NASA CR-66725-1

FINAL REPORT

BUOYANT VENUS STATION MISSION FEASIBILITY STUDY FOR 1972 AND 1973 LAUNCH OPPORTUNITIES

VOLUME I - MISSION SUMMARY DEFINITION AND COMPARISON

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FOREWORD

The use of a buoyant station -- balloon supported instrument package -- to explore in the atmosphere of Venus was considered in a previous study and the results were presented in NASA CR-66404.* The concept permits the instruments to be supported in the atmosphere in a moderate environment with the additional advantages of long duration in the atmosphere and mobility over the surface -- dependent on the existing wind patterns. From such a station measurements relating both to the atmopshere and the surface can be made, the latter either indirectly or by sondes dropped to the surface from the parent station. Because the problems of surviving and operating in the extremes of the lower altitude environments are localized in the relatively small sondes or probes, considerably more leeway is possible in the design of the instrumentation as well as the other supporting equipment.

The present study expands the work reported in NASA CR-66404 to consider the feasibility of the buoyant station concept with the constraints and requirements that would be imposed by a variety of complete missions, i.e., orbital, flyby and swingby missions.

This final report on the Buoyant Venus Station Mission Feasibility Study for 1972-1973 Launch Opportunities is submitted by the Martin Marietta Corporation, Denver Division, in accordance with Contract NAS1-7590.

This report is submitted in three volumes as follows:

Volume I - Mission Summary Definition and Comparison;

Volume II - Trajectory Analysis for 1972 and 1973 Missions;

Volume III - Configuration Definition.

The purpose of this first volume is to provide a brief summary of the missions considered and the design concepts involved. For further information the reader is referred to Volumes II and III.

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*J. F. Baxter: Final Report, Buoyant Venus Station Feasibility Study, Volume I, Summary and Problem Identification.

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by John F. Baxter, Ronald E. Frank, John F. Froistad, and
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SUMMARY

Three mission modes and launch opportunities in which the buoyant station can be employed are considered:

1) A 1972 mission with a flyby spacecraft;
2) A 1973 mission with an orbiter spacecraft;
3) A 1973 mission in conjunction with a Mercury/Venus swingby opportunity.

The buoyant station concept is found not to be highly sensitive to the mission mode selected. With minor differences, a station (fig. 1) weighing approximately 400 lb at deployment (floating a 175-lb gondola/instrument package) is appropriate for each of the missions considered.

ACCOMPLISHMENT OF SCIENCE OBJECTIVES

The unique features of a BVS (Buoyant Venus Station) mission are given in table 1. These attributes are generally not achievable by other available means of in situ exploration and are particularly worthy of consideration in light of the Russian success with a probe mission into the Venus atmosphere.

Balloon			
	Volume, cu ft	3090	
	Diameter, ft	18	
Weight, lb			
	Balloon		15
	Gondola		175
	Science	58	
	Telecommunication	46	
	Power	33	
	Inflation		177
	Gas		10
	Tanks	128	
	Miscellaneous	49	
	Chute system		26
	Total weight		403

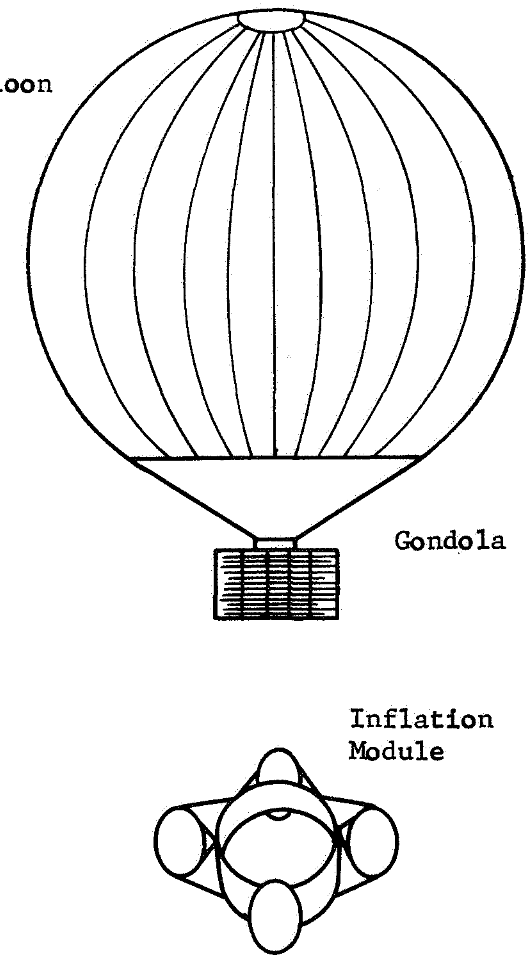


Figure 1.- Buoyant Venus Station (Typical)

TABLE 1.- UNIQUE BVS FEATURES

Environment
Design and packaging restraints (high temperature and pressure) are localized to small sondes and probes.
Time
Duration to make detail measurements and analysis
Ability to deal with time variable phenomena
Command possibilities
Mobility
Winds
Multiple probes to surface
Ability to deal with phenomena that vary with location

In general, the BVS concept has the following unique capabilities:

1) Temperate and well-defined environment. The Mariner V and Venera IV missions have shown that the conditions near the BVS floatation altitude approximate those of Earth. A corollary is that the problems of designing probes or landers for survival in the extreme near-surface environment are localized in small sondes;

2) Mobility and multilocation sounding to the surface giving spatial variations of phenomena;

3) Long life allowing investigation of time-dependent phenomena and experiment format adaptability;

4) Exploratory nature. The BVS is driven by the winds to and from the regions of meterological activity. The likelihood of new phenomena being discovered is enormously enhanced.

Generally, measurements that can be made by an entry probe (or probes) can be made as well and often better using a Buoyant Venus Station (BVS) with several small sondes. In addition, many objectives can be accomplished only through the use of a BVS with drop sondes because the investigation of temporal or spatial variations requires the BVS concept. The specific experiments or objectives that can be satisfactorily accomplished only through the use of a BVS with drop sondes include:

1) General circulation pattern, winds, turbulence, spatial and temporal variations;

2) Biological experiments. These typically require long times (~50 to 100 hr) and a temperate environment for collection, growth, and analysis;

3) Cloud physics and chemistry including horizontal and vertical structure and variations, particle size, concentration, composition, etc., breaks, variations with location, and detailed compositional analysis;

4) Trace and time-variable atmospheric constituents (e.g., H_2O, volcanic emissions, organic compounds, dust, etc.) and correlation with other phenomena;

5) Variations of radiation flux (visible and infrared) with zenith angle, altitude, cloud cover, and correlation with other phenomena (e.g., winds, surface temperature);

6) High resolution imaging (visible, passive, or active microwave) of surface features and topography at many points.

From the viewpoint of accomplishing science objectives, the BVS missions differ primarily in entry locations and predicated drift of the BVS in the atmosphere. In this regard, the orbiter mission is most attractive in permitting the BVS to approach the polar area.

SCHEDULE AND COST

A preliminary program plan for the designated missions, including development program plans for the heat shield and the flotation system, is presented. Cost and schedule data are provided for each mission and for the development items.

From a common starting point (September 1969), the 1973 orbiter and Venus/Mercury missions allow 50 months to launch, while the 1972 flyby allows 31 months to launch. No development items have been identified that preclude any of these schedules; however, the short time span available for the 1972 opportunity suggests the impracticality of implementing the 1972 flyby mission. Therefore, only a schedule has been prepared for this mission.

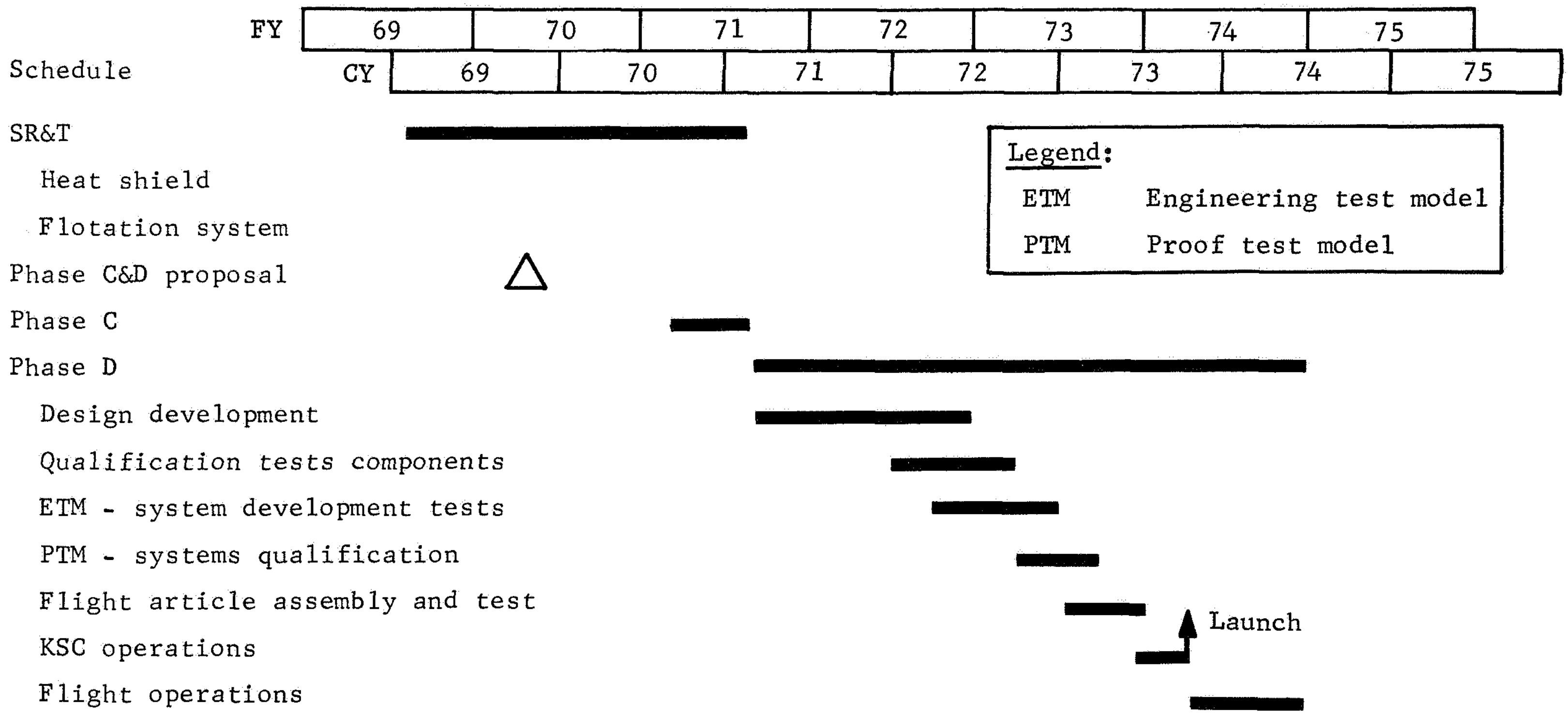
The variation in cost for the three missions is approximately 10% from the least cost mission to the highest cost mission. The total cost comparison of these three missions is given in table 2.

The major items of development are identified for all missions as:

1) Heat shield development;

2) Flotation system development.

The data generated for this study indicate that a 1973 mission is feasible with major funding not starting (Phase C study) until fiscal year 1971 as shown in figure 2.



FY Funding, & mission (FY 1968 dollars)	69	70	71	72	73	74	Total
	1	2	19	66	32	8	128

Figure 2.- 1973 Venus Orbital Mission Optional Plan

TABLE 2. - TOTAL PROGRAM COST

	Cost, FY68 dollars		
	1973 orbital	1973 Venus/Mercury	1973 flyby
BVS hardware	121 270 x 10^3	135 284 x 10^3	127 017 x 10^3
Probe	5 087	6 181	5 087
BVS science	12 240	12 240	12 240
Mission integration	14 113	14 113	14 113
Spacecraft	85 000	75 000	75 000
Launch vehicle	18 000	18 000	18 000
Total	255 710	260 818	251 457

INTRODUCTION

The objective of the study was to investigate the feasibility of several specific Venus exploration missions using the buoyant station concept; the feasibility was investigated by performing trajectory analyses (interplanetary, orbital, flyby approach, and atmospheric entry), by defining modifications to specified spacecraft, and by defining configurations for the buoyant station/entry system. The final steps of the study consisted of comparing the specified missions including preparation of preliminary cost and schedule information.

The technical guidelines to which the study was performed are as follows:

1) The missions to be investigated and compared are,
   a) 1972 flyby mission,
   b) 1973 orbiter mission,
   c) 1973 Mercury/Venus swingby;
2) The SLV 3C/Centaur and Titan IIIC shall be considered as candidate launch vehicles;
3) Interplanetary trajectory parameters as defined in JPL TM 33-334, TM 33-342, and TM 32-1062 shall be used;

4) Venus atmospheres as defined in NASA SP-3016;

5) A complete DSIF network shall be assumed to be available;

6) The Mariner 1969 as defined in Mariner Mars 1969 Functional Requirements shall be used for the flyby mission spacecraft;

7) The modified Boeing lunar orbiter, as defined in NASA CR-66302, shall be used for the orbital mission spacecraft;

8) The Mercury/Venus spacecraft shall be as defined in JPL document 760-1;

9) The spacecraft will not be sterile;

10) The spacecraft may serve as relay station for data transmission;

11) The minimum weight BVS (investigated under Contract NAS1-6607, ref. 1) shall be used as the baseline station configuration;

12) The entry system shall provide conditions compatible with BVS deployment requirements;

13) The external shape of the entry system capsule shall be a large angle blunted cone;

14) Sterilization requirements as defined in JPL Specification no. XSO-30275-TST-AJ and GMO 50198ETS-A shall be used.

The above technical guidelines permitted the buoyant station concept to be considered within the framework mission of specific modes and opportunities. The value of such an approach, aside from extending the understanding of the buoyant station feasibility and further delineating the problem areas, was to assess the mission modes that best complement, and are complemented by, the buoyant station.

Several of the listed guidelines were modified early in the study -- primarily on the basis of the better understanding of Venus, which resulted from the Venus Mariner and the Russian missions in 1967.

The concept of using the minimum weight BVS developed under Contract NAS1-6607 was discarded on the grounds that the 20-lb science complement was no longer reasonable in the light of the Russian and Mariner successes, which made a larger payload more appropriate for consideration. The baseline science payload was increased to 58 lb.

The SLV 3C Centaur was deleted from further consideration early in the study because it severely limited the size of the BVS under consideration -- particularly for the orbiter missions.

The atmospheric models of NASA SP-3016 were not used for the reason that better data were available and could be applied with reasonable assurance of their validity (see appendix A of vol. III).

Finally, although not specified in the guidelines, it was decided to float the buoyant station within (rather than above) the clouds on the basis that the scientific value of the mission would be significantly increased. Also considered, was a dual-altitude mission performed initially above the clouds with a second phase of descent and flotation at lower altitudes (see appendix E of vol III).

At the end of the second month of the study, the recommendation was made to identify the entry-from-orbit concept and the flyby mission with direct-to-earth-communication as the approved configurations for the orbital and flyby modes, respectively, and to concentrate the remaining design effort on these configurations. The Venus/Mercury mission was added in the seventh month as was the dual-altitude concept.

This volume of the final report summarizes the approved mission configurations to permit a comparison to be made between the mission modes and opportunities under consideration. Included in this volume is a preliminary plan (cost and schedule) for each mission and an identification of mandatory or desirable technology effort related to the BVS concept.

The appendix to this volume, Buoyant Venus Station Test Program, was prepared by Dale E. White.

Volume II, Trajectory Analysis for 1972 and 1973 Mission, presents the mission analyses performed for the three missions. For each mission, a baseline is defined, including interplanetary trajectories, orbital parameters, and flyby, approach, and atmospheric entry trajectories.

Volume III, Configuration Definition, defines and documents the approved configuration for each mission. Included are the buoyant station/entry system and modifications to the spacecraft.

SYMBOLS

AFETR	Air Force Eastern Test Range
bps	bits per second
BVS	Buoyant Venus Station
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
ETM	engineering test model
IR	infrared
NCAR	National Center for Atmospheric Research
OSE	operational support equipment
P/L	payload
PTM	proof test model
S/C	spacecraft
SRT	supporting research and technology
SSB	Space Science Board
STC	system test complex
TCTM	thermal control test model
TV	television
ϵ	orbit eccentricity
γ	capsule entry flight path angle, deg
ρ	density g/cc
☉	Sun
⊕	Earth
♀	Venus
☿	Mercury

B_E capsule ballistic coefficient, slugs/ft^2

V_E capsule entry velocity, ft/sec

V_{HE} hyperbolic excess velocity, km/sec

C_3 earth departure energy, km^2/sec^2

P pressure, mb

MISSION SUMMARY

Three missions, which include operating with either orbiting or flyby spacecraft and both relay and direct-to-Earth communications, are summarized in figure 3. From entry through flotation of the BVS, the missions are generally similar, as illustrated in figure 4, which shows the entry phase, the separation and descent to the surface of the subsonic probe, the BVS deployment and inflation, and, finally, the release of the drop sondes.

The model atmosphere for the mission is depicted in figure 5, which results in the entry decelerations of figure 6 and the aerodynamic heating of figure 7. As indicated, the balloon deployment, inflation, and flotation are accomplished under very moderate environmental conditions. The experiment complement for the baseline BVS is listed in table 3.

The entry targeting for the three missions is described in figures 8 thru 10, which illustrate the constraints around which they were developed. The anticipated path that the BVS will take under the influence of the winds is described in figures 11 thru 13. The 1972 flyby mission and the 1973 Mercury/Venus swingby enter the atmosphere and remain in view of earth for a direct-Earth communication link. For the mission with orbiter, the BVS remains near the plane of orbit for relay communications. The orbit plane is restricted by "50-year lifetime" constraints to a relatively narrow band.

The feasibility of the missions, from the standpoint of payload capability and the weight allocation, is indicated in figures 14 thru 16. The mission margins available are shown in each case.

Table 4 compares the major characteristics of the mission, the parameters of which are summarized in table 5.

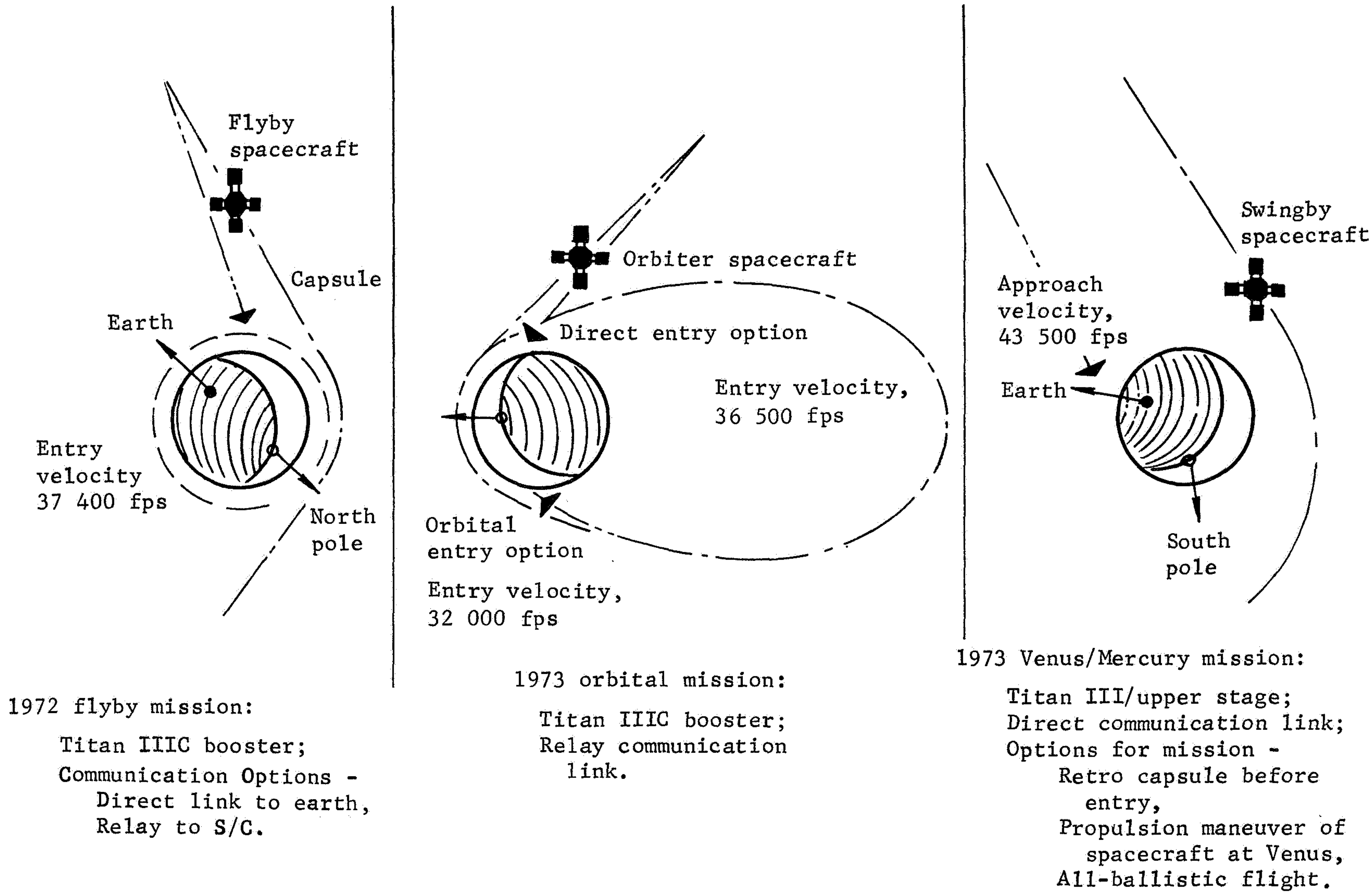


Figure 3.- Mission Options of Study

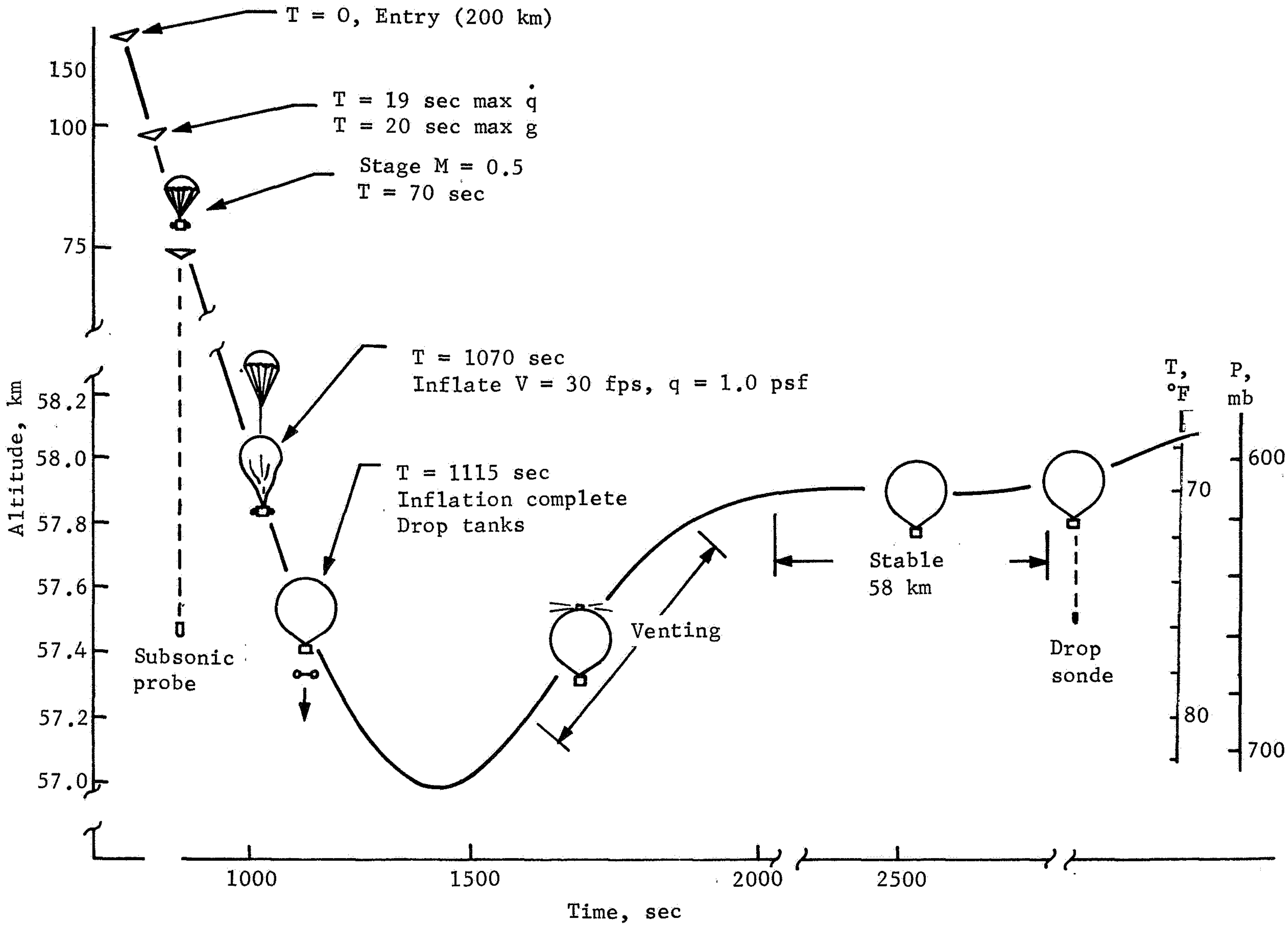


Figure 4.- Entry and Deployment Sequence

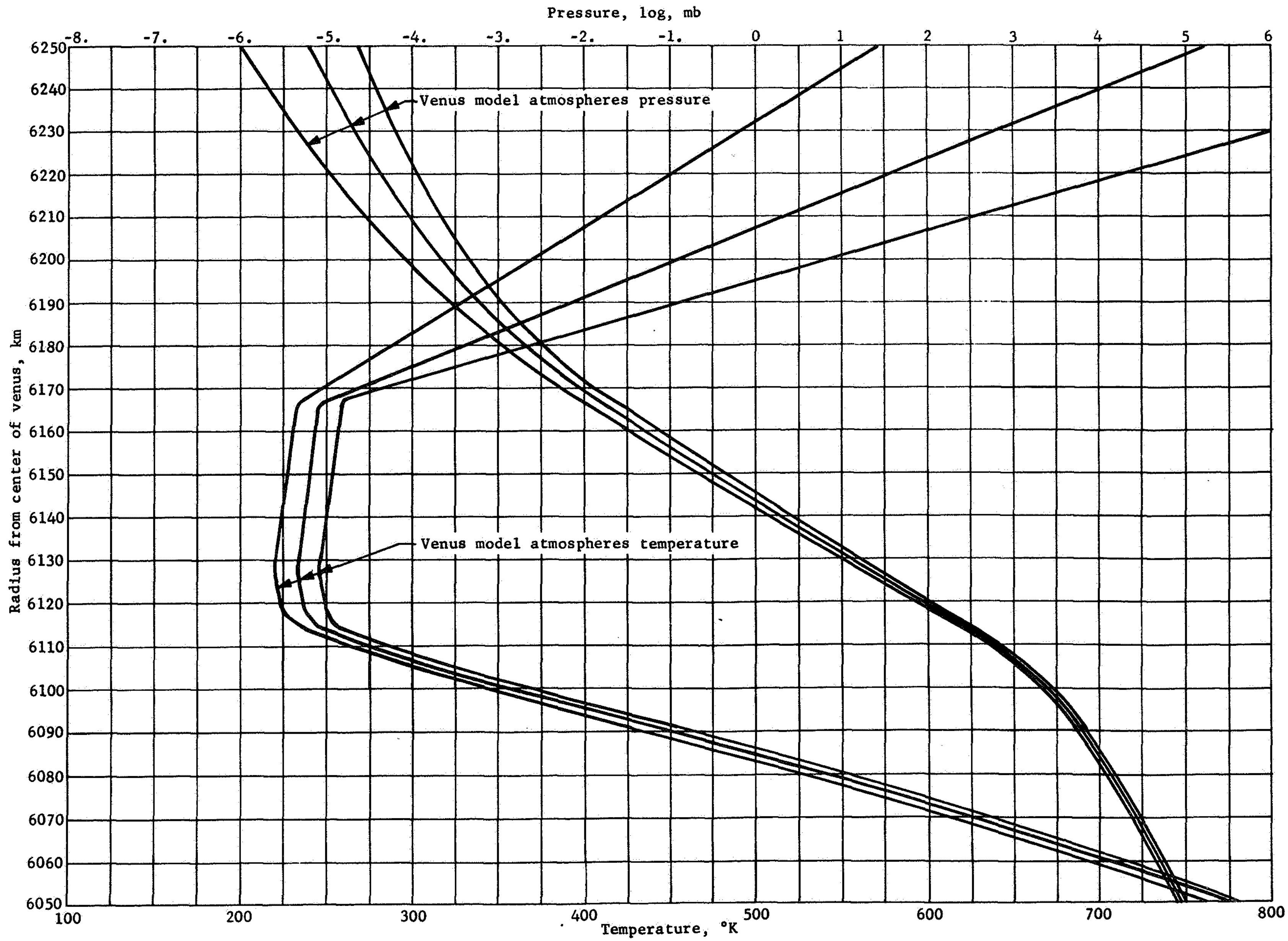


Figure 5. - Venus Pressure and Temperature Profile Models Used in Study

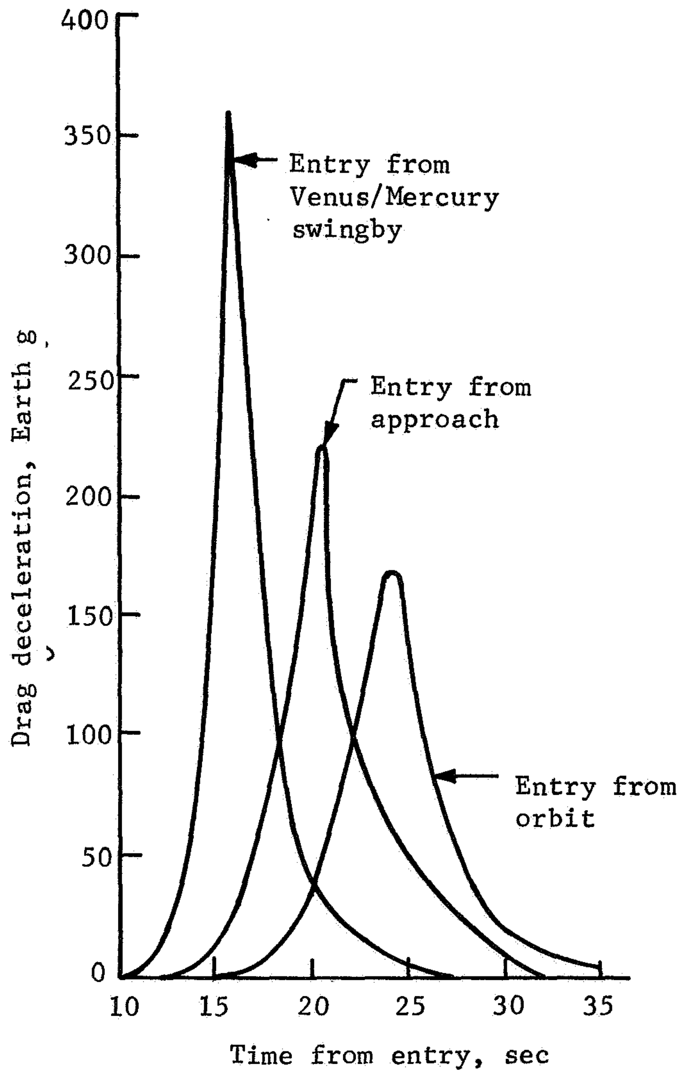


Figure 6.- Entry Drag Deceleration

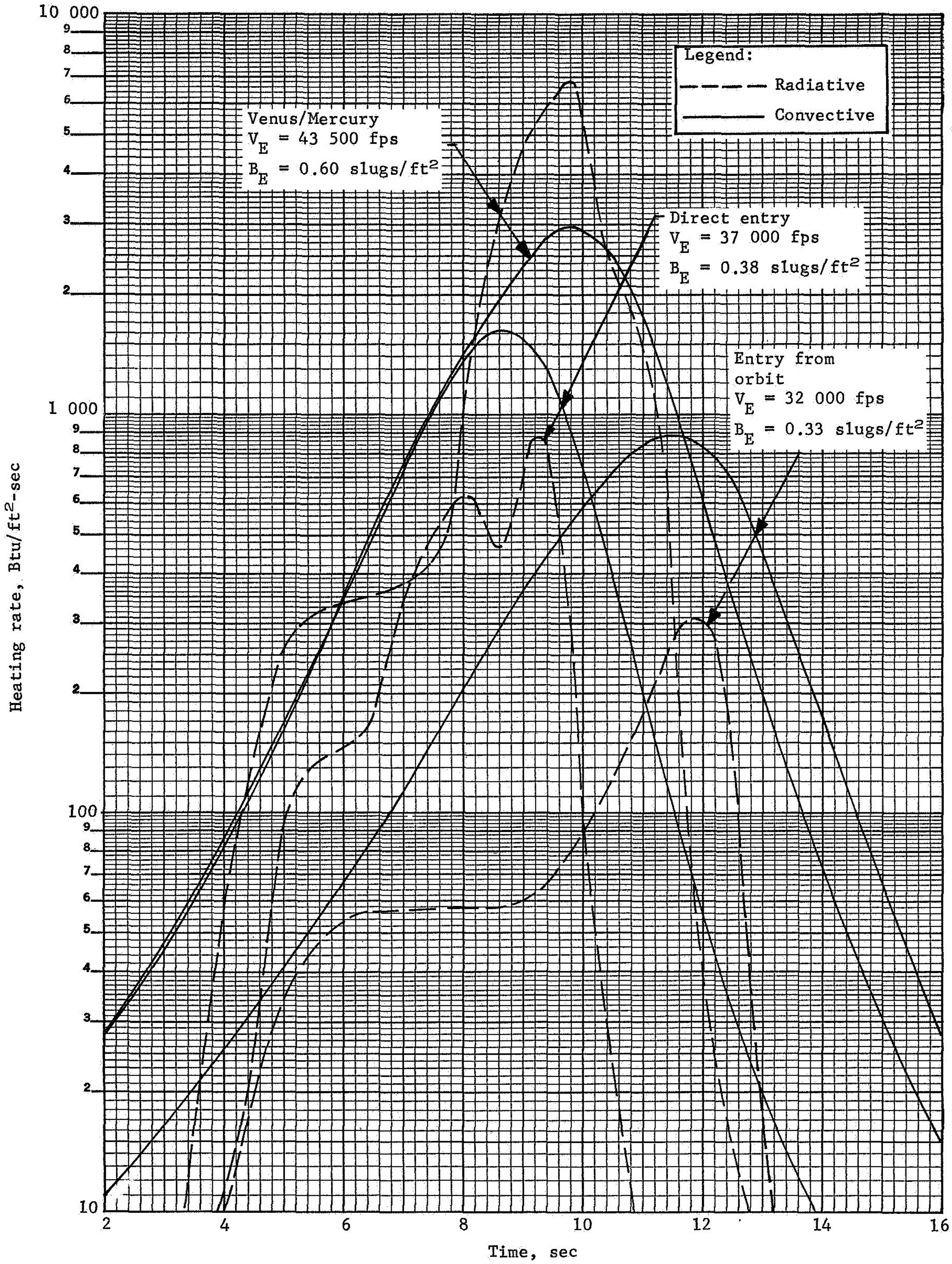


Figure 7.- Entry Aerodynamic Heating

TABLE 3.- ILLUSTRATIVE BVS EXPERIMENT COMPLEMENT

Experiment	Weight, lb	Objectives
Triaxial Accelerometer	1.5	Wind, turbulence
Pressure sensors	1.0	Atmosphere structure
Temperature sensors	1.3	Atmosphere structure
H_2O sensor	0.8	Water vapor in atmosphere
Light backscatter	1.5	Cloud particle properties
Solar aspect angles	1.5	Sun position, location of BVS
Visual photometers	2.0	Radiation environment, cloud properties, heat flux
Mass spectrometer (MS)	9.0	Atmospheric and cloud composition
Gas chromatograph (GC)	6.0	Atmospheric and cloud composition
Aerosol collector	1.0	Collect samples for MS, GC, life experiment
Radar Altimeter	12.5	Altitude reference, BVS velocity, topography, surface properties
Biolab	10.0	Search for life in clouds
Drop sondes (2 @ 5 lb)	10.0	P, T, H_2O, or radiation flux sounding to surface.
Total Weight	58.1	

