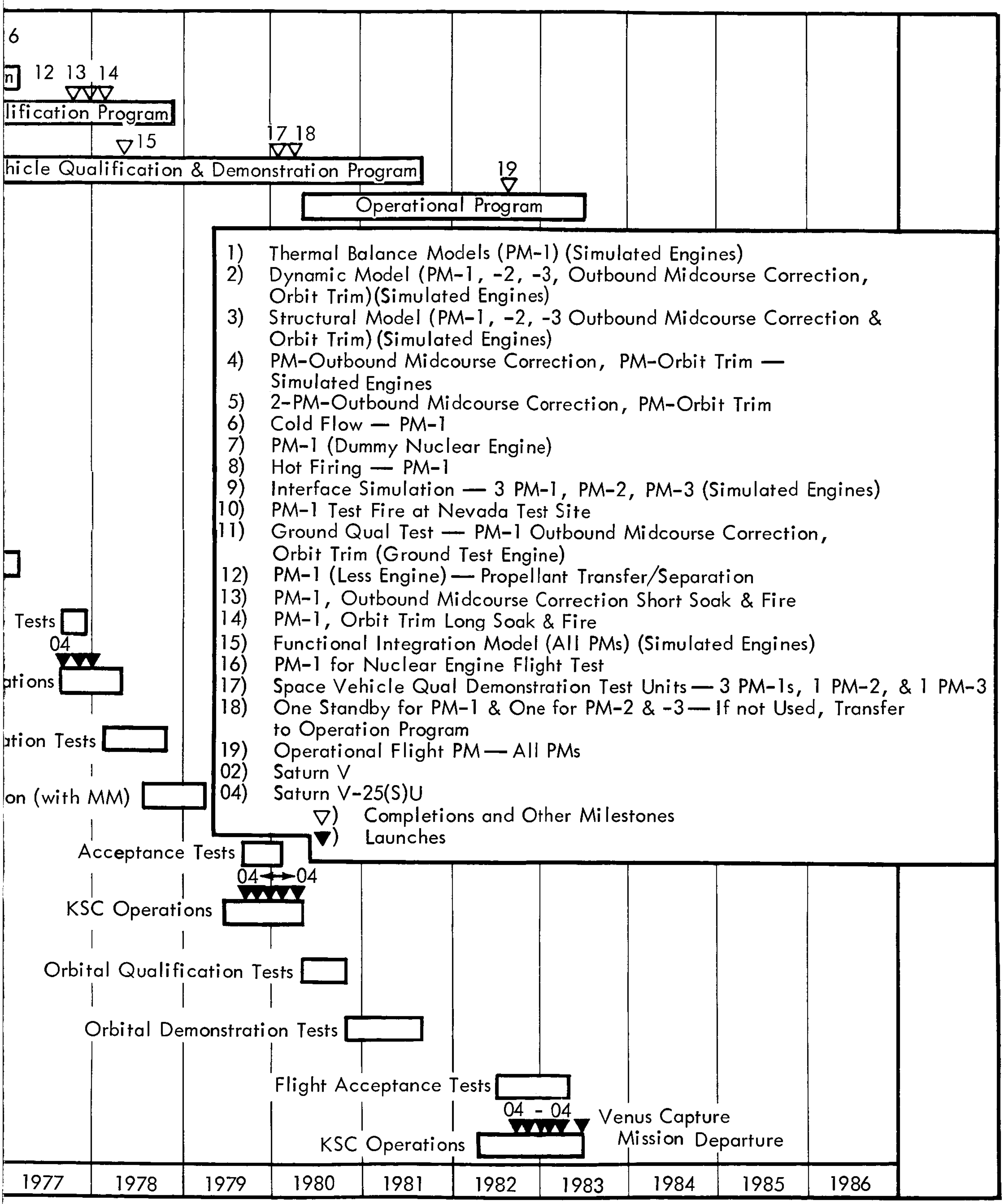

1) Thermal Balance Models (PM-1) (Simulated Engines)
2) Dynamic Model (PM-1, -2, -3, Outbound Midcourse Correction, Orbit Trim)(Simulated Engines)
3) Structural Model (PM-1, -2, -3 Outbound Midcourse Correction & Orbit Trim) (Simulated Engines)
4) PM-Outbound Midcourse Correction, PM-Orbit Trim — Simulated Engines
5) 2-PM-Outbound Midcourse Correction, PM-Orbit Trim
6) Cold Flow — PM-1
7) PM-1 (Dummy Nuclear Engine)
8) Hot Firing — PM-1
9) Interface Simulation — 3 PM-1, PM-2, PM-3 (Simulated Engines)
10) PM-1 Test Fire at Nevada Test Site
11) Ground Qual Test — PM-1 Outbound Midcourse Correction, Orbit Trim (Ground Test Engine)
12) PM-1 (Less Engine) — Propellant Transfer/Separation
13) PM-1, Outbound Midcourse Correction Short Soak & Fire
14) PM-1, Orbit Trim Long Soak & Fire
15) Functional Integration Model (All PMs) (Simulated Engines)
16) PM-1 for Nuclear Engine Flight Test
17) Space Vehicle Qual Demonstration Test Units — 3 PM-1s, 1 PM-2, & 1 PM-3
18) One Standby for PM-1 & One for PM-2 & -3 — If not Used, Transfer to Operation Program
19) Operational Flight PM — All PMs
02) Saturn V
04) Saturn V-25(S)U
▽) Completions and Other Milestones
▼) Launches

Figure 2.2-7: PROPULSION MODULE SCHEDULE

MM hardware for the Venus capture mission, including standbys, is 13 items, while the EEM hardware items total 19. The propulsion modules, PM-3, PM-2, and PM-1, require 39 separate major articles of which 21 have simulated engines.

Two subsystems each for the MM and EEM are required for the ground qualification. The subsystems qualification level will not require module installation, and the test is at the subsystem level. The subsystems used for system qualification level testing will be installed in the module and the module will be subjected to tests as a complete unit. Most of the subsystem testing is expected to be beyond design limits. Therefore, two separate subsystems are required because of the degradation that occurs under each qualification test level. Finally, the ground subsystem qualification may induce specification or design changes before system qualification occurs.

Ground qualification tests for the propulsion module will require one PM-1. The propulsion module will be subjected to full burn time testing at the Nevada Test Site. A spare PM-1 will also be at the test site to augment any malfunction that may occur during the first propulsion module test.

2.2.6 MEM INCORPORATION PHASING SCHEDULES--(SECOND MISSION PROGRAM)

The program plan for the MEM incorporation is in the same sequence and pattern as the Venus capture program. Figure 2.2-8 depicts the phasing plan and scheduling of the MEM for the 1986 Mars opposition mission. The MEM or Mars landing mission go-ahead is in mid 1976, or about 4.5 years after Venus capture program go-ahead.

The Mars mission development program will utilize the same hardware as the Venus program. The flow time is primarily for the development of the MEM with minor allocation for the MM and EEM functional checkout. Refurbishing of the spacecraft (MM and EEM), due to system degradation during the lapsed period, will be accomplished during the time between programs as indicated by the dashed lines on the schedule.

Figure 2.2-9 separates the MEM modules by configuration, accounts for the number of modules, and designates the demand dates. The MEM hardware items required for the program totals 21, including a scale model and one standby backup unit. Only one thermal model is required, since the voluminous design and development effort and the major thermal testing have been completed for the earlier Venus mission.

Two subsystems are required for the MEM ground qualification, as for the MM and EEM.

The Mars mission operational program requires a complete set of propulsion modules, while the spacecraft is comprised of the MM, EEM, and MEM, and probes.

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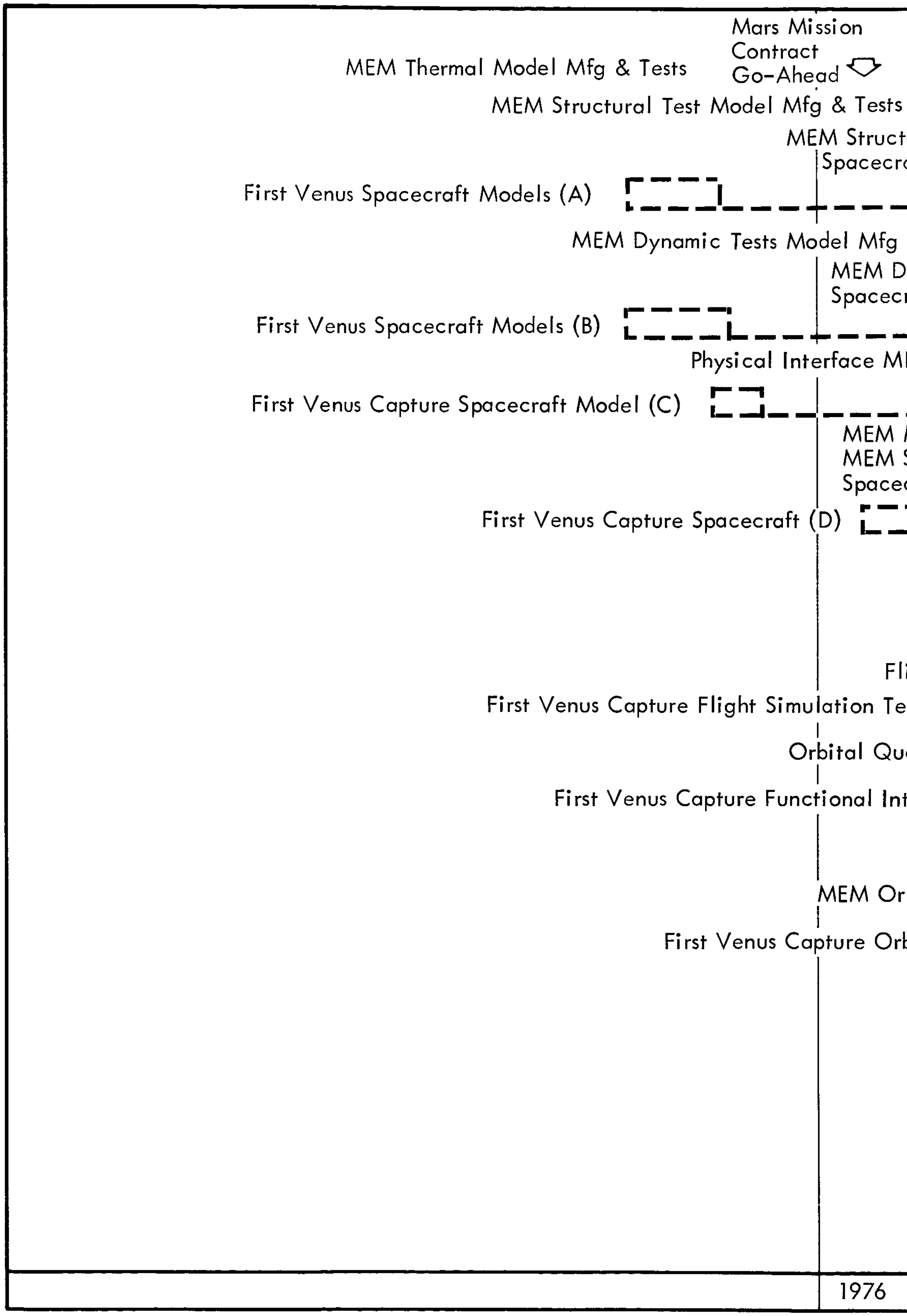

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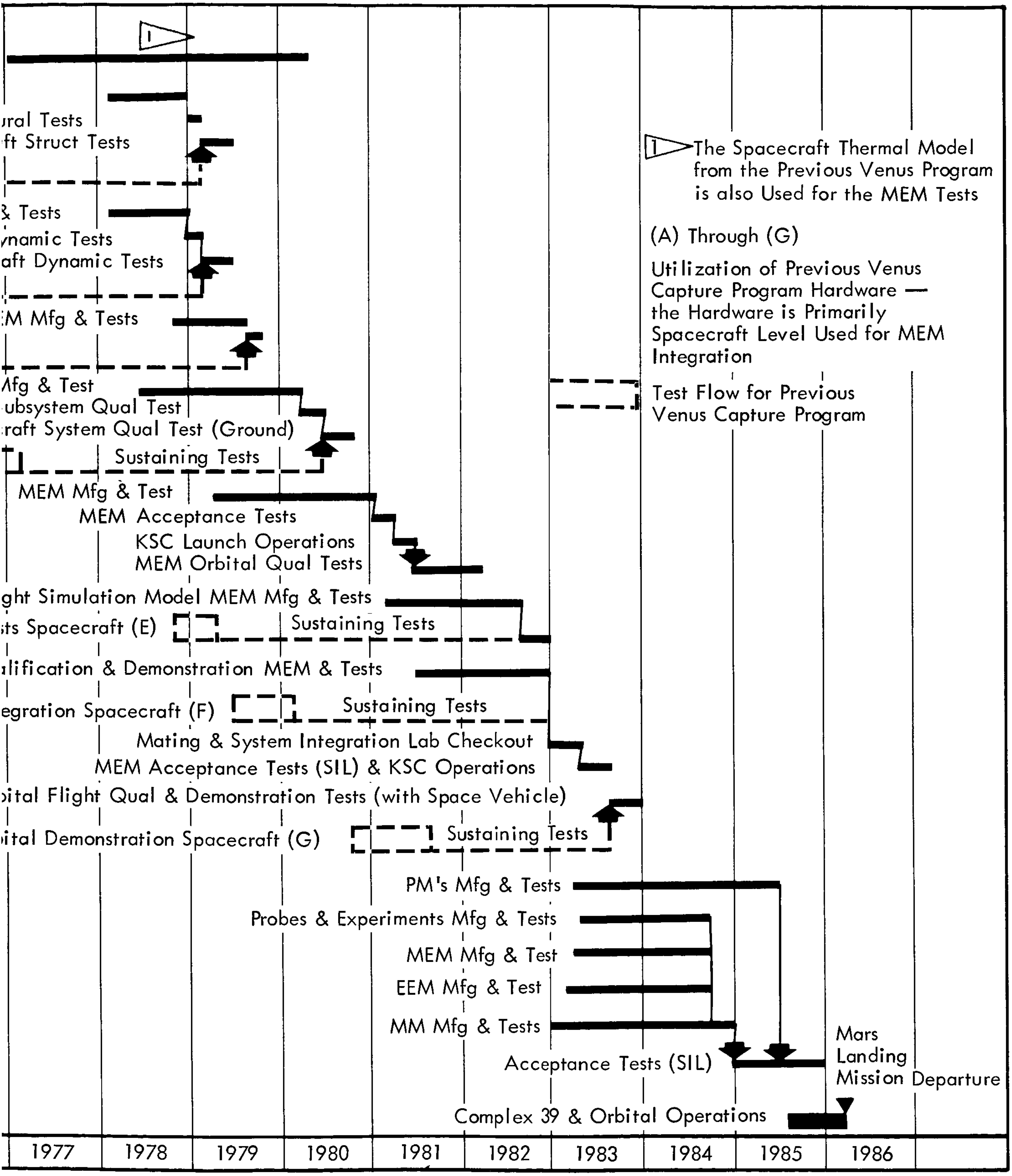
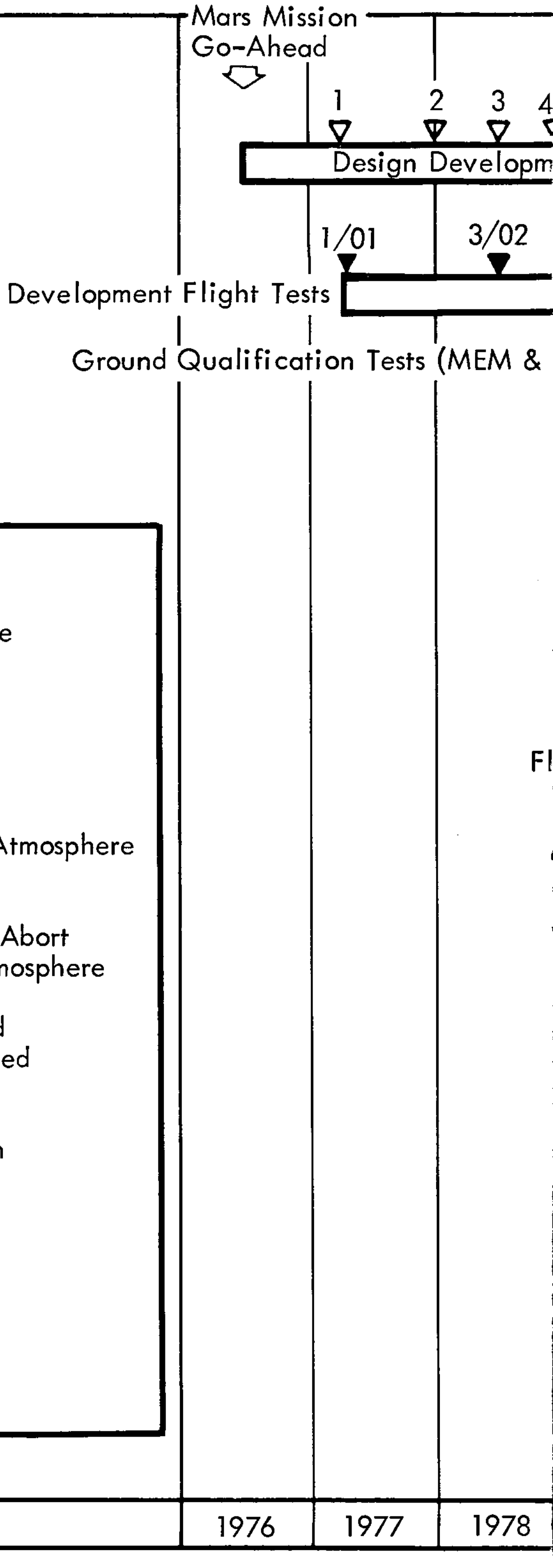


Figure 2.2-8: MEM INCORPORATION PHASING SCHEDULE (SECOND MISSION PROGRAM)



1) MEM — Scale Model
2) MEM Thermal Model
3) MEM — Ballutes - Earth Atmosphere
4) Dynamic Test Model
5) Structural Test Model
6) Ascent Stage — Guidance
7) Physical Interface Model
8) Ascent & Descent Stages
(Ground Static Firing)
9) Descent Stage — Unmanned Earth Atmosphere
10) Ground Qual MEM — Subsystem
11) Ground Qual MEM — System
12) Ascent - Descent Stage — Landing Abort
13) Descent Stage — Manned Earth Atmosphere
14) Orbital Qualification — MEM
15) Boilerplate — Suborbital Unmanned
16) Ascent Stage — Suborbital Unmanned
17) MEM — Suborbital Manned
18) Flight Simulation Model
19) Orbital Qual Tests & Demonstration
20) MEM as Backup — If not Used,
Transter to Operational Program
21) First Operational MEM
01) Atlas-Agena Launch Vehicle
02) Saturn IB
03) Saturn V-25(S)U Core
▽) Completions and Other Milestones
▼) Launches

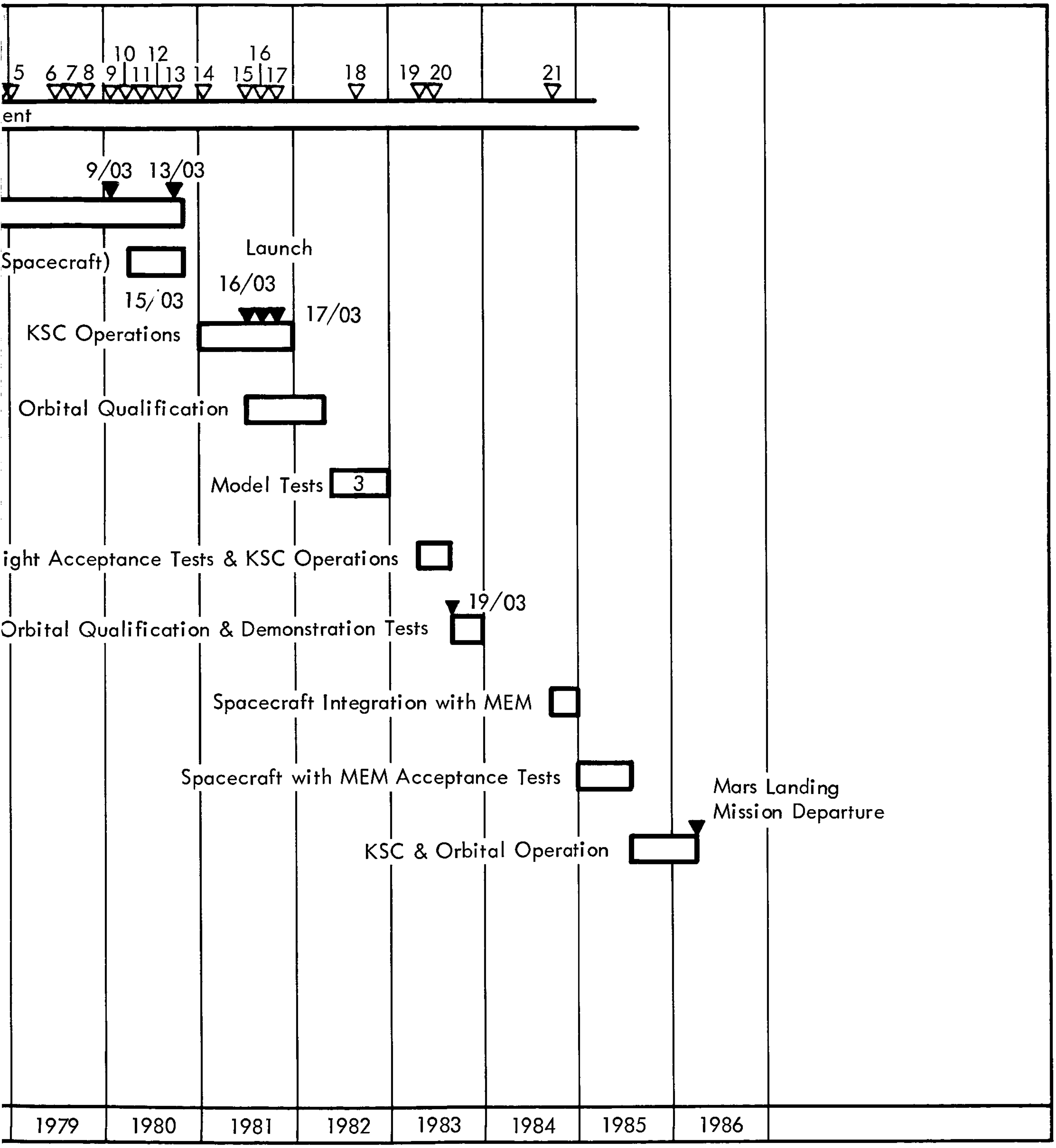


Figure 2.2-9: MARS EXCURSION MODULE SCHEDULE

2.2.7 PROBES PROGRAM

The soft lander was chosen to represent a typical probe development program. The reasons for the selection of the soft lander are listed below.

- It has the longest procurement lead time items.
- It is the most complex of the probes to be developed.
- It has the longest overall development flow time

Figures 2.2-10 and 2.2-11 depict the soft lander probe phasing and schedule. The plan requires the thermal, dynamic, and structural developmental models be scheduled. Component testing precedes subsystem design verification (SDV) that will be accomplished at the subsystem level using engineering models to verify design. However, flight hardware, when available, is preferred over engineering models.

System qualification begins after SDV. Because of the preliminary and analytical data of the planet, space, and planet environmental conditions, testing beyond design limits will be conducted. The qualification program will require two sets of hardware, one for subsystem qualification and the other for system qualification. The separate sets are required because of the above design limit testing to be conducted at both levels. The spacecraft qualification and demonstration test program will require a complete set of hardware and standbys. Unused standbys will be transferred to the operational program.

The probe interface model will be of prototype equipment and will verify the interface with the mission module or remote data processing Earth stations. An additional model is provided for lifetime and reliability demonstration testing.

The operational probes will be manufactured at the contractor's facility and shipped directly to the launch site to be integrated with the mission module. Intermediate requirements for integration can be determined between contractors with mockups and engineering models.

2.3 ALTERNATE VENUS AND MARS SCHEDULES

Alternate schedules for earlier Venus and Mars missions are shown on Figures 2.3-1 and 2.3-2. The alternate Venus 1981 capture and Mars 1984 landing mission examples are high-risk schedules. The high risk evolves from two important reasons:

- Testing phases prior to operational flight are concurrent. This concurrency does not allow for data and design changes to be made between completed and succeeding phases.
- Test success predictions are optimistic. Planning for almost complete success means transferring less than normal engineering changes to the succeeding phase.

Programs with concurrent activities for testing, manufacturing, and engineering compound problems and usually result in program slides and higher costs, and sometimes involve taking risks that would normally be undesirable.

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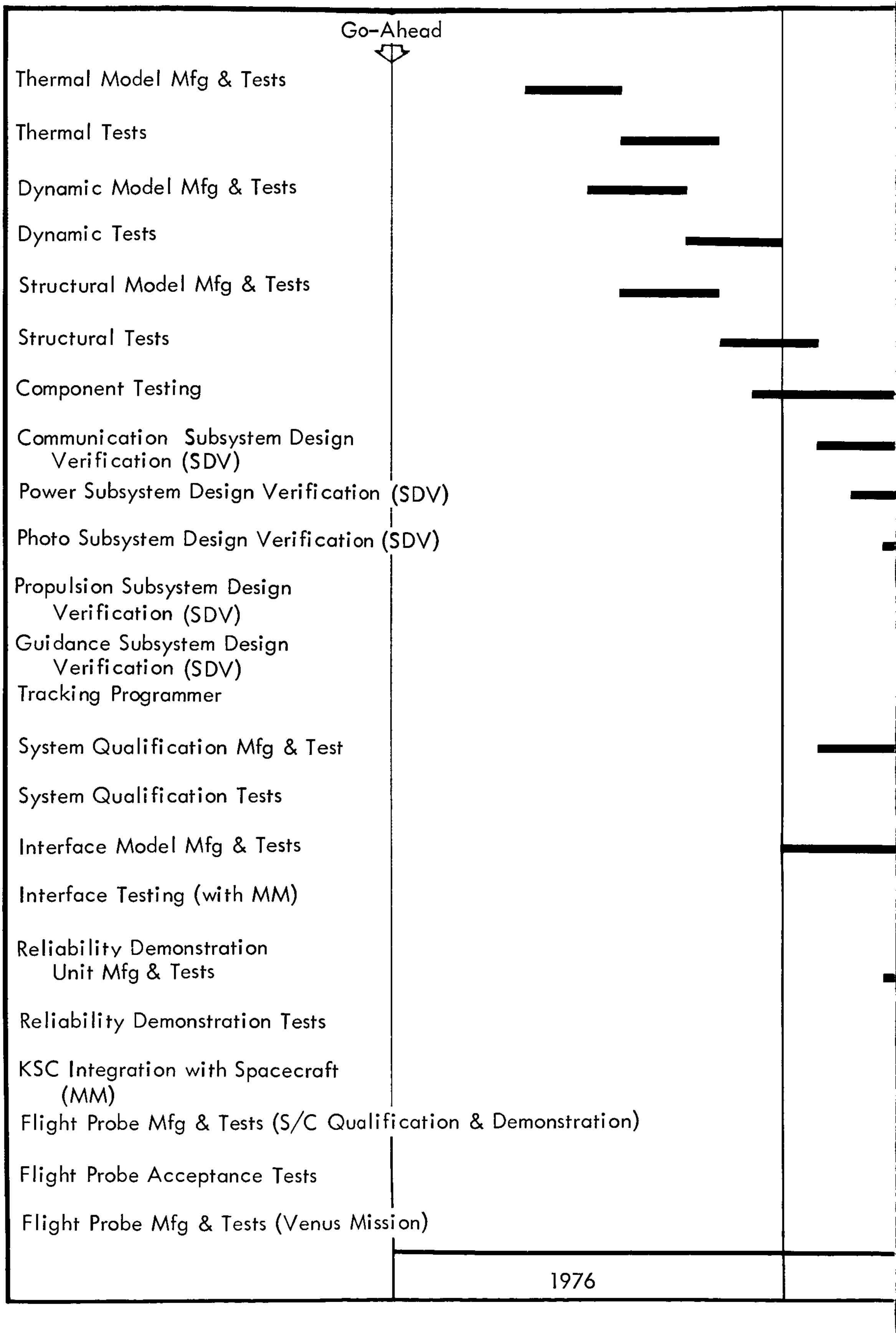
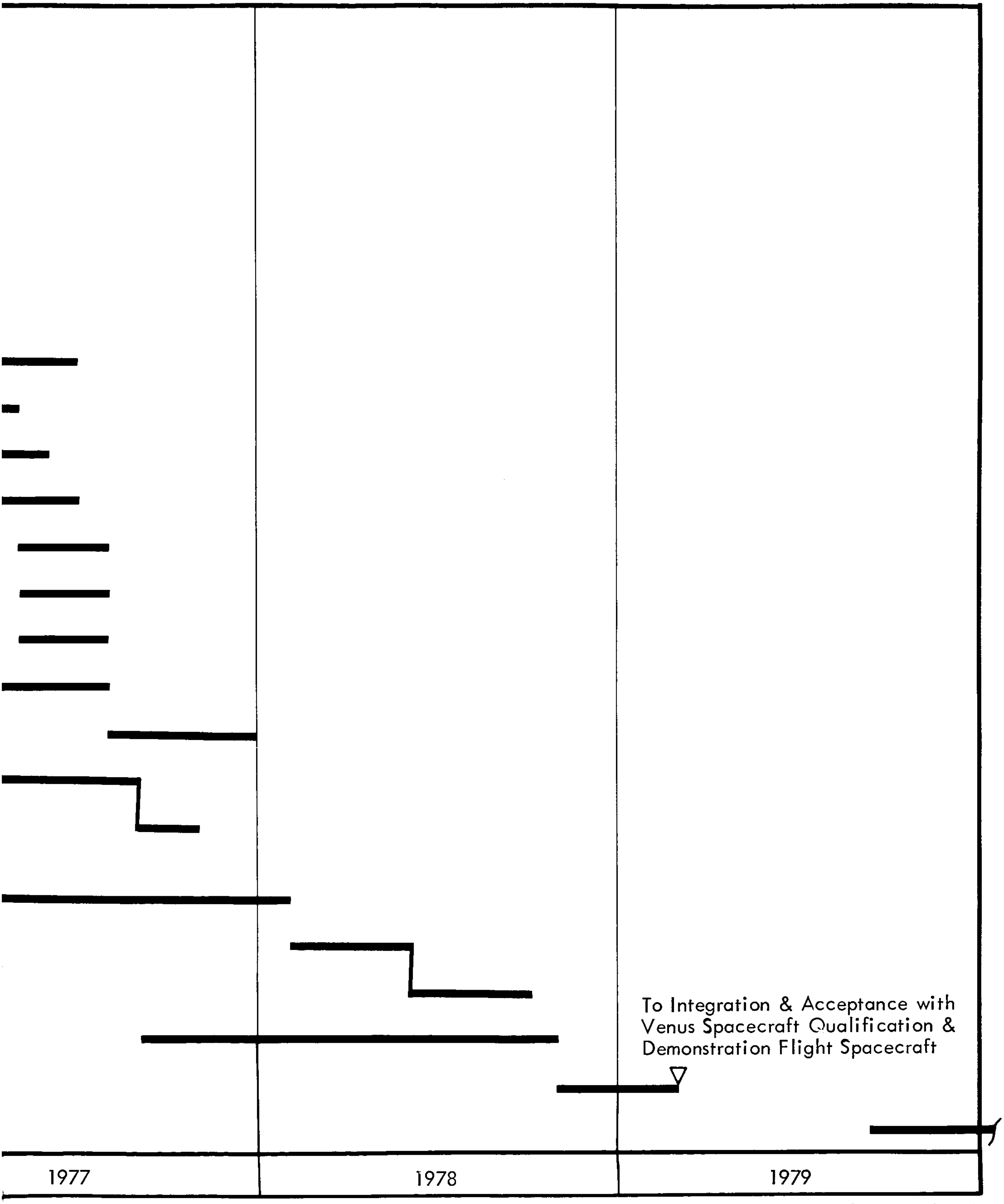
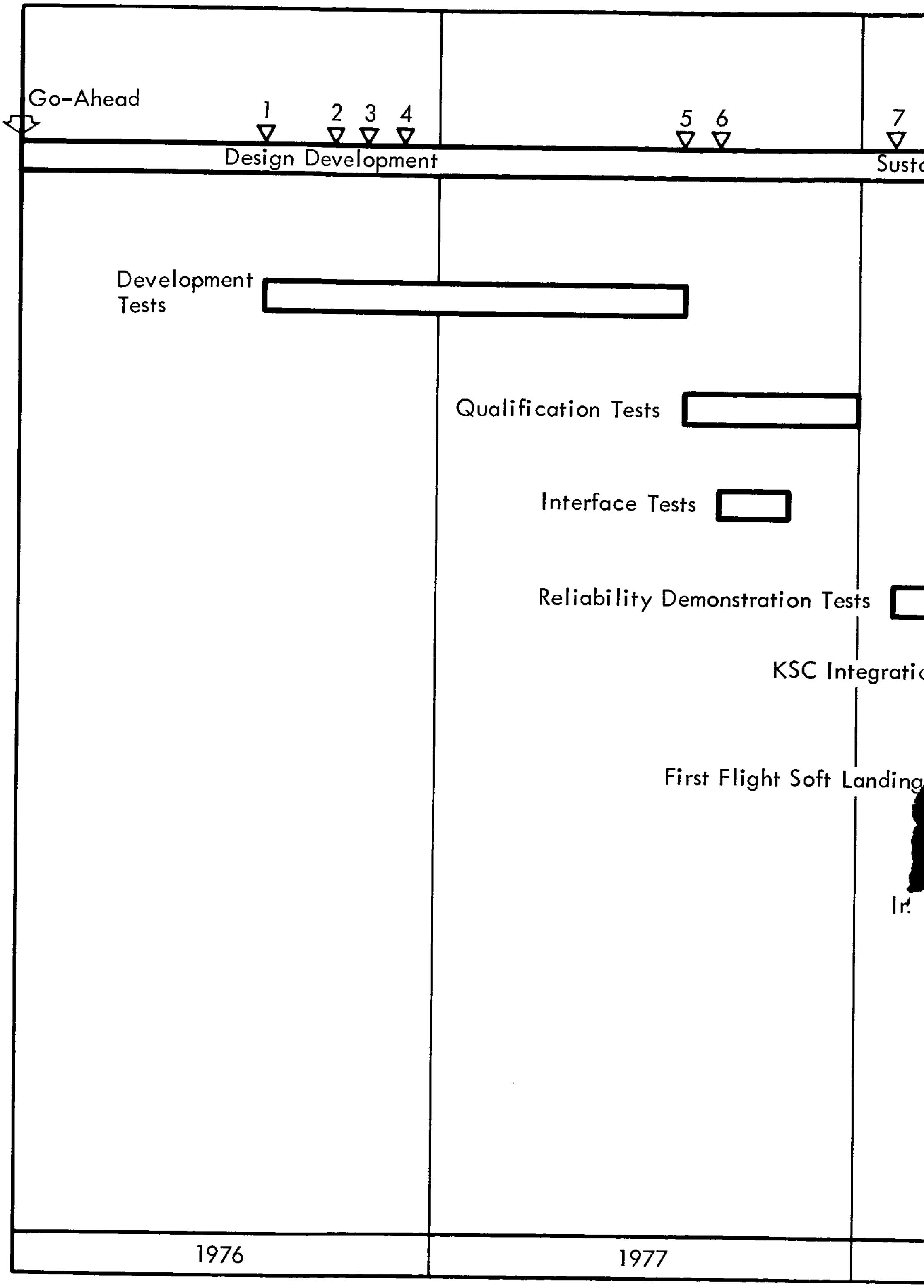




To Integration & Acceptance with Venus Spacecraft Qualification & Demonstration Flight Spacecraft

Figure 2.2-10: SOFT LANDER PROBE PHASING


Go-Ahead
1
2
3
4
5
6
7
Design Development
Susta
Development Tests
Qualification Tests
Interface Tests
Reliability Demonstration Tests
KSC Integratio
First Flight Soft Landing
In
1976
1977

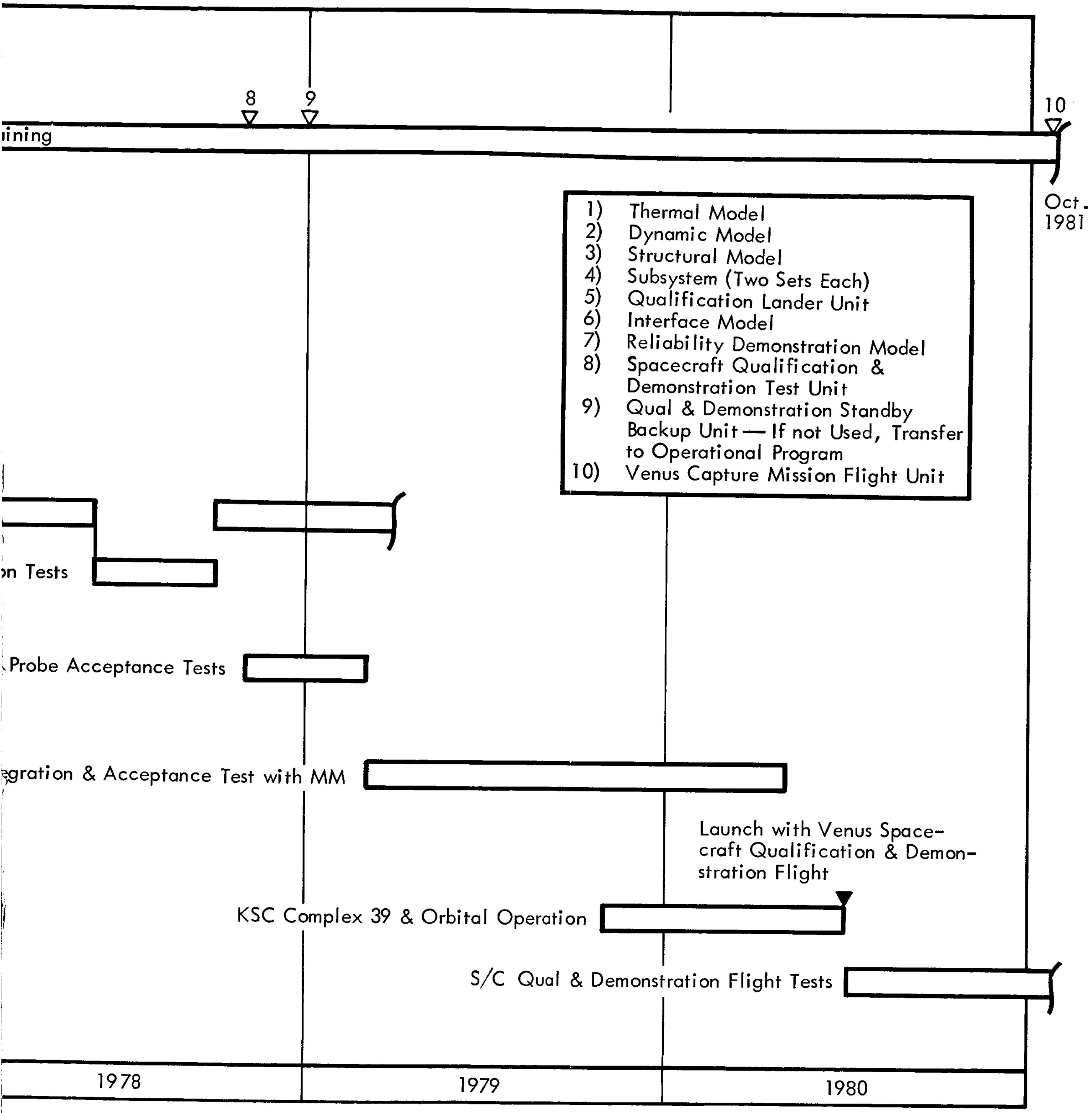


Figure 2.2-11: SOFT LANDER PROBE SCHEDULE

Contr
Go-A

GROUND QUALIFICATION PROGRAM	Manufacturing Thermal Model Thermal Test Manufacturing Structural Test Model Module Structural Test Spacecraft Structural Tests Manufacturing Dynamic Test Model Module Dynamic Test Spacecraft Dynamic Test Physical Interface Model Mfg & Test Interface Test Ground Qualification Hdwe Mfg & Test Subsystem Qualification Test (Ground) Spacecraft System Qualification Test (Ground
ORBITAL HARDWARE QUALIFICATION PROGRAM	PM's Manufacturing & Test MM Manufacturing & Test EEM Manufacturing & Test Acceptance Test SIL (System Integration Lab) EEM Mfg & Test Unmanned Suborbital EEM Boilerplate Manufacturing & Test Launch Operations Module & PM Orbital Qualification
SPACE VEHICLE QUALIFICATION & DEMONSTRATION PROGRAM	Flight Simulation Model Mfg & Test Flight Simulation Test Sustain Flight Simulation Test Probe Mfg & Test Mfg & Test Func Integ Model (EEM & MM) SIL Functional Checkout PM's Manufacturing & Tests Spacecraft Manufacturing & Test Acceptance Tests (SIL) Complex 39 & Orbital Operations Space Vehicle Orbital Qualification Tests Space Vehicle Orbital Flight Demonstration Tests
OPERATIONAL PROGRAM	Design Improvement & Test Allowance Probes Manufacturing & Tests EEM Manufacturing & Tests Critical Experiments MM Manufacturing & Tests PM's Manufacturing & Tests Acceptance Tests (SIL) Complex 39 & Orbital Operations

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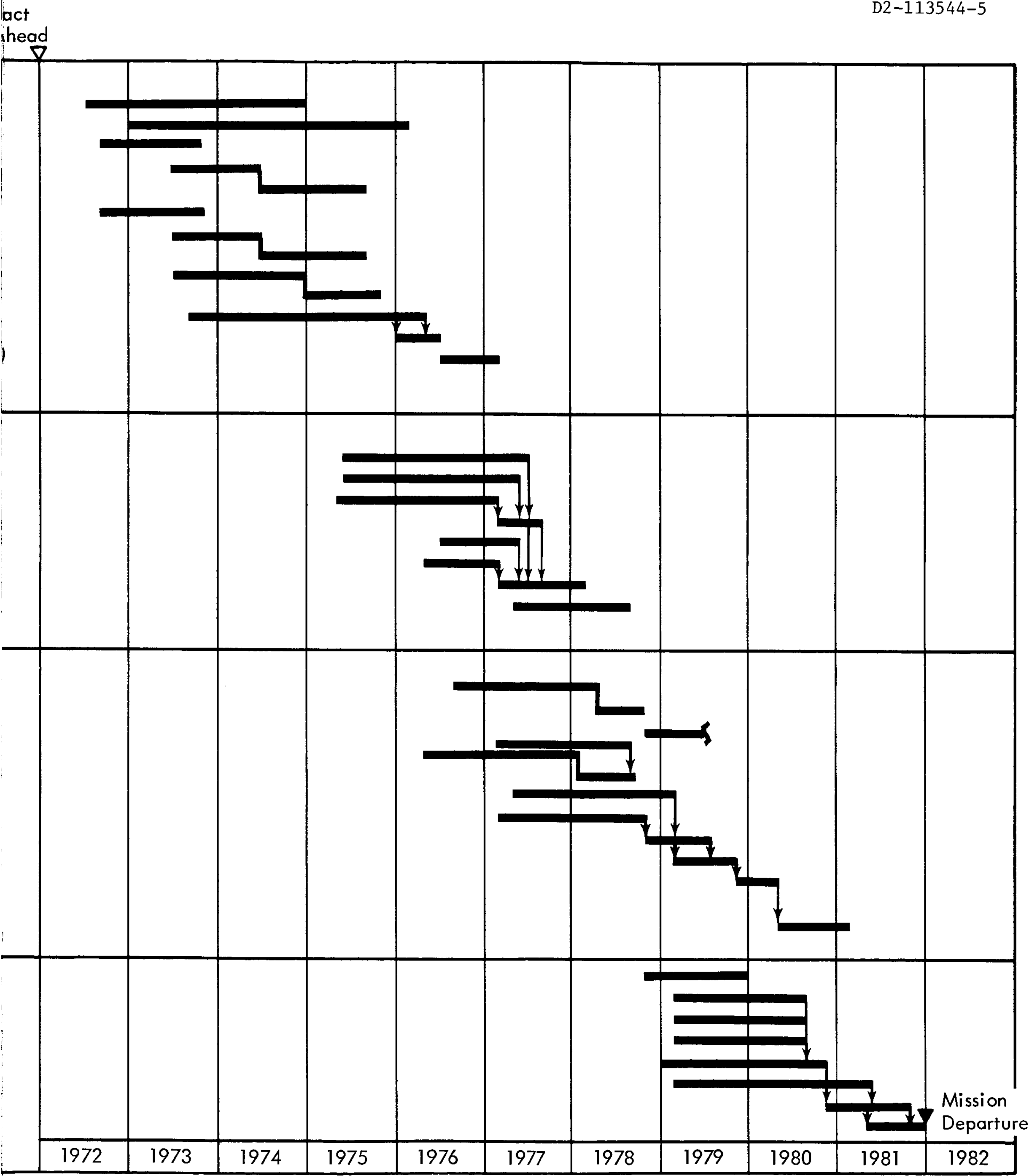

Figure 2.3-1: VENUS CAPTURE PROGRAM SCHEDULE — ALTERNATE EXAMPLE

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Contract
Go-Ahead

GROUND QUALIFICATION PROGRAM	Manufacturing Thermal Model
	Thermal Test
	Manufacturing Structural Test Model
	Module Structural Test
	Spacecraft Structural Tests
	Manufacturing Dynamic Test Model
	Module Dynamic Test
	Spacecraft Dynamic Test
	Physical Interface Model Mfg & Test
	Interface Test
	Ground Qualification Hdwe Mfg & Test
	Subsystem Qualification Test (Ground)
	Spacecraft System Qualification Test (Ground)
ORBITAL HARDWARE QUALIFICATION PROGRAM	PM's Manufacturing & Test
	MM Manufacturing & Test
	MEM Manufacturing & Test
	EEM Manufacturing & Test
	Acceptance Test (SIL) (System Integration Lab)
	EEM Mfg & Test Unmanned Suborbital
	EEM Boilerplate Manufacturing & Test
	Launch Operations
	Module & PM Orbital Qualification
SPACE VEHICLE QUALIFICATION & DEMONSTRATION PROGRAM	Flight Simulation Model Mfg & Test
	Flight Simulation Test
	Sustain Flight Simulation Test
	Probe Mfg & Test
	Mfg & Test Func Integr Model (EEM & MM)
	System Integration Lab (SIL) Functional Checkout
	PM's Manufacturing & Test
	Spacecraft Manufacturing & Test
	Acceptance Tests (SIL)
	Complex 39 & Orbital Operations
	Space Vehicle Orbital Qualification Tests
	Space Vehicle Orbital Flight Demonstration Tests
OPERATIONAL PROGRAM	Design Improvement & Test Allowance
	MEM Manufacturing & Tests
	Probes Manufacturing & Tests
	EEM Manufacturing & Tests
	Critical Experiments
	MM Manufacturing & Tests
	PM's Manufacturing & Tests
	Acceptance Tests (SIL)
	Complex 39 & Orbital Operations

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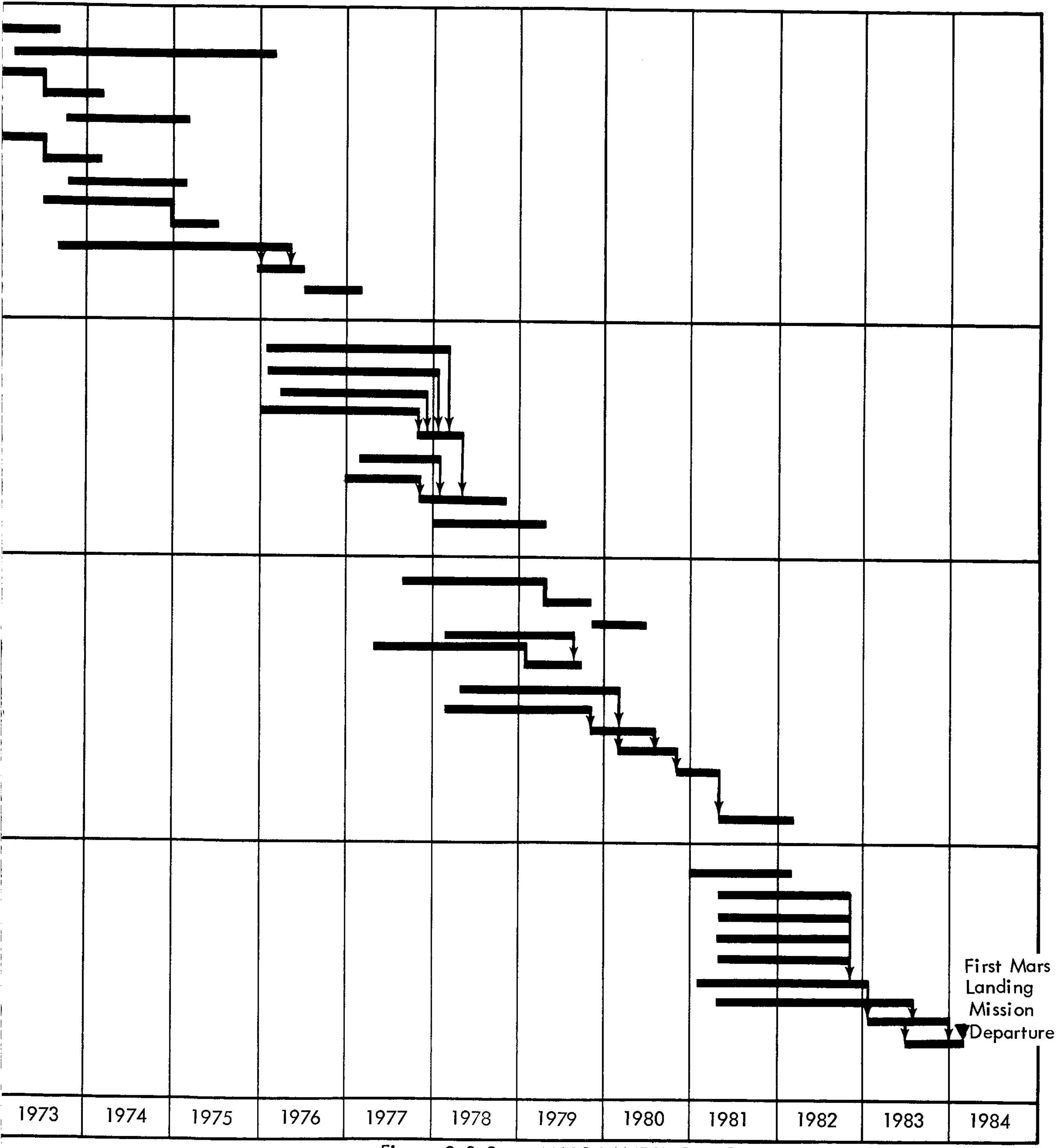

Figure 2.3-2: MARS LANDING PROGRAM — ALTERNATE EXAMPLE

The alternate Venus mission shcedule, Figure 2.3-1, and an alternate Mars mission schedule, Figure 2.3-2, are separate and independent, allowing a program planner the option of selecting either mission as the first. If Mars is selected as the first mission, a full development, including the MEM, is included. If Venus is selected as the first mission, the MEM would be the only major development for the follow-on Mars mission. The MEM development for a Mars follow-on mission to Venus poses no lead time problem in the basic or alternate examples.

The two schedules use the same sequence and phasing pattern as the example schedule. Each schedule is divided into the same four phases and the nomenclature of the two is identical to facilitate easy comparison and understanding.

2.4 VAB, PAD AND ORBITAL OPERATIONS

Preliminary planning and the scheduling of launches for Complex 39 have been studied and are portrayed in Figure 2.4-1. Payloads are assembled with their Earth launch vehicle in the VAB. The VAB and pad flow time is approximately 3.75 months before launch. The first three launch payloads are the spacecraft, PM-3, and PM-2; therefore, the three pads of the modified Complex 39 will be fully utilized. The interval between each of the three launches is 3 days. These three short, successive launches are called salvo launching. To accomplish the salvo launch, there are three separate launch crews, one for each vehicle and its payload. Each crew will process its launch vehicle and payload through the VAB, pad, and the launch control center.

To support this rapid launch rate and requirements for resources, the following conditions are imposed on KSC facilities:

- The program will have complete and exclusive use of Launch Complex 39;
- Pad refurbishment will be nine days;
- Launch control rooms will be modified and increased to six.

The modifications and additions of KSC facilities are defined in Section 4.0, Facilities Plan.

After the pad turn-around time of approximately 2 months, the second salvo will be launched. The second salvo is the fourth, fifth, and sixth launches, each with one PM-1 payload.

Standby time of approximately two months is planned for the VAB, pad and orbital operations. This standby time is presently shown after the second salvo, but because the use of a standby is unpredictable, it may actually occur any time and, more likely, not at all. The standby time is actually an allowance to process a standby unit, if required. Processing would be on a 7-day week, overtime basis. On the other hand, if the launches are highly successful, the residual standby flow time can be applied to orbital operations, ensuring the mission launch date.

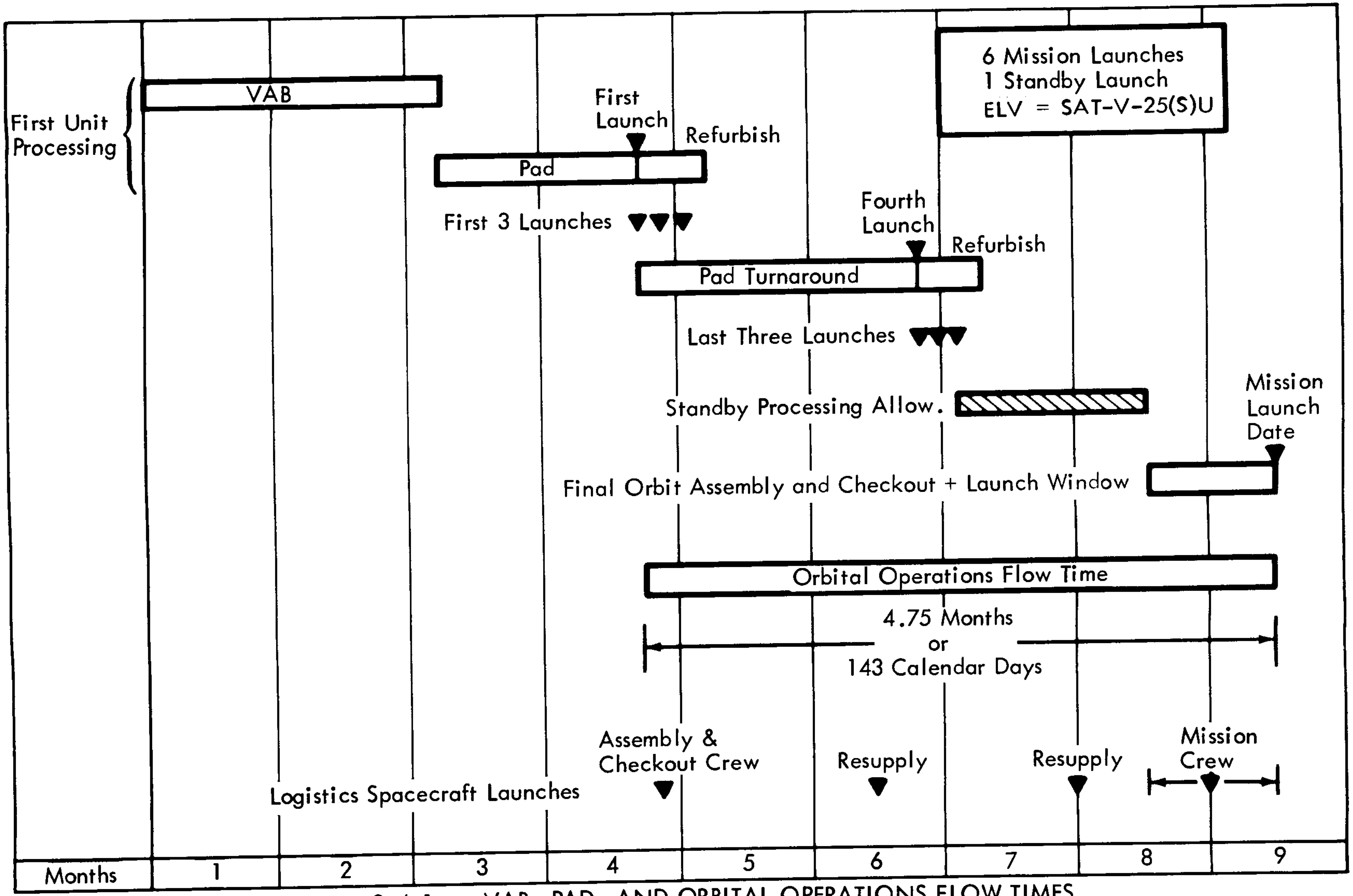

Figure 2.4-1: VAB, PAD, AND ORBITAL OPERATIONS FLOW TIMES

Orbital operations, the assembly of the modules into a space vehicle configuration and system checkout, including the standby and launch window allowances, is 4.75 months or 143 calendar days flow time.

Detailed KSC operation flow time backup is depicted in Figure 2.4-2. The flow times for the high-bay activities are identical to Saturn V. The launch complex flow time is identical to the Saturn V-25S. Six additional days are allowed for each launch operation. The allocation of this time to either the VAB or pad allows flexibility in the plans and schedule. This flexibility assures meeting the launch schedules, because the schedule and the mission date cannot slide beyond the window dates.

2.5 FLIGHT HARDWARE REQUIREMENTS

Flight hardware requirements are categorized nonrecurring and recurring, as depicted in Figures 2.5-1 and 2.5-2. Nonrecurring flight hardware consists of development, qualification, and demonstration flight tests; recurring consists of mission hardware. Flight test hardware accountability is at the module and ELV levels. R&D hardware such as breadboards, engineering models, and prototype of subsystems and ground test models of the various modules have been identified on detailed schedules, but are not included in the figures.

Parametric data available for basic R&D costs includes allowances for all hardware except flight hardware. It is not necessary, therefore, to designate quantity requirements for R&D hardware.

The parametric cost data does not differentiate between breadboards, engineering models, and prototypes, of the R&D phase; instead, it determines the R&D cost by dollars/pound, dollars/kw, etc. Details of parametric cost methodology are in Section 5.0.

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Location	Activity	Time (days)	ΔDays 0
VAB Hi-Bay **Flow times in hi-bay are identical to Saturn V		**	From SAT-V 25(S)
	Off-load and erect MS-IC on ML	2.5	
	Install MS-IC platforms, swing arms, etc.	2	
	Install SRM attachment hardware	2	
	Install mech stage hardware & connect umbilicals	4	
	Mechanical systems tests	15.5	
	Transfer MS-II, erect on MS-IC and connect	4	
	Transfer MS-IVB, erect on MS-II and connect	3	
	Install IU and connect	2.5	
	Electrically compatibility tests - electrically mate all stages	4	
	Electronic system tests (RF, TM, etc.)	31	
	Electrical interstage functional tests	5	
	Launch vehicle OAT 1 & 2 (swing arms)	5	
	Transfer, erect, and mate payload	2.5	
	Perform payload integration tests	4.5	
	Launch vehicle OAT 3 (elec. plug drop)	2	
	Space vehicle OAT 1 & 2 (elec. plug drop)	3	
	Install MLV ordnance	12	
	Perform simulated flight test	2	
	Prepare S/V and ML for transfer	2	
	Transfer S/V and ML to pad	0.5	
LC-39	ML connection on pad and preliminary checks	2.05	
	Position MEPS	0.5	
	Prepare for SRM installation & erect scaffolding	1.5	
	Transfer SRM segments on MEPS to pad	0.75	
	Install and assemble first two SRMs	3*	
	Install and assemble second two SRMs	3*	
	Attach TVC tank assemblies	0.5* (3)	
	Remove mobile MEPS	(0.5)	
	Integrate SRMs with MS-IC stage, mech/electrical	2* (4)	
	Test and accept all SRMs	1.5* (4)	
	Remove scaffolding & position MSS	0.5* (1)	
	Perform SRM electrical power tests	(0.5)	
	Perform flight readiness tests	2	
	Perform propulsion tanking tests and evaluation	4	
	Simulated flight test	1	
	Launch preparations including SRM/TVC tank loading	2	
	Countdown & launch	1	
	Launch window		+6
	Refurbish launch pad	9	
	Remove and refurbish ML	15	

*Two shift operations ( ) Not in critical time path

⊛ Hurricane protection at pad

Analysis is based on the MLV-SAT-V-

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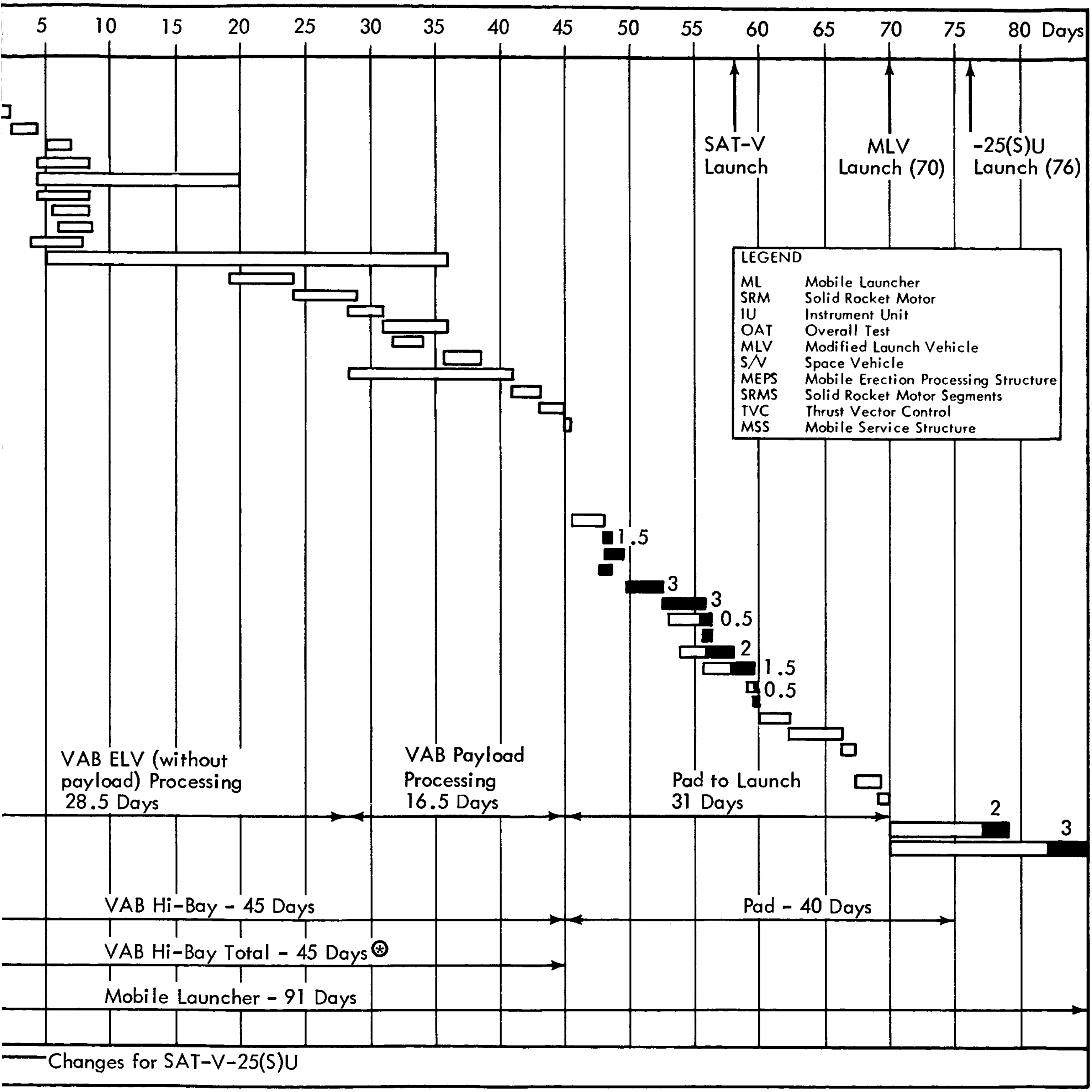


5(S) timeline & SOP from NAS8-20266

Figure 2.4-2: SATURN V-25(S)U LAUNCH OPERATIONS FLOW TIME ANALYSIS

Major Hardware Elements	Development Flight	Flight Qualification	Demonstration	Demonstration Standby	Totals
Mission Module (MM)	----	(1)	1	1	3
Earth Entry Module (EEM)	(1) Scale model (1) Complete heat shield not required (1) Unmanned reentry	(1) Boilerplate (2) Suborbital (2) Reentry	1	1	7 +Scale model
Mars Excursion Module (MEM)	(3) Earth atmosphere	(1) Boilerplate (2) Reentry	1	1	6
Probes	----	----	1	1	2
PM-1 Modules			3	1	
PM-2	(1) With dummy engine (1)	(1) Less engine (2)	1	1	12
PM-3			1		
Logistics Spacecraft	(1)	(5)	7	1	14
SAT-V-25(S)U) (Core only)	(3) For MEM	(2) +S-IVB for EEM (1) For MM (3) for MEM	1 for payload	----	10 +(2) S-IVB stages
SAT-V-25(S)U	----	(3) For PM 's	5	1	9
SAT-V-25(S)U (2 stage)	(2) For PM's	----			2
SAT-V-3 Stages Including S-IVB	(1) For EEM	----	----	----	1
Saturn IB	(1) For EEM (1) For Logistics spacecraft	(3) For EEM (5) For logistics spacecraft	7 for logistics spacecraft	1	18
Atlas/Agena	(1) For EEM scale model	----	----	----	1

Figure 2.5-1 NONRECURRING FLIGHT HARDWARE REQUIREMENTS SUMMARY

	First Mission - Venus Short		Second Mission - Mars Opposition	
	Mission	Standby	Mission	Standby
Mission Module (MM)	1	[1]	1	[2]
Earth Entry Module (EEM)	1	[1]	1	[2]
Mars Excursion Module (MEM)	0	0	1	[1]
Probes	1	1	1	1
PM-1 (Modules)	3	1 - [1]	3	[2]
PM-2	1	1 - [1]	1	[2]
PM-3	1		1	
SAT-V-25(S)U - Core	1	--------	1	--------
SAT-V-25(S) U	5	1	5	1
Logistics Spacecraft [3]	4	1	4	1
Saturn IB	4	[2]	4	[2]

[1] The demonstration test standby units may be refurbished and used -- allowance for refurbishment = 50% .

[2] Previous standby units may be refurbished and used -- allowance for refurbishment = 50%.

[3] Logistics spacecraft are reusable and may be used five times.

Figure 2.5-2: RECURRING HARDWARE REQUIREMENT SUMMARY

3.0 IMISCD TEST PROGRAM

3.1 INTRODUCTION

The IMISCD test program was developed in detail for a baseline Mars landing mission. Tests were developed to verify that program hardware fully meets the operational and environmental requirements of the mission, based on mission functional analyses. Emphasis has been placed on meeting these requirements through ground tests where mission operations and environment can adequately be simulated. Where these conditions cannot be met, appropriate flight tests are defined. Furthermore, to minimize costs, tests are performed at the lowest possible hardware level, i.e., mission module versus spacecraft, and built up on an evolutionary basis to the space vehicle level. Unless interface problems exist, tests are not repeated at the next higher hardware level. Development integration tests, between spacecraft modules and propulsion modules, are instituted early in the program to forestall schedule-sliding integration problems later in the program.

The approach used in formulating the test program is shown graphically in Figure 3.1-1. Mission requirements tempered by test guidelines are the basis for developing test-operational requirements. These are defined at the module (Mission Module, Mars Entry Module, Earth Entry Module, and Propulsion Module), spacecraft, and space vehicle level. Once requirements have been defined, specific development-integration and qualification tests are outlined to satisfy the requirements. Test hardware configurations are chosen and integrated with overall program plans and schedules based on facility and launch capabilities. With the program elements defined, associated costs can be determined.

Since this detailed test program has been developed around a basic Mars landing mission only, test program changes or alternates must be considered for other missions. In addition, the test program chooses specific methods for meeting the test requirements. Where alternate means of meeting the requirements are feasible, they will be covered in summary form.

3.2 MISSION REQUIREMENTS

Mission requirements forming the basis for the test program were developed through an operations analysis of a typical interplanetary mission. This analysis is documented in Volume III of this report. The major mission events were drafted into an event-logic network for a planet capture and landing mission. The events were broken down to a level of detail wherein functions could be identified at the individual module level, such as the mission module.

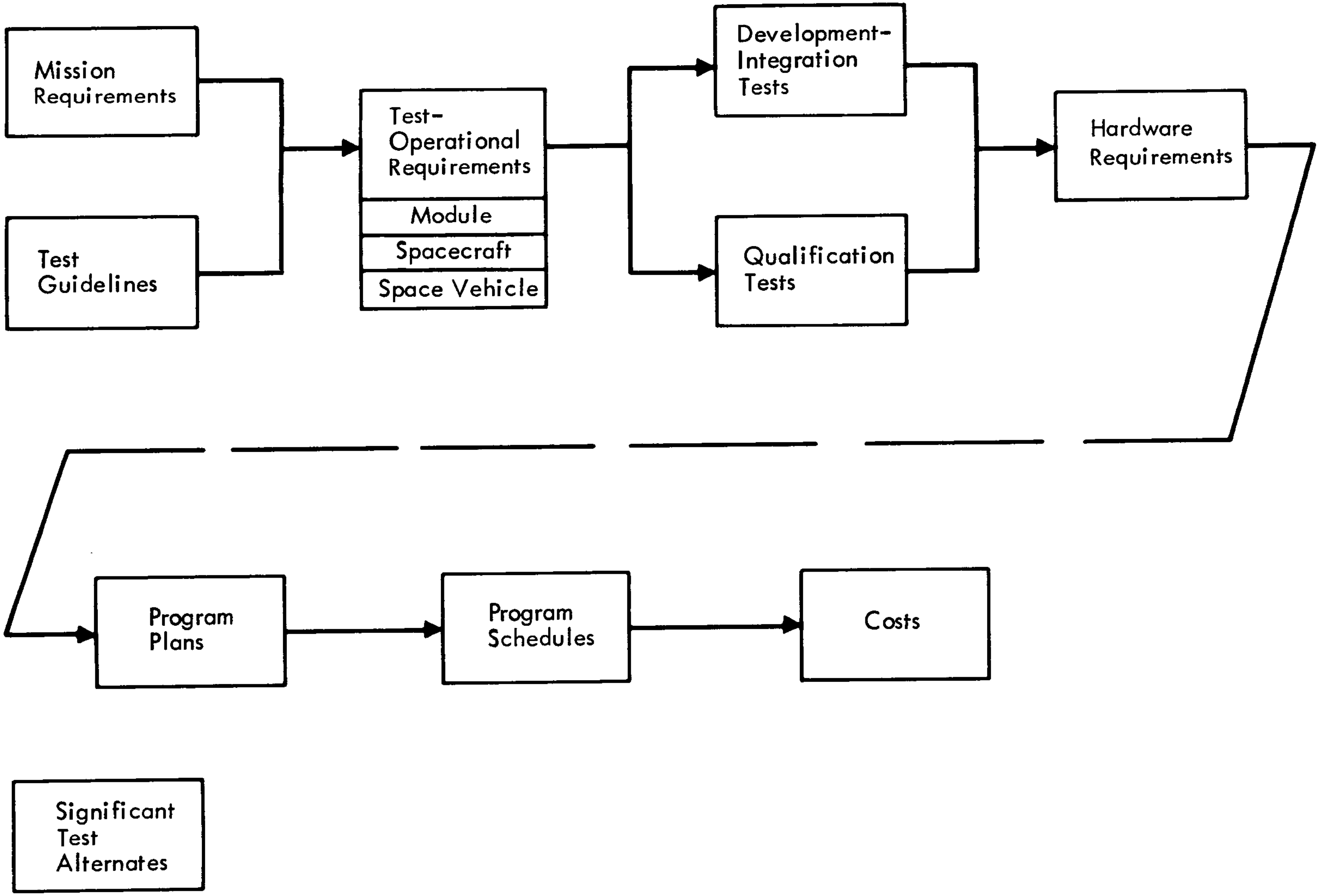


Figure 3.1-1: IMISCD TEST PROGRAM DEVELOPMENT

In the operations analysis, the mission requirements were categorized as follows:

1) General requirements (those overall requirements primarily regarding the overall mission operations and space vehicle systems);
2) Systems requirements (those more directly associated with specific subsystems or types of subsystems of the space vehicle);
3) Special operational requirements (those requirements that involve or evolve from some special operational problem).

For purposes of the test program, each of the above phases is involved. The general requirements provide the basis for overall space vehicle or module tests to satisfy major mission functions or interactions between modules. The systems requirements form the basis for subsystem tests within the confines of their respective modules. Generally, the subsystem test envelope may be contained within a module except for the case where the subsystem interfaces physically or functionally with other modules or with Earth-based support equipment. Two striking examples of this are the mission module communications subsystem and its attitude control subsystem. Special operational requirements such as abort, nuclear engine aftercooling, and spent-stage separation may involve both module- and space-vehicle-level testing. These mission requirements, tempered by a set of test guidelines, were used directly to develop the test-operational requirements of Section 3.4.

3.3 TEST GUIDELINES

To facilitate a consistent and cohesive test program philosophy, the following guidelines have been established:

1) Test justification shall be based strictly on mission operational and environmental requirements;
2) Verification of onboard checkout capability with astronaut participation will be an integral part of system-level tests;
3) Where feasible, conduct hazardous tests unmanned or in isolation, initially, to eliminate avoidable human risk;
4) The sum total of tests performed on a spacecraft shall exercise all operational, redundant, and abort modes of its associated systems.
5) Minimize redundant testing by selecting a logical buildup of test capability from the module to the space vehicle level;
6) Where feasible, conduct environmental tests on the ground if mission environments can adequately be simulated;
7) Build up entry module technology by preceding full-scale flight tests with scale model flight tests and/or ground tests;
8) Spacecraft and space-vehicle-level development tests shall include functional and dynamic simulation of mission operations;
9) Breadboard space vehicle development tests shall be conducted to highlight and resolve module functional interface problems early in the program and forestall schedule slides at a later date;

10) Flight control dynamic simulation tests shall encompass the use of development hardware and computer simulation with astronaut participation in the control loop;

11) Maximum utilization of Earth launch vehicle payload capability shall be made for Earth orbital and reentry tests.

3.4 TEST-OPERATIONAL REQUIREMENTS

The IMISCD test requirements were developed by taking the mission operations analysis of Volume III and analyzing the events from a testing standpoint. The operations were viewed from the standpoint of establishing a test requirement to verify that hardware would be capable of meeting mission requirements. In accordance with the test guidelines, requirements were oriented to verify hardware capability at the lowest possible level.

The mission events were broken down into major elements of prelaunch, launch, Earth orbit, mission flight, and mission support operations. Prelaunch covers all activities conducted before delivery of hardware to the launch pad. Launch operations cover the testing, servicing, and countdown of the flight hardware in the launch pad area. Earth orbit operations include all activities necessary to ready the space vehicle for launch into the transplanetary trajectory. It includes assembly and test of major space vehicle elements, the spacecraft, and its associated propulsion modules. The mission flight operations encompass events from planetary injection, Mars capture and orbit, planet landing and ascent, launch from planet orbit, through Earth capture, atmosphere entry, terminal maneuvers, and landing. These major mission phases are listed across the top of the Test-Operational Requirements Matrix, Figure 3.4-1, along with subsidiary events within each phase.

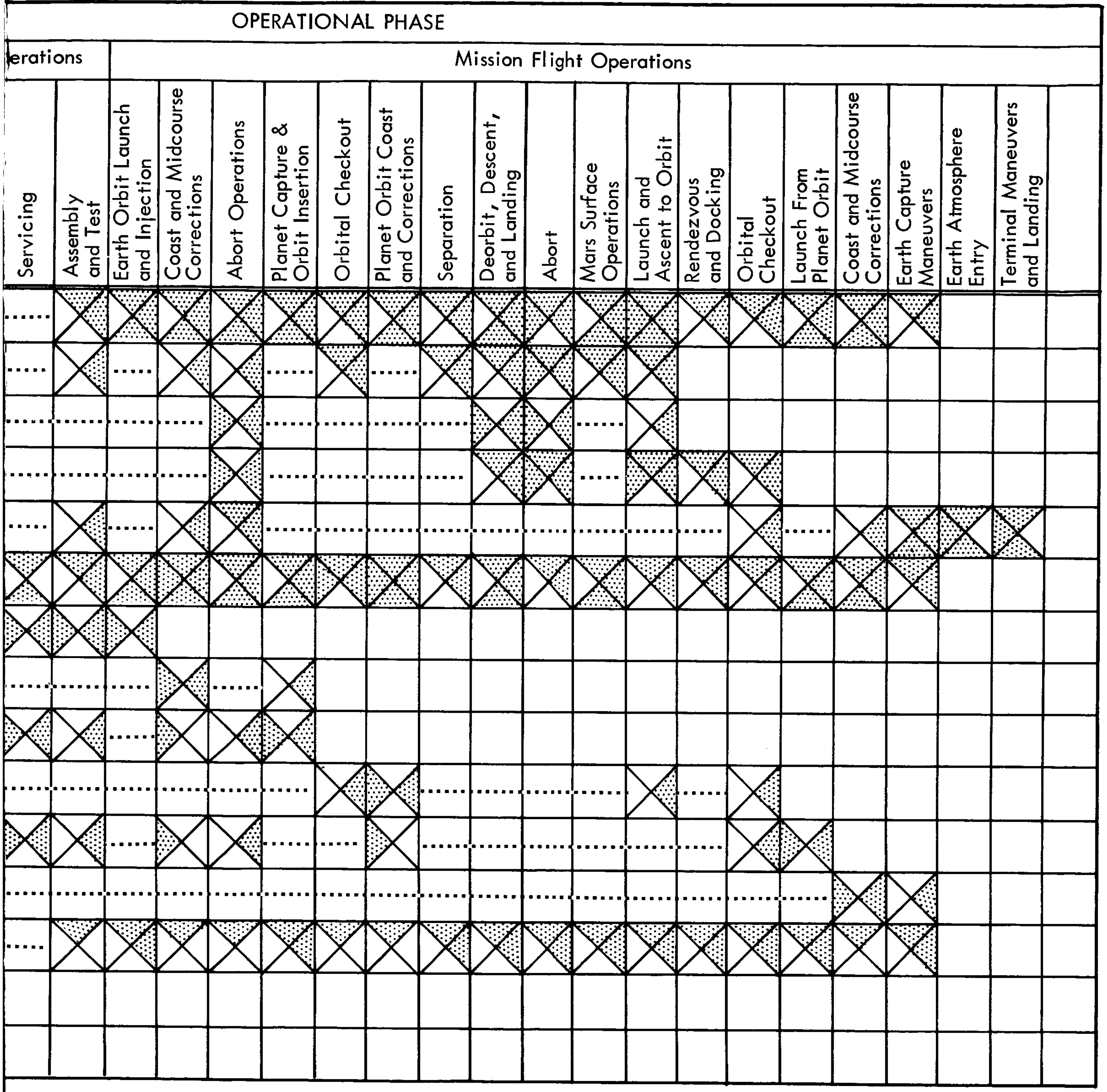
To support the guideline of a logical buildup of tests from the module to the space vehicle level, test requirements were established at the mission module, Mars entry module, and Earth entry module level followed by the spacecraft, propulsion module, and space vehicle level. Details of these requirements are included in the appendix. Data from these test requirements have been summarized in Figure 3.4-1 in terms of hardware level versus mission operations. It includes a somewhat finer breakdown of hardware than is shown in the original work. The MEM has been subdivided into its ascent and descent stages, while the PM's have been broken down on an individual basis: PM-1, PM-2, and PM-3 are used for orbital launches and planet capture, PM-OBMC and PM-IBMC are used, respectively, for outbound and inbound midcourse corrections, while PM-OT is used for Mars orbit trim corrections.

The matrix relationship of Figure 3.4-1 summarizes the test requirements in terms of hardware level versus mission operations. An ☒ in the respective matrix block shows that the hardware is operationally active during the subsidiary mission event and that tests will be required to verify that the hardware has the capability of meeting these requirements. If the hardware is inactive or dormant during the mission event, a dashed line will appear in the matrix block. There are cases where an

MISSION OPERATIONS / HARDWARE LEVEL	Prelaunch Operations		Launch Operations			Earth Orbit Op		
	Receive and Inspect	Assembly and Test	Test and Checkout	Servicing	Countdown	Boost and Orbit Injection	Test and Checkout	Rendezvous
MM		⊠◀▶▼	⊠▼	⊠▼	⊠▼	⊠◀▼	⊠▲◀▼	⊠▲▶
MEM		⊠◀▶▼	⊠▼	⊠▼	⊠▼	⊠◀▼	⊠◀▶	·····
Descent Stage	·····	·····	·····	·····	·····	·····	·····	·····
Ascent Stage	·····	·····	·····	·····	·····	·····	·····	·····
EEM		⊠◀▶▼	⊠▼	⊠▼	⊠▼	⊠◀▼	⊠◀▶	·····
Spacecraft		⊠◀▼	⊠▼	⊠▼	⊠▼	⊠◀▼	⊠▲◀▼	⊠▲▶
PM-1		⊠◀▼	⊠▼	⊠◀▼	⊠◀▼	⊠◀▼	⊠◀▼	⊠▶
PM-OBMC	·····	·····	·····	·····	·····	·····	·····	·····
PM-2	·····	⊠◀▼	⊠▼	⊠◀▼	⊠◀▼	⊠◀▼	⊠◀▼	⊠▶
PM-OT	·····	·····	·····	·····	·····	·····	·····	·····
PM-3	·····	⊠◀▼	⊠▼	⊠◀▼	⊠◀▼	⊠◀▼	⊠◀▼	⊠▶
PM-IBMC	·····	·····	·····	·····	·····	·····	·····	·····
Space Vehicle								⊠▲

Legend:

·····	Dormant	⊠▶	Flight Hardware interface
⊠	Active	⊠▼	Ground equipment interface
⊠▲	Astronaut interface	⊠◀	Area requiring technological development



OPERATIONAL PHASE																				
erations		Mission Flight Operations																		
Servicing	Assembly and Test	Earth Orbit Launch and Injection	Coast and Midcourse Corrections	Abort Operations	Planet Capture & Orbit Insertion	Orbital Checkout	Planet Orbit Coast and Corrections	Separation	Deorbit, Descent, and Landing	Abort	Mars Surface Operations	Launch and Ascent to Orbit	Rendezvous and Docking	Orbital Checkout	Launch From Planet Orbit	Coast and Midcourse Corrections	Earth Capture Maneuvers	Earth Atmosphere Entry	Terminal Maneuvers and Landing	
……	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
……	X	……	X	X	……	X	……	X	X	X	X	X								
……	……	……	……	X	……	……	……	……	X	X	……	X								
……	……	……	……	X	……	……	……	……	X	X	……	X	X	X						
……	X	……	X	X	……	……	……	……	……	……	……	……	……	X	……	X	X	X	X	
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
X	X	X																		
……	……	……	X	……	X															
X	X	……	X	X	X															
……	……	……	……	……	……	X	X	……	……	……	……	X	……	X						
X	X	……	X	X	……	……	X	……	……	……	……	……	……	X	X					
……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	X	X			
……	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			

Figure 3.4-1: TEST/OPERATIONAL REQUIREMENTS MATRIX

FOLDOUT FRAME 2

environmental test requirement applies although the hardware is in a dormant mode, such as space soak; this will be covered in the following sections on development and qualification testing. Further refinement of the matrix is achieved by filling in sections of the ☒. Major areas of test are associated with interface requirements and are covered on the matrix. An ☒ indicates a direct interface between astronaut(s) and the hardware. Where interfaces exist between flight hardware elements, such as MM and MEM, an ☒ will appear in the matrix. This interface may be physical and/or functional as in the case of communications between the MM and MEM. If an interface exists between flight hardware and ground equipment, such as test and checkout, launch, or mission control equipment, an ☒ will appear in the matrix. There may also be cases where all three types of interfaces occur simultaneously. These interface requirements are used later in defining integration tests. The last item on the matrix represents areas requiring technological development and is indicated by ☒. These are long lead items forming the basis for development tests early in the program.

3.5 DEVELOPMENT-INTEGRATION TESTS

In accordance with the test guidelines, the development-integration tests will be conducted at the lowest hardware level and on the ground where appropriate requirements can be met. The development-integration tests are based on the requirements of Section 3.4 backed up by the detailed studies of Volume III, Part 1, of this report. Development tests are based on the requirements of Figure 3.4-1, indicated by the symbol ☒ showing areas requiring technological development. Significant integration test areas are also supported by Figure 3.4-1, with symbols denoting astronaut, flight hardware, or ground equipment interfaces.

3.5.1 DEVELOPMENT TESTS

Development tests are required where specific technologic data is lacking but necessary to support the design of spacecraft hardware. For the IMISCD baseline mission, specific ground and flight development tests have been outlined as indicated by the matrix of Figure 3.5-1. In the figure, ground tests and flight tests are depicted by the letters G and/or F. These tests are oriented to support various mission phase requirements.

Initially, ground development tests will be required on the propulsion and spacecraft modules to determine thermal balance characteristics under steady-state irradiation. The complex module configurations and materials prohibit design based on thermal analysis above. More refined thermal balance testing will be conducted at the spacecraft level under Earth orbit, transplanet, and Mars orbit irradiation modes. These same hardware elements need be subjected to vibration mode testing over applicable frequency ranges to assist in defining structure modal characteristics. Where module subsystems are sensitive to such launch environments as vibration, acoustics, acceleration, and rapid altitude change, specific tests at the subsystem level may be required to support their development. Because many of the smaller propulsion modules are of new design

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MISSION OPERATIONS / HARDWARE LEVEL	Prelaunch Operations		Launch Operations			Earth Orbit Opera			
	Receive and Inspect	Assembly and Test	Test and Checkout	Servicing	Countdown	Boost and Orbit Injection	Test and Checkout	Rendezvous	Servicing
MM		G				G	G		
MEM		G				G	G		
Descent Stage									
Ascent Stage									
EEM		G				G	G		
Spacecraft		G				G	G		
PM-1		G		G	G	G&F	G&F		G&
PM-OBMC									
PM-2									
PM-OT									
PM-3									
PM-IBMC									
Space Vehicle									

Legend: G = Ground tests required
F = Flight tests required

▷ Covered by Norm
PM Firing Operat

▶ Covered by PM-1

FOLDOUT FRAME 1

OPERATIONAL PHASE																			
tions	Mission Flight Operations																		
Assembly and Test	Earth Orbit Launch and Injection	Coast and Midcourse Corrections	Abort Operations	Planet Capture and Orbit Insertion	Orbital Checkout	Planet Orbit Coast and Corrections	Separation	Deorbit, Descent, and Landing	Abort	Mars Surface Operations	Launch and Ascent to Orbit	Rendezvous and Docking	Orbital Checkout	Launch From Planet Orbit	Coast and Midcourse Corrections	Earth Capture Maneuvers	Earth Atmosphere Entry	Terminal Maneuvers and Landing	
									G		G								
								F	F										
			G					G&F	F										
			G						F		G&F								
																	G&F	F	
		G			G	G													
F	G&F																		
		G&F																	
		G	▷	▶															
						G													
		G	▷			G								▶					
															G				

al Mission
ions

Development

Figure 3.5-1: DEVELOPMENT TESTS MATRIX

66

FOLDOUT FRAME 2

or new application, they will require ground developmental static firing tests. In the case of the nuclear propulsion modules, more extensive tests will be required. These will include liquid hydrogen loading and thermal conditioning, propellant transfer, cold flow and hot firings, and tests to determine the pad abort effects of nuclear stages. In the case of the MEM and EEM, scale-model development tests will be required to help define aerodynamic and heat-shield characteristics.

Although flight tests are more costly than ground tests, they are necessary to supplement ground testing where design conditions can only be simulated in flight. Module components,whose design is sensitive to zero gravity,will need to be tested under orbital conditions. Finalization of the MEM design will require considerable flight testing to determine descent stage characteristics during hovering and touchdown modes, under both remote and direct astronaut control. Because of its critical rendezvous requirements, MEM ascent stage engine and guidance systems will need developmental flight tests. Both the ascent and descent stage must be tested in conjunction, to meet MEM abort requirements during Mars descent. Ballutes may be tested separately in Earth atmosphere flights. In the case of the EEM, a logical test buildup will be used progressing from model to full-scale reentry tests. These would be preceded by suborbital tests to develop EEM characteristics under terminal maneuver and landing impact conditions. Because of the limitation of ground tests, flight tests with multiple firings will be conducted on the midcourse propulsion modules. To finalize nuclear PM design, flight tests will check out propellant transfer, separation of the nuclear PM from an ELV upper stage, and developmental firing of the nuclear engine.

3.5.2 INTEGRATION TESTS

In contrast to development tests, all integration tests defined herein will be conducted on the ground. Generally they will use flight configuration hardware, although integration testing begun in the development phase of the program will reduce or eliminate mismatching of space vehicle elements later in the program. As previously mentioned, integration tests are based primarily on the interface requirements depicted in Figure 3.4-1. These tests may be broken down into (1) Functional Integration, (2) Physical Integration, and (3) Flight Control Simulation tests. Functional Integration tests encompass all tests needed to verify functional compatibility between space vehicle modules and between flight hardware and supporting ground equipment. Functions may include command, control checkout, and electrical power. Physical Integration is defined to mean areas where major space vehicle modules or ground equipment are mated and demated during the baseline mission operations. Examples are ground equipment hookup for test and checkout, orbital rendezvous and docking, and MEM-spacecraft separation. Flight Control Simulation tests are applicable to major space vehicle maneuvers and will use combinations of flight hardware and computer simulation with astronaut participation. These tests are denoted respectively by the letters I, P, and C on Figure 3.5-2 and are discussed on the following page.

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MISSION OPERATIONS / HARDWARE LEVEL	Prelaunch Operations		Launch Operations			Earth Orbit Operati			
	Receive and Inspect	Assembly and Test	Test and Checkout	Servicing	Countdown	Boost and Orbit Injection	Test and Checkout	Rendezvous	Servicing
MM		IP	IP		IP		I	I	I
MEM		IP					I		
Descent Stage									
Ascent Stage									
EEM		IP					I		
Spacecraft		IP	IP		IP		I	IPC	
PM-1		IP	IP	IP	IP		I	IPC	IP
PM-OBMC		I							
PM-2		IP	IP	IP	IP		I	IPC	IP
PM-OT		I							
PM-3		IP	IP	IP	IP		I	IPC	IP
PM-IBMC									
Space Vehicle								I C	

Legend:

I = Functional integration tests required
P = Physical Integration tests required
C = Flight control simulation tests required

OPERATIONAL PHASE																			
ons	Mission Flight Operations																		
Assembly and Test	Earth Orbit Launch and Injection	Coast and Midcourse Corrections	Abort Operations	Planet Capture & Orbit Insertion	Orbital Checkout	Planet Orbit Coast & Corrections	Separation	Deorbit, Descent, and Landing	Abort	Mars Surface Operations	Launch and Ascent to Orbit	Rendezvous and Docking	Orbital Checkout	Launch From Planet Orbit	Coast & Modcourse Corrections	Earth Capture Maneuvers	Earth Atmosphere Entry	Terminal Maneuvers and Landing	
I	I	I	I	I	I	I	IP	I	I	I	I	IP	IP	I	I	IPC			
I		I			I		IPC	IC	I	I	I								
								I	P		P								
									IPC		IPC	IPC	IPC						
I		I											I		I	IPC	IPC	IPC	
IP	I	I	I	I	I	I	IP					IP	IP	IP	IP				
IP	IPC																		
		I																	
IP	IP		I	IPC															
					I	I					I		IPC						
IP			I	IP									IP	IPC					
															IPC				
I	IC	IC		IC	I	IC	C		I		I	C	IC	IC	IC				

Figure 3.5-2: GROUND INTEGRATION TESTS MATRIX

The core of functional integration begins at the mission module because it is the space vehicle command and control center during most of the mission. Astronauts should be used freely during these tests. In the prelaunch and launch operations phase, the spacecraft interfaces with ground and launch support equipment primarily through the MM. Integration test models will precede flight hardware at these locations in sufficient time to allow changes to hardware if interface deficiencies are found. In addition to testing with support equipment, the spacecraft integration model must verify that its MM, MEM, and EEM are compatible with each other. Nuclear PM's or major functioning portions thereof will also be used to verify interfaces with GSE and LSE. At the space vehicle level, ground functional interface tests will take place between the spacecraft and PM-3, PM-2, and PM-1. Major command and control functions must be verified, although execution of many operations will be incomplete because of the ground environment and lack of direct physical connection between elements. Generally, only test cables will suffice for spacecraft and nuclear PM connection.

To completely verify hardware interfaces, physical as well as functional compatibility must be shown. During mission ground operations, flight hardware must mate physically with GSE and LSE through test cabling, fluid servicing lines, and umbilicals. Physical connections with supporting ELV's must also be checked out. The physical integration test models may be the same as the functional models for ground interfaces.

When flight interfaces are checked out on the ground, usually an interface simulator will be required for one of the mating elements. This is based on the limitation that most docking and separation hardware is designed for operation in zero gravity. This simulator will resemble the applicable module only in the vicinity of the mating hardware. The following table indicates the major interfaces that occur inflight and designates whether they take place at a docking and/or separation operation.

The final portion of integration tests includes flight control simulation tests of major mission operations. These tests will verify the vehicle flight control dynamics using flight configuration hardware or models supplemented by computer simulation. Astronauts will be used in the control loops. Tests will include all the operations of Table 3.5-1 and also the effect of major PM firings on the total space vehicle. In addition, flight control simulation will include MEM descent and ascent, as well as EEM Earth entry and landing.

3.6 QUALIFICATION TESTS

Qualification tests subject the space vehicle hardware to functional and environmental tests which verify that the hardware is capable of meeting mission requirements. The qualification tests are based on the test-operational requirements of Section 3.4, backed up by the detailed studies of Volume III, Part I, of this report. The specific areas for the ground and flight tests are plotted on the matrix in Figure 3.6-1.

Table 3.5-1: IMISCD INFLIGHT PHYSICAL INTERFACES

Hardware	Operation
SC/PM-3/PM-2/PM-1	Docking and Separation
PM-OT/PM-3	Separation
PM-IBMC/SC	Separation
MEM/SC	Separation
MEM DS/AS	Separation
MEM AS/MM	Docking
MEM AS/SC	Separation
MM/EEM	Separation

The degree of mission requirement satisfaction is also shown on the matrix. In accordance with the guidelines, these tests are to be conducted at the lowest hardware level and on the ground, if the required capabilities can thereby be verified. Where these conditions cannot be met, appropriate flight tests must be conducted. Astronauts will participate in the tests wherever practicable. Hardware levels are based on individual modules and proceed upward as necessary for the qualification tests. Tests for the ELV's are discussed elsewhere in the study. Specific tests for subsystems or components of a module will be indicated only in the case of physical or functional interfaces with other modules.

Functional tests verify intramodule operations and functional compatibility between modules of the space vehicle. Primary emphasis is placed upon verifying the capability of the MM (and of the MEM and EEM when they are executing mission phases) to monitor, command, and control space vehicle operations within the limits of mission performance and safety requirements. This in turn depends on mating hardware capabilities for receipt and response to commands---often under severe environmental constraints such as prolonged space soak or excessive thermal loads. Such hardware operations must therefore be verified during or after exposure to the environmental conditions that apply.

Environmental tests verify the capability of space vehicle hardware to withstand the steady-state and transient environments that will be encountered during the various mission phases. Primary emphasis is places upon verifying the capabilities to withstand the rapid environmental changes during Earth launch, the thermal-vacuum and zero gravity environment of interplanetary space, and the hazardous atmosphere entry environment.

MISSION OPERATIONS HARDWARE LEVEL	Prelaunch Operations		Launch Operations			Earth Orbit Operations				
	Receive and Inspect	Assembly and Test	Test and Checkout	Servicing	Countdown	Boost and Orbit Injection	Test and Checkout	Rendezvous	Servicing	Assembly and
MM	- -	⊞	⊞	⊞	⊞	⊞	◰	◰	- -	◰
MFM	- -	⊞	⊞	⊞	⊞	⊞	◰	- -	- -	-
Descent Stage	- -	- -	- -	- -	- -	- -	- -	- -	- -	-
Ascent Stage	- -	- -	- -	- -	- -	- -	- -	- -	- -	-
EEM	- -	⊞	⊞	⊞	⊞	⊞	◰	- -	- -	-
Spacecraft	- -	⊞	⊞	⊞	⊞	⬚	◰ ⬚	◰ ⬚	⬚	◰
PM-1	- -	⊞	⊞	⊞	⊞	◰ ▩	◰ ▩	◰ ▩	▩	◰
PM-OBMC	- -	⊞	- -	- -	- -	- -	- -	- -	- -	-
PM-2	- -	⊞	⊞	⊞	⊞	◰ ▩	◰ ▩	◰ ▩	▩	◰
PM-OT	- -	⊞	- -	- -	- -	- -	- -	- -	- -	-
PM-3	- -	⊞	⊞	⊞	⊞	◰ ▩	◰ ▩	◰ ▩	▩	◰
PM-IBMC	- -	⊞	- -	- -	- -	- -	- -	- -	- -	-
Space Vehicle	- -	- -	- -	- -	- -	- -	- -	▩	- -	

Legend:

Ground Test		Flight Test	
◰	Partially satisfies mission requirements	⬚	Partially satisfies mission Requirements
⊞	Fully satisfies mission requirements	▩	Fully satisfies mission requirements

	OPERATIONAL PHASE																	
	Mission Flight Operations																	
Test	Earth Orbit Launch and Injection	Coast and Midcourse Corrections	Abort Operations	Planet Capture & Orbit Insertion	Orbital Checkout	Planet Orbit Coast and Corrections	Separation	Deorbit, Descent, and Landing	Abort	Mars Surface Operations	Launch and Ascent to Orbit	Rendezvous and Docking	Orbital Checkout	Launch From Planet Orbit	Coast and Midcourse Corrections	Earth Capture Maneuvers	Earth Atmosphere Entry	Terminal Maneuvers and Landing
▓	▦	⊟ ▓	▦	▦	⊟ ▓	⊟ ▓	▦	▦	▦	⊟ ▓	⊟	⊟	▦	▦	⊟ ▓	⊟	- -	- -
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▓	▓	⊟ ▓	▦	▓	▓	⊟ ▓	▓	- -	▦	- -	⊟ ▓	▓	▓	▓	⊟ ▓	- -	- -	- -

No Test

- -	No tests required for this phase of mission operations

Figure 3.6-1: QUALIFICATION TESTS MATRIX

3.6.1 GROUND QUALIFICATION TESTS

Ground tests provide the simplest and most economical means for verifying hardware capabilities so long as they can measure the capabilities actually required for mission performance. They do not require the major effort and expense of Earth launch, and they reduce the likelihood of malfunctions when later flight tests are conducted. In the matrix of Figure 3.6-1, ground qualification tests for the different hardware levels are shown by symbols on the horizontal lines, placed in the columns of the mission operational phases to which the tests apply. The symbol ◰ represents ground tests that partially satisfy requirements for the indicated mission phase, while the symbol ◱ indicates ground tests that fully satisfy these requirements.

The spacecraft is ground tested at the module level (MM, MEM, EEM) for the capabilities required to withstand the launch environment. Vibration-acoustic tests verify structural adequacy; acceleration tests and altitude-pressure tests verify ability to withstand the rapid changes during launch. Intermodule operations are then tested, and the physical and functional interfaces of the spacecraft with the ELV are qualified by simulation. Spacecraft subsystems are functionally qualified for the Earth orbit environment, responding to command and control inputs in all operational modes. Ground environmental test chambers provide the appropriate thermal-vacuum conditions for the successive space environments of the mission. During the tests, particular attention is paid to the varying intensity and direction of solar irradiation on the hardware. In the simulated outbound transplanetary environment, spacecraft capabilities for experiments, maintenance, and abort are verified. In the simulated Mars orbit environment, spacecraft capabilities for planet capture and for orbital control of the planet mission operations are tested. MEM tests are described in the following paragraph. In the simulated inbound transplanetary environment, the functioning of the modified spacecraft configuration is tested as applicable. Earth entry module tests during Earth entry are described in a later paragraph.

The MEM is ground tested under conditions approximating the Mars atmosphere as closely as possible. Scale-model ballutes, as well as entry and retropropulsion capabilities for deceleration, are tested. Environmental control and life support subsystems of the module are tested at design minimum and maximum operating levels. Mars surface operations are qualified through simulated excursions, by astronauts fully equipped with exploration devices.

The EEM is ground tested with scale models of the biconic configuration. Aerodynamic characteristics and effects of shape changes due to heat-shield ablation, under conditions simulating high Earth reentry speeds, are verified.

The PM's are ground tested in the same simulated environments as indicated for the spacecraft, approximating the duration prior to separation of each spent stage. On the actual mission, the PM-1 is dropped after Earth orbit launch, the PM-OBMC after outbound interplanetary coast, the PM-2 after Mars capture, the PM-OT after Mars orbit coast, the PM-3 after launch from Mars orbit, and the PM-IBMC after inbound interplanetary coast. Cold flow and hot firings of the nuclear PM's are conducted in ground test facilities after simulated space soak under appropriate thermal-vacuum conditions. PM's and propellants are subjected to the same types of tests indicated for the spacecraft modules to verify capabilities for withstanding the Earth launch environment. Command receipt and response is verified by simulated inputs from MM. Testing of one selected primary PM satisfies requirements for PM-1, PM-2, and PM-3 by testing to the worst-case environment conditions.

3.6.2 FLIGHT QUALIFICATION TESTS

Flight tests are required to verify hardware capabilities that cannot be adequately qualified by ground tests. Since flight tests consume a great deal of effort and expense, they must accomplish as much as possible with each Earth launch. Suborbital tests with scale models and boilerplate vehicles are specified where significant results can be obtained with the smaller ELV's. Unmanned tests are initially necessary to verify critical capabilities that have not been man-rated. Multiple test vehicles are put into orbit by the same ELV where practicable. In the matrix of Figure 3.6-1, flight qualification tests for the different hardware levels are shown by symbols on the horizontal lines, placed in the columns of the mission operational phases to which the tests apply. The symbol ◳ represents "flight tests" that partially satisfy requirements for the indicated mission phase, while the symbol ◲ indicates "flight tests" that fully satisfy these requirements.

MM flight testing will be initiated early in the qualification program and continued throughout to qualify the mission control capabilities that must be effective through a wide range of constraints. A fully configured MM is placed, unmanned, into a highly elliptical Earth orbit that reaches far into space and avoids the excessive thermal cycling of low-altitude circular orbits. Capability to monitor, command, and control remote operations, after space soak, is verified by inputs from and to ground control stations. Astronauts are then sent up in logistic vehicles for onboard qualifying of MM mission control capabilities throughout the long test flight. This will include orbital support for PM flight tests.

MEM flight tests begin with unmanned, followed by manned, suborbital tests to qualify heat shields and ballutes in high Earth atmosphere. Descent, hover, and landing capabilities are verified in unmanned and manned tests from Earth orbit. Ascent propulsion and abort capabilities are tested from unmanned suborbital flights. Ascent, rendezvous, docking, and separation maneuvers are qualified, in conjunction with the MM, by manned flight from a long-duration Earth parking orbit.

EEM flight tests begin with the unmanned suborbital drop tests to evaluate landing dynamics. Terminal maneuvers, particularly the ability to withstand landing impact, are qualified by unmanned and manned suborbital flights. Guidance and control characteristics of the module, its responsiveness to Earth-based communications, and its ability to execute the rollover manuever under high inertial, buffeting, and thermal loads, are initially tested by an unmanned scale model and are then qualified by unmanned and manned propulsive launch from a simulated spacecraft interface, after a long flight in an highly elliptical Earth orbit.

Nuclear PM flight tests with a dummy nuclear engine installed initially verify the insulation system, long-term storage of propellants, and rendezvous and docking operations in Earth orbit. Identical PM's are then used to flight qualify all nuclear engines; one is fired after short space soak, and one is fired after long space soak. The PM-OBMC and PM-OT are flight tested, with multiple firings after appropriate space soak. MM orbital tests provide orbital support for these PM flight tests. Simulated mission operations of the space vehicle in the Earth-Moon region include the required firing of PM-1, PM-2, and PM-3.

Space vehicle flight tests are incorporated in a simulated mission of abbreviated duration, in the Earth-Moon region, for final flight qualification of all hardware. This simulated mission is termed a demonstration test. With the space vehicle continually oriented toward the Sun when simulating the outbound and inbound interplanetary coasts, the thermal-vacuum and zero gravity conditions will provide reasonable simulation of most mission environments to be encountered in transit. The mission simulation begins with verification that all space vehicle elements (spacecraft, PM-3, PM-2, PM-1) are satisfactorily docked in Earth orbit and that all space vehicle assembly and test operations are flight qualified by the astronaut-test crew. The PM's are fired and the spent stages are separated in mission sequence. Space vehicle attitudes, trajectory, acceleration, guidance and control, and rendezvous capabilities are verified inflight. Integrated systems, astronaut performance, and ground support effectiveness are verified under flight conditions.

3.7 HARDWARE REQUIREMENTS

To generate data for inclusion in the program plan, the development-integration and qualification tests of Sections 3.5 and 3.6 were analyzed to determine the types of hardware required for each test. These were originally broken down according to mission phases. Since test hardware may satisfy requirements in a multiplicity of mission phases, this original list was reduced using a given piece of hardware to satisfy as many tests as possible. Results of this effort are shown in Table 3.7-1 which lists the required hardware versus test purpose for development ground and flight tests, integration tests, and qualification ground and flight tests. The data of Table 3.7-1 are subsequently used to develop program plans and schedules.

Table 3.7-1: IMISCD TEST HARDWARE REQUIREMENTS

Hardware Required	Purpose
Development Ground Tests	
MM MEM EEM S/C (Built up from above modules)	Thermal balance and vibration mode tests. Initial integration tests.
PM-1 (Will also suffice for PM-2 and PM-3 development)	Thermal balance and vibration mode tests. Initial integration tests.
PM-OBMC PM-OT MEM Ascent Propulsion MEM Descent Propulsion	Ground static firing tests.
PM-1	Hot firing tests. Pad abort effects tests.
MEM Scale Model EEM Scale Model	Aerodynamic and heat-shield development tests.
Development Flight Tests	
MEM Descent Stage	Unmanned descent test in Earth atmosphere.
MEM Descent Stage	Manned descent test in Earth atmosphere.
MEM Ascent Stage	Engine and guidance system development test.
MEM	Landing abort test of combined ascent and descent stage.
MEM Ballutes	High Earth atmosphere test of ballute characteristics.
EEM Scale Model	Heat shield reentry test.
EEM (Complete heat shield not required)	Suborbital test to determine EEM terminal maneuver and landing impact characteristics.
EEM	Unmanned reentry test.

Table 3.7-1: IMISCD TEST HARDWARE REQUIREMENTS (Continued)

Hardware Required	Purpose
PM-OBMC (Will also suffice for PM-IBMC development)	Flight test with multiple firings after interim space soak.
PM-1 (With dummy nuclear engine)	Develop propellant transfer and stage separation techniques.
PM-1 (Will also suffice for PM-2 and PM-3 development)	Flight test firing of nuclear engine.
Integration Tests (Ground)	
MM MEM EEM S/C (Built up from above modules) PM-1 PM-2 PM-3	Functional integration between space vehicle modules and between mocules and supporting ground, launch, and MSFN equipment. Physical integration between spacecraft modules. Physical and functional integration between flight modules and appropriate ELV's.
Interface Simulators SC/PM-3 PM-3/PM-2 PM-2/PM-1	Verification of physical interface compatibility between major space-vehicle elements.
Flight Control Simulators* MM MEM Descent Stage Ascent Stage (Components of MEM simulator) EEM SC (Built up from above simulators) Space Vehicle	Verification of space vehicle and vehicle element flight control dynamics through the combined use of flight configuration hardware, models, and computer simulation.
Ground Qualification Tests	
MM MEM EEM	Vibration-acoustic, acceleration, and altitude-pressure tests.
S/C (Built up from above module)	Testing of intermodule operations and functional qualification of S/C subsystems for thermal-vacuum environments.

*Appropriate computer hardware and software will be required to supplement the above simulators.

Table 3.7-1: IMISCD TEST HARDWARE REQUIREMENTS (Continued)

Hardware Required	Purpose
MEM Descent Stage MEM Ascent Stage	Static firing tests in simulated Mars environment.
MEM Ballutes	Scale-model tests of ballute characteristics.
EEM Scale Model	Tests to verify aerodynamic characteristics and effects of shape changes due to heat-shield ablation.
PM-1 (Nuclear engine not required)	Cold flow test.
PM-1	Vibration-acoustic, altitude-pressure, and thermal-vacuum environment tests. Testing of intermodule function by simulation. Hot firing of nuclear engine.
PM-OBMC PM-OT	Environmental and functional qualification including static firing.
<u>Flight Qualification Tests</u>	
MM	Qualifying mission control capabilities in Earth orbit.
MEM Boilerplate	Suborbital unmanned test of heat shields and ballutes.
MEM Ascent Stage	Suborbital unmanned test of ascent propulsion and abort.
MEM	Suborbital manned test to qualify descent, hover, and landing capabilities.
MEM Ascent Stage	Qualification of ascent, rendezvous, docking and separation by manned flight.
EEM Boilerplate	Unmanned reentry test to verify guidance and control and heat transfer capabilities.
EEM	Unmanned suborbital test of terminal maneuvers and landing impact effects.

Table 3.7-1: IMISCD TEST HARDWARE REQUIREMENTS (Continued)

Hardware Required	Purpose
EEM	Manned suborbital test of terminal and landing maneuvers.
EEM	Unmanned test of complete reentry, terminal and landing maneuvers.
EEM	Manned qualification of reentry, terminal, and landing maneuvers.
PM-1 (Less nuclear engine)	Qualification of PM docking, separation, and propellant storage system.
PM-1	Firing of nuclear engine after short space soak.
PM-1	Firing of nuclear engine after long space soak.
PM-OBMC PM-OT	Multiple firings after appropriate space soak.
Space Vehicle (Includes S/C, PM-1, PM-2, and PM-3)	Simulation of all mission operations, but abbreviated duration of the interplanetary transit times, conducted in the Earth-Moon region for final flight qualification of all hardware.

4.0 FACILITIES PLAN

4.1 LAUNCH FACILITIES

4.1.1 CONDITIONS AND RATIONALE

Selection of the SAT-V-25(S)U for the ELV makes possible the use of Launch Complex 39 and other facilities at KSC to support the manned planetary program. The increase in length of the MS-1C Stage, the omission of the S-1VB Stage and the addition of the four segment solid rocket engines (SRM's) will require extensive modifications of existing facilities and construction of some new facilities.

The procedure for assembly, checkout, and launch of the SAT-V-25(S)U and of the various payload elements of the space vehicle will, with the exception of the SRM integration, basically follow that developed for Saturn V.

The launch schedules as shown in Section 2.0, indicate a launch rate of six launches in approximately 2 months. To support a launch rate of this magnitude, the following conditions are imposed on the launch facilities:

1) Exclusive use of LC-39 during the launch period;
2) Hurricane protection at the launch pad;
3) Pad refurbishment in 9 days.

The following sections describe the major modifications, additions, and new facilities that will be required at KSC to support the program. In addition, certain facility/GSE requirements are identified as being of such scope or importance to the program to warrant additional detailed study. Figure 4.1-1 shows the concept for use of Launch Complex 39 and lists some of the major modifications and additions required.

4.1.2 OPERATIONAL SEQUENCE

The assembly, checkout and launch of the ELV and a PM payload begins with the arrival by barges at KSC of the MS-IC Stage, the MS-II Stage, and a PM tank. The SRM's are also water transported in railroad cars on barges. Because of the increased length of the first stage, a new transportation vehicle will be required to move the MS-IC Stage from the unloading dock to the VAB. A new vehicle will also be required to transport the PM tank to the nuclear engine/fuel tank mating facility. The railroad cars containing the live rocket motor components go directly to a new open rail car storage area. The inert components are transferred to the new inert components building (ICB).

In the VAB, erection of the ELV on the mobile launcher follows the Saturn V procedure. Following the integration and checkout of the payload, the vehicle is moved by crawler-transporter to the launch pad.

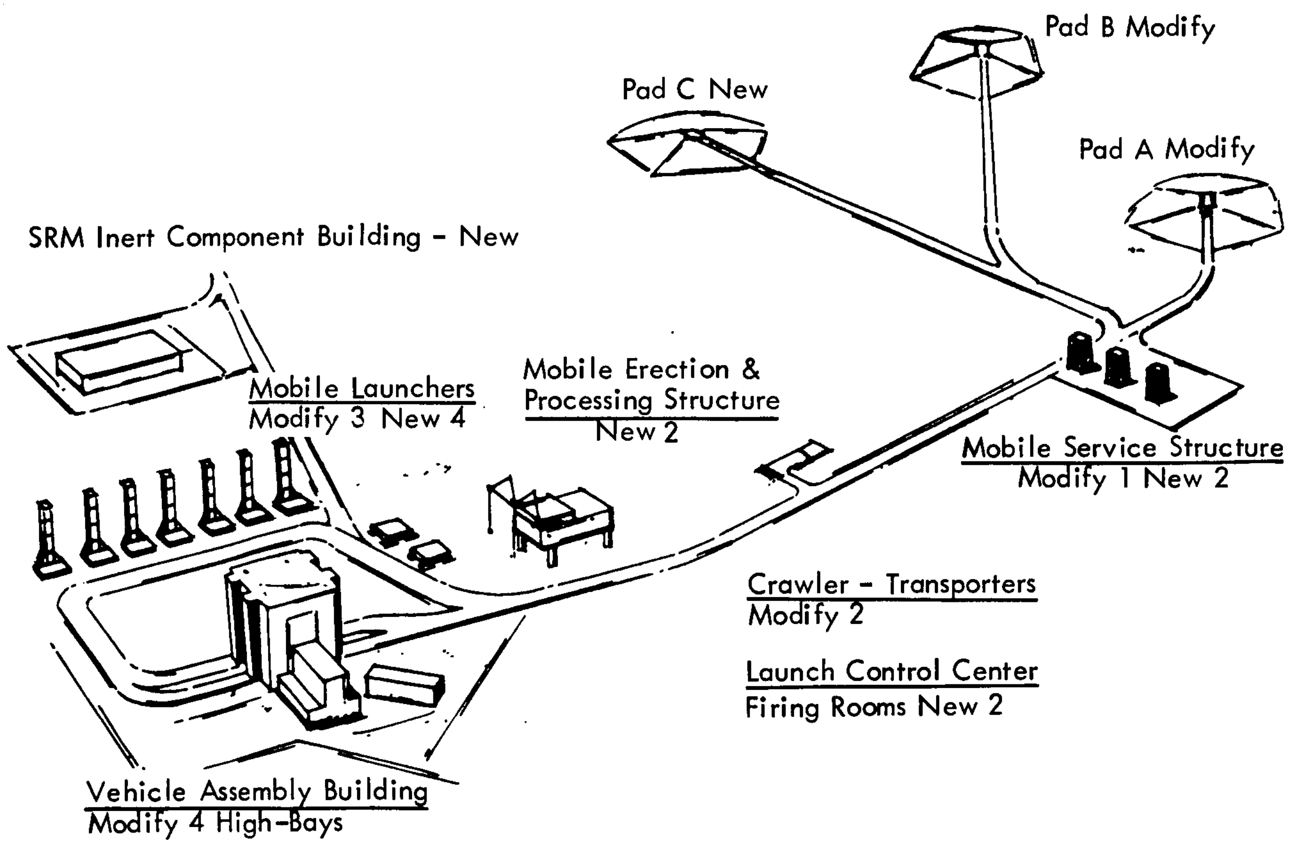

Figure 4.1-1: LAUNCH COMPLEX 39

Concurrent with the assembly and checkout of the ELV core, the SRM components are being processed through the new ICB and the new mobile erection and processing structure (MEPS).

Upon completion of checkout, the SRM's are transported to the launch pad in the MEPS by use of the crawler-transporter. At the pad, the SRM segments are assembled and integrated with the core of the ELV.

Completion of the pad checkout procedure, fueling operations, and launch follow the Saturn V routine.

4.1.3 VEHICLE ASSEMBLY BUILDING (VAB)

Four high bays in the VAB will be required to serve the proposed launch rate. Three bays will be configured to accommodate an ELV and a PM payload, with PM-1, -2 and -3 identical in size. The fourth bay will be configured for the spacecraft as a payload.

At present two of the bays are completely outfitted for Saturn V/Apollo. Modifications required for SAT-V-25(S)U in these two bays will include relocation upward of the work platforms and utilities for the longer first stage and the corresponding new level of the second stage. The platforms formerly serving the S-IVB stage and Apollo will require modification or replacement to accommodate a 33-foot diameter payload.

The two remaining high bays must be outfitted completely, including work platforms, enclosures, utilities, and test systems.

A major problem presents itself in adapting the VAB for assembly and checkout of the Saturn V-25(S)U and the payload. This problem occurs due to the ELV/PL height, when assembled on a ML, which is greater than the VAB high-bay door opening and also exceeding the hook height of the 250 ton crane. The height of the vehicle, less nose cone, above the VAB floor is 463 feet 6 inches. The door height is 456 feet 2 inches and the hook height is 462 feet 6 inches. In arriving at the clearance requirements, the operational procedure of raising the ML before leaving the VAB must be taken into account as well as an allowance for a payload handling fixture.

To provide a reasonable margin of clearance a change in elevation of 8 feet must be added to the VAB high-bay doors and cranes or the height of the vehicle reduced by that amount.

A brief examination of the work involved in altering the VAB roof structure to gain the necessary height indicates this approach to be extremely costly. The principal complication results from the increased wind loads when the height is increased and probable need to strengthen the basic building structure.

A more reasonable solution appears to be reducing the vehicle height through modification of the mobile launcher platform in conjunction with changes required for the SRM's. Basically the modification would allow the vehicle to set deeper into the ML platform structure. If this lowered position adversely affects the flame deflection at the launch pad, the ML support piers could be modified to compensate as required. A detailed study will be required to resolve this problem fully.

The increased weight of the Saturn V-25(S)U and the payload plus the increase in weight of the ML could exceed the designed capability of the ML supporting piers. A detailed study of this problem will be required.

4.1.4 LAUNCH CONTROL CENTER (LCC)

The proposed launch rate and continuance of the concept of one firing room assigned to an ELV/PL from assembly to launch will require six equipped firing rooms in the launch control center. This requirement will be met by modifying the three existing outfitted firing rooms to accommodate consoles for the SRM's and new payloads, outfitting the fourth room, and constructing and outfitting two additional rooms.

Checkout of the spacecraft will be accomplished by expansion of the acceptance checkout equipment (ACE).

4.1.5 MOBILE LAUNCHERS (ML)

Seven ML's will be required to support the program. This will require modification of the three existing ML's and construction of four new units. Modifications will consist of changes in the launch platform opening to accommodate the SRM's, addition of heat shields, and relocation and modification of umbilical arms and fluid systems piping.

4.1.6 MOBILE SERVICE STRUCTURE (MSS)

Three MSS's will be required. This requirement can be met by modification of the existing structure and construction of two new units, including parking facilities and crawlerways.

Revisions to the existing MSS will include increasing the height to accommodate raising the work platform due to the larger MS-IC stage and altering the SRM's and new payload platforms.

4.1.7 MOBILE ERECTION AND PROCESSING STRUCTURE (MEPS)

A previous study by the Martin Company evaluated several methods of integrating the 156-inch solid rocket motors into the assembly, checkout, and launch procedure for a modified Saturn V core. Their recommended concept, which has been adopted for this study, will require the development of a mobile facility to inspect and checkout the SRM's and to provide derricks for erecting the segments on the launch pad.

A parking facility for the MEPS will be required near the open rail car storage. This facility will be similar to that provided for the MSS. As the MEPS will be transported to the launch pad by the crawler-tractor a new spur from the crawlerway must be extended to the MEPS parking position.

4.1.8 CRAWLER-TRANSPORTERS (C-T's)

Two crawler-transporters will be required. A comprehensive study will be necessary to determine the feasibility of modifying the existing units to carry the increased load imposed by the ELV/PL and heavier ML.

4.1.9 LAUNCH PADS

The increase in size, weight, and thrust of the SAT-V-25(S)U over the Saturn V will require extensive modifications to the existing launch pads. Because three vehicles will be undergoing launch pad processing concurrently, three pads will be required.

The major complication in developing launch pad requirements is the practical requirement for pad separation for catastrophic failure of a fueled vehicle. Pad separation for Complex 39 is 8730 feet, which was determined by using TNT equivalencies of 10% of the LOX-RP.1 weight and 60% of the LOX-LH_2 weight, and 0.4 psi overpressure. The 0.4 psi limit is imposed by the Saturn V structure.

With the introduction of the SRM's and the increased fuel capacity of the MS-IC stage the separation distance required for 0.4 psi becomes 16,700 feet. This figure is based upon assigning 100% TNT equivalency to the solid propellants when in the presence of a fully fueled core.

Earlier studies have recommended that a waiver be granted on the separation requirements, because overpressures near the theoretical value are highly improbable due to inadequate mixing of propellants and the difficulty in detonating solid propellants. Further study and evaluation is required to establish criteria for pad siting. For this study present separation has been considered adequate.

Major modifications to the existing launch pads include reinforcement of the ML and MSS support piers and pad structure, new flame deflectors, increased industrial water pumping, and increased fluid systems capacity. A tabulation of present propellant storage and ELV/PL requirements is shown below.

	Existing Pad Storage	On-board Requirement Saturn V-25(S)U + PM
RP-1	258,000 gallons	300,000 gallons
LOX	700,000 gallons	550,000 gallons
LH_2	850,000 gallons	950,000 gallons*

*687,000 gallons for propulsion module--to be subcooled or slush.

Increased propellant storage requirements at each existing launch pad would include one 86,000-gallon RP-1 reservoir, manifolded to the three existing tanks, one 200,000-gallon LOX dewar for boiloff replenishment, and two additional 850,000-gallon LH_2 dewars.

Minor modifications to the high-pressure gas system will be required to interface with the new vehicle. The existing N_2O_4 system will be modified to service the TVC system on the SRM's. Further study and evaluation is required for manufacture, transport, and storage of large amounts of subcooled or slush LH_2.

One new launch pad that includes the crawlerway extension and has the same capability as the modified pads will be required.

4.2 INDUSTRIAL FACILITIES

This section describes major new or modified facilities that will be required to support the manufacture, assembly, and test of the hardware components that make up the manned interplanetary system. Development and fabrication facilities for the nuclear engines and the solid rocket motors are assumed to be available at the time required through provisioning separate from this program. They are thus not treated here, except for those occurring as a direct result of the manned interplanetary requirement.

4.2.1 MANUFACTURING AND ASSEMBLY

The major facility changes evolve from the increase in the length of the first stage of the ELV and provisions for the solid strap-on rocket motors and the PM hydrogen tanks.

Major tooling and assembly requirements at Michoud include an additional tank assembly station, an additional hydrotest position, and some additional and modified tooling. Additional warehousing, quality assurance, and receiving inspection areas will be required. The final assembly position in the VAB can be adapted to the longer stage.

The aft skirt structure and aft attachment structure for the SRM's will require new assembly and handling equipment as well as boring machines and a new welding facility.

4.2.2 TEST FACILITIES

Major additions and modifications that will be required to the test facilities at MSFC and MTF to support this program are:

1) Dynamic test facility: The present Saturn V dynamic test stand at MSFC has a foundation limit of 12 x 10^6 pounds, and because the SAT-V-25(S)U plus a PM weighs 15 x 10^6 pounds, a new facility must be constructed to meet this test requirement;
2) Static firing facility: The S-IC stand at MTF will require modification to accommodate the MS-IC stage. The SRM's will not be fired. Modifications to the stand will include revisions to platforms because of the increased length of the stage and revisions to propellant and gas piping systems. Three new LOX barges will be needed to provide the additional propellant required for the MS-IC.

4.3 FACILITY COSTS (MAJOR ITEMS)

4.3.1 KENNEDY SPACE CENTER

Facility	$ (millions)
Vertical Assembly Building (Mod)	10.1
Launch Control Center (Mod)	1.5
Mobile Launcher 3 (Mod)	52.4
4 (New)	180.0
Mobile Service Structure 1 (Mod)	5.0
2 (New)	80.0
Launch Pads 2 (Mod)	23.1
1 (New)	20.4
Deflectors 2 (New)	6.7
Fueling (New)	59.7
Crawler-Transporter 2 (Mod	19.3
Payload Assembly and c/o Building	16.4
SRM Inert Component Assembly Building (New)	3.0
SRM Mobile Erection and Processing Structure 2 (New)	25.0
Total	$ 502.5

4.3.2 INDUSTRIAL FACILITIES

Facility	$ (millions)
MSFC	
Dynamic Test Facility	15.2
MTF	
Static Test Stand	4.9
Michoud	19.6
Total	$ 40.0

4.4 FACILITY CONSTRUCTION SCHEDULES

Construction schedules for the major facilities required to support the this program are shown in Figures 4.4-1 and 4.4-2. The time indicated on the bar graph for each item includes design, "brick and mortar" construction, and equipment provisioning where applicable.