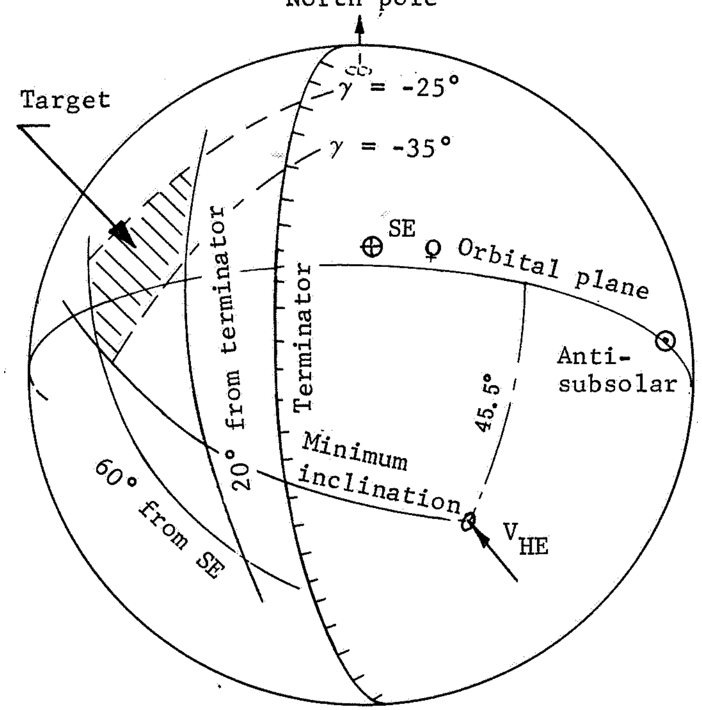


Figure 8.- Entry Vehicle Targeting, 1972 Flyby Mission

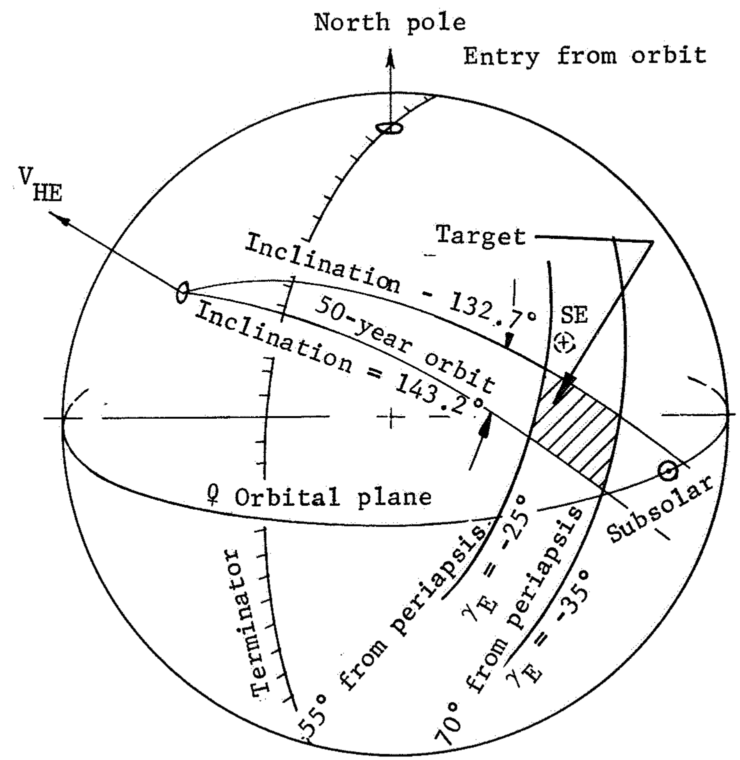


Figure 9.- Entry Vehicle Targeting, 1973 Orbital Mission

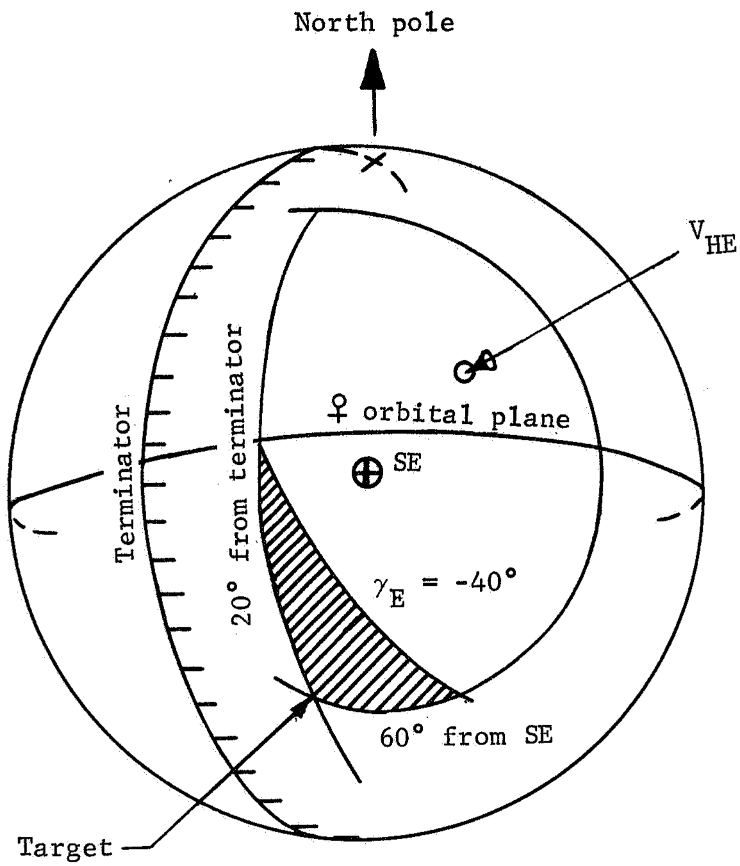


Figure 10.- Entry Vehicle Targeting,
1973 Venus/Mercury Mission

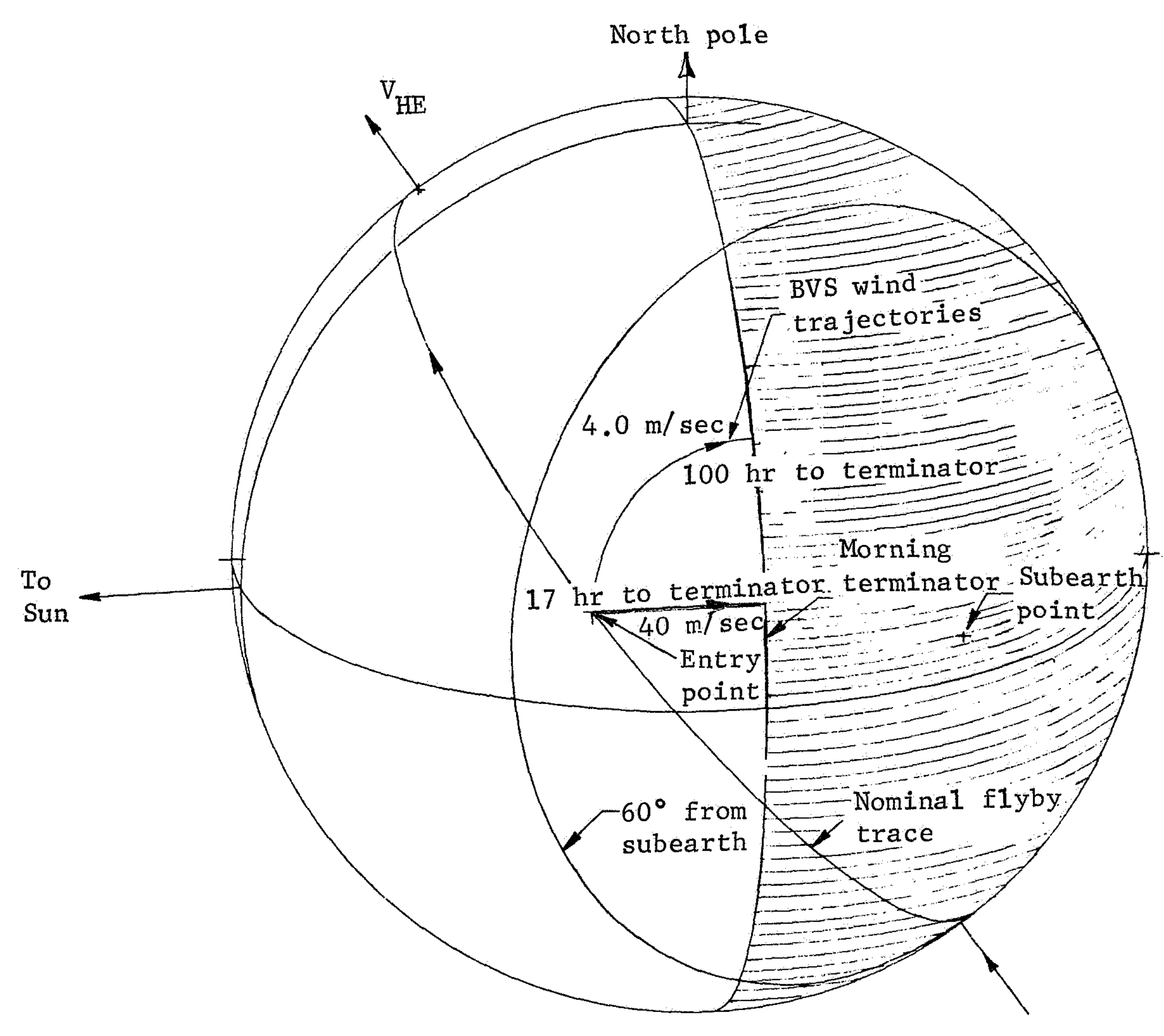


Figure 11.- BVS Wind Trajectories, 1972 Flyby Mission

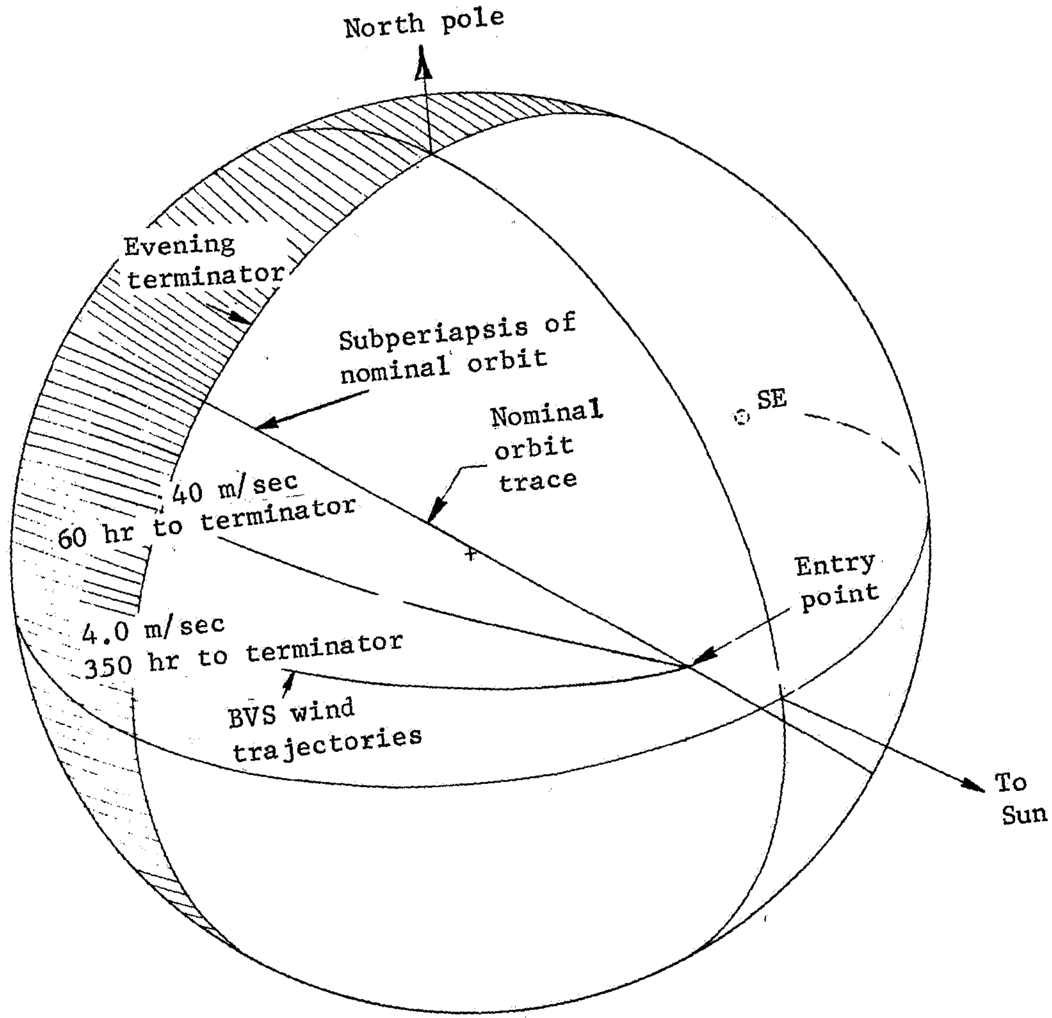


Figure 12.- BVS Wind Trajectories, 1973 Orbiter Mission

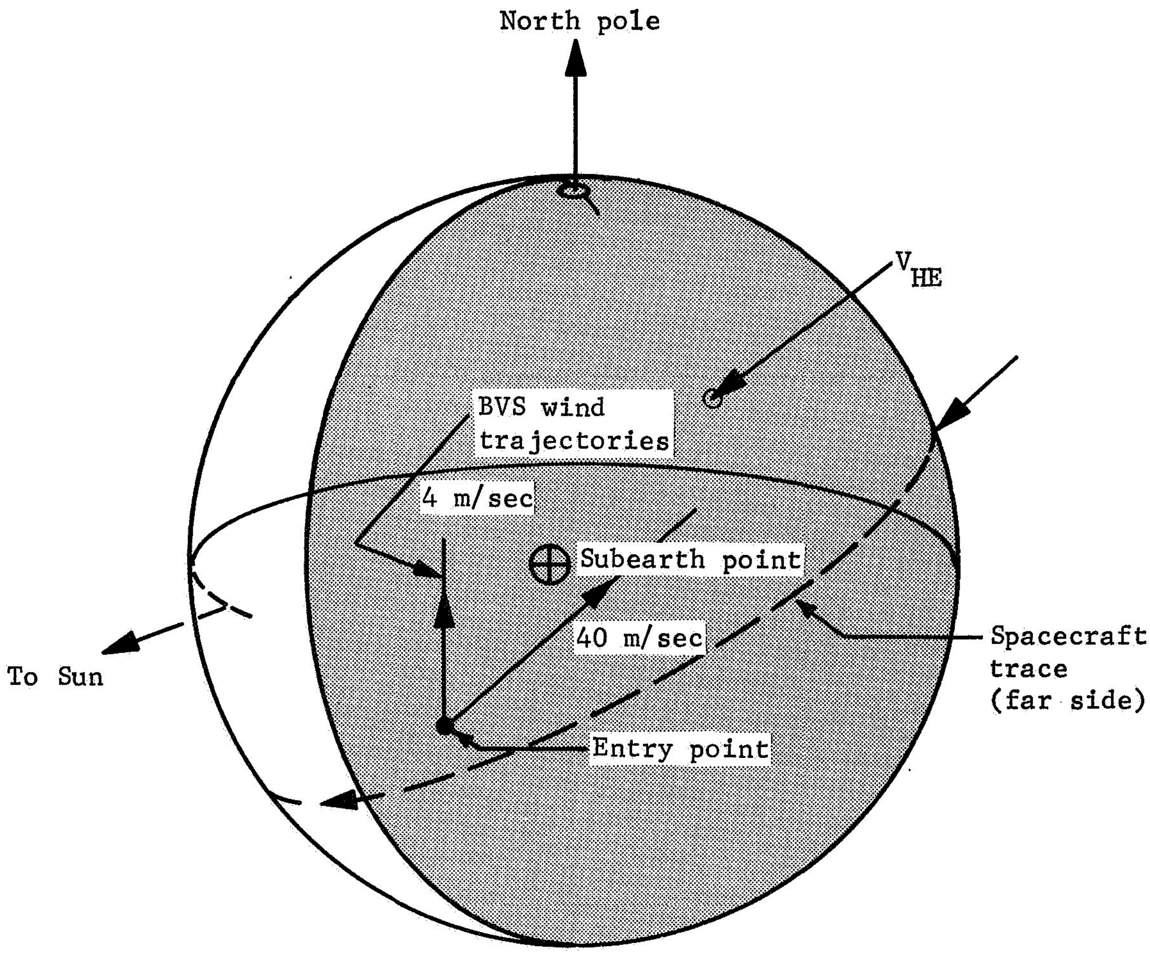


Figure 13.- BVS Wind Trajectories, 1973 Venus/Mercury Mission

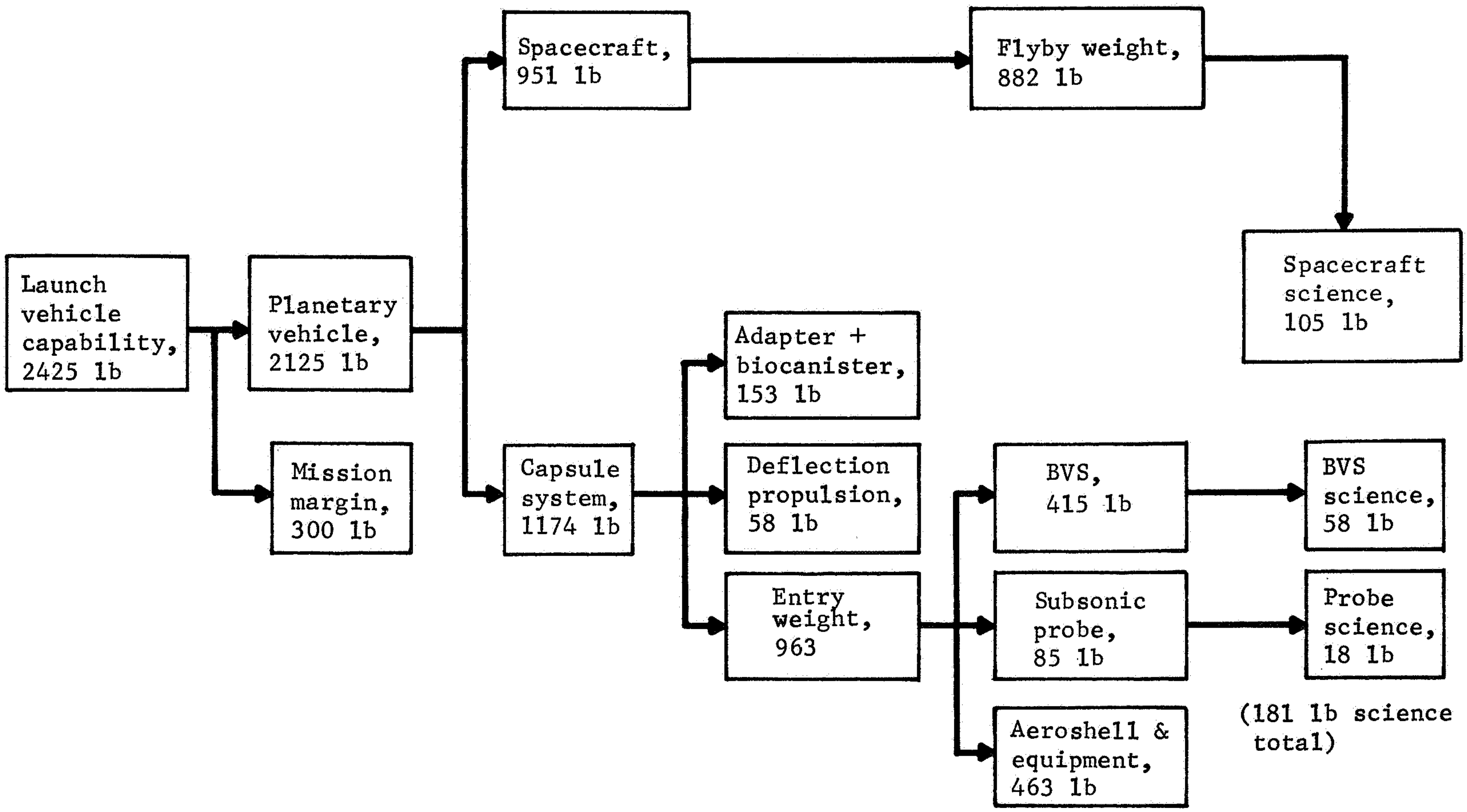


Figure 14.- Mission Weight Allocation, 1972 Flyby

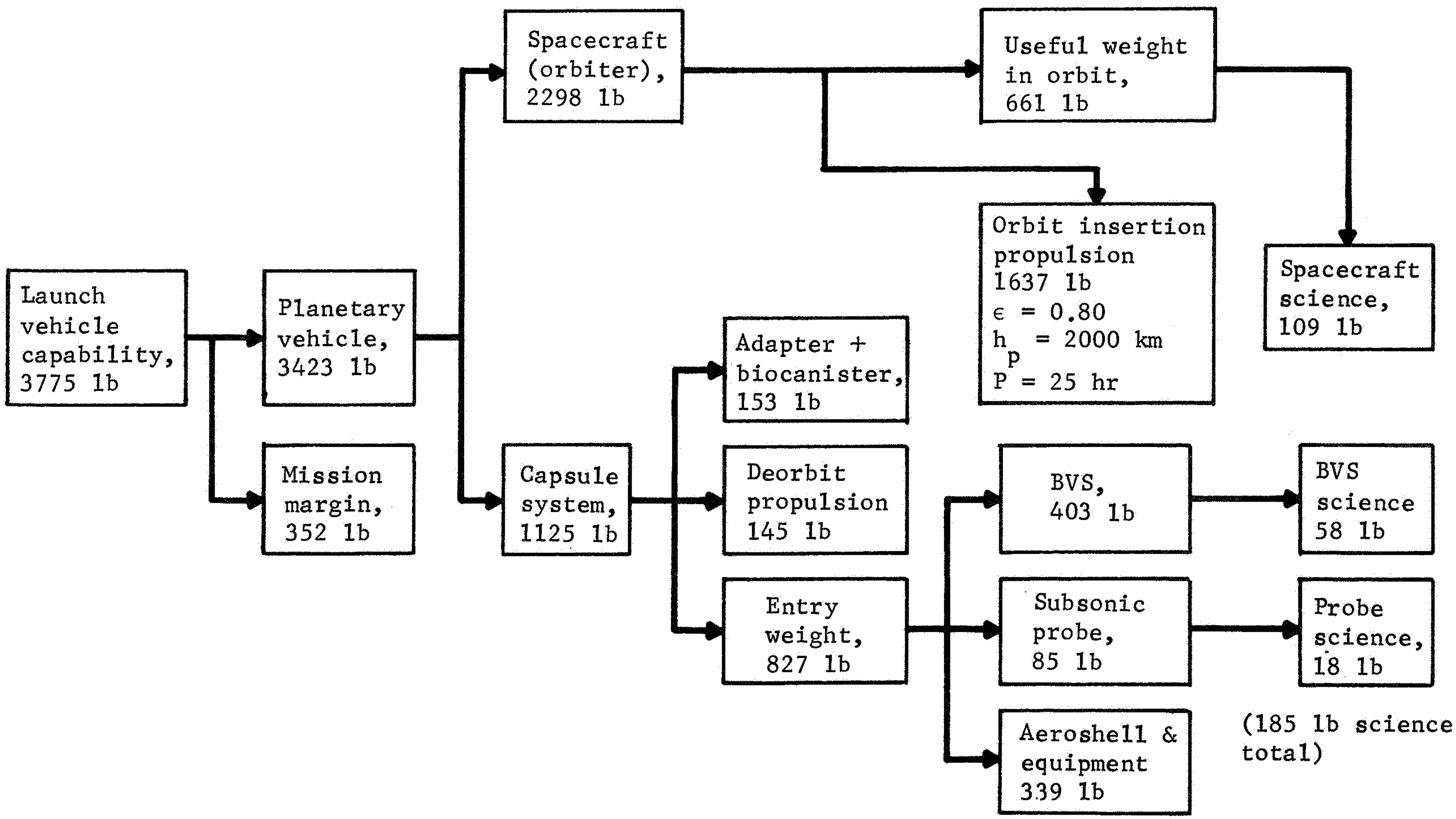


Figure 15.- Mission Weight Allocation, 1973 Orbital (Entry from Orbit Mode)

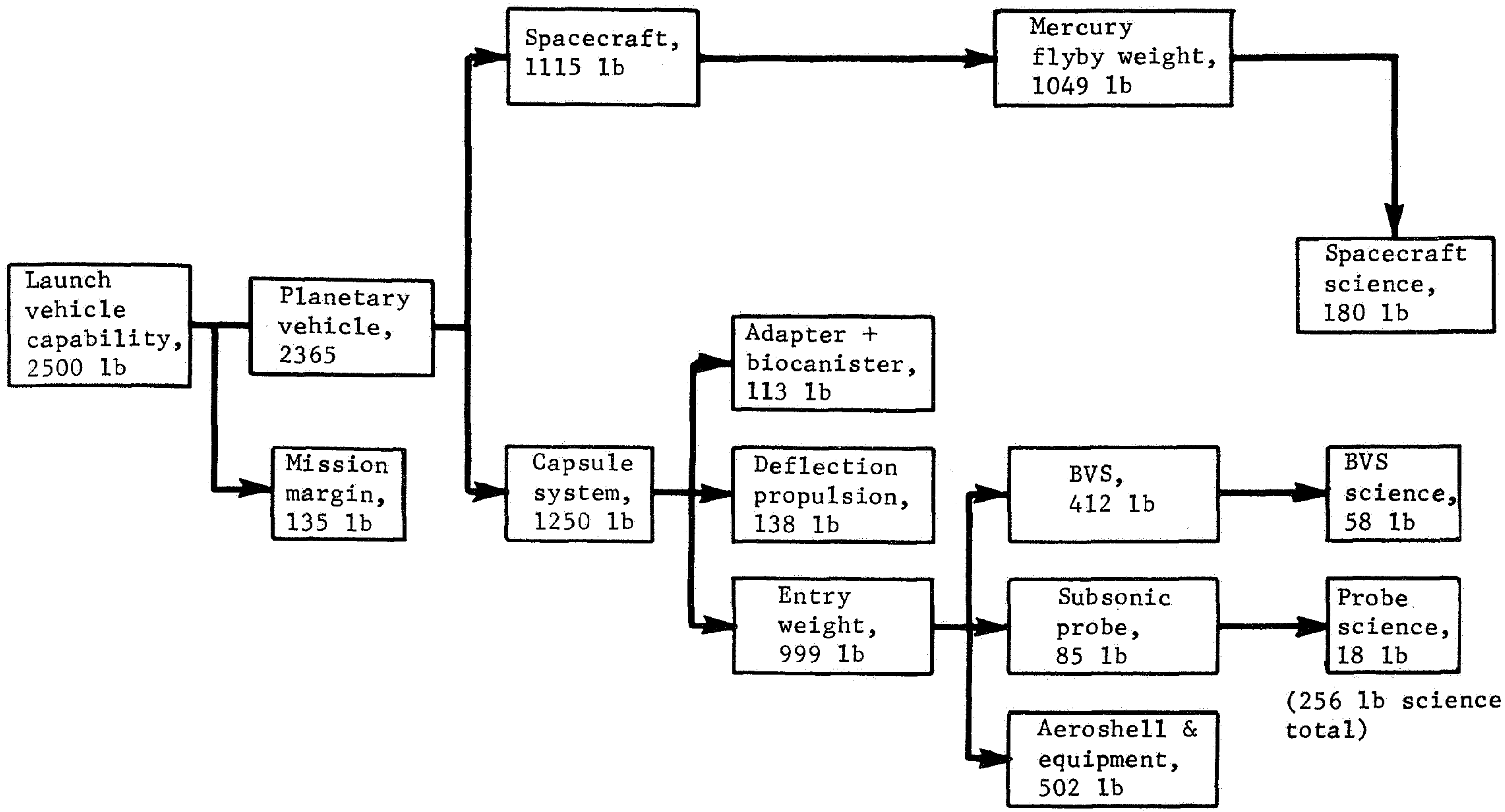


Figure 16.- Mission Weight Allocation, 1973 Venus/Mercury

TABLE 4.- MISSION COMPARISON

Parameter	1972 flyby (Type I)	1973 orbiter (Type II) (entry from orbit)	Venus/Mercury
Weight allowable, lb	2425	3775	2500
Spacecraft, lb	951	661 (useful in orbit)	1115
Flight capsule, lb	1174	1125	1250
Mission margin, lb	300	352	135
Target	In view Sun and Earth drift generally to terminator (40-100 hrs) - toward subearth	Sun side - not in view of Earth - drift to terminator - possibly near pole - (60-350 hrs) generally parallel orbit plane (communications)	Dark side - in view of Earth - drift toward subearth point
Entry environment			
V_E, fps	37 400	32 000	43 550
Deceleration, g	220	170	340
Ablator weight, lb	235 (elastomeric)	119 (elastomeric)	270 (carbon phenol)
Aeroshell diam, ft	8.5	8.5	7.0
Telecommunications	Relay (entry phase) direct Earth (0.62 AU) during flotation phase	Relay to S/C (orbiter) (nominal 10 min in 25-hr period)	Direct Earth for both entry and flotation phases (.31 AU)
Position determination	From Earth	Range or doppler from orbiter	From Earth

TABLE 5.- MISSION PARAMETERS

Parameter	1972 flyby mission	1973 orbital mission	1973 Venus/Mercury mission
Launch period	4/1-4/21/72	11/1-11/21/73	10/25-11/7/73
Arrival date	8/1/72	4/13-4/19/74	4/5/74
Type mission	I	II	I
Max. C_3/max. V_{HE}, $(km^2/sec^2)/(km/sec)$	20/5.0	8.36/4.32	19.0/8.5
Max. V_E, fps	37 400	32 000	43 550
Entry mode	Direct	From orbit	Direct (ballistic)
Capsule entry location	Lightside, in view of Earth	Lightside, not in view of Earth	Darkside, in view of Earth
Spacecraft	Modified Mariner '69	Modified Lunar Orbiter	Modified Mariner '69
Spacecraft science allocation, lb	105	109	180
BVS weight, lb	415	403	412
BVS science allocation, lb	58	58	58
BVS telecommunications	uhf relay to S/C for entry and deployment; S-band direct for flotation	uhf relay to S/C for total mission	S-band to Earth for total mission
BVS power	All-battery	Battery plus solar cell	All-battery

DESIGN CONCEPT

The planetary vehicle, consisting of the spacecraft, either orbiter or flyby, and the BVS/entry vehicle system is shown in a 10-ft diameter booster shroud in figure 17. The 8.5-ft diameter entry vehicle is encapsulated in a biological canister that is integral with the S/C adapter. The separation planes and concept for providing each separation are shown.

An exploded view of the BVS/entry vehicle system is shown in figure 18. The subsonic probe is supported from the inflation module that also supports the BVS gondola. The afterbody parachute, a 10-ft diameter flat type, which is deployed at a Mach number of 0.5 with a mortar, is stowed above the balloon canister. The BVS main parachute, which is deployed by the afterbody through a break-tie, is a 32-ft diameter, disc-gap band design, stowed concentrically about the afterbody parachute. This parachute produces a terminal condition of 1.0 lb/ft^2 dynamic pressure in which the balloon is inflated.

An afterbody heat shield is required for Venus entry for all three missions. A 0.24-in. thick lightweight elastometer protects the BVS. This afterbody must incorporate a radome over the BVS antenna.

The 58-lb science payload is mounted on the lower shelf of the gondola as shown in figure 19. The upper shelf contains the telecommunications and power subsystems as shown in figure 20. The solar array, if used, is mounted around the outer surface of the gondola.

The communication links between the spacecraft, BVS, and subsonic probe for separation, entry, and deployment phases of the flyby and orbital missions are shown in figure 21. The flotation phase for these two missions are shown in figures 22 and 23. The Venus/Mercury mission, all direct link, is shown in figure 24.