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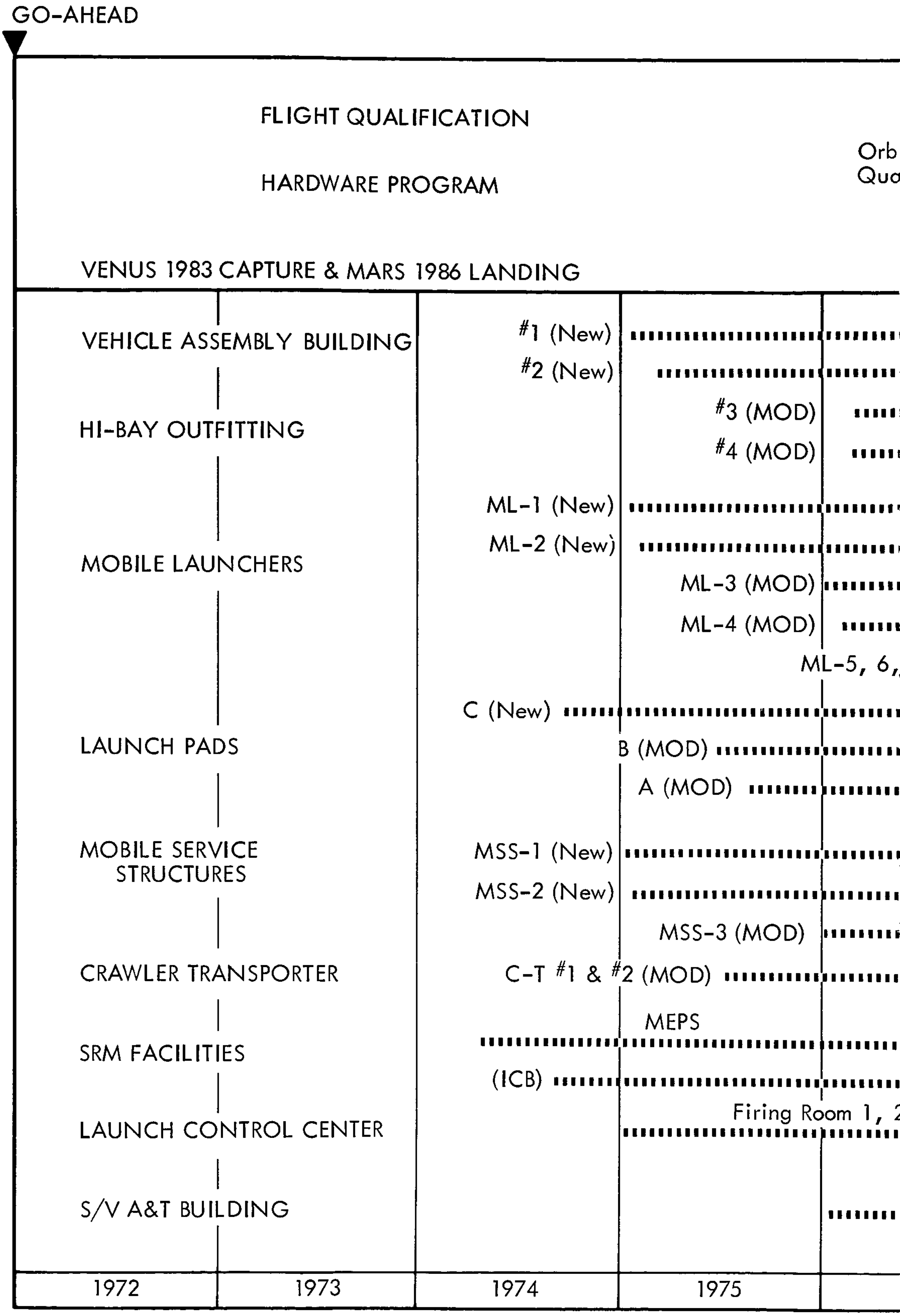

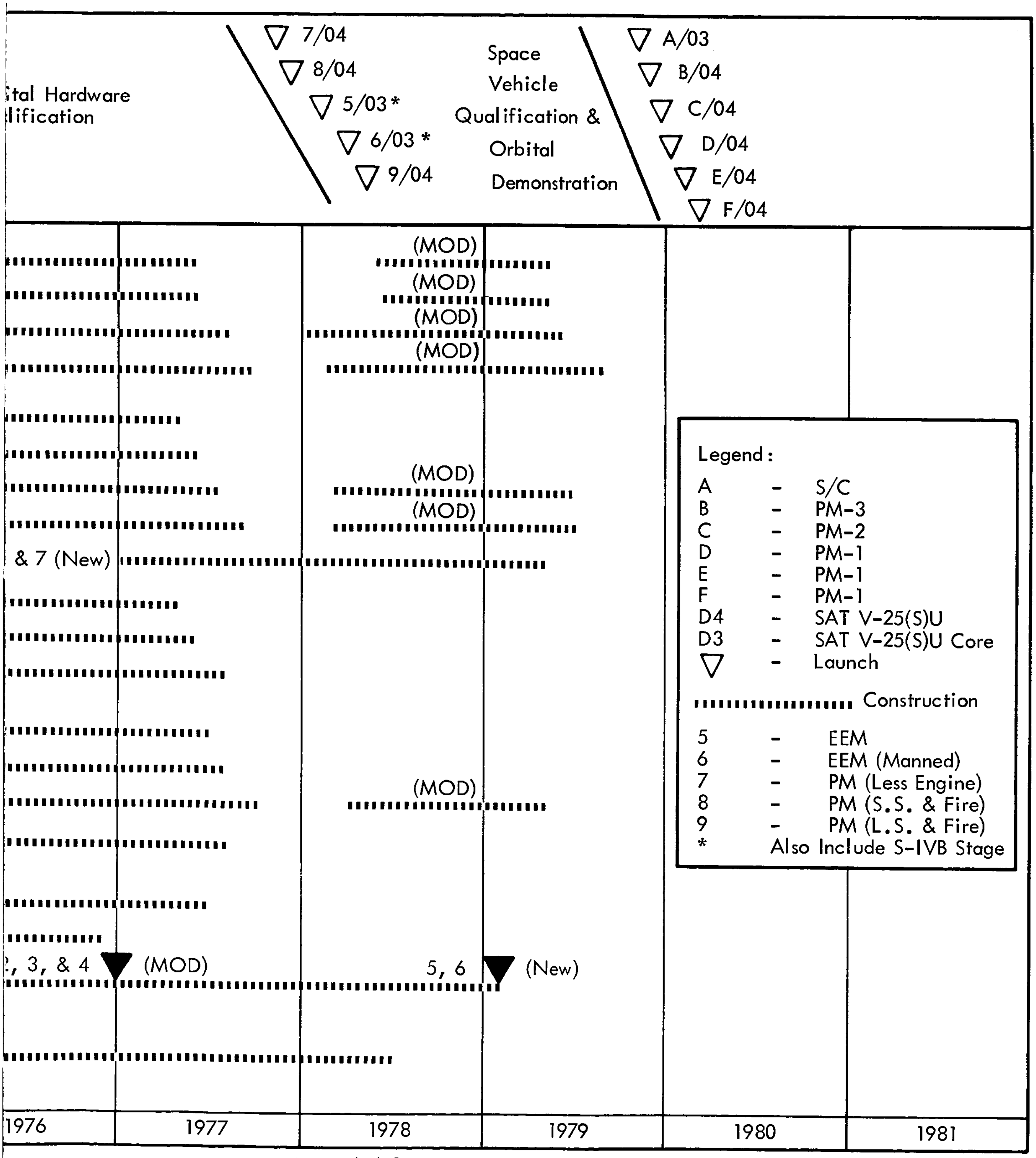

Figure 4.4-1: MAJOR FACILITIES CONSTRUCTION SCHEDULE — SHORT 1

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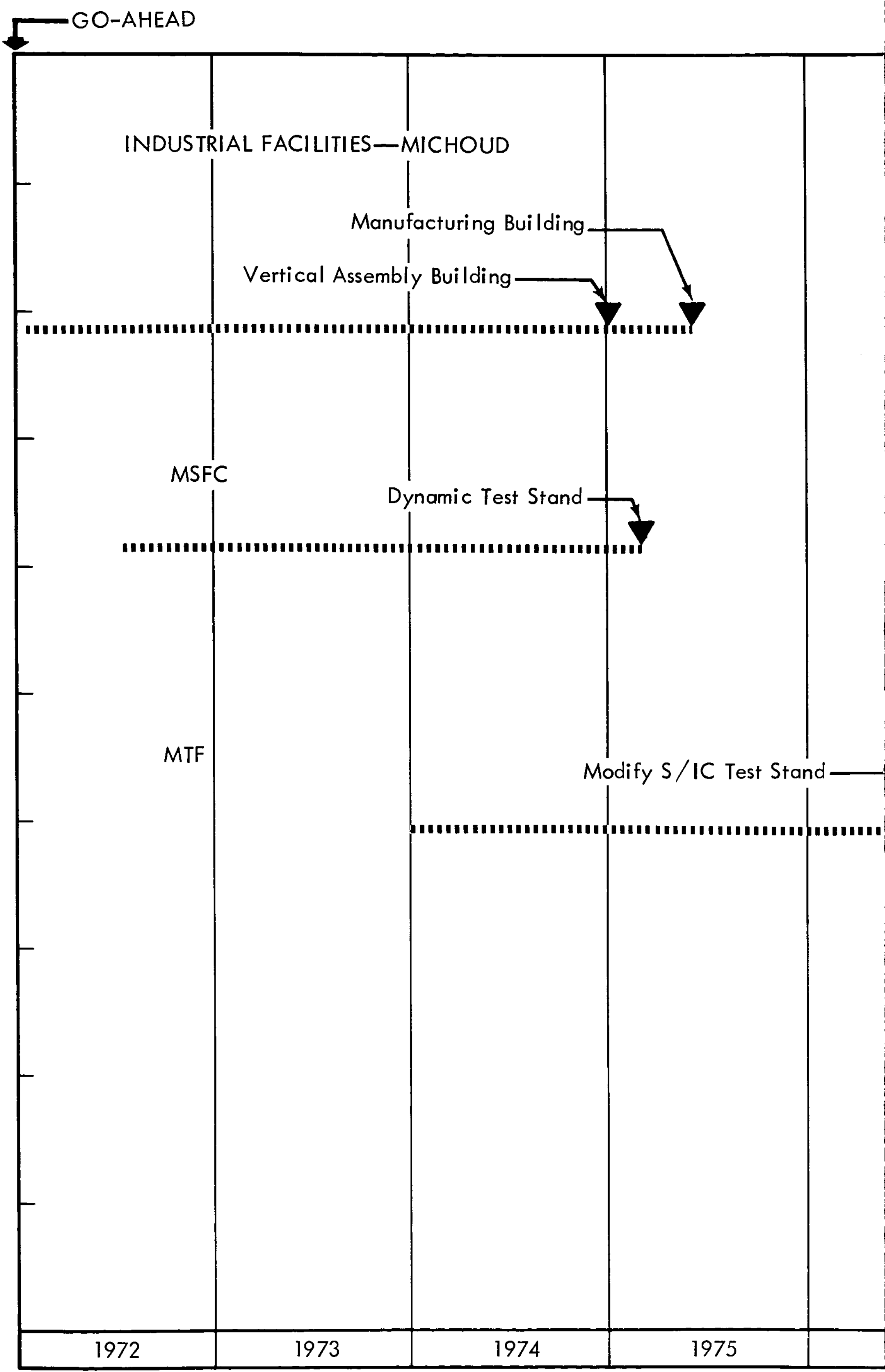

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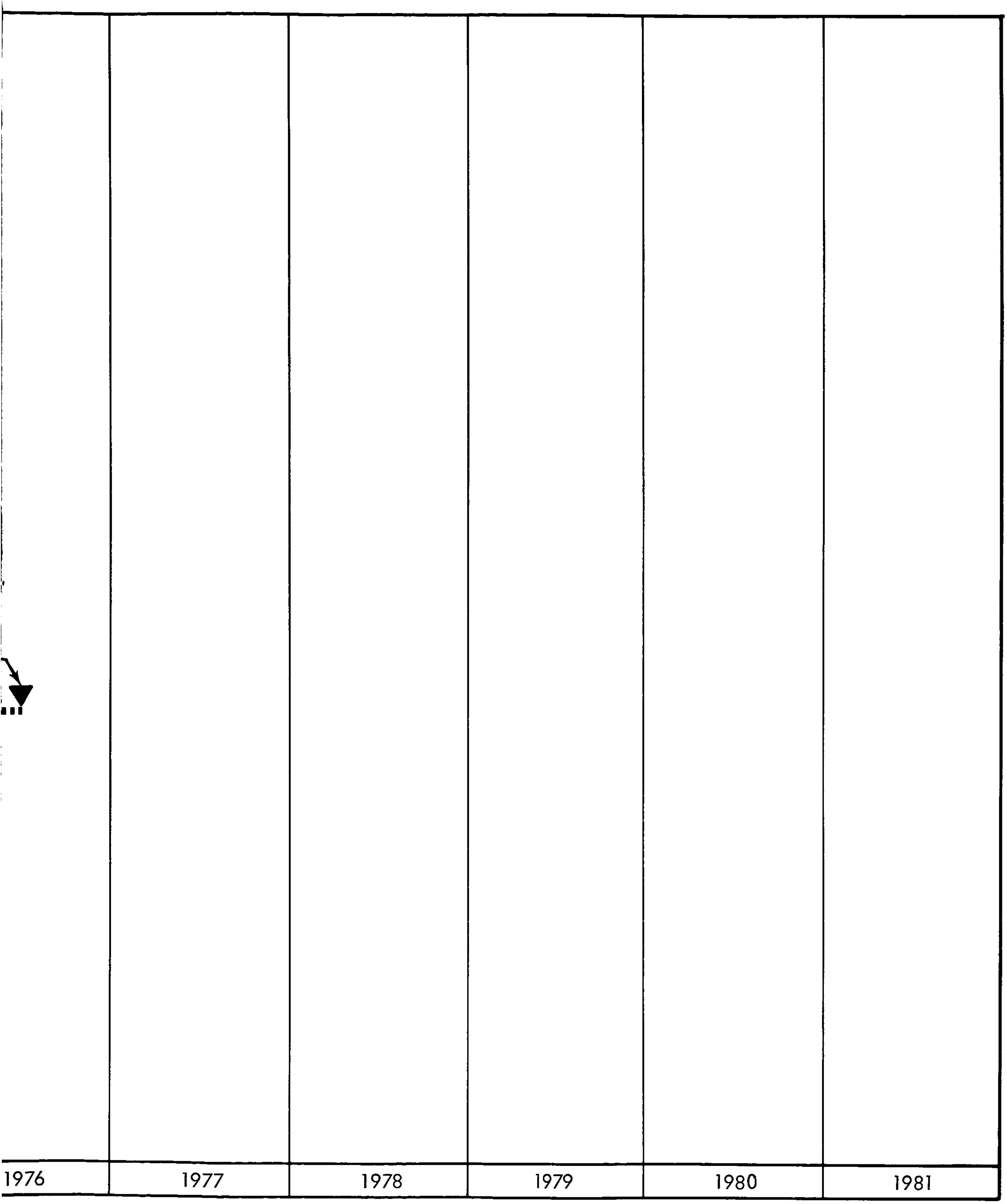


Figure 4.4-2: MAJOR FACILITIES CONSTRUCTION SCHEDULE — SHORT 2

4.5 ADDITIONAL STUDY CONSIDERATIONS

A number of the conditions imposed upon the new or modified facilities that will be required for the manned interplanetary program are so severe or so complex that further detailed study will be necessary for a complete evaluation and resolution.

The following items are problem areas in this category.

1) Hurricane protection at the launch pad. (This has been assumed feasible in order to keep the number of launch pads and VAB positions at a reasonable value.)
2) Manufacture, storage, and handling of subcooled or slush hydrogen.
3) VAB height limitation. (Present ELV/PL combinations exceed door opening and crane hook height. Several approaches have been examined, but a detailed trade study is required to arrive at the best solution to this problem.)
4) Blast effects. (See Section 4.1.9)
5) Sterilization facilities for Mars lander.

5.0 PROGRAM COSTS

Program cost and fiscal year funding for the IMISCD system are developed in this section. The Venus and Mars missions defined in this report provide the technical data upon which the cost estimate is built. It should be noted that the aerospace vehicle configuration priced is the survivor of over twenty candidates studied during the past year.

A 1983 Venus Short mission and a 1986 Mars Opposition landing mission provide the example program used in the costing effort. A 1981 Venus Short mission and a 1983 Mars Opposition mission are also analyzed to exhibit the effect on funding caused by the accelerated schedule. This alternate program is considered to involve a higher degree of risk.

The results of the costing effort provide basic cost data that can be rearranged to devise other interplanetary mission programs. A "Program Planners' Guide" is included in this section to exploit the available cost data and help put together other desirable mission programs.

The total program costs generated from the example 1983 Venus - 1986 Mars program are as follows:

Phase	Millions
R&D	$23,695.6
Venus Mission	2,572.1
Mars Mission	2,681.9
Program Total	$28,949.6

To facilitate the reading of the program costs, it is of value to highlight its organization.

The cost report is divided into three major areas:

1) Subsection 5.1, Conditions and Rationale
2) Subsection 5.2, Cost Summaries and Funding Schedules
3) Subsection 5.3, Costing Methodology

Subsection 5.1, *Conditions and Rationale*, lays the ground rules and states the assumptions under which the cost effort is performed.

Subsection 5.2, *Cost Summaries and Funding Schedules*, displays the results in graphical and pictorial form of the cost analysis. The Program Planners' Guide is also included in this subsection.

Subsection 5.3, *Costing Methodology*, presents the technique and mechanics used to perform the cost analysis. This subsection is broken down into three major parts that are the essence of the cost analysis. They are:

1) WORK BREAKDOWN STRUCTURE WITH ELEMENT COSTS

   Identifies and *defines* the work.

2) ELEMENT COST BREAKDOWN

   Builds the cost estimates.

3) COSTING TOOLS

   Supports the estimating technique.

5.1 CONDITIONS AND RATIONALE

The cost estimates developed for this program were based on the following conditions and ground rules:

1) Development costs for all major program elements are included with the exception of the following:
   - SAT-V-INT 21 (two-stage Saturn V),
   - Saturn IB,
   - Six-man logistics spacecraft.
2) Escalation allowances are not included.
3) Costs were estimated assuming that industry will be responsible for design, development, and manufacture of all elements. Included are allowances for integration and management at all program levels. Government administrative costs, however, are excluded.
4) Standby costs are based on the probability of use. Unused standby units will be refurbished and reused. Allowances have been included for storage and refurbishment.
5) Nerva II development costs are included.
6) Earth-based support costs do not include synchronous orbit satellite relays or possible deep space network stations for laser communications, i.e., Earth orbit support costs are for existing stations and do not include any new facility investments.
7) The six-man logistics spacecraft has been priced on the basis of four reuses for each spacecraft.

5.2 COST SUMMARIES AND FUNDING SCHEDULES

The two-mission example cost in total and by element is displayed graphically in this section. Both the basic example and an alternative higher risk example are depicted. A program funding schedule is included for the basic and alternative examples to exhibit the yearly funding levels that an interplanetary program would conceivably require.

The various graphs and charts break out cost by categories such as spacecraft, propulsion modules, and Earth based support to highlight the relative cost requirements the defined programs produce.

Nonrecurring and recurring costs are separated to point up the financial resources that must be expended before a mission can be launched and the monies necessary for the mission and subsequent missions.

A guide for program planners is included in this section to provide a tool that would allow an analyst to put together a tailored mission plan that fits within a range of mission alternatives and combinations provided.

5.2.1 BASIC EXAMPLE

The following tables, charts, and illustrations show the costs associated with a Venus capture mission in 1983 and a Mars landing mission in 1986.

Figure 5.2-1 presents the total example overview by major element. The spacecraft category, which includes the mission module, the Earth entry module, and the Mars Excursion Module is almost twice as costly as the next largest cost element of the program, the Earth launch vehicles. Probes and experiments appear next in cost closely followed by the space propulsion system. The remaining support, integration and management efforts are about as costly in total as the Earth launch vehicles.

The funding graph, Figure 5.2-2, is a gross allocation of monies distributing the examples total costs over 19 years. This graph was prepared by funding each element individually, then phasing the element fundings into the total example funding by using the detailed program event schedules. This graph shows only how the money would be spent, and not necessarily how the government would choose to allocate the funds.

Figure 5.2-3 is a pictorial illustration of total nonrecurring costs including detailed Design, Development, and Flight Demonstration Test Program costs.

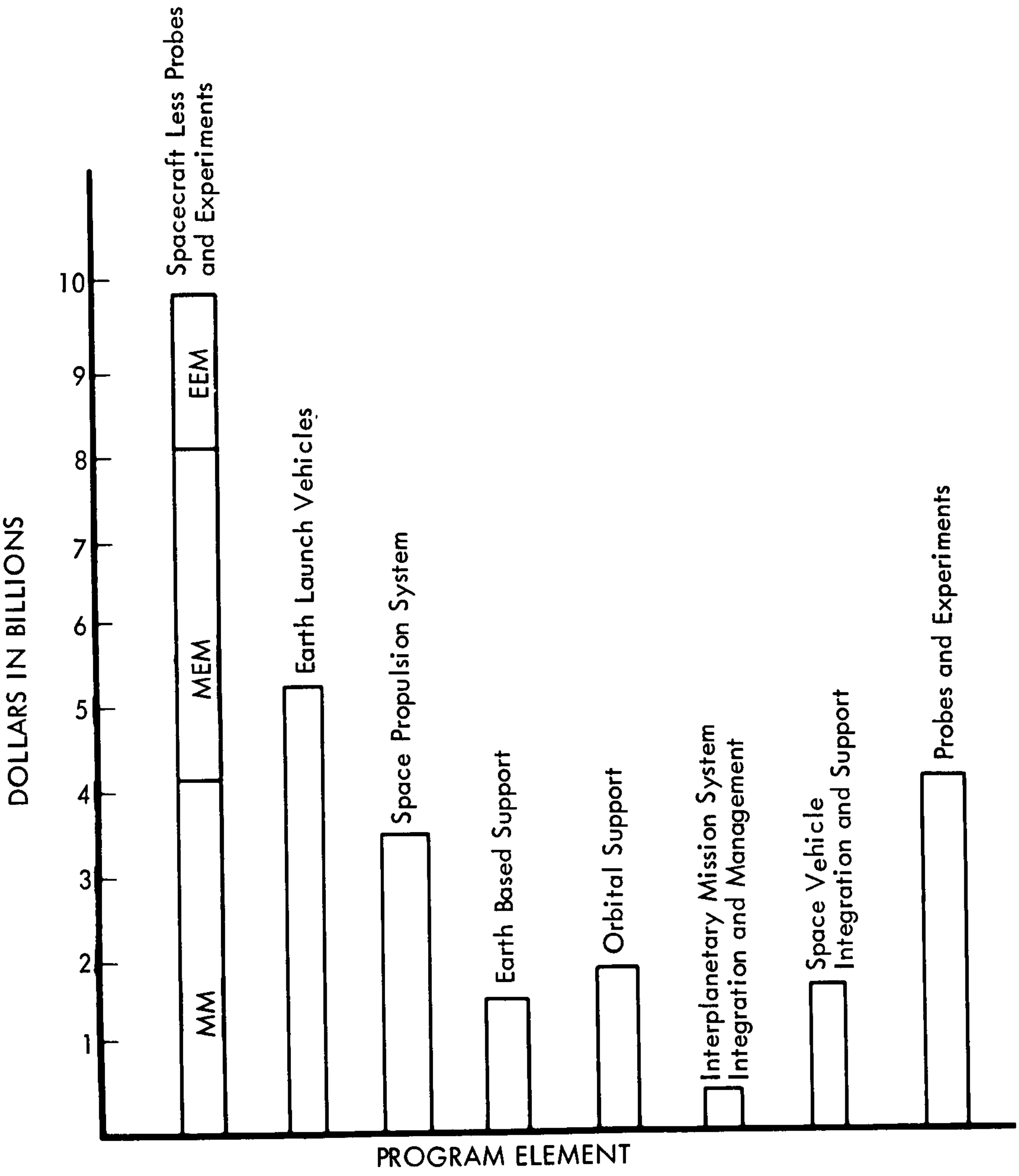
Figures 5.2-4 and 5.2-5 display the Venus and Mars Mission costs.

Figure 5.2-6 illustrates nonrecurring or total R&D cost for spacecraft, Earth launch vehicles and propulsion module hardware.

Figure 5.2-7 presents mission hardware cost for spacecraft, earth launch vehicles and propulsion modules.

Figure 5.2-8 presents total example hardware cost for spacecraft, Earth launch vehicles and propulsion modules. These hardware costs are next broken down into R&D and unit costs on Figures 5.2-9 through 5.2-11.

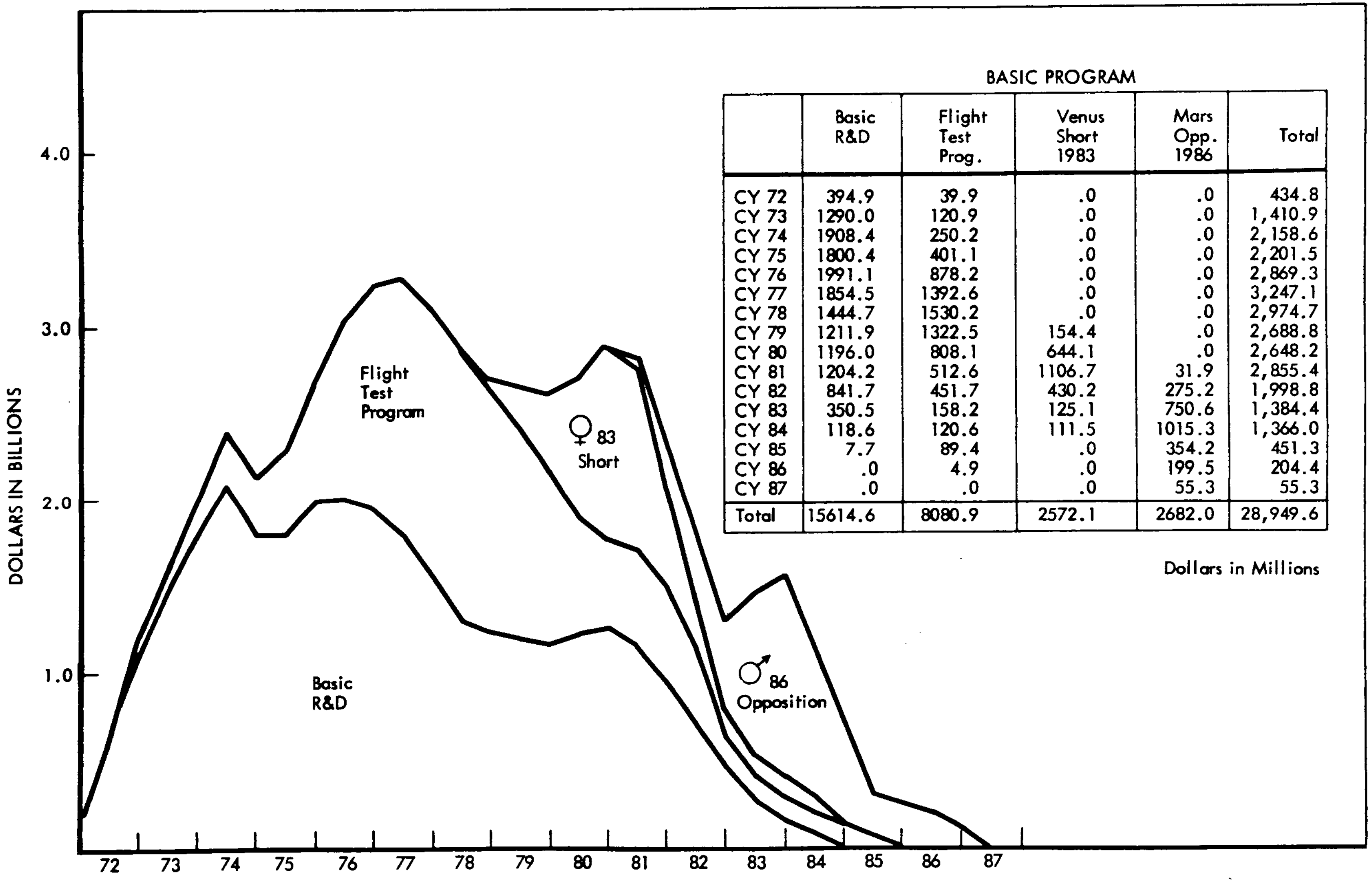
Figure 5.2-12 breaks out the items involved in experiment and probe costs by nonrecurring and recurring categories and in total. Finally, Figure 5.2-13 presents program support, integration, and management costs.



Totals

Phase	(Millions)
R&D	$23,695.6
Venus Mission	2,572.1
Mars Mission	2,681.9
Program Total	$28,949.6

Figure 5.2-1: TOTAL TWO MISSION COSTS



BASIC PROGRAM

	Basic R&D	Flight Test Prog.	Venus Short 1983	Mars Opp. 1986	Total
CY 72	394.9	39.9	.0	.0	434.8
CY 73	1290.0	120.9	.0	.0	1,410.9
CY 74	1908.4	250.2	.0	.0	2,158.6
CY 75	1800.4	401.1	.0	.0	2,201.5
CY 76	1991.1	878.2	.0	.0	2,869.3
CY 77	1854.5	1392.6	.0	.0	3,247.1
CY 78	1444.7	1530.2	.0	.0	2,974.7
CY 79	1211.9	1322.5	154.4	.0	2,688.8
CY 80	1196.0	808.1	644.1	.0	2,648.2
CY 81	1204.2	512.6	1106.7	31.9	2,855.4
CY 82	841.7	451.7	430.2	275.2	1,998.8
CY 83	350.5	158.2	125.1	750.6	1,384.4
CY 84	118.6	120.6	111.5	1015.3	1,366.0
CY 85	7.7	89.4	.0	354.2	451.3
CY 86	.0	4.9	.0	199.5	204.4
CY 87	.0	.0	.0	55.3	55.3
Total	15614.6	8080.9	2572.1	2682.0	28,949.6

Dollars in Millions

Figure 5.2-2: TOTAL PROGRAM FUNDING BASIC EXAMPLE

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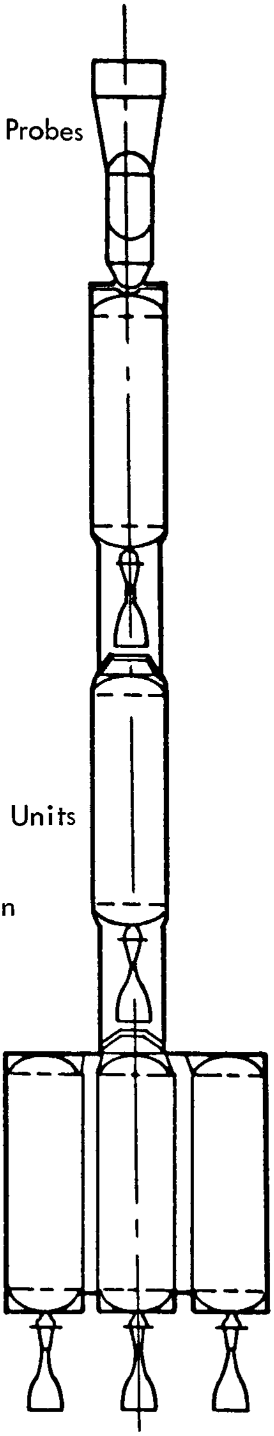

SPACE VEHICLE

	Basic R&D	Flight Test	Tot
MEM Experiments & Probes	$2,906.2	$ 826.7	$3,73
MM	3,288.0	581.8	3,86
EEM	3,049.0	532.0	3,58
PM-3	1,457.7	263.5	1,72
	0	62.0	6
PM-2	0	201.0	20
Assembly & Docking Units	355.9	137.3	49
Midcourse Correction and Orbit Trim	140.0	22.5	16
PM-1	2,040.0	155.0	2,19
Space Vehicle Integration & Support	1,323.7	278.2	1,60
Subtotal	$14,560.5	$3,060.0	$17,62
	Total Space Vehicle		$17,62

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al

2.9

9.8

1.0

1.2

2.0

1.0

3.2

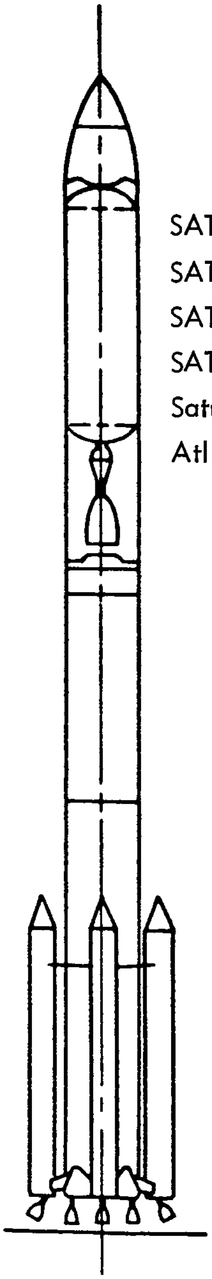
2.5

5.0

1.9

0.5

0.5



EARTH LAUNCH VEHICLES

	Basic R&D	Flight Test	Total
SAT-25(S)U with S/O	$248.6	$1,463.0	$1,711.6
SAT-V-25(S) Uoore only	574.8	906.4	1,481.2
SAT V	-0-	124.0	124.0
SAT-V INT-21	-0-	178.6	178.6
Saturn IB	-0-	164.0	164.0
Atlas Agena	-0-	7.9	7.9
Subtotal	$823.4	$2,843.9	$3,667.3

Other Costs

Earth Support	$1,035.0
Orbital Support	1,022.6
Interplanetary Mission System Integration and Management	350.2
	$2,407.8

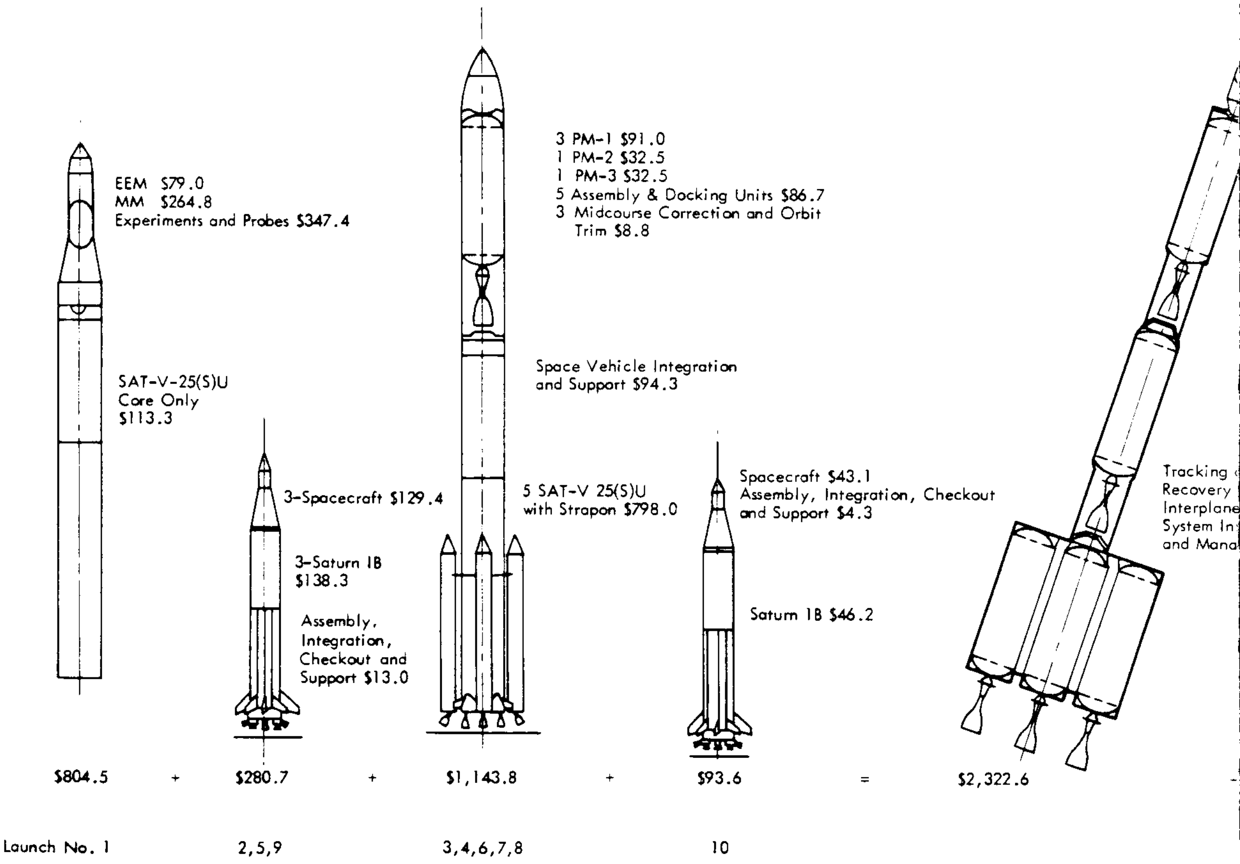
TOTAL R&D

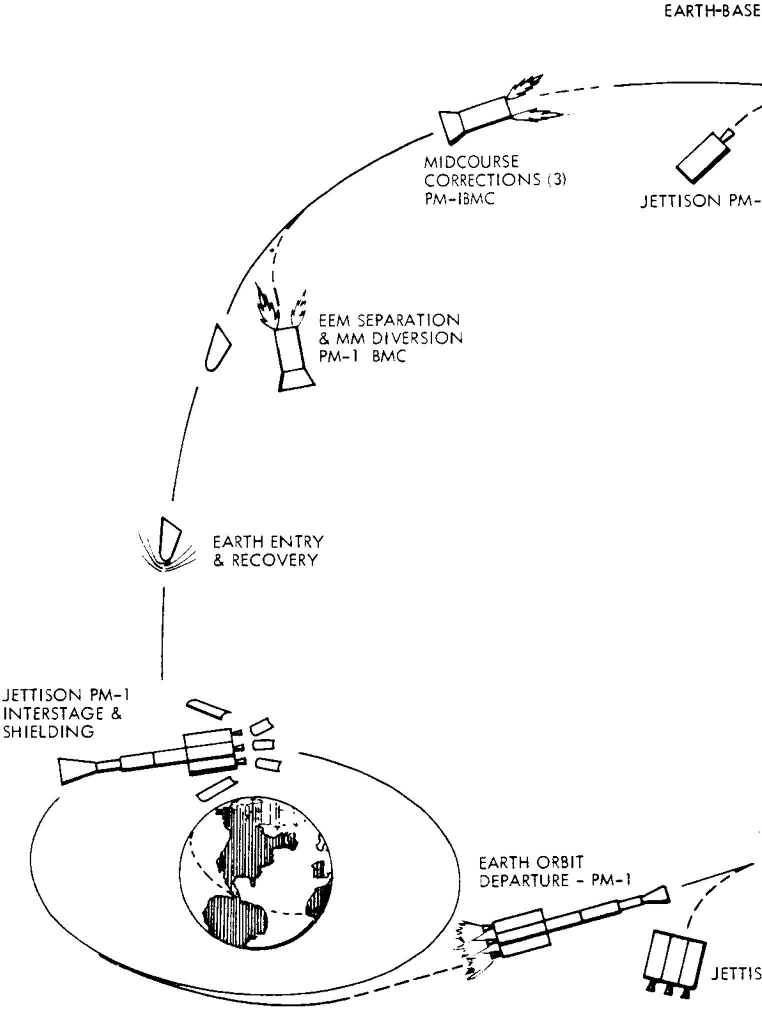
\+ Total ELV and other $3,667.3 + $2,407.8 = $23,695.6

Figure 5.2-3: NONRECURRING COSTS DESIGN DEVELOPMENT AND FLIGHT DEMONSTRATION TEST COSTS (dollars in millions)

FOLDOUT FRAME 2

HARDWARE, ASSEMBLY, INTEGRATION, CHECKOUT AND ORBITAL SUPPORT





ınd Data Management	$209.5
	2.0
tary Mission egration gement	38.0
	$249.5

= Total Mission Cost
$2,572.1

FOLDOUT FRAME 2

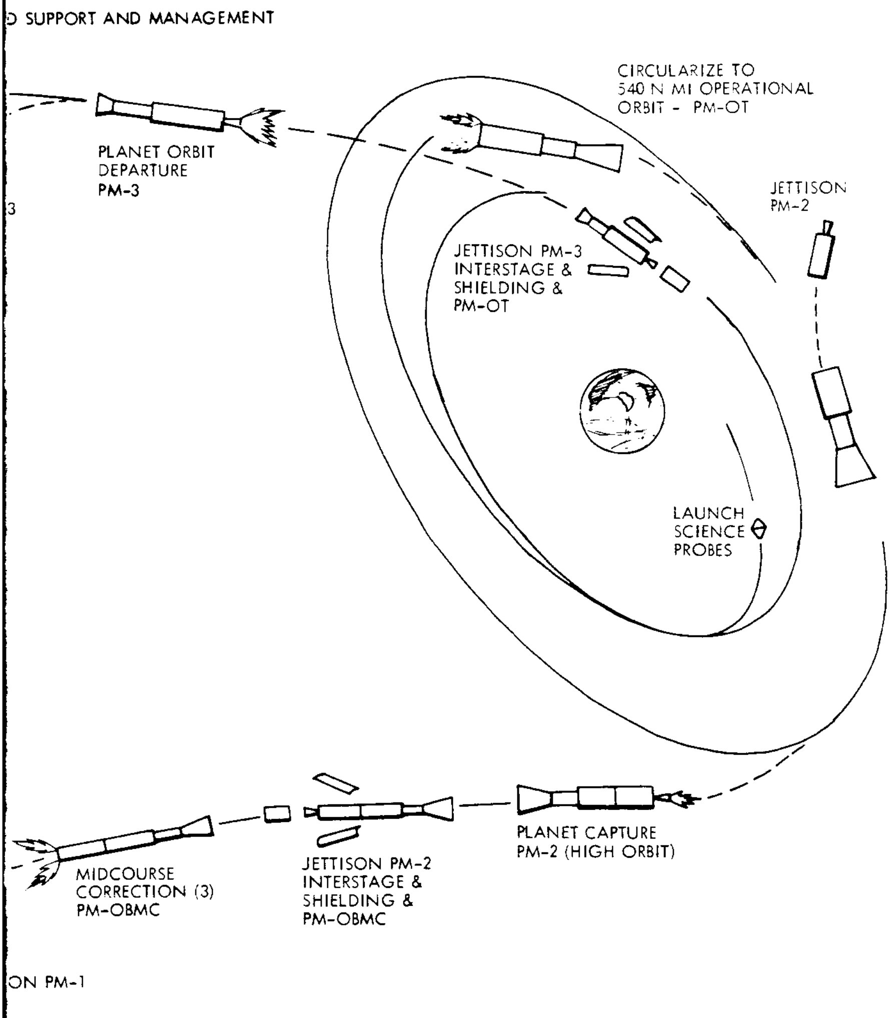
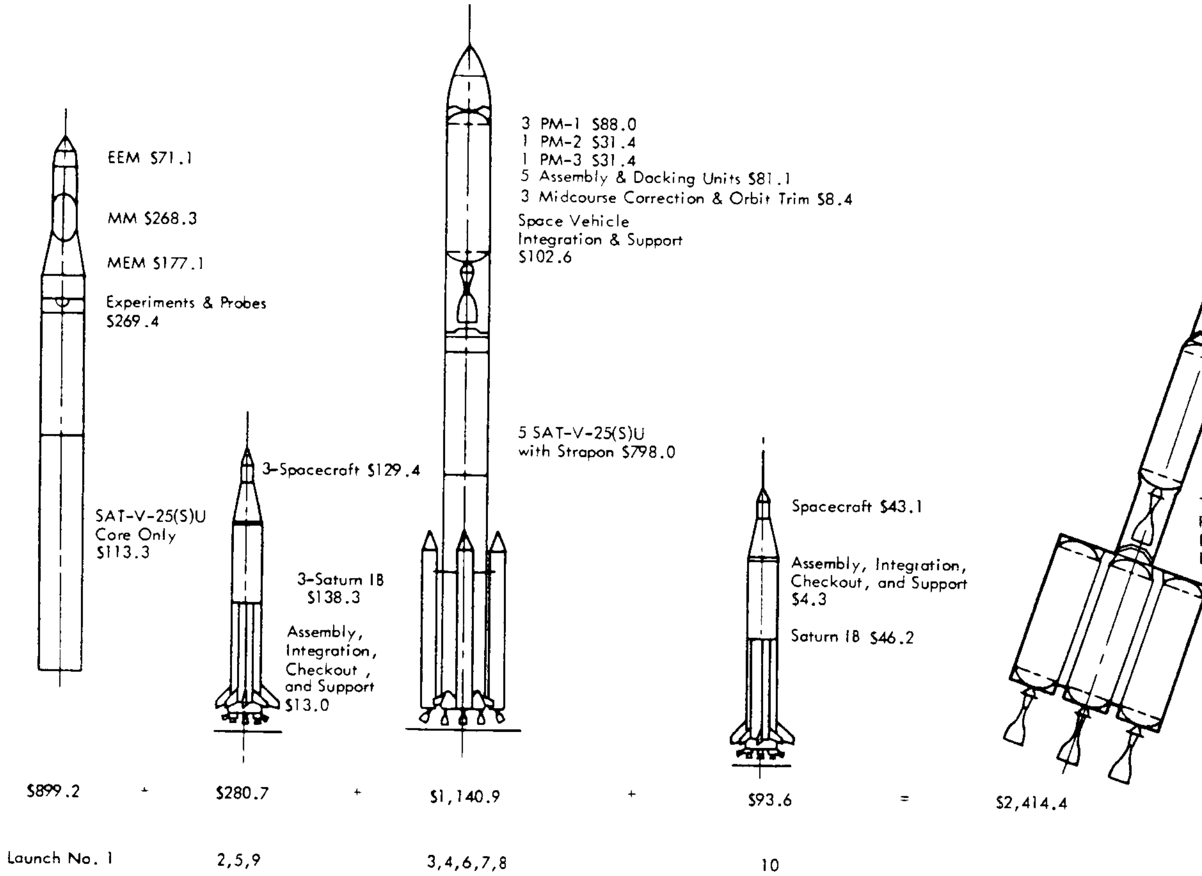


Figure 5.2-4: VENUS SHORT MISSION COST (dollars in millions)

HARDWARE, ASSEMBLY, INTEGRATION, CHECKOUT, AND ORBITAL SUPPORT



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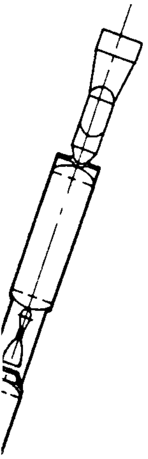
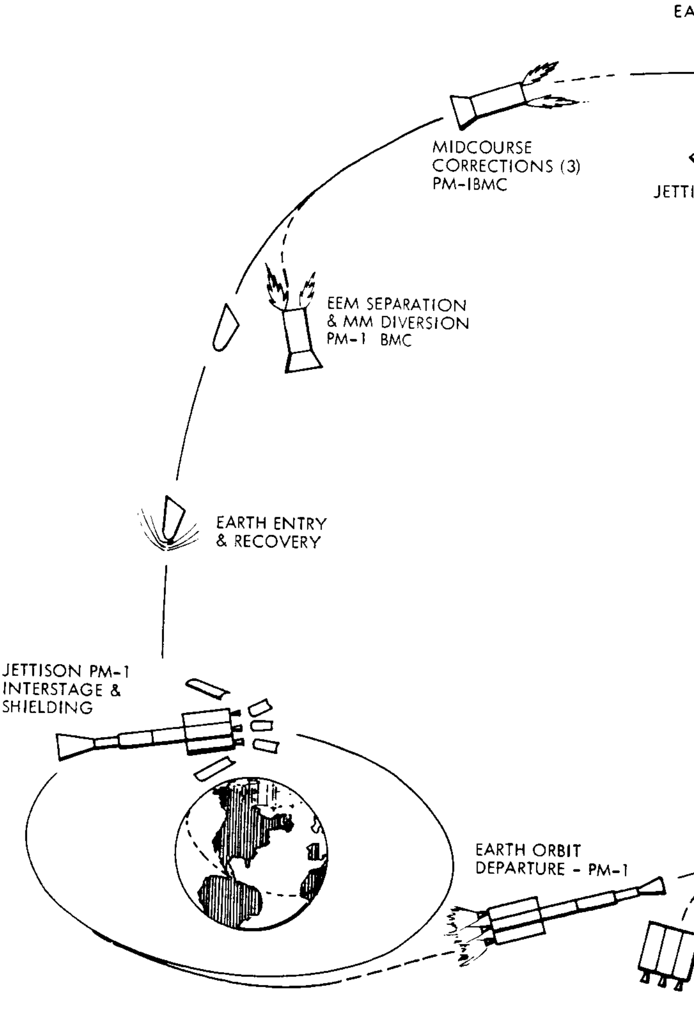


racking and Data Management	$225.9
ecovery	2.0
nterplanetary Mission System ntegration and Management	39.6
	$267.5



= Total Mission Cost $2,681.9

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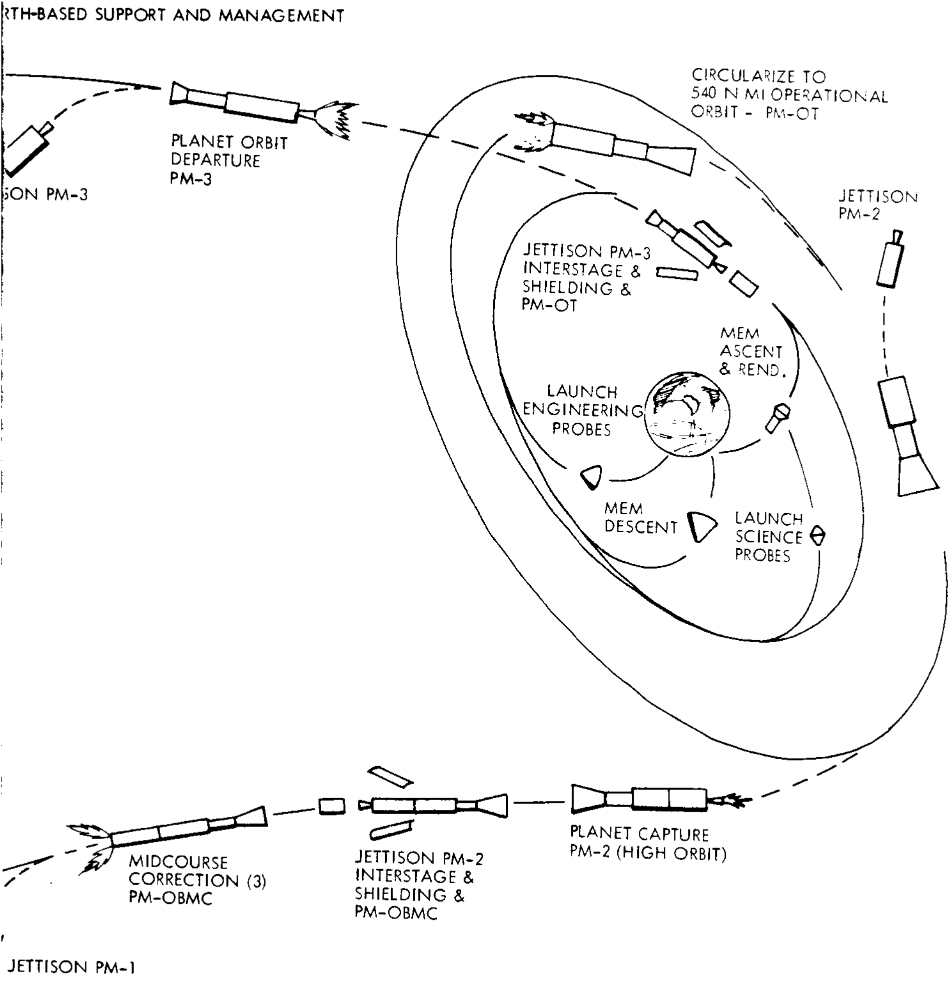


Figure 5.2-5: MARS OPPOSITION MISSION COST (dollars in millions)

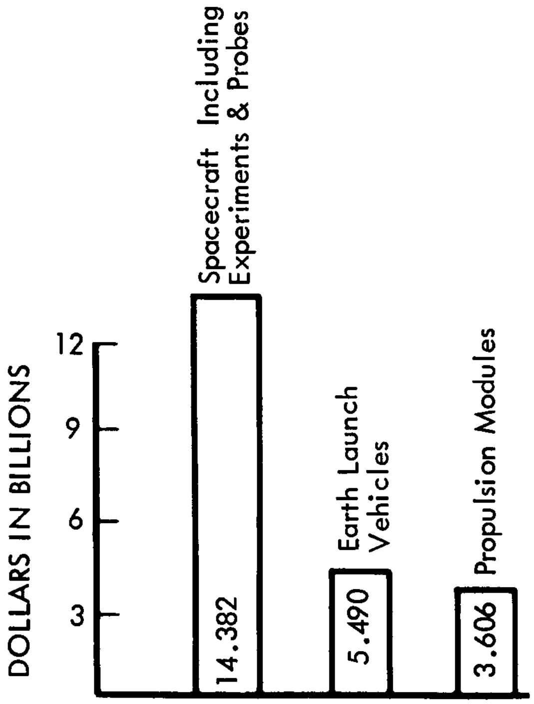


Figure 5.2-6: R&D HARDWARE COST

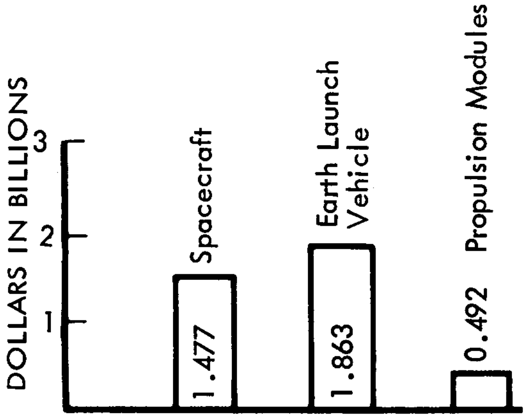


Figure 5.2-7: MISSION HARDWARE COST

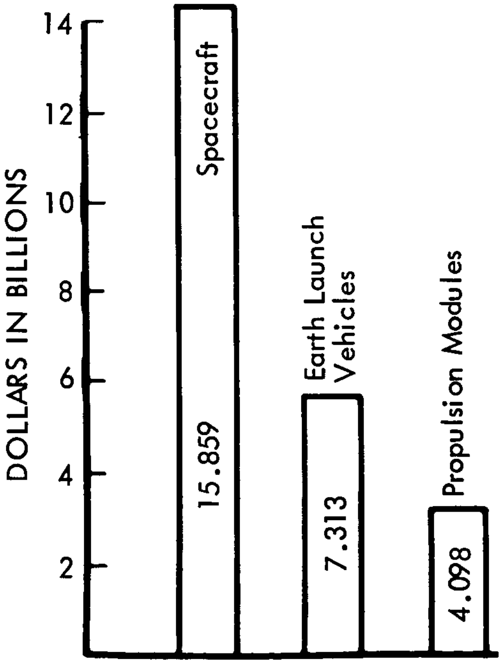


Figure 5.2-8: TOTAL PROGRAM HARDWARE COST

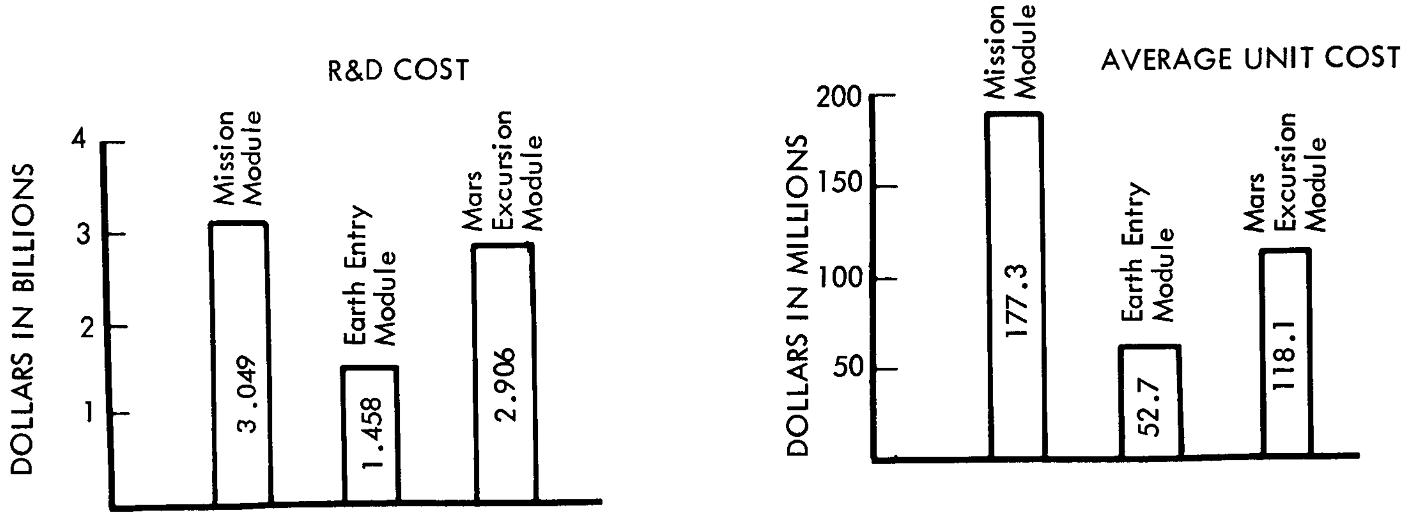


Figure 5.2-9: SPACECRAFT COSTS

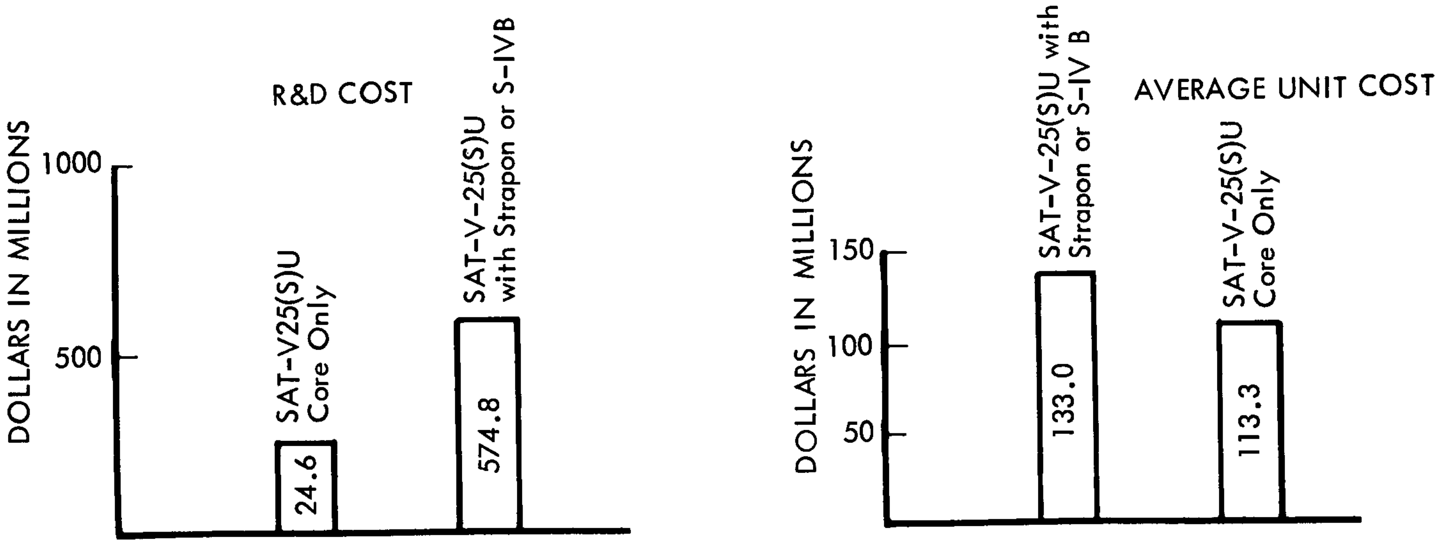


Figure 5.2-10: EARTH LAUNCH VEHICLE COSTS

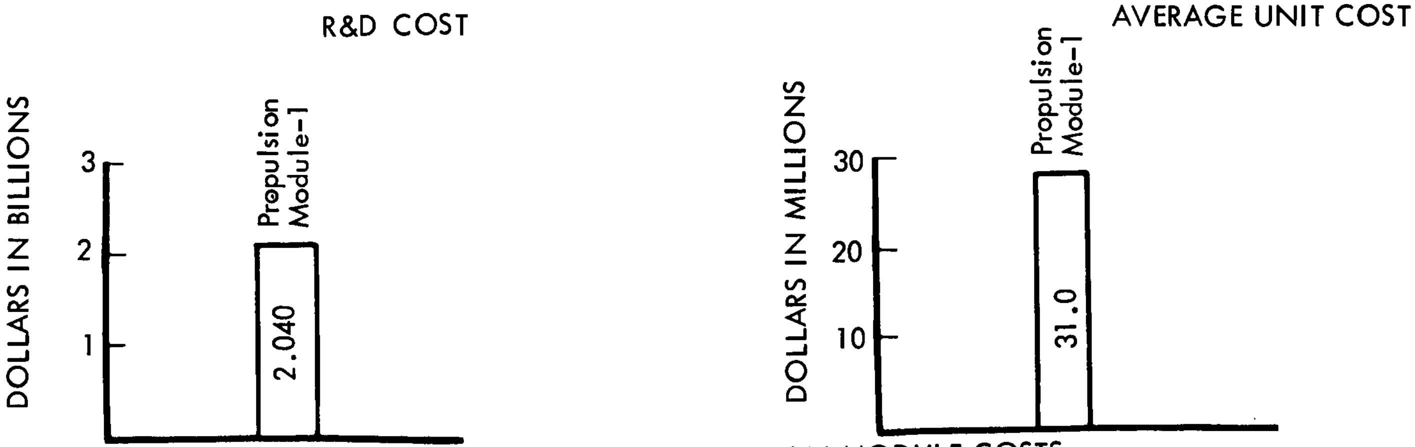


Figure 5.2-11: PROPULSION MODULE COSTS

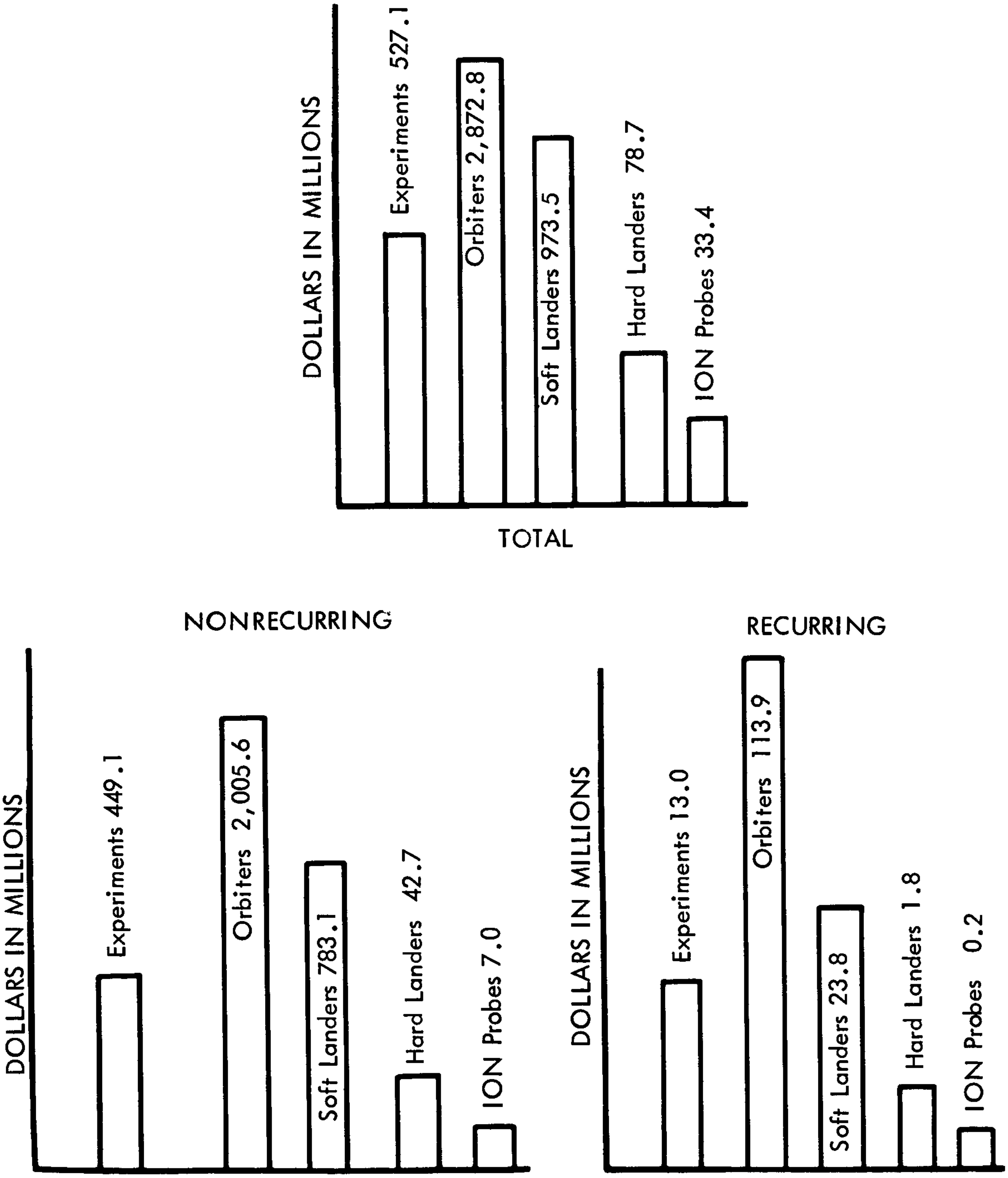
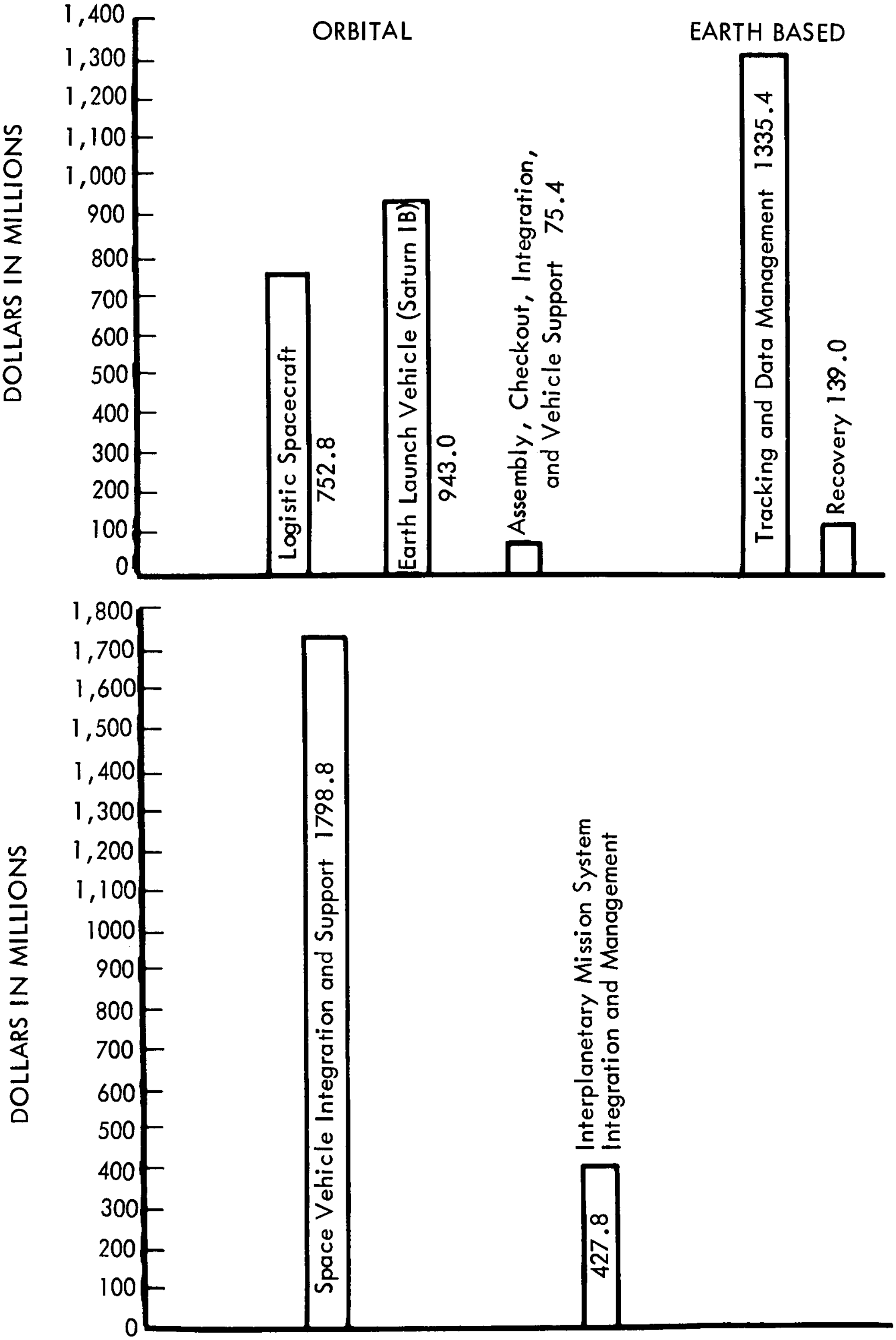


Figure 5.2-12: PROBES AND EXPERIMENTS — TOTAL COST



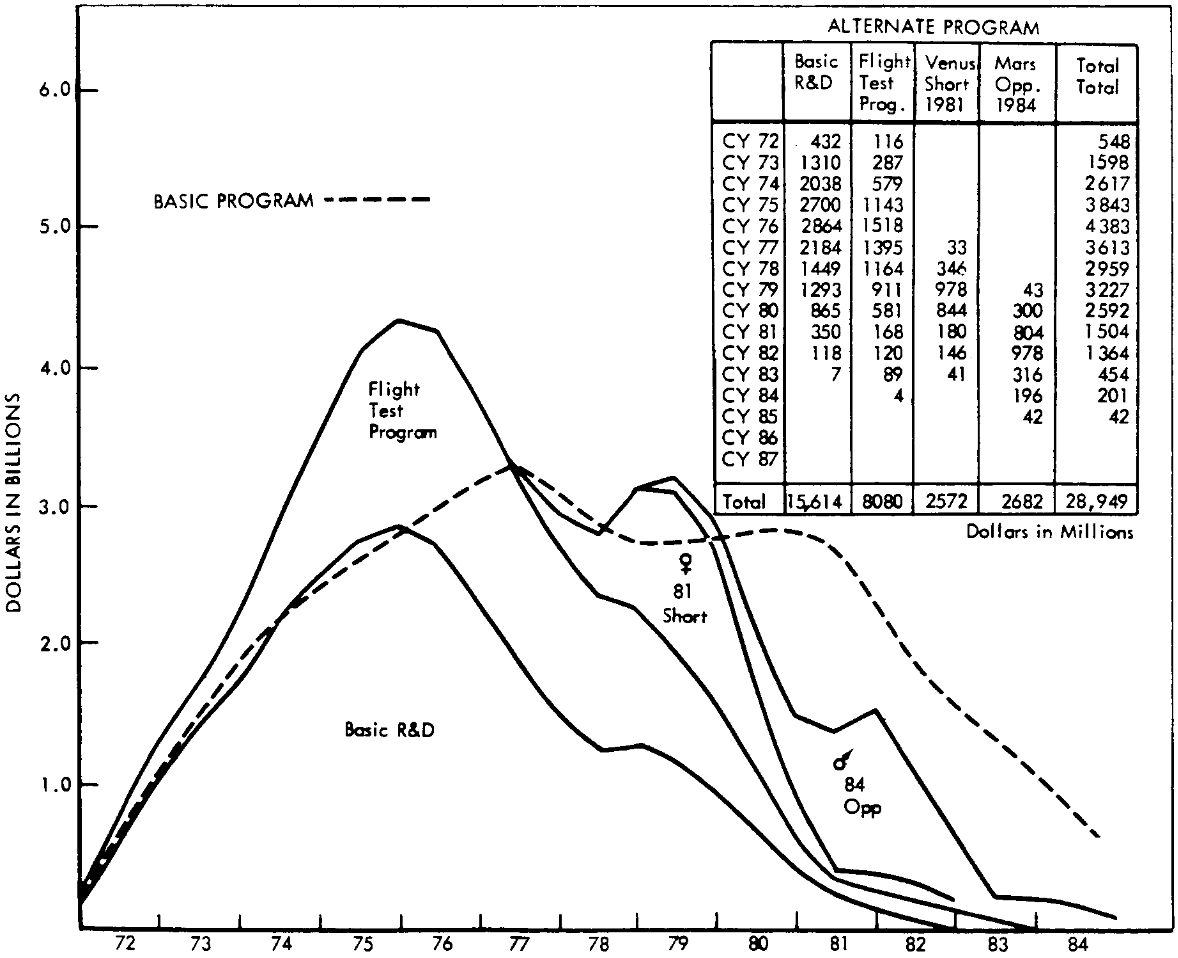
5.2-13: PROGRAM SUPPORT

5.2.2 ALTERNATE EXAMPLE

In the alternate example, the Venus capture mission is scheduled for 1981 and the Mars landing mission for 1983. The impact on total costs was not assessed, but there is a considerable change in funding requirements. The combined effect of shorter flow times for the Venus mission, and earlier go-ahead dates for the Mars mission lead to higher annual funding requirements through 1980.