BVS power is supplied by silver-zinc batteries providing a minimum of 50 hr of mission life. The orbital mission also employes a solar array of silicon, N/P cells.

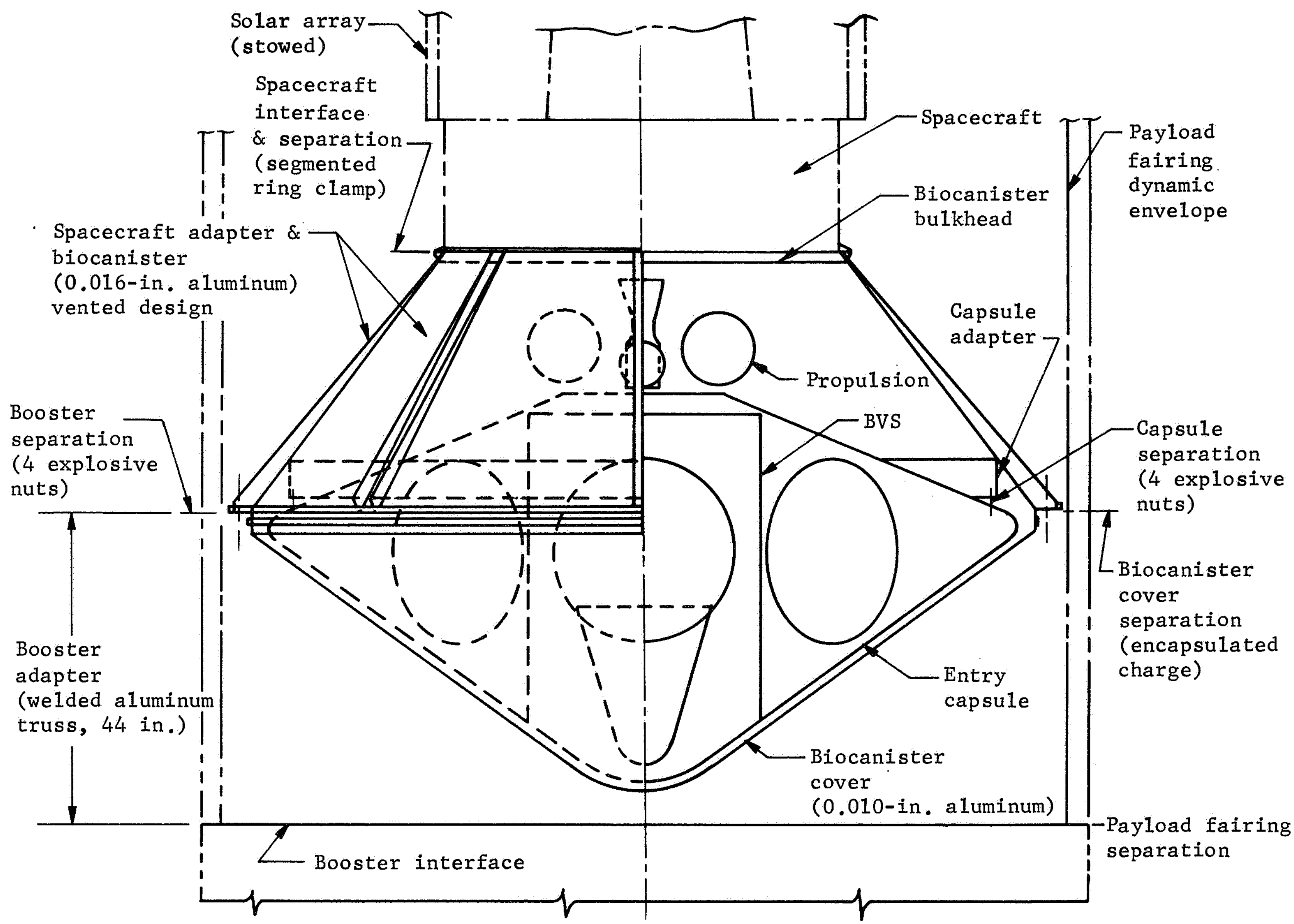


Figure 17.- Capsule, Spacecraft with Booster Interfaces

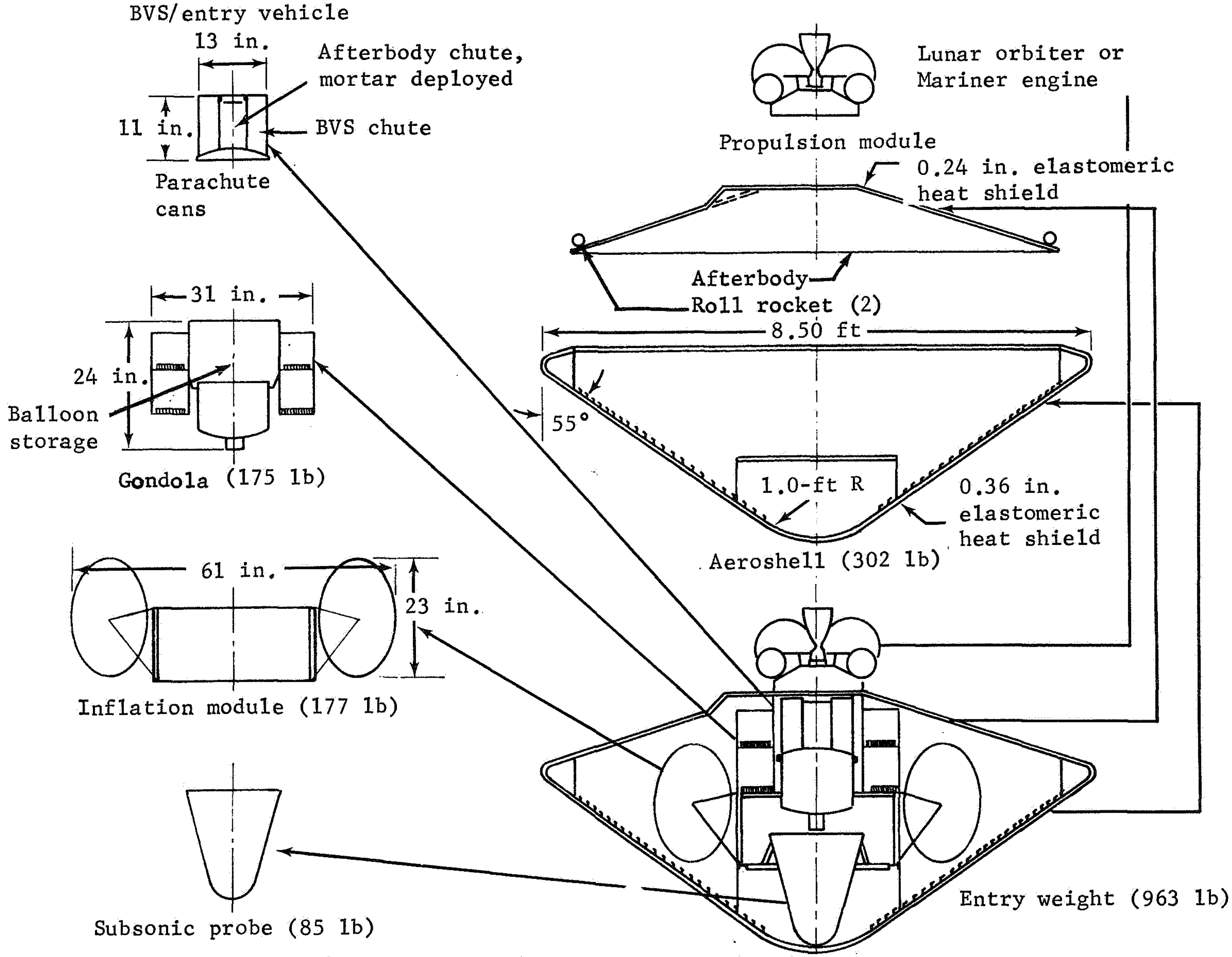


Figure 18.- BVS/Entry Vehicle (Typical)

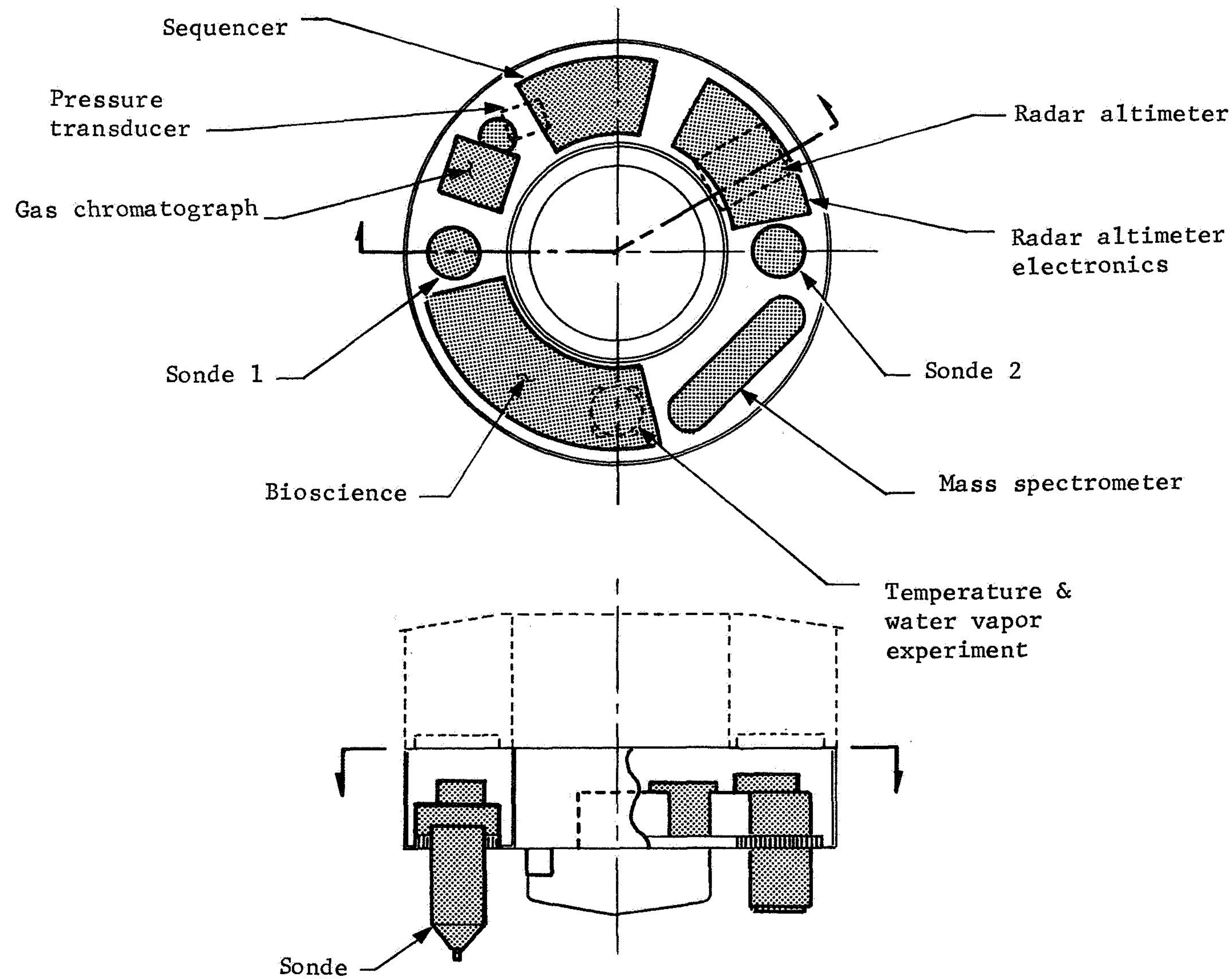


Figure 19.- Gondola Science Equipment

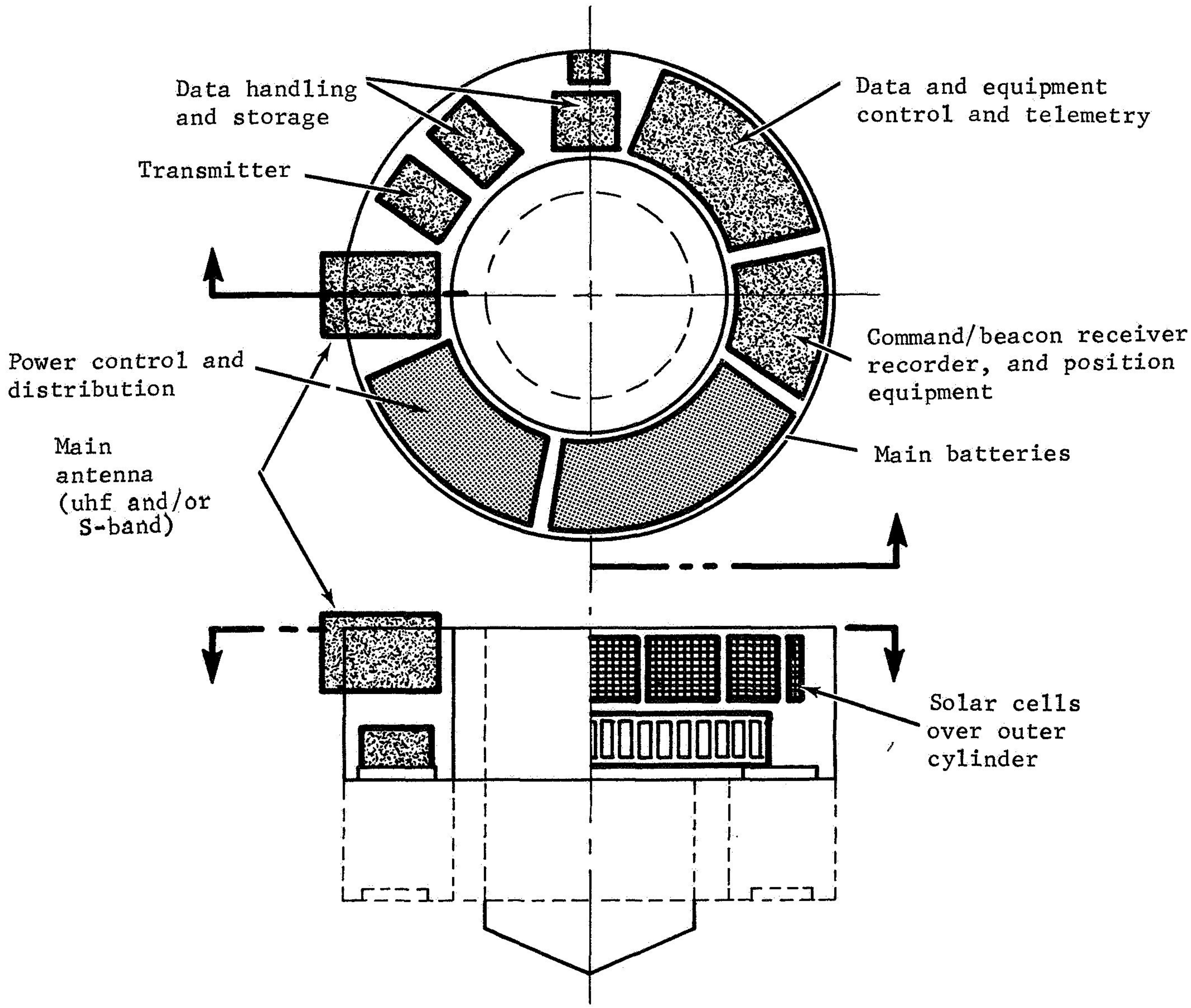
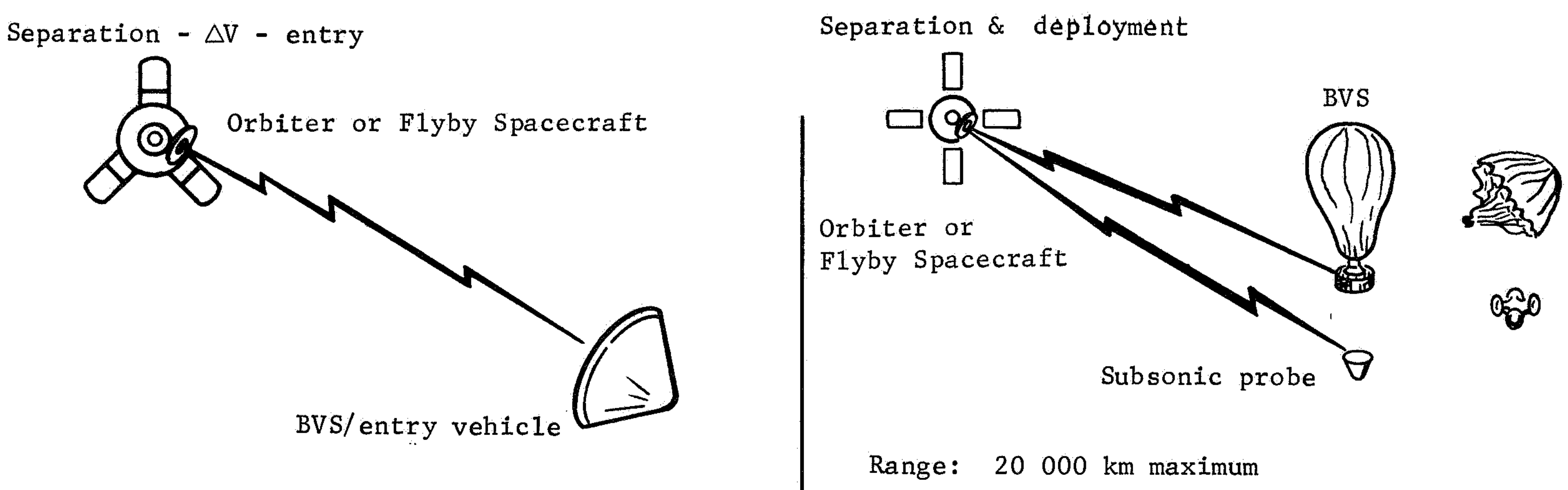
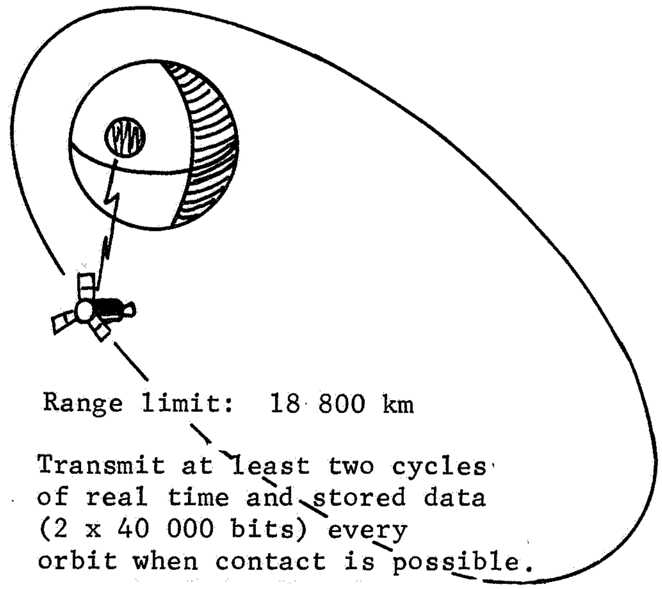


Figure 20.- Gondola Support Equipment



Characteristics	Characteristics
240 bps relay link	240 bps BVS/spacecraft relay link
Store 20 sec of entry data	Transmit stored data while BVS on parachute
BVS transmitter	Transmit deploy engineering
20 W rf	Transmit real time science and engineering after full deployment
	240 bps subsonic probe to spacecraft link, probe is released from BVS

Figure 21.- Telecommunications for Entry, Separation, and Deployment



Range limit: 18 800 km

Transmit at least two cycles of real time and stored data (2 x 40 000 bits) every orbit when contact is possible.

Accept commands from spacecraft.

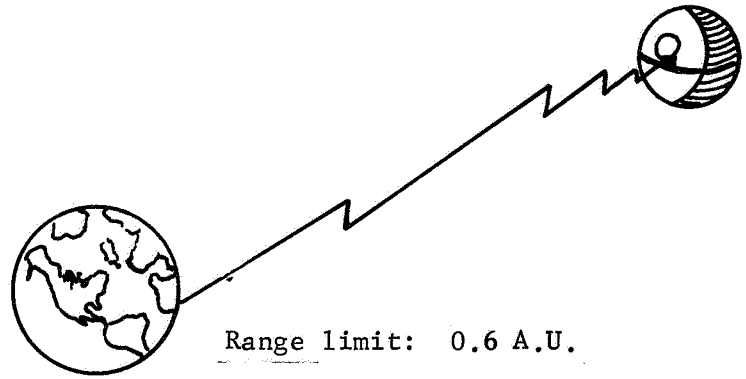
Sample science and engineering on a schedule basis and store until data can be transmitted.

Data rate of 240 bps.

FSK.

20 W transmitter.

Figure 22.- Telecommunication Concept for Orbital Operation



Range limit: 0.6 A.U.

Transmit at least two cycles of real time and stored data (2 x 20 000 bits) every 8 hr to DSN.

Accept commands from Earth.

Sample science and engineering on a schedule basis and store until data can be transmitted.

Data rate of 30 bps.

S-band.

20 W transmitter.

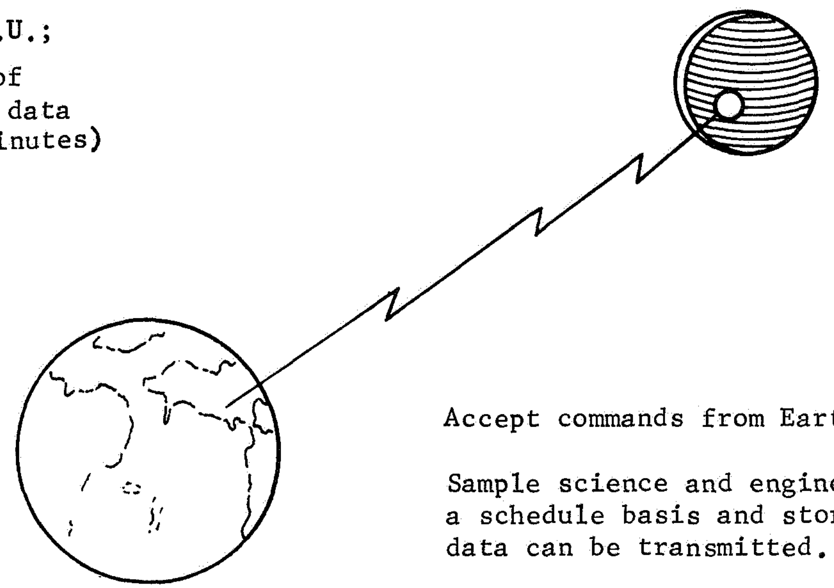
Fig. 23.- Telecommunication Concept for Direct Link to Earth Operation, 1972 Flyby

Direct link to Earth for separation, entry, and deployment.

Direct link to Earth for flotation:

Range limit: 0.31 A.U.;

Transmit two cycles of real time and stored data (144 000 bits, 20 minutes) every 8 hr to DSN.



Accept commands from Earth.

Sample science and engineering on a schedule basis and store until data can be transmitted.

Entry and deploy data rate of 120 bps.

Flotation mission data rate of 120 bps.

S-band.

20 W transmitter.

Figure 24.- Telecommunication Concept for Venus/Mercury Mission

The subsonic probe and two 5-lb drop sondes are shown in figure 25. The science complement of experiments for the subsonic probe is listed in table 6.

The balloon assembly for the 400-lb station is an 18-ft diameter, superpressure concept as shown in figure 26. The diffuser tube assembly reduces the gas kinetic energy during inflation and carries the load of the gondola when the balloon is extracted from its canister during deployment while the balloon is supported from the parachute. The actual material used for the mission may not be Mylar; however, at this date Mylar is the leading candidate. One of the major developments required for the BVS is a balloon material investigation (test) program.

The inflation subsystem is a simple, blowdown (i.e., unregulated), type with four manifolded tanks transporting ambient hydrogen gas at 4500 psia. The subsystem is shown in figure 27 with its ordnance operated valving and tube cutter. The tube cutter is required for staging the inflation module from the gondola immediately after gas tank depletion. The tankage transports approximately 10% excess gas, which provides the necessary buoyancy for minimizing station altitude undershoot. The excess gas is valved off as the cold gas is warmed by the atmosphere. The correct balloon superpressure is maintained by a pressure switch and solenoid valve. The four tanks are of a glass filament wrapped, aluminum liner design.

The capsule propulsion requirements for the missions are summarized in table 7. Mariner '69 monopropellant engine and lunar orbiter bipropellant engine, both qualified, can be used for these missions.

Figure 28 presents a detailed inboard profile of the BVS/entry vehicle for the orbital and flyby missions. The heatshield is approximately 0.35-in. thick, lightweight, carbon filled, elastomeric, ESA5500(M). The aeroshell structure is a ring stiffened shell design of aluminum.

The Venus/Mercury mission BVS/entry vehicle is 7.0 ft in diameter as shown in figure 29. This mission has an atmospheric entry velocity of 43 550 fps requiring a heat shield of carbon phenolic varying in thickness from 0.65 to 0.75 in. thick. This mission also required an active attitude control system as opposed to the spin control used for the flyby and orbital missions. The attitude control allows the capsule to be properly oriented for entry following the impulse maneuver of the capsule.

For further detail, the reader is referred to volume III of this report.

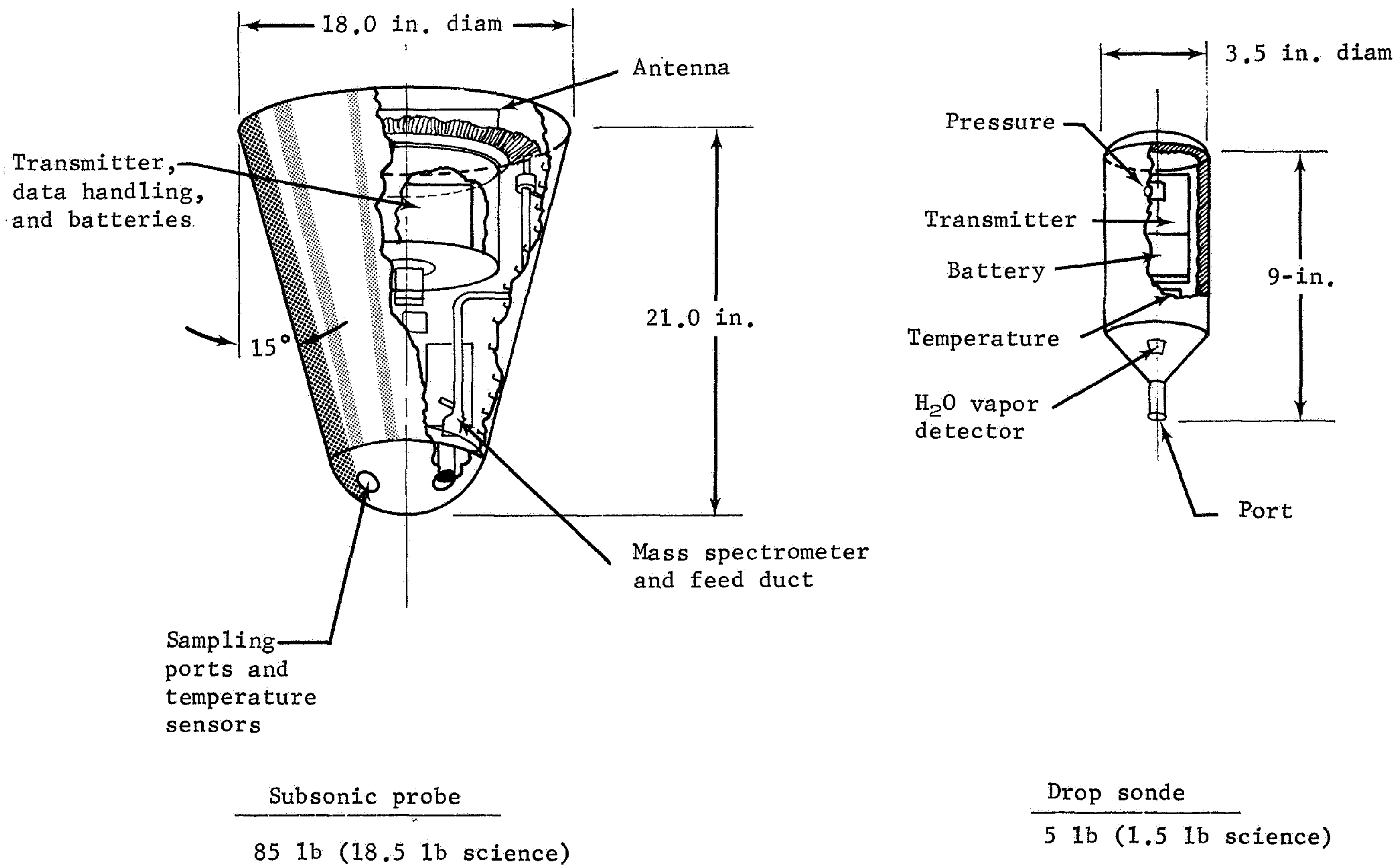
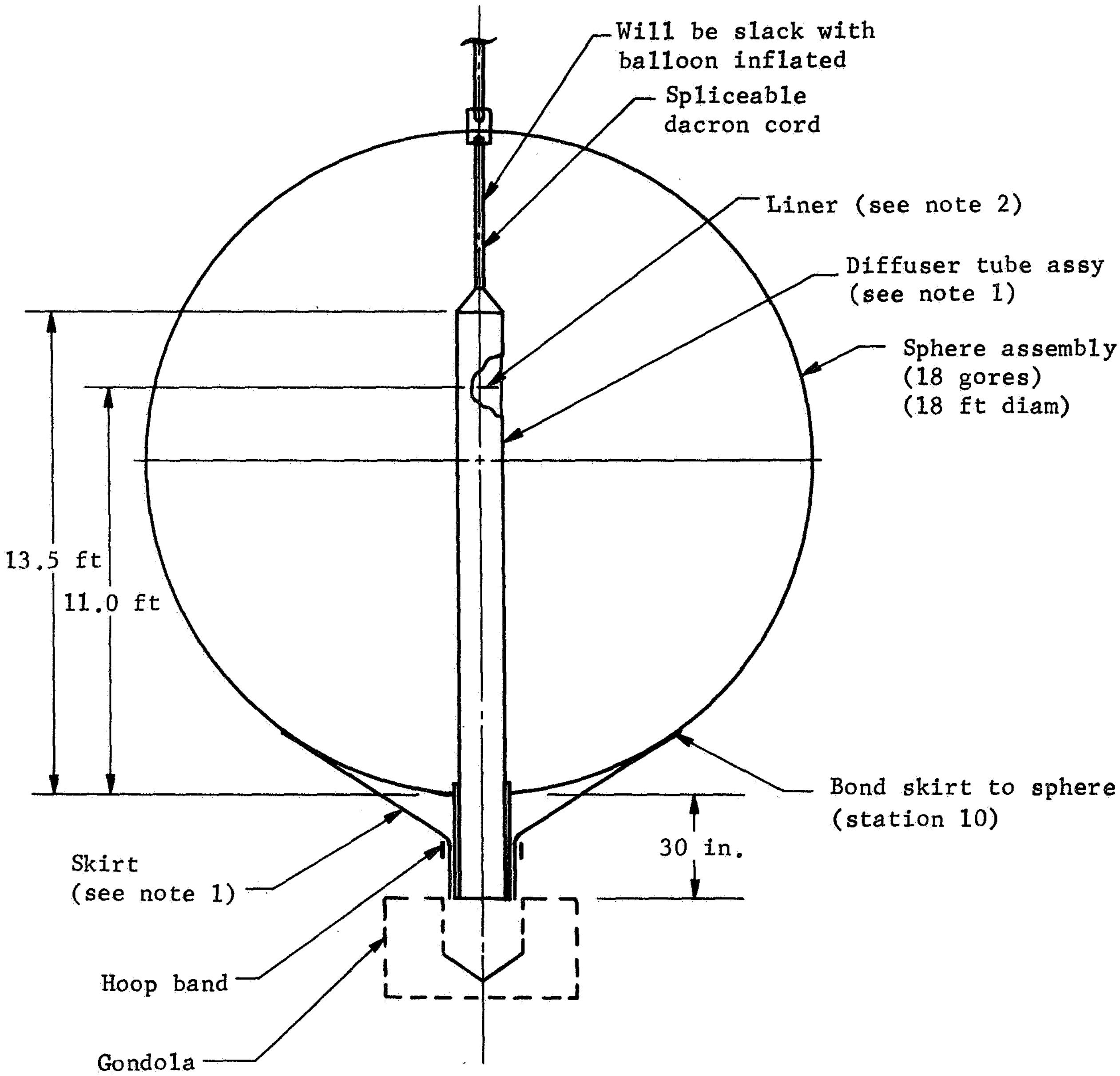


Figure 25.- Probes with BVS Mission

TABLE 6.- ILLUSTRATIVE SUBSONIC PROBE EXPERIMENT COMPLEMENT

Experiment	Weight, lb
Pressure sensors	1.7
Temperature sensors	1.3
Density sensor (β-source and detector)	.9
Light backscatter	3.0
Visual photometers	2.0
IR photometers	1.6
Total insolation radiometer	1.0
Mass spectrometer	7.0
Total weight	18.5



Note: 1. Cloth, dacron, ripstop, natural, J.P. Stevens & Co. S/N-2468/1, 1.25 oz/sq yd.
2. Mylar 3/4 mil x 1/2 mil adhesive x 3/4 mil Trilam.

[a] Raven Industries, Inc., design drawing no. 07532.

Figure 26.- Balloon Assembly[a]

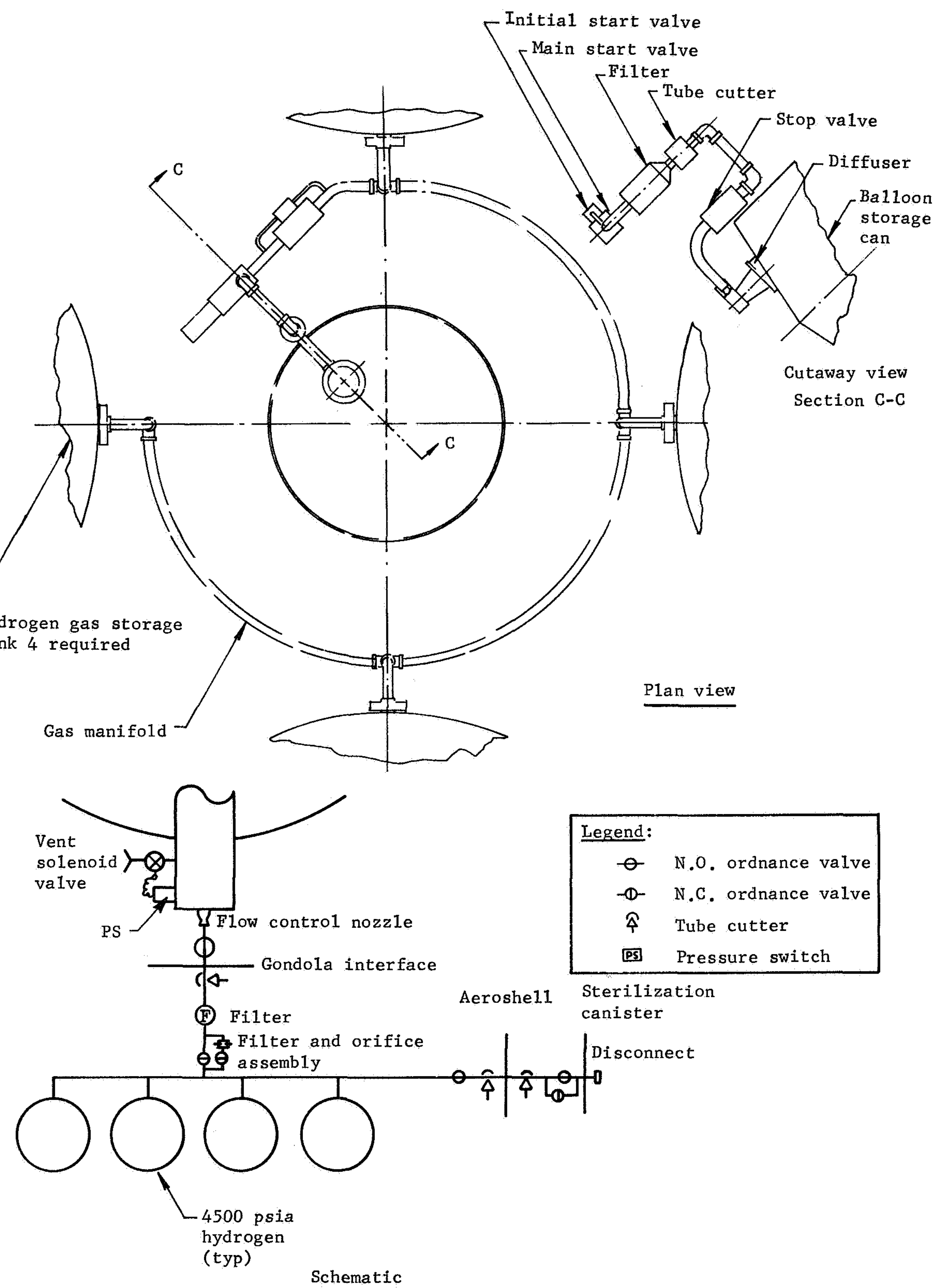
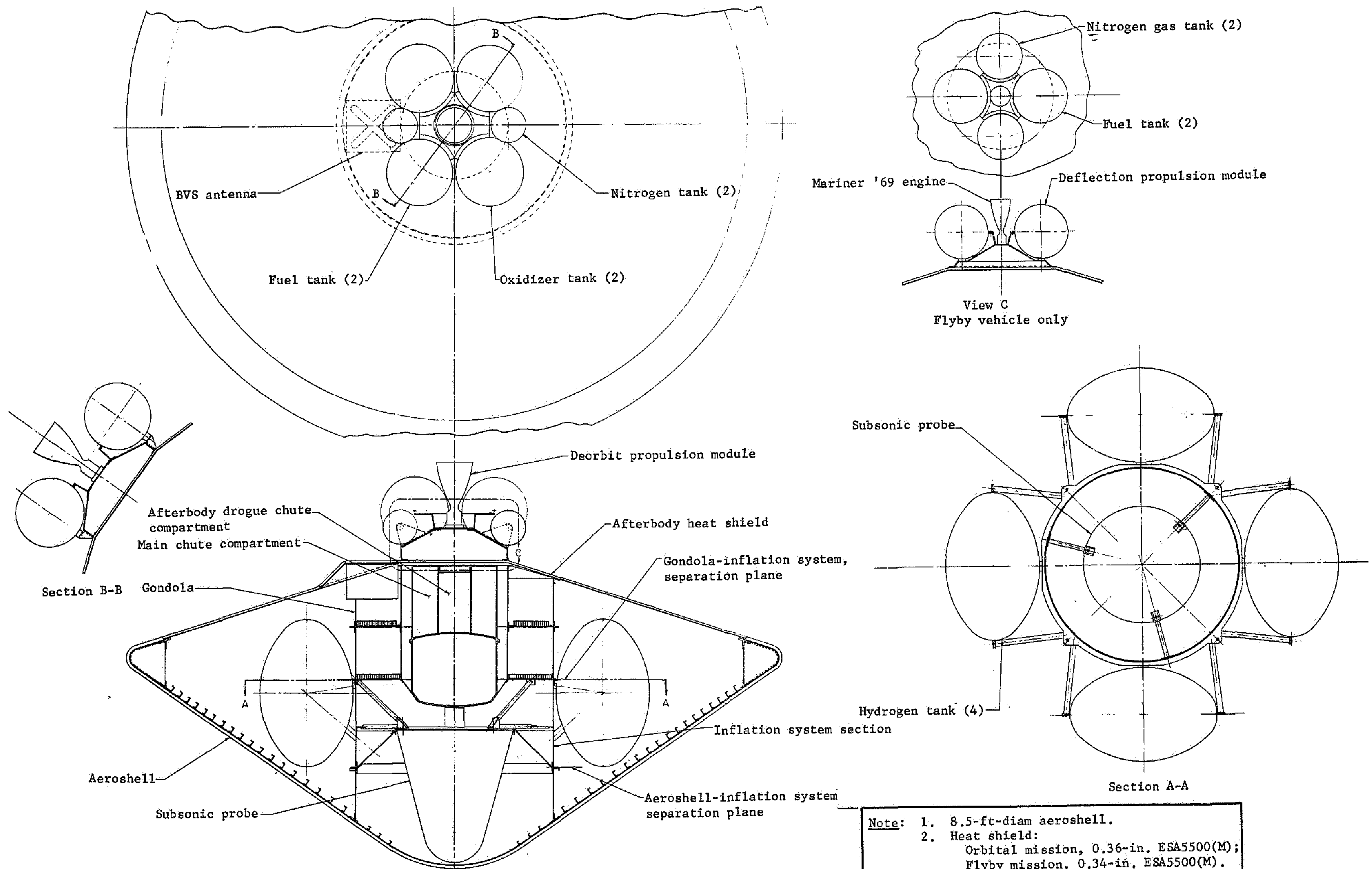


Figure 27.- Balloon Inflation Subsystem

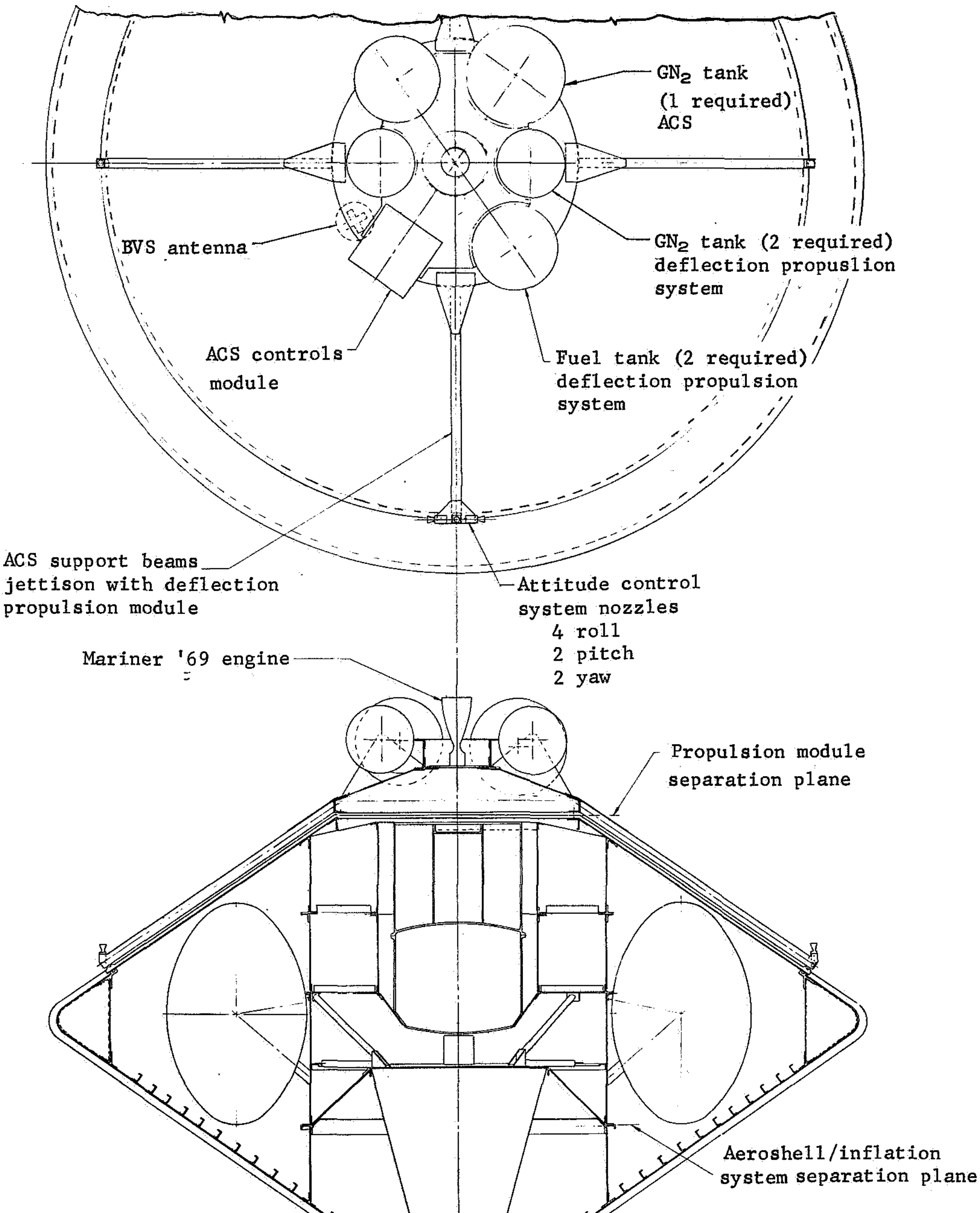
TABLE 7.- CAPSULE PROPULSION

Requirement	1973 orbit mission	1972 flyby mission	1973 Venus/Mercury mission
Velocity increment, m/sec	250 maximum	50 ± 0.5	$93 \pm .5$
Capsule weight, lb	840	960	1045
Function	Deorbit	Deflect-in S/C plane	Deflect-out of S/C plane
Fixed/variable impulse	Variable, 100 to 250 m/sec	Fixed	Fixed
Use developed engine, Thrust, lb_f	Lunar orbiter, 100	Mariner '69, 50	Mariner '69, 50
Sterilizable	Yes	Yes	Yes
Spin during thrusting, rad/sec	2.2	2.2	None
Thrust misalignment	0.5° along thrust axes	0.5° along thrust axes	0.5° along thrust axes
System weight, lb	131	49	80



Note: 1. 8.5-ft-diam aeroshell.
2. Heat shield:
Orbital mission, 0.36-in. ESA5500(M);
Flyby mission, 0.34-in. ESA5500(M).
3. Afterbody, 0.24-in. ESA5500(M).

Figure 28.- BVS Entry Vehicle Configuration (Orbital and Flyby Missions)



Note:	1. 7.0-ft-diam aeroshell.
	2. Heat shield:
	0.75-in. carbon phenolic at stagnation point;
	0.65-in. carbon phenolic at cone edge.

Figure 29.- BVS Entry Vehicle Configuration (Venus/Mercury Mission)

ACCOMPLISHMENT OF SCIENCE OBJECTIVES

The Space Science Board (SSB) of the National Academy of Sciences, National Research Council has published a report (reference 2) in which earlier recommendations for planetary exploration are reappraised and new priorities and objectives set forth for the 1968-1975 time period.

The report sets forth the following specific objectives as being of highest priority for Venus:

1) *In situ* exploration of the lower atmosphere and cloud layer with emphasis on the physical and dynamic properties of the cloud cover, thermal and dynamic characteristics of the atmosphere at a number of locations, the radiation environment, and the chemical composition of the atmosphere;

2) An exploratory mapping from orbit of portions of the surface -- 1-km resolution for radar imaging, 100-km resolution for thermal emission mapping;

3) Determination of variations in the gravitational field from orbit perturbations;

4) Precise definition of the effects of solar wind sweeping on the high atmosphere, synoptic study of the near-Venus environment, and investigation of the formation of the ionosphere.

This ordering is in general agreement with the assignment of priorities that (predating ref. 1) were made in this study:

1) Group I, highest priority,

   a) Determination of the surface radius by direct measurement of surface temperature and pressure,

   b) Thermal mapping of large portions of surface, particularly near poles, subsolar point,

   c) Cloud composition, horizontal and vertical structure,

   d) General atmospheric circulation pattern, wind velocities,

   e) Identify other major atmospheric constituents,

   f) Intensity of visible and infrared radiation at surface and variation with altitude;

2) Group II, medium priority,

   a) Detailed atmospheric and cloud composition, trace constituents, physical properties of cloud particles, analysis for organic or life-related compounds, variations with altitude,

   b) Local winds, velocities, turbulence, and shears,

   c) Incoming and outgoing radiation fluxes (uv to IR) as functions of wavelength and zenith angle from above clouds to surface,

   d) Refinement of mean radius, mass, rotation rate, and direction,

   e) Remote investigation of general surface properties, topography, gross surface composition, density, etc.,

   f) General ionospheric structure (as it affects communication);

3) Group III, low priority,

   a) General body characteristics, differentiation into core, mantle, and crust, moments of inertia, seismic, tectonic, and/or volcanic activity,

   b) Physical and chemical composition of surface, topography, minerology, and surface structure,

   c) Isotopic abundances and distributions of radiogenic elements in atmosphere, surface, and subsurface materials,

   d) Magnetic field (if any), strength, orientation, multipolarity, relation to surface and/or body characteristics, interaction with solar wind, and interplanetary fields,

   e) Intensive search for life in atmosphere and clouds or in cool regions on surface.

For the Mercury/Venus mission, the Venus objectives retain their relative priorities, but the primary objective is to get a "first look" at Mercury, i.e., visual and thermal imaging. Interplanetary measurements are also given higher priority because of the close approach to the sun. The objectives (from JPL TM 33-332) selected for the Mercury encounter are listed below in approximate order of priority:

1) Provide TV pictures of planetary surface to a resolution of about 150 m/TV line. Photograph entire visible disc of planet to obtain diameter, and, from this information, in conjunction with mass from trajectory, obtain an order of magnitude density determination;

2) Obtain a three-dimensional thermal map of planet surface/subsurface. From these data, one would hope to interpret the thermal and electrical properties of the planetary surface in terms of geological processes, structure, etc. Also, at shorter wavelengths, one would hope to get information on temperature, pressure, and density of the planetary atmosphere;

3) Determine abundance and distribution of upper atmospheric constituents, obtained from uv spectra of Mercury;

4) Measure changes at several frequencies of spacecraft radio signal resulting from occultation of spacecraft by Venus and perhaps Mercury and the sun. Give atmospheric scale heights for Venus and Mercury and planetary diameter for Mercury;

5) Measure change in range signal between space probe and Earth resulting from relativistic effect when range signal passes near the sun;

6) Investigate planetary and interplanetary magnetic fields, their relationship, characteristics, magnitude, direction, and orientation;

7) Make detailed energy and flux measurement, similar to OGO-E plasma experiment;

8) Determine mass of Mercury.

The spacecraft experiment complement defined by these objectives must be used to accomplish Venus objectives as well. In the comparisons discussed below, only Venus objectives are considered.

Because the objectives are equivalent, the BVS experiment complements selected early in the study remain valid. However, because the SSB objectives are stated differently and will undoubtedly gain wide acceptance, the mission comparisons are more useful if discussed in terms of the objectives as stated by the SSB. Accordingly, the SSB objectives are summarized in table 8;

TABLE 8.- SCIENCE OBJECTIVES

Objectives	Requirements
Planetary atmospheres	
T, P, ρ profiles at several locations	Near poles, subsolar, antisolar, equatorial terminators; from above clouds to surface.
Radiation fluxes (visible, IR)	From above clouds to surface at several points between subsolar and terminator; near antisolar point, poles.
Physical and chemical composition of clouds	Major constituents, particle concentrations, size distributions, refractive indices; horizontal and vertical variations especially near subsolar, terminator, poles, antisolar.
Horizontal and vertical cloud structure, dynamics	Layering, breaks, structural differences near subsolar, terminators, antisolar.
Winds, general circulation, turbulence, shears	Circulation near cloud tops, below, near surface; winds, etc., near subsolar poles terminators antisolar versus altitude, time variations.
Detailed atmospheric composition	Traces, condensibles, organics, isotopic abundances of noble gases. Time variations, light side to dark side variations.
Upper atmosphere composition	Ionized and neutral components, variations about planet and vertically.
Exospheric temperature	Horizontal and vertical variations.
Ionospheric electron densities	Horizontal and vertical variations.
Planetary surfaces	
Exploratory radar mapping, topography	~1 km resolution; high latitudes or poles.
Thermal emission mapping	~100 km resolution; high latitudes or poles, subsolar to pole, subsolar to antisolar.
Physical and chemical surface composition electrical properties	General surface characteristics, (rock, sand, dust, layering, etc.,); dielectric constant reflectivity; chemical analysis from short term lander.
High resolution imaging of select locations	Visual (or microwave) imaging of radar "features" from descending probe.
Planetary dynamics and interiors	
Gravitational field mapping	Satellite orbit perturbations, high and low inclination. Moments of inertia, shape, density distribution.
Activity (seismic, tectonic, volcanic)	Seismic: lander with seismograph Volcanic: surface temperature mapping, detection of gaseous emissions in atmosphere.
Heat flow from interior	Observations of radiation balance over planet.
Particles, fields, and solar wind	
Synoptic study of near-Venus environment	Orbiters at different inclinations, UV fluxes in upper atmosphere, neutral and ion identity and concentrations, airglow observations.
Interaction of solar wind with upper atmosphere	
Formation of ionosphere	
Exobiology	
Search for temperate surface environment near poles	Direct measurement of surface conditions at poles.
Direct search for life in atmosphere and clouds	Collection and analysis of aerosols, requires ~50 to 100 hr.

objectives not explicitly stated in the SSB report are identified by asterisks. The second column in table 11 lists the requirements and desiderata for optimum accomplishment of these objectives. As can be seen, there are several requirements common to many of the objectives:

1) Most measurements are desired at several widely separated locations with particular emphasis on the poles and the subsolar and antisolar points;

2) Variations with altitude from above the cloud tops to the surface at these same locations are required. An altitude reference is also desired;

3) Time variations as well as spatial variations are required;

4) Several of the objectives required durations of several tens of hours for successful accomplishment.

ACCOMPLISHMENT OF OBJECTIVES WITH BVS MISSIONS

An advantage of multiple probes is that they can be targeted to precisely the locations desired while only the initial location of the BVS is independent of the wind pattern. (However, if the poles are much colder than the equatorial regions, it is likely that the BVS will be driven toward them -- or toward the coolest spot on the planet wherever it may be.)

The BVS concept is compared in table 9 to the multiple or single probe concept on the basis of potential for accomplishing the scientific objectives listed. The BVS configuration is assumed to consist of an entry vehicle, a subsonic probe to the surface, and a BVS with several small sondes. Thus, it is essentially a multiple probe mission plus a long lived BVS mission.

In table 9, plus (+) indicates that the objective can be (potentially) accomplished to an acceptable degree while plus-plus (++) indicates complete or nearly complete accomplishment; a minus (-) indicates inability to accomplish the objective listed or only token accomplishment. All cases in which the probes are given a double plus rating are due to the ability to target a multiplicity of probes at the locations desired.

From the veiwpoint of accomplishing science objectives, the BVS missions differ primarily in entry locations and predicted drift of the BVS in the atmosphere. In this regard, the orbiter mission is most attractive in permitting the BVS to approach the polar area.

TABLE 9. - COMPARISON OF BVS AND PROBE CONCEPTS

Scientific objective	Entry probe(s)	BVS with sondes
<u>Planetary atmospheres, lower</u>		
Temperature and pressure profiles to surface near poles, subsolar, and antisolar points	+(+Mult)	+
Radiation fluxes (visible, IR) cloud tops to surface at several points	+(+Mult)	+
Chemical composition of clouds	+	++
Horizontal and vertical cloud structure, dynamics	+	++
Winds, general circulation at several altitudes, turbulence, shears	-	++
Detailed atmospheric composition; traces, condensibles, organics, isotopic abundances	-	++
<u>Upper atmosphere and ionosphere</u>		
Composition and altitude variations	+	+
Exospheric temperature and variations	+	+
Ionospheric electron densities and variations	+	+
<u>Planetary surfaces</u>		
Radar imaging with 1 km resolution; particularly at high latitudes	-	+
Thermal emission plots with ~100 km resolution; particularly poles	-	+
Physical and chemical composition of surface, electrical properties	+(+Mult)	++
Visual imaging of select locations at high resolution	++(VIP)[a]	+
<u>Planetary dynamics and interiors</u>		
Satellite orbit perturbations; shape, moments of inertia, density distribution		
Activity (seismic, tectonic, volcanic)	-	+
Heat flow from interior	+	++
Differentiation (core, mantle, crust)	-	-
<u>Particles, fields, and interactions with solar wind</u>		
Synoptic study of near-Venus environment		
Formation of ionosphere		
<u>Exobiology</u>		
Search for temperate surface environment near poles	++	+
Direct search for life in atmosphere and clouds	-	++

[a]Venus Imaging Probe

The baseline experiment complements for the BVS were designed to be nearly identical for the mission modes of this study. As summarized in table 10, they have been selected to accomplish many of the objectives. The significant differences between the mission modes are not in the payloads, but rather with respect to how well or to what extent the objectives can be accomplished subject to the constraints of each mission; e.g., entry and deployment locations, mission duration, wind drift trajectories, coverage, etc. In the discussion below, the three baseline BVS mission modes are compared with respect to these differences.

TABLE 10.- BVS EXPERIMENT COMPLEMENT COMPARISON

Experiment/instrument	Mission			Objectives
	1972 flyby	1973 orbiter	1973 Venus/ Mercury	
Pressure, temperature sensors (density known from BVS mass)	X	X	X	Monitor P, T at float altitude, correlate with other measurements.
Triaxial accelerometer	X	X	X	Monitor wind turbulence
H_2O vapor sensor	X	X	X	Water vapor content and variations, correlation with other measurements.
Light backscatter	X	X	X	Presence of aerosol, particle concentration and size distributions.
Solar aspect angle sensors	X	X		Solar zenith angle, correlation with other data for BVS position, cloud cover, heat budget.
Visual photometer	X	X		Atmospheric transmission at several wavelengths, cloud cover.
Mass spectrometer	X	X	X	Detailed atmospheric and cloud composition.
Gas chromatograph	X	X	X	Detailed atmospheric and cloud composition.
Aerosol collector	X	X	X	Collect and distribute samples for MS, GC, and life experiment.
Biolab	X	X	X	Search for life in clouds and atmosphere.
Radar altimeter	X	X	X	Altitude reference, BVS velocity over surface, surface slopes, reflectivity.
Drop sondes (2)	X	X	X	P, T profiles to surface at several points plus H_2O or radiation fluxes.

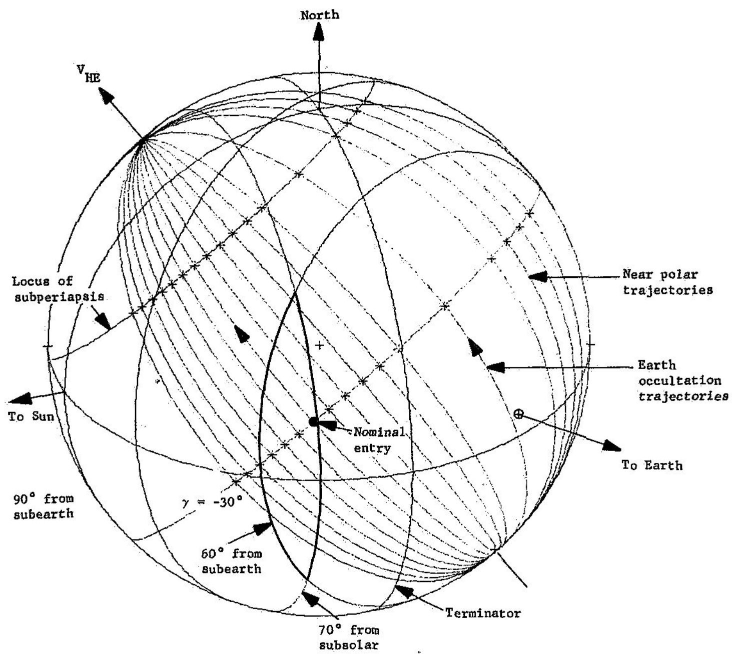
MISSION COMPARISONS

The most significant comparisons are with respect to the encounter geometry and entry locations. Figures 30 thru 33 depict the encounter geometry for each of the three missions. The scientific objectives and desiderata dictate the following constraints on the selection of the trajectories and entry locations:

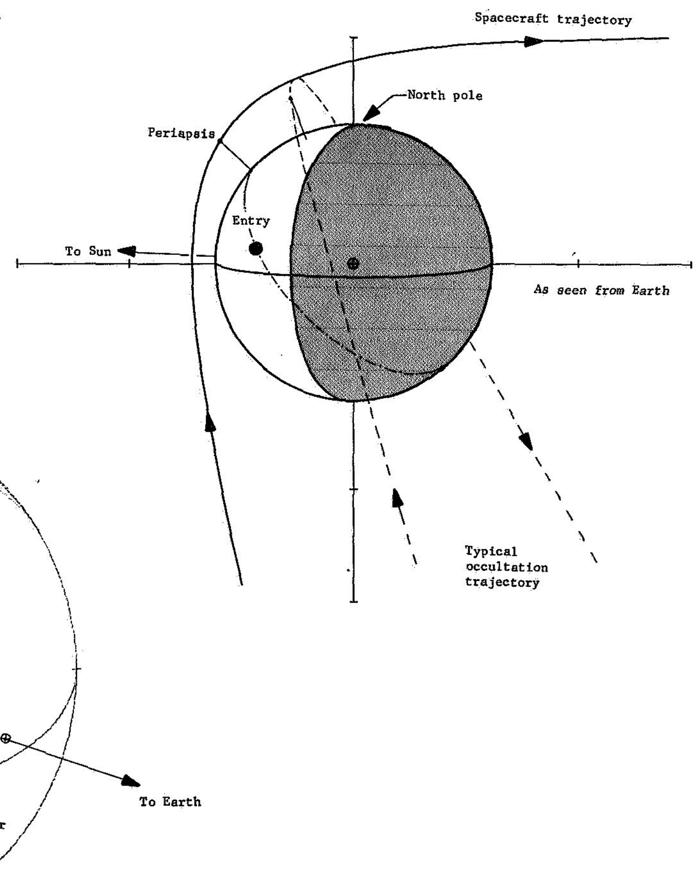
1) The requirement to measure light levels below and within the clouds restricts the entry locations to within 70° of the subsolar point and preferably within 10° of subsolar;
2) Near normal viewing of a polar region from the S/C is required for thermal mapping of that region;
3) Viewing of the illuminated hemisphere for visual imaging from the S/C is also required. This conflicts somewhat with the previous requirement for polar viewing, but a compromise is possible;
4) Viewing of the hemisphere about the subearth point is required for bistatic radar mapping;
5) Entry should be as near subsolar as possible and such that the winds will drive the BVS up to a high latitude or pole;
6) Earth occultation of the S/C, preferably over a polar region, is desirable;
7) A short period orbit is desirable for determination of the wind patterns from BVS tracking.

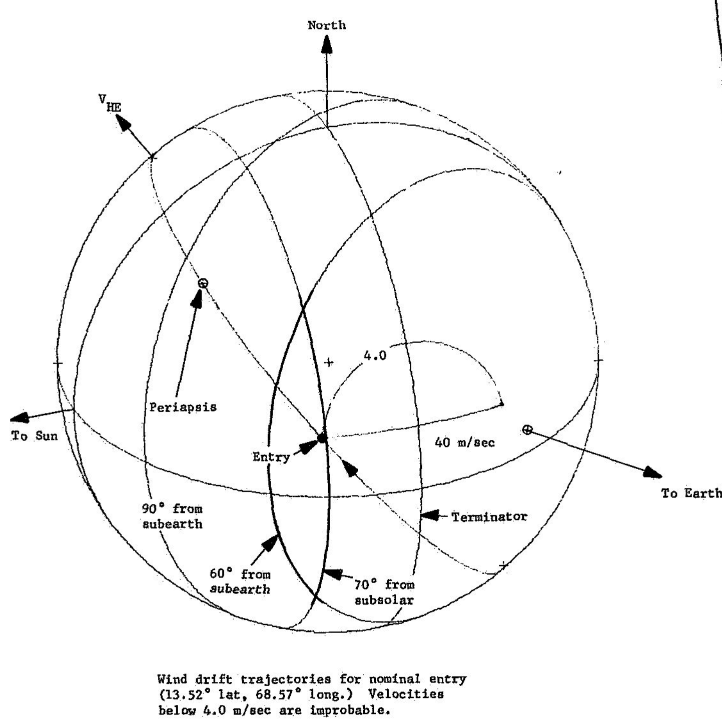
Other mission constraints effecting the trajectory and entry location selections include the following:

1) The desire to use solar cells as a power supply strengthens the requirement that entry be within 70° from subsolar;
2) Uncertainty in the BVS temperature change across the terminator makes it desirable to choose an entry point that maximizes the light side BVS mission;
3) Entry and deployment within view of earth (within 60° of subearth) is desirable for the 1973 orbiter mission and mandatory for the 1972 flyby and 1973 Venus/Mercury swingby missions. For the latter missions, the BVS should also remain within 60° of subearth for at least 50 hr;



Encounter geometry for first day of launch window. Desired entry points are within 60° of subearth and 70° of subsolar.





Wind drift trajectories for nominal entry (13.52° lat, 68.57° long.) Velocities below 4.0 m/sec are improbable.