The cost figures appearing (except for funding) in the previous section are valid for the alternate mission example. Funding requirements for both the basic and alternate plans are compared on Figure 5.2-14.

The basic example has a peak yearly funding rate of approximately $3.2 billion, while the alternate yearly funding peak is in excess of $4.0 billion.



ALTERNATE PROGRAM

	Basic R&D	Flight Test Prog.	Venus Short 1981	Mars Opp. 1984	Total Total
CY 72	432	116			548
CY 73	1310	287			1598
CY 74	2038	579			2617
CY 75	2700	1143			3843
CY 76	2864	1518			4383
CY 77	2184	1395	33		3613
CY 78	1449	1164	346		2959
CY 79	1293	911	978	43	3227
CY 80	865	581	844	300	2592
CY 81	350	168	180	804	1504
CY 82	118	120	146	978	1364
CY 83	7	89	41	316	454
CY 84		4		196	201
CY 85				42	42
CY 86					
CY 87					
Total	15,614	8080	2572	2682	28,949

Dollars in Millions

Figure 5.2-14: TOTAL PROGRAM FUNDING COMPARISON

5.2.3 PROGRAM PLANNER'S GUIDE

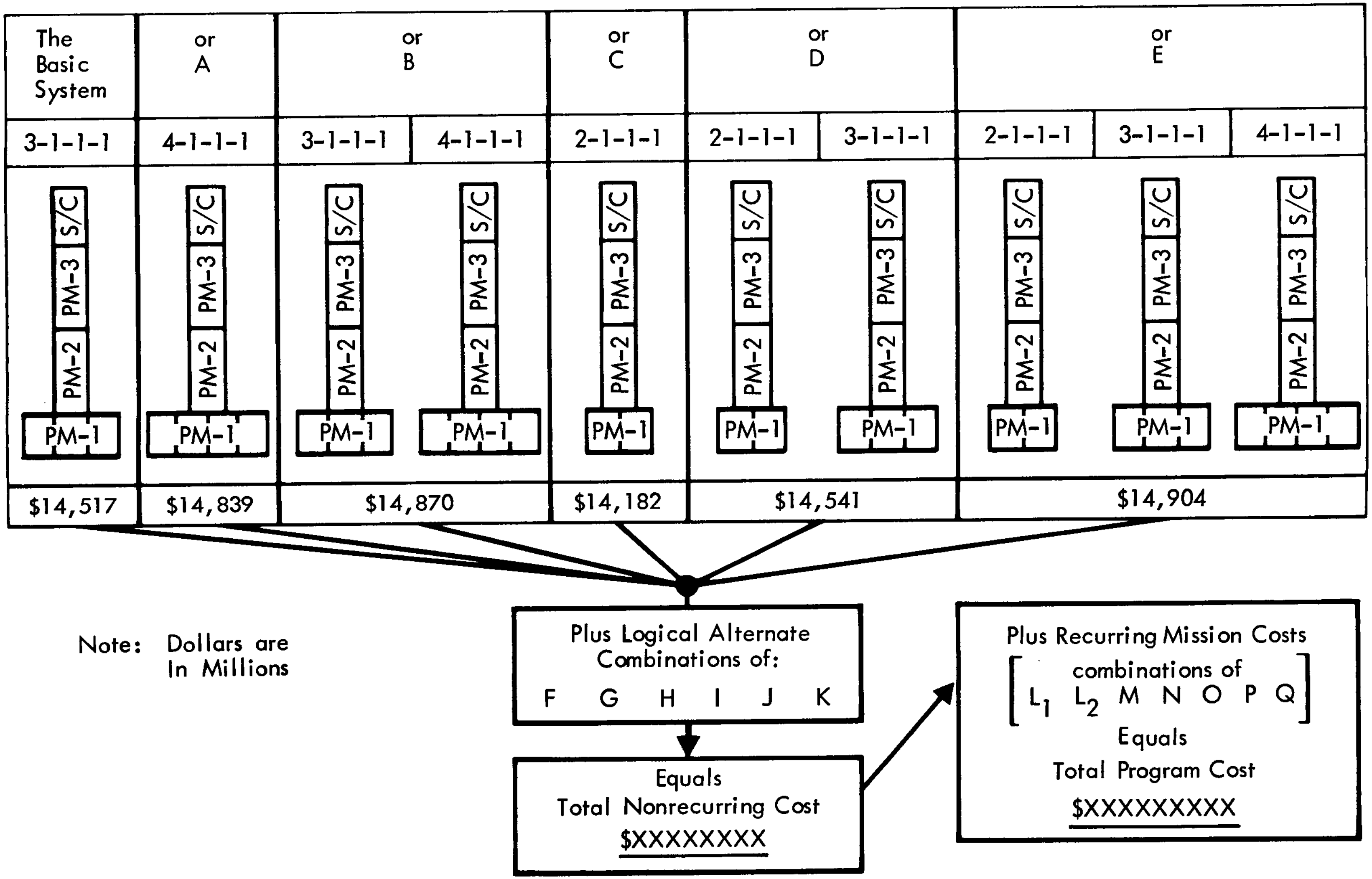
The basic program elements arranged in different configurations and combinations provide a range of conceivable program concepts. The program planner's guide is intended to display some of these elements and combinations to allow tailored systems to be devised by mission analysts. Figure 5.2-15 shows the sequence of application for using this guide. The letters, which are further defined in Table 5.2-2, refer to the individual cost building blocks used in the guide to develop an interplanetary program.

Table 5.2-1 is a "Program Planner's Combination Capability List" and exhibits potential space vehicle combinations that can be used for the 1980 through 1988 Mars/Venus mission opportunities. Potential space vehicle combinations include PM-1 stages (the Earth depart stage) of two, three, and four common propulsion modules tied together. All of the combinations have single PM-2 (planetary capture) and PM-3 (planetary depart) stages. Additional versatility is given to the propulsion elements by fuel transfer systems, i.e., the transfer of fuel from PM-3 to PM-2 and PM-2 to PM-1. The final element is the spacecraft, which in the basic system consists of a mission module (MM) and an Earth entry module (EEM). The Mars excursion module (MEM), and the experiments and probes are treated in this guide as mission dependent alternates.

The "Program Planner's Price List," Table 5.2-2, displays the costs involved in securing element combinations that can be used to build tailored programs. Programs can be priced by adding costs assigned to the alternates that comprise these programs. Costs for the basic system and each of the alternates are further defined on the right side of the table. The costs for the major elements were extracted directly from Figure 5.3-2.

Table 5.2-3, the "Program Planner's Funding Distribution List," allows a reasonable dissemination of funds to be planned to meet a program's financial requirements.

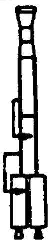
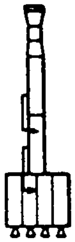
An example of the use of the price list is provided in Exhibit 5.2-1. The basic example mission of the IMISCD study is used to illustrate how total program cost can be generated using the guide.



Note: Dollars are In Millions

Figure 5.2-15: PROGRAM PLANNER'S GUIDE — SEQUENCE OF APPLICATION

Table 5.2-1: PROGRAM PLANNER'S COMBINATION CAPABILITY LIST

MISSION		 2-1-1	 3-1-1	 4-1-1
CLASS	YEAR			
MARS OPPOSITION	82		●	●
	84		●	●
	86	●	●	●
	88		●	●
MARS CONJUNCTION	80	●	●	●
	86	●	●	●
MARS SWINGBY VENUS	75			(5-2-1)
	78			(5-1-1)
	80			●
	82	●	●	●
	84			●
	86			●
VENUS SHORT	80		●	●
	81		●	●
	83	●	●	●
	85	●	●	●
	86	●	●	●
VENUS LONG	80		●	●
	81	●	●	●
	83	●	●	●

RECOMMENDED SYSTEM

Table 5.2-2: PROGRAM PLANNER'S PRICE LIST:

NONRECURRING COSTS (Dollars in Millions)

I. BASIC SYSTEM (VENUS MISSION LESS EXPERIMENTS) - 3-1-1-1 COMBINATION $14,517.1

II. ALTERNATE:			Δ $ ONLY
A	-	For 4-1-1-1 Combination Only	332.0
B	-	For 4-1-1-1 & 3-1-1-1 Mix (A+31.0)	363.0
C	-	For 2-1-1-1 Combination Only	-335.0
D	-	For 2-1-1-1 & 3-1-1-1 Mix	24.0
E	-	For 4-1-1-1 & 3-1-1-1 & 2-1-1-1 Mix	387.0
F	-	For Mars Mission (MEM)	4,857.9
G	-	For Venus Experiments Only	2,782.5
H	-	For Mars Experiments Only **	2,085.8
I	-	For Swingby Experiments Only	1,344.3
J	-	For Venus & Mars Experiments	4,320.6
K	-	For Venus & Mars & Swingby Experiments	4,416.1

RECURRING COSTS (Dollars in Millions)

			TYPICAL MISSION COSTS FOR COMBINATIONS:		
				Q	R
III. MISSION TYPE			3-1-1-1	2-1-1-1	4-1-1-1
N	-	Mars* — Conjunction	2,759.4	2,601.3	2,917.5
M	-	Mars* — Venus Swingby	2,755.7	2,597.6	2,913.8
L_1	--	Venus — Short (Basic Program Example)	2,572.1	2,413.1	2,731.1
O	-	Venus — Long	2,608.7	2,449.7	2,767.7
L_2	-	Mars* — Opposition (Basic Program Example)	2,681.9	2,523.8	2,840.0
P		Mars Orbiter	2,571.2	2,413.1	2,729.3

* Mars missions assume a Venus mission has been run earlier.

** Consists of :

Surface Exp.	220.1
Basic Exp.	310.3
Probes	1555.4

Support For Table 5.2-2

I. BASIC SYSTEM (VENUS MISSION LESS EXPER
(3-1-1-1 Combination)

Nonrecurring Costs

3,581.0		MM
1,721.2		EEM
2,195.0		PM-1
201.0		PM-2
62.0		PM-3
165.5		PM-M
493.2		AEDU
8,415.9		Subtotal
841.6		Space Vehicle Inte and Support
1,711.6		SAT-V-25(S)U
266.6	+ 574.8	SAT-V-25(S)U Cor
124.0		SAT-V
178.6		INT-21
164.0		Saturn-IB
7.9		Atlas-Agena
900.0		T&DA
135.0		Recovery
407.8		Logistics Spacecraf
574.0		ELV
40.8		Assembly Checkout
14,302.6		Subtotal
214.5		Interplanetary Miss Integration and M
14,517.1		Total

II. NONRECURRING ALTERNATE

A. For 4-1-1-1 Combination Only

Flight Test

One Flight Unit + One Spare Needed i

Unit	Qty $/U
PM Module	2 x $31
ELV	2 x 133

CLUSTERING
Three 8,000 lb. = $31.0 }
Four 10,666 lb. = $35.0 } D

Total

B. For 4-1-1-1 and 3-1-1-1 Mix

A + clustering for three modules

$332.0 + 31.0 = $363.0

MENTS)

ration

s Only

& Integration

on System
anagement

Flight Test Program
nit

0	=	$62.0
0	=	266.0
fference		4.0
		$332.0

C. For 2-1-1-1 Combination Only

Flight Test

One less Flight Unit and One Less Spare Needed in Flight Test

Unit	Qty $/Unit		
PM	2 x $31.0	=	-$62.0
ELV	2 x 133.0	=	-266.0
CLUSTERING			
Three 8,000 lb. = $31.0			– 7.0
Two 5,334 lb. = $24.0			
			$-335.0

D. For 2-1-1-1 and 3-1-1-1 Mix

Clustering for two modules
3 Modules - 1 Module = 2 Modules
8,000 lb - 2,666 lb = 5,334 lb (Cluster Wt for 2 Modules)
5,334 lb = $24.0 R&D Cost for 2-1-1-1 Capability

E. For 4-1-1-1 and 3-1-1-1 and 2-1-1-1 Mix

A + Clustering for Two Modules + Clustering for Three Modules
332.0 + 24.0 + 32.0 = 387.0 (Cost for This Mix)

F. For Mars Mission

3,732.9	MEM R&D & Flight Test Units
873.4	Space Vehicle Integration and Support
679.8	-25(S)U Cores for Flight Test
4,786.0	Subtotal
71.8	Interplanetary Missile System Integration & Management
$4,857.9	Δ For Mars Lander Capability

G. For Venus Experiments Only

R&D

$ 449.1	Experiments
$ 1,695.7	Probes
$ 2,144.8	Total

Flight Test

($13.00 + $160.88) 2 = $347.36

Total

$ 2,144.8 + 347.4 = $2,492.2

290.3	Integration & MGT
$2,782.5	Total

H. For Mars Experiments Only

R&D

$ 449.1	Experiments
$ 1,149.7	Probes
$ 1,598.8	Total

Flight Test

($13.00 + $121.70) 2 = $269.40

Total

$ 1,598.80 + $269.40 = $1,868.20

217.6	Integration &
$2,085.8	Total

I. For Swingby Experiments Only

R&D

$ 449.1	Experiments
643.4	Probes
$ 1,092.5	Total

Flight Test

($13.00 + $42.74)2 = $111.48

Total

$ 1,092.5 + $111.5 = $1,204.0

139.3	Integration & MG
$1,344.3	Total

J. For Venus and Mars Experiments

3,869.8	Experiments & Probe R&D
386.9	Space Vehicle Integration & S
4,256.7	Subtotal
63.9	Interplanetary Missile System & Management
4,320.6	Total

K. For Venus & Mars & Swingby Experiments

R&D

$ 449.1	Experiments
$ 2,838.9	Probes
$ 3,288.0	Total

Flight Test

$ ($13.00 + $277.90 + $42.74) 2 = $667.28

Total

$ 3,288.0 + $667.3 = $3,955.3

460.8	Integration & MG
$4,416.1	Total

III. MISSION TYPE RECURRING COSTS

L_1 and L_2 Venus Short and Mars Opposition From the Basic Program Example

M. Mars-Venus Swingby Recurring Cost

$ 250.04	MM
345.90	Experiments and Probes
71.10	EEM

177.10	MEM
240.30	Space Propulsion
108.44	Integration (10%)
911.30	ELV's
236.50	Earth Based Support (60 Days)
374.30	Orbital Support
40.72	Interplanetary Mission System Integration and Management
$ 2,755.70	Total Mission Cost

N. Mars Conjunction Resurring Cost

$ 271.80	MM
269.40	Experiments and Probes
71.10	EEM
177.10	MEM
240.30	Space Propulsion
102.97	Integration (10%)
911.30	ELV'S
300.30	Earth Based Support (1,040 Days)
374.30	Orbital Support
40.78	Interplanetary Mission System Integration and Management
$ 2,759.35	Total Mission Cost

O. Venus Long Recurring Cost (dollars in millions)

$ 277.35	MM
347.40	Experiments and Probes
79.00	EEM
251.50	Space Propulsion
$ 955.25	Subtotal
95.50	Integration
911.30	ELV's
260.78	Earth Based Support (800 Days)
374.30	Orbital Support
38.55	Interplanetary Mission Integration and Management
$ 2,608.68	Total Mission Cost

P. Mars Orbiter Recurring Cost (dollars in millions)

3-1-1-1 Combination

$ 268.3	Mission Module
347.4	Experiments and Probes (Like Venus)
71.1	Earth Entry Module
240.3	Space Propulsion
92.7	S/V Integration of Vehicle Support
911.3	Earth Launch Vehicles
227.9	Earth-Based Support (Like Mars Opposition)
374.3	Orbital Support
37.9	Interplanetary Mission System Integration and Management
$ 2,571.2	Total Mission Cost (Less than Venus short due to learning curve effect; Venus mission has been run previously.)

Mars Mission

Recurring Costs Assuming a Venus Mission has Been Flown Earlier

(Recurring Costs that Must be Added or Subtracted from 3-1-1-1 Combination to Accommodate 2-1-1-1 and 4-1-1-1 Combination)

Space Propulsion and ELV's

Q. Venus

2-1-1-1 Combination

Subtract one PM and one ELV

$ - 26.0	PM
$ - 133.0	ELV
$ - 159.0	Total

Mars

2-1-1-1 Combination

Subtract one PM and one ELV

$ - 25.1	PM
$ - 133.0	ELV
$ - 158.1	Total

R. Venus

4-1-1-1 Combination

Add one PM and ELV

$ + 26.0	PM
$ +133.0	ELV
$ +159.0	Total

Mars

4-1-1-1 Combination

Add one PM and ELV

$ + 25.1	PM
$ +133.0	ELV
$ +158.1	Total

Table 5.2-3: PROGRAM AND MISSION PLANNER'S FY FUNDING DISTRIBUTION LIST

NONRECURRING COSTS - % DISTRIBUTION:

									DEMONSTRATION TEST ▽		
IF VENUS IS FIRST MISSION		3	8	13	14	16	18	14	9	4	1
									DEMONSTRATION TEST ▽		
IF MARS IS FIRST MISSION		2	7	11	12	17	18	17	11	4	1
										MISSION LAUNCH ▽	
Δ IF MARS IS SUBSEQUENT MISSION	3	8	14	19	24	19	7	3	2	1	
										MISSION LAUNCH ▽	
Δ IF VENUS IS A SUBSEQUENT MISSION				3	24	28	24	18	2	1	

RECURRING COSTS - % DISTRIBUTION
(PER MISSION COSTS)

	▼				▽ MISSION LAUNCH			
VENUS SHORT MISSION	5	21	45	20	5	4		
	▼							
VENUS LONG MISSION	9	24	27	20	13	5	2	
	▼							
MARS OPPOSITION MISSION	10	26	40	14	7	3		
	▼							
MARS CONJUNCTION MISSION	9	24	26	20	12	4	4	1
	▼							
MARS SWINGBY MISSION	9	24	27	21	13	5	1	

▼ DEMONSTRATION TEST FOR FIRST MISSION ONLY

EXHIBIT 5.2-1

Program Planner's Price List

Example Problem:

The price list can be used to find the costs of the basic program considered in the IMISCD study.

Nonrecurring Costs:

● Basic system	$14,517.1
● Alternate (see Table 5.2-2)	
F. For MEM	4,857.9
J. For Venus and Mars Experiments	4,320.6
Total	$23,695.6

Recurring Costs:

● Venus short	$ 2,572.1
● Mars opposition	2,681.9
Total Program Cost	$28,949.6

5.3 COSTING METHODOLOGY

The following sections define and support the IMISCD program cost estimate.

Section 5.3.1, *Work Breakdown Structure with Element Costs*, identifies and defines the elements of the IMISCD program that are costed. Each element and each cost category is described.

Section 5.3.2, *Element Cost Breakdown*, presents the estimates of each element identified on the IMISCD work breakdown structure. All inputs that build up to the cost of an element are tabulated in this section.

Section 5.3.3, *Costing Tools*, brings forward the tools needed for estimating, and describes the techniques used to develop these tools.

5.3.1 WORK BREAKDOWN STRUCTURE WITH ELEMENT COSTS

To facilitate total costing, a work breakdown structure was developed to identify program elements. Costs associated with each program element were then developed and displayed on a program cost summary by element.

All elements and cost categories associated with the program are defined in this section.

5.3.1.1 IMISCD Work Breakdown Structure (WBS)

The IMISCD WBS (Figure 5.3-1) displays the building blocks of the interplanetary mission system. Costs are developed using this building block approach. Level Zero, total program cost, comes from accumulating the costs of the lower levels. The lowest level being Number Five, Module Subsystems.

Level Four consists of the mission module, experiments and probes, EEM, Mars excursion module, the propulsion modules, midcourse correction stages, and Assembly and Docking Units. These were built up from Level Five.

Level Three consists of spacecraft, the space propulsion system, space vehicle integration and support, various launch vehicles, and the elements of the logistic system.

Level Two defines the space vehicle to include the spacecraft, the space propulsion system and space vehicle integration and support. The launch vehicle category fits in at this level along with the logistic system and the elements that make up Earth based support.

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
INTERPLANETARY MISSION SYSTEM	Aerospace Vehicle	Space Vehicle	Spacecraft	Mission Module	Structures and Mechanical Equipment
					Environmental Control
					Electrical Power
					Communications and Data Handling
					Attitude Control
					Guidance and Navigation
					Crew Systems - Life Support
					Assembly, Checkout, and Integration
					Vehicle Support
					Mission Module Interstage
				Experiments and Probes	
				Earth Entry Module	Structures and Mechanical Equipment
					Environmental Control
					Electrical Power
					Commmunications and Data Handling
					Attitude Control
					Guidance and Navigation
					Crew System - Life Support
					Terminal Recovery System
					Experiments
					Assembly, Checkout and Integration
					Vehicle Support
				Mars Excursion Module	Structures and Mechanical Equipment
					Environmental Control
					Electrical Power
					Communications and Data Handling
					Attitude Control
					Guidance and Navigation
					Crew Systems - Life Support
					Propulsion
					Terminal Recovery System
					Experiments
					Assembly, Checkout, and Integration
					Vehicle Support
					MEM Interstage
			Space Propulsion System	Propulsion Module (EDS) PM-1	Structures and Equipment
					Engine System
				Propulsion Module (PCS) PM-2	Structures and Equipment
					Engine System
				Propulsion Module (PDS) PM-3	Structures and Equipment
					Engine System
				Midcourse Correct PM-M	Structures and Equipment
					Engine System
				Assembly and Docking Units A&DU	Structures and Equipment
					Engine System
			Space Vehicle Integration and Support		
		Launch Vehicles	Int-21		
			SAT-V-25(S)U		
			SAT-V/4-260 SRM		
	Earth Based Support	Tracking and Data Management			
		Recovery			
	Orbital Support	Logistic System	Spacecraft		
			Earth Launch Vehicle		
			Assembly, Checkout, Integration and Support		
	Interplanetary Mission System Integration and Management				

*Level 5 costs are displayed in Section 5.5.4, Element Cost Breakdown.

Figure 5.3-1: INTEGRATED MANNED INTERPLANETARY SPACECRAFT CONCEPT DEFINTION (IMISCD)

Level One consists of four broad categories: (1) the aerospace vehicle, which contains all the equipment to lift to orbit the mission systems and the equipment needed to make the interplanetary trip; (2) the support that is provided from the Earth; (3) the support that is required for assembling and manning the expedition in orbit; and (4) the overall interplanetary mission system integration and management.

This work breakdown structure forms the cost breakdown structure used for delineating manageable cost areas.

5.3.1.2 Definitions of Vertical Elements on IMISCD Work Breakdown Structure to Lowest Level Shown

Spacecraft

Structures and Mechanical Equipment---The structure subsystem includes the external spacecraft structure and fittings, supporting members, aerodynamic surfaces, heat and radiation shields, partitions and flooring, windows and hatches, docking structures, all accessways for equipment and personnel, and separation provisions.

Environmental Control---This subsystem controls the atmosphere and temperature inside the spacecraft. It removes the carbon dioxide and water vapor generated by man along with lesser amounts of hydrogen, methane, dusts, and microorganism. It also maintains a suitable temperature for efficient operation of man and instruments.

Electrical Power---This subsystem includes all equipment which generates, converts, controls, and distributes electrical power within the spacecraft. Power sources can include batteries, fuel cells, and isotopes.

Communications and Data Handling---This subsystem includes the equipment providing the audio, visual, and telemetry links between one spacecraft and another and Earth. It includes such equipment as radio and television transmitters and receivers, recorders, and antennas.

Instrumentation is also included in the communication and data handling category. This equipment converts physical parameters into electrical signals suitable for recording, displaying, or transmitting.

Attitude Control---This subsystem maintains the correct orientation of the spacecraft. Reaction control, momentum storage, and spin stabilization are the more common methods used to maintain this orientation.

Guidance and Navigation---This subsystem includes all items of equipment contributing directly to the sensing, computation, display, and command functions required to determine, select, and pursue a given course.

Crew Systems-Life Support---This subsystem provides equipment for life sustenance and crew comfort in the spacecraft and during extravehicular operations. The system includes a spacesuit for EVA and life support in an unpressurized environment. The system also supplies provisions and facilities necessary for the routine functions of eating, drinking, sleeping, body cleansing, elimination of wastes, and cleaning of garments.

Propulsion---This subsystem provides velocity change capability to the spacecraft. It is not used for orientation (attitude control), but contributes the prime means of propelling or slowing the spacecraft.

Terminal Recovery System---This subsystem provides landing capability for the spacecraft. It can consist of retrorockets, parachutes, ballutes, landing legs, or other landing devices used singly or in any combination necessary to secure a soft landing in a particular environment.

Experiments---Equipment used for scientific examination of the space environment, the planets and their atmospheres as encountered on these missions is included in this classification. Experiment descriptions can be found in the technical body of this document.

Assembly, Checkout, and Integration---This cost category represents the effort needed to assemble the subsystems into a working vehicle system. It includes the necessary integration effort needed to make all systems technically compatible and capable of meeting the desired performance levels. The vehicle ground testing needed to verify system workability is also included in this category.

Vehicle Support---This category includes the costs of equipment and effort directed to each individual spacecraft at the launch site, its associated ground support equipment, the training required to operate the vehicle, and spacecraft component spares.

Mission Module-Interstage---Structural components form the outer shell, supporting the MM and the EEM, and are carried throughout the entire trip up to Earth entry.

Mars Excursion Module Interstage---This structure houses the MEM and probes and is staged at Mars for the Mars configuration; it also houses the probes in the Venus configuration and is staged at Venus.

Space Propulsion System

Structures and Equipment---This covers all hardware, software, assembly, checkout, integration, and component spares associated with the propulsion module, including engine integration and mating but excluding the engine itself. Included is all propellant tankage and plumbing.

Engine System---This system includes the basic engine and all assembly, checkout, and component spares.

Space Vehicle

Space Vehicle Integration and Support---This effort encompasses the integration activities of the complete space vehicle including the Earth launch booster, propulsion modules, and all spacecraft. It includes GSE, checkout, and assembly of the entire space vehicle system.

Launch Vehicles

This categorization includes hardware, launch vehicle integration, management effort, and vehicle launch operations for each of the following vehicles.

Int-21---An intermediate size Saturn family boost vehicle.

Saturn V-25(S)U---An uprated Saturn family boost vehicle with strap-on solid boost assist motors.

SAT-V-25(S)U (Family)---This is an uprated Saturn V launch vehicle used with or without 156-inch solid strap-on rocket motors. The core is a two-stage version of the Saturn V with increased stage lengths and uprated F-1 and J-2 engines. If the strap-on rockets are not used, the configuration can include a standard S-IVB third stage.

Atlas-Agena D---The Atlas-Agena D booster is a two-stage vehicle consisting of a liquid Atlas first stage and liquid Agena D second stage.

Saturn V---This is the three-stage booster designed for the Apollo program.

Earth Based Support

Tracking and Data Management---This classification includes all Earth-spacecraft tracking, communication, and telemetry operations. Real time data analysis, data evaluation, and data storage for later evaluation is also included in this effort.

Recovery---This category accounts for the physical recovery of Earth-returning spacecraft and crews.

Orbital Support

Spacecraft---This item includes the logistics spacecraft used in orbital assembly and manning operations.

Earth Launch Vehicle---This category refers to the boost vehicle used to lift the logistic spacecraft to the orbital assembly altitude.

Assembly, Checkout, Integration, and Support---This classification accounts for the effort of assembling, integrating, and checking out of the complete booster/spacecraft logistic vehicle. It includes GSE for the entire logistic system.

Interplanetary Mission System Integration and Management---This category covers the effort that runs through the entire interplanetary mission program. Activities include: continuous assessment of overall reliability encompassing all spacecraft, boosters, propulsion modules, ground equipment, personnel, operations, and checkout procedures; assuring intelligible communications between government and industry participants; developing common methods, procedures, and standards for all major systems; and searching for problems that may be going unnoticed.

5.3.1.3 Program Cost Summary By Element

The program cost summary, Figure 5.3-2, exhibits the costs defined on the IMISCD work breakdown structure through Level Four.

Total program design, development, and demonstration costs by element and in total are displayed and broken into research and development and flight test program categories. Venus short and Mars opposition mission costs are also presented in this summary. Finally, total costs for each element and a grand total is given in the last column.

5.3.1.4 Definition of Horizontal Columns in Program Cost Summary by Element

R&D Cost - Column 1---This category covers all costs from program inception to that point in time where the first flight configured vehicle is ready for production, plus all costs thereafter not a function of, or related to, the number of units produced. Included in this category are ground test units, associated testing, subsystem integration, GSE and launch site support development, and training associated with the use of the vehicle and spares development.

Number of Flight Units - Column 2---This category represents the number of units scheduled for development flight tests, qualification and demonstration test programs.

Number of Spares - Column 3---This entry shows the number of complete standby units that can be used as substitutes for scheduled flight articles.

Dollars/Unit - Column 4---This gives the estimated dollar value per unit.

- For spacecraft (MM, EEM, MEM) in the flight test program, this dollar amount is the same as the vehicle's number one cost. No learning curve is applied to these first flight test articles. Spacecraft used after the flight test program (mission articles) are run down a 90% learning curve.

	DESIGN DEVELOPMENT & DEMONS				
	R&D Cost	FLIGHT TEST PROGRAM			
		Flight Units	Stand-bys	Dollars per Unit	Tota Test
Column Number	1	2	3	4	
Interplanetary Mission System					
Aerospace Vehicle					
Space Vehicle					
Spacecraft					
Mission Module	$ 3,049.0	2	1	177.3	$ 5
Experiment & Probes	3,288.0	1	1	290.9	5
Earth Entry Module	1,457.7	4	1	52.7	2
Mars Excursion Module	2,906.2	6	1	118.1	
	$10,700.9				$2,2
Space Propulsion System					
PM-1 (EDS)	$ 2,040.0	3	2	31.0*	$ 1
PM-2 (PCS)		4*/2**	1		2
PM-3 (PDS)		1	1	23.0**	
PM-M Midcourse Correct & Orbit Trim	140.0	7	1	2.8	
Assembly & Docking Unit	355.9	7	1	17.2	
	$ 2,535.9				$ 5
Space Vehicle Integration & Support	$ 1,323.7				$ 2
Earth Launch Vehicles					
SAT-V-25(S)U (With S/O OR S-IVB)	$ 248.6	10	1	133.0	$1,
SAT-V-25(S)U Core Only	574.8	8		113.3	9
SAT-V		1		124.0	
SAT-V-INT-21		2		89.3	
Saturn IB		4		41.0	
Atlas-Agena		1		7.9	
	$ 823.4				$2,
Earth Based Support					
Tracking & Data Management					$ 9
Recovery					
					$1,0
Orbital Support					
Logistic Support					
Spacecraft		13	1	62.7/15.7	$ 4
Earth Launch Vehicle		13	1	41.0	
Assembly, Checkout, Integration, & Support					
					$1,0
Interplanetary Mission System					
Integration & Management	$ 230.8				$
Total Program	$15,614.7				$8,

* Complete ** Less Engines

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FOLDOUT FRAME 1

TRATION		INTERPLANETARY MISSIONS								Total Program Cost
	Total Cost	VENUS SHORT				MARS OPP				
Cost		Flight Units	Stand-bys	Dollars per Unit	Total Mission Cost	Flight Units	Stand-bys	Dollars per Unit	Total Mission Cost	
5	6	7	8	9	10	11	12	13	14	15
32.0	$ 3,581.0	1	0.5	176.1	$ 264.8	1	0.5	178.9	$ 268.3	$ 4,114.1
81.8	3,869.8	1	1	173.7	347.4	1	1	134.7	269.4	4,486.6
63.5	1,721.2	1	0.5	52.7	79.0	1	0.5	47.7	71.1	1,871.3
26.7	3,732.9	1					0.5	118.1	179.1	3,910.0
04.0	$12,904.9				$ 691.2				$ 785.9	$14,382.0
55.0	$ 2,195.0	3	0.5		$ 91.0	3	0.5		$ 88.0	$ 2,374.0
01.0	201.0	1	0.25	26.0	32.5	1	0.25	25.1	31.4	264.9
62.0	62.0	1	0.25		32.5	1	0.25		31.4	125.9
22.5	162.5	3	1	2.2	8.8	3	1	2.1	8.4	179.7
37.3	493.2	5	1	14.5	86.7	5	1	13.5	81.1	661.0
77.8	$ 3,113.7				$ 251.5				$ 240.3	$ 3,605.5
78.2	$ 1,601.9				$ 94.3				$ 102.6	$ 1,798.8
63.0	$ 1,711.6	5	1	133.0	$ 798.0	5	1	133.0	$ 798.0	$ 3,307.6
06.4	1,481.2	1		113.3	113.3	1		113.3	113.3	1,707.8
24.0	124.0									124.6
78.6	178.6									178.6
64.0	164.0									164.0
7.9	7.9									7.9
43.9	$ 3,667.3				$ 911.3				$ 911.3	$ 5,489.9
00.0	$ 900.0				$ 209.5				$ 225.9	$ 1,335.4
35.0	135.0				2.0				2.0	139.0
35.0	$ 1,035.0				$ 211.5				$ 227.9	$ 1,474.4
07.8	$ 407.8	4	1	41.0	$ 172.5	4	1	41.0	$ 172.5	$ 752.8
74.0	574.0	4	0.5		184.5	4	0.5		184.5	943.0
40.8	40.8				17.3				17.3	75.4
22.6	$ 1,022.6				$ 374.3				$ 374.3	$ 1,771.2
119.4	$ 350.2				$ 38.0				$ 39.6	$ 427.8
080.9	$23,695.6				$2,572.1				$2,681.9	$28,949.6

Figure 5.3-2: PROGRAM COST SUMMARY BY ELEMENT (dollars in millions)
(Basic Program Example)

- For propulsion modules (PM-1, PM-2, PM-3, PM-M, A&DU) the unit cost varies with the number of modules built. A 90% learning curve is applied.
- For Earth launch vehicles (Int-21, Saturn V-25 (S)U, Saturn V, S-1B, Atlas-Agena) the dollar value is the average unit cost over the total number of ELV's used in the program.

Total Test Cost - Column 5---This category includes test hardware costs and all other expenditures in the flight test programs and includes space vehicle integration and support, Earth based support, orbital support, and interplanetary mission system integration and management.

Total Nonrecurring Cost - Column 6---This category includes all costs incurred in the design, development, and demonstration of interplanetary mission system elements.

Flight Units - Columns 7 and 11---These columns show the number of units of each type that are used in the Venus and Mars missions.

Standbys - Columns 8 and 12---This entry shows the number of equivalent complete units allocated as standby units that can be subtituted for the scheduled flight articles of each mission.

Unit Cost - Columns 9 and 13---Cost per unit for mission elements is shown in these columns.

Total Cost - Columns 10 and 14---These columns include all hardware cost, space vehicle integration and management, Earth based support, orbital support and interplanetary mission system integration, and management cost associated with a Venus or Mars mission.

Program Cost - Column 15---All design, development, demonstration, and mission costs incurred for the entire manned interplanetary mission program are included here. Figure 5.3-2 portrays the total for the two mission example.

5.3.2 ELEMENT COST BREAKDOWN

The detailed estimates for spacecraft, space propulsion systems, and Earth launch vehicles are presented in this section.

Earth based support is broken down into constituent elements. The approach for applying this activity to programs of varying length is described.

The logistic spacecraft system required for orbital support is explained, and the method of pricing is shown. Costs for spacecraft refurbishment are also presented.

The task of interplanetary mission system integration and management is discussed and the allowance provided is described in this section.

The allowance for space vehicle integration and support with its application to the program is also explained along with experiment and probe estimates for Venus and Mars missions.

The element cost breakdown by subsection number is as follows:

5.3.2.1	Mission Module and Interstage Structure
5.3.2.2	Experiments and Probes
5.3.2.3	EEM
5.3.2.4	MEM
5.3.2.5	Space Propulsion
5.3.2.6	Space Vehicle Integration and Support
5.3.2.7	ELV's
5.3.2.8	Earth Based Support
5.3.2.9	Orbital Support
5.3.2.10	Interplanetary Mission System Integration and Management

Estimates for these units are developed by:

1) Pricing the selected subsystems;
2) Adding the costs of the effort required to install and integrate these subsystems into a system;
3) Adding the costs of ground testing the system;
4) Applying vehicle support costs consisting of launch site support, ground support equipment, the spares complement, and personnel training.

Intrinsic to these estimating procedures are all costs of direct and indirect labor, general and administrative (G&A) costs, and contractor fees. Costs include all materials, purchased equipment, tooling, special test equipment and contractor burden.

5.3.2.1 Mission Module and Interstage Structure

The mission module cost estimates are displayed on Tables 5.3-1 and -2. The cost variations shown for alternate mission configurations are dependent on mission duration.

Plutonium 238 is used as the heat source of the mission modules electrical system. Fuel cost per thermal watt is used to calculate the cost of Pu-238 in the module. Our current estimate is $530 per thermal watt. The MM for the Mars mission example is priced assuming Pu-238 will be available from a test program flight or standby unit.

Table 5.3-1: MISSION MODULE COST ESTIMATE

- Nonrecurring Costs from Mars 1986 Conjunction Configuration
- Spares Development is Excluded
- Six Men - 1,070 Days (1986 Conjunction), 510 Days (1984 Opposition)

		Cost (millions)					
			Recurring				
Subsystem	Weight	Non Recurring	Mars Opposition	Mars Conjunction	Mars Swingby	Venus Short	Venus Long
Structure	19,910	102.0	12.50	14.90	12.70	12.30	13.80
ECS/Life Support	9,140	392.0	6.20	7.80	6.32	6.08	7.22
Crew Systems/Life Support	2,830	115.0	8.75	11.60	8.60	7.70	10.04
Communications & Data Handling* Display and Controls	1,370 510	595.0	13.76	13.76	13.76	13.76	13.76
Attitude Control	1,380	96.4	2.58	2.58	2.58	2.58	2.58
Guidance and Navigation	140	54.0	2.52	2.52	2.52	2.52	2.52
Electrical Power (Isotope Brayton)	11,440	101.4	4.90	4.90	4.90	4.90	4.90
Spares	9,220	-	11.46	11.46	11.46	11.46	11.46
Growth and Contingency	17,060	531.5	21.21	21.21	21.21	21.21	21.21
Experiments			Costed Separately				
Subtotal		$1,987.3	$ 83.88	$ 90.73	$ 84.05	$ 82.51	$ 87.49
NDVC		$ 437.0	$ 20.15	$ 21.77	$ 20.20	$ 19.82	$ 20.98
Vehicle Support		534.0	36.42	39.40	36.48	35.80	38.00
Total Less PU-238		$2,958.3	$140.45	$151.90	$140.73	$138.13	$146.47
Fuel Cost, PU-238 + (Purchased)			$ 37.10	$ 37.10	$ 37.10	$ 37.10	$ 37.10
Total		$2,958.3	$177.55	$189.00	$177.83	$175.23	$183.57

*780 pounds is Laser System

Table 5.3-2: MM INTERSTAGE ESTIMATES (dollars in millions)

	R&D	Recurring				
		Mars Opposition	Mars Conjunction	Mars Swingby	Venus Short	Venus Long
Interstage	$61.0	$ 8.20	$ 8.20	$ 8.20	$8.20	$8.20
NDVC	13.4	1.94	1.94	1.94	1.94	1.94
Vehicle Support	16.3	3.56	3.56	3.56	3.56	3.56
Total	$90.7	$13.70	$13.70	$13.70	$13.70	$13.70

Total mission module costs in millions of dollars used for the basic example are as follows:

Venus	\$138.13	Mission module without PU-238
	13.70	Mission module interstage
	\$151.83	Total mission module without PU-238
	$\frac{151.83}{2}$	= \$75.91 Spare (50% Spare Philosophy)
	175.23	Mission module with PU-238
	13.70	Mission module interstage
	188.93	Total mission module with PU-238
	188.93	Complete MM
	75.91	MM Spare
	\$264.84	Total cost for mission module in Venus program
Mars	\$140.45	
	13.70	
	154.15	without PU-238
	$\frac{154.15}{2}$	= \$77.07 (Spare)
	191.25	Mission module with PU-238
	191.25	Complete MM
	77.07	MM Spare
	\$268.32	Total mission cost for Mars module complement

5.3.2.2 Probes and Experiments Cost

A variety of experiment packages and instrumented probes are planned for the interplanetary missions. The diversity of functions these equipments perform dictate a broad range of physical and electrical requirements.

Instead of discrete units the equipment is categorized by functional characteristics and this is the way it is priced.

Probes are conceived of as structural envelopes with flight systems housing instruments. Many are small spacecraft in themselves.

It is noted that the concept of recurrring cost must be applied cautiously to this probe and experiment category. Exact duplication of experimental equipment for subsequent missions is not generally experienced. Refinements in equipment and changes in emphasis usually result in modification. This estimate assumes new equipment changes will not be extensive redesigns, but modifications within the limits of the present design, precluding large engineering costs.

A summary of the basic two mission R&D and unit costs (in millions of dollars) for experiments and probes is as follows:

● Experiment R&D	$368.1	
System Installation and Integration (SI&I) and Ground Testing	81.0	
Total	449.1	
● Experiment number one	10.48	
SI&I and Ground testing	2.52	
	13.00	
● Probe total R&D, Mars and Venus (See Probe Cost Summaries, Table 5.4.2-2)		2,838.9
● Probe complement recurring (See Probe Cost Summaries, Table 5.4.2-2)		
Venus	160.68	
Mars	121.70	
● Demonstration Program		13.00
Experiment and probe dollars/unit		277.90
		290.90

● Mission Costs	Recur Exp	Recur Probes	Total
Venus mission	$13.00 +	160.68 =	$173.58*
Mars mission	$13.00 +	121.70 =	$134.70*

*The detailed cost estimates are shown in Tables 5.3-3, -4, and -5.

Table 5.3-3: PROBES AND EXPERIMENTS SUMMARY

Total Cost

Experiments

449.1	R&D
13.0	Test
13.0	
13.0	Venus mission
13.0	
13.0	Mars mission
13.0	
527.1	

Orbiters

2,005.6	R&D
216.8	Test
216.8	
133.0	Venus mission
133.0	
83.8	Mars mission
83.8	
2,872.8	

ION Probes

7.0	R&D
4.4	Test
4.4	
4.4	Venus mission
4.4	
4.4	Mars mission
4.4	
33.4	

Hard Landers

42.7	R&D
9.0	Test
9.0	
9.0	Mars mission
9.0	
78.7	

Soft Landers

783.1	R&D
47.6	Test
47.6	
23.2	Venus mission
23.2	
24.4	Mars mission
24.4	
973.5	

Table 5.3-4: PROBES --- COST SUMMARY

Mars Orbiters --- Requirements for Each Mission

Probe	Quantity	Inside* Instrument	Probe Envelope	Cost (millions) R&D+	Recurring
#1	2	Occulation Detector	Weight 100 lb Cylinder	24.5	1.481
#2	2	Topside Sounder	Weight 155 lb Cylinder	31.0	2.331
#3	2	Magnetometer	Weight 100 lb Cylinder	21.2	1.541
#4(a)	2	Television	Weight 2,600 lb	396.5	14.38
(b)	2	Television	Weight 3,305 lb	19.0	16.74
#5	1	Mapping Radar	Weight 1,415 lb Cylinder	212.7	10.96

Venus Orbiters --- Requirements for Each Mission

Probe	Quantity	Inside* Instrument	Probe Envelope	Cost (millions) R&D+	Recurring
#1	2	Cloud Data Probe	Weight 1,500 lb Cylinder	230.3	10.30
#2	2	Atmospheric Drifter	Weight 775 lb Cylinder	315.1	9.424
#3	2	Mapping Radar	Weight 11,575 lb Cylinder	427.0	37.03
#4	2	Radio Frequency Window Probe	Weight 825 lb Cylinder	328.3	9.759
#5	2	Soft Lander	Weight 2,370 lb	388.0	11.61

*Cost the same as Experiments - use only recurring cost, if instrument has already been developed in experiment package.

+ Reflects:
1) Envelope R&D.
2) Instrument R&D if instrument has not been developed in experiment package.
3) Instrument - Envelope Integration.

Table 5.3-4: PROBES --- COST SUMMARY (Continued)

Engineering Probes - Mars - Precursor to Mars Landing

		Inside*	Probe	Cost	(millions)
Probe	Quantity	Instruments	Envelope	R&D+	Recurring
Hard Lander	5	Tracking Transponder	Weight 330 lb	42.7	1.798
Soft	2	Weather Station Instrument Package Like Surveyor	Weight 3,335 lb	395.1	12.18

Ion Probes (Intransit Probes) - Interplanetary

		Inside*	Probe	Cost	(millions)
Probe	Quantity	Instruments	Envelope	R&D+	Recurring
Ion Dispersion Device	20	Ion Dispersion Device	Weight 15 lb Cylinder	7.0	0.220

Venus Probes for Swingby

		Inside*	Probe	Cost	(millions)
Probe	Quantity	Instruments	Envelope	R&D+	Recurring
#1	2	Atmospheric Biprobe Drifter	Weight 775 lb Cylinder	315.1	9.424
#2	2	Radio Frequency Window Probe	Weight 825 lb Cylinder	328.3	9.759

*Cost the same as Experiments - use only recurring cost, if instrument has already been developed in experiment package.

\+ Reflects:
1) Envelope R&D.
2) Instrument R&D if instrument has not been developed in experiment package.
3) Instrument - envelope integration.

Table 5.3-5: MARS AND VENUS EXPERIMENTS COST ESTIMATE

Instrument Class	Mass (Pounds)	Mass (Kilograms)	Power (Watts)	Volume (Cubic feet)	Mounting	Pointing Accuracy	Peak Data Rate (Kbs/sec)	Cost (Millions)* R&D**	Cost (Millions)* Recurring**
UV Spectrophotometer	35	15.9	40	3.0	Scan Platform	0.02-0.05 deg/sec	10-20	11.0	0.21
IR Spectrophotometer	55	25	48	7.0	Scan Platform	0.02-0.5 deg/sec	10-20	15.8	0.26
Vis Spectrophotmeter	100	45.4	50	2.0	Scan Platform	0.02-0.5 deg/sec	1.5	25.8	0.32
UV Interferometer	55	25	30	1.0	Scan Platform	0.01 deg/sec	10-20	15.8	0.26
Vis Interferometer	50	22.7	30	1.2	Scan Platform	0.01 deg/sec	2.0	14.5	0.24
IR Interferometer	50	22.7	25	2.0	Scan Platform	0.01 deg/sec	2.0	14.5	0.24
Gamma-ray Spectrometer	300	136.4	190	360	Scan Platform	0.05 deg/sec	0.1	62.9	0.52
IR Radiometer Scanner	55	25	48	2.1	Scan Platform	0.02-0.5 deg/sec	10-20	15.8	0.26
RF Radiometer Scanner	60	27.3	55	3.9	Scan Platform	0.02 deg/sec	19	5.1	0.23
RF Noise Detector	40	18.2	40	2	Spacecraft Outside	±1°	3	4.0	0.17
Photometers	10	4.5	2	0.2	Scan Platform	±1°	0.1	4.3	0.13
Television	18	8	30	0.04	Camera on Scan Platform	±1°	$5x10^3$	6.6	0.16
Photographic System	2000		30	23.0	Scan Platform	±.5°	60,000 Photos	64.4	3.03
IR Mapping	100	45.4	70	7.0	Scan Platform	0.1°	7.2	25.8	0.32
Radar Mapping	420	191	550	13.0	Scan Platform	0.050 yaw - 1° pitch and roll	$1.8x10^5$	18.4	1.34
Radiometer	100	45.4	200	27	Scan Platform	±25°	0.72	7.0	0.34
Radar Altimeter	50	22.7	220	18	Spacecraft	±1° $4x10^6$	1.7x10	4.3	0.20
Tracking and Ranging R	290	131.8	485	8	Tracking Platform	±10°	1.2x10	14.8	0.92
Magnetometer	6	2.7	7	0.2	Spacecraft Boom	Spacecraft	0.02	6.1	0.18
Charged Particle Detector	50	22.7	15	1.0	Spacecraft Boom	Spacecraft	0.10	13.6	0.47
Micrometeroid Detector	20	9.1	10	1.0	Spacecraft Body	Spacecraft	0.01	2.5	0.12
Polarimeters	20	9.1	10	2.0	Scan Platform	0.01 deg/sec	0.01	7.2	0.18
Topside Sounder	120		6	1.3	Spacecraft Planet Viewing	±10	10	7.9	0.38

5.3.2.3 Earth Entry Module

The Earth entry module basic R&D and number one cost estimates are displayed on Table 5.3-6. The EEM as priced is a completely new biconic vehicle designed for the maximum reentry velocities expected upon return from an interplanetary mission. This EEM once developed will be usable without modification for any of the Mars-Venus missions studied. The following is a summary of the cost developed for the basic mission example.

Basic R&D			$1,457.7
Flight Test Program			
Orbital Qualification	3 Units	$158.1	
Demonstration	1 Unit	52.7	
Standby	1 Unit	52.7	263.5
Venus short	1.5 Units		79.0
Mars opposition	1.5 Units		71.1
Total			$1,871.3

The fractional units costed are for mission standby requirements. A 90% learning curve is used starting with the Venus mission.

Table 5.3-6: EARTH ENTRY MODULE COST ESTIMATE

Six Man Crew
V_e = 60,000 fps
Occupancy Time = One Day

		Cost (millions)	
Subsystem	Weight (pounds)	R&D	No. 1*
Crew and Seats	1,362	$ 28.5	$ .30
Controls	270		
Communications	185	92.0	2.94
Guidance and Navigation	300	115.0	4.20
Science (Samples)	912	-	-
Life Support (ECS)	732	47.0	.93
Electrical Power	659	187.0	3.10
Attitude Control	1,120 (Wet) 136 (Dry)	32.0	.50
Recovery	870	8.8	1.27
Heat Shield	4,340	In Structure	
Structure	4,160	340.0	13.60
Growth and Contingency	2,240	146.4	4.62
Subtotal		$996.7	$31.46
NDVC		$192.2	$ 7.56
Vehicle Support		268.8	13.65
TOTAL		$1,457.7	$52.67

*For Recurring Cost, use weights for Mars opposition 1984 configuration.

5.3.2.4 Mars Excursion Module

The Mars excursion module basic R&D and number one cost estimates are displayed on Tables 5.3-7 and -8. The basic program example is priced assuming flight test and one and one-half mission units (including standby's). The learning curve was not used in pricing the basic two mission example, but a 90% learning curve would be applicable for pricing MEM's for subsequent missions.

Table 5.3-7: MARS EXCURSION MODULE COST ESTIMATE

- Three Men — Thirty Days on Surface

SUBSYSTEM	Weight	COST (MILLIONS) R&D	No. 1
ASCENT CAPSULE	(5,590)		
Crew Systems	500	$ 62.0	$ 1.3
Life Support	90	In Crew Systems	
RCS	520	66.0	1.3
Guidance and Navigation	310	155.0	5.1
Rendezvous Radar	100	In Guidance & Nav.	
ECS	470	108.0	2.2
Auxiliary Power (Fuel Cells)	880	100.0	2.1
Periscope	50	12.0	.12
Structure	2,300		
Thermal Protect	230	80.0	5.6
ASCENT STAGE I PROP.	4,450	311.0	8.9
F = 30 K		140.0	1.1
ASCENT STAGE II PROP.	1,060	In	2.1
F = 30 K		Same Eng.	-
DESCENT STAGE	(11,100)		
Landing Legs	2,400	28.5	2.0
Descent Eng.	900		
F = 110 K		240.0	2.3
Tank, Etc.	4,800	In	9.6
Structure Thermal Protect	3,000	90.0	6.4
DE-ORBIT MOTOR	4,200	14.2	.07
GROWTH AND CONT. (30%)	7,920	440.0	15.4
SUBTOTAL - Basic	34,320	$1,881.7	$ 66.9
+22 - 24 SE&I, Ground Test.		415.0	16.0
+22 - 35 Vehicle Support		505.3	29.0
TOTAL		$2,802.0	$111.9

Table 5.3-8: INTERSTAGE ESTIMATES

	R&D	Recurring				
		Mars Opposition	Mars Conjunction	Mars Swingby	Venus Short	Venus Long
Interstage MEM & Probes	70.0	9.40	9.40	9.40	3.71	3.71
NDVC	15.4	2.26	2.26	2.26	0.89	0.89
Vehicle Support	18.8	4.08	4.08	4.08	1.61	1.61
Total	$104.2	$15.74	$15.74	$15.74	$6.21	$6.21

5.3.2.5 Space Propulsion

Included in space propulsion are PM-1, -2, and -3, the midcourse correct and orbit trim stages, and the assembly and docking units used for initial positioning of all space vehicle elements in Earth orbit.

Table 5.3-9 is the R&D and number one cost estimate for a common module which can be readily modified for any PM-1, -2, or -3 requirement. The basic R&D cost includes allowances for variations in insulation, meteoroid shielding, and structures for staging and/or clustering. Also included are the costs for fuel transfer systems. The number one cost shown is used in the total program cost estimates to calculate the average cost for all propulsion modules.

The midcourse correction and orbit trim cost estimates are shown in Table 5.3-10. The estimates were prepared assuming identical units for outbound midcourse and orbit trim corrections each utilizing a single modified MEM 30K thrust engine. The inbound midcourse correction unit being considerably smaller requires separate engine and tankage development programs. Recurring costs are charged to the program on the basis of one complete set per space vehicle.

Table 5.3-11 is the cost estimate for an Assembly and Docking unit typical of the IMISCD requirements. One unit is required for each launching of a propulsion module.

Table 5.3-9: COMMON PROPULSION MODULE COST ESTIMATE (dollars in thousands)

	Weights	Basic R&D	Number One
Basic Module*			
Tankage & Baffles	40,230	800,000	4,260
Tank Supports	7,540		1.430
Thrust Structure	950		380
Insulation	12,400		4,520
Meteroid Short	46,240		3,880
Equipment	6,240		3,400
Total	113,600		17,870
Nerva 2	28,530		14,000
Engine Systems	2,500	1,000,000	2,580
Growth	15,909	200,000	3,790
Total	160,539	2,000,000	38,240
Interstages**	14,592	40,000	1.470
Total	175,131	2,040,000	39,710

*Dry weights based on worst case conditions.
**Average weight for PM-1, -2, & -3 (includes clustering structure & growth).

Table 5.3-10: MIDCOURSE CORRECTION AND ORBIT TRIM ESTIMATE

	R&D	Unit	Quantity Per Set	Set
Tankage				
Outbound Midcourse and Orbit Trim	15.0	0.5	2	1.0
Inbound Midcourse	10.0	0.2	1	0.2
Propulsion Systems				
30 K Engine	5.0*	0.95	4	3.8
5 K Engine	64.0	0.35	2	0.7
SE&I	21.0			1.5
Vehicle Support	25.0			2.7
	140.0			9.9

*Modified MEM Engine

Table 5.3-11: ASSEMBLY & DOCKING UNIT

Length 6 feet Propellant N_2O_4/Aero-50
Diameter 33 feet Δ V 250 fps
Payload 200,000 pounds

			Cost in Millions	
		Weight	R&D	No. 1
	Structure			
	Outer Shell	2,500	30.6	3.6
	Docking Cone	70		
	Equipment Supports	70		
	Propulsion - RC			
	Useful Propellant (Storable)	6,000	-	-
	Tankage and Pressurization	1,300		
RC	Thrusters - F=200, 16 Units	100	98.0	2.6
	Feed Lines, Valves, etc.	100		
	Equipment			
	Rendezvous Radar (G&N)	50	57.0	2.7
	Guidance & Control (G&N)	100		
	Communications	50		
	Electrical Power and Wiring - Bat. 100W	200	.8	.1
	Tracking	100	52.0	2.2
	Instrumentation	100		
	Cooling Provisions (GE Study)	50	1.5	.05
	Cold Plates			
	Simple Water Boiler			
	Open System			
	Miscellaneous - Like spares	1,010	-	1.2
	Total	11,800	239.9	12.5M
	SE & I		52.0	3.0
	Vehicle Support		64.0	5.4
	Total		355.9	20.9

5.3.2.6 Space Vehicle Integration and Support

The space vehicle is a massive assembly of spacecraft and propulsion modules, yet it is a coordinated system and must perform as a unit. The job of assuring this performance is accomplished in this section.

Space vehicle interfacing activities, configuration control, test equipment, and overall space vehicle system integration effort are included here. The costs of planning and practicing the orbital assembly and checkout operation plus the simulation equipment needed are also included.

All this effort is applied as a percentage factor of the total space vehicle cost. This factor is developed through analysis of Apollo expenditures and the Gemini program. The factor appropriate for a program of the complexity of the manned interplanetary effort is 10%.

5.3.2.7 Earth Launch Vehicles

Table 5.3-12 depicts the cost estimates for the SAT-V-25(S)U family of Earth launch vehicles. The estimates were developed using data obtained from a series of separate SAT-V uprating studies. Once the total $824 million development program is completed, any variation of the SAT-V-25(S)U shown can be used. The launch costs shown are averages based on a total of 30 units produced at a rate of six vehicles per year for all Saturn-V (standard or uprated) launch vehicles.

The SAT-V, SAT-V-INT, Saturn-IB, and Atlas-Agena ELV's used in the IMISCD flight test program are priced as follows:

Saturn-V	$124 million per launch
Saturn-V-INT 21	$ 89.3 million per launch
Saturn-IB	$ 41 million per launch
Atlas-Agena	$ 7.9 million per launch

5.3.2.8 Earth Based Support

Earth based support costs are directly related to the flight of the spacecraft. Included in this cost are tracking and data acquisition, maintenance cost, and mission support at Kennedy Space Center and the Manned Spacecraft Center.

The mission support costs at KSC and MSC include: flight mission control operation, mission planning and analysis, contract development of real-time computer programs for flight missions, flight monitoring, and systems engineering which provides for the integrated technical support, review, and analysis of manned space flight missions.

The tracking and data acquisition costs consist of manned space network, deep space network, communications and data processing.

Table 5.3-13 shows the dollar breakdown. The costs are based on data researched from the Apollo program, which were approximately $250 million per year.

Table 5.3-12: EARTH LAUNCH VEHICLE COST ESTIMATES (dollars in millions)

	SAT-V-25(S)U Core (2 Stages)	SAT-V-25(S)U + 2 Strapons	SAT-V-25(S)U + 4 Strapons
Development			
Stage 1			
Structure	$ 78.4		$ 78.4
Engines	133.0		133.0
Strapons	-		137.0
Pods	-		-
Total	$211.4		$348.4
Stage 2			
Structure	80.0	+ Δ =	80.0
Engines	123.0		123.0
Total	$203.0		$203.0
I. U.	-		-
Total ELV	$414.4		$551.4
Launch Site			
Launch Complex	125.9		247.5
GSE	24.5		24.5
Total Development	$574.8 →	+ Δ of 248.6 =	$823.4
Average Launch Cost			
Stage 1			
Structure	$ 21.4	$ 21.4	$ 21.4
Engines	14.6	14.6	14.6
Strapons	-	8.4	16.7
Pods	-	-	-
Total	$ 36.0	$ 44.4	$ 52.7
Stage 2			
Structure	$ 24.3	$ 24.3	$ 24.3
Engines	9.6	9.6	9.6
Total	$ 33.9	$ 33.9	$ 33.9
I. U.	7.7	7.7	7.7
Total ELV	$ 77.6	$ 77.6	$ 77.6
Launch Site	2.7	2.7	2.7
Launch Operations	24.0	24.1	24.2
Integration	9.0	11.0	11.8
Total Launch	$113.3	$123.8	$133.0

Table 5.3-13: EARTH BASED SUPPORT

Costs for Earth based support were estimated to be approximately as follows, if the equipment was used exclusively for the manned interplanetary system.