Figure 30.- 1972 Flyby Mission

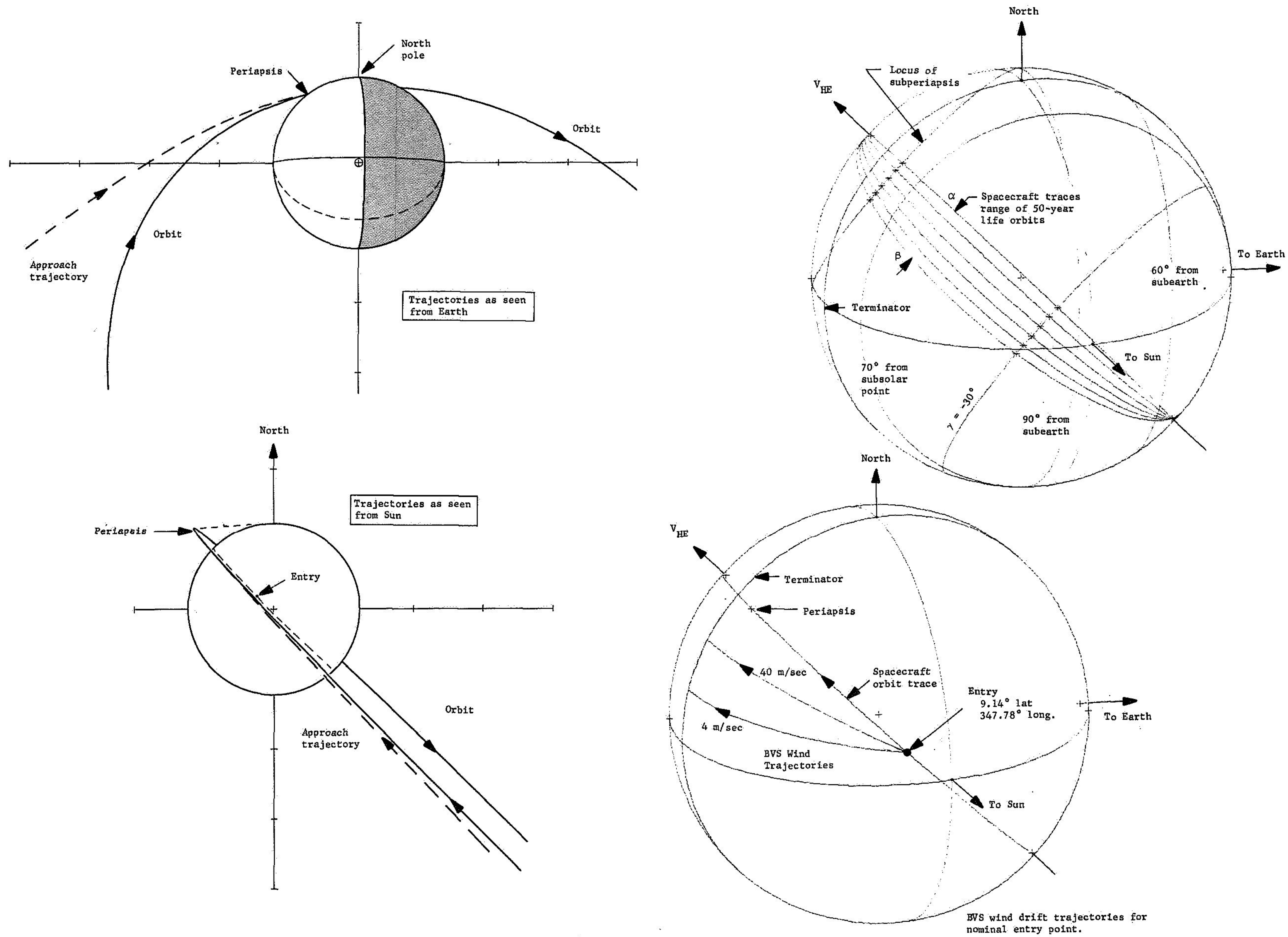


Figure 31.- 1973 Type II Orbiter Mission Approach Trajectory and Orbit

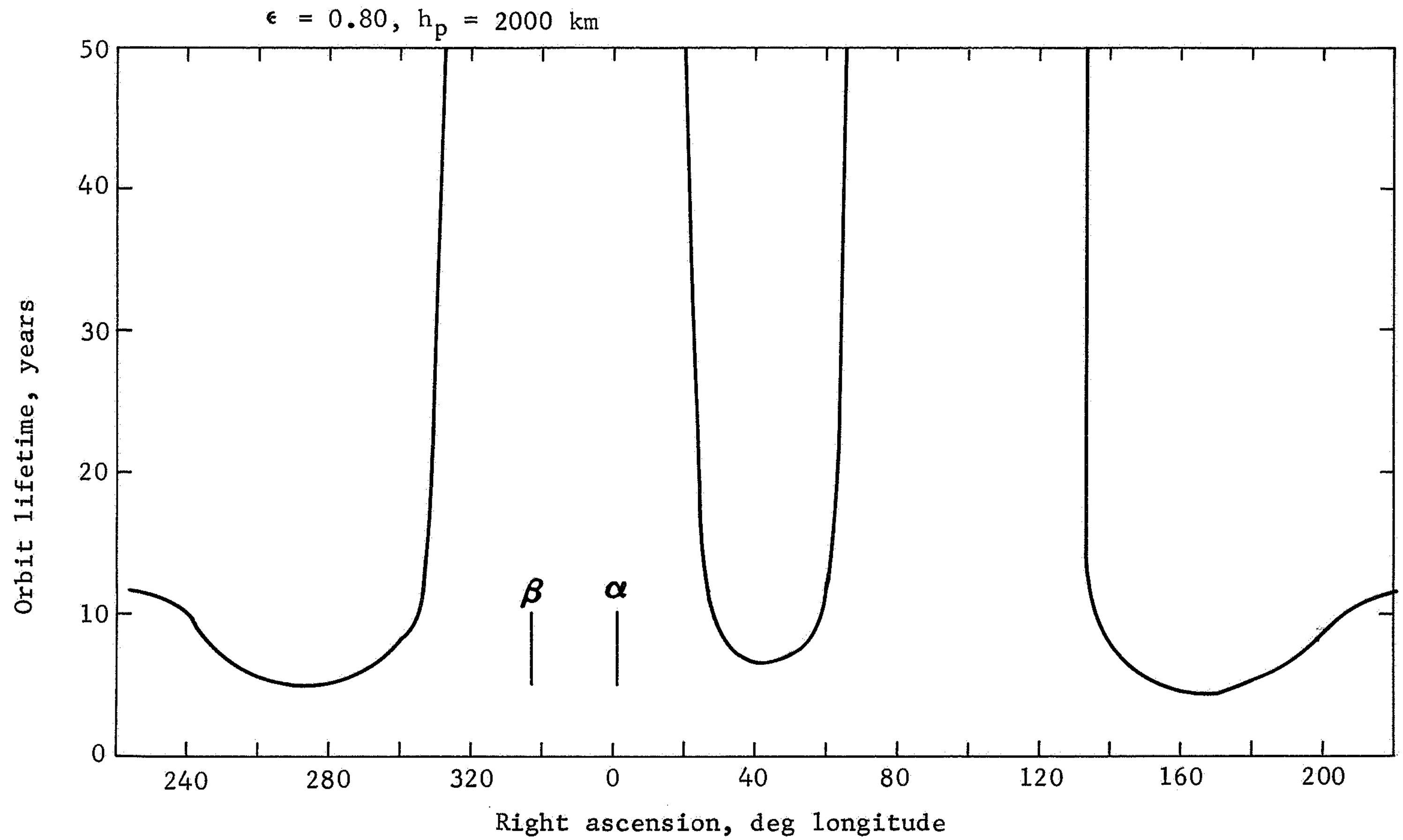


Figure 32.- Orbit Lifetimes

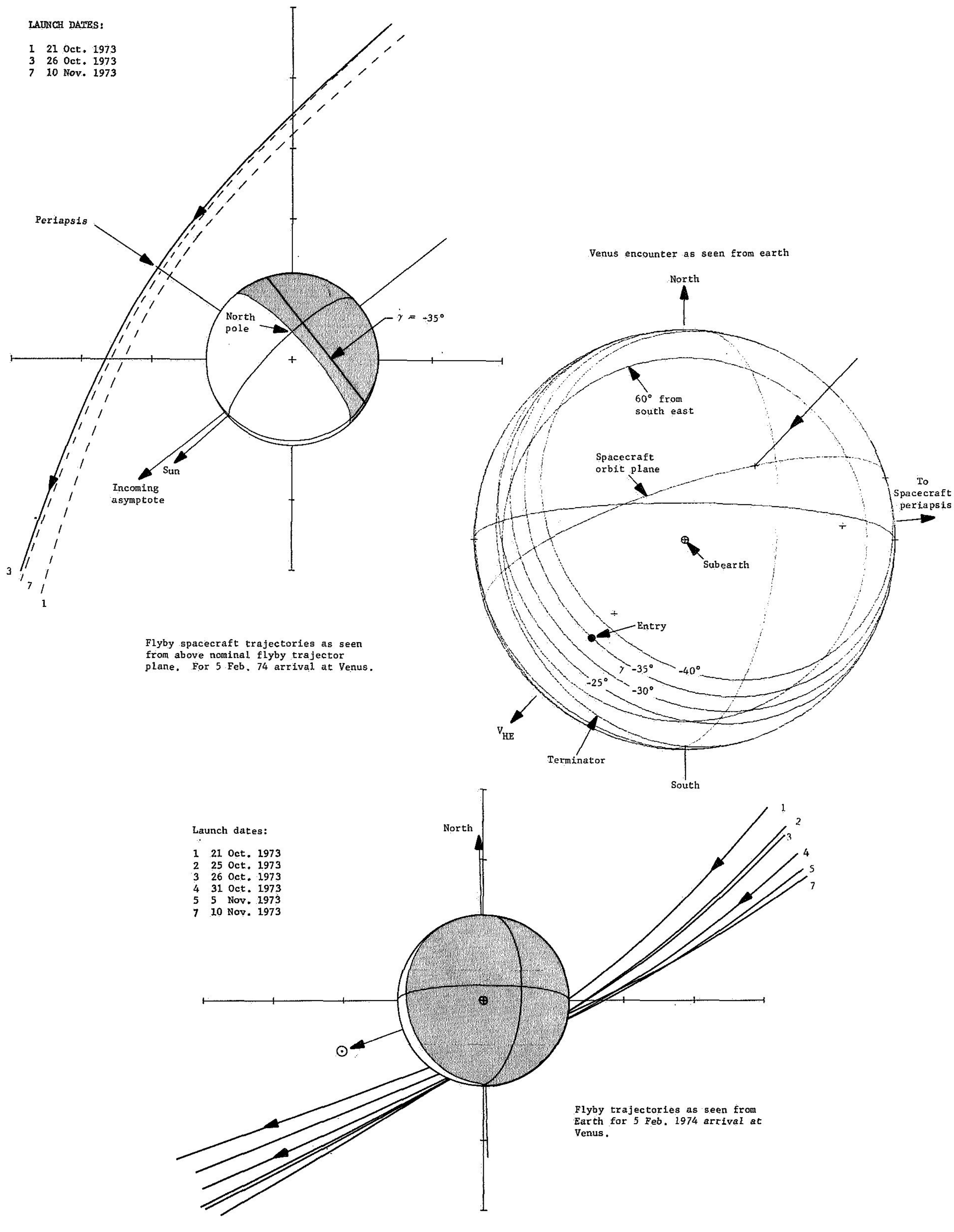


Figure 33.- 1973 Venus Mercury Swingby Trajectories

4) The 50-year orbiter lifetime requirement restricts the choice of orbits for the 1973 mission. Propulsion weight limitations also dictate the choice of highly eccentric orbits (~0.8);

5) Entry flightpath angles are generally restricted to the range $\pm 5°$ about $-30°$. However, a range of $\pm 10°$ or $\pm 15°$ is not out of the question.

The baseline trajectories and entry points which were selected after consideration of these general constraints are summarized in table 11 for each opportunity. Other selections are possible and some of these will be discussed below.

1973 Venus Orbiter Mission

The baseline approach trajectory and orbit are shown in figure 31. The choice of this trajectory was dictated mainly by the requirement for a 50-year orbit life (fig. 32). The range of orbits that satisfy this constraint and which allow entry near the subsolar point are depicted in figure 32. As can be seen, none of the entry points are within view of Earth. Aside from this, the entry points are ideal for the BVS mission; they are close to the subsolar point and the expected winds will carry the BVS toward the terminator.

A more optimum BVS mission is obtained at some expense to the orbiter mission because close polar viewing is at tangential angles and the Earth occultation is not an optimum. Better viewing of the polar region can be obtained by raising periapsis; this would also increase the BVS-to-orbiter communication time. Although the Earth occultation is not the best for probing the neutral atmosphere below the clouds, the signals will probe the plasma pause and ionospheric transition region very effectively. In addition, signal loss will probably not occur, and continuous closed loop data will be obtained from entry to exit.

1972 Venus Flyby Mission

The encounter geometry and baseline trajectory for this mission are shown in figure 30. The choice of entry point is dictated by the requirements for a direct Earth link and a light side entry. These define an entry area as shown. The wind drift trajectories for an entry closest to Earth cause the BVS to drift toward the terminator and the subearth point.

TABLE 11. - TRAJECTORIES AND ENTRY POINTS

Trajectory (first day launch)	1972 flyby with BVS and probe	1973 orbiter with BVS and probe	1973 Venus/Mercury swingby with BVS and probe
Type	I	II	I
V_{HE}, km/sec	5.00	4.32	8.03
r_p, km	8050	8050	11 680
Inclination[a], deg	129.46	134.80	-18.6
Right ascension[a], deg	80.00	357.00	316.75
Argument of periapsis[a], deg	60.64	77.95	-33.96
ϵ (orbit)	---	0.8	---
Entry angle, deg	-30	-30	-35
Entry latitude[a], deg	13.5	9.1	[b]~-41
Entry longitude[a], deg	68.5	347.7	[b]~120

[a]Reference system is Venus orbital plane with zero longitude being the sub-solar point.

[b]Entry is on far side from spacecraft trajectory.

Neither Earth occultation nor good viewing of the pole are possible. Polar and Earth occultation trajectories are also shown. The entry points for these, while in view of Earth, are on the dark side. An out-of-plane entry is required for these trajectories if the BVS is to be deployed on the light side in view of Earth. This is to be desired because the flyby trajectory will give an optimum Earth occultation over the north pole and allow scanning of the polar regions.

1973 Venus/Mercury Swingby Mission

The choice of trajectories for this mission is restricted to a very narrow range as shown in figure 33. As can be seen, Earth occultation is obtained in all cases but polar viewing is near tangential.

The encounter geometry for an October 26, 1973 launch date and a February 5, 1974 arrival places entry points within view of Earth on the dark side, while those beneath the spacecraft trajectory are out of view of Earth. Thus, an out-of-plane entry maneuver is required. The entry point closest to earth has been selected. From this point, the BVS will drift toward the equator and the subearth point. The BVS mission is entirely on the dark side.

The 1973 BVS/orbiter mission accomplishes the high-priority objectives to a much greater degree than the other two missions. The baseline 1973 BVS/orbiter mission falls short of being ideal for the high-priority objectives in that direct measurements of surface temperature at the poles (with a drop sonde) are not possible according to the wind drift model. If the entry point could be shifted to a point about 25°N lat and 6 or 7° longitude, the wind patterns predict that the BVS would drift to higher latitudes and perhaps directly over a pole. However, this requires an orbit with a lifetime of less than 50 years or an out-of-plane entry maneuver. The latter is probably required.

An orbiter mission (with relay link) is the only one that offers the possibility of reaching a pole because flyby missions imply a direct link to Earth and the poles are always on the Earth view horizon. While not impossible, the use of the flyby spacecraft as a relay link between Earth and a probe to a pole is extremely impractical (and short lived), especially for the 1973 Venus/Mercury flyby.

Therefore, on the basis of accomplishment of the high priority Venus objectives, the 1973 baseline orbiter/BVS mission is the best of the three. The 1973 Venus/Mercury flyby is the least satisfactory in terms of accomplishing the Venus objectives. It is not within the scope of this report to argue the relative merits of Venus vs Venus/Mercury missions, but it is clear that a Venus/Mercury mission restricts the accomplishment of Venus objectives.

OPERATIONAL COMPLEXITY

To assess the relative complexity of the three missions, the comparison was made in terms of the subsystem equipment complexity and in terms of the complexity of the sequence of operations required. Table 12 lists the differences in each subsystem required by the missions.

Three subsystems have significant differences, the deflection propulsion subsystem, the radio subsystem, and the attitude control subsystem. The orbiter mission requires a maximum velocity increment of 250 m/sec compared to 50 m/sec for the Venus flyby and 93 m/sec for the Venus/Mercury swingby. This increased impulse requirement for the orbiter resulted in the selection of the lunar orbiter, bipropellant engine as being more weight effective, although the more complex bipropellant engine is not an absolute requirement. The radio subsystem of the Venus flyby mission is the most complex of the three missions because it contains two separate rf systems. The attitude control subsystem is required only on the Venus/Mercury mission, to provide an angular change of the capsule spin axis of approximately 70° for entry.

To compare the sequence of operations, figure 34 shows functional block diagrams for the three missions. The blocks enclosed in dashed lines represent spacecraft functions. The solid lined blocks are BVS functions that are equivalent except as noted in table 12.

The orbiter mission contains three additional major functions that are required for BVS success. The orbiter must be inserted into orbit and perform a portion of its orbital science mission before the separation of the BVS capsule. In addition the orbiter must survive throughout the BVS mission to serve as a data relay station.

The Venus flyby mission requires the spacecraft relaying entry data, which requires the spacecraft life to be extended a little over two days beyond capsule separation. This includes the requirement for attitude control, electric power and sequencing, as well as relay radio equipment that was considered in the radio system equipment complexity. The Venus/Mercury mission, on the other hand, requires no spacecraft functions beyond the common launch and interplanetary cruise.

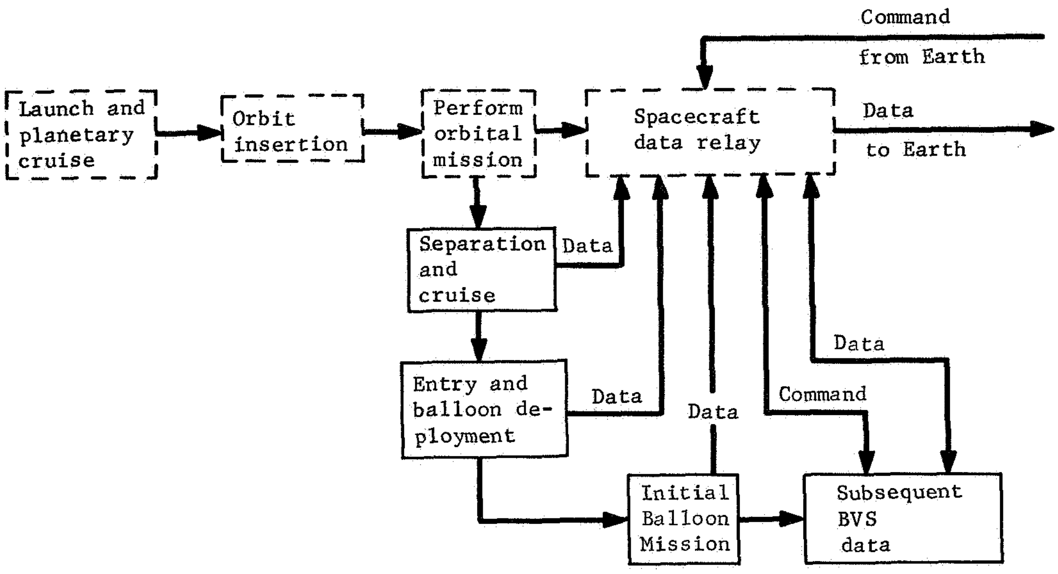
As may be seen from table 12, the orbiter mission is more complex in terms of functions that must be performed.

TABLE 12.- BVS SUBSYSTEM COMPLEXITY COMPARISON

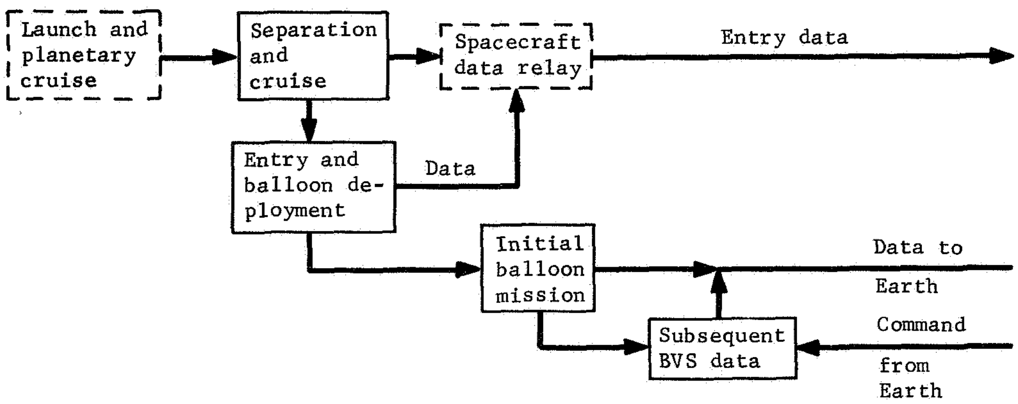
Subsystem	Orbital	Flyby	Venus/Mercury swingby
Science subsystem			
Equipment difference	Visual photometer Solar aspect angle sensors	Visual photometer Solar aspect angle sensors	No visual photometer No solar aspect angle sensors
Reason for difference	Venus/Mercury mission is darkside mission.		
Conclusion	No significant difference between missions.		
Data subsystem			
Equipment difference	Contains position determination data unit	No position data unit	No position data unit
Reason for difference	Position determination on flyby missions must be Earth-based by BVS ranging and/or doppler shift, on baseline systems.		
Conclusion	Orbiter data system 11% more complex with position determination.		
Radio subsystem			
Equipment differences	Single 20 W 390 MHz transmitter and receiver providing 240 bps Orbiter transmitter beacon, and receiver required for all data transmission	20 W 390 MHz transmitter for relay of entry data at 240 bps 20 W 2295/2115 MHz transmitter and receiver providing 30 bps on direct link to Earth Flyby transmitter and receiver required to relay entry data	20 W, 2295/2115 MHz transmitter and receiver for direct link communications at 120 bps Entry data stored for later transmission
Reason for difference	Entry and drift not in sight of Earth	Geometry prevents direct link during entry	Geometry prevents relay to spacecraft during entry and deployment
Conclusion	Although the BVS single uhf system for the orbital mission and the Venus/Mercury S-band system are simpler in so far as the radio subsystem is concerned, the former requires the successful operation of the orbiter radio system while the latter requires an expanded BVS memory system.		
Balloon subsystem			
Equipment difference	None	None	None
Conclusion	No anticipated equipment differences.		
Inflation subsystem			
Equipment difference	None	None	None
Conclusion	No anticipated equipment differences.		
Parachute subsystem			
Equipment difference	None	None	None
Conclusion	No anticipated equipment differences.		

TABLE 12. - BVS SUBSYSTEM COMPLEXITY COMPARISON - Concluded

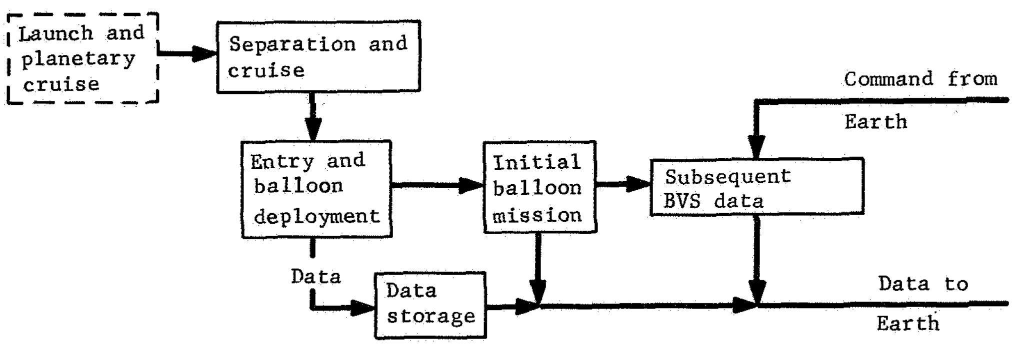
Subsystem	Orbital	Flyby	Venus/Mercury swingby
Structures and mechanisms			
Equipment differences	390 MHz antenna only	390 and 2119 MHz antennas with 390 MHz antenna jettisonable	2119 MHz antenna only
	Solar cells	No solar cells	No solar cells
Conclusion	No significant structural changes but the addition of an ordnance-operated mechanism to eject antenna for the flyby mission.		
Pyrotechnic subsystem			
Equipment difference	No antenna thruster	390 MHz antenna	No antenna thruster
Reason for difference	To eliminate gondola weight, low frequency cavity-backed antenna is jettisoned on flyby mission.		
Conclusion	Venus flyby mission has one more ordnance function.		
Power subsystem			
Equipment difference	Solar panels, undervoltage sensor, and battery charger	No solar panels, undervoltage sensor or battery charger Increased battery capacity	No solar panels, undervoltage sensor or battery charger Increased battery capacity
Reason for difference	Venus flyby and Venus/Mercury mission BVS must perform without sunlight over most of mission -- Venus/Mercury mission is all dark side.		
Conclusion	Orbiter is more complex, but the increased battery capacity of the other two missions probably negate this advantage.		
Propulsion subsystem			
Equipment difference	100-lb thrust bipropellant engine, 250 m/sec	50-lb thrust monopropellant engine, 50 m/sec	50-lb thrust monopropellant engine, 93 m/sec
Reason for difference	The larger impulse required for the orbiter mission favors the more complex; higher performance bipropellant system -- a monopropellant system would weigh about 12 lb more.		
Conclusion	Orbiter mission more complex but could be made comparable with small weight addition.		
Thermal control subsystem			
Equipment differences	Coatings	Coatings with phase change material for S-band transmitter	Coatings with phase change material for S-band transmitter
Conclusion	Although the three missions will involve different coatings and heater capacities, the systems are similar with the exception of the phase change material.		
Heat shield subsystem			
Equipment differences	Lightweight elastomer	Lightweight elastomer	Carbon phenolic
Conclusion	The Venus/Mercury mission heat shield requirements present the greater risk.		
Attitude control subsystem			
Equipment difference	Spin control	Spin control	Three axis control plus gyro reference required.
Conclusion	Venus/Mercury is the most complex.		



Orbital mission



Flyby mission



Venus-Mercury mission

Figure 34.- Mission Functional Block Diagram

COST AND SCHEDULE

BVS costs for three missions are compared in table 13. Costs are shown for a 1973 flyby mission in lieu of the 1972 flyby mission because of the impracticality of implementing the 1972 mission at this late date. Schedule spans are compared by program phase in table 14.

The program master schedule for the 1973 Venus orbital entry mission is shown in figure 35 from the issuance of a Phase C and D request for proposal (RFP) through Venus encounter and the subsequent mission activities. A competition for Phases C and D is assumed, with the contractor selected for Phase C also performing Phase D. An 8-month span for the performance of Phase C has been selected. Similar programs or proposed programs that have provided a basis for this time estimate are Mariner Mars 64, Voyager spacecraft, Applications Technology Satellite, and the Synchronous Meteorological Satellite.

Considering anticipated funding, 5 months of Phase C will occur in FY 70 and three months in FY 71, and then a 2-month period to negotiate Phase D. The result of this planning is to avoid Venus mission expenditures in FY 69 and provide for limited expenditures in FY 70.

Products of the Phase C effort include the detailed definition of the selected configuration and the breadboarding of critical systems and subsystems that provide reasonable assurance that the technical milestone schedules and resources estimates for the next phase can be met. A firm price proposal is prepared for Phase D and submitted along with the program plans (Configuration Management, Reliability, Sterilization, Quality Assurance, Program Control, etc.).

Phase D will begin in December 1970, which provides for a 35-month program to a launch on November 1, 1973. The Phase D schedule provides for a minimum of overlap of the major activities ensuring a maximum confidence level in the success of the next step.

Engineering release and fabrication of the engineering test model from nonflight hardware begins in the first year of Phase D, to provide early system evaluation and identification of major system problems. The proof test model tests will be completed before the acceptance of the first flight article assuring that the flight articles are of the same configuration as the article

TABLE 13. - BVS PROGRAM COST COMPARISON BY PHASE

Mission	Cost, FY68 dollars		
	Phase C	Phase D	Total
1973 orbital	8409×10^3	$112\ 861 \times 10^3$	$121\ 270 \times 10^3$
1973 Mercury/Venus	9744	125 540	135 284
1973 flyby	8637	118 380	127 017

TABLE 14. - SCHEDULE COMPARISON BY PHASE

Mission	Time, months		
	Phase C	Phase D	Total
1973 orbital	8	[a]37	45
1973 Mercury/Venus	8	36.5	44.5
1972 flyby	6	[b]20	26

[a]Includes 2 months for Phase D contract negotiations.

[b]1973 flyby schedule is essentially the same as other 1973 missions.

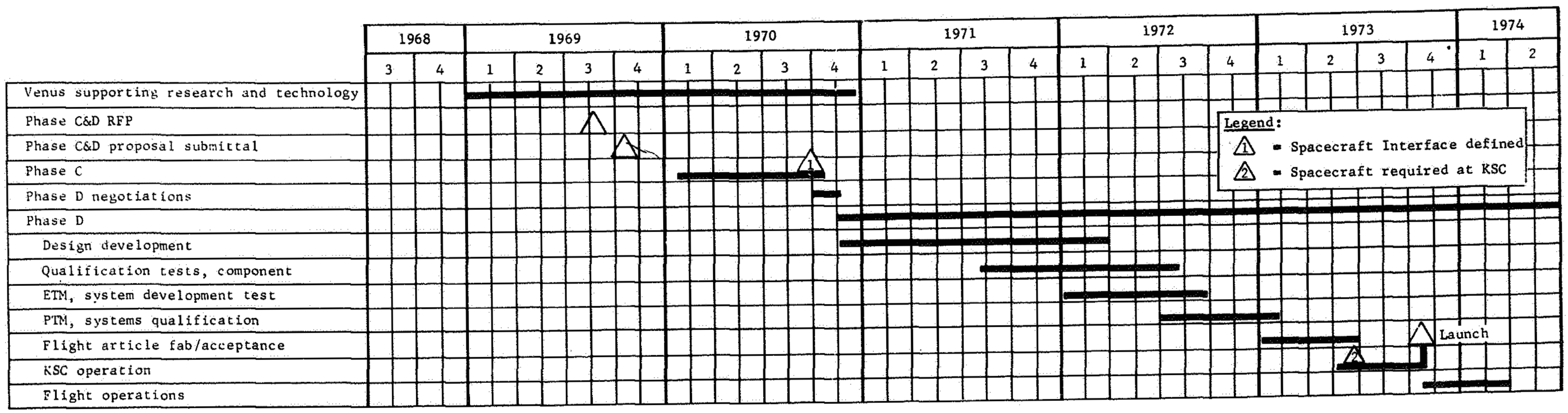


Figure 35.- Master Schedule, 1973 Orbital Mission

that has successfully completed systems qualification testing. The technical areas that require advancement of the state of the art such as the heat shield, the flotation system, and certain science instruments would be started and conducted under supporting research and technology programs on a time schedule that will support this program master schedule. Additional detail to support this program schedule is shown in the lower tier schedules provided in this section.

Figure 36 is a schedule of the Phase C program activities. At the initiation of Phase C, the basic mission specifications, design data for the selected orbiter, and a preliminary science list provide the basis for the design analyses and the resulting specifications.

Program plans for Phase D are submitted and negotiated during this phase. They provide the basis for the Phase D proposal submitted at the conclusion of Phase C.

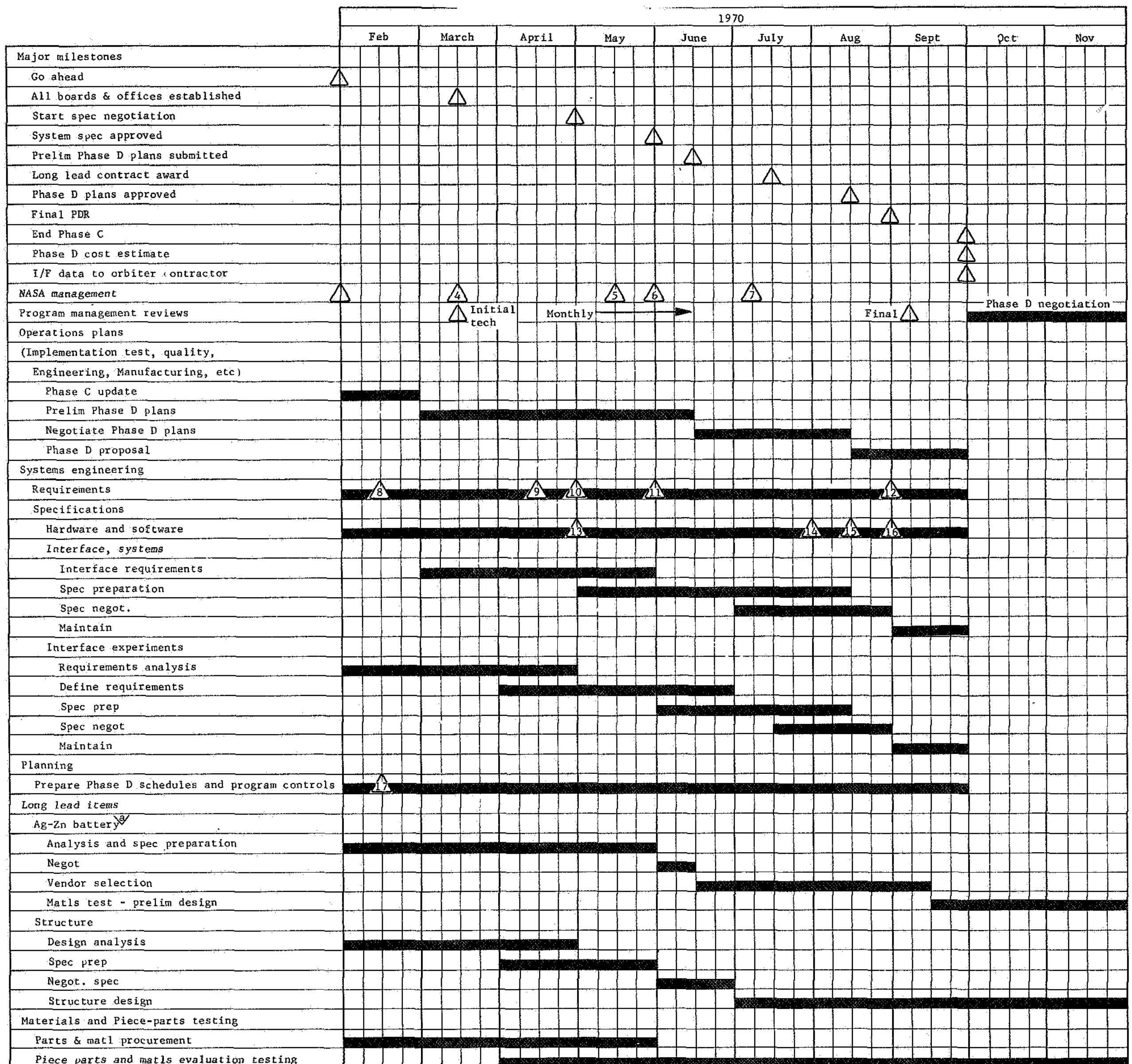
The primary emphasis during Phase C is the accomplishment of design analyses and preliminary engineering to enable the preparation and negotiation of program specifications. For hardware and software (computer programs), a recommended contract end item list is submitted for approval. Interface specifications defining the interfaces between the BVS and the orbiter, the BVS system and the facility/launch pad, and the BVS and the science instruments that are assumed to be government-furnished property are prepared and negotiated. Science instruments present a peculiar problem in that they are provided by various sources having varied types of management and technical controls.

The planning effort in Phase C consists of the preparation of detail schedules and program controls for the performance of Phase D.

In Phase C, the initiation of long-lead procurement actions occur on program go-ahead. This Phase C schedule does not show development of the balloon flotation system and the heat shield, which occur under supporting research and technology (SRT) programs. These programs are carried through the development phase that coincides with Phase D hardware requirements.

The long-lead items worked directly in Phase C are the silver-zinc (Ag-Zn) battery and the design of the BVS structure. The Ag-Zn battery has been included as a long-lead item, even though there are development programs in progress.

The design of the structure is initiated in Phase C so that structural test models and a structure for the Engineering Test Model (ETM) may be fabricated early in Phase D.



[a]Assumes present development programs not completely applicable

Legend:

1	Mission specification available	9	System specification submitted
2	Orbiter design data	10	CEI list submitted
3	Prelim science list	11	OSE criteria
4	Resident offices established	12	Final PDR
5	CEI list approved	13	Specs for long leads submitted
6	Final science list	14	OSE specification submitted
7	Phase D instructions issued	15	Software specifications submitted
8	Mission specification updated	16	All specifications negotiated
		17	Phase C schedules finalized

Figure 36.- Phase C Schedule, 1973 Orbital Mission

The schedule for Phase D is shown in figure 37. Emphasis is placed on having proven hardware for the systems qualification testing, proof test model (PTM), which will reduce the time required for system qualification. Reutilization of test models reduces program costs and provides schedule incentive as the availability of these models control the succeeding task. Emphasis on the development stage of the hardware program with a minimum of overlap with the qualification program provides schedule recovery capability and the ability for program management to exercise alternatives in the development stage. Breadboard/brassboard development commence shortly after the start of Phase D and lead to the production of hardware for development testing the subsystems and for the ETM, which is used for development testing at the system level.

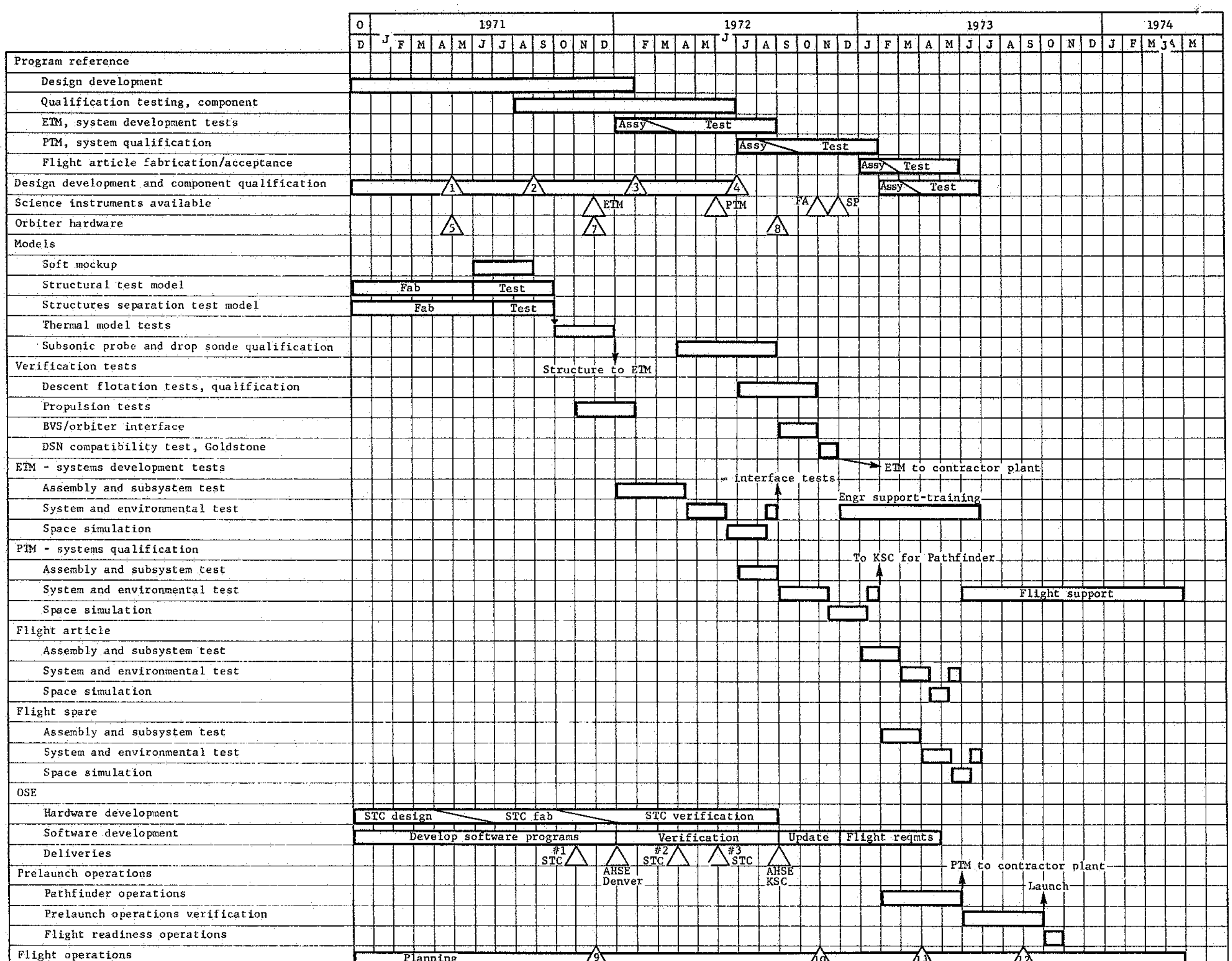
Structural test models are built early in Phase D to verify structural integrity and the capability of the various structural modules to separate as planned. The structure used for the structure separation tests will be used to conduct the thermal effects tests. Upon completion of the thermal tests, the structure is used for the structure of the ETM.

Verification or qualification tests are conducted on the entry flotation components to assure proper operation of this system with qualified hardware. These aircraft drops provide for the main chute deployment, which in turn provides for balloon deployment and inflation.

The ETM is used to verify the BVS systems operations. At the completion of testing at the contractor's plant, the ETM is mated with the orbiter at a location designated, and interface testing with the orbiter is conducted. When these tests are completed, the BVS is transported to Goldstone to conduct compatibility tests with the Deep Space Net (DSN). The ETM is then returned to the contractor's plant to serve as a vehicle to analyze any problems found on succeeding vehicles and to serve as a training aid for the test crews and mission operations team.

The PTM is used to qualify the BVS systems. After completion of the PTM tests, the vehicle is shipped to KSC to act as a pathfinder in the checkout, sterilization, and launch facilities to verify procedures and provide crew handling and checkout training.

Science instruments and their associated operational support equipment (OSE) are provided by the government. The schedule shows the delivery requirement for this equipment at the contractor's plant to mate it with the data acquisition equipment before installation in the vehicle.



Legend:

1 Development engineering available
2 Development hardware available
3 Critical design review
4 Qualification test complete, component
5 Master gage for interface verification
6 Orbiter structural model available
7 Thermal control model available
8 Orbiter for interface tests
9 Missions operations plan update
10 DSN compatibility check
11 Final space flight operations plan
12 Mission operations team certified

Figure 37.- Phase D Schedule, 1973 Orbital Mission

The OSE schedule for this program is predicated upon the use of a computer for checkout procedures. The Systems Test Complex (STC) equipment is used for all systems tests at the contractor's plant and at KSC, thus assuring commonality of equipment. Test equipment and test tools are used for component and subsystem tests.

1973 VENUS ORBITAL MISSION

Program Costs

Estimated total program cost for the 1973 Venus orbital mission is $255 710 000 as shown in table 15. This total excludes $3 190 000 for the development of the heat shield and the flotation system as these are considered to be supporting research and technology items.

Methodology

The basis for the BVS cost is the reference configuration as detailed in volume III of this report. The work breakdown structure (fig. 38) identifies the cost elements to which each department estimated labor, material, subcontract, and direct charge requirements. Costing ground rules are as follows:

1) The program consists of one launch from AFETR with one complete backup flight article;

2) Government costs such as range support, operation of DSN, and other NASA activities, including program management and technical direction are excluded;

3) All costs are FY 1968 dollars;

4) No facility costs are included;

5) The dollars shown contain labor, material, subcontract, direct charges, overhead, and G&A applications, and profit;

6) All science instruments were assumed to be developed by industry with limited assistance from universities;

7) Propellant costs are excluded;

TABLE 15.- TOTAL PROGRAM COST, 1973 ORBITAL MISSION

Item	Cost, FY68 dollars		
	Phase C	Phase D	Total
Buoyant Venus Station			
Program management	4060×10^3	$28\ 708 \times 10^3$	$32\ 768 \times 10^3$
Systems engineering, integration, and test	1934	15 612	17 546
BVS hardware			
Structures and thermal	803	6 166	6 969
Propulsion	65	1 611	1 676
Aeroshell	269	2 763	3 032
Balloon flotation	246	6 211	6 457
Guidance and control	142	1 348	1 490
Power, Pyro, and cabling	106	4 876	4 982
Telecommunications	119	8 176	8 295
Science	78	777	855
Production services	137	3 871	4 008
System operational support equipment	259	27 656	27 915
Mission operations	139	2 641	2 780
Logistics	52	2 445	2 497
Subtotal BVS	8409	112 861	121 270
Subsonic probe			5 087
Mission integration			14 113
BVS science			12 240
Spacecraft			85 000
Launch vehicle			18 000
Total program cost			255 710

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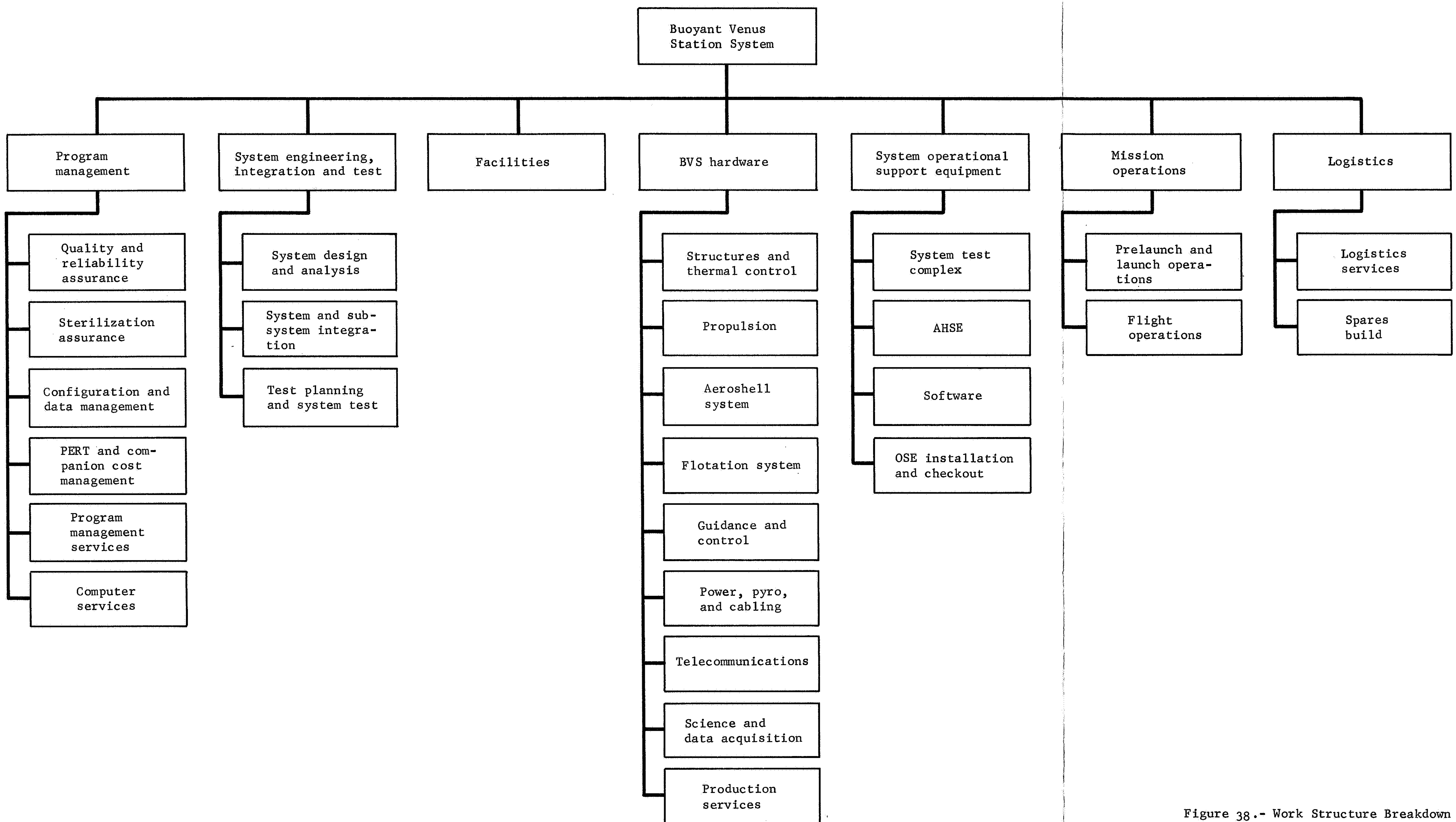


Figure 38.- Work Structure Breakdown

8) Launch vehicle is a Titan IIIC;

9) Sterilization is by dry heat only.

VENUS 1972 FLYBY MISSION

The master schedule for the Venus 1972 flyby mission is shown in figure 39. This mission launch period occurs 19 months earlier than the 1973 launch period major program activity. This may increase the schedule and technical risks for this mission.

The major schedule differences between the 1972 and the 1973 mission, using the same assumptions previously stated for the 1973 mission, are:

1) Phase C has been shortened from 8 to 6 months. This shortened span results in the specification preparation, design analyses, and preliminary design occurring simultaneously;

2) Phase D will immediately follow Phase C for the 1972 mission, rather than be separated by a 2-month Phase D negotiation period, as provided for in the 1973 mission schedule.

The design development phase has been shortened 4 months, increasing the requirement to use previously developed hardware.

Component qualification has been shortened from 12 to 8 months. Note that component qualification is still being conducted while the flight article is in the final assembly and acceptance test phase. To lessen the risk, the method selected was to combine the ETM and PTM objectives into one test article. The test article would be built as soon as feasible in Phase D, using qualification configured hardware, and systems testing would be conducted, and hardware updated or replaced depending on component qualification results. After component qualification is completed, systems qualification is conducted.

It was concluded that the schedule risks involved make the 1972 mission significantly less attractive. For this reason, detail plans are not presented; however, for comparison, the costs for a 1973 flyby mission are considered below.

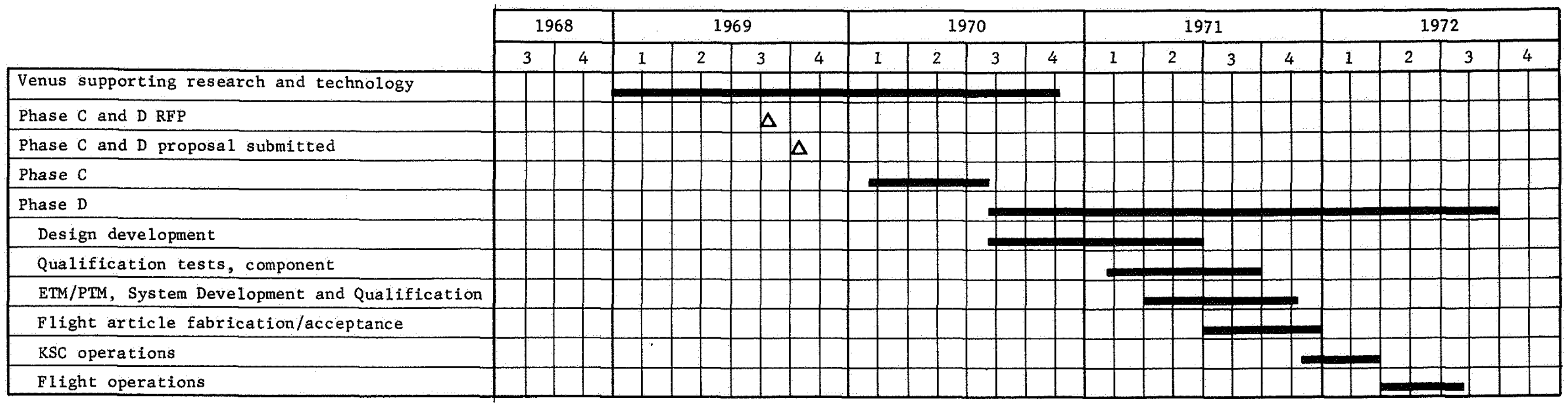


Figure 39.- Master Schedule, 1972 Flyby Mission

Program Cost

Estimated total program cost for the 1973 Venus flyby mission is $251 457 000 as shown in table 16. This total excludes $3 345 000 for the development of the heat shield and the flotation system, as these are considered to be supporting research and technology items.

The basis for the BVS cost is the reference configuration as detailed in volume III of this report. The work breakdown structure (fig. 38) and costing ground rules are the same as described for the 1973 orbital mission.

1973 VENUS/MERCURY MISSION

The schedule for the 1973 Venus/Mercury mission, as shown in figure 40, is basically the same as for the 1973 orbital mission. The launch period for the Venus/Mercury mission starts two weeks earlier, which is insignificant when considering the total schedule span for the mission.

When comparing the technical requirements of the Venus/Mercury mission with the orbital mission, it is concluded that the differences create no overall impact on the Venus/Mercury mission schedule. The inertial measuring unit required for Venus/Mercury may become a long-lead item.

Program Cost

The estimated total program cost for the 1973 Venus/Mercury mission is $260 818 000 as shown in table 17. This total excludes $4 375 000 for the development of the heat shield and the flotation system, as these are considered to be supporting research and technology items.

The basis for the BVS cost is the reference configuration as detailed in volume III of this report. The work breakdown structure (fig. 38) and costing ground rules are the same as used for the 1973 orbital mission.

Two major configuration changes account for the increased cost of the Venus/Mercury mission; adding an S-band communications link to the telecommunications and an inertial measuring unit to the guidance and control.

TABLE 16.- TOTAL PROGRAM COST, 1973 FLYBY MISSION

Item	Cost, FY68 dollars		
	Phase C	Phase D	Total
Buoyant Venus Station			
Program management	4060×10^3	$28\ 708 \times 10^3$	$32\ 768 \times 10^3$
Systems engineering, integration and test	1934	15 612	17 546
BVS hardware			
Structures and thermal	803	6 166	6 969
Propulsion	106	1 290	1 396
Aeroshell	269	2 686	2 955
Balloon flotation	246	6 211	6 457
Guidance and control	142	1 348	1 490
Power, pyro and cabling	96	4 407	4 503
Telecommunications	316	14 362	14 678
Science	78	777	855
Production services	137	3 871	4 008
System operational support equipment	259	27 656	27 915
Mission operations	139	2 770	2 909
Logistics	52	2 516	2 568
Subtotal BVS	8 637	118 380	127 017
Subsonic probe			5 087
Mission integration			14 113
BVS science			12 240
Spacecraft			75 000
Launch vehicle			18 000
Total program cost			251 457

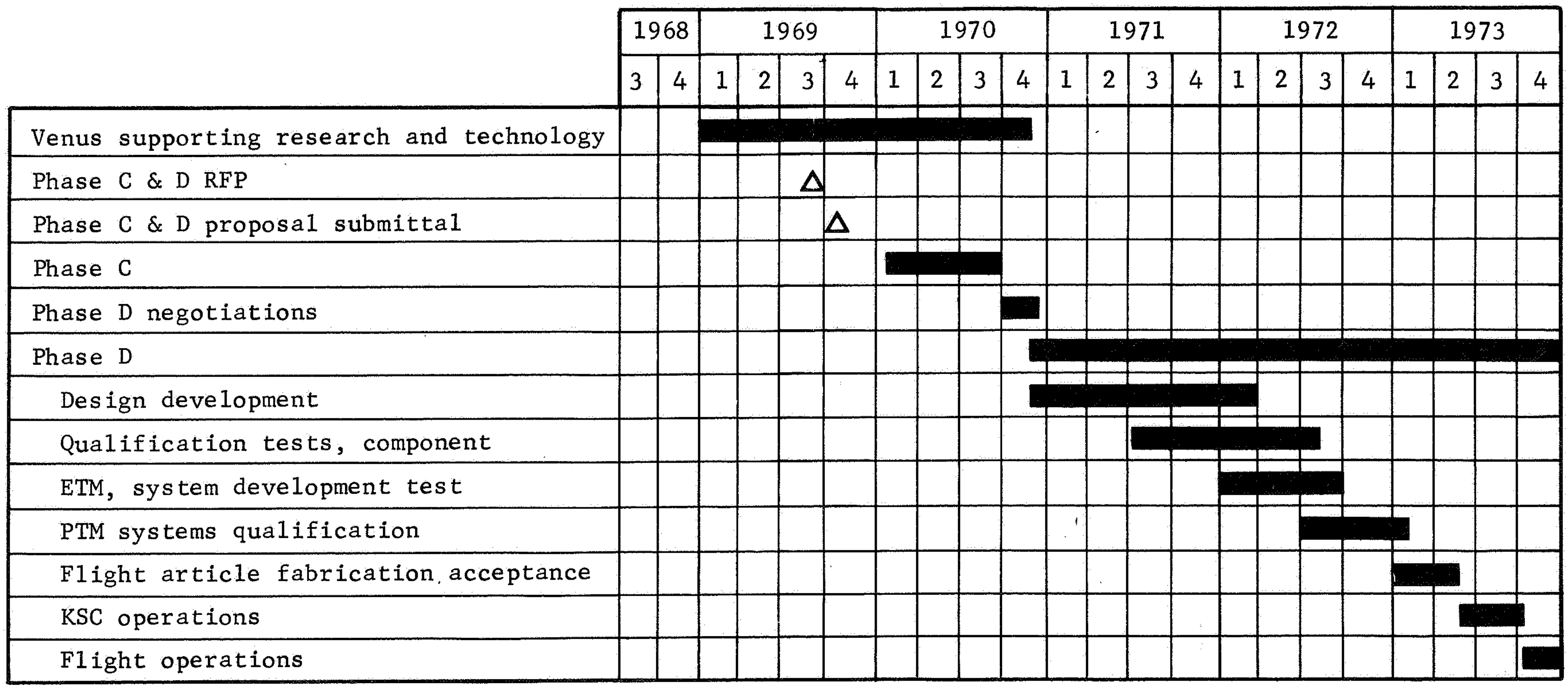


Figure 40.- Master Schedule, 1973 Venus/Mercury

TABLE 17.- TOTAL PROGRAM COST, 1973 VENUS/MERCURY MISSION

Item	Cost, FY68 dollars		
	Phase C	Phase D	Total
Buoyant Venus Station			
Program management	4421×10^3	$30\ 007 \times 10^3$	$34\ 428 \times 10^3$
Systems engineering integration and test	2038	15 931	17 969
BVS hardware			
Structure and thermal	1085	6 114	7 199
Propulsion	106	1 290	1 396
Aeroshell	406	3 327	3 733
Balloon flotation	246	6 211	6 457
Guidance and control	417	8 241	8 658
Power, pyro, and cabling	96	4 407	4 503
Telecommunications	264	12 424	12 688
Science	78	777	855
Production services	137	3 973	4 110
System operational support equipment	259	27 656	27 915
Mission operations	139	2 770	2 909
Logistics	52	2 412	2 464
Subtotal BVS	9744	125 540	135 284
Subsonic probe			6 181
Mission integration			14 113
BVS science			12 240
Spacecraft			75 000
Launch vehicle			18 000
Total program cost			260 818

SUPPORTING RESEARCH AND TECHNOLOGY (SRT)

The results of this study have determined the requirement for development programs to be initiated in 1969 for the BVS flotation system and the heat shield. Some science instruments will also require development. The development programs for the flotation system and the heat shield are described in the following paragraphs.

BVS Flotation System

The design of the BVS balloon flotation system is a vital development task and is a critical factor in the performance of the entire program. A schedule for the development of this system is shown in figure 41. The completion of this program coincides with the start of Phase D for the 1973 mission. The total cost for development of the flotation system is $1 805 000. The tasks required to accomplish the development program and the estimated cost for each task are described below.

Material tests.- Materials tests are described below.

Objective: To determine the best materials for constructing a balloon that will withstand sterilization, packing, deployment, and the Venus mission environment without significant deterioration.

Scope: Phase 1 and 2 scope is as follows:

1) Phase 1,

    a) Materials selection,

    b) Materials characterization,

    c) Screening;

2) Phase 2,

    a) Investigate construction techniques,

    b) Special environment tests,

    c) Model tests.

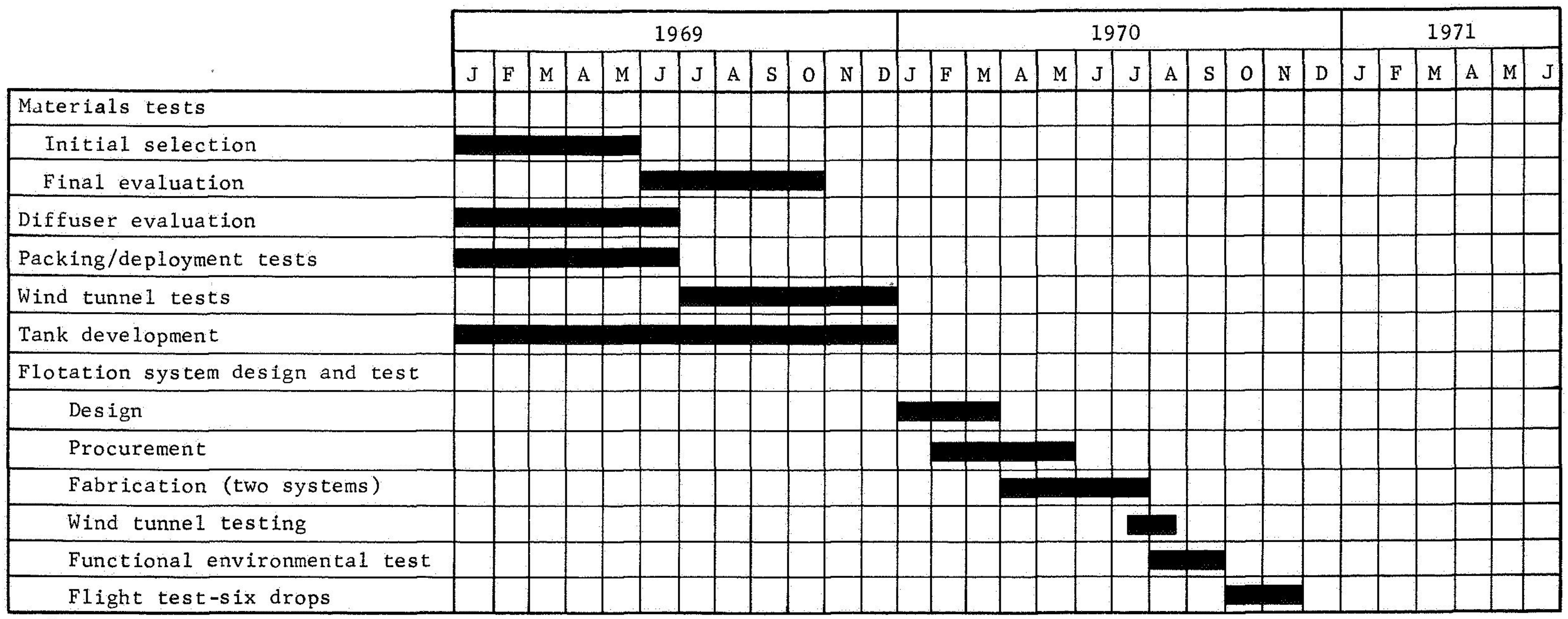


Figure 41.- Flotation System Development

Output: Output includes

1) Material specification;

2) Recommended material;

3) Recommended construction techniques.

Cost: $100 000.

Diffuser evaluation.- Diffuser evaluation is described below.

Objective: Develop and build an inflation system diffuser that will allow rapid balloon inflation from high-pressure tankage blowdown without damage to the balloon.

Scope: Using results of previously derived data, design and build a diffuser with diffuser sock for blowdown test. Design and build both an orifice/nozzle type and a baffle type for parallel testing.

Output: Outputs include

1) Diffuser design requirements;

2) Test results and recommendations on best diffuser design.

Cost: $15 000.

Packing/deployment tests.- Packing/deployment tests are described below.

Objective: To determine the best method of folding, packing, deploying and inflating the balloon to minimize possible damage to balloon.

Scope: The scope is as follows

1) Design and build balloon canister;

2) Design and build deployment test rig;

3) Design and build test inflation system;

4) Develop folding packing technique;

5) Perform tests.

Output: Design criteria for the following are developed.

1) Balloon handling/packing;

2) Balloon canister;

3) Deployment sequence.

Cost: $40 000.

Balloon wind tunnel tests.- Balloon wind tunnel tests are described below.

Objective: To study the qualitative and quantitative aspects of the dynamics of deployment and inflation of a full-scale balloon in an airstream at the design dynamic pressures.

Scope: Scope is as follows.

1) Use NASA/Langley 30x60-ft full-scale wind tunnel;

2) Fabricate various balloons;

3) Design and build deployment packing rig and simulated gondola;

4) Design, build necessary mockup inflation system for wind tunnel testing;

5) Perform wind tunnel tests.

Output: Output includes

1) Balloon/canister/deploy specification;

2) Recommendations for balloon design, deployment sequence.

Cost: $100 000.

Inflation tank development.- The following paragraphs describe inflation tank development.

Objective: To develop lightweight tanks using filament-winding techniques and metal liners.

Work statement: Work items include

1) Develop techniques for bonding tank liner portions to each other;

2) Develop boss designs and transition areas to relieve concentrated strains;

3) Develop analytical techniques to relate filament stresses to tank pressure;

4) Fabricate test tanks;

5) Test tanks.

Output: A tank design specification will be prepared.

Cost: $300 000.

Flotation system air drop tests.- These tests are described below.

Objective: To design and fabricate a complete flotation system and test under simulated Venus mission conditions.

Scope: The scope of the effort is as follows.

1) Design a prototype flotation system;

2) Procure/fabricate all required hardware for two flotation systems;

3) Assemble and conduct ground checkout of two flotation systems;*

4) Conduct drop tests (six) at a government facility such as Holloman AFB.

Output: The output is

1) Flotation system design specification;

2) Prototype design for a basic flotation system.

---

*Included in checkout are wind tunnel tests using the Langley Research Center 30x60-ft wind tunnel facility.

Cost: $1 250 000.

The sequence of the complete BVS flotation system test program through qualification is shown in figure 42.

Heat Shield

The development program is designed to proceed from resolution of general problem areas for any type of Venus mission to a point before the start of Phase C where the mission is adequately defined with specific testing accomplished to support the mission. This specific testing is completed by the time Phase D starts and subsequent heat shield effort applied directly to the BVS program. Figure 43 shows the proposed schedule for the development of the heat shield.

Total program costs for the heat shield development are:

1) 1973 orbital - $1 385 000;

2) 1973 Venus/Mercury - $2 570 000;

3) 1972 flyby - $1 540 000.

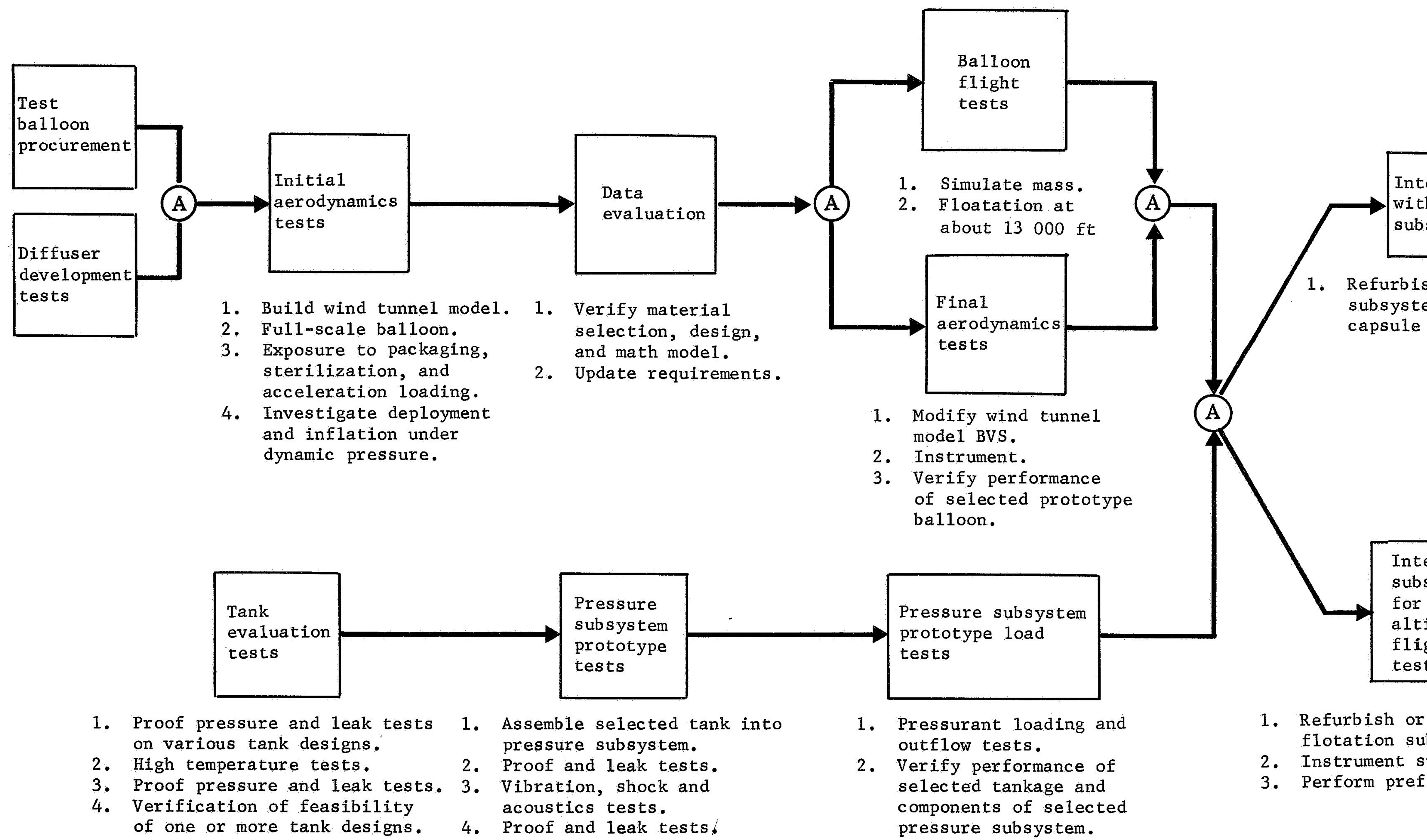
Items 4 and 10 (fig. 43) are not requirements for the 1973 orbital mission, thus accounting for a lesser total cost.

Because of the greater entry velocity required for the Venus/ Mercury mission (approximately 44 000 fps), a greater amount of analysis and testing is required.