	Cost/Year
Mission Support at KSC and MSC	$ 70,300,000
Manned Space Network	78,000,000
Deep Space Network	15,000,000
Communications	50,200,000
Data Processing	6,500,000
Recovery	30,000,000
Total	$250,000,000

Since the equipment will not be utilized exclusively for manned interplanetary missions costs are as follows:

Fixed cost independent of orbital and mission operations	$ 80,000,000 per year
Cost of support for orbital operations	465,000 per day
Cost of support for mission operations	145,000 per day

plus $2,000,000 for one recovery

<u>IMISCD EBS Costs</u> (dollars in millions)

- Flight and Demonstration Program

  Approximately $200 per year in flight test and demonstration program for tracking and data acquisition and $30 per year for recovery:

  4.5 years @ $230/yr = $1,035 Total EBS for Flight and Demonstration Program

- Mission

  $80.000 fixed $ 0.145 per day when on trip
  0.465 per day in Earth orbit, 2.000 for recovery

  Venus 135 days @ $0.465 = $62.78
  460 days @ 0.145 = 66.70 $131.48 Total variable cost
  2.00

  Mars 145 days @ $0.465 = $67.50
  540 days @ 0.145 = 78.40 $147.90 Total variable cost
  2.00

- Total Earth Based Support for Missions: (variable + fixed cost)

  Venus $131.48 + 80.00 = $211.48

  Mars $147.90 + 80.00 = $227.90

5.3.2.9 Orbital Support

For assembling and manning the space vehicle, an orbital support system is required. This is a logistics operation and consists of three major elements: the logistics spacecraft, the Earth launch vehicle for the logistics spacecraft, and the effort needed to assemble, checkout, integrate, and support the logistics system.

The development effort for the logistics spacecraft and its launch vehicle is assumed completed. Therefore the total costs of this system consists of the summation of recurring expenditures (see Table 5.3-14).

It is assumed the concept of spacecraft refurbishment will be feasible. Refurbishment offers the possibility of cost savings by vehicle reuse. Admittedly, there is little information on what spacecraft refurbishment costs would be as a percentage of the original spacecraft cost or how many times a spacecraft could be reused. However, it is legitimate to make assumptions and develop a scheme of vehicle reuse. This scheme is construed as a baseline from which improvements can be incorporated as our knowledge of the subject is advanced.

5.3.2.10 Interplanetary Mission System Integration and Management

Interplanetary mission system integration and management is a complex endeavor involving the assemblage of government and industrial effort so that all parts constitute a perfectly functioning unit. Activities included in this category are: continuous assessment of overall reliability encompassing all spacecraft, boosters, propulsion modules, ground equipment, personnel, operations, and checkout procedures; assurance of intelligible communication between government and industry participants; development of common methods, procedures, and standards for all major systems; and a search for unnoticed problems.

This effort is applied as a percentage factor of the total program cost. This factor is derived from an analysis of historical program costs that have a similar categorization. The factor appropriate for a program of the complexity of IMISCD is 1.5%.

Table 5.3-14: LOGISTICS VEHICLE COST USING REFURBISHMENT MODE

(dollars in millions)

Flight Test, Demonstration Program

Flight No.		Spacecraft Cost
1		$ 62.7 New
2		15.7 Refurbishment
3		15.7 Refurbishment
4		15.7 Refurbishment
5		15.7 Refurbishment
6		62.7 New
7		15.7 Refurbishment
8		15.7 Refurbishment
9		15.7 Refurbishment
10		15.7 Refurbishment
11		62.7 New
12		15.7 Refurbishment
13		15.7 Refurbishment
14		62.7 Spare
	Total	$407.8

Venus Mission

Flight No.		Spacecraft Cost
1		$ 15.7 Left Over from Demonstration
2		15.7 Left Over from Demonstration
3		62.7 New
4		15.7 Refurbishment
5		62.7 Spare
	Total	172.5

Mars Mission

Flight No.		Spacecraft Cost
1		$ 15.7 Left Over from Venus Mission
2		15.7 Left Over from Venus Mission
3		15.7 Left Over from Venus Mission
4		62.7 New
5		62.7 Spare
	Total	172.5

5.3.3 COSTING TOOLS

The tools needed to price out the Basic and Alternative Interplanetary Programs are contained in this section. The estimator uses cost models, cost estimating relationships, costing factors, operations cost analysis and funding relationships to develop element and program costs.

By conforming to a logical method, a complex program can be built up from manageable sub-areas. The IMISCD WBS defines these sub-areas and the costing tools are used to price them.

5.3.3.1 COST MODEL

In this study three cost models, two of which were computerized, were used. The first model was used to develop the Phase I estimate, which required several complete iterations to obtain total program cost. The second model was used to prepare the Phase II acceleration system trades. The third model requiring only one application was used to generate the basic program cost estimate.

The heart of the models are the cost estimating relationships (CER) and cost factors, which are also discussed in this section. With the application of CER's and cost factors to the design data all of the cost inputs for a program cost estimate are available and ready to be organized into the final product. The cost model then is a step by step procedure starting with design data, CER's, and cost factors generating cost inputs, which are organized into the cost estimate.

Figure 5.3-3 is a diagram showing how the cost models were used to generate the IMISCD cost estimates.

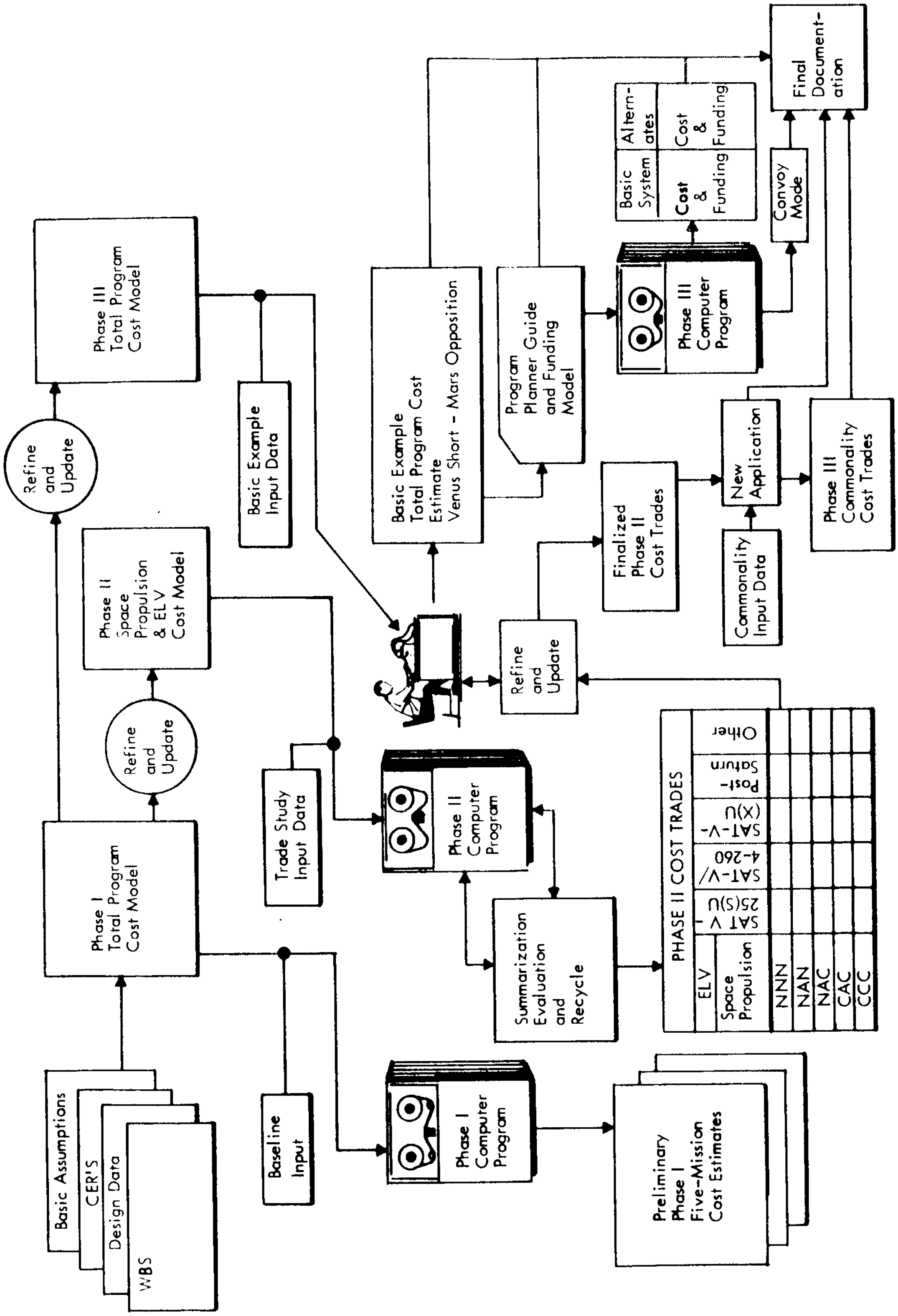


Figure 5.3-3: IMISCD COST MODEL APPLICATIONS

5.3.3.2 COST ESTIMATING RELATIONSHIPS

Decision makers in the areas of military and space activities have demonstrated an ever increasing concern for accurate system cost estimates. An important result of this heightened emphasis upon cost has been the necessity of prospective contractors providing credible cost estimates of the various elements that constitute the total cost of a program.

Cost models, CER's, costing factors, and fiscal year funding are various levels of costing methodology needed to develop a total cost of a program. This section covers cost estimating relationship and its relationship to the systematic approach of predicting costs.

Detailed cost estimates and statistical cost estimates are two types of cost techniques that can be utilized to meet the cost requirements set forth in this study. The statistical or parametric approach was the method chosen for development in this study.

It frequently happens that the long lead-times associated with space systems and space planning make it necessary for preliminary decision and guidelines to be developed before the systems or the missions are defined in detail. Consequently, the detailed estimating-type of costing has been eliminated as a method for conducting the cost analyses associated with this type of planning. Moreover, a detailed estimating procedure would be so time consuming that it would preclude the use of an analytical approach as a method for narrowing this field of missions or candidate vehicles, even if the systems were well defined.

The statistical approach is, essentially, an outgrowth of the detailed cost estimating procedure, both methods being based in differing proportions on historical data and engineering judgment. Generally, statistical cost estimating relationships are used when the primary concern is to obtain total costs for long range problems; also, CER's are formulated on a broad historical data base to ensure that the total costs are actually obtained.

CER's or functional relationships are equations describing mathematically the causative mechanisms that link design, performance, and similar parameters to cost. Ideally, CER's should be based upon consistent and well-defined physical and performance characteristics, complete and accurate cost data derived from actual programs, and a sufficient number of cases to support statistical significance. At the present time, these requirements can not be met for manned spacecraft. While Earth orbital operations have been conducted, lunar operations involving landing and return are some years in the future, and planetary missions are only in the study phase. Actual cost data exist on only three programs--Mercury, Gemini and Apollo.

Finally, the number of cases for most of the subsystems parameters are depressingly low. This lack of data precludes the application of meaningful statistical techniques either in the development of the CER's themselves or in the establishment of confidence levels for the predictive values generated by CER's. Although this unfavorable situation exists, it does not mean that useful relationships can not be developed. If experience with other types of aerospace equipment can be relied upon, it is possible to relate costs to physical, design, and performance characteristics and, within limits, to project these relationships to more advanced systems. Therefore, despite severe data limitation, CER's have been derived for use in this study.

The preparation of CER's requires a thorough knowledge and understanding of the technical aspects of a system. To develop effective CER's, the technical characteristics having the greatest influence on cost must be carefully screened from the files of technical data.

Determining which variables had the greatest effect on cost for the respective subsystems was determined through technical and engineering judgment and statistical analysis. Technical and engineering judgment consists primarily of obtaining through informal talks and documents physical characteristics and operating specification of the individual subsystem under consideration. Table 5.3-15 shows an example of a few subsystems and their prospective variables as developed through the aid of engineering support.

After formulating a matrix the variables were then run through regression analysis to determine which variables had the greatest influence on cost. Finally, each subsystem was portrayed graphically, using as the independent variable the best physical characteristic explaining cost and as the dependent variable the R&D or number one unit cost.

5.3.3.3 COSTING FACTORS

A spacecraft estimate includes two major cost categories that are added to the subsystem cost total. These are: (1) nondistributable cost, made up of subsystem installation and integration and ground testing; and (2) vehicle support cost, composed of launch site support, GSE, training, and spares.

These categories are added as factors to the total subsystem cost.

Table 5.3-15: PARAMETERS FOR CER DEVELOPMENT

Subsystem / CER Parameter	V_1	V_2	V_3	V_4
Electrical or Power	Total kwh for Mission Peak required. Subsystem Weight	Kilowatt hours per pound of subsystem weight	Number of subsystems requiring electrical power	Maximum Operating Distance and Mission Duration. Critical Time
Reaction Control	Total Impulse Subsystem Weight	Isp	Mono-versus-Bi-Propellant. No. of thrust chambers	Maximum Operating Distance Mission Duration
Propulsion	Total Impulse Weight of Propellant	Isp	Thottling Ratio Number of Starts	Critical Time Burn Time Mission Duration

Where: V_1 = Capacity or size

V_2 = Considers the efficiency accuracy or sensitivity

V_3 = Considers the number of separate functions each subsystem has to perform as an indication of complexity

V_4 = Reliability

These costing factors were developed based on data from the following programs: Apollo Command and Service Module, Lunar Excursion Module, Dyna Soar, Lunar Orbiter, Burner II, and Saturn V S-IC Stage.

Table 5.3-16 shows the method of application of the factors.

5.3.3.4 OPERATION COST ANALYSIS

An estimated annual cost for mission operations is derived from summing the estimates of mission support at KSC and MSC, tracking and data acquisition, recovery, and maintenance costs. These estimates are obtained from historical mission operations costs and information obtained from MSC.

Table 5.3-16: SYSTEM COSTING FACTORS

	R&D	Unit
Subsystems		
Structures	$XXX	$XXX
ECS	XXX	XXX
Communications and Data Management	XXX	XXX
Electrical Power	XXX	XXX
Guidance and Control	XXX	XXX
Life Support	XXX	XXX
Etc	XXX	XXX
Subtotal	$S.T.	$S.T.
Nondistributable Cost		
SI&I	Add 12% of S.T.	13% of S.T.
Ground Testing	10% of S.T.	11% of S.T.
Subtotal Number 2	S.T. Number 2	S.T. Number 2
Vehicle Support Cost		
Launch Site Support		
GSE	22% of S.T. #2	35% of S.T. #2
Training		
Spares		
Etc.		

5.3.3.5 FUNDING DOLLAR-TIME RELATIONSHIPS

Funding, for the IMISCD mission program examples, was accomplished using a Beta distribution function for each line item appearing on the Program Element Cost Summary (Table 5.3-2). Figure 5.3-4 shows a typical spreading pattern developed by the Beta distribution function. To use the function, start/stop dates, peak rate (H), time of occurrence of peak rate (T), and the value of each line item is determined in accordance with the schedules and cost estimates. An example of the applied technique is shown below.

BASIC INPUT

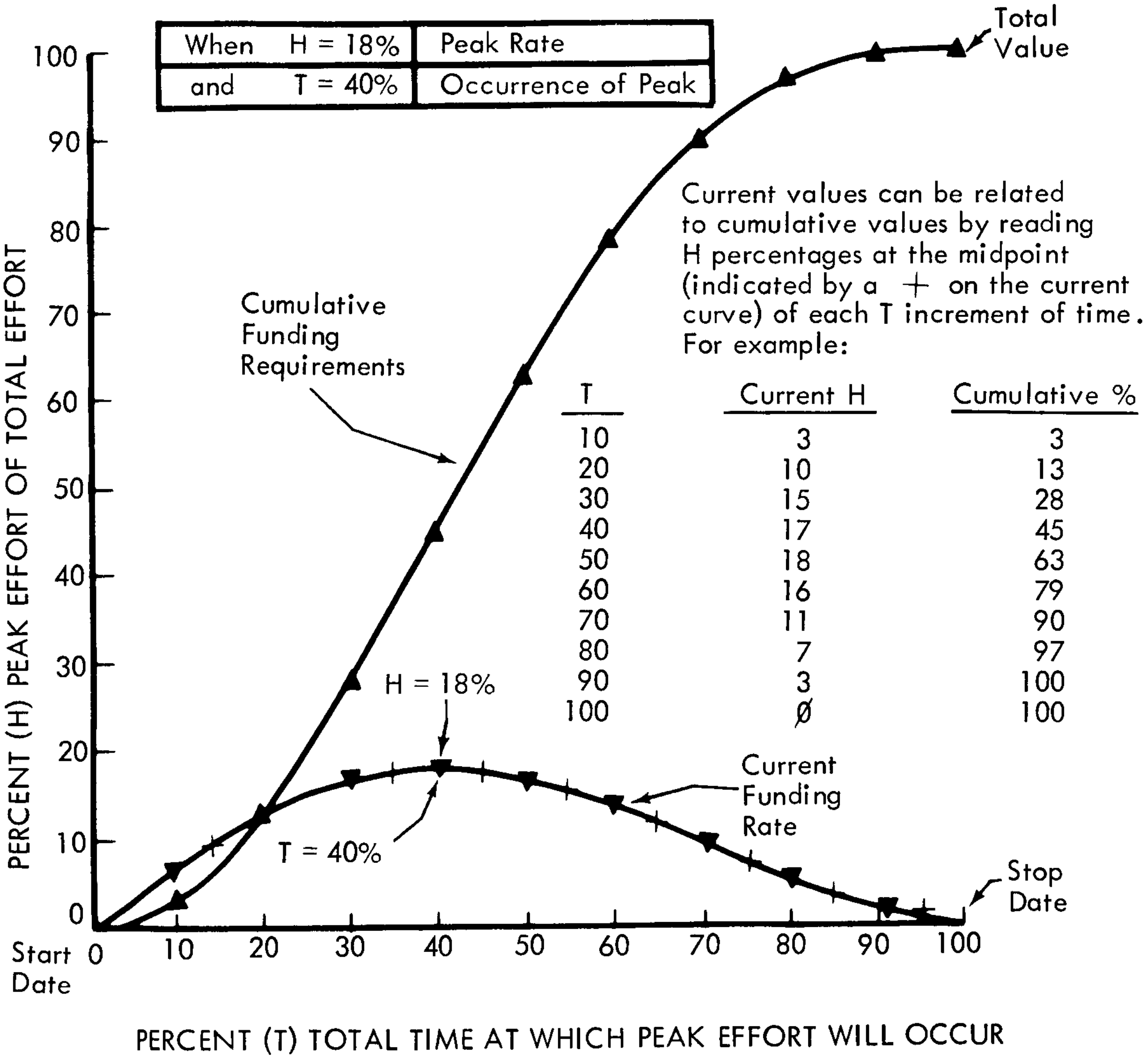
Mission Module	Value $ in Millions	Start Date	Stop Date	H	T
R&D	3,049.0	72/01	79/12	18%	60%
Flight Test	532.0	74/06	80/04	15%	50%
Venus Short	264.8	80/06	83/06	18%	40%
Mars OPP	268.3	83/03	86/03	18%	40%

OUTPUT

See: Table 5.3-17 and Figure 5.3-5

The output as shown also includes costs for three subsequent missions that were generated from the basic Mars/Venus mission values using factors derived from the Program Planners' Guide (Section 5.2.3). Using this Beta function/computer technique, the funding requirements of any number of schedule and program variations can be analyzed.

This routine required several iterations to generate the funding schedules for the basic and alternate program examples, shown in summary in Tables 5.3-18 through 5.3-24 and in detail in Appendix B. A graphic display on the basic program example is also contained in Appendix B. This basic data will be retained on tape for future refinement and analysis.



Current values can be related to cumulative values by reading H percentages at the midpoint (indicated by a + on the current curve) of each T increment of time. For example:

T	Current H	Cumulative %
10	3	3
20	10	13
30	15	28
40	17	45
50	18	63
60	16	79
70	11	90
80	7	97
90	3	100
100	0	100

Figure 5.3-4: BETA DISTRIBUTION FUNCTION — CURRENT AND CUMULATIVE EXPENDITURE PATTERN

Table 5.3-17

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IMISCO PROGRAM FUNDING AEROSPACE VEHICLE SPACE VEHICLE
CASE NUMBER 1 SPACECRAFT MISSION MODULE
CALENDAR YEARS DOLLARS IN THOUSANDS

	BASIC R & D	FLIGHT TEST	VENUS SHORT	MARS OPP	MISSION 3	MISSION 4	MISSION 5	MISSION 6	TOTAL
1HY 72	60676								30338
2HY 72	221052								110526
1HY 73	381734								190367
2HY 73	515464								257732
1HY 74	612666	234							306450
2HY 74	668586	12704							340645
1HY 75	684256	33612							358934
2HY 75	662852	53818							358335
1HY 76	608764	72042							340403
2HY 76	528940	87706							308323
1HY 77	431556	100228							265892
2HY 77	324840	109200							217020
1HY 78	217942	114252							166097
2HY 78	122570	114816							118693
1HY 79	48784	110390							79567
2HY 79	7318	100176							53747
1HY 80		83056	794						41925
2HY 80		56582	57880						57231
1HY 81		15184	132666						73925
2HY 81			151210						75605
1HY 82			117996						58998
2HY 82			58764						29382
1HY 83			10290	18062					14176
2HY 83				102400					51200
1HY 84				151380	14918				83149
2HY 84				141640	50466				96053
1HY 85				90708	78332				84520
2HY 85				31020	92554				61787
1HY 86				1390	92732	15222			54672
2HY 86					80998	51492			66245
1HY 87					60990	79926			70458
2HY 87					37472	94438			65955
1HY 88					15972	94620	15586		63089
2HY 88					2518	82644	52726		68944
1HY 89						62232	81840		72036
2HY 89						38234	96700		67467
1HY 90						16296	96886		56591
2HY 90						2570	84624		43597
1HY 91							63722		31861
2HY 91							39150		19575
1HY 92							16686		8343
2HY 92							2632		1316
TOTAL	6098000	1064000	529600	536600	526952	537674	550552		4921689

Value in the indicated columns are doubled for use in the plotting program

Actual half year total values

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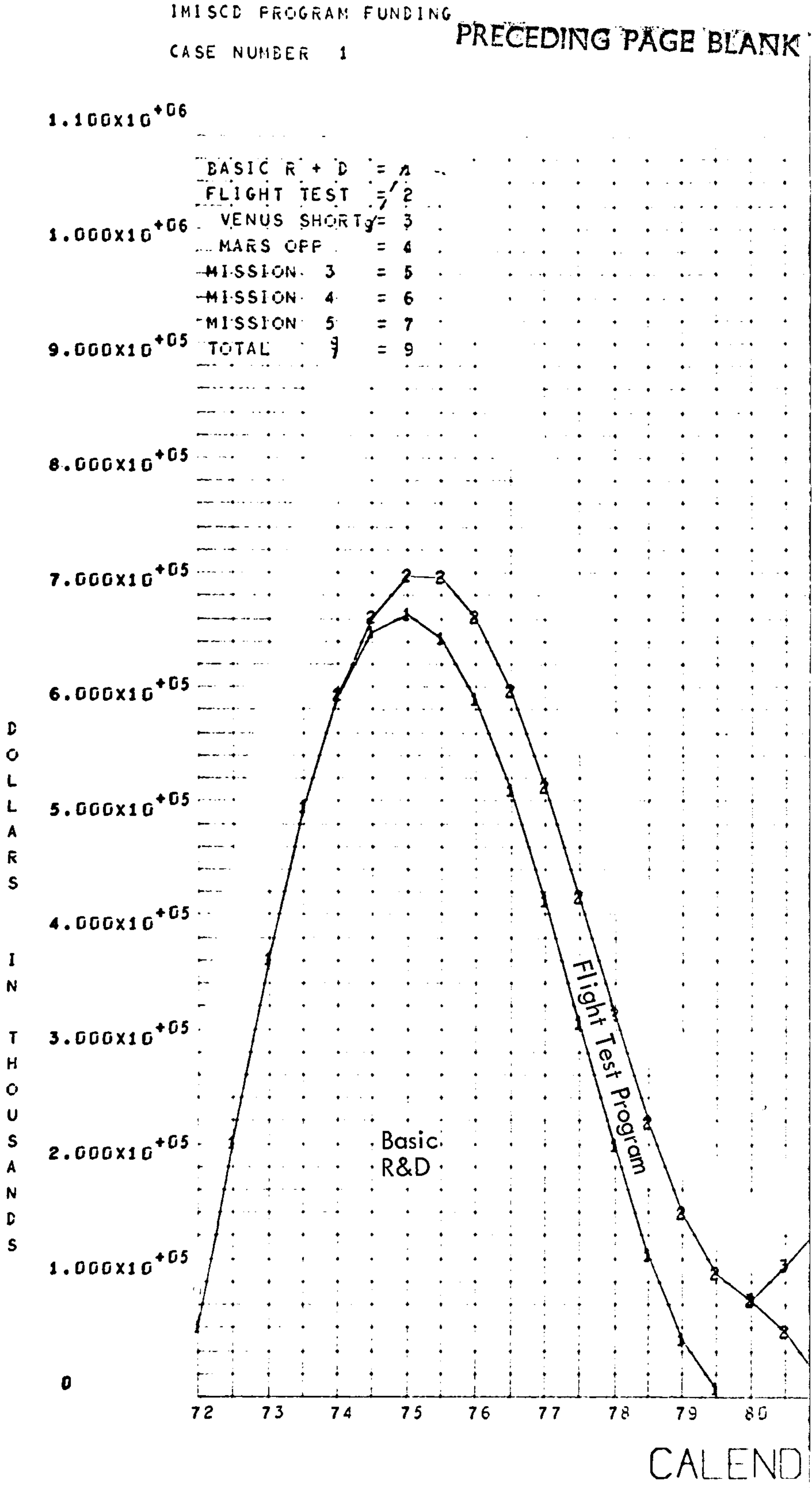

Figure 5.3-5:

FOLDOUT FRAME 1

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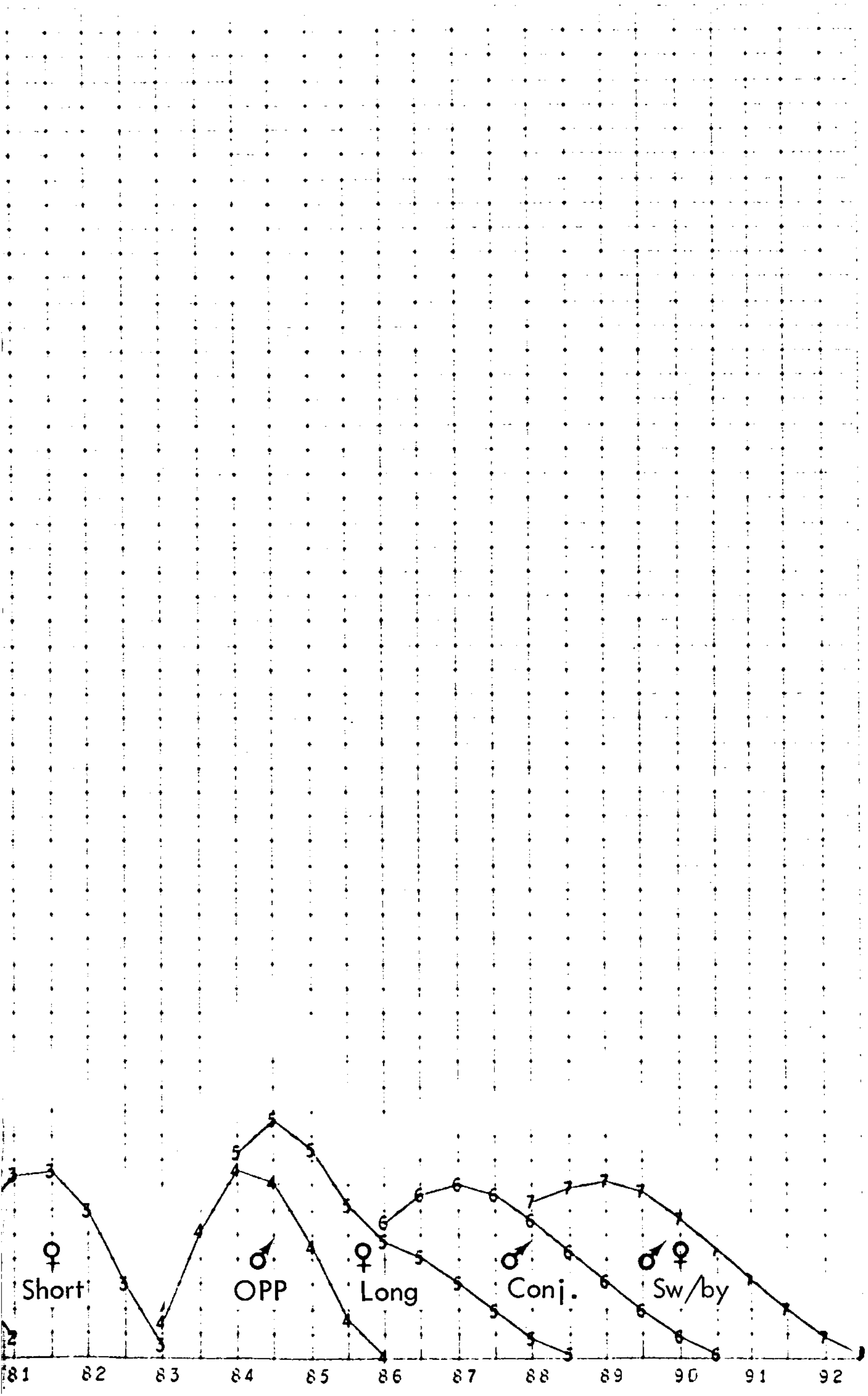

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MISSION MODULE

Table 5.3-18
IMISCD PROGRAM FUNDING EXAMPLES
TOTAL PROGRAM

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	394.9	39.9	.0	.0	434.8	432.1	116.2	.0	.0	548.3
CY 73	1290.1	120.9	.0	.0	1,410.9	1310.4	287.6	.0	.0	1,598.0
CY 74	1908.4	250.2	.0	.0	2,158.6	2038.2	579.1	.0	.0	2,617.3
CY 75	1800.4	401.1	.0	.0	2,201.5	2700.0	1143.7	.0	.0	3,843.6
CY 76	1991.1	878.2	.0	.0	2,869.3	2864.3	1518.7	.0	.0	4,383.0
CY 77	1854.6	1392.6	.0	.0	3,247.1	2184.3	1395.4	33.9	.0	3,613.6
CY 78	1444.5	1530.2	.0	.0	2,974.7	1449.4	1164.1	346.2	.0	2,959.7
CY 79	1212.0	1322.5	154.4	.0	2,688.8	1293.2	911.7	978.8	43.3	3,227.1
CY 80	1196.0	808.1	644.1	.0	2,648.2	865.8	581.3	844.7	300.5	2,592.3
CY 81	1204.1	512.6	1106.7	31.9	2,855.4	350.5	168.4	180.8	804.5	1,504.3
CY 82	841.8	451.7	430.2	275.2	1,998.8	118.6	120.6	146.6	978.4	1,364.1
CY 83	350.5	158.2	125.1	750.6	1,384.4	7.7	89.4	41.1	316.2	454.3
CY 84	118.6	120.6	111.5	1015.3	1,366.0	.0	4.9	.0	196.8	201.7
CY 85	7.7	89.4	.0	354.2	451.3	.0	.0	.0	42.3	42.3
CY 86	.0	4.9	.0	199.5	204.4	.0	.0	.0	.0	.0
CY 87	.0	.0	.0	55.3	55.3	.0	.0	.0	.0	.0
TOTAL	15614.6	8080.9	2572.1	2682.0	28,949.6	15614.6	8080.9	2572.1	2682.0	28,949.6

Table 5.3-19

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	389.1	39.4	.0	.0	428.4	425.7	114.5	.0	.0	540.2
CY 73	1271.0	119.1	.0	.0	1,390.1	1291.0	283.3	.0	.0	1,574.3
CY 74	1880.2	246.5	.0	.0	2,126.7	2008.1	570.5	.0	.0	2,578.6
CY 75	1773.8	395.1	.0	.0	2,168.9	2660.1	890.0	.0	.0	3,550.0
CY 76	1961.7	689.8	.0	.0	2,651.5	2822.0	1038.6	.0	.0	3,860.6
CY 77	1827.2	869.1	.0	.0	2,696.2	2152.0	865.6	33.4	.0	3,051.0
CY 78	1423.1	901.2	.0	.0	2,324.3	1428.0	698.3	335.1	.0	2,461.4
CY 79	1194.0	818.0	152.1	.0	2,164.2	1274.1	595.0	813.7	42.6	2,725.5
CY 80	1178.3	551.3	572.5	.0	2,302.1	853.1	470.4	663.9	295.8	2,283.2
CY 81	1186.3	461.8	899.3	31.5	2,578.9	345.4	165.9	102.2	738.0	1,351.4
CY 82	829.3	445.0	309.4	271.1	1,854.8	116.8	118.8	.0	775.1	1,010.7
CY 83	345.4	155.9	14.9	692.4	1,208.6	7.6	88.0	.0	187.9	283.5
CY 84	116.8	118.8	.0	820.9	1,056.6	.0	4.8	.0	.7	5.6
CY 85	7.6	88.0	.0	221.7	317.4	.0	.0	.0	.0	.0
CY 86	.0	4.8	.0	2.5	7.3	.0	.0	.0	.0	.0
TOTAL	15383.9	5903.9	1948.3	2040.1	25,276.2	15383.9	5903.9	1948.3	2040.1	25,276.2

Table 5.3-20

IMISCO PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	266.7	.0	.0	.0	266.7	222.0	.0	.0	.0	222.0
CY 73	952.0	.0	.0	.0	952.0	904.8	.0	.0	.0	904.8
CY 74	1513.5	10.6	.0	.0	1,524.2	1776.4	103.8	.0	.0	1,880.2
CY 75	1758.4	113.1	.0	.0	1,871.5	2658.2	288.1	.0	.0	2,946.4
CY 76	1961.7	279.8	.0	.0	2,241.5	2822.0	400.7	.0	.0	3,222.7
CY 77	1827.2	365.7	.0	.0	2,192.9	2152.0	458.8	.3	.0	2,611.1
CY 78	1423.1	397.9	.0	.0	1,821.0	1428.0	421.4	90.9	.0	1,940.3
CY 79	1194.0	346.4	23.5	.0	1,563.9	1274.1	539.1	414.5	.0	2,227.7
CY 80	1178.3	272.0	234.8	.0	1,685.1	853.1	470.4	429.0	46.4	1,798.9
CY 81	1186.3	461.8	494.9	.0	2,143.1	345.4	165.9	102.2	346.4	959.9
CY 82	829.3	445.0	268.8	38.3	1,581.4	116.8	119.8	.0	547.4	783.1
CY 83	345.4	155.9	14.9	307.4	823.6	7.6	88.0	.0	187.9	283.5
CY 84	116.8	118.8	.0	558.9	794.5	.0	4.8	.0	.7	5.6
CY 85	7.6	88.0	.0	221.7	317.4	.0	.0	.0	.0	.0
CY 86	.0	4.8	.0	2.5	7.3	.0	.0	.0	.0	.0
TOTAL	14560.5	3060.0	1037.0	1128.8	19,786.3	14560.5	3060.0	1037.0	1128.8	19,786.3

Table 5.3-21
IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
EARTH LAUNCH VEHICLES

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	122.3	39.4	.0	.0	161.7	203.7	114.5	.0	.0	318.2
CY 73	319.0	119.1	.0	.0	438.1	386.2	283.3	.0	.0	669.5
CY 74	366.7	235.8	.0	.0	602.5	231.7	466.7	.0	.0	698.4
CY 75	15.4	282.0	.0	.0	297.4	1.8	601.8	.0	.0	603.7
CY 76	.0	410.0	.0	.0	410.0	.0	637.9	.0	.0	637.9
CY 77	.0	503.3	.0	.0	503.3	.0	406.8	33.1	.0	439.9
CY 78	.0	503.3	.0	.0	503.3	.0	277.0	244.2	.0	521.1
CY 79	.0	471.6	128.6	.0	600.3	.0	55.9	399.1	42.6	497.7
CY 80	.0	279.3	337.7	.0	617.0	.0	.0	234.9	249.4	484.3
CY 81	.0	.0	404.4	31.5	435.8	.0	.0	.0	391.5	391.5
CY 82	.0	.0	40.7	232.8	273.4	.0	.0	.0	227.7	227.7
CY 83	.0	.0	.0	385.0	385.0	.0	.0	.0	.0	.0
CY 84	.0	.0	.0	262.1	262.1	.0	.0	.0	.0	.0
TOTAL	823.4	2843.9	911.3	911.3	5,489.9	823.4	2843.9	911.3	911.3	5,489.9

Table 5.3-22

IMISCD PROGRAM FUNDING EXAMPLES

EARTH BASED SUPPORT

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 75	.0	.0	.0	.0	.0	.0	119.1	.0	.0	119.1
CY 76	.0	88.2	.0	.0	88.2	.0	230.2	.0	.0	230.2
CY 77	.0	253.0	.0	.0	253.0	.0	256.1	.0	.0	256.1
CY 78	.0	305.0	.0	.0	305.0	.0	225.6	.0	.0	225.6
CY 79	.0	243.9	.0	.0	243.9	.0	152.5	.0	.0	152.5
CY 80	.0	123.1	.0	.0	123.1	.0	51.4	.0	.0	51.4
CY 81	.0	21.7	.0	.0	21.7	.0	.0	26.6	.0	26.6
CY 82	.0	.0	.0	.0	.0	.0	.0	144.4	.0	144.4
CY 83	.0	.0	101.6	.0	101.6	.0	.0	40.4	8.5	48.9
CY 84	.0	.0	109.9	.0	109.9	.0	.0	.0	177.7	177.7
CY 85	.0	.0	.0	.0	.0	.0	.0	.0	41.7	41.7
CY 86	.0	.0	.0	173.4	173.4	.0	.0	.0	.0	.0
CY 87	.0	.0	.0	54.5	54.5	.0	.0	.0	.0	.0
TOTAL	.0	1035.0	211.5	227.9	1,474.4	.0	1035.0	211.5	227.9	1,474.4

Table 5.3-23
IMISCD PROGRAM FUNDING EXAMPLES

ORBITAL SUPPORT

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 75	.0	.0	.0	.0	.0	.0	117.7	.0	.0	117.7
CY 76	.0	87.2	.0	.0	87.2	.0	227.4	.0	.0	227.4
CY 77	.0	249.9	.0	.0	249.9	.0	253.1	.0	.0	253.1
CY 78	.0	301.4	.0	.0	301.4	.0	222.9	6.0	.0	228.9
CY 79	.0	241.0	.0	.0	241.0	.0	150.7	150.7	.0	301.4
CY 80	.0	121.7	62.1	.0	183.8	.0	50.8	168.3	.2	219.3
CY 81	.0	21.5	191.1	.0	212.5	.0	.0	49.3	54.7	104.0
CY 82	.0	.0	114.4	.0	114.4	.0	.0	.0	188.9	188.9
CY 83	.0	.0	6.7	47.0	53.7	.0	.0	.0	115.1	115.1
CY 84	.0	.0	.0	179.4	179.4	.0	.0	.0	15.4	15.4
CY 85	.0	.0	.0	127.3	127.3	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	20.6	20.6	.0	.0	.0	.0	.0
TOTAL	.0	1022.6	374.3	374.3	1,771.2	.0	1022.6	374.3	374.3	1,771.2

Table 5.3-24
IMISCD PROGRAM FUNDING EXAMPLES

INTERLANETARY MISSION SYS MGT

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHCRT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	5.8	.6	.0	.0	6.4	6.4	1.7	.0	.0	8.1
CY 73	19.1	1.8	.0	.0	20.9	19.4	4.3	.0	.0	23.6
CY 74	28.2	3.7	.0	.0	31.9	30.1	8.6	.0	.0	38.7
CY 75	26.6	5.9	.0	.0	32.5	39.9	16.9	.0	.0	56.8
CY 76	29.4	13.0	.0	.0	42.4	42.3	22.4	.0	.0	64.8
CY 77	27.4	20.6	.0	.0	48.0	32.3	20.6	.5	.0	53.4
CY 78	21.3	22.6	.0	.0	44.0	21.4	17.2	5.1	.0	43.7
CY 79	17.9	19.5	2.3	.0	39.7	19.1	13.5	14.5	.6	47.7
CY 80	17.7	11.9	9.5	.0	39.1	12.8	8.6	12.5	4.4	38.3
CY 81	17.8	7.6	16.4	.5	42.2	5.2	2.5	2.7	11.9	22.2
CY 82	12.4	6.7	6.4	4.1	29.5	1.8	1.8	2.2	14.5	20.2
CY 83	5.2	2.3	1.9	11.1	20.5	.1	1.3	.6	4.7	6.7
CY 84	1.8	1.8	1.6	15.0	20.2	.0	.1	.0	2.9	3.0
CY 85	.1	1.3	.0	5.2	6.7	.0	.0	.0	.6	.6
CY 86	.0	.1	.0	2.9	3.0	.0	.0	.0	.0	.0
CY 87	.0	.0	.0	.8	.8	.0	.0	.0	.0	.0
TOTAL	230.8	119.4	38.0	39.6	427.8	230.8	119.4	38.0	39.6	427.8

APPENDIX A
TEST/OPERATIONAL REQUIREMENTS WORKSHEETS FOR IMISCD MISSION HARDWARE

INTRODUCTION

The analysis of mission operations (in Volume III - Part I - of this report) provides the foundation for all IMISCD test requirements. The baseline mission events have geen translated into the detail test requirements listed below.

- The first series of work sheets, A_1 through A_5, develops requirements for the mission module (MM). The events defined in the mission operations analysis are identified in the blocks across the top of the work sheets. Immediately below each block, the MM operational requirements imposed by the particular mission event are briefly summarized. Below that, the technological development and interface aspects of the MM operational requirements are identified as MM development tests. Finally, the means for verifying MM capability to satisfy operational requirements for the mission event are identified as qualification tests. The symbol "G" denotes a ground test, while "F" denotes a flight test.
- Subsequent work sheets are developed in the manner just described for the mission module, but apply to the other IMISCD mission hardware as follows:

  B_1 through B_5 for the Mars excursion module (MEM);

  C_1 through C_5 for the Earth entry module (EEM);

  D_1 through D_5 for the propulsion modules (PM's);

  E_1 through E_5 for the spacecraft (S/C);

  F_1 through F_5 for the total space vehicle (S/V).
- Additional pages are inserted as needed to include all the requirements that apply to a particular set of mission events.

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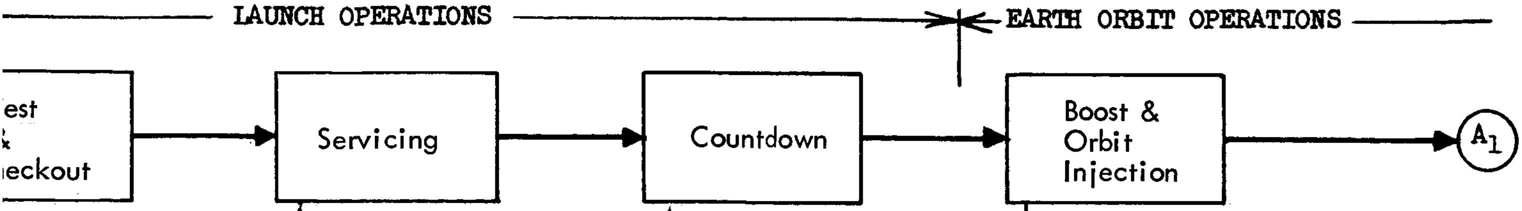
	PRELAUNCH OPERATIONS		
	Receive & Inspect	Assembly & Test	T & Ch
TEST/ OPERATIONAL REQUIREMENTS	-Not operational.	-Intra- and inter-subsystem functional operation under ambient conditions. Limited environment tests, vibration and thermal/vacuum. Assemble spacecraft (MM, MEM & EEM). Mate payload to ELV.	-Lim ope mar T/M
DEVELOPMENT TESTS	Not applicable.	-Subsys. tests to check out functional interaction between subsystems as installed in dev. MM. (G) -Limited thermal balance & vibration mode testing, more detailed testing at S/C level. (G) -Flight tests not applicable.	-Che ica wit Equ -Fli app
QUALIFICATION TESTS	Not applicable.	-Acceptance test to prove out intra- and inter-subsystem functional operation under ambient conditions. (G) -Qualify physical and functional interfaces between MM & MEM, EEM, & ELV by use of simulators. (G)	-Ver MM mit tes lat (G)

LEGEND: (G) = ground test
(F) = flight test

MISSION MODULE (MM)



ited functional ration with pri- y monitoring via l.	-Load ECS/LSS expendables; cryogens, gases, absorbents, water & food. Load RCS propellants.	-Limited monitoring of T/M.	-T/M monitoring boost environment; vibration, acoustics, temperature/altitude, acceleration.
ckout MM T/M commun- tions compatibility h Launch Support ipment (G). ght tests not licable.	-No dev. tests req'd.	-Tests to verify compatibility between MM & launch equipment. (G) -Flight tests not applicable.	-Subsystem tests to checkout items sensitive to vibration, acoustic, acceleration, and rapid altitude change environment (G). -Flight tests not req'd.
ify capability of telemetry to trans- launch operations t data to simu- ed ground station.	-Verify capability of loading ECS & RCS expendables onboard the MM at nominal, maximum & minimum design temperature, pressure, density, etc., conditions & maintaining the expendables within required design conditions throughout launch operations. (G)	-Qualify MM telemetry to transmit countdown data to launch equipment. (G)	-Conduct vibration/acoustic & temperature/altitude tests on MM. (G) -Conduct acceleration tests only on components susceptible to acceleration. This is not a MM level test. (G)

Figure A1: TEST/OPERATIONAL REQUIREMENTS MISSION MODULE (MM) WORKSHEET

FOLDOUT FRAME 2

EARTH ORBIT OPERATIONS

A_1 → Test & Checkout → Rendezvous → Servi

	Test & Checkout	Rendezvous	Servi
TEST/ OPERATIONAL REQUIREMENTS	-Remote activation of command & control, & stabilization subsystem. Rendezvous & dock with logistics ATC crew. Activation & functional checkout of all MM subsystems. -Environment - thermal/ vacuum, zero "g".	-Rendezvous & docking, spacecraft to PM-1. Provide control for rendezvous & docking operations.	-Not a servi on gr
DEVELOPMENT TEST	-Subsystem tests to checkout functional interaction between subsystems as installed in dev. MM. (G) -Checkout remote activation & operation of applicable subsystems. (G) -Subsystem tests to checkout items sensitive to thermal/vac. environment. (G) -Flight tests not required.	-Dev. tests with rendezvous and docking simulators with control from MM. (G)	-Not
QUALIFICATION TEST	-Functional qual. of MM subsystems under all operational modes. (G) -Verify remote command & control capability thru checkout of signal functions (G). - Qualify MM stabilization & control subsystem thru test with a dynamic simulator (G). -Environmental qual. at S/C level.	-Verify MM control capability over simulated rendezvous & docking operations. (G). - Verify MM control capability of rendezvous & docking opns. during Flight qual. test at S/V level.(F).	-Not a

LEG

(G

(F

MM

MISSION FLIGHT OPERATIONS

cing	Assembly & Test	Earth Orbit Launch & Injection	Coast & Midcourse Corrections	A2
pplicable - cing completed ound.	-Assemble spacecraft to primary propulsion systems. Test spacecraft command & control capability over the propulsion systems. Integrate astronauts into spacecraft operations.	-Verify space vehicle spatial positioning & interface with ground control. Conduct final on-board checkout. Program PM-1 engine ignition, ΔV maneuver & shutdown. Provide S/V attitude control.	-Exercise command & control, T & C/O, mission operations drills. Establish spatial positioning, correlate with earth tracking data. Experiment operations. MM maintenance. Initiate & monitor correction maneuvers using PM-OBMC. Repeat for other corrections as required. Perform readiness check on PM-2.	
applicable.	-Test capability of MM to control S/V assy & test operations via simulation. (G)	-Test capability of MM to control PM & S/V orbital launch operations via use of ground simulators. (G)	-Test capability of MM to control mission operations, including midcourse corrections & PM-2 readiness checks via use of ground simulator. (G)	
pplicable	-Qualify MM command & control capability over S/C test.(G) & (F). Simulate command receipt & response for PM's. (G). -Qualify MM internal operations with astronaut participation. (F).	-Qualify MM command & control capability over S/V. (G). Simulate command receipt & response for PM's. (G). -Qualify MM to S/V vibration/acceleration environment under operational conditions.(G).	-Qualify MM command & control capability over S/V with use of simulators where req'd. (G). -Qualify MM operations in earth orbital flight with astronaut participation.(F).	

END:

-Ground Tests

-Flight Tests

Figure A2: TEST/OPERATIONAL REQUIREMENTS MISSION MODULE (MM) WORKSHEET

A_2	Abort Operations	Planet Capture & Orbit Insertion	Orbit Check
TEST/ OPERATIONAL REQUIREMENTS	-All crew members to abort positions. Provide command & control capability for abort operations. Periodic abort drills.	-Activate meteoroid shield & insulation release mechanisms. Initiate separation sequence. Verify final spatial positioning. Program PM-2 engine ignition, ΔV maneuver & shutdown. Provide S/V attitude control during PM-2 firing. Dispose PM-2.	--Conduct spacecra ticular MM and MI tion sys PM-OT sys fer astro MEM. Up board co
DEVELOPMENT TESTS	-Operations to be included as part of ground simulator tests. (G)	-Test capability of MM to control PM & S/V orbit insertion operations via use of ground simulator. (G)	-Test capa to contro checkout via use o simulato
QUALIFICATION TESTS	-Verify capability of MM to support abort operations thru functional simulation. (G). -Verify capability of MM, in conjunction with appropriate ground stations, to provide abort trajectory reqmt's. (G).	-Qualify MM command & control capability over S/V. Simulate command receipt & response for PM's.(G) -Qualify MM to S/V vibration/accel. environment under operational conditions after simulated space soak. (G).	-Verify or and check ity of MM ular emph interface Astronaut will part flight te

LEGEND:

(G) = Ground Test

(F) = Flight Test

MM

MISSION FLIGHT OPERATIONS

l out	Planet Orbit Coast & Corrections	Separation	Deorbit, Descent & Landing → (A3)
heckout of t, with par- mphasis on M separa- em. Checkout stems. Trans- nauts (3) to late MEM on- puters.	-Monitor & control spacecraft operations. Establish spacecraft spatial orientation. Control orbital experiments. Initiate & monitor correction maneuvers using PM-OT, Re-establish S/C spatial orientation after correction. Mars orbital environment, thermal cycling. →	-Control MM-MEM separation maneuver. Provide required MM stabilization and control.	-Monitor MEM operations. Verify spatial orientation with earth based mission control.
bility of MM l orbital operations f ground . (G)	-Integrate orbital experiment control by MM into ground simulation operations. (G) -Thermal balance tests covered at S/C level. -Simulate orbit trim control via MM. (G)	-Simulate stabilization, control, & separation maneuvers on ground simulator. (G)	-Simulate MEM-MM communications. (G)
-board test out capabil- with partic- asis on MEM s. (G) & (F). -test crew icipate in st.	-Qualify MM command & control capability over S/V. Simulate command receipt & response for PM-OT. (G). -Qualify MM operations in near earth flight with astronaut participation. (F).	-Verify MM control capability over MM-MEM separation operations. (G).	-Verify capability of MM communications and data management subsystems, via simulators, to monitor and display MEM position and trajectory within design limits for sampling rates and accuracy. (G).

Figure A3: TEST/OPERATIONAL REQUIREMENTS MISSION MODULE (MM) WORKSHEET

A3	Abort	Mars Surface Operations	Laun Asce Orbi
TEST/ OPERATIONAL REQUIREMENTS	-Monitor MEM operations for abort necessity. Maintain communications with MEM.	-Control orbital experiments. Maintain communications with MEM on Mars surface during each orbit & relay data to Earth-based mission control. Verify & correct spatial orientation as required.	-Position MEM rend Monitor checkout Provide sion con directin down, la to orbit to Earth trol.
DEVELOPMENT TESTS	-Simulate time variant spatial positioning of S/C and MEM to optimize MEM-S/C communications opportunities. (G)	-Use functional simulator to test MM capability for monitoring surface operations. (G)	-Simulate spatial S/C & ME MEM-S/C opportun -Test mis capabili function (G)
QUALIFICATION TEST	-Qualify MM operations required to support MEM abort during ground tests with astronaut participation. (G)	-Verify MM capability to monitor planet surface operations and to relay data to Earth-based mission control, each orbit, during manned Earth orbital tests. (G) & (F).	-Verify M to provi mission MEM. (G) -MM is qu spatial of MEM-M specifie craft.

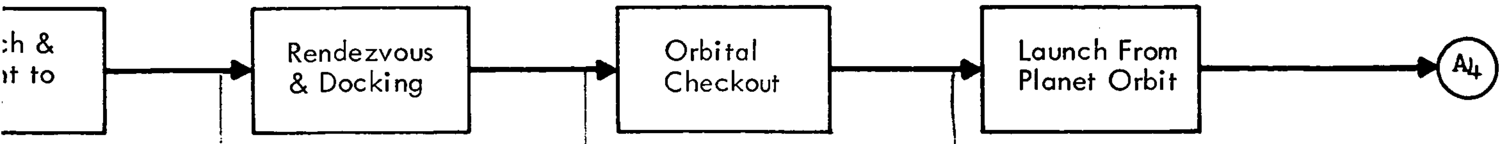
LEGEND

(G) =

(F) =

MM

- MISSION FLIGHT OPERATIONS



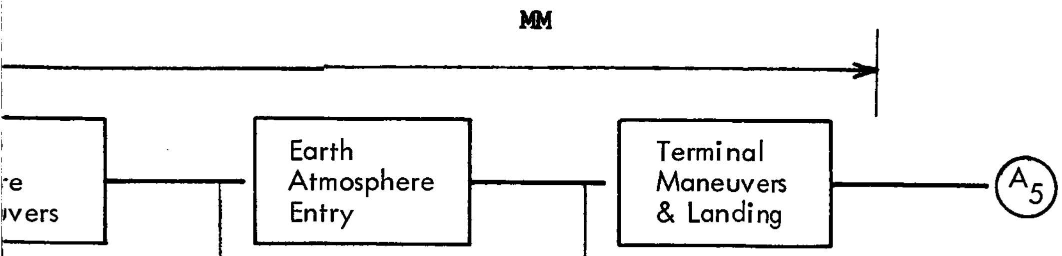
orbit for ezvous. prelaunch of MEM. orbital mis- trol for g MEM count- unch & ascent . Relay info based con-	-Determine MM-MEM relative spatial orientation. Conduct docking maneuvers, maintain MM in stabilized attitude. Maneuver MEM into MM docking mechanisms. Verify satisfactory attachment.	-Perform checkout of S/C systems. Transfer Mars samples to S/C. Shutdown MEM systems & transfer crew. Update navigation systems. Perform final orbit experiments. Control MEM and PM-3 meteoroid shield & insulation separation, and verify proper separation.	-Verify space vehicle satisfactory spatial positioning. Control orbital launch countdown. Program PM-3 engine ignition, ΔV maneuver & shutdown. Provide S/V attitude control. Dispose PM-3.
time variant positioning of M to optimize communications ities. (G) sion control ties of MM on al simulator.	-Test attitude & maneuvering command & control capabilities of the MM & responsiveness of MEM in dynamic simulator for docking.(G)	-Test interfaces and sequences on functional simulator. (G)	-Test command & control of positioning & launch operations via ground simulator. (G)
M capability de orbital control for . alified for correlations M by tests d for space- : Ground Test Flight Test	-Verify MM-MEM docking thru use of ground dynamic simulation of respective interfaces. (G) -Flight qualify rendezvous and docking operations at S/C level. (F)	-Verify MM command and control capability over S/V orbital checkout, sample transfer, MEM separation and PM-3 meteoroid shield and insulation separation with use of ground equipment to simulate receipt of commands and transmission of responses. (G)	-Qualify MM command and control capability over PM-3 firing and separation thru simulation of appropriate interface functions. (G) -Qualify MM to S/V vibration/acceleration environment under operational conditions. (G)

Figure A4: TEST/OPERATIONAL REQUIREMENTS MISSION MODULE (MM) WORKSHEET

MISSION FLIGHT OPERATIONS

A_4	Coast & Midcourse Correction	Earth Captu Maneu
TEST/ OPERATIONAL REQUIREMENTS	-Exercise command & control, T & C/O, mission operations. Establish spatial positioning, correlate with earth tracking data. Initiate and monitor correction maneuvers using PM-IBMC. Repeat as required.	-Control course p module s and veri separati fer crew shutdown tems. I separati -Activate tems and final ch
DEVELOPMENT TESTS	Not required.	Not req
QUALIFICATION TESTS	-Qualify MM command & control capability over S/V with use of simulators where req'd. (G). -Qualify MM operations required for interplanetary coast and midcourse corrections, during flight tests with astronaut participation. (F).	-Verify of sepa systems in an e simulat beyond minimum voltage -Verify c of MM se to deter ity of r PM-IBMC, lator. -Capabili ate & ch subsyste ified at

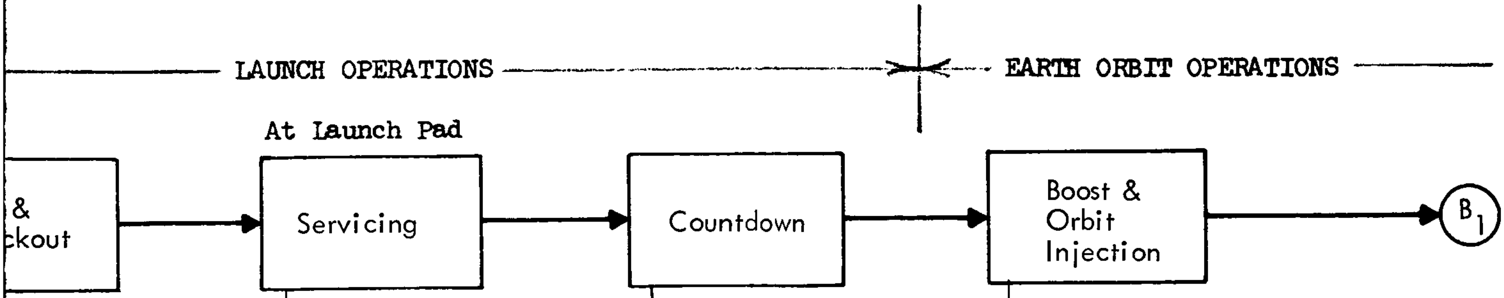
LEGEND: (G) = ground test
(F) = flight test



inbound mid- ropulsion eparation, fy proper on. Trans- to EEM & MM subsys- nitiate on sequence. EEM subsys- perform eckout.	Not applicable.	Not applicable.
uired.	Not applicable.	Not applicable.
capability ration sub- by firing nvironmental or at and maximum and design s. (G). apability nsing devices mine proxim- eleased in a simu- (G). ty to activ- eckout EEM ns is qual- S/C level.	-Not applicable.	-Not applicable.

Figure A5: TEST/OPERATIONAL REQUIREMENTS MISSION MODULE (MM) WORKSHEET

MEM	PRELAUNCH OPERATIONS		
	Receive & Inspect	Assembly & Test	Test Che
OPERATIONAL/TEST REQUIREMENTS	Not operational.	-Functional operation of subsystems & interfaces with MM under ambient conditions. Limited environmental, vibration & thermal/vacuum tests. Incorporate MEM into spacecraft assembly (with MM & EEM). Mate this payload to ELV.	-Limi oper moni
DEVELOPMENT TEST	Not applicable.	-Subsystem tests to checkout functional interaction between subsystems as installed in dev. MEM. (G) -Limited thermal balance & vibration mode testing, more detailed testing at S/C level. (G). -Flight tests not applicable.	-No d
QUALIFICATION TESTS	Not applicable.	-Acceptance test to prove out intra- and inter-subsystem functional operation under ambient conditions. (G) -Qualify physical and functional interfaces with MM & ELV by use of simulators. (G)	-Ver MEM mit tes a s sta lat



ted functional ation with primary toring via T/M.	-Load ECS/LSS expendables; gases, absorbents. -Load RCS propellants, and selected experiment equipment packages.	-Limited monitoring by T/M.	-T/M monitoring boost environment: vibration, acoustics, temperature/altitude, acceleration.
ev. tests req'd.	-No dev. tests req'd.	-No dev. tests req'd.	-Subsystem tests to checkout items sensitive to vibration, acoustic, acceleration, and rapid altitude change environment. (G). -Flight tests not req'd.
fy capability of telemetry to trans launch operations data directly to imulated ground tion or to a simu d MM. (G)	-Verify capability of loading ECS & RCS expendables onboard the MEM at nominal, maximum, & minimum design temperatures, pressure, density, etc., conditions & maintaining the expendables within required design conditions throughout launch operations. (G)	-Verify capability of MEM telemetry to transmit launch countdown data to simulated launch equipment or to the MM. (G)	-Conduct vibration/acoustic & temperature/altitude tests on MEM. (G) -Conduct acceleration tests only on components susceptible to acceleration. This is not an MEM level test. (G)

Figure B1: TEST/OPERATIONAL REQUIREMENTS
MARS EXCURSION MODULE (MEM) WORKSHEET

MEM

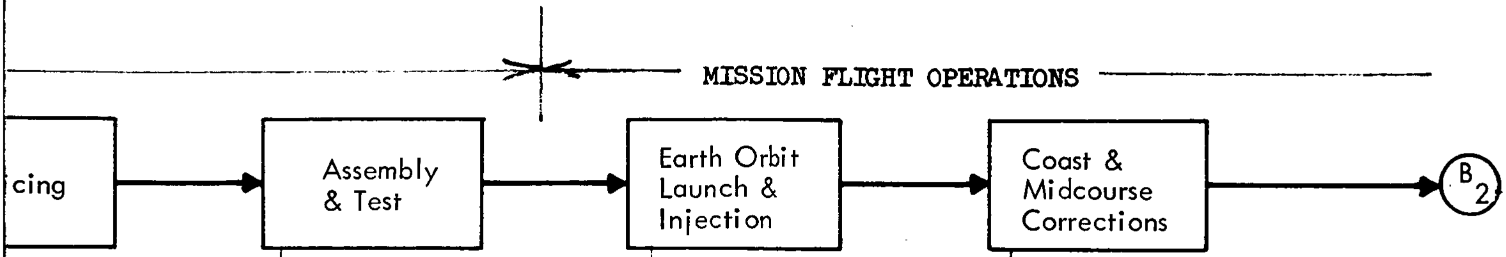
EARTH ORBIT OPERATIONS

(B1)	Test & Checkout	Rendezvous	Servi
OPERATIONAL/TEST REQUIREMENTS	-Rendezvous & docking (as part of spacecraft) with ATC crew. Activation & functional checking of all MEM subsystems. -Environment - thermal/vacuum, zero "g".	Not operational	Not servi on g
DEVELOPMENT TEST	-Subsystem tests to checkout functional interaction between subsystems as installed in dev. MEM. (G) -Subsystem tests to checkout items sensitive to thermal/vac. & zero-g environment. (G) -Flight tests not required.	-Not applicable.	-Not
QUALIFICATION TEST	-Verify remote test capability of MEM thru simulated MM or ground equipment inputs. (G). -Environmental qual. at S/C level.	-Not applicable.	-Not

LEGE

(G)

(F)



cing	Assembly & Test	Earth Orbit Launch & Injection	Coast & Midcourse Corrections
applicable - icing completed round.	Functional interface with MM systems.	Not operational.	-Scheduled maintenance & housekeeping. -Astronaut checkout & monitoring of MEM subsystems; practice of critical operations. -Unscheduled maintenance & repair as required.
applicable.	-Checkout functional interfaces via ground simulator. (G)	-Not applicable.	-Checkout & monitor MEM operations via use of ground simulator. (G) Checkout maintenance capability of MEM. (G)
applicable.	-Qualify test capability of MM over the MEM at S/C test level. (G) & (F).	-Qualify MEM to S/V vibration/acceleration environment. MEM non-operational during this mission phase. Thermal/vac. cycling should precede this test. (G).	-Qualify test and maintenance capabilities of MEM at S/C test level. (G) & (F).