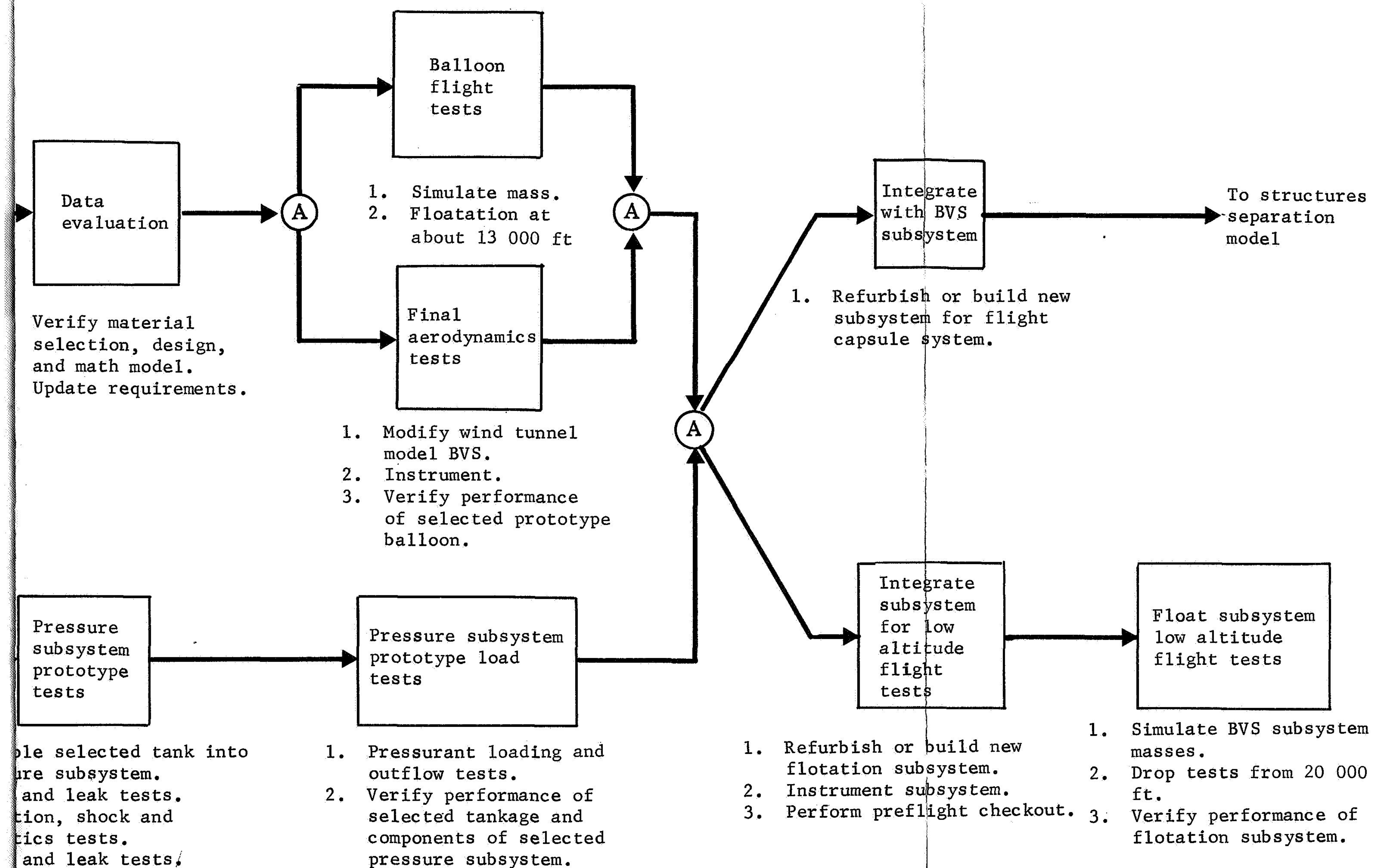
The flyby mission requirements are similar to the orbit mission but do include tasks 4 and 10 (fig. 43). The tasks to be accomplished in the development program are as follows (cost shown for each task reflects effort for orbital or flyby mission).

Task 1, entry radiant and combined heating tests and analysis.- The following paragraphs discuss task 1.

Objective: To confirm the ablation analysis model for the degradation of candidate materials under these heating conditions and to establish material ablation performance characteristics (properties) for inputs to analytical ablation computations.


Test balloon procurement
Diffuser development tests
A
Initial aerodynamics tests
1. Build wind tunnel model.
2. Full-scale balloon.
3. Exposure to packaging, sterilization, and acceleration loading.
4. Investigate deployment and inflation under dynamic pressure.
Data evaluation
1. Verify material selection, design, and math model.
2. Update requirements.
A
Balloon flight tests
1. Simulate mass.
2. Floatation at about 13 000 ft
Final aerodynamics tests
1. Modify wind tunnel model BVS.
2. Instrument.
3. Verify performance of selected prototype balloon.
A
A
1. Refurbish
Tank evaluation tests
1. Proof pressure and leak tests on various tank designs.
2. High temperature tests.
3. Proof pressure and leak tests.
4. Verification of feasibility of one or more tank designs.
Pressure subsystem prototype tests
1. Assemble selected tank into pressure subsystem.
2. Proof and leak tests.
3. Vibration, shock and acoustics tests.
4. Proof and leak tests.
Pressure subsystem prototype load tests
1. Pressurant loading and outflow tests.
2. Verify performance of selected tankage and components of selected pressure subsystem.
2. Instrument
3. Perform

1



Test areas

1. Full-scale, wind tunnel at Langley Research Center.
2. Cold flow test area.
3. Environmental laboratory.
4. Flight test field site.

Support equipment requirements

1. Instrumentation.
2. Leak-check equipment.
3. Aircraft drop vehicle.
4. Handling equipment.

Figure 42.- Floatation System Development Program

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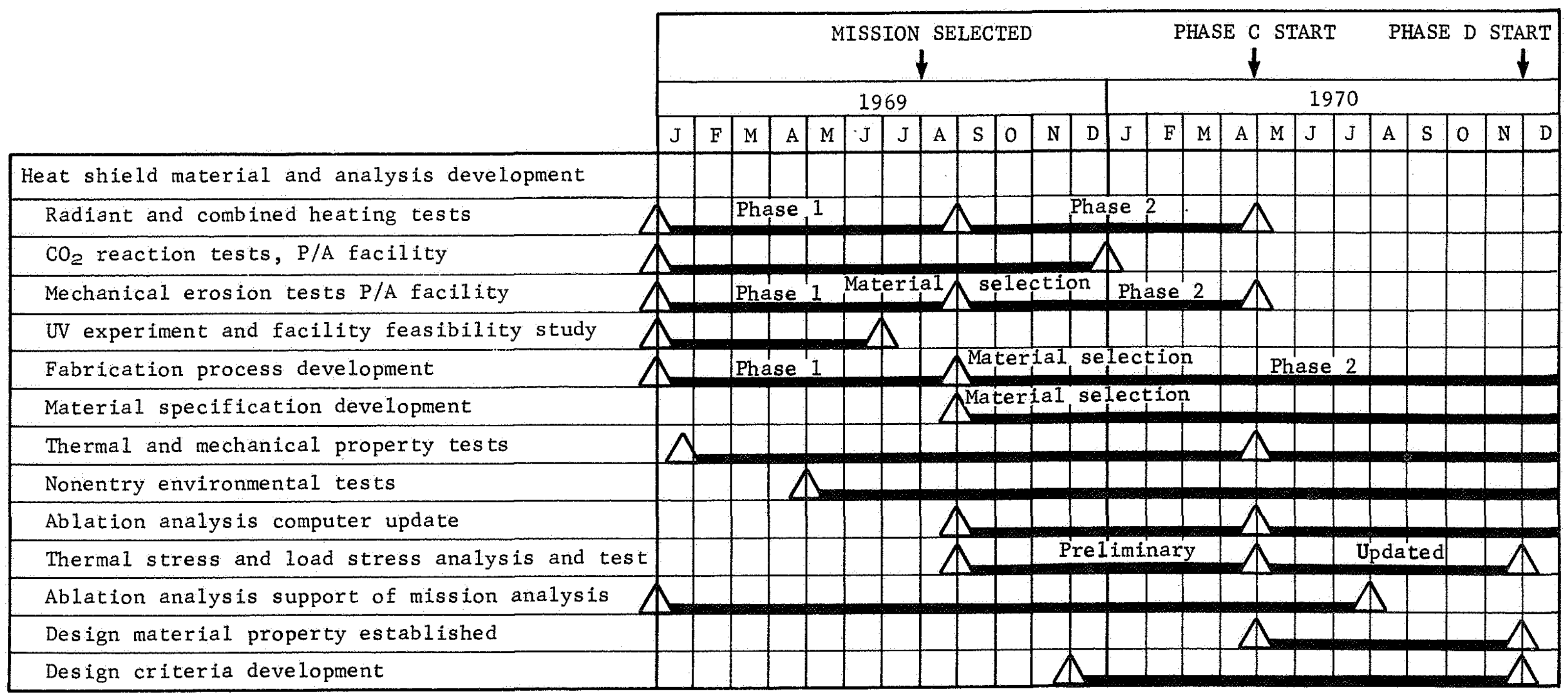

Figure 43.- Heat Shield Development

Scope: The task will be conducted in two phases; Phase I will involve exposing four or five candidate materials to various discrete levels of "radiant-only" heating, "convective-only" heating, and selected combinations of combined radiant and convective heating. Comparison will be made of the test response with the predicted response from thermochemical theory to confirm the analytical model or dictate changes. Relating performance of the materials will also be ascertained. In Phase II, additional tests will be conducted on one or two materials to establish preliminary values for the material ablation properties. Candidate materials will include several variations of the modified ESA-5500 material.

Outputs: Task 1 outputs include

1) Relative material performance;

2) Analytical model;

3) Preliminary ablation properties for selected materials.

Cost: $220 000.

Government facility requirements: Ames combined heating facility (current and '69 versions).

<u>Task 2, CO_2 - char reaction, tests and analysis</u>.- Task 2 is described below.

Objective: To establish quantitively a method of accounting for the presence of CO_2 in the Venus atmosphere in performing thermochemical ablation analysis.

Scope: Extend existing test data on graphite behavior in CO_2 and CO_2-N_2 gas mixtures to include charring ablative materials of interest (including modified ESA-5500), and to cover the range of pressure and convective heating rates anticipated in entry. Ascertain analytically whether differences observed (relative to air atmospheres) are due to presence of atomic species or due to different diffusion coefficients. Tests are conducted in the plasma arc under very closely control conditions.

Output: An analytical procedure will be developed for predicting surface behavior of char in presence of CO_2-N_2 gas during entry.

Cost: $160 000.

Task 3, mechanical erosion, analysis and test.- Task 3 is described below.

Objective: To establish recession characteristics of candidate materials under conditions of high surface shear forces (aerodynamic shear) and to determine an analytical model for correlating and predicting this recession for selected materials.

Scope: The task will be conducted in two phases. Phase I will involve exposing four or five candidate materials to various levels of shear, heating rate, and surface temperature. Candidate materials will include several variations of the modified ESA-5500 silicone material as well as existing materials. In Phase II, additional tests will be conducted on selected materials for correlation with analytical procedures.

Outputs: Task 3 outputs include

1) Relative material performance;

2) Analytical model;

3) Preliminary ablation properties for selected materials.

Cost: $200 000.

Task 4, entry ultraviolet radiation heating effects on materials study and facility feasibility study.- The following paragraphs discuss task 4.

Objective: To determine if intense uv radiation causes a different ablator degradation process than intense radiation in the visible wavelengths and to examine the desirability and feasibility of designing and constructing a high-intensity uv materials test facility.

Scope: An ablation materials engineer and a physicist will examine the problem theoretically and devise, if possible, a laboratory experiment to demonstrate influence of high-intensity uv on carbon and carbonaceous char materials. They will study the possible ways of achieving a uv materials test facility, including an H_2 arc and concentrating energy from the uv portion of an argon or xenon arc. Ways of filtering out unwanted wavelengths will be examined.

Output: Task 4 outputs include conclusions on the necessity for uv testing and conclusions on the feasibility of developing a uv materials test facility.

Cost: $45 000.

Task 5, fabrication process development.- The following paragraphs describe task 5.

Objective: To develop techniques for applying ablative materials to large-diameter shallow-cone structures.

Scope: Examine techniques on small flat panels, through intermediate size cones, and, finally, large-diameter parts. Investigate staging of resin system for better handling, pressures required for good parts, cure cycles, influence of sterilization temperatures, etc. Prepare and maintain a heat shield fabrication process. Assist in development of materials requirements and acceptance criteria.

Output: Engineering process documentation for heat shield will be developed.

Cost: $120 000.

Task 6, material specifications development.- Task 6 is described below.

Objective: To prepare material specifications and monitor control test data during early purchases to ascertain a degree of material reproducibility.

Scope: Define the tests to be performed that will evaluate and control all raw materials used in the heat shield (primers, resins, cloth curing agents filler materials, treatment fluids, adhesives, fiber materials, etc.). Conduct laboratory studies on mixing variables and filters to control density. Evaluate variables such as pot life, primer effectiveness, moisture content control, etc. Assist in basic heat shield design concept development.

Output: A heat shield material specification will be prepared.

Cost: $70 000.

Task 7, thermal and mechanical property tests.- The following paragraphs describe task 7.

Objective: To obtain values for thermal and physical properties of candidate ablative materials for inputs to ablation analysis and thermal stress analysis computer programs.

Scope: Laboratory "coupon" tests will be conducted to obtain candidate heat shield material properties including thermal conductive specific heat, stress/strain relations, coefficient of expansion and reaction kinetics. These will be obtained to supplement existing property data and will be concentrated on the modified silicone material for which little data currently exist. The upper temperature range will be 2000 to 3000°F; low temperature limit will be -150°F. Property data above laboratory capability temperature will be derived from ablation tests in arc and radiant facilities (see tasks 1 thru 4).

Output: Material property vs temperature data will be developed.

Cost: $125 000.

Task 8, nonentry environmental tests.- The following paragraphs describe task 8.

Objective: To evaluate the compatibility of heat shield materials with the environment encountered from fabrication to the start of atmospheric entry at Venus.

Scope: Expose candidate heat shield materials to environmental conditions established for each phase of the mission excluding entry, and measure any change in properties that effect entry performance, e.g., conductivity, elastic modulus, stress/strain characteristics, etc. Also, measure effects of offgassing products relative to deposition on optical or thermal control surfaces. The exposures will include humidity, vacuum, temperature, radiation, and contact with thermal control coating.

Output: Task 8 output will include data on the relative performance of ablative materials and specific performance of selected materials under the exposures listed above.

Cost: $110 000.

Task 9, ablation analysis computer program update.- Task 9 is described below.

Objective: To include the capability for handling the aspects of ablation peculiar to Venus entry in the existing T-CAP ablator program.

Scope: The findings of the studies concerning the CO_2-char reaction, combined radiative and convective heating uv influence, and mechanical erosion will be incorporated into the existing computer program.

Output: Current programs will be revised to include boundary layer/ablator interaction update and internal reactions in char update.

Cost: $110 000.

Task 10, heat shield thermal stress and loads stress analysis and test.- The following paragraphs describe task 10.

Objective: To determine the influence of temperature gradients through the ablator on

1) Tendency for surface spallation or cracking during entry and during cold soak before entry;

2) Overall tendency of ablator to pull away from substrate during entry and during cold soak before entry.

Scope: Thermal stress analyses will be made for three candidate materials including rigid high-density material, rigid low-density material, and an elastomeric material for the two conditions listed above. In addition, tests will be defined and conducted on scaled-down heat shield parts. Material properties used will be obtained from existing data supplemented by task 7 results. Heating will be provided either by large nozzle plasma arc, radiative lamps, or surface resistance heaters as determined during experiment design phase.

Output: Quantitive information will be developed relative to thermal stress behavior of candidate materials, and a preliminary estimate of thermal stress levels during anticipated missions will be prepared.

Cost: $90 000.

Task 11, ablation analysis support of mission analysis and vehicle configuration studies.- Task 11 is described below.

Objective: To maintain an up-to-date set of entry environment conditions for use in defining test programs such as tasks involving CO_2, uv, combined heating, thermal stress, etc.; and to assist in mission selection and vehicle configuration studies.

Scope: Conduct ablation analyses for various materials configurations and missions as required. Use existing T-CAP III computer program and existing ablation property data.

Output: Heat shield thickness requirements, temperature gradients, backface temperatures, etc. will be developed for various missions and configurations.

Cost: $75 000.

Task 12, design material property tests and confirmation of ablation analysis model.- The following paragraphs describe task 12.

Objective: To establish the characteristic material performance parameters of the selected materials at conditions representative of critical times in the anticipated entry trajectory; and to confirm the analysis model and procedures used in ablative design computations.

Scope: Small models will be exposed in the radiant heat, convective heat, combined heat, and shear force facilities at levels selected from specific entry trajectory environment plots. Sufficient numbers of models will be tested at each point to establish scatter patterns. A limited number of heat points will be selected. A second type of testing will involve conducting time-dependent heat pulse tests to compare with analysis results (temperature recession and char depth histories) calculated using the test heat pulse as the input. Agreement will constitute qualification of the analysis procedure (model) and the design properties.

Output: Task 12 outputs include

1) Design properties of selected ablator;

2) Confirmation of ablation analysis procedure.

Government facilities, modes, materials: The Ames combined heating facility.

Cost: $145 000.

Task 13, design criteria development.- The following paragraphs describe task 13.

Objective: To establish a set of criteria for the design of the heat protection system that will yield a system capable of meeting the mission objectives with a confidence level consistent with that of the rest of the vehicle subsystems.

Scope: First, a quantitive estimate of the variability (frequency distribution of each parameter influencing the heat shield design will be obtained. Next, sensitivities of heat shield response to various levels of these parameters will be established (by use of the ablation analysis computer programs). Finally, the net variation in the output quantities of the heat shield design, i.e., thickness required, surface recession, internal temperature and char penetration depths will be calculated for the anticipated range of variation of input parameters, i.e., heating rate predictability, atmospheric density variations, entry angle variations, material property variations, etc. These results (output variations) will be used to establish required tolerances on design temperatures, recession, etc., or to establish factors to use on input quantities such as heating rates, pressures, etc.

Output: Heat shield design criteria will be developed.

Cost: $70 000.

A flow if all test activities associated with the heat shield is shown in figure 44.

Science Instruments

For the purposes of this program plan, it has been assumed that the science instruments would be supplied by the government. All planning and cost data presented herein reflect this ground rule. However, to present a complete plan for the BVS system, consideration must be made of the cost and schedule effects of these instruments. Table 18 presents a composite picture of the science instruments used on the three missions. These are instruments located in the BVS only. The list remains the same for each mission.

Estimated lead times and cost for technology development and/or new design is included under the "Development" columns. Schedule and cost for those items that are specifically allocated to a mission are included under the "Production" columns. This includes any qualification testing necessary. Figure 45 depicts the general development flow of a typical science instrument.

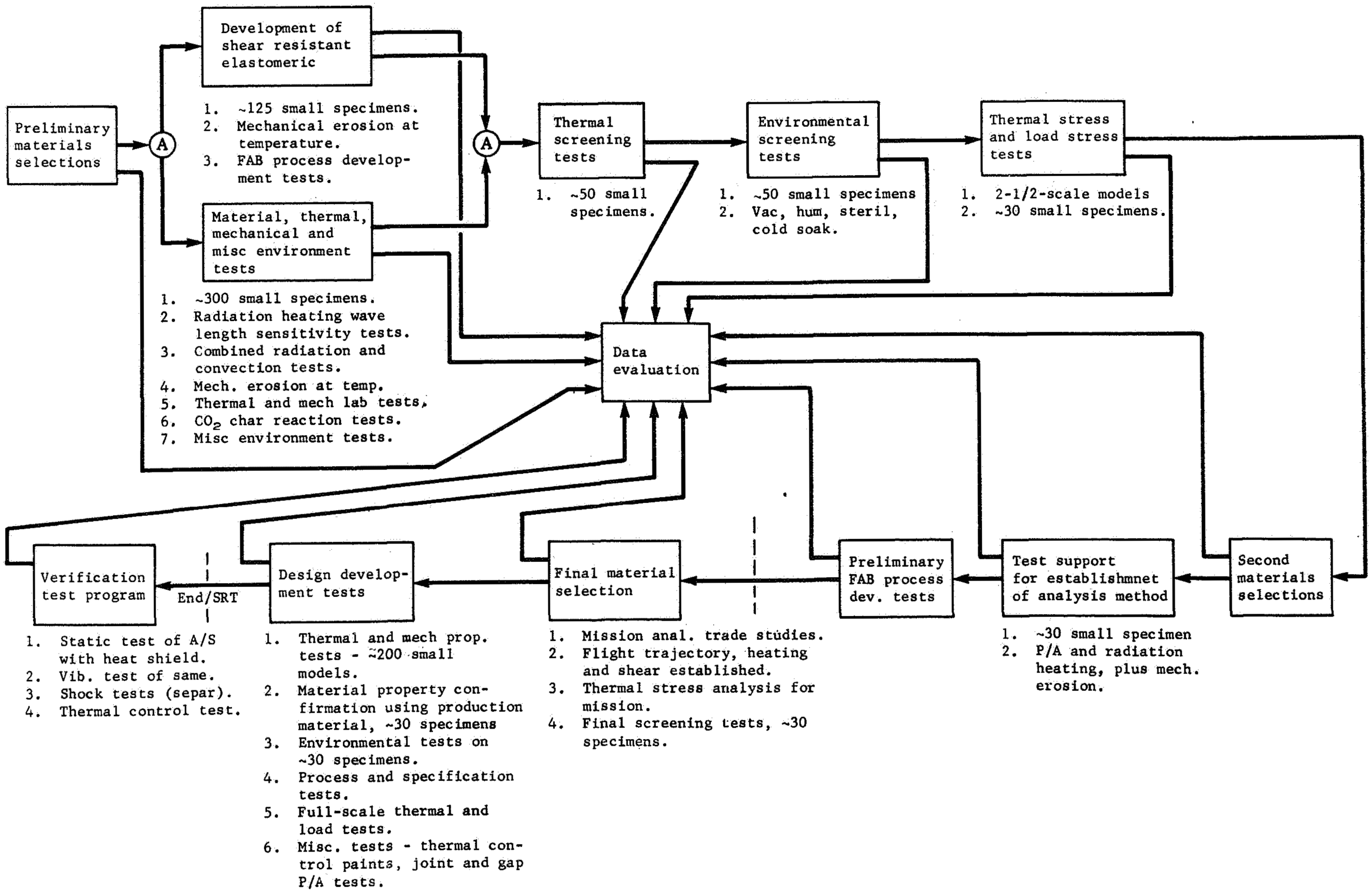

Figure 44.- Heat Shield Development Program

TABLE 18.- SCIENCE INSTRUMENTS

Science experiments	State of development		Lead time, month		Cost, $
	Design	Technology	Develop	Prod (a)	
Triaxial accelerometer	Current	Current	N/A	6	315×10^3
Pressure sensors	Current	Current	N/A	9	300
Temperature sensors	Current	Current	N/A	6	250
H_2O vapor sensor	New	New	10	8	460
Light backscatter	New	Current	10	8	450
Solar aspect angle sensor	Current	Current	N/A	12	150
Visual photometer	Current	Current	N/A	12	300
Mass spectrometer	Current	Current	N/A	12	1015
Beta source densitometer	Current	Current	N/A	12	600
Insolation radiometer	Current	Current	N/A	12	150
UV photometers	Current	Current	N/A	12	500
Gas chromatograph	Current	Current	N/A	12	1750
Mini biolab	New	New	15	9	3000
Radar altimeter	New	Current	15	9	3000

[a]Includes required qualification testing.

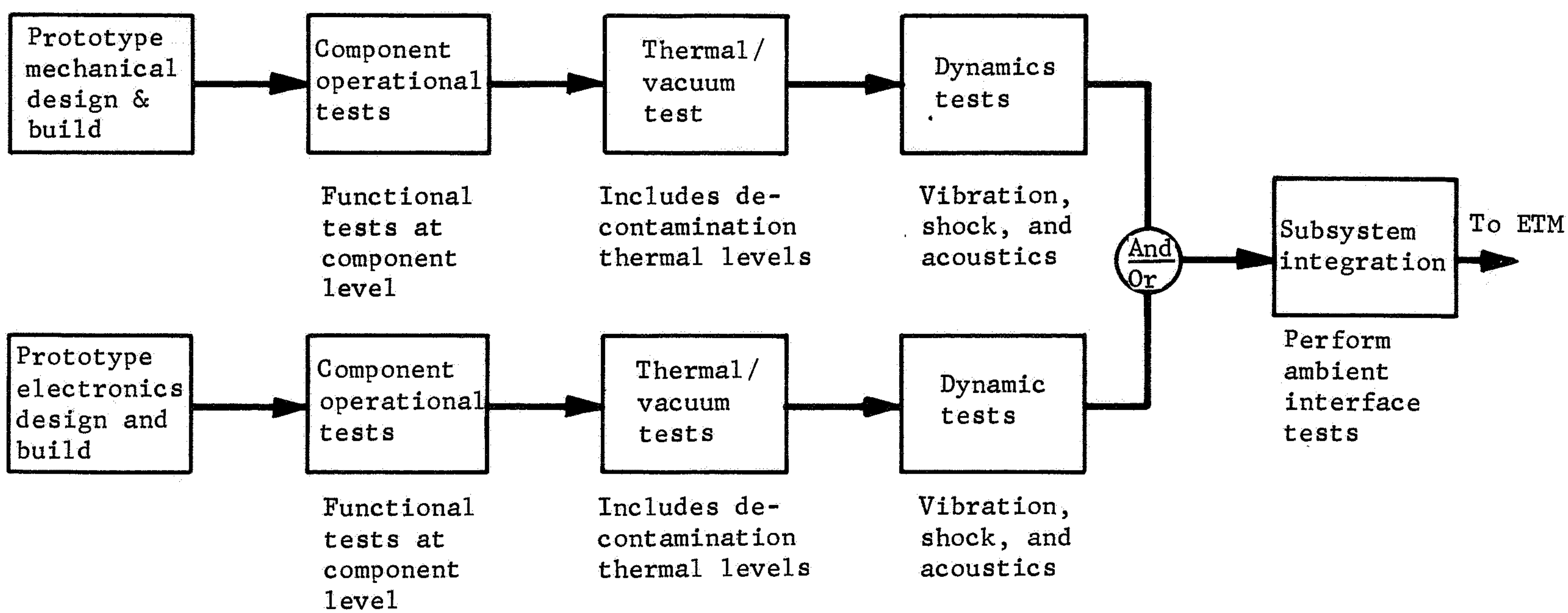

Figure 45.- Science Development Program

DEVELOPMENT REQUIREMENTS

No significant differences in technology requirements have been identified for the three missions, except to the extent that the 1972 mission provides more stringent schedule requirements. It is recognized that for either 1972 or 1973, the development of many of the individual systems and components will represent a considerable challenge, such as development of sterilizable or high-acceleration equipment; however, with few exceptions, the systems described are within the state of the art and will not represent significant development risk.

ATMOSPHERIC ENTRY

The missions under consideration involve severe entry environments as a result of approach velocities ranging from 32 000 to 44 000 fps. Attempts to reduce these velocities by modifying the launch windows do not produce significant results. (The entry environments are discussed in more detail in volume II of this report.)

Heat Shield Considerations

Although wide variations in entry conditions are involved in the three Venus missions studied, it appears that essentially state-of-the art ablative material systems can provide the required protection for the aeroshell structure for any of the missions. One of these materials, carbon-fiber reinforced phenolic, appears capable of providing protection throughout the entire range of missions; however, other materials appear more desirable for the lower and intermediate velocity missions because of their lower density (lower heat shield weight) and their flexibility. In particular, a modified version of a state-of-the-art elastomeric material, a carbon-reinforced silicone, affords such advantages for the direct (36 000 to 38 000 fps) and orbital entries (32 000 fps).

The subject of various material possibilities is discussed elsewhere; however, all candidate materials have a common requirement for formulation and fabrication development to adapt them to the BVS aeroshell configuration and preflight sequence of events, e.g., sterilization and decontamination procedures and a requirement for substantial testing to characterize their performance in the Venus entry environment. These tests are required in spite of the extensive background of earth entry flights and ground tests existing for several of the candidate ablative materials for several reasons. First, the more rapid density buildup of the Venus atmosphere, the high percentage of CO_2 in the atmosphere, and the high entry velocities combine to produce some unique conditions, including:

1) High levels of radiation heating from shock layer gases;
2) Concentration of the radiation in the uv wavelengths;
3) CO_2-char reactions;
4) Significant surface shear levels in combination with high surface temperatures occur over an extremely large area of the vehicle.

Second, the use of rigid materials such as carbon phenolic with the BVS configuration introduces potential problems with thermal and load-induced stresses, which have been of less concern in previous applications.

The heat shield design and weight studies conducted in support of the mission analyses and reported herein have accounted for the above factors in what is believed to be a conservative fashion, but confirmation of the characteristics of material response by ground tests is required. The degree of completeness with which such ground test programs can be accomplished decreases with increasing velocity. This results in an increased dependence on analysis and, consequently, an increased though still acceptable risk level associated with the designs for high velocity missions.

A program for the development of the heat shield could be conducted in four phases as summarized below.

First, small models of several different materials would be exposed to selected levels of combined radiative and convective heating in radiation-supplemented plasma arc heat sources (Ames facility primarily), to shear forces at high temperatures in pipe flow tests (plasma arc facility), and to "splash" tests in a CO_2-operated plasma arc to obtain comparative performance and to establish an ablation model for the various mechanisms of degradation involved. Second, material candidates would be narrowed to one or two, and additional tests would be conducted to verify the ablation mechanism model and to establish preliminary ablation property data. In the third phase, the material(s) selected would be completely characterized by in-depth testing at test points representative of critical conditions in the anticipated mission profile. Finally, thermal-structural verification would be conducted on large-scale parts of the aeroshell with the heat shield installed. Facilities for the latter tests would depend on final design and might include use of large-nozzle plasma arcs, banks of resistance heater elements, or, conceivably, large combustion devices (rocket engine exhausts). Concurrent with the early phases of the program would be uv radiation exposure experiments, material and fabrication process development work, and exposure of materials to the nonentry environmental aspects of the mission. Also included would be thermal stress panel tests.

A required corollary program to the material development program is one concerned with the predictive methods for radiative heat transfer to the vehicle surface from the shock layer gases. At present, little shock tube data are available for high percentage CO_2 gas mixtures for either equilibrium or nonequilibrium conditions. Also, the question of the influence of absorption by ablative products of radiant energy has not been treated thoroughly as yet. An experimental and theoretical program to establish radiation heating techniques should be conducted to reduce the requirement for the large tolerances on heating currently employed and to remove any question than even higher ones should have been employed.

The major impact on the heat shield design of increasing the entry velocity to 44 000 fps for Mercury swingby missions is seen to be limiting candidate materials to the rigid, dense ablators because of the increased recession potential that steps up the heat shield weight and increases the requirement for large-scale testing. It increases the uncertainty of radiation heating predictions and it makes a less complete simulation of combined entry parameters possible. All of these factors result in increased program costs.

Differences in the heat shield between the 32 000 and 38 000 fps are less pronounced, with the reduction of uv radiation intensity and the existence of relatively low surface temperatures simplifying the test situation, but not necessarily changing the material selection picture.

The achievement of an understanding of the ablative material response through testing and analysis, as well as developing a better understanding of the subject of radiative heating prediction, represent technology developments that are necessary to the achievement of a reliable heat protection system for any of the BVS missions.

Deceleration Consideration

The deceleration environment, while severe, is considered to be within the capability of existing design techniques, although problems may be encountered in the area of development of the science instrumentation.

FLOTATION SYSTEM

The balloon synthesized for the mission under consideration is an 18-ft hydrogen-filled superpressure balloon. It is identical for all three missions, extracted from its container by a parachute and inflated by blowdown of high pressure hydrogen gas from manifolded tankage. All operations are performed at low, subsonic velocities -- the balloon inflation at less than 30 fps ($q = 1\ lb/ft^2$), and, at the time of deployment, the balloon container pressure will approximately equal the ambient pressure ($\sim$9 psia).

Generally, similar balloons (superpressure, Mylar construction) have been flown successfully for long duration by National Center for Atmospheric Research (NCAR) under the GHOST program and deployments under similar flow conditions have been accomplished by Air Force Cambridge Research Laboratory.

This concept has been extensively simulated by computer model (see vol. III of this report) and has proven to be generally insensitive to inflation rate, altitude, or atmospheric model. By virtue of the design, wherein the hydrogen is initially cooled by expansion, it is possible to fill with an initial excess of gas that is vented through a pressure-relief system as the gas warms. In this manner, the requirement to meter a precise amount of gas is avoided, and the system is able to adapt to a range of atmospheric conditions.

A system (deployed remotely, designed for sterilization, long-term storage, high reliability with no pinholeing) must be developed and demonstrated. The problems anticipated in such a development may be summarized as follows:

1) Selection of a material suitable for the environmental requirements (particularly sterilization);
2) Development of fabrication techniques for best control of the properties of the manufactured balloon;
3) Demonstration of a complete flotation system.

A development plan for this system is described in this report.

OTHER TECHNOLOGY

Other design and study items of interest are listed in table 19. As indicated each of these would enhance the buoyant station mission although they are not necessarily critical to the feasibility of the mission.

Table 20 lists the major areas of system design that have critical features with respect to the baseline design.

TABLE 19.- ADVANCED TECHNOLOGY REQUIREMENTS AND CRITICAL DESIGN STUDIES

Item	Significance to BVS program
Lightweight, high pressure tankage	Carbon filament tankage could reduce 400 lb BVS to 370 lb.
Position determination of BVS without reference to an orbiter	Would permit locating BVS without orbiting spacecraft. Applicable to flyby missions or as a backup.
Venus radio frequency propagation anomolies	Reduce uncertainties in communication links/or permit less conservatism in link design.
Antenna arrays integral with balloon	Possible future usage for higher data rates or position determination application.
Solar cell arrays integral with balloon	Possible future use for higher power requirements.
Light transmission and scattering properties of Venus atmosphere or clouds	Reduce uncertainties of operation of solar cells in clouds. Provide basis for imaging (TV) experiments.
Spectral response of solar cells	Reduce uncertainties of operation of solar cells in clouds.
Science instrumentation for use in high pressure and temperature environment	Applicable to subsonic probe and drop sondes.
Wind model (including turbulence) for Venus	Reduce uncertainty of BVS drift in atmosphere. Provide better design requirements for BVS in deployment and floatation modes.
Sun angle sensor for operating in diffused light	Possible application to position determination.
RTG development for use in planetary applications	Permit long-term dark side missions or alternative to solar cells on light side, particularly in the clouds.

TABLE 20.- HARDWARE DEVELOPMENT FOR BASELINE SYSTEM

Item	Characteristic	Status
Experiments		
H_2O vapor sensor	----	New technology
Minibiolab	----	New technology
Drop sondes	5 lb	Develop for high temperature + pressure
Subsonic probe	85 lb	
Balloon system		
Balloon	Superpressure 18 ft diam, hydrogen gas, supports 175-lb gondola	In development, design based on NCAR-ghost balloons
Tankage	Aluminum-lined, glass filament wrapped	Development required. Development for boron and carbon filament tanks appears more promising, save 30 lb
Telecommunications		
None		
Power		
Sterilizable batteries	Silver-zinc 1.2 to 15.6 A-hr	Under development by Electric Storage Battery Co. (JPL contracts)
Structures, mechanisms		
Biocanister	0.010-in. aluminum, vented	Biofilter requires development
Heat shield	Carbon-filled, elastomeric silicone ablator, 8.5-ft diam blunt cone shape	In development at Martin Marietta Corporation, ESA 5500 (M)

CONCLUSIONS

The Buoyant Venus Station is feasible for consideration for the 1973 launch opportunity. The specific mission modes considered in this study have covered a wide range of possibilities that can reasonably be extrapolated to a designated mission. Sufficient mission and design detail has been generated (see vol. II and III of this report) to indicate the technical feasibility of such a mission.