END:

= Ground Test

= Flight Test

Figure B2: TEST/OPERATIONAL REQUIREMENTS
MARS EXCURSION MODULE (MEM) WORKSHEET

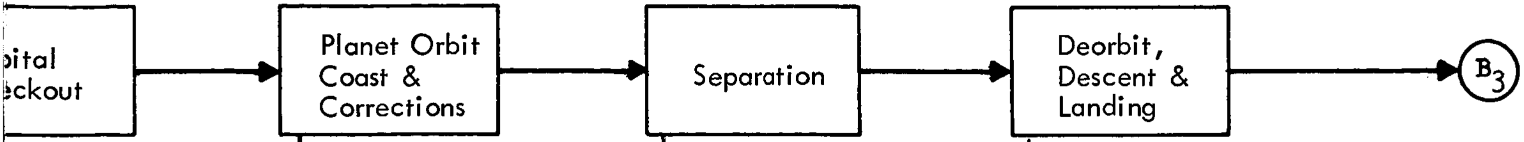
B2	Abort Operations	Planet Capture & Orbit Insertion	Orb Che
OPERATIONAL/TEST REQUIREMENTS	-Not operational. (Alternates: o Separate & dispose of MEM, OR o Use MEM propulsion to assist in deceleration.)	-Not operational.	-Che ava pos -Ast MEM sys che onb
DEVELOPMENT TESTS	-First alternate: No dev. tests req'd. -Second alternate: Dev. static firings of MEM propulsion to checkout abort modes. (G)	-Not applicable.	-Sim ope ast tio -Tra fro MEM
QUALIFICATION TESTS	-First alternate: Separation system qualified in support of normal mission operations. -Second alternate: Incorporate MEM propulsion abort modes into MEM prop. qual. if significantly different from normal mission modes. (G) & (F).	-Not applicable.	-Ve & c of ast loc

LEGEND:

(G) = Ground Test

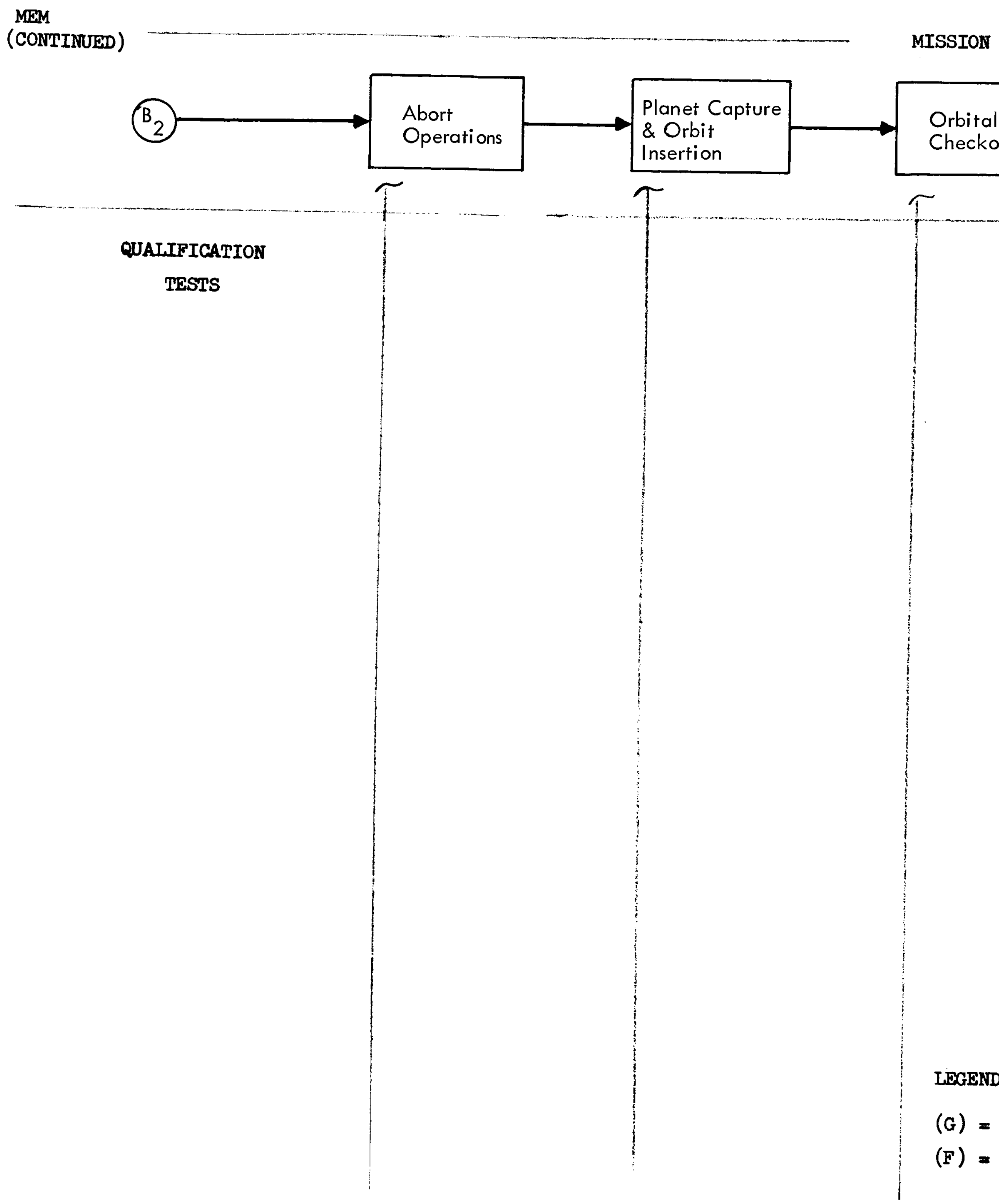
(F) = Flight Test

ISSION FLIGHT OPERATIONS



ckout MEM systems ilable in stowed ition ronauts transfer to , conduct complete tems & interface ckout, and update oard computers.	-Not operational.	-Separate from spacecraft & orient MEM in attitude & position for de-orbit.	-Conduct de-orbit sequence; monitor and adjust descent propulsion, attitude and stabilization controls & EC & LSS. -Ballutes deployed in horizontal flight to decelerate the MEM aerodynamically, prior to being jettisoned. -Final touchdown & safe landing of crew members and experiment equipment. -Recurring telemetry, television & audio linkage with MM. -Jettison portions of heat shield to reduce weight & provide clearance for descent propulsion. -Activate & maintain continuous reactions of EC & LSS to offset biological constraints in Mars descent & landing. -Terminal maneuvers (including hovering) to achieve desired landing velocities & site, coordinate with MM.
ulate MEM test rations including ronaut participa- n. (G) nsfer astronauts n MM simulator to simulator. (G)	-No dev. tests req'd.	-Simulate MEM-MM separation on ground simulator. (G)	-Dev. test of descent propulsion system, including hovering & final touchdown. Manned & unmanned. (F) -Static firing tests of descent propulsion engines. (G) -Dev. test of ballute systems in earth atmosphere. (F) -Simulate MEM functions on ground simulator. (G)
ify on-board test heckout capability MEM with use of ronauts in test p. (G) & (F).	-Not applicable.	-Verify MEM separation capability thru interface simulation during ground test. (G) (Cont.)	-Qualify heat shields & ballutes thru suborbital tests on boiler plate MEM's, unmanned, at altitudes and velocities yielding approximations of Mars descent conditions. (F) (Cont.)

Figure B3: TEST/OPERATIONAL REQUIREMENTS
MARS EXCURSION MODULE (MEM) WORKSHEET


MEM
(CONTINUED)
MISSION
B2
Abort Operations
Planet Capture & Orbit Insertion
Orbital
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QUALIFICATION
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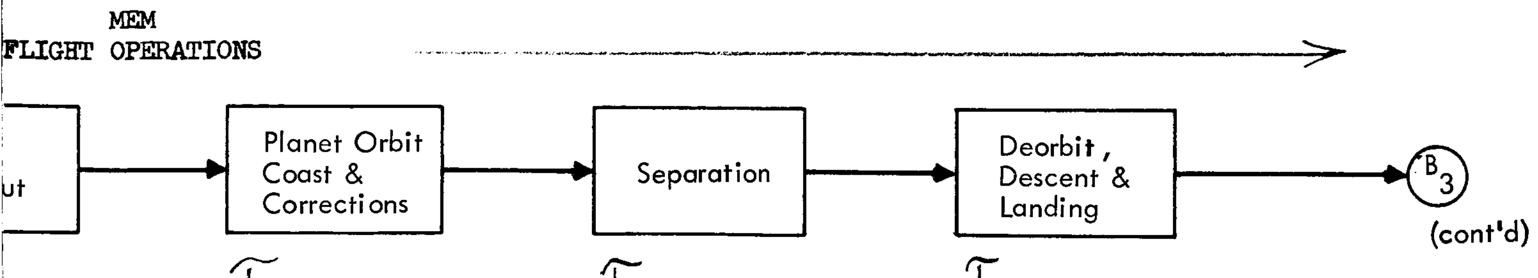


- Flight qualify separation system thru interface simulation between MEM & upper stage of ELV. (F).

- Qualify the man-ballute deceleration, guidance & control capabilities of the MEM, with minimum necessary heat shield & payload, in suborbital manned tests. (F).
- Verify capability of MEM separation subsystems by firing in an environmental simulator at and beyond maximum and minimum design voltages.(G).
- Verify capability of EC & LSS subsystems to provide nominal continuing outputs for MEM at designed minimum power levels & to provide emergency surges within designed maximum power levels. (G).
- Verify MEM communications subsystem capability to transmit & receive required data from simulated MM at designed bit-rates and accuracy.(G).
- Unmanned MEM, all systems up in Earth orbit with S/C structural shell, de-orbits at 26,000 fps and an entry angle of -3°, to verify flight capabilities of descent propulsion, attitude & stablilization controls, EC & LSS, terminal maneuvers (including hovering) to achieve desired landing velocities & site. (Heat shield is over-designed to survive descent in Earth atmosphere).(F).
- Manned MEM (With heat-shield over-designed to survive descent in Earth atmosphere) all systems up in Earth orbit with S/C structural shell, de-orbits at 26,000 fps and an entry angle of -3°, to verify MEM flight capabilities for safe descent, hovering, touch-down & landing of crew members & experiment equipment on the Mars surface.(F).

:
Ground Test
Flight Test

Figure B3: TEST/OPERATIONAL REQUIREMENTS
MARS EXCURSION MODULE (MEM) WORKSHEET (Continued)

MEM — M

B_3	Abort	Mars Surface Operations	Launch Ascent Orbit
OPERATIONAL/TEST REQUIREMENTS	-Continuing readiness at abort stations throughout de-orbit, descent & landing. -On command, arrest descent, turn-around, jettison descent stage, fire ascent motors & proceed to pre-selected orbit.	-Post-landing checkout of MEM & remote control investigation of surface & environment in proximity to MEM. -Checkout & activate experiment & personnel equipment, including portable LSS & exit mechanisms. -Perform scheduled exploration & experiments, & make other observations & tests as warranted. -Maintain continuous radio contact with exploration team & relay & coordinate pertinent info with orbiting MM. -Perform necessary MEM housekeeping & maintenance.	-Explor turns requir sample necess -Releas attach -Prelau MEM, s window meters orbiti -Verify lease stage face l -Coordi & traj orbita trol, sary c -Initia sequen perfor
DEVELOPMENT TESTS	-Determine stability characteristics of MEM descent stage as a space platform for abort launching of the ascent stage. Unmanned (F)	-Checkout required equipment & astronaut operations on functional simulator. (G)	-Vertica mentati stage t face wi stage t mize av off cap -Static stage e -Test co operati tional ulator -Determi guidanc istics (F)

LEGEND:

(G) = Ground Test

(F) = Flight Test

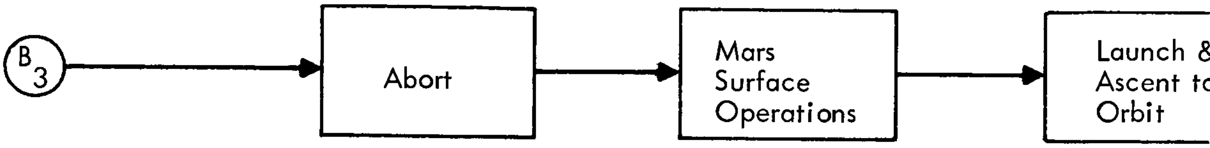
QUALIFICATION TESTS
(continued)

SSION FLIGHT OPERATIONS →

&	Rendezvous & Docking	Orbital Checkout	Launch from Planet Orbit	B 4
ation team re- to MEM, loads ed equipment & s; discards un- ary equipment. e descent stage ments. nch checkout of ystems & launch ascent para- , etc., with ng MM. positive re- from descent & initiate sur- aunch. nate velocity ectory with l mission con- & make neces- orrections. te parking orbit ces & verify mance.	-Determine MEM orbit parameters & position, & rendezvous requirements, in coordination with MM. -Initiate ascent maneuver from parking orbit to MM orbit, near MM. -Release & separate ascent stage (completely deactivated) from MEM, properly oriented away from MM. -Determine & adjust closing rate between MEM & MM. Maneuver MEM into docking mechanism of stabilized MM. Assure that MEM is satisfactorily attached to MM & that transfer system is pressurized.	-Transfer samples & equipment from MEM to MM. -Shutdown MEM systems & transfer crew to MM. -Activate release mechanism for MEM.	Not applicable.	
l lift experi- on with ascent o develop inter- th descent hat will opti- ailable lift- abilities. (F) firing of ascent ngine. (G) mplete ascent ons on func- & dynamic sim- . (G) ne thrust and e character- of ascent stage.	-Determine maneuverability characteristics of MEM ascent stage & reaction control system, on rendezvous & docking simulator. (G)	-Not required.	Not applicable.	

Figure B4: TEST/OPERATIONAL REQUIREMENTS MARS EXCURSION MODULE (MEM) WORKSHEET

M



QUALIFICATION TESTS (continued)

-Verify abort operational strategies and sequences on functional simulators. (G).

-Verify MEM abort capability by unmanned suborbital flight. Jettison the ascent stage heat shield, separate the ascent stage from the descent stage, ignite the ascent stage engine, turn around, & accelerate along a pre-programmed flight path to ascend to a simulated Mars orbit. (Earth orbit cannot actually be achieved.) (F).

-Qualify Mars surface operations by manned excursions, fully encumbered with exploration equipment, in hostile Earth environments.(G).

-Verify capability of MEM communications subsystems to maintain continuous contact with exploration teams and with simulated orbiting MM. (G).

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MM. (F).

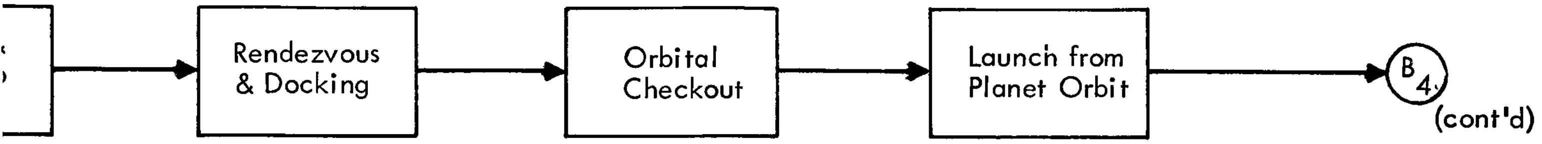
LEGEND:

(G) = Ground Test

(F) = Flight Test

MEM

ISSION FLIGHT OPERATIONS



ultiple static
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pability of
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EM-astronaut
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- Verify capability of MEM to perform rendezvous and docking operations in ground test with orbital conditions simulated as near as possible. (G)
- Verify actual docking capability in ground dynamic simulation of respective interfaces. (G)
- Conduct static firings of MEM ascent stage for transfer from parking orbit to MM orbit. (G)
- Conduct flight test of MEM capability to perform orbit transfer maneuvers and rendezvous with MM or simulated docking device. (F)

- Functionally check MEM systems shutdown capability and release mechanism activation. (G)
- Verify MEM separation capability from S/C by use of ground dynamic simulation at respective interfaces.(G)
- Conduct flight test of MEM capability to separate from MM/SC or simulated vehicle (F)

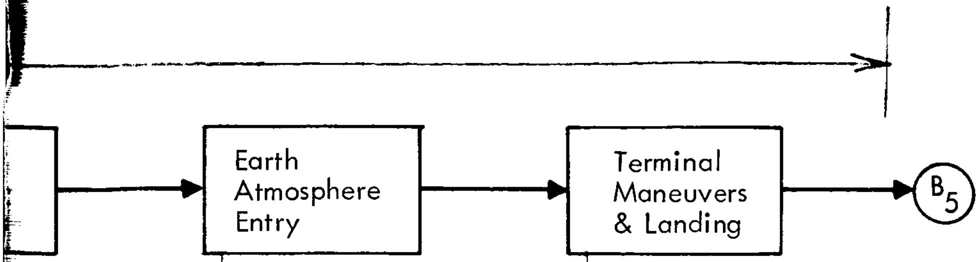
- Not applicable.

Figure B4: TEST/OPERATIONAL REQUIREMENTS
MARS EXCURSION MODULE (MEM) WORKSHEET (Continued)

MEM

MISSION FLIGHT OPERATIONS

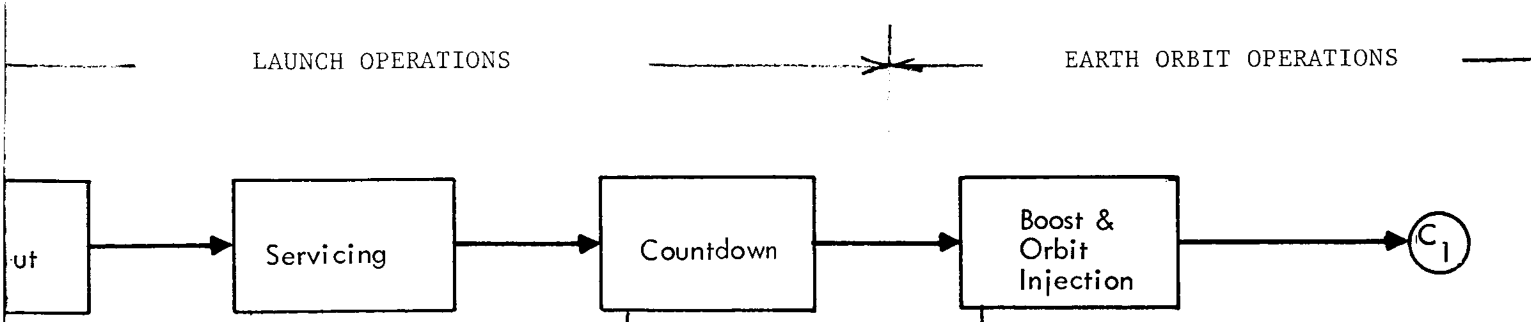
B 4	Coast & Midcourse Corrections	Earth Capture Maneuver
OPERATIONAL/TEST REQUIREMENTS	**Not operational.**	**Not ope**
DEVELOPMENT TESTS	Not applicable.	Not app
QUALIFICATION TESTS	**Not applicable.**	**Not appl**



ational.	Not operational.	Not operational.
icable.	Not applicable.	Not applicable.
icable.	Not applicable.	Not applicable.

Figure B5: TEST/OPERATIONAL REQUIREMENTS MARS EXCURSION MODULE (MEM) WORKSHEET

EEM	PRE-LAUNCH OPERATIONS		
	Receive & Inspect	Assembly & Test	Test & Checko
OPERATIONAL/TEST REQUIREMENTS	- Not operational.	-Functional operation of subsystems and interfaces with MM under ambient conditions. Limited environmental, vibration, and thermal/vacuum tests. Incorporate EEM into spacecraft assembly (with MM and MEM). Mate this payload with ELV.	-Limite operat primar by T/M
DEVELOPMENT TEST	**Not applicable.**	**-Subsystem tests to checkout functional interaction between subsystems as installed in dev. EEM. (G)** **-Limited thermal balance & vibration mode testing, more detailed testing at S/C level. (G)** **-Flight tests not applicable.**	**-No de**
QUALIFICATION TESTS	**Not applicable.**	**-Acceptance test to prove out intra- and inter-subsystem functional operation under ambient conditions. (G)** **-Qualify physical and functional interfaces with MM & ELV by use of simulators. (G)**	**-Verif EEM t trans ation direc lated or tc (G)**



d functional ion with y monitoring 1.	-Load ECS/LSS expendables: gases, absorbents.	-Limited monitoring by T/M.	-T/M monitoring boost environment: vibration, acoustics, temperature/altitude, acceleration.
v. tests req'd.	-No dev. tests req'd.	-No dev. tests req'd.	-Subsystem tests to checkout items sensitive to vibration, acoustic, acceleration, and rapid altitude change environment. (G) -Flight tests not req'd.
y capability of elemetry to mit launch oper- s test data tly to a simu- ground station a simulated MM.	-Verify capability of loading ECS & RCS expendables onboard the EEM at nominal, max., & min. design temps., pressure, density, etc., conditions and maintaining the expendables with required design conditions throughout launch operations. (G)	-Verify capability of EEM telemetry to transmit launch countdown data to simulated launch equipment or to the MM. (G)	-Conduct vibration/acoustic and temperature/altitude tests on EEM. (G) -Conduct acceleration tests only on components susceptible to acceleration. This is not an EEM level test. (G)

Figure C1: TEST/OPERATIONAL REQUIREMENTS EARTH ENTRY MODULE (EEM) WORKSHEET

FOLDOUT FRAME 2

EARTH ORBIT OPERATIONS

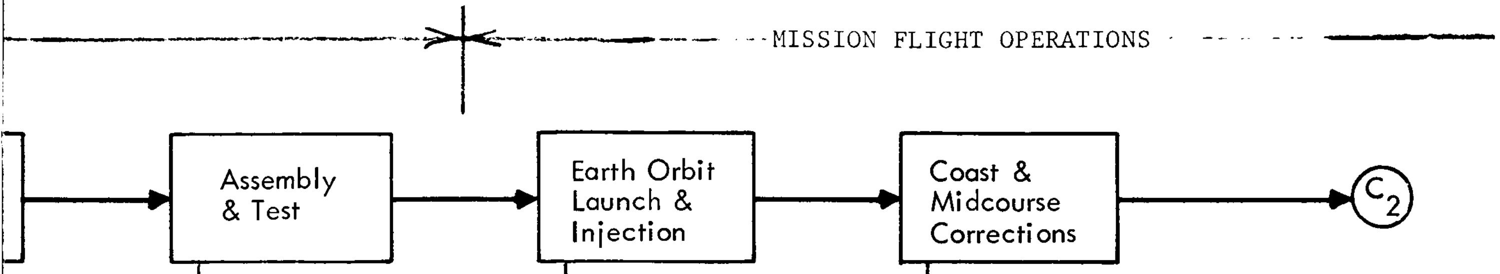
(Continued)

EEM C_1	Test & Checkout	Rendezvous	Servicing
OPERATIONAL/TEST REQUIREMENTS	-Rendezvous and docking (as part of spacecraft) with ATC. Activation and functional checking of all EEM subsystems. -Environment-thermal/ vacuum, zero "g".	-Not operational.	-Not applic vicing com ground.
DEVELOPMENT TEST	**-Subsystem tests to checkout functional interaction between subsystems as installed in dev. EEM. (G)** **-Subsystem tests to checkout items sensitive to thermal/vac. & zero-g environment. (G)** **-Flight tests not required.**	**-Not applicable.**	**-Not appli**
QUALIFICATION TEST	**-Verify remote test capability of EEM thru simulated MM or ground equipment inputs. (G).** **-Environmental qual. at S/C level.**	**-Not applicable.**	**-Not appli**

LEGEND:

(G) = G

(F) = F



able. Ser- pleted on	-Functional interface with MM systems.	-Not operational.	-Scheduled maintenance and housekeeping. -Unscheduled maintenance and repair as required. -Astronaut check-out and monitoring of EEM subsystems, practice of critical operations.
cable.	**-Checkout functional interfaces via ground simulator. (G)**	**-Not applicable.**	**-Checkout & monitor EEM operations via use of ground simulator. (G) Checkout maintenance capability of EEM. (G)**
cable	**-Qualify test capability of MM over the EEM at S/C test level. (G) & (F).**	**-Qualify EEM to S/V vibration/acceleration environment. EEM non-operational during this mission phase. Thermal/vacuum cycling should precede this test. (G).**	**-Qualify test and maintenance capabilities of EEM at S/C test level. (G) & (F).**

round Test

light Test

Figure C2: TEST/OPERATIONAL REQUIREMENTS EARTH ENTRY MODULE (EEM) WORKSHEET

EEM

C_2 →	Abort Operations →	Planet Capture & Orbit Insertion →	Orbit Check
OPERATIONAL/TEST REQUIREMENTS	-Complete checkout of EEM subsystems and interfaces with MM. -Transfer of food, water, and other necessary expendables to EEM. -Activation and monitoring of ECS/LSS. -Earth atmosphere entry and terminal maneuvers if and as necessary.	-Not operational.	-Not
DEVELOPMENT TESTS	**-No dev. tests req'd.**	**-Not applicable.**	**-Not**
QUALIFICATION TESTS	**-Qualified based on normal mission mode, except verify systems capability to operate out of normal mission sequence. (G).**	**-Not applicable.**	**-Not**

LE

(G

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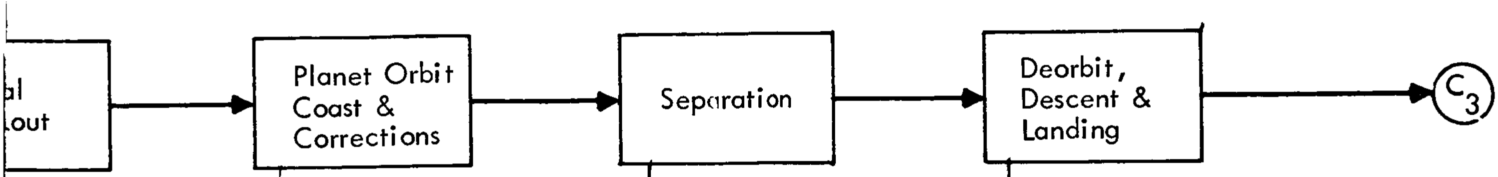
MISSION FLIGHT OPERATIONS



operational.	-Not operational.	-Not operational.	-Not operational.
applicable.	**-Not applicable.**	**-Not applicable.**	**-Not applicable.**
applicable.	**-Not applicable.**	**-Not applicable**	**-Not applicable.**

END:

= Ground Test

= Flight Test

Figure C3: TEST/OPERATIONAL REQUIREMENTS EARTH ENTRY MODULE (EEM) WORKSHEET

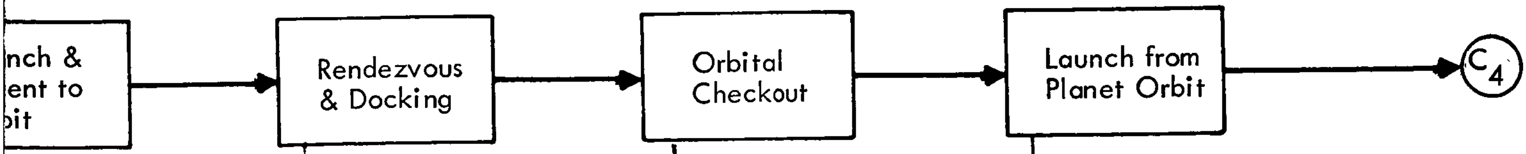
FOLDOUT FRAME 2

EEM

MISS

C_3	Abort	Mars Surface Operations	Lau Asc Or
OPERATIONAL/TEST REQUIREMENTS	-Not applicable (MEM) abort is prime concern here).	-Not operational.	-Not
DEVELOPMENT TESTS	-Not applicable.	-Not applicable.	-No
QUALIFICATION TESTS	**-Not Applicable.**	**-Not applicable.**	**-Not**

ION FLIGHT OPERATIONS



operational.	-Not operational.	-Complete checkout of EEM subsystems and interfaces with MM.	-Not operational.
t applicable.	-Not applicable.	**Test operational readiness of all EEM subsystems on functional simulator. (G)**	-Not applicable.
applicable.	**-Not applicable.**	**-Verify functional checkout capability of EEM subsystems internally, and thru MM interfaces where applicable. (G)**	**-Not applicable.**

EGEND:

G) = Ground Test

F) = Flight Test

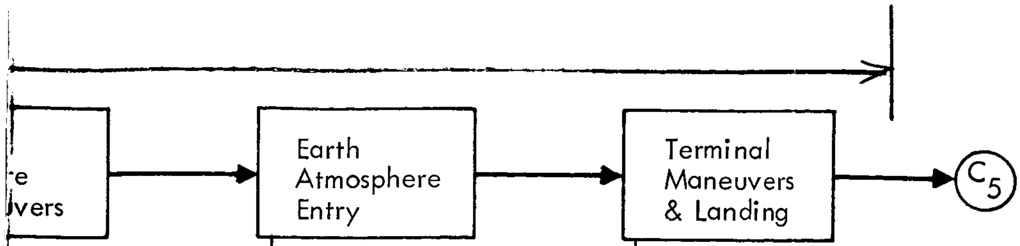
Figure C4: TEST/OPERATIONAL REQUIREMENTS
EARTH ENTRY MODULE (EEM) REQUIREMENTS

EEM —— MISSION FLIGHT OPNS. ——

(C4) → Coast & Midcourse Corrections → Earth Captu Mane

	Coast & Midcourse Corrections	Earth Captu Mane
OPERATIONAL/TEST REQUIREMENTS	-Complete checkout of EEM subsystems & interfaces with MM (2 wks before separation from MM). -Repair of defective subsystems & components (by replacement wherever possible). -Selection of most appropriate alternate modes, where necessary repairs cannot be made.	-Activ integ syste -Trans data -Estab dition reent groun -Trans ment, sampl -Erect form tory & commu coord -Progr corre cours -Shutd MM, s son r EEM.
DEVELOPMENT TESTS	-Not applicable.	-Not r

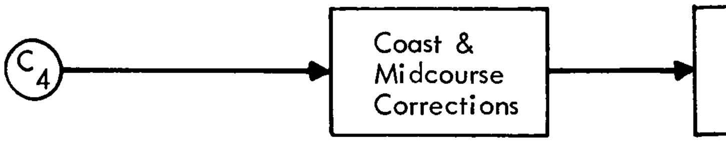
LEGEND: (G) = ground test
(F) = flight test



te & checkout rated EEM-MM s. er trajectory rom MM computer. ish initial con- s for atmosphere y & verify with tracking. er crew, equip- experiment s & data to EEM. inertial plat- or final trajec- establish Earth ication link & nation. m final thrust tion by mid- engine. wn systems of parate & jetti- maining S/C from	-Coordinate separation & trajectory information with Earth-based control. -Position EEM to the required entry attitude; monitor systems operations & make attitude corrections as required. -Execute skip-out maneuvers if and as required. -Inertial guidance only during communications blackout.	-Re-establish communications with Earth-based mission control, make attitude corrections as required & deploy deceleration chutes. -Monitor systems operations, chute deployment, in coordination with Earth-based mission control. -Assure proper EEM attitude for impact & put into impact & recovery mode. -Prepare for emergency evacuation of EEM. -Following impact, deactivate EEM systems no longer needed, & initiate recovery assist operations.
quired.	-Drop tests to evaluate landing dynamics. (F). -Testing of the biconic configuration to determine aerodynamic characteristics of afterbody flow field, and effects of shape changes due to heatshield ablation, under conditions simulating high reentry speeds. Scale model tests. (G) -Test the guidance and control characteristics of the EEM, & its responsiveness to Earth-based communications, when subjected to high inertial, buffeting & thermal loads. Particular emphasis on roll-over maneuver to stay within critical limits of reentry corridor. Scale module configuration, with applicable systems complete. Unmanned. (F) (Cont.)	-Suborbital testing of the EEM to evaluate & improve its capabilities for terminal maneuvers, particularly its ability to withstand landing impact. Full scale configuration, unmanned. (F)

Figure C5: TEST/OPERATIONAL REQUIREMENTS
EARTH ENTRY MODULE (EEM) REQUIREMENTS

EEM (Cont.) — MISSION FLIGHT OPNS.



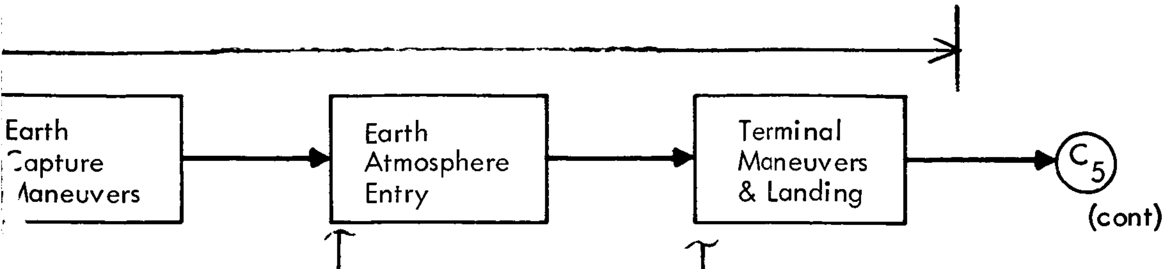
DEVELOPMENT TESTS (CONTINUED)	
QUALIFICATION TESTS	-Qualify control and maintenance capability for EEM at S/V test level in flight. Simulate operations during ground qualification. (G) & (F).

LEGEND:

(G) = Ground Test

(F) = Flight Test

FOLDOUT FRAME 1



	-Static tests & pressure loading to evaluate EEM structural properties. (G).	
Verify EEM communications system capability to transmit & receive required data from simulated Earth-tracking stations at design bit-rates. (G). Verify EEM command & control system capability, via simulators, to monitor & shut down MM systems, and to separate & jettison spacecraft. (G). Verify GCS capability to identify & correlate initial conditions for atmosphere reentry, establish required inertial platform, & program final midcourse correction--via unmanned EEM boilerplate--with complete electrical, attitude control, guidance & navigation, communications & telemetry systems. (F). Capability to activate & checkout EEM subsystems is qualified at S/C level.	-Verify overall capability of EEM & astronauts to survive reentry of earth atmosphere: 1. Unmanned EEM boilerplate, launched propulsively from Earth orbit at 36,000 fps to qualify heat shield & heat transfer capabilities. (F). 2. Manned & fully configured EEM launched propulsively from Earth orbit at 36,000 fps to test the man-EEM interactions at moderate speeds. (F). 3. Unmanned EEM, all systems up, launched propulsively from a highly elliptical orbit at approx. 65,000 fps to verify capability for Earth atmosphere reentry & precision inertial guidance at Mars return speeds, & to verify that conditions for life support can be maintained within EEM, during reentry. (F). 4. All systems up EEM, with crew transfer from MM, & propulsive launch of EEM, from highly elliptical orbit at approx. 65,000 fps to qualify EEM & astronauts for earth atmosphere reentry. (F).	-Verify EEM capability to receive & use ground-tracking data & emergency voice instructions to maintain attitude control, execute roll maneuvers & deploy parachutes for deceleration & guidance within design limits of preplanned trajectory, during unmanned orbital flight. (F). -Verify structural adequacy of EEM & capability to maintain required attitude at impact, during unmanned suborbital landing tests (F). -Qualify EEM for impacts within human tolerance, during landing from manned suborbital tests. (F). -Qualify EEM recovery mode, emergency evacuation & astronaut recovery assist operations, during landing from manned. suborbital tests. (F).

Figure C5: TEST/ OPERATIONAL REQUIREMENTS EARTH ENTRY MODULE (EEM) WORKSHEET (Continued)

FOLDOUT FRAME 2

PRELAUNCH OPERATIONS

	Receive & Inspect	Assembly & Test	Test Chec
OPERATIONAL/TEST REQUIREMENTS	-Not operational.	-Subsystem functional test under ambient conditions. Cold soak of propellant and pressurization system. Vibration test of assembled PM. Mate payload to ELV.	-Limit test monit
DEVELOPMENT TEST	Not applicable.	-Subsystem tests to checkout functional interaction between subsystems under ambient & LH_2 cold soak conditions. (G) -Vibration mode test of PM. (G) -Flight tests not applicable.	-Check catio ibili Suppo -Fligh appli
QUALIFICATION TEST	Not applicable	-Acceptance test to qualify intra- and inter-subsystem functional operation under ambient conditions. (G) -Qualify physical and functional interfaces with ELV by use of simulators. (G)	-Veri PM te mit l test lated (G)

PROPULSION MODULES (PM-1, PM-2, PM-3)

LAUNCH OPERATIONS → ← EARTH ORBIT OPNS

k cout →	Servicing →	Countdown →	Boost & Orbit Injection → (D1)
l functional with primary oring via T/M.	-PM-1 Load mainstage, transtage, and reaction control propellants. PM-2 Load mainstage, transtage, MPM, and reaction control props. PM-3 Load mainstage, transtage, orbit trim, and reaction control propellants.	-Limited monitoring of T/M.	-T/M monitoring. Boost environment; vibration, acoustic, tempo/altitude, acceleration. Establish spatial orientation in elliptical orbit. Provide transtage ΔV to rendezvous circular orbit. Separate transtage.
out PM communi- is system compat- ty with Launch rt Equip. (G) t tests not cable.	-Checkout propellant loading & thermal conditioning of nuclear stages. (G)	-Checkout PM communications system compatibility with launch equipment. (G) -Flight tests not applicable. -Dev. tests to determine nuclear stage effects on pad abort. (G).	-Subsystem tests to checkout items sensitive to vibration, acoustic, acceleration, and rapid altitude change environment. (G) -Design development tests of guidance & control, and communications system. (F) -Design development tests of transtage ΔV capability. (G) & (F)
y capability of elemetry to trans- aunch operations data to simu- l ground station.	-Verify capability of loading PM propellants at nominal, maximum & minimum design temps., pressure, density, etc., & maintaining desired conditions throughout launch operations. (G) Separate qual. tests will be req'd on PM umbilicals.	-Qualify PM telemetry to transmit countdown data to launch equipment. (G) -Conduct destruct tests on nuclear stage to qualify PM for pad abort and destruct. (G)	-Conduct vibration/acoustic and temperature/altitude tests on PM. (G) -Conduct acceleration tests on PM components. (G) -Conduct flight qual. test of transtage including separation from a simulated PM (upper stage of ELV). (F) -Static firing qual. test of transtage engines. (G)

Figure D1: TEST/OPERATIONAL REQUIREMENTS PROPULSION MODULES (PM'S) WORKSHEET

EARTH ORBIT OPERATIONS

D1 →	Test & Checkout →	Rendezvous →	Ser
TEST/OPERATIONAL REQUIREMENTS	-Functional checkout of PM rendezvous, docking, attitude, and stabilization control subsystems. Monitor propellant storage and reactor systems for safe conditions. -Environment-thermal/vacuum, zero "g".	-Rendezvous and dock with spacecraft or other PM's. Provide PM attitude and stabilization control, and rendezvous and docking ΔV. Assure docking satisfactorily completed.	-Nc (A LH
DEVELOPMENT TEST	**-Subsystem tests to checkout functional interaction between subsystems under orbital conditions. (G) & (F)** **-Subsystem tests to checkout items sensitive to thermal/vac. & zero-g environment. (G)** **-Propulsion Module thermal balance tests.** (G)	**-Dev. tests with rendezvous and docking simulators. (G)**	**-De sy an ba**
QUALIFICATION TEST	**-Conduct thermal/vacuum test of PM while monitoring systems operation. (G). (cont.)**	**-Verify S/C-PM-3 rendezvous and docking thru use of ground dynamic simulation of respective interfaces. (G). (cont.)**	**-Not (Al Orb tra par Orb fer ual** **LEGE** **(G)** **(F)**

PM's

MISSION FLIGHT OPERATIONS

vicing	Assembly & Test	Earth Orbit Launch & Injection	Coast & Midcourse Corrections
t operational. lternate: transfer z between PM's.)	-Functional checkout of PM subsystems. Separation of meteoroid shield and insulation from PM-1. Final countdown for PM-1.	-PM-1 engine startup, power buildup, and shutdown. Assure achievement of required ΔV. Provide reactor after cooling. Activate release and separation systems. Separate and dispose PM-1.	-Perform periodic functional tests on PM's, otherwise PM's not operational. Conduct midcourse correction firings using the outbound Midcourse Propulsion Module (PM-OBMC).
v. test of transfer stems on a partial d/or full scale sis. (G) & (F)	**-Checkout PM operations with MM control via use of ground simulators. (G)** **-Meteoroid shield and insulation separation, full scale tests. (F)**	**-Checkout PM firing control operations with MM via use of ground simulator. (G)** **-Cold flow & hot firing of nuclear PM stage. (G)** **-Flight testing of developmental nuclear PM stages to checkout propellant pressurization, feed, & engine systems. (F)** -Check separation of PM from ELV stage. (F)	**-Checkout control of PM's via use of ground simulation equipment. (G)** -Ground static firing of developmental PM-OBMC. (G) -Flight test of developmental PM-OBMC. (F) -Thermal balance test for coast environment. (G)
applicable. ternate: ital qual. of nsfer system with tial size p.m. (F). ital qual. of trans- system with act- PM. (F).	**-Qualify all PM subsystems including the use of LH_2 for orbital test and checkout during ground test simulation. (G). (cont.)**	**-Cold flow & hot firing of PM stage in ground test facility. (G). -Flight test and firing of single PM stage. (F). (cont.)**	**-Static firings of PM--OBMC after subjection to earth-Mars thermal-vacuum environment. (G). -Flight test and multiple firings of PM-OBMC after space soak. (F). (cont.)**

D_2

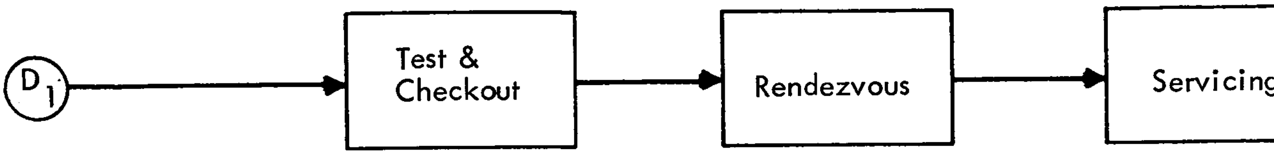
Figure D2: TEST/OPERATIONAL REQUIREMENTS PROPULSION MODULES (PM'S) WORKSHEET

ND:

= Ground Test

= Flight Test

EARTH ORBIT OPERATIONS



QUALIFICATION
TEST
(CONT.)

-Initial phase of PM flight test to verify insulation system & long term storage of propellants. (F).

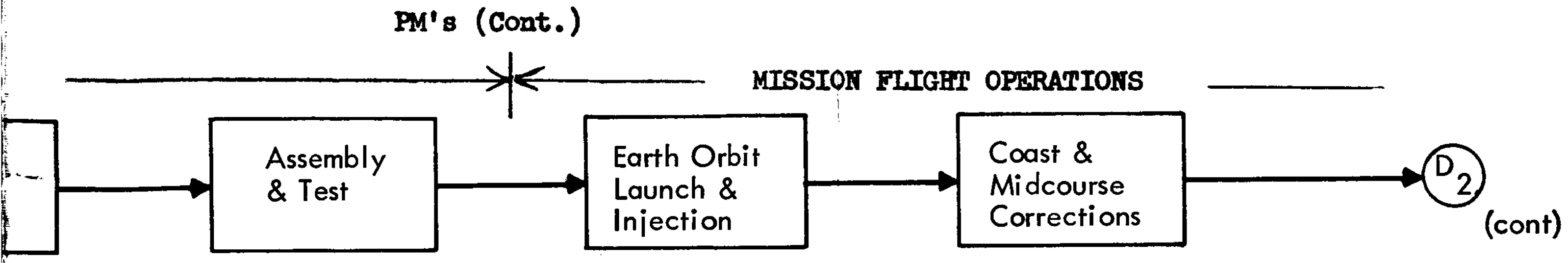
-Repeat for docking of PM-3/PM-2 etc. (G).

-Flight qualify rendezvous & docking operations with S/C and PM's. (F).
PM initially not fueled or simulated, subsequent test with LH_2 load.

LEGEND

(G) =

(F) =



-Flight qualification of PM stage including meteoroid shield & insulation separation. LH_2 loaded. (F).

-Flight test of S/V in simulated mission operations with req'd. PM-1 firing in earth-moon region. (F).

-Flight test of PM-OBMC's on assembled S/V under simulated mission conditions in earth-moon region. (F).

round Test

Flight Test

Figure D2: TEST/OPERATIONAL REQUIREMENTS PROPULSION MODULES (PM'S) WORKSHEET (Continued)

D_2	Abort Operations	Planet Capture & Orbit Insertion	Orbi Chec
TEST/OPERATIONAL REQUIREMENTS	-Determine PM engine firing sequence for abort. Separate PM-2, PM-3 meteoroid shield and insulation as required. Fire PM-2, PM-3 as required, initiate cooldown and separation.	-Separate PM-2 meteoroid and insulation shields. PM-2 engine startup, power buildup, and shutdown. Determine ΔV and spatial positioning requirements. Reactor cooldown. Activate release and separation systems. Separate and dispose PM-2.	-Func of F syst circ stor TVC
DEVELOPMENT TESTS	**-Development to support these operations covered under normal PM firing operations.**	**-Checkout PM-2 firing control operations with MM via use of ground simulator. (G)** **-PM development covered by "EARTH ORBIT LAUNCH & INJECTION" for PM-1. (G) & (F)**	**-Incl as p simu**
QUALIFICATION TEST	**-PM's qualified based on normal mission mode, except verify capability to operate out of normal mission sequence.(G).**	**-Flight test at S/V level in simulated mission operations with req'd. PM-2. Firing in earth-moon region. (F).** **-Single PM tests previously covered under "EARTH ORBIT LAUNCH & INJECTION".**	**-Veri bili simu from** **LE** **(G** **(F**

PM's

MISSION FLIGHT OPERATIONS

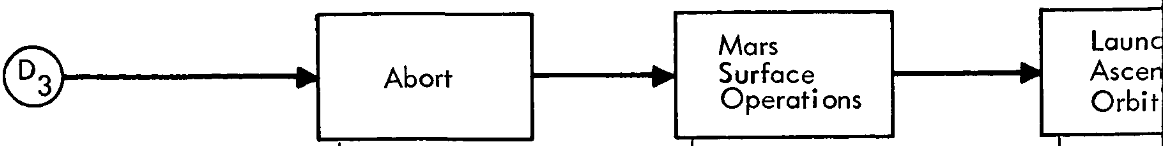
ut	Planet Orbit Coast & Corrections	Separation	Deorbit, Descent & Landing	D_3
onal checkout 3 orbit trim , electrical try, propellant e and feed, stem.	-Space vehicle spatial orientation satisfactory. Fire orbit trim engines (PM-OT). Verify that new orbit is satisfactory. Make additional orbit trim corrections as required.	-Not operational.	-Not operational.	
	Mars Orbital environment, thermal cycling.			
: PM operations **; of ground** **:ion. (G)**	**-Developmental static firings of PM-3 orbit trim propulsion system. (G)** **-Thermal balance test for Mars orbital environment. (G)**	**-Not applicable.**	**-Not applicable.**	
checkout capa- **of PM-OT thru** **:ed test inputs** **1. (G).**	**-Static firings of PM-OT after subjection to space soak environment.(G).** **-Flight test & multiple firings of PM-OT after space soak. (F).**	**-Not applicable.**	**-Not applicable.**	

ND:

= Ground Test

= Flight Test

Figure D3: TEST/OPERATIONAL REQUIREMENTS PROPULSION MODULES (PM'S) WORKSHEET



TEST/OPERATIONAL REQUIREMENTS	-Not operational.	-Not operational.	-Perfo opera quire tion with
DEVELOPMENT TESTS	**-Not applicable.**	**-Not applicable.**	**-Simul phasi which for r optim capab space**
QUALIFICATION TESTS	**-Not Applicable.**	**-Not applicable.**	**-PM's orbit by te for P "Plan Corre**

LEGEN

(G)

(F)

PM's

SSION FLIGHT OPERATIONS

& o	Rendezvous & Docking	Orbital Checkout	Launch from Planet Orbit
orbit trim on as re- in prepara- r rendezvous e MEM.	-Not operational.	-Checkout PM-3 systems. Dispose orbit trim PM, and PM-3 meteoroid shield and insulation. Assure satisfactory separation.	-PM-3 engine startup, power buildup, and shutdown. Assure achievement of required ΔV. Provide reactor after cooling. Activate release and separation systems. Separate and dispose PM-3.
e spatial ; complexities ay be required dezvous, to e orbit trim ities of the aft. (G)	-Not applicable.	-Ref: Tests of PM-1 for "Assembly & Test-Earth Orbit Operations".	-Ref: Tests of PM-1 for "Earth Orbit Launch and Injection."
alified for rim operations s specified s relating to Orbit Coast & ions".	-Not applicable.	-Verify PM-OT separation thru use of ground dynamic simulation of respective interfaces. (G) -PM-3 meteoroid shield and insulation separation qualified by similarity to PM-1. -Flight qualify PM-OT separation at SV level.	-Ground qualification and single PM flight qualifition verified by similarity to PM-1. -Flight test of S/V in simulated mission operations with required PM-3 firing in Earth-Moon region. (F)

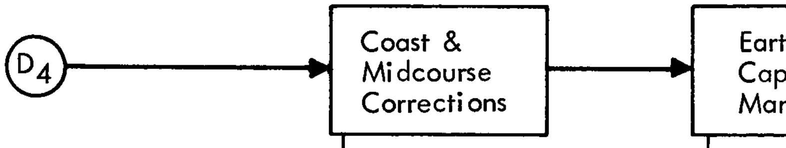
D4

round Test

light Test

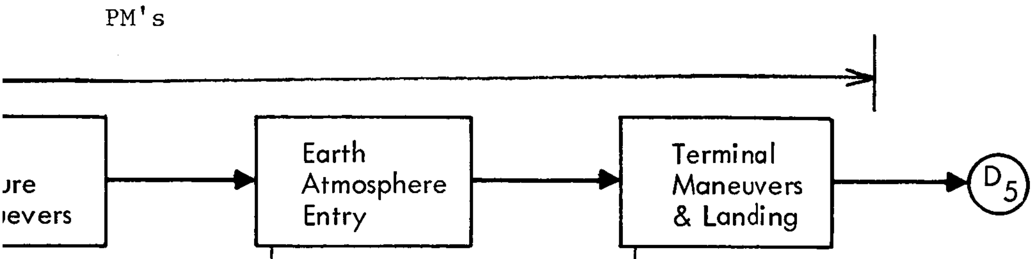
Figure D4: TEST/OPERATIONAL REQUIREMENTS PROPULSION MODULES (PM'S) WORKSHEET

MISSION FLIGHT OPERATIONS



TEST/OPERATIONAL REQUIREMENTS	-Not operational. Return midcourse propulsion module considered part of spacecraft.	-Not
DEVELOPMENT TESTS	**Not applicable.**	**Not**
QUALIFICATION TESTS	-PM-IBCM's are qualified at the spacecraft test level.	Not

LEGEND: (G) = ground test
(F) = flight test



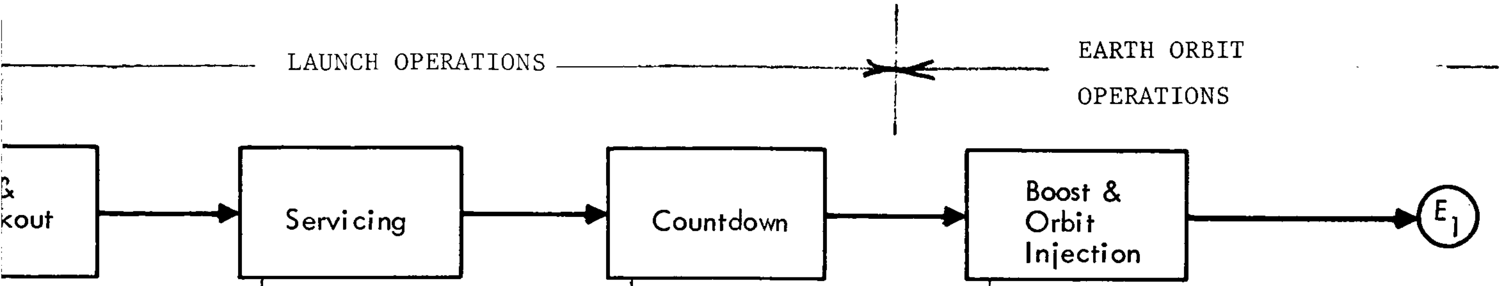
perational.	-Not operational.	-Not operational.
applicable.	Not applicable.	Not applicable.
pplicable.	Not applicable.	Not applicable.

Figure D5: TEST/OPERATIONAL REQUIREMENTS PROPULSION MODULES (PM'S) WORKSHEET

SPACECRAFT ← PRE-LAUNCH OPERATIONS →

	Receive & Inspect	Assembly & Test	Test Chec
OPERATIONAL/TEST REQUIREMENTS	-Not operational.	-Assemble modules (MEM, MM, EEM) into single spacecraft configuration. Mate this payload to ELV. Intra- and inter-system functional operation under ambient conditions. Limited environmental vibration and thermal/vacuum tests.	-Compr out t elimi S/C i and m while groun -Limit opera prima via T
DEVELOPMENT TEST	**Not applicable.**	**-S/C operational tests to checkout inter-module functions and to integrate astronauts into command & control functions. (G)** **-Thorough thermal balance & vibration mode testing. (G)** **-Flight tests not applicable.**	**-Chec** **of M** **syst** **MEM** **T/M** **stat** **-Flig** **appl**
QUALIFICATION TEST	**Not applicable.**	**-Qualify functional operation of overall spacecraft with emphasis on inter-module operations. Test at ambient conditions. (G)** **-Qualify physical and functional interfaces with ELV thru use of simulators. (G)**	**-Veri** **MM t** **mit** **laun** **test** **grou** **(G)**

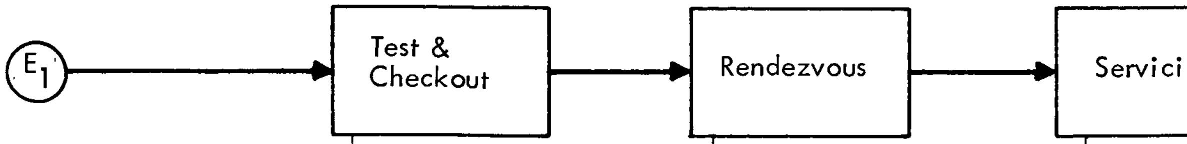
FOLDOUT FRAME 1



ehensive check- o discover and nate incomplete nstallations alfunctions still on the d. ed functional tion with ry monitoring /M.	-Load ECS/LSS expendables: cryogens, gases, absorbents, water and food. Load RCS propellants.	-Limited monitoring of S/C launch readiness via T/M.	-Launch of assembled spacecraft (MEM, MM, EEM, plus propellants for long missions) on ELV. -T/M monitoring boost environment: vibration, acoustics, temperature/altitude, acceleration. -Assembly, tanking and checkout (ATC) crew launched all up in man-rated logistic vehicle.
kout capability M communications em to transmit & EEM monitored data to ground ions. (G) nt tests not icable.	**-No dev. tests req'd.**	**-Checkout capability of MM communications system to transmit MEM & EEM monitored T/M data to launch equipment. (G) -Flight tests not applicable.**	**-Vibration mode testing of spacecraft. (G) -No flight tests required.**
y capability of elemetry to trans- all required S/C h operations data to simulated nd T/M stations.	**-Verify capability of servicing S/C thru use of launch umbilical simulators to checkout physical interfaces. Actual fluid checks will be done during umbilical qualification tests. (G)**	**-Verify capability of MM telemetry to transmit all required S/C launch countdown data to simulated launch equipment. (G)**	**-Flight qual. test of S/C to qualify all systems under actual mission launch conditions. (F)**

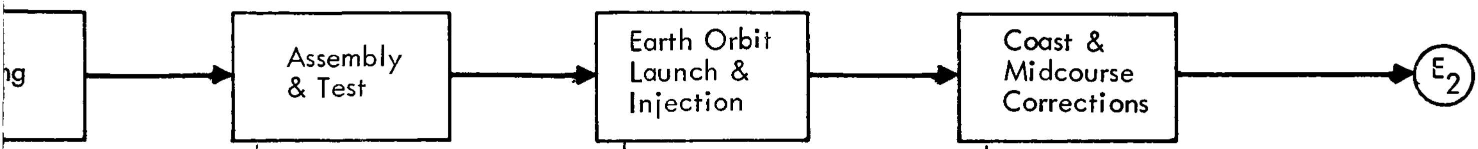
Figure E1: TEST/OPERATIONAL REQUIREMENTS SPACECRAFT (S/C) WORKSHEET

SPACECRAFT ——— EARTH ORBIT OPERATIO



	Test & Checkout	Rendezvous	Servici
OPERATIONAL/TEST REQUIREMENTS	-ATC crew rendezvous and docking with spacecraft. -Activation and functional checkout of all spacecraft systems.	-Payload is docked to the space vehicle configuration already assembled in orbit by ATC crew.	-Orbita suppor brough vehicl
	-Environment--- thermal/vacuum, zero "g".		
DEVELOPMENT TEST	**-S/C operational tests using onboard T & C/O equipment to checkout inter-module functions and to integrate astronauts into command & control functions. (G)** **-Flight tests not req'd.** **-S/C thermal balance tests. (G)**	**-Dev. tests with rendezvous & docking simulators. (G)**	**-Dev.**
QUALIFICATION TEST	**-Thermal/vacuum environmental tests on spacecraft in ground environ. test chamber. Operate subsystems as applicable. (G).** **-Flight qual. test of S/C under actual mission conditions, initially unmanned then manned.** (F)	**-Verify S/C -PM-3 docking thru use of ground dynamic simulation of respective interfaces. (G).** **-Flight qualify rendezvous & docking operations with S/C & PM. (F). PM initially not fueled, subsequent test with LH_2 load.**	**-Veri tran from icle** **LEGE** **(G)** **(F)**

IS ——— MISSION FLIGHT OPERATIONS



l supplies and t equipment t up by logistic es.	-Assemble spacecraft to primary propulsion systems. Test spacecraft command and control capability over the propulsion systems. -Mission crew is brought up and ATC crew is sent back to Earth in a man-rated logistics vehicle. Astronauts take over final checkout and countdown, and subsequent mission operations.	-Verify spatial positioning and interface of spacecraft with ground control. -Earth orbit countdown for complete verification of mission readiness. -Earth orbit launch and injection into interplanetary trajectory. -Dispose of PM-1. -Readiness at abort stations.	-Determine and adjust spacecraft position and trajectory, in coordination with earth-based tracking stations. -Perform scheduled maintenance and housekeeping, and unscheduled maintenance and repair as required. -Astronaut checkout and monitoring of spacecraft systems and subsystems. -Recurring personnel operations, including personal hygiene, crew training and conditioning, nutrition, recreation, sleep, etc. -Readiness check on PM-2.
ests not req'd.	**-Checkout test operations with use of ground simulators. Integrate astronauts into test operations. Control via MM. (G)**	**--Checkout orbital operations with use of ground simulators. (G)**	**-Checkout mission operations with use of ground simulators. Integrate astronauts into mission operations. Control via MM. (G)** **-Thermal balance test for coast environment. (G)**
fy capability to sfer supplies logistics veh- to S/C.	**-Qualify test capability of S/C over the PM's at S/V test level in flight. Simulate these opn's. during ground qual. of S/C. (G) & (F). (cont.)**	**-Verify S/C earth orbital countdown. Simulate command receipt and response of PM's. (G).** **-Qualify control capability of S/C over (cont.)**	**-Qualify control & maintenance capability of S/C at S/V test level in flight. Simulate operations during ground qual. (G) & (F).** **-Verify capability to checkout PM-2. (G) & (F). (cont.)**

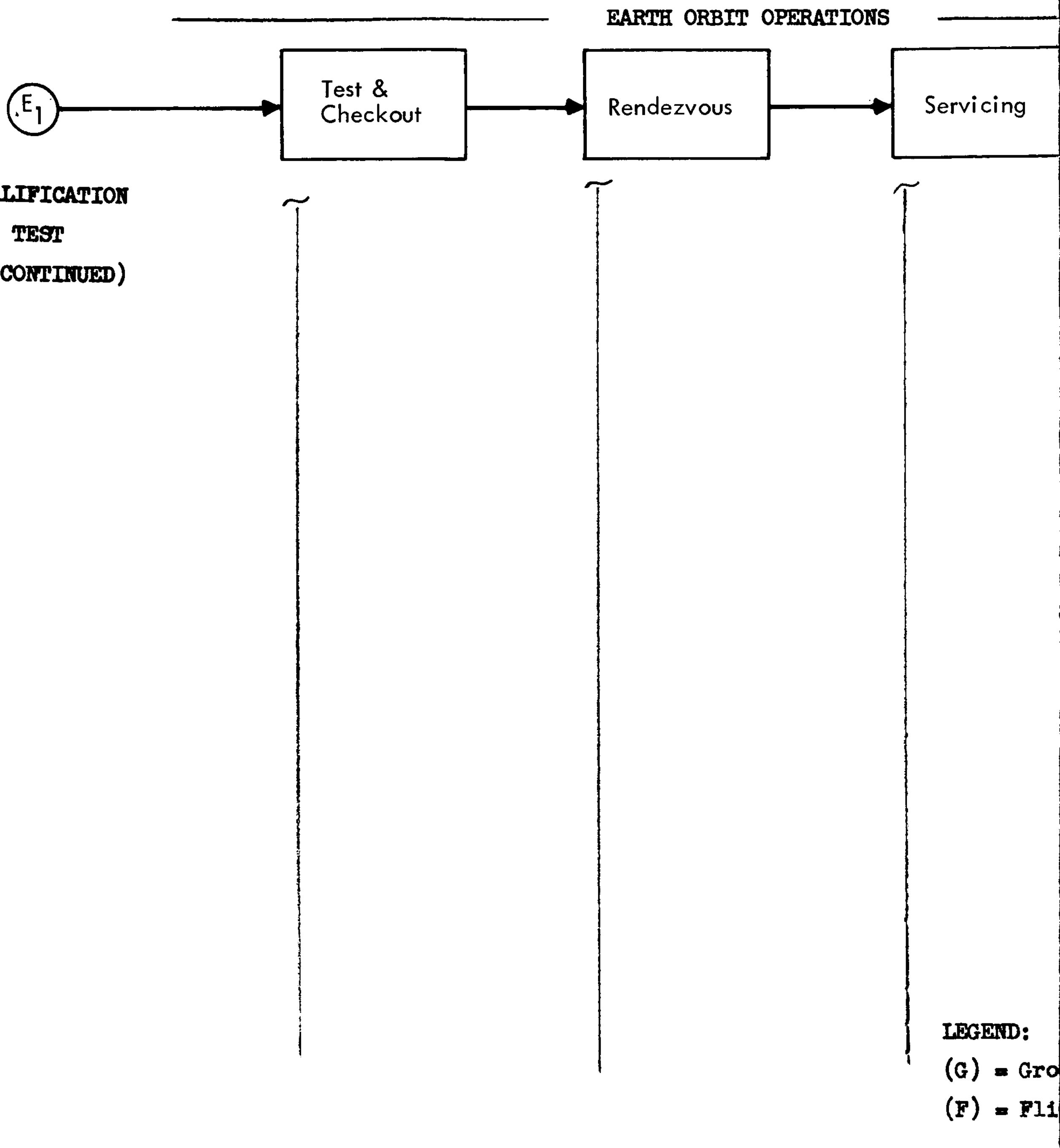
ND:

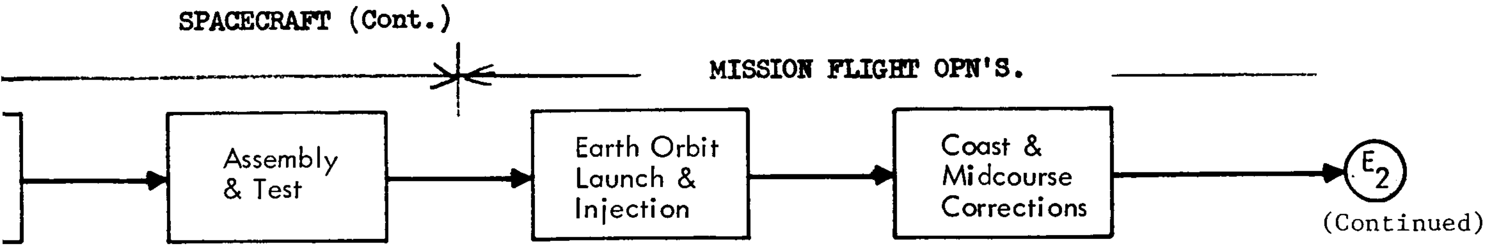
= Ground Test

= Flight Test

Figure E2: TEST/OPERATIONAL REQUIREMENTS SPACECRAFT (S/C) WORKSHEET

QUALIFICATION TEST (CONTINUED)





- Integrate astronauts into both ground & flight qual. testing. (G) & (F).

- the PM's at S/V test level. (F).
- Astronauts will be utilized during the qual. test. (F).

- Earth/Mars thermal-vacuum environmental test on spacecraft in ground environmental test chamber.
- Operate subsystems as applicable. (G).

und Test
ght Test

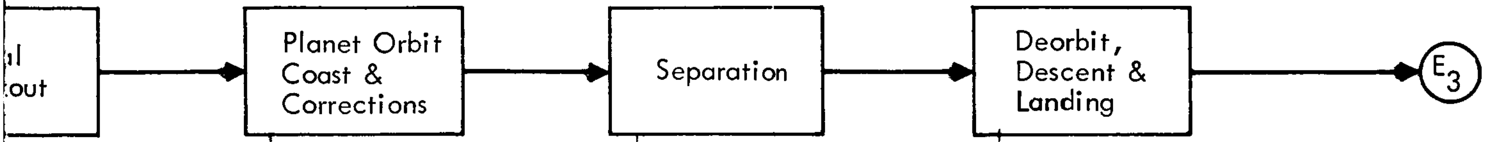
Figure E2: TEST/OPERATIONAL REQUIREMENTS SPACECRAFT (S/C) WORKSHEET (Continued)

SPACECRAFT

E_2	Abort Operations	Planet Capture & Orbit Insertion	Orbit Check
OPERATIONAL/TEST REQUIREMENTS	-All crew members to abort positions. -Provide supplies and equipment transfer, and command and control capability for abort operations. -Periodic abort drills.	-Determine and adjust positioning within limits of mid-course PM. -Release meteoroid shield and insulation, and mid-course PM. -Maintain S/V attitude control during PM-2 firing. Dispose of PM-2 after planet capture.	-Condu space parti on op ness syste EEM. activ propu Trans (3) t -Mars ment. cycli
DEVELOPMENT TESTS	**-Simulation of S/C abort operations by use of ground test simulator. (G)**	**-Support design thru mission operations simulation in ground based facilities. (G)**	**-Condu latic chec (G)** **-Therm under orbit (G)**
QUALIFICATION TEST	**-Qualified based on normal mission mode, except verify systems capability to operate out of normal mission sequence. (G).**	**-Verify capability of S/C to control planet capture operations. Simulate command receipt & response of PM's. (G).** **-Qualify control capability of S/C over the PM's at S/V test level. (F).**	**-Quali capab MM co readi MEM & check propu Integ into both (F).** **-Therm menta groun simul al en ate s able.**

FOLDOUT FRAME /

ISSION FLIGHT OPERATIONS



ct checkout of craft, with cular emphasis erational readi- and separation ms of MEM and Checkout and ate orbit trim lsion system. fer astronauts o MEM.	-Establish spatial orientation of spacecraft and make necessary corrections for desired orbit. -Maintain S/C spatial orientation after corrections.	-Provide required spacecraft stabilization and control during MEM separation maneuver.	-Verify spacecraft spatial orientation with earth-based mission control during MEM deployment.
orbital environ- Thermal ng.	→	→	→
ct ground simu- n of S/C orbital out operations. **al balance tests simulated Mars al environment.**	**-Ground simulation of orbital guidance & navigation operations. (G)** **-Thermal balance test for Mars orbital environment. (G)**	**-Simulate stabilization & control operations on ground simulator. (G)**	**-No dev. tests required.**
fy on-board test ility of S/C with ntrol, emphasize ness checks on EEM. Simulate out of PM-OT lsion system. rate astronauts test loop for MM & MEM.(G) & **al/vacuum environ- l tests on S/C in d test chamber ating Mars orbit- vironment. Oper- ystems as applic- (G).**	**-Verify capability of S/C to attain and maintain desired S/V spatial attitude during S/V qual. tests in earth-moon region. (F).** **-Continued environmental tests. (G).**	**-Verify stabilization & control capability of S/C during MEM separation maneuvers during S/V mission qualification tests. (F).**	**-Verify capability of S/C communications & data management subsystems to monitor & display orientation data from simulated earth-based mission control. (G).**

LEGEND:

(G) = Ground Test

(F) = Flight Test

Figure E3: TEST/OPERATIONAL REQUIREMENTS SPACECRAFT (S/C) WORKSHEET

SPACECRAFT

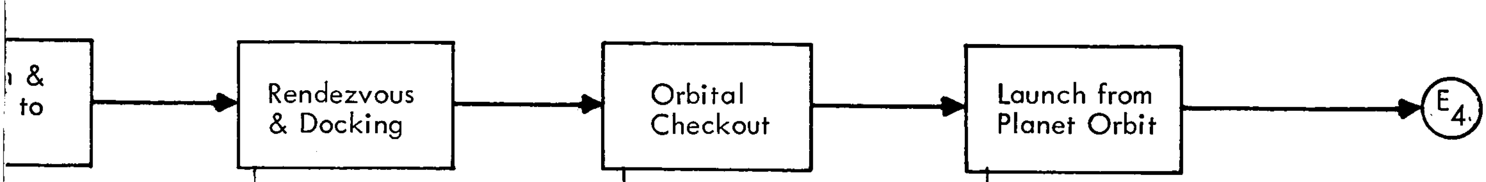
E_3	Abort	Mars Surface Operations	Launc Ascen Orbit
OPERATIONAL/TEST REQUIREMENTS	-Remaining crew members in abort mode for all possible aid to returning MEM.	-Verify and correct spatial orientation of spacecraft, in coordination with earth-based control. -Make necessary checkouts and maintenance in readiness of spacecraft for MEM rendezvous.	-Positi MEM re mainta stabil contro
DEVELOPMENT TESTS	**-Devel. tests not required.**	**-Devel. tests not required.**	**-Devel requi**
QUALIFICATION TESTS	**-S/C is qualified for abort support activities by the tests specified for MM.**	**-S/C is qualified for support of Mars surface operations by the tests specified for MM.**	**-Verif to co energ traje spati of ME**

LEGEN

(G) -

(F) -

MISSION FLIGHT OPERATIONS



on orbit for ndezvous, and in attitude ization and l.	-Maintain spacecraft in stabilized attitude during MEM docking maneuvers. Maneuver MEM into spacecraft docking mechanisms. Verify satisfactory attachment.	-Transfer MEM crew and Mars samples to spacecraft. Shut down MEM systems, and separate MEM and PM-3 meteoroid shield and insulation from spacecraft. Complete checkout and rehearsal of EEM functioning. Prepare spacecraft for return trip.	-Verify satisfactory spatial positioning of spacecraft. Provide S/V attitude control. Dispose of PM-3 after ΔV maneuver and shutdown.
. tests not red.	-Test attitude control via ground simulator. (G)	-Checkout launch readiness via ground simulator. (G)	-Checkout launch operations on functional simulator. (G)
y S/C capability rrelate low y rendezvous ctories and al positioning M-S/C. (G).	-Flight qualify docking operations of MEM and S/C in near-Earth mission qualification tests. See S/V level qual. test. (F)	-Qualify integrated orbital checkout operations within S/C modules thru simulation during ground test including astronaut participation. (G)	-Verify Mars orbit launch capability of S/C thru simulated command receipt and response of PM's. (G) -Qualify control capability of S/C over PM's at S/V test level. (F)

D:

Ground Test

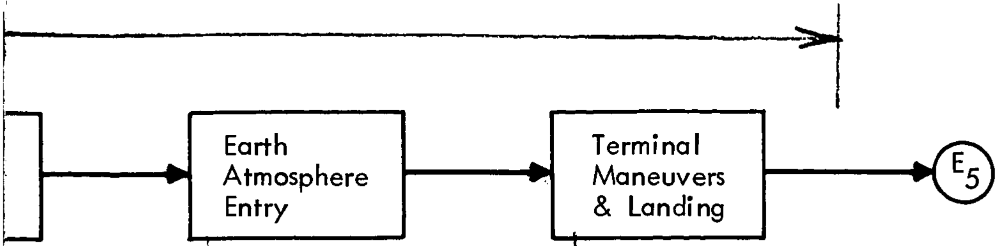
Flight Test

Figure E4: TEST/OPERATIONAL REQUIREMENTS SPACECRAFT (S/C) WORKSHEET

MISSION FLIGHT OPERATIONS

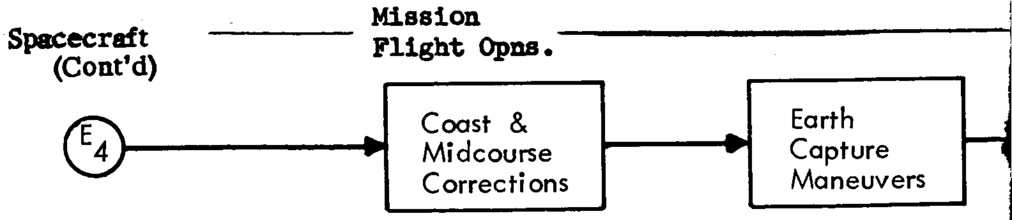
SPACECRAFT E4	Coast & Midcourse Corrections	Earth Capture Maneuvers
OPERATIONAL/TEST REQUIREMENTS	-Establish spatial positioning, correlated with earth tracking data. Use PMM to achieve correction maneuvers as required. -Unscheduled and scheduled maintenance and housekeeping. -Astronaut checking and monitoring of spacecraft systems, with particular attention to EEM readiness and separation mechanisms (2 weeks before earth capture).	-Shutdown systems. -Erect ine form to c trajector entry. -Separate of spacec EEM for r earth atm predeterm tory.
DEVELOPMENT TESTS	**--Ground firing tests of midcourse correction engines.** (G)	**--Not req**
QUALIFICATION TESTS	-Qualify control & maintenance capability of S/C at S/V test level in flight. Simulate operations during ground qualification (G) & (F). -Verify capability to check out readiness of EEM. (G) & (F) -Earth/Mars thermal-vacuum test on S/C in ground environmental test chamber. Operate subsystems as applicable (G).	-Verify S/C trol subsy ties via s establish & stable atti sign limits launch EE reentry tra -Verify cap tivate & fu rate integr systems af "soak" in t environme verify com EEM comp for transfe data to EE these cond

LEGEND: (G) = ground test
(F) = flight test



spacecraft rtial plat- ontrol EEM y during and dispose raft, freeing eentry of osphere on ined trajec-	-Not applicable.	-Not applicable.
uired.	**--Not applicable.**	**--Not applicable.**
attitude con- stem capabili- imulators, to maintain ude within de- required to M on critical ajectory. (G) ability to ac- ctionally ope- ated EEM-S/C ter prolonged hermal-vacuum nt simulator, & patibility of MM- uters & capability r of trajectory M computer under itions (G).	-(Spacecraft considerations during Earth atmosphere reentry are qualified on the EEM test specification sheets.)	-(Spacecraft considerations during terminal maneuvers and landing are qualified on the EEM test specification sheet.)

Figure E5: TEST/OPERATIONAL REQUIREMENTS SPACECRAFT (S/C) WORKSHEET



QUALIFICATION TESTS
(Continued)

-Static firings of PM-IBMC after subjection to Earth/Mars thermal-vacuum environment. (G)

-Flight test and multiple firings of PM-IBMC's after space soak. (F)

-Flight test of PM-IBMCs on assembled S/V under simulated conditions in Earth-Moon region. (F)

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LEGEND: (G) = ground test
(F) = flight test

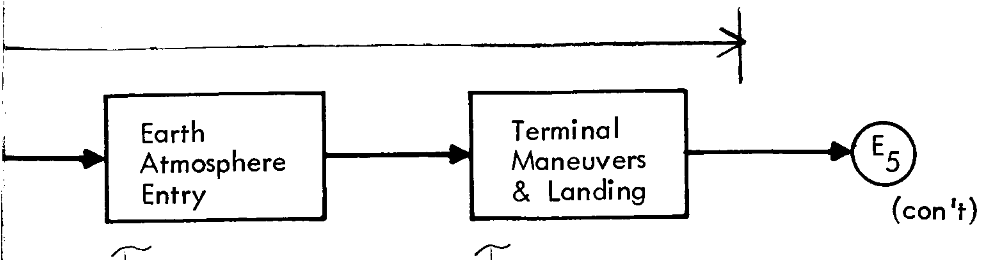

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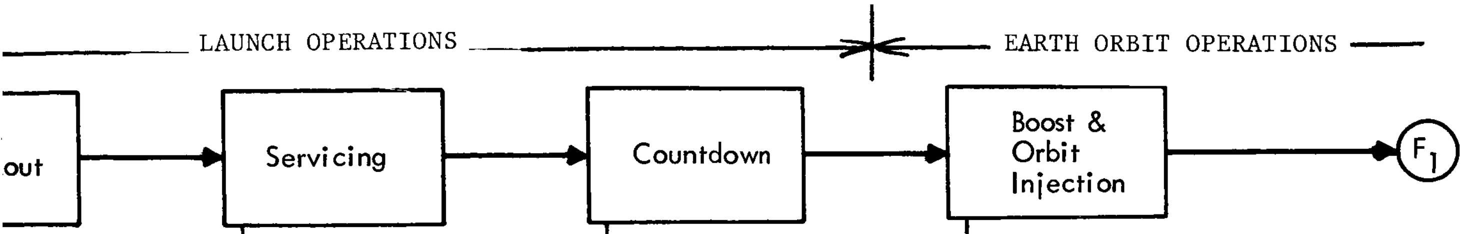
Figure E5: TEST/OPERATIONAL REQUIREMENTS SPACECRAFT (S/C) WORKSHEET (Continued)

FOLDOUT FRAME 2

	PRELAUNCH OPERATIONS		
	Receive & Inspect	Assembly & Test	Test & Chec
TEST/OPERATIONAL REQUIREMENTS	-Not operational.	-Not applicable, see S/C and PM writeups.	-Not ap
DEVELOPMENT TEST	**Not applicable.**	**Not applicable.**	**Not a**
QUALIFICATION TEST	**Not applicable.**	**Not applicable.**	**Not a**

SPACE VEHICLE (S/C + PM-3 + PM-2 + PM-1)



plicable.	-Not applicable.	-Not applicable.	-Not applicable.
pplicable.	**Not applicable.**	**Not applicable.**	**Not applicable.**
pplicable.	**Not applicable.**	**Not applicable.**	**Not applicable.**

Figure F1: TEST/OPERATIONAL REQUIREMENTS SPACE VEHICLE (S/V) WORKSHEET

EARTH ORBIT OPERATIONS

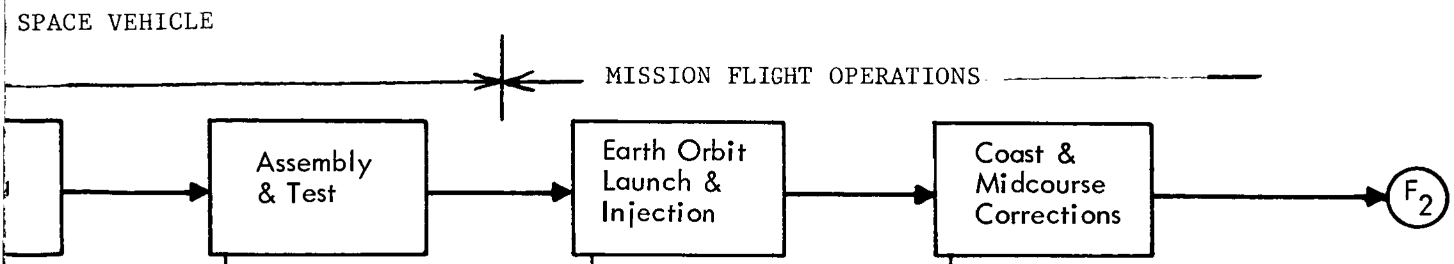
F_1 → Test & Checkout → Rendezvous → Servicin

	Test & Checkout	Rendezvous	Servicin
TEST/OPERATIONAL REQUIREMENTS	-Functional checkout of space vehicle elements to assure readiness for rendezvous and docking. -Environment-thermal vacuum, zero "g".	-Rendezvous and dock- space vehicle elements. Assure all docking operations satisfactorily completed.	-Not appl ternate: LHz betw
DEVELOPMENT TEST	**-Not applicable.**	**-Dev. tests with rendezvous & docking simulators. (G)**	**-Dev. te**
QUALIFICATION TEST	**-Not applicable.**	**-Verify all S/V elements satisfactorily docked. (F).**	**-See PM req'd.**

LEGE

(G)

(F)



icable. (Al- Transfer een PM's.)	-Functional checkout of space vehicle with emphasis on interfacing functions between PM's and S/C. Assure capability of MM crew to control S/V operations. Vehicle countdown. Separate meteoroid shield and insulation from PM-1. Separate OSE from S/V.	-S/V final countdown. Engine ignition. Perform propulsive maneuver. Shut down engine. Release and separate PM-1 from S/V.	-Systems monitoring and control. Maintain space vehicle attitude and control. Conduct experiment operations. Space vehicle scheduled and unscheduled maintenance. Orient space vehicle prior to mid-course correction based on earth station data. Conduct correction maneuvers. Repeat as required for additional correction maneuvers. Perform checkout of PM-2.
sts not req'd.	**-Checkout S/V test operations via use of ground simulators. (G)**	**-Checkout S/V orbital launch & injection operations via use of ground simulator. (G)**	**-Checkout S/V coast & mid-course operations via use of ground simulator. (G)**
section for qual. tests.	**-Verify all S/V operations in earth orbital qual. test. with astronaut-test crew. (F).**	**-Conduct simulated mission firing of PM-1 and S/V in earth-moon region. Separate PM-1 from S/V. (F).**	**-Qualify dynamics of mid-course correction on S/V thru ground test & simulation. (G).** **-Conduct simulated mission midcourse correction with PM-OBMC and S/V. (F).**

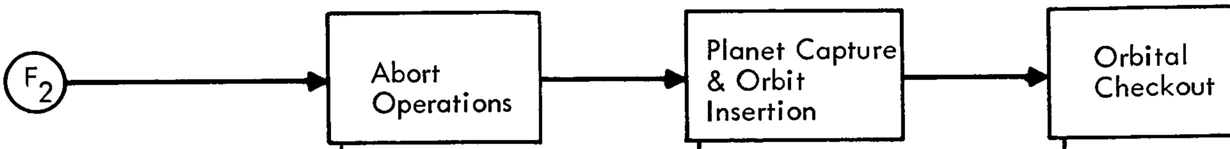
ND:

Ground Test

Flight Test

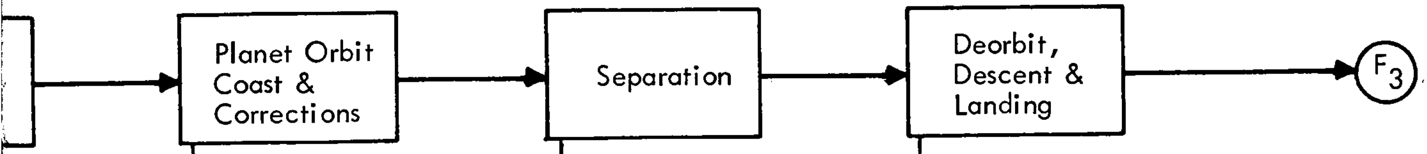
Figure F2: TEST/OPERATIONAL REQUIREMENTS SPACE VEHICLE (S/V) WORKSHEET

MISS



	Abort Operations	Planet Capture & Orbit Insertion	Orbital Checkout
TEST/OPERATIONAL REQUIREMENTS	--Crew to abort stations. Determine PM firing sequence for abort. Determine abort trajectory and orient S/V. Initiate abort operations.	--Make final spatial positioning corrections with PM-OBMC. Determine S/V capture and injection requirements. S/V countdown, engine ignition, propulsive maneuver and engine shutdown. Release and engine shutdown. Release and separate PM-2 from S/V. Dispose PM-2.	--S/V check trim prop tem C/O. uled and maintenan
DEVELOPMENT TESTS	**-Support design thru ground simulation of mission abort operations. (G)**	**-Support design thru ground simulation of planet capture & orbit insertion operations. (G)**	**-Ground si S/V funct**
QUALIFICATION TEST	**-Qualified based on normal mission mode, except verify capability to operate out of normal mission sequence. (G).**	**-Conduct simulated mission firing of PM-2 and S/V in earth-moon region. Separate PM-2 from S/V. (F).**	**-Qualify M checkout at S/V le simulated condition earth reg**

SPACE VEHICLE
ON FLIGHT OPERATIONS

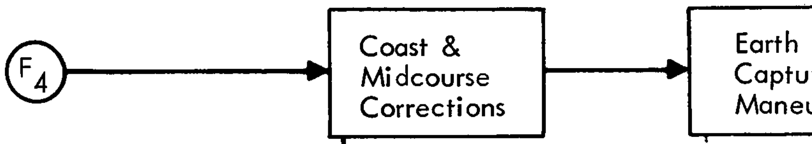


out. Orbit ulsion sys- S/V sched- unscheduled ce.	-Orient space vehicle with respect to planet. Conduct orbit correction maneuvers using PM-3 orbit trim propulsion. Evaluate new orbit positioning and coordinate with earth control. S/V maintenance.	-Coordinate navigational and deorbiting flight data. Separate MEM from space vehicle. Provide S/V stabilization and control.	-Maintain S/V attitude and control.
	Mars orbital environment, thermal cycling. →	→	→
mulation of ions. (G)	**-Checkout S/V orbit coast & corrections via ground simulator. (G)**	**-Simulate stabilization & control on ground simulator. (G)**	**-Ground simulation of S/V attitude control functions. (G)**
ars orbital capability vel under mission s in near ion. (F).	**-Qualify dynamics of orbit trim correction on S/V thru ground test & simulation. (G).** **-Conduct simulated orbit correction with PM-OT and S/V. (F).**	**-Final flight qual. of separation system on S/V qual. mission in earth-moon region. (F).**	**-Not required.**

Figure F3: TEST/OPERATIONAL REQUIREMENTS SPACE VEHICLE (S/V) WORKSHEET

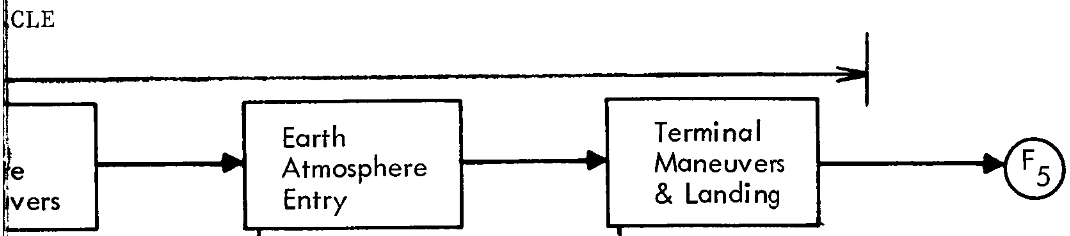
SPACE VEH

MISSION FLIGHT OPERATIONS



TEST/OPERATIONAL REQUIREMENTS	--Not applicable. See spacecraft requirements.	--NA, s ments
DEVELOPMENT TESTS	**Not applicable.**	**Not**
QUALIFICATION TESTS	-Qualify dynamics of mid-course correction on S/V through ground test & simulation. (G) -Conduct simulated mission midcourse correction with PM-IBMC & S/V. (F)	Not

LEGEND: (G) = ground test
(F) = flight test



ee S/C require- .	--NA, see EEM requirements.	--NA, see EEM requirements.
pplicable.	**Not applicable.**	**Not applicable.**
pplicable.	Not applicable.	Not applicable.

Figure F5: TEST/OPERATIONAL REQUIREMENTS SPACE VEHICLE (S/V) WORKSHEET

APPENDIX B
DETAILED FUNDING EXAMPLES

This appendix is a detailed graphic and tabular presentation of the output obtained from the funding model previously discussed in Section 5.3.3.5. Its organization follows the IMISCD Work Breakdown Structure (Table 5.3-1) from the summary level down to and including Level 4.

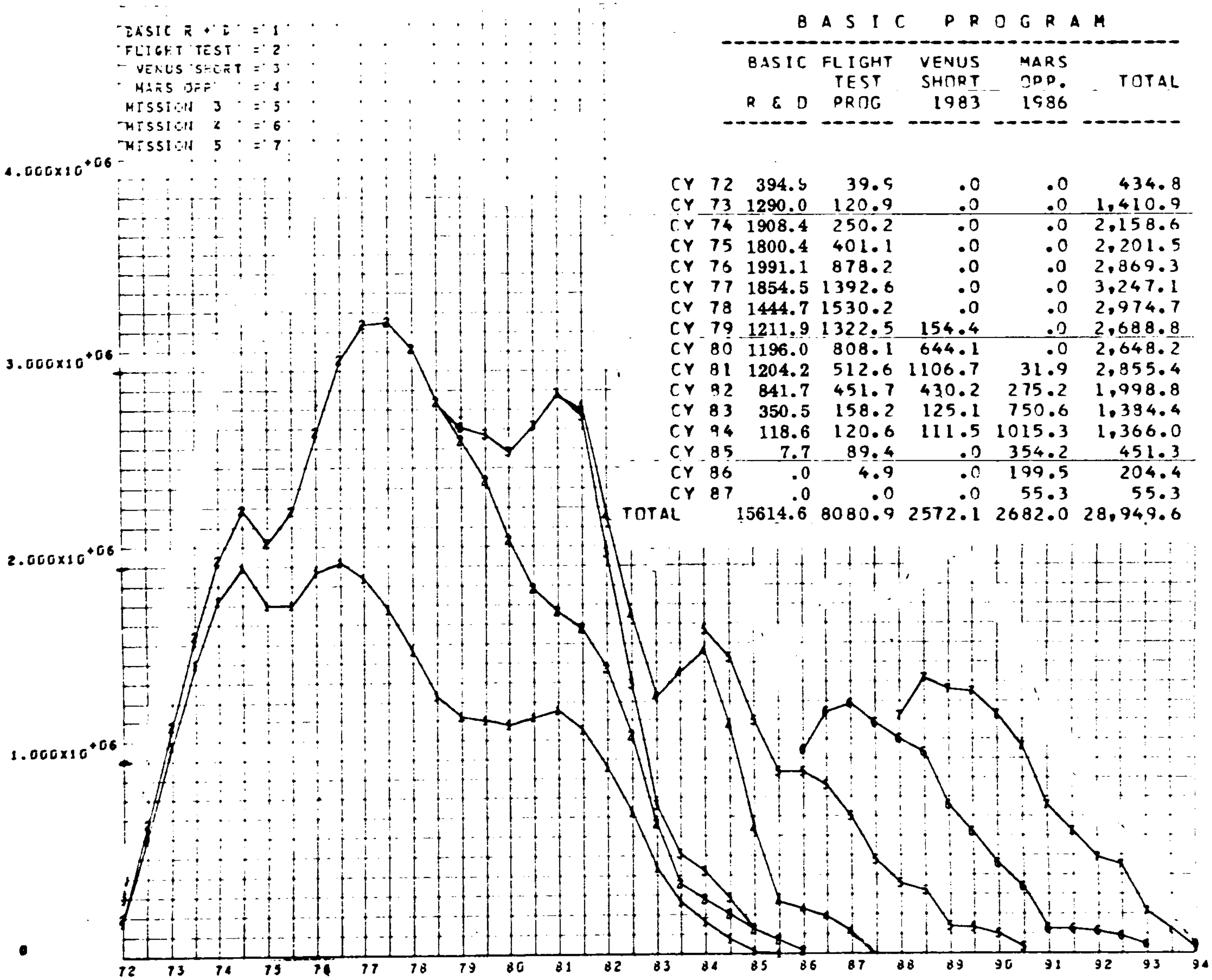
In Figures 1 and 2 total program funding is shown for the IMISCD Basic and Alternate program examples. Figures 3 and 4 are iterations of the Basic program example showing the effect on Funding requirements if: (1) All missions are scheduled *one* year later and all end item flow times are stretched by *one* year, and (2) all missions are scheduled *two* years later and all end item flow times are stretched by two years.

The funding iterations assume that the schedule changes would have no effect on cost. In an actual contract situation, where near optimum schedules are established, any schedule change would result in increased costs. This leads to some interesting applications of the funding model that could be accomplished individually or in combination. For instance: (a) Assume an optimum schedule (probably the Basic example) and assess the cost penalties of schedule variations; (b) Assume various rates of dollar escalation per year (1, 2, 3, 4, and 5 percent) and examine the effect on funding requirements; (c) Assume various annual budget levels (2, 3, 4, and 5 billion per year) and determine the effect on schedules and (d) etc. As in Figures 1 through 4, such applications of the funding model could be displayed at the total program level or they could be presented in detail as shown in Figures 4 through 16 and in Tables 1 through 23.

IMISCD PROGRAM FUNDING

CASE NUMBER 1

Figure 1



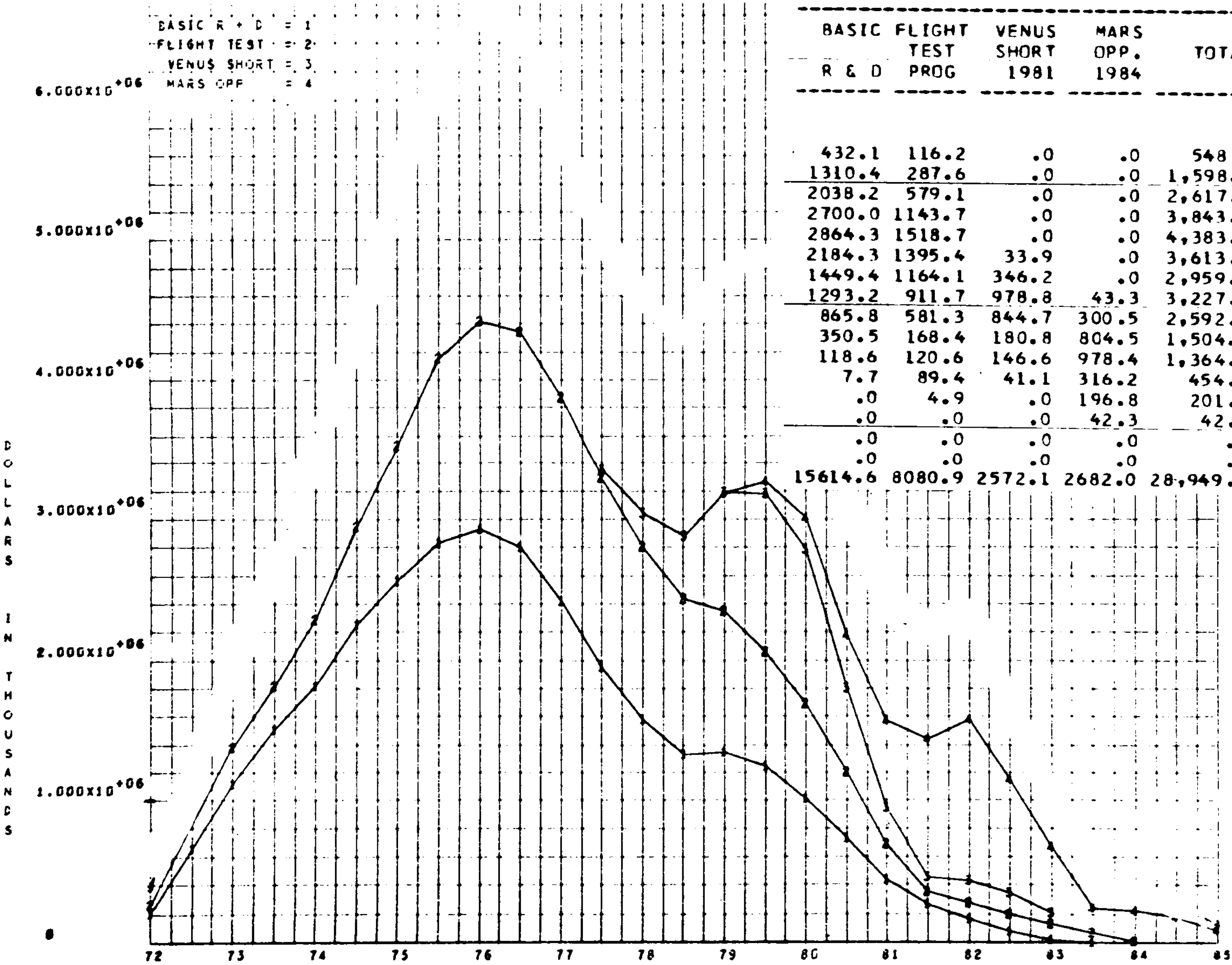
B A S I C   P R O G R A M

	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL
CY 72	394.5	39.9	.0	.0	434.8
CY 73	1290.0	120.9	.0	.0	1,410.9
CY 74	1908.4	250.2	.0	.0	2,158.6
CY 75	1800.4	401.1	.0	.0	2,201.5
CY 76	1991.1	878.2	.0	.0	2,869.3
CY 77	1854.5	1392.6	.0	.0	3,247.1
CY 78	1444.7	1530.2	.0	.0	2,974.7
CY 79	1211.9	1322.5	154.4	.0	2,688.8
CY 80	1196.0	808.1	644.1	.0	2,648.2
CY 81	1204.2	512.6	1106.7	31.9	2,855.4
CY 82	841.7	451.7	430.2	275.2	1,998.8
CY 83	350.5	158.2	125.1	750.6	1,384.4
CY 94	118.6	120.6	111.5	1015.3	1,366.0
CY 85	7.7	89.4	.0	354.2	451.3
CY 86	.0	4.9	.0	199.5	204.4
CY 87	.0	.0	.0	55.3	55.3
TOTAL	15614.6	8080.9	2572.1	2682.0	28,949.6

IMISCD PROGRAM FUNDING

CASE NUMBER 2

Figure 2



A L T E R N A T E   P R O G R A M

BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
432.1	116.2	.0	.0	548.3
1310.4	287.6	.0	.0	1,598.C
2038.2	579.1	.0	.0	2,617.3
2700.0	1143.7	.0	.0	3,843.6
2864.3	1518.7	.0	.0	4,383.0
2184.3	1395.4	33.9	.0	3,613.6
1449.4	1164.1	346.2	.0	2,959.7
1293.2	911.7	978.8	43.3	3,227.1
865.8	581.3	844.7	300.5	2,592.3
350.5	168.4	180.8	804.5	1,504.3
118.6	120.6	146.6	978.4	1,364.1
7.7	89.4	41.1	316.2	454.3
.0	4.9	.0	196.8	201.7
.0	.0	.0	42.3	42.3
.0	.0	.0	.0	.0
.0	.0	.0	.0	.0
15614.6	8080.9	2572.1	2682.0	28,949.6

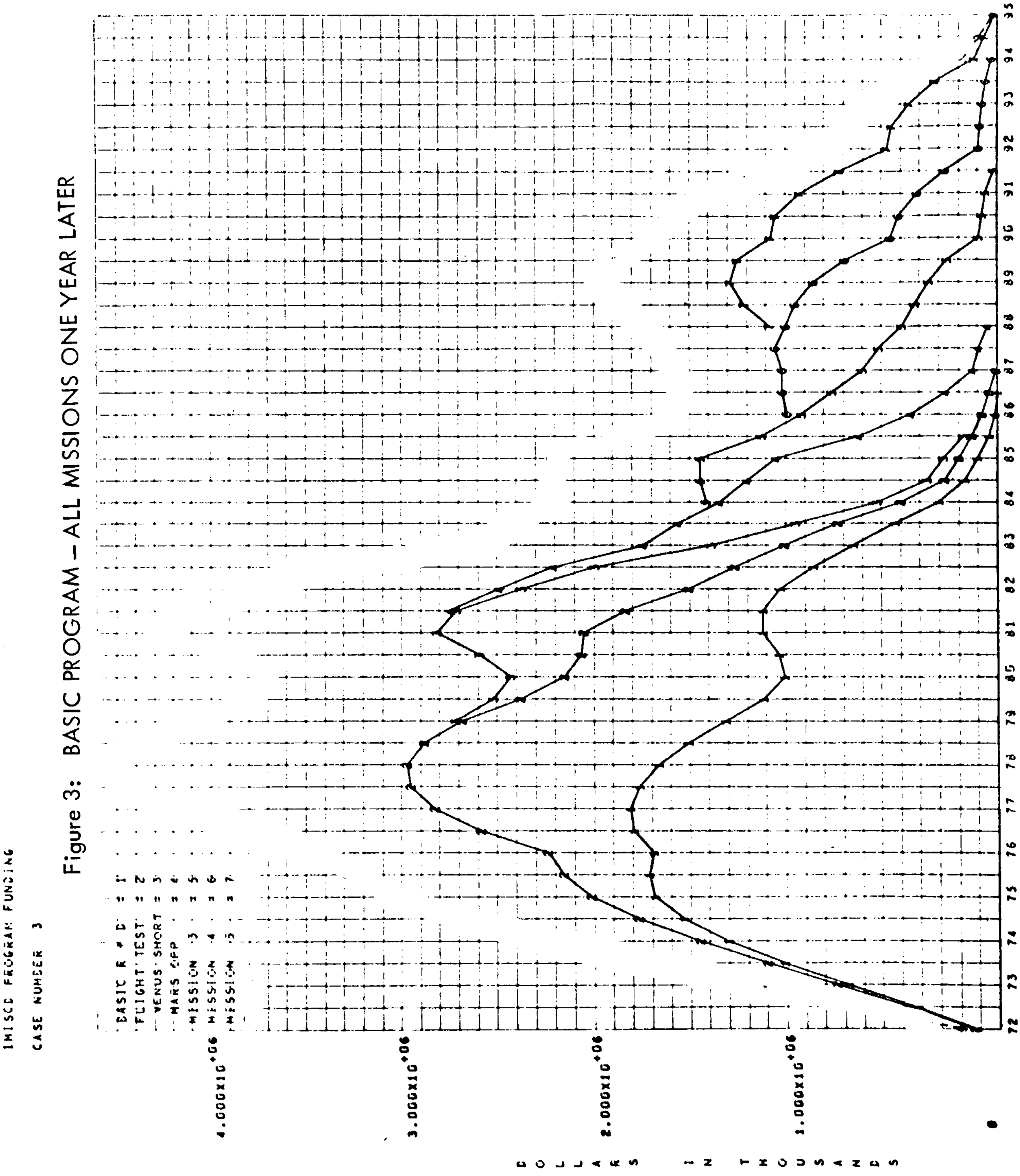
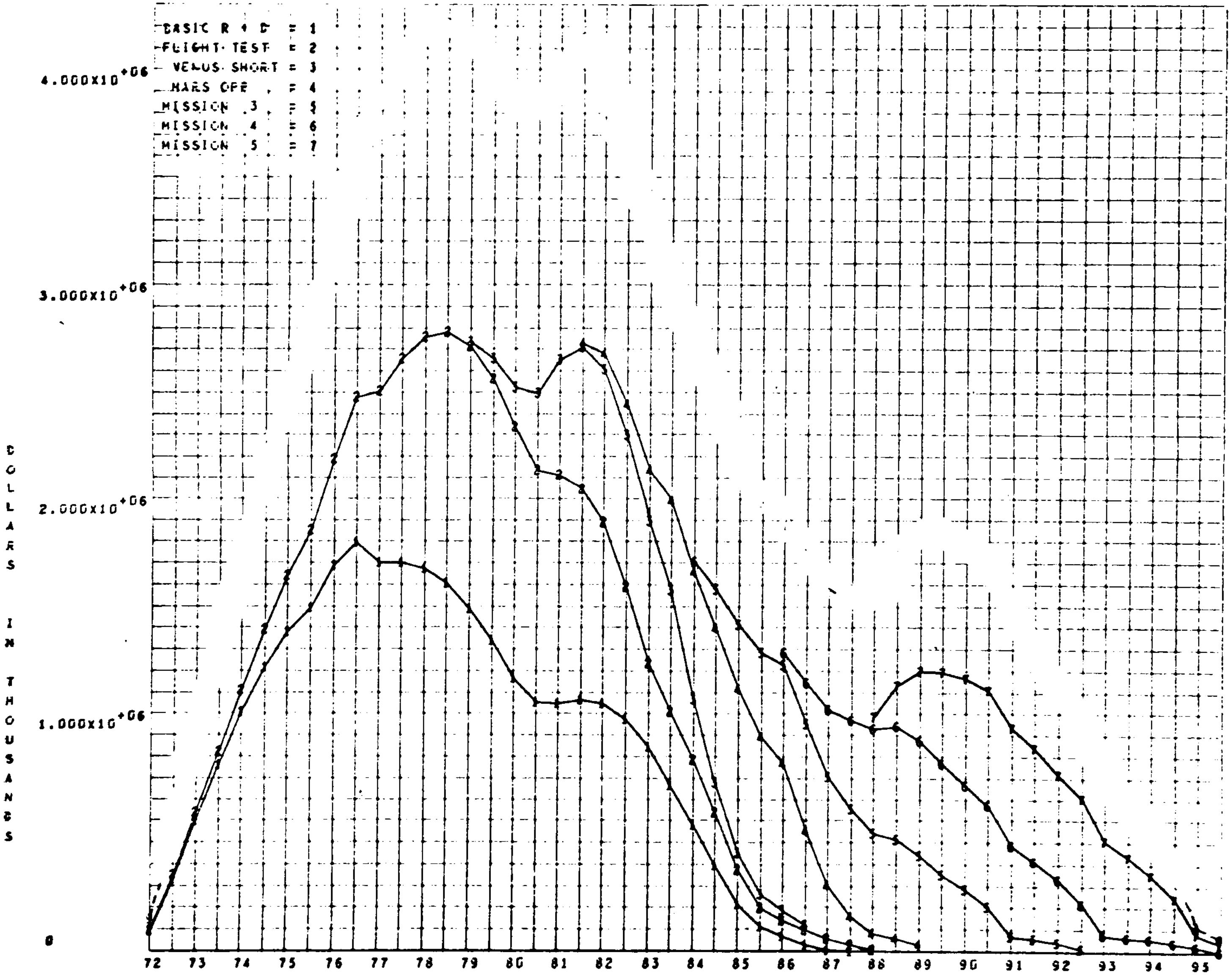


Figure 3: BASIC PROGRAM — ALL MISSIONS ONE YEAR LATER

IMISCD PROGRAM FUNDING

CASE NUMBER 4

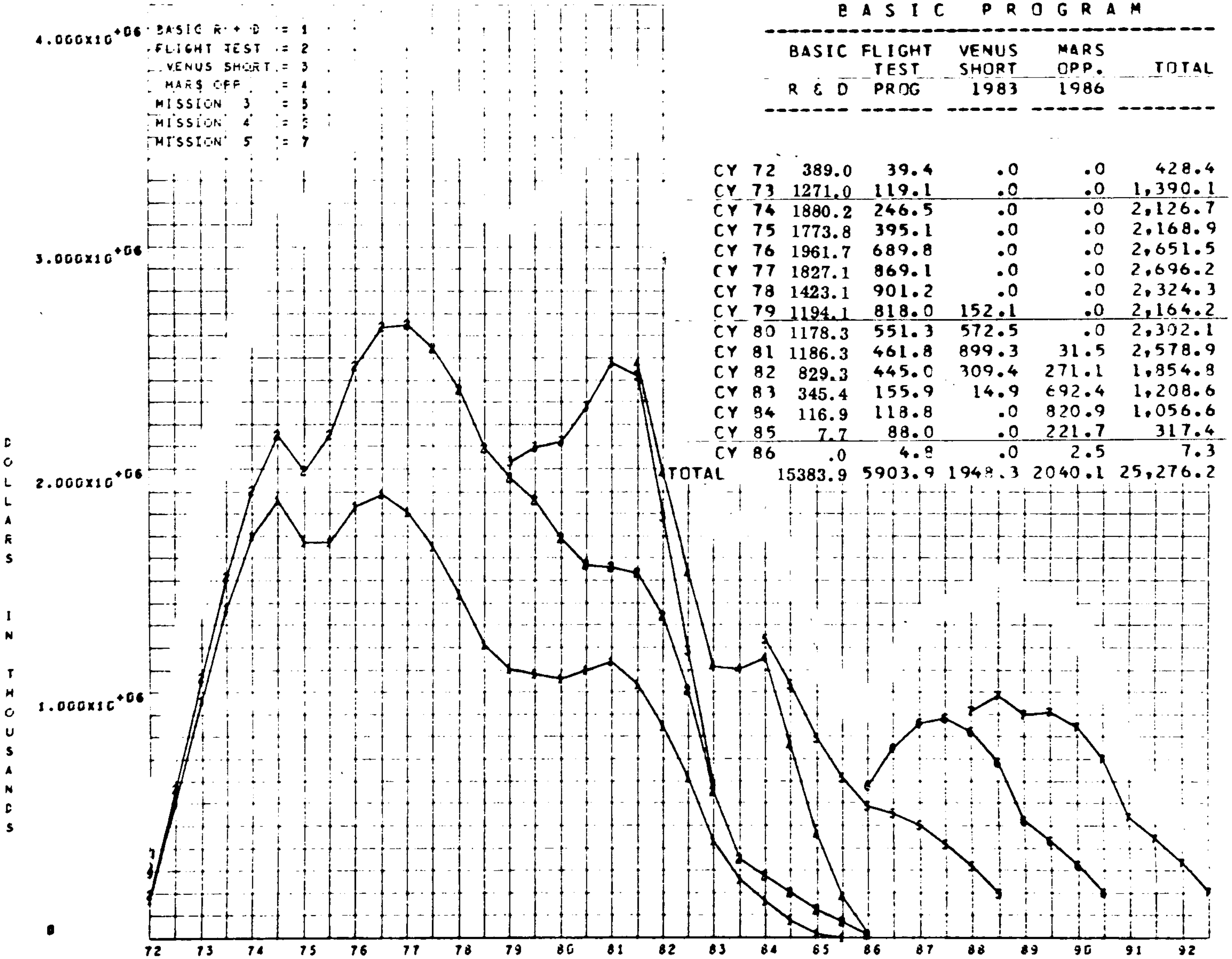
Figure 4: BASIC PROGRAM – ALL MISSIONS TWO YEARS LATER



IMISCD PROGRAM FUNDING AEROSPACE VEHICLE

CASE NUMBER 1

Figure 5



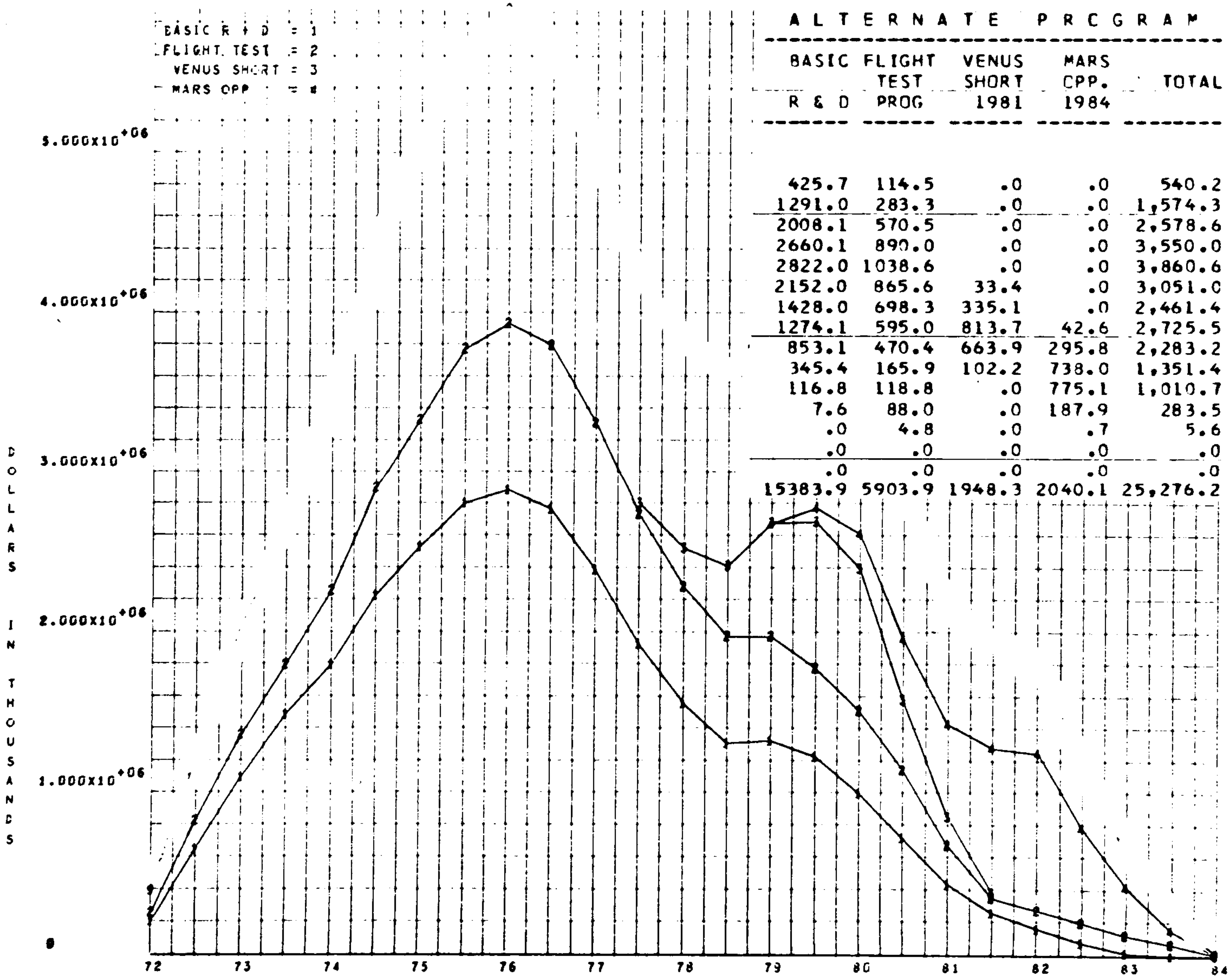
B A S I C   P R O G R A M

	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL
CY 72	389.0	39.4	.0	.0	428.4
CY 73	1271.0	119.1	.0	.0	1,390.1
CY 74	1880.2	246.5	.0	.0	2,126.7
CY 75	1773.8	395.1	.0	.0	2,168.9
CY 76	1961.7	689.8	.0	.0	2,651.5
CY 77	1827.1	869.1	.0	.0	2,696.2
CY 78	1423.1	901.2	.0	.0	2,324.3
CY 79	1194.1	818.0	152.1	.0	2,164.2
CY 80	1178.3	551.3	572.5	.0	2,302.1
CY 81	1186.3	461.8	899.3	31.5	2,578.9
CY 82	829.3	445.0	309.4	271.1	1,854.8
CY 83	345.4	155.9	14.9	692.4	1,208.6
CY 84	116.9	118.8	.0	820.9	1,056.6
CY 85	7.7	88.0	.0	221.7	317.4
CY 86	.0	4.8	.0	2.5	7.3
TOTAL	15383.9	5903.9	1948.3	2040.1	25,276.2

IMISCD PROGRAM FUNDING   AEROSPACE VEHICLE

CASE NUMBER 2

Figure 6



A L T E R N A T E   P R O G R A M

BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
425.7	114.5	.0	.0	540.2
1291.0	283.3	.0	.0	1,574.3
2008.1	570.5	.0	.0	2,578.6
2660.1	890.0	.0	.0	3,550.0
2822.0	1038.6	.0	.0	3,860.6
2152.0	865.6	33.4	.0	3,051.0
1428.0	698.3	335.1	.0	2,461.4
1274.1	595.0	813.7	42.6	2,725.5
853.1	470.4	663.9	295.8	2,283.2
345.4	165.9	102.2	738.0	1,351.4
116.8	118.8	.0	775.1	1,010.7
7.6	88.0	.0	187.9	283.5
.0	4.8	.0	.7	5.6
.0	.0	.0	.0	.0
.0	.0	.0	.0	.0
15383.9	5903.9	1948.3	2040.1	25,276.2

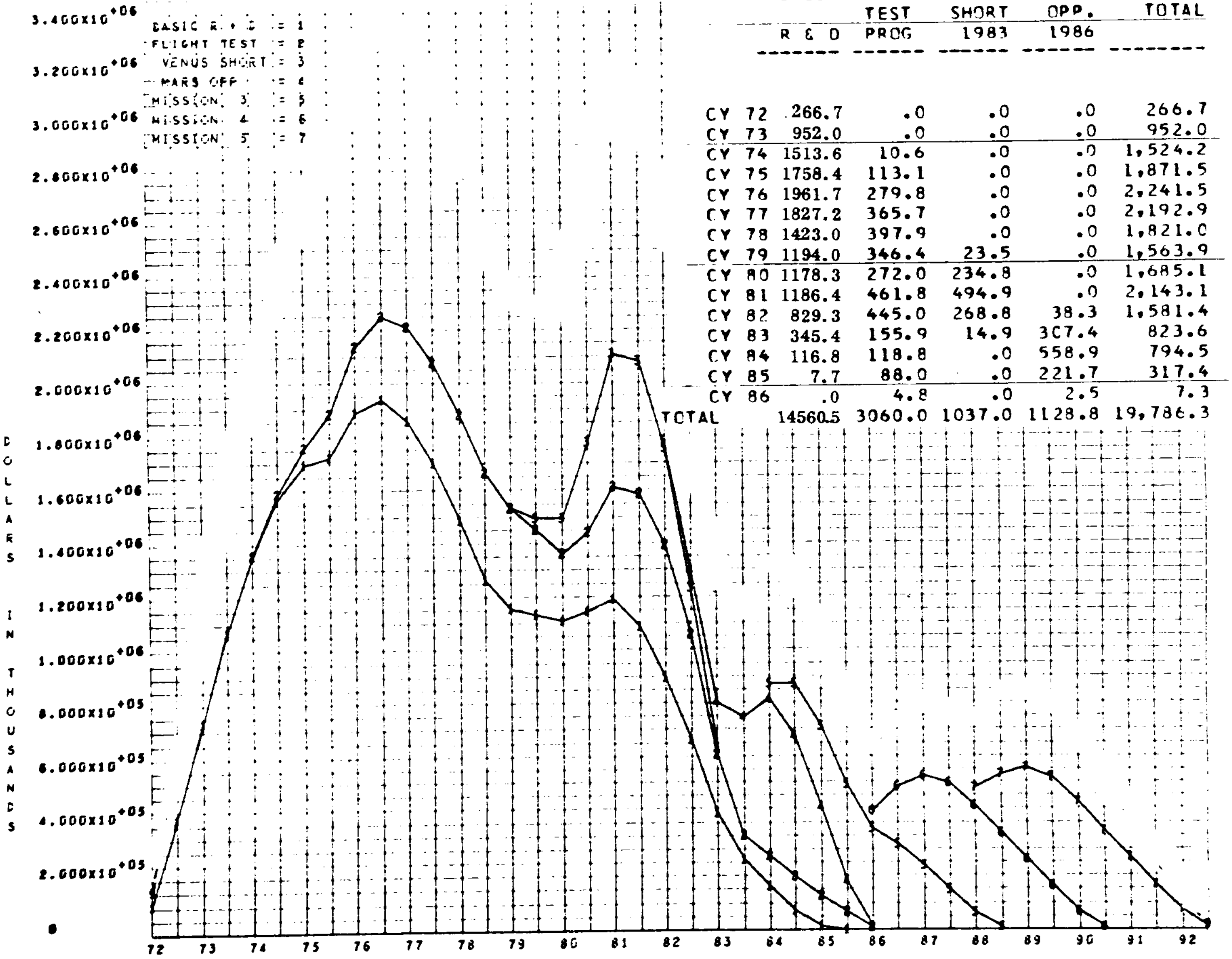
IMISCD PROGRAM FUNDING AEROSPACE VEHICLE SPACE VEHICLE

CASE NUMBER 1

Figure 7

BASIC PROGRAM

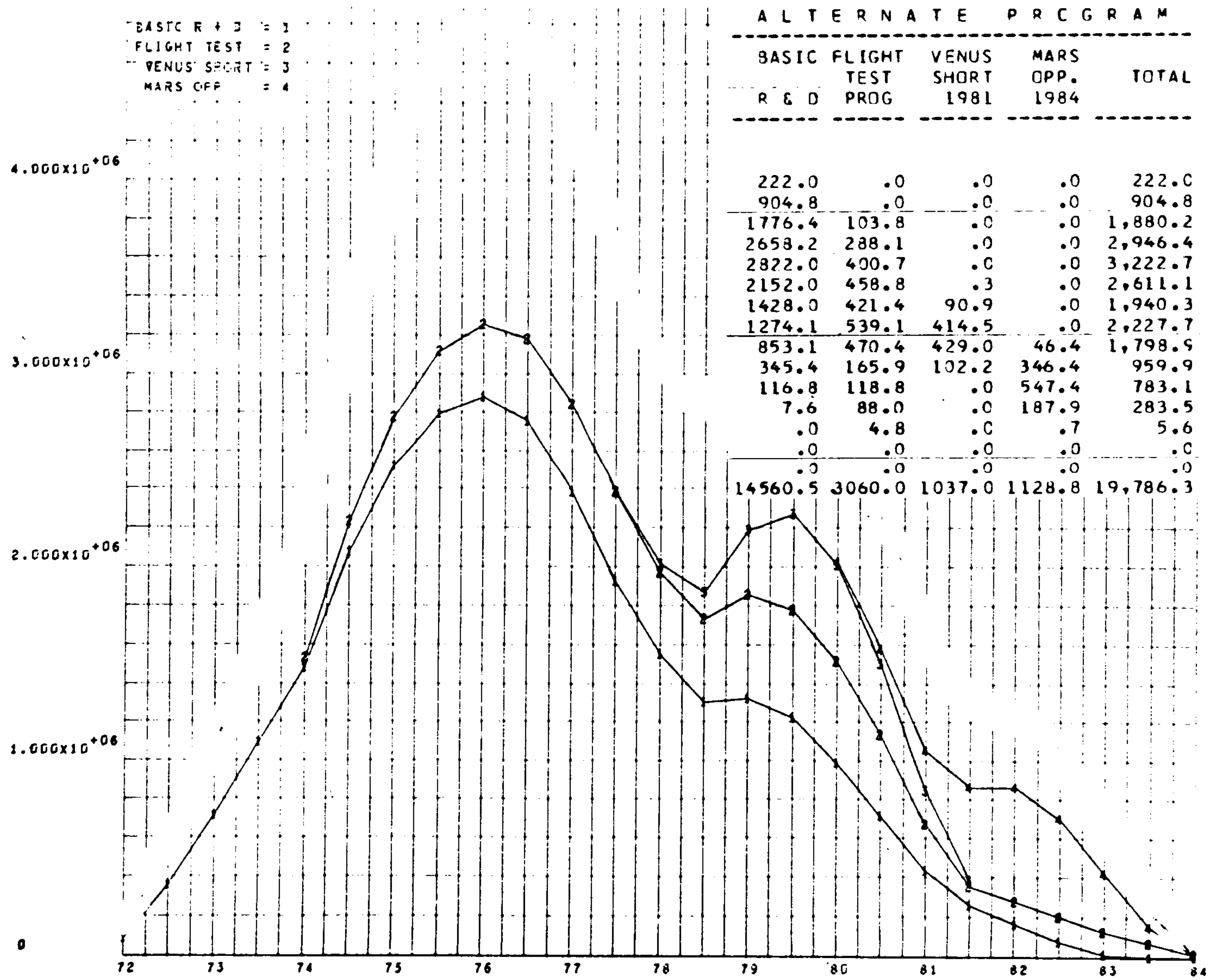
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL
CY 72	266.7	.0	.0	.0	266.7
CY 73	952.0	.0	.0	.0	952.0
CY 74	1513.6	10.6	.0	.0	1,524.2
CY 75	1758.4	113.1	.0	.0	1,871.5
CY 76	1961.7	279.8	.0	.0	2,241.5
CY 77	1827.2	365.7	.0	.0	2,192.9
CY 78	1423.0	397.9	.0	.0	1,821.0
CY 79	1194.0	346.4	23.5	.0	1,563.9
CY 80	1178.3	272.0	234.8	.0	1,685.1
CY 81	1186.4	461.8	494.9	.0	2,143.1
CY 82	829.3	445.0	268.8	38.3	1,581.4
CY 83	345.4	155.9	14.9	3C7.4	823.6
CY 84	116.8	118.8	.0	558.9	794.5
CY 85	7.7	88.0	.0	221.7	317.4
CY 86	.0	4.8	.0	2.5	7.3
TOTAL	14560.5	3060.0	1037.0	1128.8	19,786.3



IMISCD PROGRAM FUNDING AEROSPACE VEHICLE SPACE VEHICLE

CASE NUMBER 2

Figure 8



A L T E R N A T E P R O G R A M

BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
222.0	.0	.0	.0	222.C
904.8	.0	.0	.0	904.8
1776.4	103.8	.C	.0	1,880.2
2658.2	288.1	.0	.0	2,946.4
2822.0	400.7	.C	.0	3,222.7
2152.0	458.8	.3	.0	2,611.1
1428.0	421.4	90.9	.0	1,940.3
1274.1	539.1	414.5	.0	2,227.7
853.1	470.4	429.0	46.4	1,798.9
345.4	165.9	102.2	346.4	959.9
116.8	118.8	.0	547.4	783.1
7.6	88.0	.C	187.9	283.5
.0	4.8	.C	.7	5.6
.0	.0	.0	.0	.C
.0	.0	.0	.0	.0
14560.5	3060.0	1037.0	1128.8	19,786.3

Table 1
IMISCO PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE
SPACECRAFT

MISSION MODULE

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	140.9	.0	.0	.0	140.9	45.7	.0	.0	.0	45.7
CY 73	448.6	.0	.0	.0	448.6	267.8	.0	.0	.0	267.8
CY 74	640.6	6.5	.0	.0	647.1	559.6	28.0	.0	.0	587.6
CY 75	673.6	43.7	.0	.0	717.3	768.2	82.6	.0	.0	850.8
CY 76	568.9	79.9	.0	.0	648.7	775.4	121.2	.0	.0	896.6
CY 77	378.2	104.7	.0	.0	482.9	523.4	135.4	.0	.0	658.9
CY 78	170.3	114.5	.0	.0	284.8	108.9	117.1	.4	.0	226.4
CY 79	28.1	105.3	.0	.0	133.3	.0	47.6	95.3	.0	142.9
CY 80	.0	69.8	29.3	.0	99.2	.0	.0	134.6	.0	134.6
CY 81	.0	7.6	141.9	.0	149.5	.0	.0	34.5	72.0	106.5
CY 82	.0	.0	88.4	.0	88.4	.0	.0	.0	144.4	144.4
CY 83	.0	.0	5.1	60.2	65.4	.0	.0	.0	51.7	51.7
CY 84	.0	.0	.0	146.5	146.5	.0	.0	.0	.2	.2
CY 85	.0	.0	.0	60.9	60.9	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.7	.7	.0	.0	.0	.0	.0
TOTAL	3049.0	532.0	264.8	268.3	4,114.1	3049.0	532.0	264.8	268.3	4,114.1

Table 2
IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE
SPACECRAFT

EXPERIMENTS AND PROBES

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 74	.0	.0	.0	.0	.0	133.2	.0	.0	.0	133.2
CY 75	.0	.0	.0	.0	.0	445.6	.0	.0	.0	445.6
CY 76	299.5	.0	.0	.0	299.5	519.4	12.7	.0	.0	532.1
CY 77	494.8	.0	.0	.0	494.8	477.2	67.4	.3	.0	544.9
CY 78	512.9	35.0	.0	.0	547.9	409.8	97.8	75.0	.0	582.7
CY 79	435.7	83.9	21.4	.0	541.0	505.0	96.5	147.5	.0	749.0
CY 80	343.8	101.1	126.7	.0	571.7	408.5	63.4	103.2	42.2	617.3
CY 81	425.2	86.6	136.9	.0	648.7	276.1	51.6	21.4	111.9	461.0
CY 82	386.9	40.3	59.4	34.8	521.4	106.2	108.0	.0	90.2	304.4
CY 83	276.1	42.4	3.0	109.6	431.1	6.9	80.0	.0	25.1	112.0
CY 84	106.2	108.0	.0	94.8	309.0	.0	4.4	.0	.1	4.5
CY 85	6.9	80.0	.0	29.9	116.8	.0	.0	.0	.0	.0
CY 86	.0	4.4	.0	.3	4.7	.0	.0	.0	.0	.0
TOTAL	3288.0	581.8	347.4	269.4	4,486.6	3288.0	581.8	347.4	269.4	4,486.6

Table 3

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE
SPACECRAFT

EARTH ENTRY MODULE

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	67.3	.0	.0	.0	67.3	21.9	.0	.0	.0	21.9
CY 73	214.5	.0	.0	.0	214.5	128.0	.0	.0	.0	128.0
CY 74	306.3	3.2	.0	.0	309.5	267.5	13.9	.0	.0	281.4
CY 75	322.0	21.7	.0	.0	343.7	367.3	40.9	.0	.0	408.2
CY 76	272.0	39.6	.0	.0	311.5	370.7	60.0	.0	.0	430.8
CY 77	180.8	51.9	.0	.0	232.7	250.2	67.1	.0	.0	317.3
CY 78	81.4	56.7	.0	.0	138.1	52.1	58.0	.1	.0	110.2
CY 79	13.4	52.1	.0	.0	65.6	.0	23.6	28.4	.0	52.0
CY 80	.0	34.6	8.8	.0	43.3	.0	.0	40.2	.0	40.2
CY 81	.0	3.8	42.3	.0	46.1	.0	.0	10.3	19.1	29.4
CY 82	.0	.0	26.4	.0	26.4	.0	.0	.0	38.3	38.3
CY 83	.0	.0	1.5	16.0	17.5	.0	.0	.0	13.7	13.7
CY 84	.0	.0	.0	38.8	38.8	.0	.0	.0	.1	.1
CY 85	.0	.0	.0	16.1	16.1	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.2	.2	.0	.0	.0	.0	.0
TOTAL	1457.7	263.5	79.0	71.1	1,871.3	1457.7	263.5	79.0	71.1	1,871.3

Table 4
IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE
SPACECRAFT

MARS EXCURSION MODULE

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 74	.0	.0	.0	.0	.0	7.9	.0	.0	.0	7.9
CY 75	.0	.0	.0	.0	.0	131.2	.0	.0	.0	131.2
CY 76	7.9	.0	.0	.0	7.9	373.2	.0	.0	.0	373.2
CY 77	131.2	.0	.0	.0	131.2	608.4	.0	.0	.0	608.4
CY 78	373.2	.0	.0	.0	373.2	727.4	41.3	.0	.0	768.6
CY 79	608.4	.0	.0	.0	608.4	653.3	321.9	.0	.0	975.3
CY 80	727.4	41.3	.0	.0	768.6	367.0	364.2	.0	.0	731.3
CY 81	653.3	321.9	.0	.0	975.3	37.8	99.3	.0	47.5	184.6
CY 82	367.0	364.2	.0	.0	731.3	.0	.0	.0	95.3	95.3
CY 83	37.8	99.3	.0	39.8	176.9	.0	.0	.0	34.1	34.1
CY 84	.0	.0	.0	96.7	96.7	.0	.0	.0	.1	.1
CY 85	.0	.0	.0	40.2	40.2	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.5	.5	.0	.0	.0	.0	.0
TOTAL	2906.2	826.7	.0	177.1	3,910.0	2906.2	826.7	.0	177.1	3,910.0

Table 5

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE
SPACE PROPULSION SYSTEM

PM - 1 EDS

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	27.6	.0	.0	.0	27.6	121.0	.0	.0	.0	121.0
CY 73	162.8	.0	.0	.0	162.8	353.3	.0	.0	.0	353.3
CY 74	345.1	.0	.0	.0	345.1	508.3	15.6	.0	.0	523.9
CY 75	485.1	10.0	.0	.0	495.1	546.8	37.5	.0	.0	584.3
CY 76	510.9	36.2	.0	.0	547.1	424.8	45.1	.0	.0	470.0
CY 77	382.9	47.2	.0	.0	430.1	85.8	38.6	.0	.0	124.4
CY 78	125.5	41.7	.0	.0	167.2	.0	18.0	2.6	.0	20.6
CY 79	.0	19.7	.0	.0	19.7	.0	.1	38.2	.0	38.4
CY 80	.0	.1	17.6	.0	17.7	.0	.0	40.5	.0	40.5
CY 81	.0	.0	46.6	.0	46.6	.0	.0	9.7	23.6	33.3
CY 82	.0	.0	25.4	.0	25.4	.0	.0	.0	47.4	47.4
CY 83	.0	.0	1.4	19.8	21.2	.0	.0	.0	16.9	16.9
CY 84	.0	.0	.0	48.1	48.1	.0	.0	.0	.1	.1
CY 85	.0	.0	.0	20.0	20.0	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.2	.2	.0	.0	.0	.0	.0
TOTAL	2040.0	155.0	91.0	88.0	2,374.0	2040.0	155.0	91.0	88.0	2,374.0

Table 6

IMISCO PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE
SPACE PROPULSION SYSTEM

PM - 2 PCS

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 74	.0	.0	.0	.0	.0	.0	20.3	.0	.0	20.3
CY 75	.0	13.0	.0	.0	13.0	.0	48.6	.0	.0	48.6
CY 76	.0	46.9	.0	.0	46.9	.0	58.5	.0	.0	58.5
CY 77	.0	61.2	.0	.0	61.2	.0	50.1	.0	.0	50.1
CY 78	.0	54.1	.0	.0	54.1	.0	23.3	.9	.0	24.3
CY 79	.0	25.6	.0	.0	25.6	.0	.2	13.7	.0	13.8
CY 80	.0	.2	6.3	.0	6.5	.0	.0	14.5	.0	14.5
CY 81	.0	.0	16.6	.0	16.6	.0	.0	3.5	8.4	11.9
CY 82	.0	.0	9.1	.0	9.1	.0	.0	.0	16.9	16.9
CY 83	.0	.0	.5	7.0	7.6	.0	.0	.0	6.0	6.0
CY 84	.0	.0	.0	17.1	17.1	.0	.0	.0	.0	.0
CY 85	.0	.0	.0	7.1	7.1	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.1	.1	.0	.0	.0	.0	.0
TOTAL	.0	201.0	32.5	31.4	264.9	.0	201.0	32.5	31.4	264.9

Table 7

IMISCO PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
  SPACE VEHICLE
    SPACE PROPULSION SYSTEM

PM - 3 PDS

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 74	.0	.0	.0	.0	.0	.0	6.3	.0	.0	6.3
CY 75	.0	4.0	.0	.0	4.0	.0	15.0	.0	.0	15.0
CY 76	.0	14.5	.0	.0	14.5	.0	18.1	.0	.0	18.1
CY 77	.0	18.9	.0	.0	18.9	.0	15.5	.0	.0	15.5
CY 78	.0	16.7	.0	.0	16.7	.0	7.2	.9	.0	8.1
CY 79	.0	7.9	.0	.0	7.9	.0	.1	13.7	.0	13.7
CY 80	.0	.1	6.3	.0	6.3	.0	.0	14.5	.0	14.5
CY 81	.0	.0	16.6	.0	16.6	.0	.0	3.5	8.4	11.9
CY 82	.0	.0	9.1	.0	9.1	.0	.0	.0	16.9	16.9
CY 83	.0	.0	.5	7.0	7.6	.0	.0	.0	6.0	6.0
CY 84	.0	.0	.0	17.1	17.1	.0	.0	.0	.0	.0
CY 85	.0	.0	.0	7.1	7.1	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.1	.1	.0	.0	.0	.0	.0
TOTAL	.0	62.0	32.5	31.4	125.9	.0	62.0	32.5	31.4	125.9

Table 8
IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE
SPACE PROPULSION SYSTEM

PM - M M/C AND ORBIT TRIM

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	1.9	.0	.0	.0	1.9	3.8	.0	.0	.0	3.8
CY 73	11.2	.0	.0	.0	11.2	20.7	.0	.0	.0	20.7
CY 74	23.7	.0	.0	.0	23.7	39.1	1.5	.0	.0	40.5
CY 75	33.3	1.5	.0	.0	34.7	44.4	5.3	.0	.0	49.7
CY 76	35.1	5.3	.0	.0	40.3	28.8	6.9	.0	.0	35.6
CY 77	26.3	6.9	.0	.0	33.1	3.2	6.1	.0	.0	9.3
CY 78	8.6	6.1	.0	.0	14.7	.0	2.9	.2	.0	3.1
CY 79	.0	2.9	.0	.0	2.9	.0	.0	3.7	.0	3.7
CY 80	.0	.0	1.7	.0	1.7	.0	.0	3.9	.0	3.9
CY 81	.0	.0	4.5	.0	4.5	.0	.0	.9	2.3	3.2
CY 82	.0	.0	2.5	.0	2.5	.0	.0	.0	4.5	4.5
CY 83	.0	.0	.1	1.9	2.0	.0	.0	.0	1.6	1.6
CY 84	.0	.0	.0	4.6	4.6	.0	.0	.0	.0	.0
CY 85	.0	.0	.0	1.9	1.9	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	140.0	22.5	8.8	8.4	179.7	140.0	22.5	8.8	8.4	179.7

Table 9

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
SPACE VEHICLE
SPACE PROPULSION SYSTEM

ASSY. AND DOCKING UNIT

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	4.8	.0	.0	.0	4.8	9.6	.0	.0	.0	9.6
CY 73	28.4	.0	.0	.0	28.4	52.7	.0	.0	.0	52.7
CY 74	60.2	.0	.0	.0	60.2	99.4	8.9	.0	.0	108.3
CY 75	84.6	8.9	.0	.0	93.5	113.0	32.1	.0	.0	145.1
CY 76	89.1	32.1	.0	.0	121.2	73.1	41.8	.0	.0	114.9
CY 77	66.8	41.8	.0	.0	108.6	8.2	36.9	.0	.0	45.1
CY 78	21.9	36.9	.0	.0	58.8	.0	17.5	2.5	.0	19.9
CY 79	.0	17.5	.0	.0	17.5	.0	.1	36.4	.0	36.5
CY 80	.0	.1	16.8	.0	16.9	.0	.0	38.6	.0	38.6
CY 81	.0	.0	44.4	.0	44.4	.0	.0	9.2	21.8	31.0
CY 82	.0	.0	24.2	.0	24.2	.0	.0	.0	43.7	43.7
CY 83	.0	.0	1.3	18.2	19.6	.0	.0	.0	15.6	15.6
CY 84	.0	.0	.0	44.3	44.3	.0	.0	.0	.1	.1
CY 85	.0	.0	.0	18.4	18.4	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.2	.2	.0	.0	.0	.0	.0
TOTAL	355.9	137.3	86.7	81.1	661.0	355.9	137.3	86.7	81.1	661.0

Table 10

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
  SPACE VEHICLE
    SPACE VEH INTEG AND SUPPORT

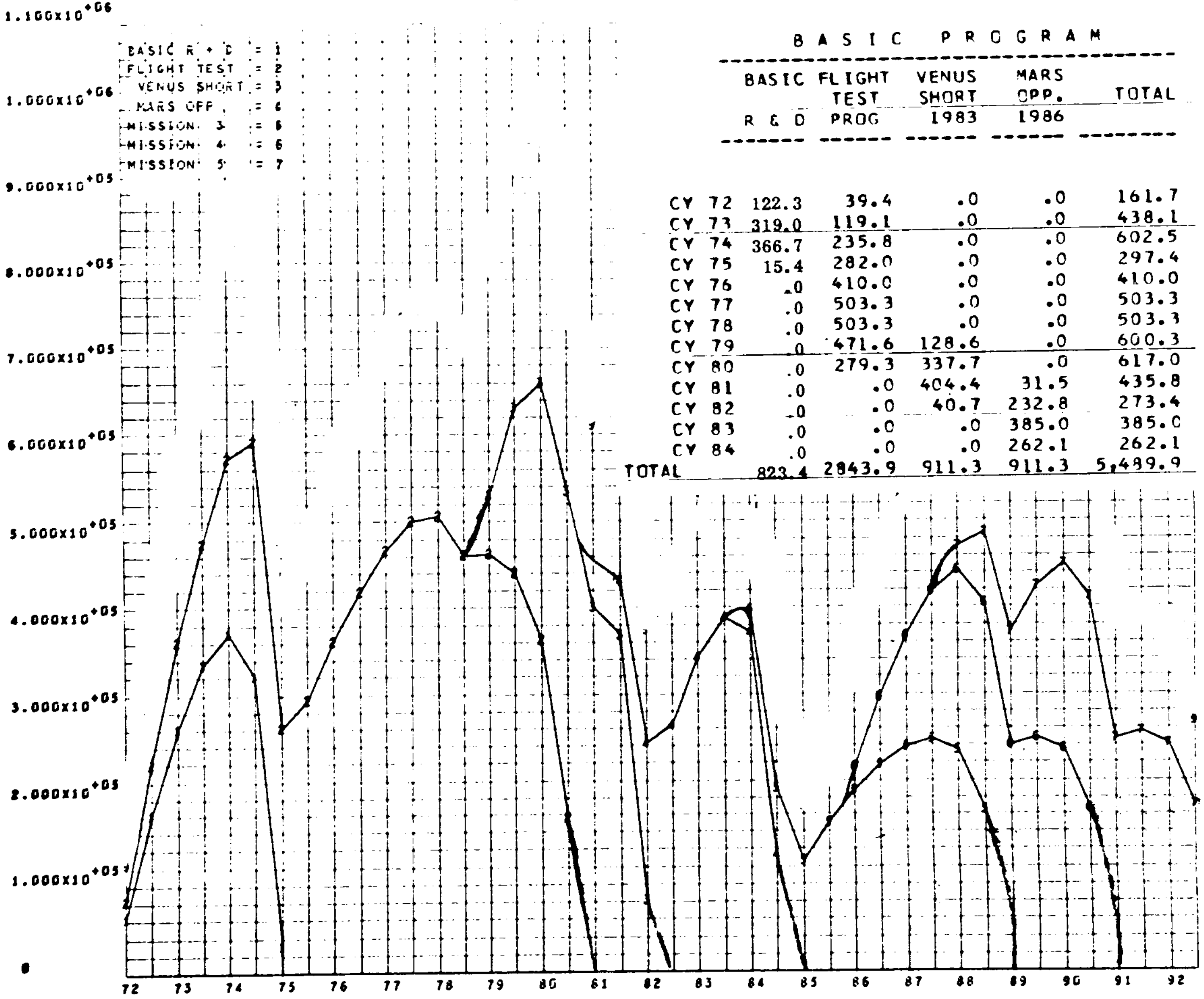
SPACE VEH INTEG AND SUPPORT

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	24.3	.0	.0	.0	24.3	20.2	.0	.0	.0	20.2
CY 73	86.5	.0	.0	.0	86.5	82.3	.0	.0	.0	82.3
CY 74	137.6	1.0	.0	.0	138.6	161.5	9.4	.0	.0	170.9
CY 75	159.9	10.3	.0	.0	170.1	241.7	26.2	.0	.0	267.9
CY 76	178.3	25.4	.0	.0	203.8	256.5	36.4	.0	.0	293.0
CY 77	166.1	33.2	.0	.0	199.4	195.6	41.7	.0	.0	237.4
CY 78	129.4	36.2	.0	.0	165.5	129.8	38.3	8.3	.0	176.4
CY 79	108.5	31.5	2.1	.0	142.2	115.8	49.0	37.7	.0	202.5
CY 80	107.1	24.7	21.3	.0	153.2	77.6	42.8	39.0	4.2	163.5
CY 81	107.8	42.0	45.0	.0	194.8	31.4	15.1	9.3	31.5	87.3
CY 82	75.4	40.5	24.4	3.5	143.8	10.6	10.8	.0	49.8	71.2
CY 83	31.4	14.2	1.4	27.9	74.9	.7	8.0	.0	17.1	25.8
CY 84	10.6	10.8	.0	50.8	72.2	.0	.4	.0	.1	.5
CY 85	.7	8.0	.0	20.2	28.9	.0	.0	.0	.0	.0
CY 86	.0	.4	.0	.2	.7	.0	.0	.0	.0	.0
TOTAL	1323.7	278.2	94.3	102.6	1,798.8	1323.7	278.2	94.3	102.6	1,798.8

IMISCD PROGRAM FUNDING AEROSPACE VEHICLE EARTH LAUNCH VEHICLES

CASE NUMBER 1

Figure 9



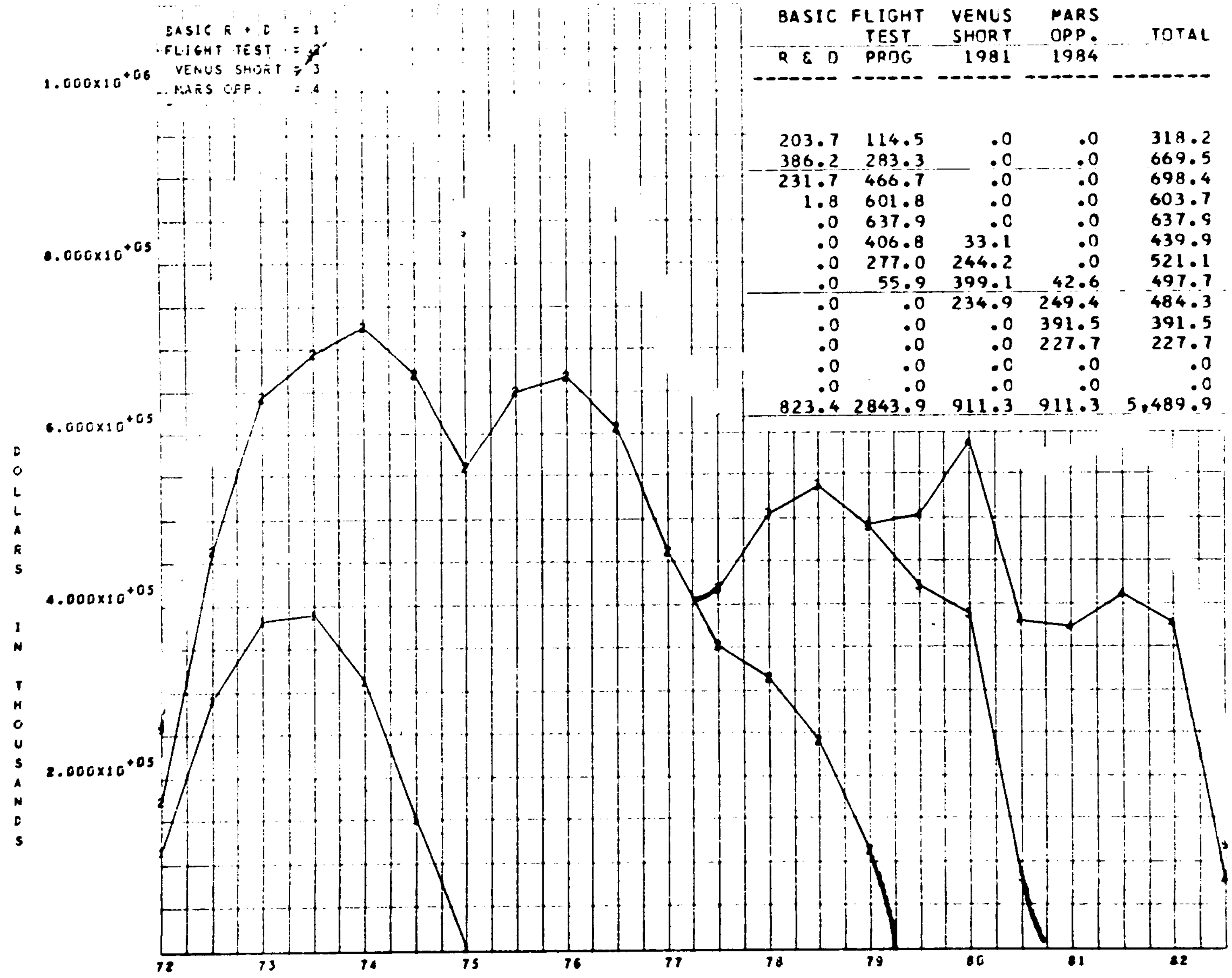
B A S I C P R O G R A M

	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL
CY 72	122.3	39.4	.0	.0	161.7
CY 73	319.0	119.1	.0	.0	438.1
CY 74	366.7	235.8	.0	.0	602.5
CY 75	15.4	282.0	.0	.0	297.4
CY 76	.0	410.0	.0	.0	410.0
CY 77	.0	503.3	.0	.0	503.3
CY 78	.0	503.3	.0	.0	503.3
CY 79	.0	471.6	128.6	.0	600.3
CY 80	.0	279.3	337.7	.0	617.0
CY 81	.0	.0	404.4	31.5	435.8
CY 82	.0	.0	40.7	232.8	273.4
CY 83	.0	.0	.0	385.0	385.0
CY 84	.0	.0	.0	262.1	262.1
TOTAL	823.4	2843.9	911.3	911.3	5,489.9

IMISCD PROGRAM FUNDING AEROSPACE VEHICLE EARTH LAUNCH VEHICLES

CASE NUMBER 2

Figure 10



ALTERNATE PROGRAM

BASIC	FLIGHT TEST	VENUS SHORT	MARS OPP.	TOTAL
R & D	PROG	1981	1984	
203.7	114.5	.0	.0	318.2
386.2	283.3	.0	.0	669.5
231.7	466.7	.0	.0	698.4
1.8	601.8	.0	.0	603.7
.0	637.9	.0	.0	637.9
.0	406.8	33.1	.0	439.9
.0	277.0	244.2	.0	521.1
.0	55.9	399.1	42.6	497.7
.0	.0	234.9	249.4	484.3
.0	.0	.0	391.5	391.5
.0	.0	.0	227.7	227.7
.0	.0	.0	.0	.0
.0	.0	.0	.0	.0
823.4	2843.9	911.3	911.3	5,489.9

Table 11
IMISCO PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
EARTH LAUNCH VEHICLES
SAT V FAMILY

SAT V - 25-S-U

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	36.9	.0	.0	.0	36.9	61.5	.0	.0	.0	61.5
CY 73	96.3	.0	.0	.0	96.3	116.6	.0	.0	.0	116.6
CY 74	110.7	39.6	.0	.0	150.4	70.0	78.9	.0	.0	148.8
CY 75	4.7	115.0	.0	.0	119.7	.5	230.3	.0	.0	230.9
CY 76	.0	181.0	.0	.0	181.0	.0	331.4	.0	.0	331.4
CY 77	.0	234.3	.0	.0	234.3	.0	356.5	29.0	.0	385.5
CY 78	.0	269.7	.0	.0	269.7	.0	277.0	213.8	.0	490.8
CY 79	.0	277.1	112.6	.0	389.8	.0	55.9	349.5	37.3	442.8
CY 80	.0	213.1	295.7	.0	508.8	.0	.0	205.7	218.4	424.1
CY 81	.0	.0	354.1	27.5	381.6	.0	.0	.0	342.9	342.9
CY 82	.0	.0	35.6	203.8	239.4	.0	.0	.0	199.4	199.4
CY 83	.0	.0	.0	337.2	337.2	.0	.0	.0	.0	.0
CY 84	.0	.0	.0	229.5	229.5	.0	.0	.0	.0	.0
TOTAL	248.6	1330.0	798.0	798.0	3,174.6	248.6	1330.0	798.0	798.0	3,174.6

Table 12

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
EARTH LAUNCH VEHICLES
SAT V FAMILY

SAT V - 25-S-U CORE

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	85.4	.0	.0	.0	85.4	142.2	.0	.0	.0	142.2
CY 73	222.7	.0	.0	.0	222.7	269.6	.0	.0	.0	269.6
CY 74	256.0	31.3	.0	.0	287.3	161.7	179.7	.0	.0	341.5
CY 75	10.8	90.4	.0	.0	101.1	1.3	369.9	.0	.0	371.2
CY 76	.0	141.1	.0	.0	141.1	.0	306.5	.0	.0	306.5
CY 77	.0	180.3	.0	.0	180.3	.0	50.2	4.1	.0	54.4
CY 78	.0	202.6	.0	.0	202.6	.0	.0	30.4	.0	30.4
CY 79	.0	194.5	16.0	.0	210.5	.0	.0	49.6	5.3	54.9
CY 80	.0	66.1	42.0	.0	108.1	.0	.0	29.2	31.0	60.2
CY 81	.0	.0	50.3	3.9	54.2	.0	.0	.0	48.7	48.7
CY 82	.0	.0	5.1	28.9	34.0	.0	.0	.0	28.3	28.3
CY 83	.0	.0	.0	47.9	47.9	.0	.0	.0	.0	.0
CY 84	.0	.0	.0	32.6	32.6	.0	.0	.0	.0	.0
TOTAL	574.8	906.4	113.3	113.3	1,707.8	574.8	906.4	113.3	113.3	1,707.8

Table 13
IMISCO PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
EARTH LAUNCH VEHICLES
SAT V FAMILY

SAT V - 25-S-U & S-IVB

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	.0	19.8	.0	.0	19.8	.0	24.9	.0	.0	24.9
CY 73	.0	51.5	.0	.0	51.5	.0	59.7	.0	.0	59.7
CY 74	.0	59.2	.0	.0	59.2	.0	47.7	.0	.0	47.7
CY 75	.0	2.5	.0	.0	2.5	.0	.7	.0	.0	.7
TOTAL	.0	133.0	.0	.0	133.0	.0	133.0	.0	.0	133.0

Table 14

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
EARTH LAUNCH VEHICLES
SAT V FAMILY

SAT V THREE STAGE

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	.0	18.4	.0	.0	18.4	.0	28.3	.0	.0	28.3
CY 73	.0	48.0	.0	.0	48.0	.0	69.1	.0	.0	69.1
CY 74	.0	55.2	.0	.0	55.2	.0	26.6	.0	.0	26.6
CY 75	.0	2.3	.0	.0	2.3	.0	.0	.0	.0	.0
TOTAL	.0	124.0	.0	.0	124.0	.0	124.0	.0	.0	124.0

Table 15
IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
EARTH LAUNCH VEHICLES
SAT V FAMILY

SAT V - INT - 21

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	.0	.0	.0	.0	.0	.0	28.5	.0	.0	28.5
CY 73	.0	8.6	.0	.0	8.6	.0	76.5	.0	.0	76.5
CY 74	.0	24.5	.0	.0	24.5	.0	73.7	.0	.0	73.7
CY 75	.0	37.4	.0	.0	37.4	.0	.0	.0	.0	.0
CY 76	.0	45.8	.0	.0	45.8	.0	.0	.0	.0	.0
CY 77	.0	46.3	.0	.0	46.3	.0	.0	.0	.0	.0
CY 78	.0	16.1	.0	.0	16.1	.0	.0	.0	.0	.0
TOTAL	.0	178.6	.0	.0	178.6	.0	178.6	.0	.0	178.6

Table 16

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
EARTH LAUNCH VEHICLES
OTHER ELV@S

SAT -IB

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	.0	.0	.0	.0	.0	.0	30.7	.0	.0	30.7
CY 73	.0	7.9	.0	.0	7.9	.0	73.6	.0	.0	73.6
CY 74	.0	22.5	.0	.0	22.5	.0	58.8	.0	.0	58.8
CY 75	.0	34.3	.0	.0	34.3	.0	.9	.0	.0	.9
CY 76	.0	42.0	.0	.0	42.0	.0	.0	.0	.0	.0
CY 77	.0	42.5	.0	.0	42.5	.0	.0	.0	.0	.0
CY 78	.0	14.8	.0	.0	14.8	.0	.0	.0	.0	.0
TOTAL	.0	164.0	.0	.0	164.0	.0	164.0	.0	.0	164.0

Table 17

IMISCD PROGRAM FUNDING EXAMPLES

AEROSPACE VEHICLE
EARTH LAUNCH VEHICLES
OTHER ELV@S

ATLAS AGENA

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC P & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC P & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	.0	1.2	.0	.0	1.2	.0	2.2	.0	.0	2.2
CY 73	.0	3.1	.0	.0	3.1	.0	4.5	.0	.0	4.5
CY 74	.0	3.5	.0	.0	3.5	.0	1.2	.0	.0	1.2
CY 75	.0	.1	.0	.0	.1	.0	.0	.0	.0	.0
TOTAL	.0	7.9	.0	.0	7.9	.0	7.9	.0	.0	7.9

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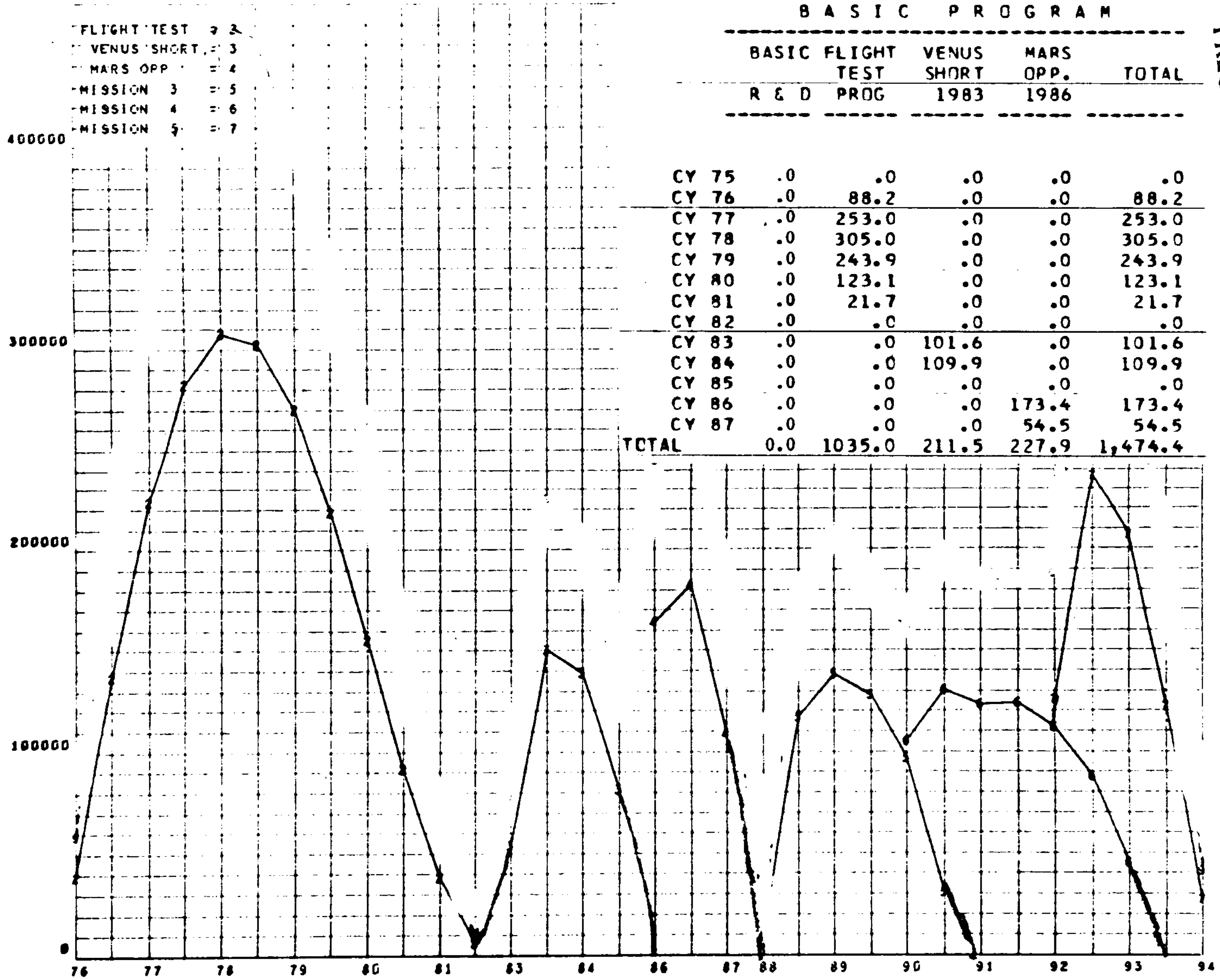
IMISCD PROGRAM FUNDING EARTH BASED SUPPORT

CASE NUMBER 1

Figure 11



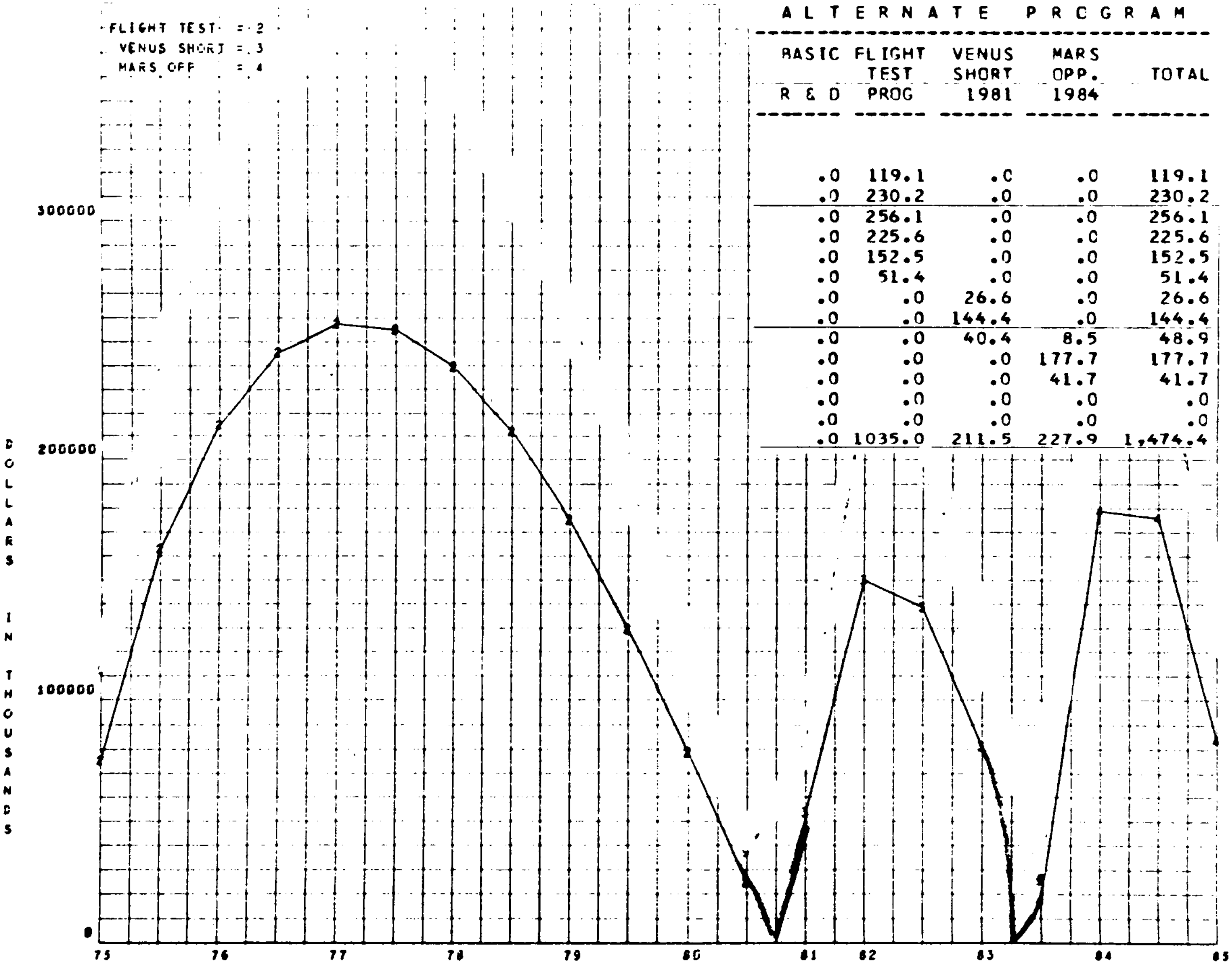
BASIC PROGRAM

	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL
CY 75	.0	.0	.0	.0	.0
CY 76	.0	88.2	.0	.0	88.2
CY 77	.0	253.0	.0	.0	253.0
CY 78	.0	305.0	.0	.0	305.0
CY 79	.0	243.9	.0	.0	243.9
CY 80	.0	123.1	.0	.0	123.1
CY 81	.0	21.7	.0	.0	21.7
CY 82	.0	.0	.0	.0	.0
CY 83	.0	.0	101.6	.0	101.6
CY 84	.0	.0	109.9	.0	109.9
CY 85	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	173.4	173.4
CY 87	.0	.0	.0	54.5	54.5
TOTAL	0.0	1035.0	211.5	227.9	1,474.4

IMISCD PROGRAM FUNDING EARTH BASED SUPPORT

CASE NUMBER 2

Figure 12



ALTERNATE PROGRAM

BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
.0	119.1	.C	.0	119.1
.0	230.2	.0	.0	230.2
.0	256.1	.0	.0	256.1
.0	225.6	.0	.C	225.6
.0	152.5	.0	.0	152.5
.0	51.4	.0	.0	51.4
.0	.0	26.6	.0	26.6
.0	.0	144.4	.0	144.4
.0	.0	40.4	8.5	48.9
.0	.0	.0	177.7	177.7
.0	.0	.0	41.7	41.7
.0	.0	.0	.0	.0
.0	.0	.0	.0	.0
.0	1035.0	211.5	227.9	1,474.4

Table 18

IMISCD PROGRAM FUNDING EXAMPLES

EARTH BASED SUPPORT
EBS
FBS

TRACKING AND DATA MGT

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 75	.0	.0	.0	.0	.0	.0	103.6	.0	.0	103.6
CY 76	.0	76.7	.0	.0	76.7	.0	200.2	.0	.0	200.2
CY 77	.0	220.0	.0	.0	220.0	.0	222.7	.0	.0	222.7
CY 78	.0	265.2	.0	.0	265.2	.0	196.2	.0	.0	196.2
CY 79	.0	212.1	.0	.0	212.1	.0	132.6	.0	.0	132.6
CY 80	.0	107.1	.0	.0	107.1	.0	44.7	.0	.0	44.7
CY 81	.0	18.9	.0	.0	18.9	.0	.0	26.6	.0	26.6
CY 82	.0	.0	.0	.0	.0	.0	.0	144.4	.0	144.4
CY 83	.0	.0	101.6	.0	101.6	.0	.0	38.4	8.5	46.9
CY 84	.0	.0	107.9	.0	107.9	.0	.0	.0	177.7	177.7
CY 85	.0	.0	.0	.0	.0	.0	.0	.0	39.7	39.7
CY 86	.0	.0	.0	173.4	173.4	.0	.0	.0	.0	.0
CY 87	.0	.0	.0	52.5	52.5	.0	.0	.0	.0	.0
TOTAL	.0	900.0	209.5	225.9	1,335.4	.0	900.0	209.5	225.9	1,335.4

Table 19

IMISCO PROGRAM FUNDING EXAMPLES

EARTH BASED SUPPORT
  EBS
    EBS

RECOVERY

	B A S I C P R O G R A M					A L T E R N A T E P R O G R A M				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 75	.0	.0	.0	.0	.0	.0	15.5	.0	.0	15.5
CY 76	.0	11.5	.0	.0	11.5	.0	30.0	.0	.0	30.0
CY 77	.0	33.0	.0	.0	33.0	.0	33.4	.0	.0	33.4
CY 78	.0	39.8	.0	.0	39.8	.0	29.4	.0	.0	29.4
CY 79	.0	31.8	.0	.0	31.8	.0	19.9	.0	.0	19.9
CY 80	.0	16.1	.0	.0	16.1	.0	6.7	.0	.0	6.7
CY 81	.0	2.8	.0	.0	2.8	.0	.0	.0	.0	.0
CY 83	.0	.0	.0	.0	.0	.0	.0	2.0	.0	2.0
CY 84	.0	.0	2.0	.0	2.0	.0	.0	.0	.0	.0
CY 85	.0	.0	.0	.0	.0	.0	.0	.0	2.0	2.0
CY 87	.0	.0	.0	2.0	2.0	.0	.0	.0	.0	.0
TOTAL	.0	135.0	2.0	2.0	139.0	.0	135.0	2.0	2.0	139.0

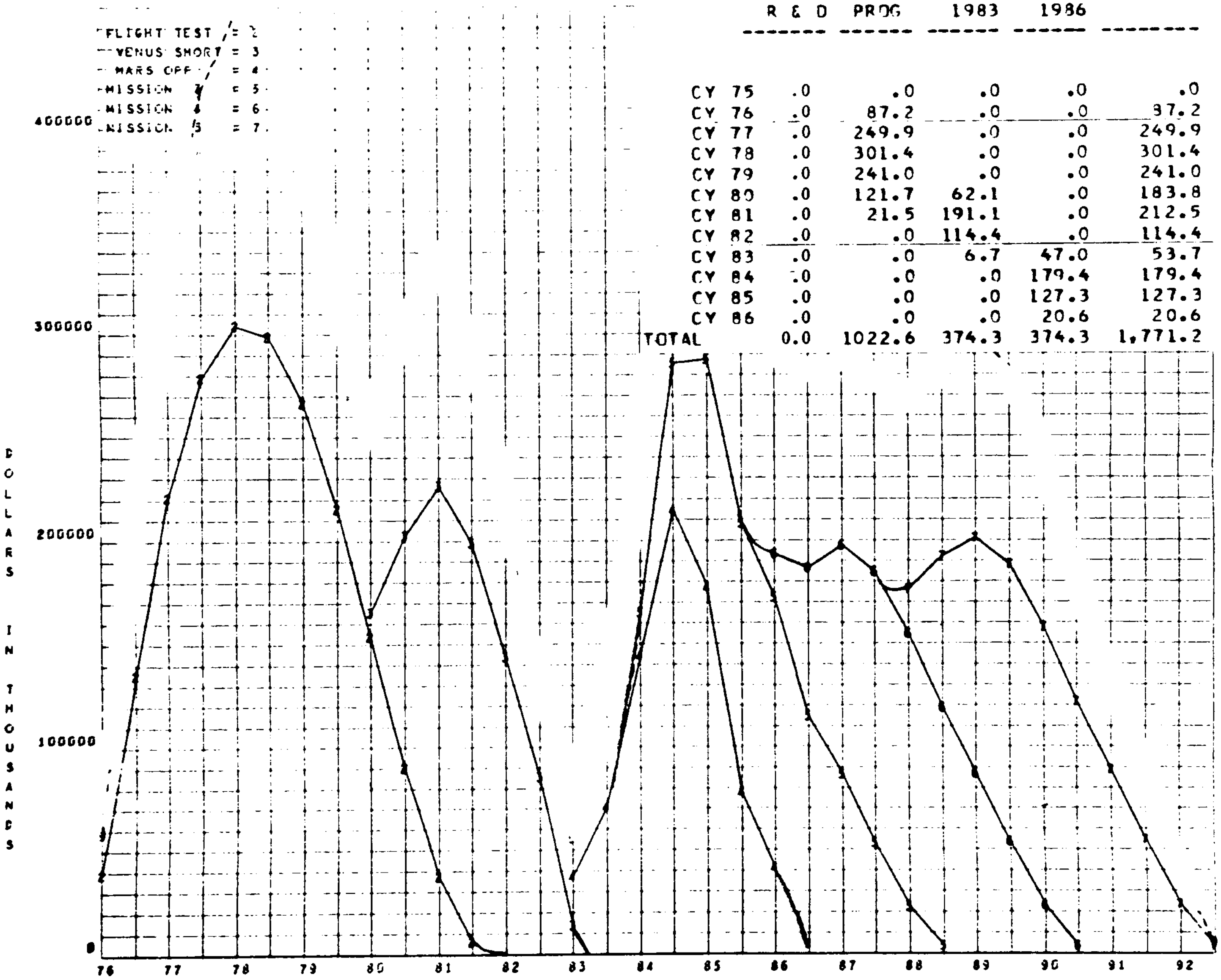
IMISCD PROGRAM FUNDING ORBITAL SUPPORT

CASE NUMBER 1

Figure 13

BASIC PROGRAM

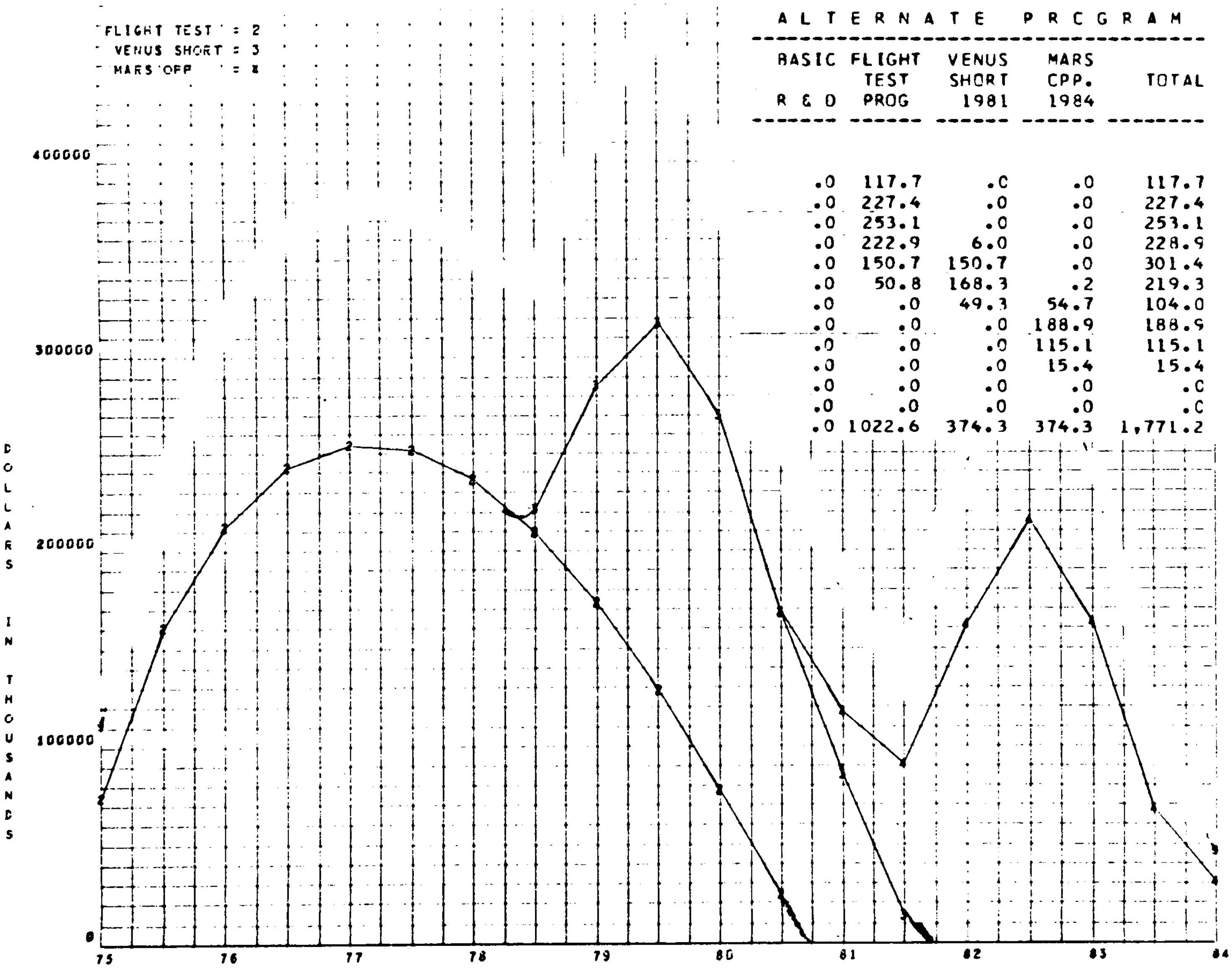
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL
CY 75	.0	.0	.0	.0	.0
CY 76	.0	87.2	.0	.0	87.2
CY 77	.0	249.9	.0	.0	249.9
CY 78	.0	301.4	.0	.0	301.4
CY 79	.0	241.0	.0	.0	241.0
CY 80	.0	121.7	62.1	.0	183.8
CY 81	.0	21.5	191.1	.0	212.5
CY 82	.0	.0	114.4	.0	114.4
CY 83	.0	.0	6.7	47.0	53.7
CY 84	.0	.0	.0	179.4	179.4
CY 85	.0	.0	.0	127.3	127.3
CY 86	.0	.0	.0	20.6	20.6
TOTAL	0.0	1022.6	374.3	374.3	1,771.2



IMISCD PROGRAM FUNDING ORBITAL SUPPORT

CASE NUMBER 2

Figure 14



ALTERNATE PROGRAM

BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS CPP. 1984	TOTAL
.0	117.7	.C	.0	117.7
.0	227.4	.0	.0	227.4
.0	253.1	.0	.0	253.1
.0	222.9	6.0	.0	228.9
.0	150.7	150.7	.0	301.4
.0	50.8	168.3	.2	219.3
.0	.0	49.3	54.7	104.0
.0	.0	.0	188.9	188.9
.0	.0	.0	115.1	115.1
.0	.0	.0	15.4	15.4
.0	.0	.0	.0	.C
.0	.0	.0	.0	.C
.0	1022.6	374.3	374.3	1,771.2

Table 20

IMISCO PROGRAM FUNDING EXAMPLES

ORBITAL SUPPORT
LOGISTICS SUPPORT
LS

SPACECRAFT

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 75	.0	.0	.0	.0	.0	.0	46.9	.0	.0	46.9
CY 76	.0	34.8	.0	.0	34.8	.0	90.7	.0	.0	90.7
CY 77	.0	99.7	.0	.0	99.7	.0	100.9	.0	.0	100.9
CY 78	.0	120.2	.0	.0	120.2	.0	88.9	2.9	.0	91.8
CY 79	.0	96.1	.0	.0	96.1	.0	60.1	72.8	.0	132.9
CY 80	.0	48.5	30.0	.0	78.5	.0	20.3	80.1	.2	100.6
CY 81	.0	8.6	92.3	.0	100.9	.0	.0	16.7	54.2	70.8
CY 82	.0	.0	48.3	.0	48.3	.0	.0	.0	85.5	85.5
CY 83	.0	.0	1.8	47.0	48.9	.0	.0	.0	32.3	32.3
CY 84	.0	.0	.0	87.2	87.2	.0	.0	.0	.4	.4
CY 85	.0	.0	.0	37.5	37.5	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	.8	.8	.0	.0	.0	.0	.0
TOTAL	.0	407.8	172.5	172.5	752.8	.0	407.8	172.5	172.5	752.8

Table 21

IMISCD PROGRAM FUNDING EXAMPLES

ORBITAL SUPPORT
LOGISTICS SUPPORT
LS

EARTH LAUNCH VEHICLE

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 75	.0	.0	.0	.0	.0	.0	66.1	.0	.0	66.1
CY 76	.0	48.9	.0	.0	48.9	.0	127.7	.0	.0	127.7
CY 77	.0	140.3	.0	.0	140.3	.0	142.0	.0	.0	142.0
CY 78	.0	169.2	.0	.0	169.2	.0	125.1	3.1	.0	128.2
CY 79	.0	135.3	.0	.0	135.3	.0	84.6	77.9	.0	162.5
CY 80	.0	68.3	32.1	.0	100.4	.0	28.5	85.7	.0	114.2
CY 81	.0	12.1	98.7	.0	110.8	.0	.0	17.8	.5	18.3
CY 82	.0	.0	51.7	.0	51.7	.0	.0	.0	103.4	103.4
CY 83	.0	.0	2.0	.0	2.0	.0	.0	.0	79.5	79.5
CY 84	.0	.0	.0	92.2	92.2	.0	.0	.0	1.1	1.1
CY 85	.0	.0	.0	89.8	89.8	.0	.0	.0	.0	.0
CY 86	.0	.0	.0	2.5	2.5	.0	.0	.0	.0	.0
TOTAL	.0	574.0	184.5	184.5	943.0	.0	574.0	184.5	184.5	943.0

Table 22

IMISCD PROGRAM FUNDING EXAMPLES

ORBITAL SUPPORT
LOGISTICS SUPPORT
LS

ASSY C10 INTEG AND SUPPORT

	B A S I C P R O G R A M					A L T E R N A T E P R O G R A M				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 75	.0	.0	.0	.0	.0	.0	4.7	.0	.0	4.7
CY 76	.0	3.5	.0	.0	3.5	.0	9.1	.0	.0	9.1
CY 77	.0	10.0	.0	.0	10.0	.0	10.1	.0	.0	10.1
CY 78	.0	12.0	.0	.0	12.0	.0	8.9	.0	.0	8.9
CY 79	.0	9.6	.0	.0	9.6	.0	6.0	.0	.0	6.0
CY 80	.0	4.9	.0	.0	4.9	.0	2.0	2.5	.0	4.5
CY 81	.0	.9	.0	.0	.9	.0	.0	14.8	.0	14.8
CY 82	.0	.0	14.4	.0	14.4	.0	.0	.0	.0	.0
CY 83	.0	.0	2.9	.0	2.9	.0	.0	.0	3.3	3.3
CY 84	.0	.0	.0	.0	.0	.0	.0	.0	14.0	14.0
CY 86	.0	.0	.0	17.3	17.3	.0	.0	.0	.0	.0
TOTAL	.0	40.8	17.3	17.3	75.4	.0	40.8	17.3	17.3	75.4

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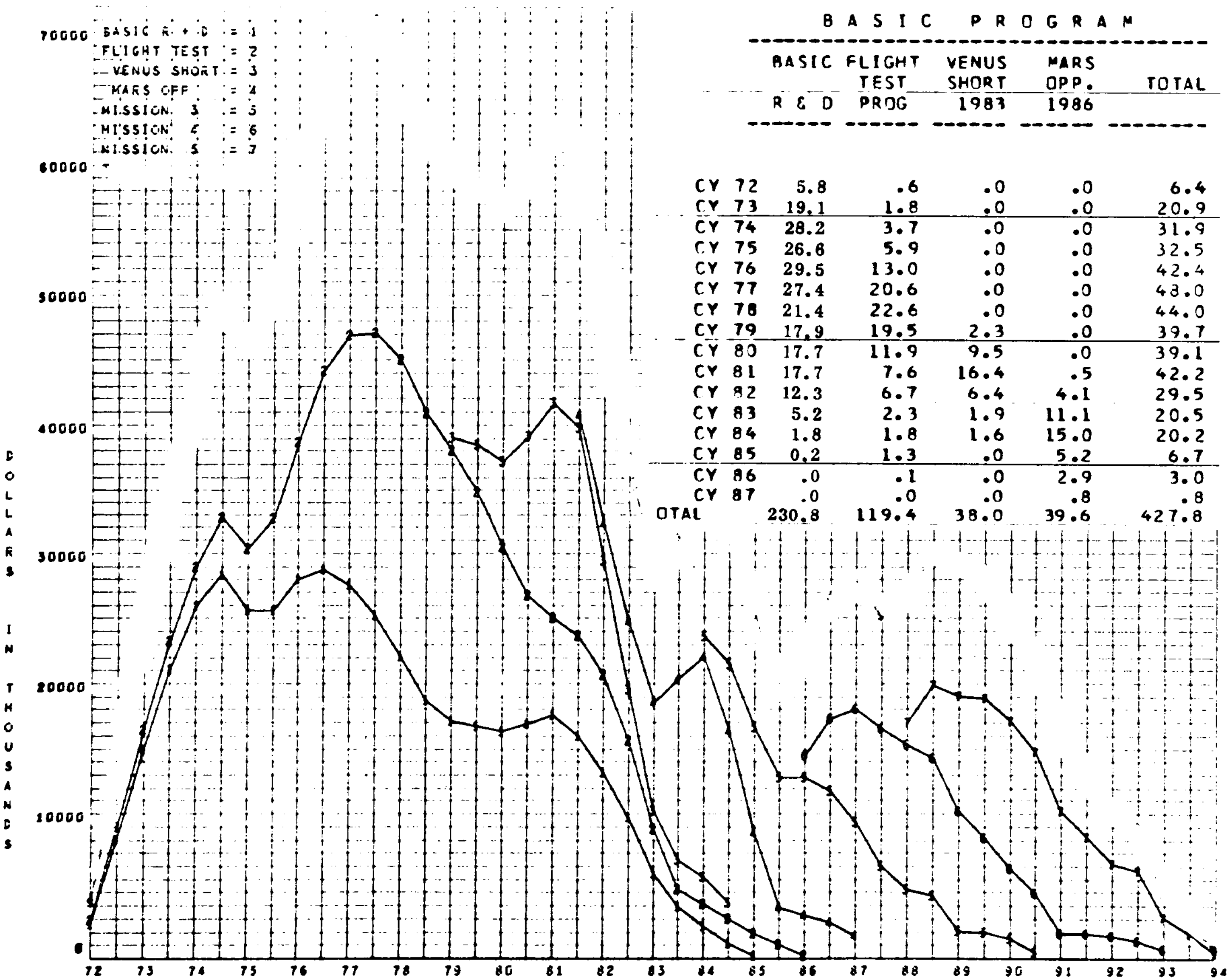
IMISCD PROGRAM FUNDING   INTERLANETARY MISSION SYS MGT

CASE NUMBER 1

Figure 15



B A S I C   P R O G R A M

	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL
CY 72	5.8	.6	.0	.0	6.4
CY 73	19.1	1.8	.0	.0	20.9
CY 74	28.2	3.7	.0	.0	31.9
CY 75	26.6	5.9	.0	.0	32.5
CY 76	29.5	13.0	.0	.0	42.4
CY 77	27.4	20.6	.0	.0	48.0
CY 78	21.4	22.6	.0	.0	44.0
CY 79	17.9	19.5	2.3	.0	39.7
CY 80	17.7	11.9	9.5	.0	39.1
CY 81	17.7	7.6	16.4	.5	42.2
CY 82	12.3	6.7	6.4	4.1	29.5
CY 83	5.2	2.3	1.9	11.1	20.5
CY 84	1.8	1.8	1.6	15.0	20.2
CY 85	0.2	1.3	.0	5.2	6.7
CY 86	.0	.1	.0	2.9	3.0
CY 87	.0	.0	.0	.8	.8
OTAL	230.8	119.4	38.0	39.6	427.8

IMISCO PROGRAM FUNDING INTERLANETARY MISSION SYS MGT

CASE NUMBER 2

Figure 16

A L T E R N A T E P R O G R A M

BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
6.4	1.7	.0	.0	8.1
19.4	4.3	.0	.0	23.6
30.1	8.6	.0	.0	38.7
39.9	16.9	.0	.0	56.8
42.3	22.4	.C	.0	64.8
32.3	20.6	.5	.0	53.4
21.4	17.2	5.1	.0	43.7
19.1	13.5	14.5	.6	47.7
12.8	8.6	12.5	4.4	38.3
5.2	2.5	2.7	11.9	22.2
1.8	1.8	2.2	14.5	20.2
.1	1.3	.6	4.7	6.7
.0	.1	.0	2.9	3.0
.0	.0	.0	.6	.6
.0	.0	.0	.0	.0
.0	.0	.0	.0	.0
230.8	119.4	38.0	39.6	427.9

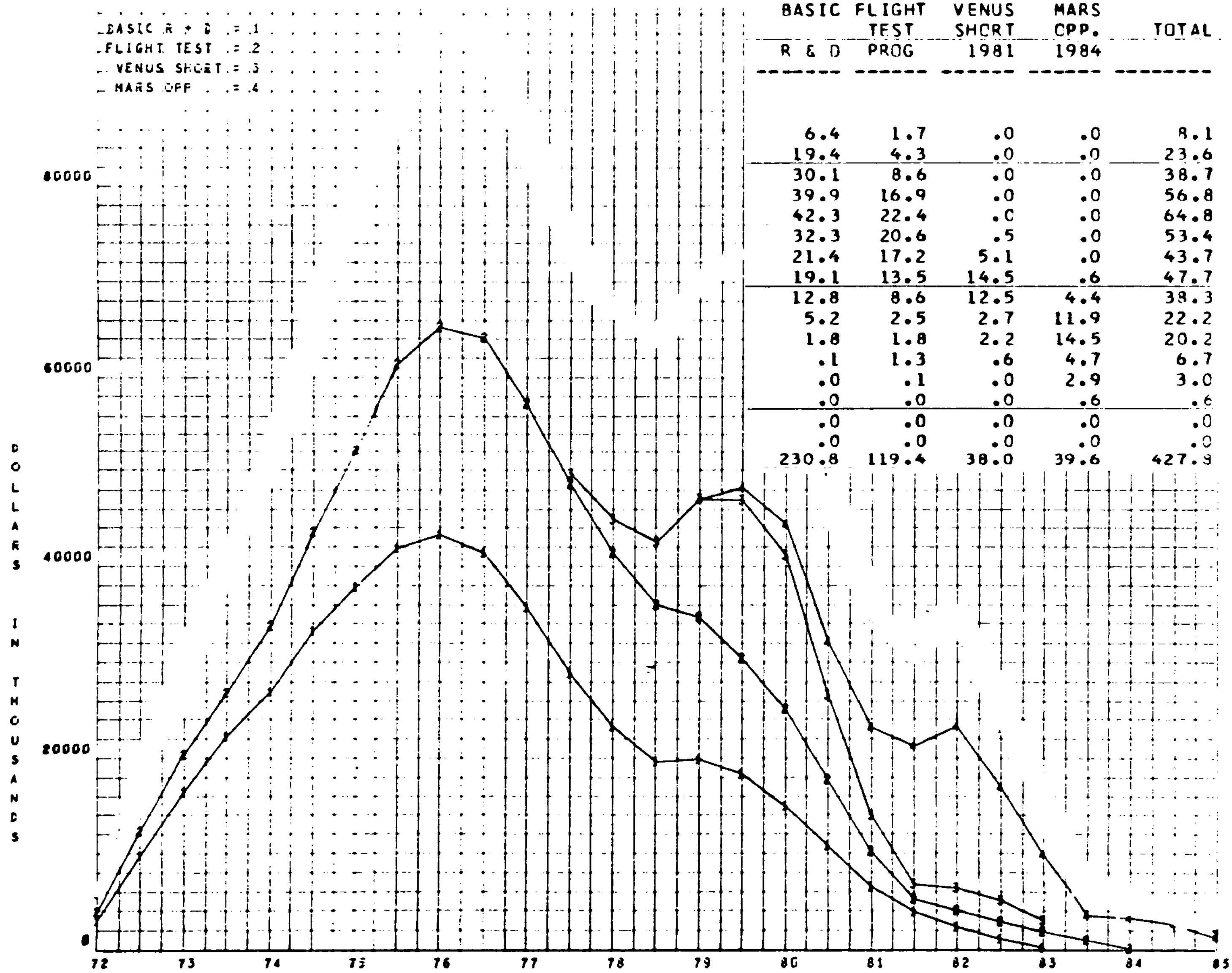


Table 23

IMISCD PROGRAM FUNDING EXAMPLES

INTERPLANETARY MISSION SYS MGT
IMSIM
IMSIM
IMSIM

	BASIC PROGRAM					ALTERNATE PROGRAM				
	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1983	MARS OPP. 1986	TOTAL	BASIC R & D	FLIGHT TEST PROG	VENUS SHORT 1981	MARS OPP. 1984	TOTAL
CY 72	5.8	.6	.0	.0	6.4	6.4	1.7	.0	.0	8.1
CY 73	19.1	1.8	.0	.0	20.9	19.4	4.3	.0	.0	23.6
CY 74	28.2	3.7	.0	.0	31.9	30.1	8.6	.0	.0	38.7
CY 75	26.6	5.9	.0	.0	32.5	39.9	16.9	.0	.0	56.8
CY 76	29.4	13.0	.0	.0	42.4	42.3	22.4	.0	.0	64.8
CY 77	27.4	20.6	.0	.0	48.0	32.3	20.6	.5	.0	53.4
CY 78	21.3	22.6	.0	.0	44.0	21.4	17.2	5.1	.0	43.7
CY 79	17.9	19.5	2.3	.0	39.7	19.1	13.5	14.5	.6	47.7
CY 80	17.7	11.9	9.5	.0	39.1	12.8	8.6	12.5	4.4	38.3
CY 81	17.8	7.6	16.4	.5	42.2	5.2	2.5	2.7	11.9	22.2
CY 82	12.4	6.7	6.4	4.1	29.5	1.8	1.8	2.2	14.5	20.2
CY 83	5.2	2.3	1.9	11.1	20.5	.1	1.3	.6	4.7	6.7
CY 84	1.8	1.8	1.6	15.0	20.2	.0	.1	.0	2.9	3.0
CY 85	.1	1.3	.0	5.2	6.7	.0	.0	.0	.6	.6
CY 86	.0	.1	.0	2.9	3.0	.0	.0	.0	.0	.0
CY 87	.0	.0	.0	.8	.8	.0	.0	.0	.0	.0
TOTAL	230.8	119.4	38.0	39.6	427.8	230.8	119.4	38.0	39.6	427.8