The buoyant concept is anticipated to be highly attractive to the scientific community as an instrument platform from which probes may be dropped to the surface. A major part of this appeal may lie in the adaptability of the platform to accommodate a variety of experiments, minimizing the requirements for dense packaging, and thermal control, thus potentially reducing the lead time required for instrumentation development.

The major areas requiring development are the heat shield, science instrumentation, and balloon. The heat shield requirements are not unique to the BVS, but apply to any entry mission. It appears that these requirements can be met by an orderly engineering development program. The balloon requirements are not severe since it is designed for a low velocity deployment in a moderate environment. However, early attention to system development is considered necessary.

Martin Marietta Corporation
Denver, Colorado, January 8, 1969

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APPENDIX

BUOYANT VENUS STATION TEST PROGRAM

by Dale E. White
Martin Marietta Corporation

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APPENDIX

INTRODUCTION

The Buoyant Venus Station (BVS) test program is designed to provide positive confidence in mission success by establishing that all functions are successful in a simulated mission environment, by demonstrating compliance with specifications, and by identifying design problems early.

Testing starts at the lowest assembly level, and interaction effects of each subsequent assembly operation are evaluated from piece-parts through subsystems to the complete system and related operational support equipment (OSE).

The test program requirements result from analysis of the interrelation of the BVS subsystems with functional and operational requirements of both prelaunch operations and the in-flight mission.

Verification of each of these requirements is accomplished during one or more of the planned tests. Development testing obtains basic performance data and identifies problem areas; qualification testing demonstrates design maturity by providing performance margins; and flight acceptance testing, including launch site operations, verifies continued product integrity, demonstrates flight readiness, and provides additional confidence data.

Test Program Summary

Figure A1 provides an overview of the integrated development and qualification test phases for the BVS capsule.

The first phase of this program consists of the supporting research and technology (SRT) development and investigative effort concerned with:

1) Development of the science instruments;
2) Investigation and development of a heat shield design;
3) Development of a complete flotation system consisting of balloon and inflation subsystems.

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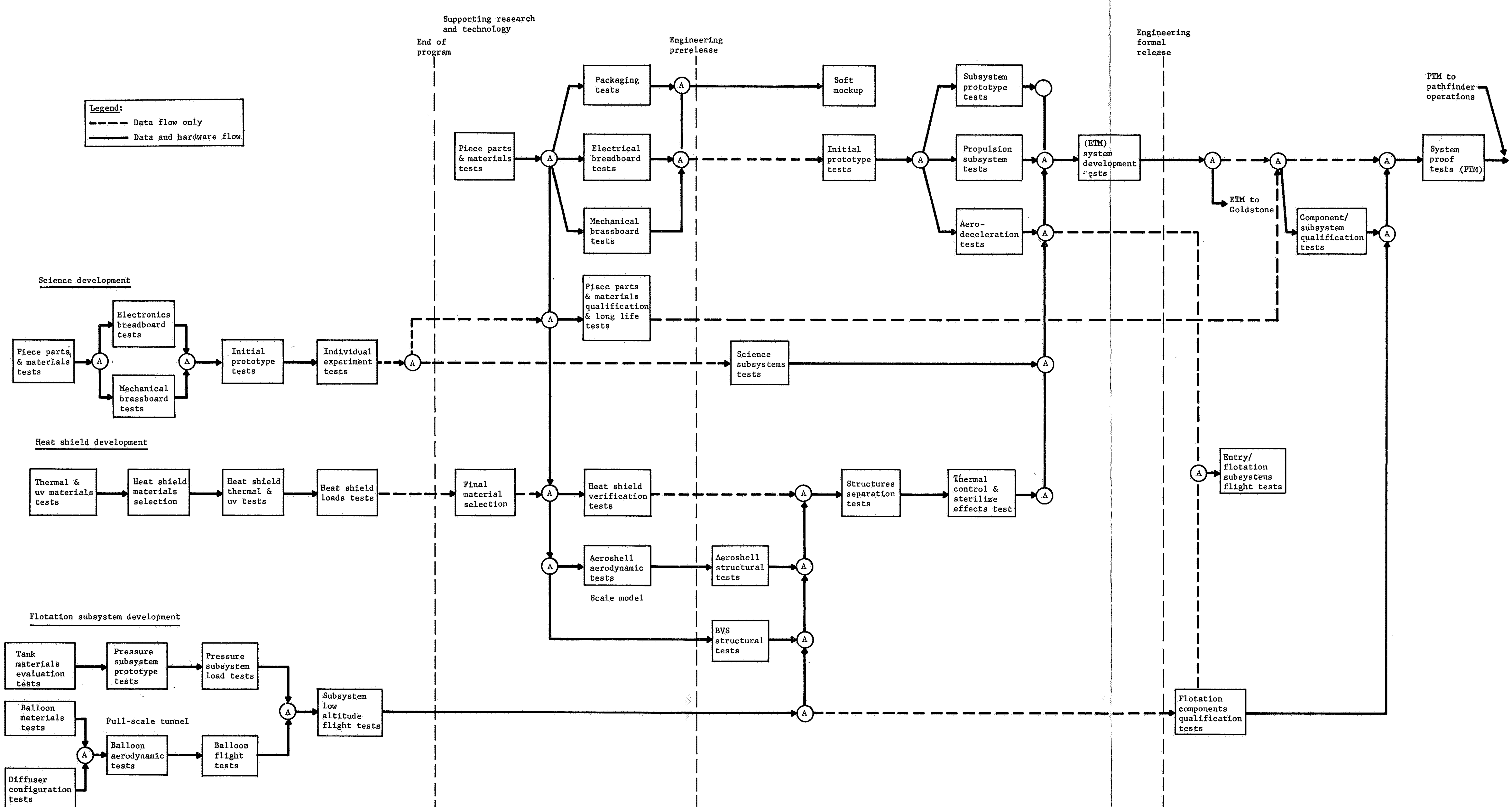

Figure A1.- Integrated Test Plan for Bouyant Venus Station

Initial hardware development involves breadboarding and testing circuits, brassboarding mechanical elements, and testing potential packaging concepts. Scale model aeroshells will be tested in the wind tunnel to evolve the required configuration. Figure A2 shows the aeroshell development test program. This configuration will be assembled into a full-scale model using materials evolved from preliminary materials qualification tests. Stress and load tests will be performed on this model to verify the math model design. A similar sequence of tests will be performed on the BVS structure (fig. A3). Propulsion subsystem testing will be performed to verify vacuum start ability in addition to normal environmental tests as shown in figure A4. The aerodecelerator development tests as shown in figure A5 will be performed to simulate, as nearly as possible, actual deployment loads after having been subjected to normal packing and environmental tests.

Full-scale structural elements will be assembled into the thermal control test model (TCTM). This model will be subjected to both thermal vacuum and simulated heat-sterilization tests to evaluate the thermal controls and to evolve a requisite heat-sterilization cycle (fig. A6).

At the conclusion of these tests, the prototype equipment and structures will be modified as necessary and assembled into the engineering test model. This full-scale functional model of the BVS system will be tested to evaluate subsystem interfaces and system performance (fig. A7).

Formal engineering release will initiate the qualification phase. These tests will demonstrate the ability of the equipment to function according to specification during and after exposure to all mission environments and operations (see fig. A8).

The flotation system is subjected to an environment simulating the Venus atmosphere by deployment tests from an aircraft.

OSE development and test will parallel that of the flight capsule system. The system test complex will be integrated with flight capsule system at appropriate points, which will verify the interactions of this equipment.

Figure A9 shows the flight acceptance test operations performed at contractor's facilities before shipment of the BVS/entry vehicle to KSC. These tests are performed to verify that each item accepted is identical in all respects to the qualified configuration. All of the exposures will be of sufficient functional or environmental severity to permit potential failures to be screened out before an item is incorporated in the capsule.

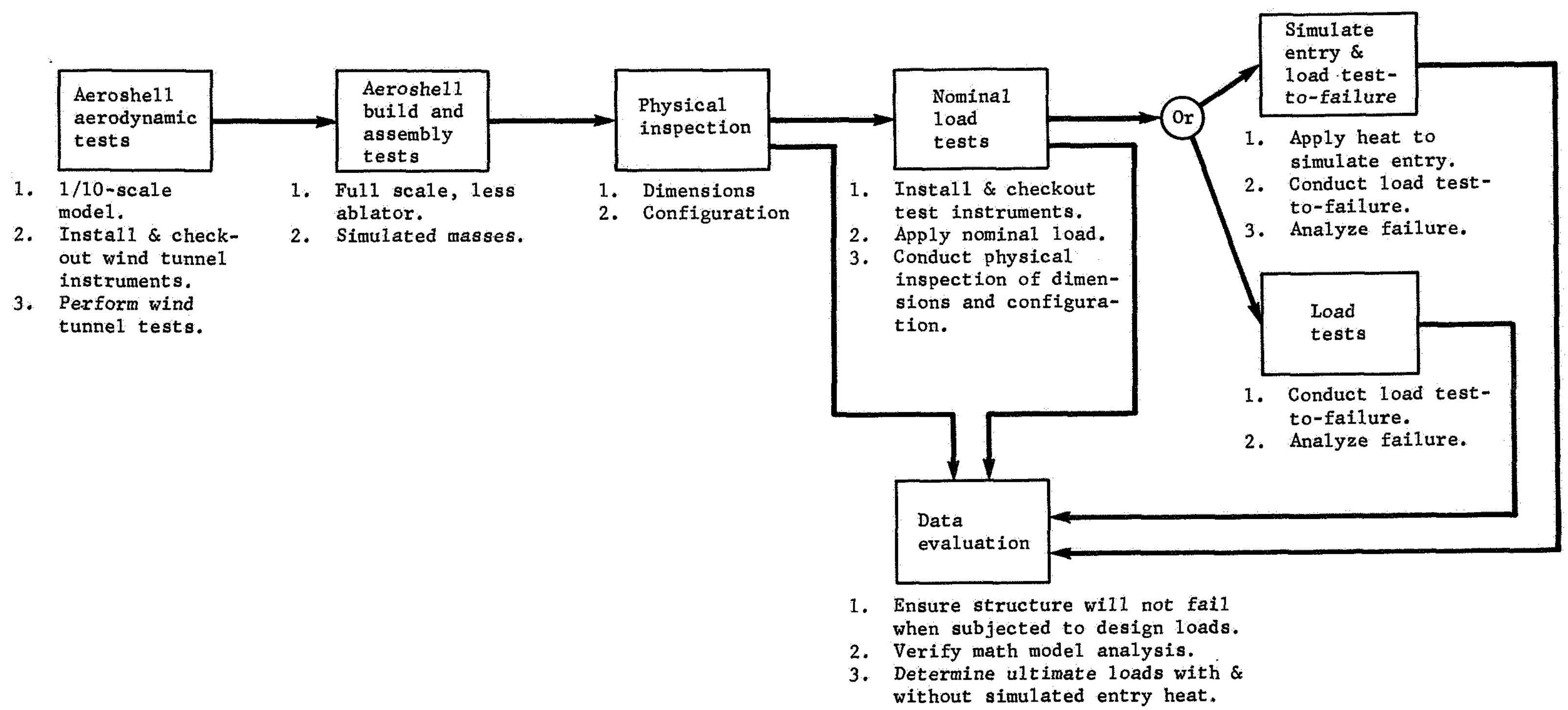

Figure A2.- Aeroshell Development Program

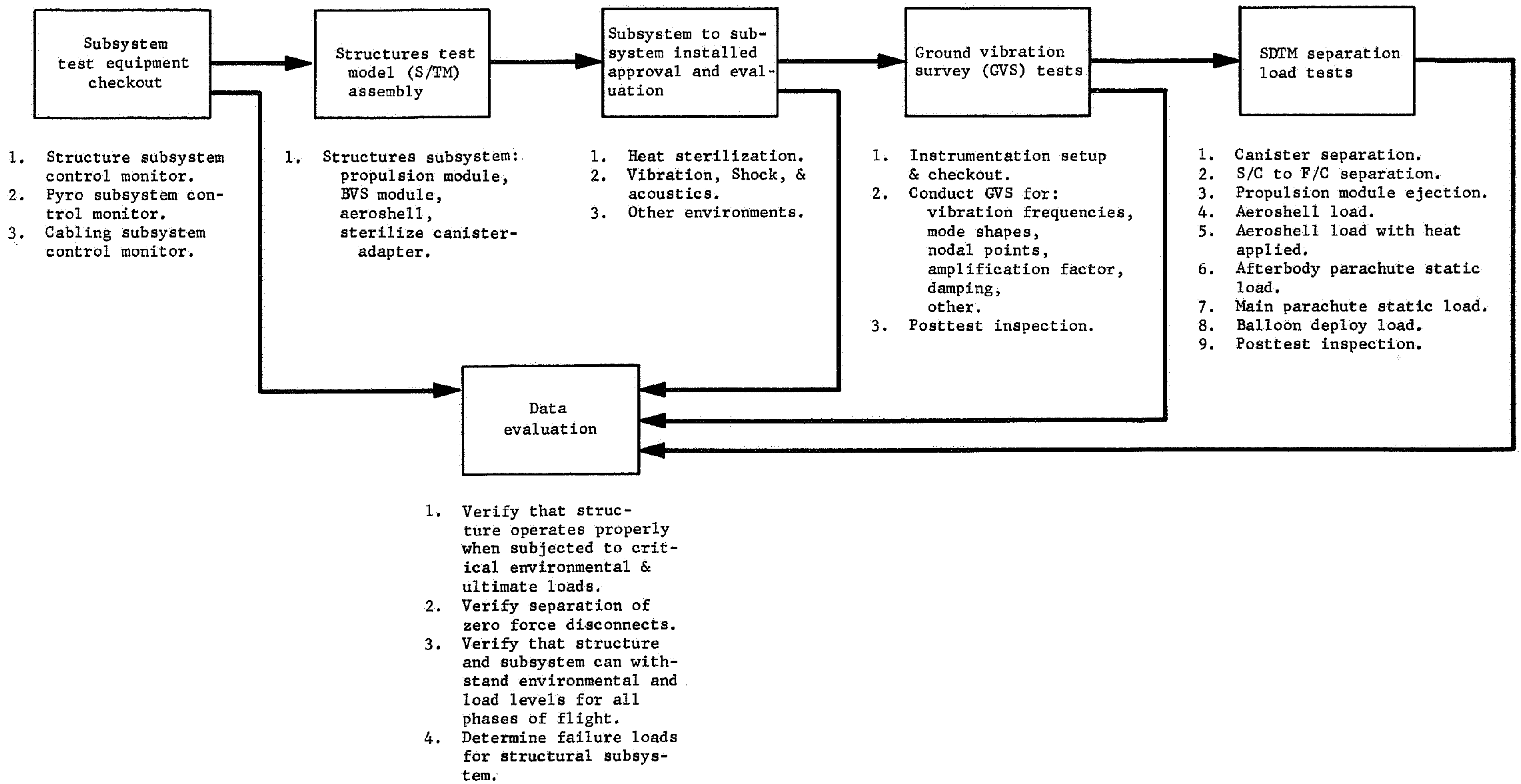

Figure A3.- BVS Structural Development Program

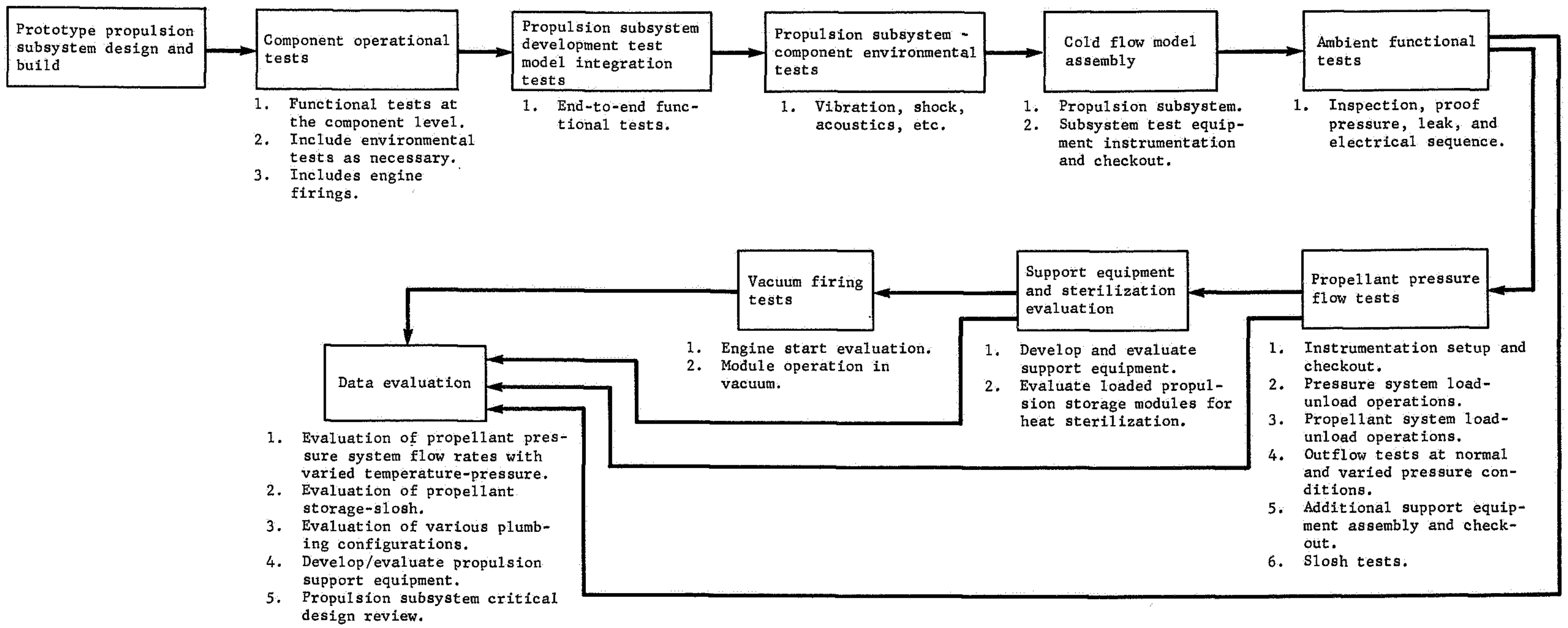

Figure A4.- Propulsion Subsystem Development Program

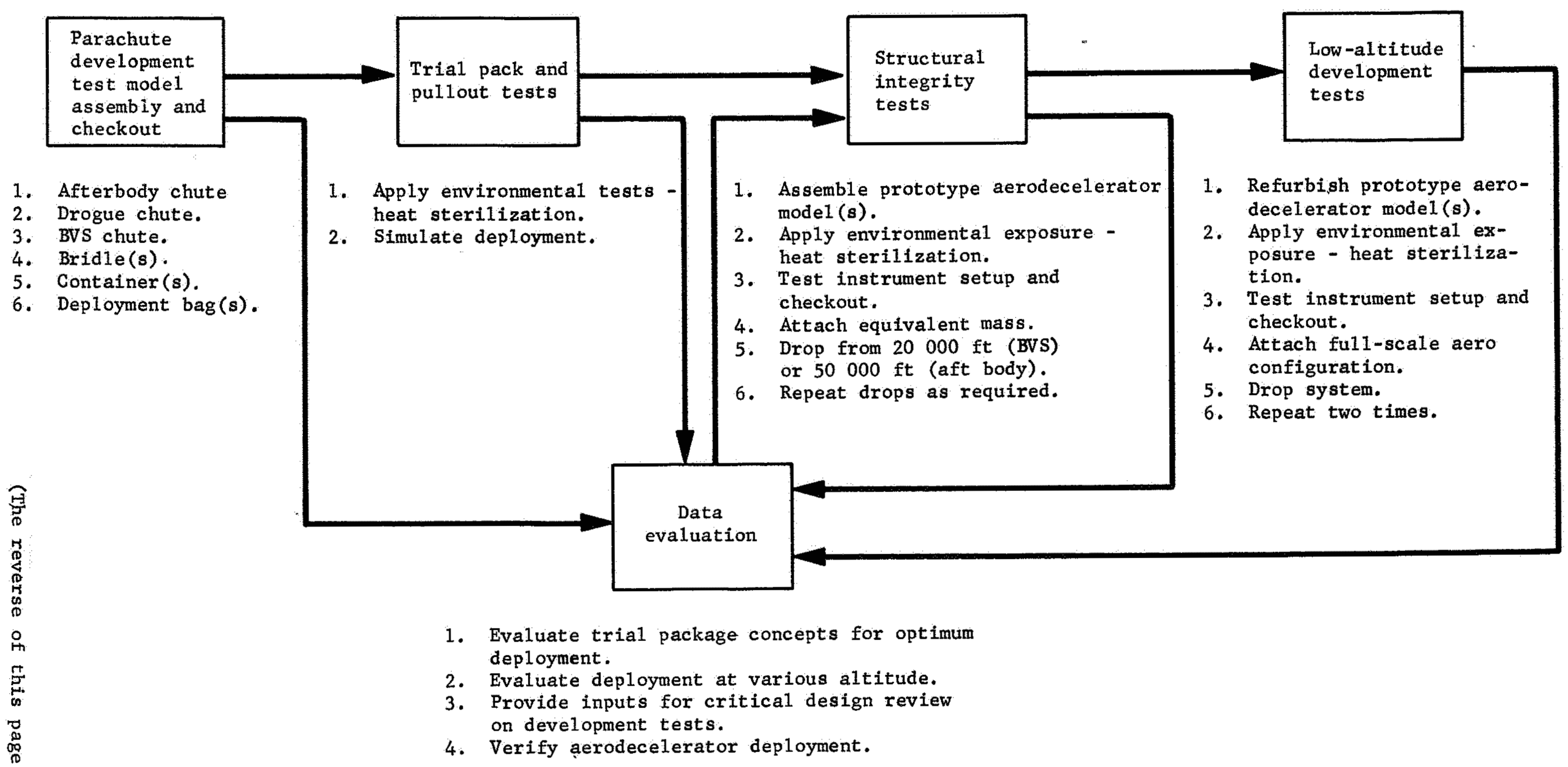

Figure A5.- Aerodecelerator Development Program

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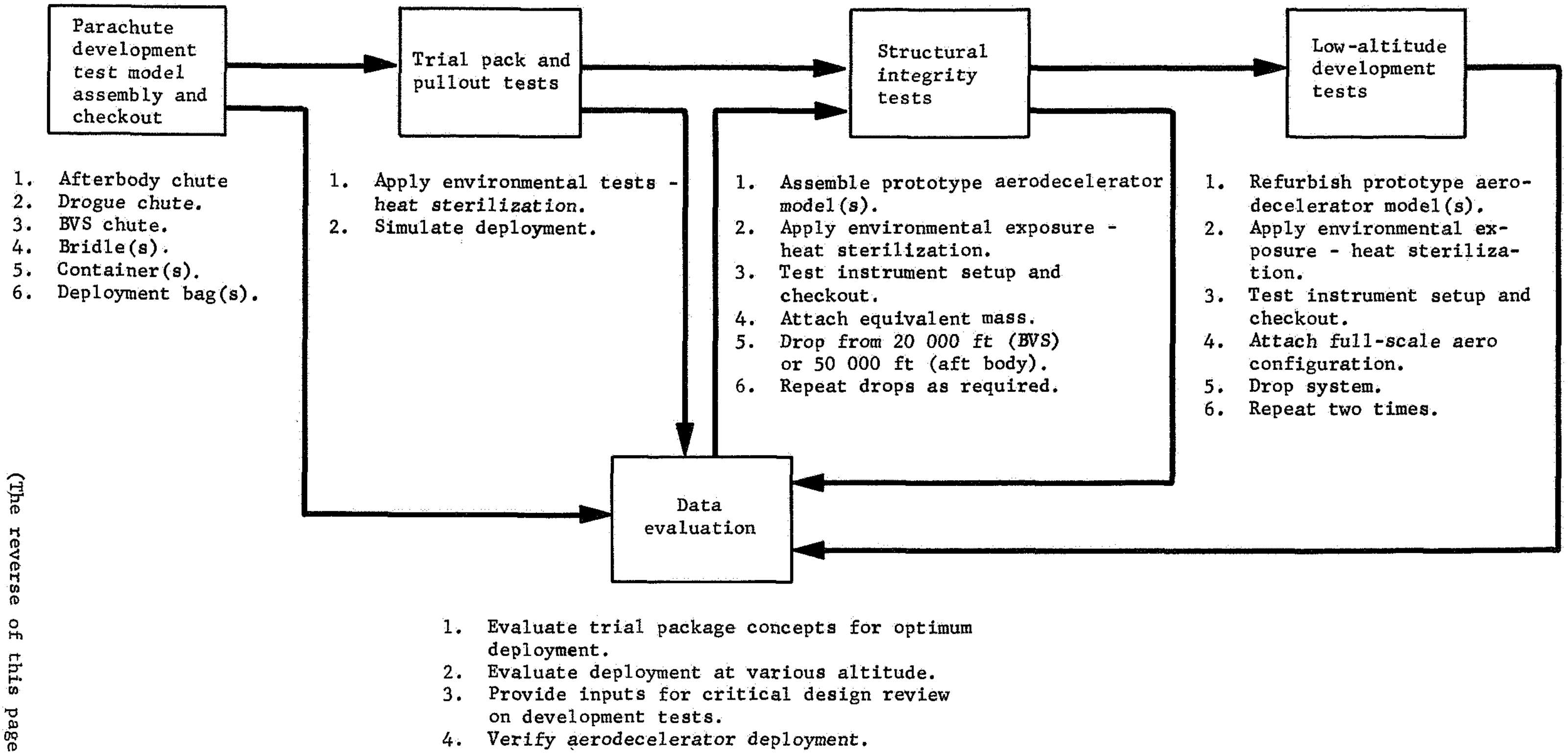

Figure A5.- Aerodecelerator Development Program

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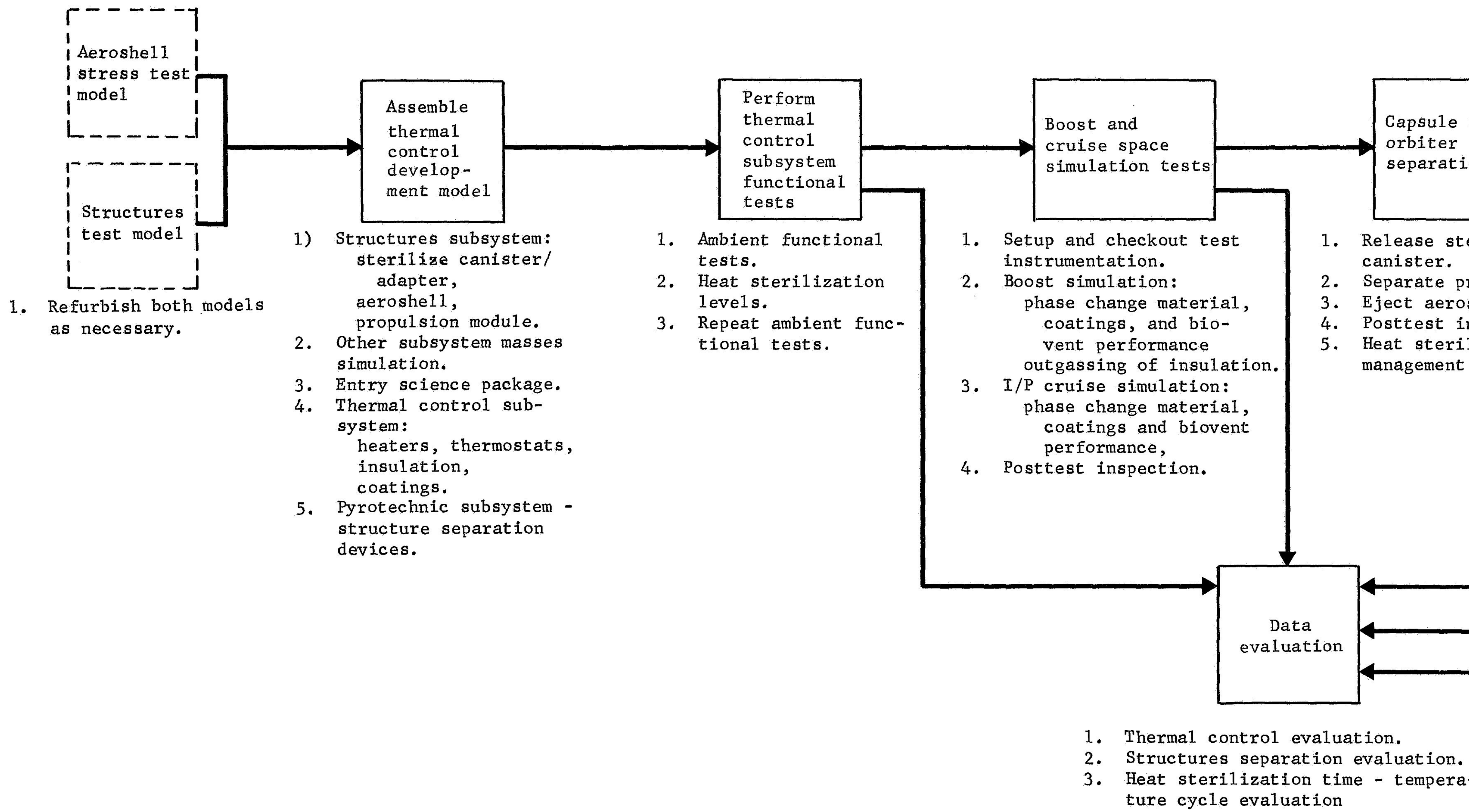
Aeroshell stress test model
Structures test model
1. Refurbish both models as necessary.
Assemble thermal control develop-ment model
1) Structures subsystem: sterilize canister/ adapter, aeroshell, propulsion module.
2. Other subsystem masses simulation.
3. Entry science package.
4. Thermal control sub-system: heaters, thermostats, insulation, coatings.
5. Pyrotechnic subsystem - structure separation devices.
Perform thermal control subsystem functional tests
1. Ambient functional tests.
2. Heat sterilization levels.
3. Repeat ambient func-tional tests.
Boost and cruise space simulation tests
1. Setup and checkout test instrumentation.
2. Boost simulation: phase change material, coatings, and bio-vent performance outgassing of insulation.
3. I/P cruise simulation: phase change material, coatings and biovent performance,
4. Posttest inspection.
Capsule
orbiter
1. Release
canister.
2. Separate
3. Eject
4. Posttest
5. Heat
management
Data evaluation
1. Thermal control evaluation.
2. Structures separation evaluation.
3. Heat sterilization time - tempera-ture cycle evaluation

1

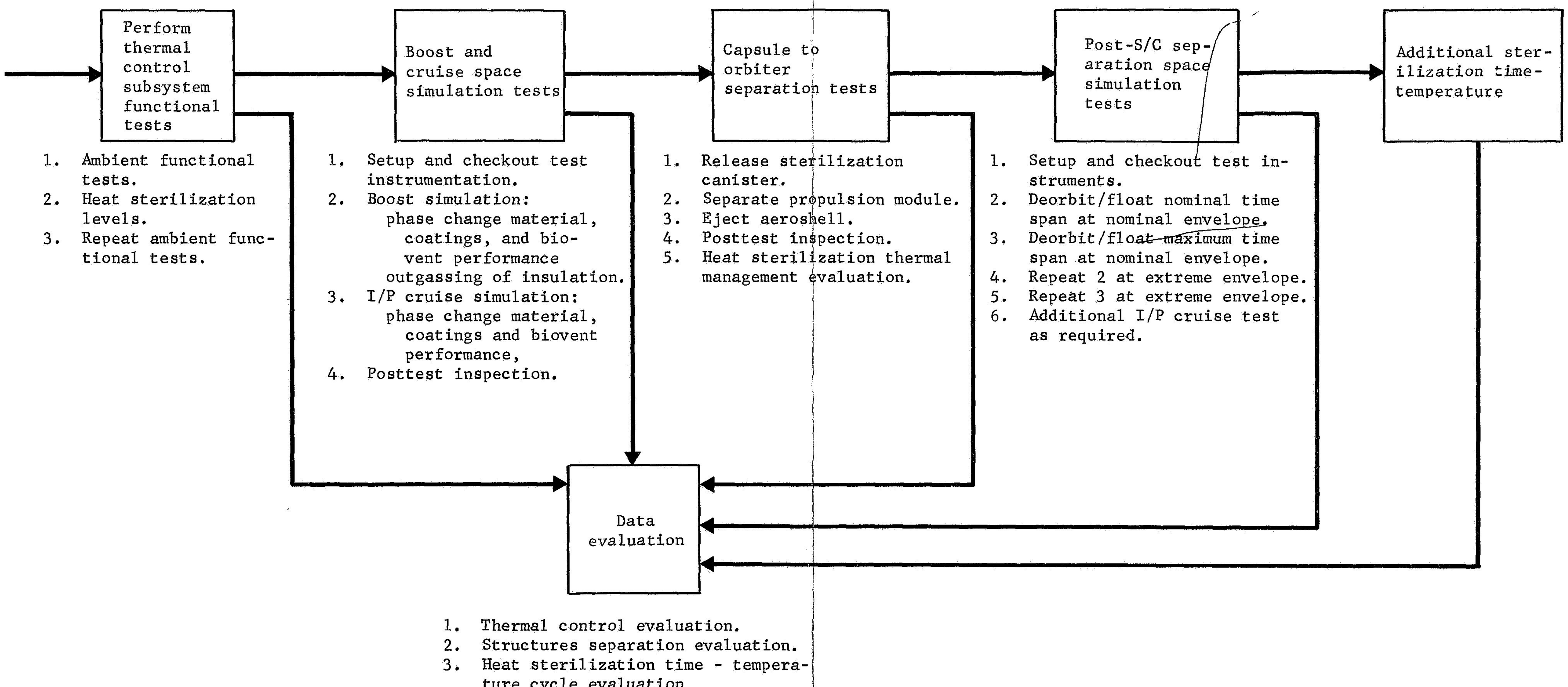

Figure A6.- Thermal Control and Sterilization Effects Test Program

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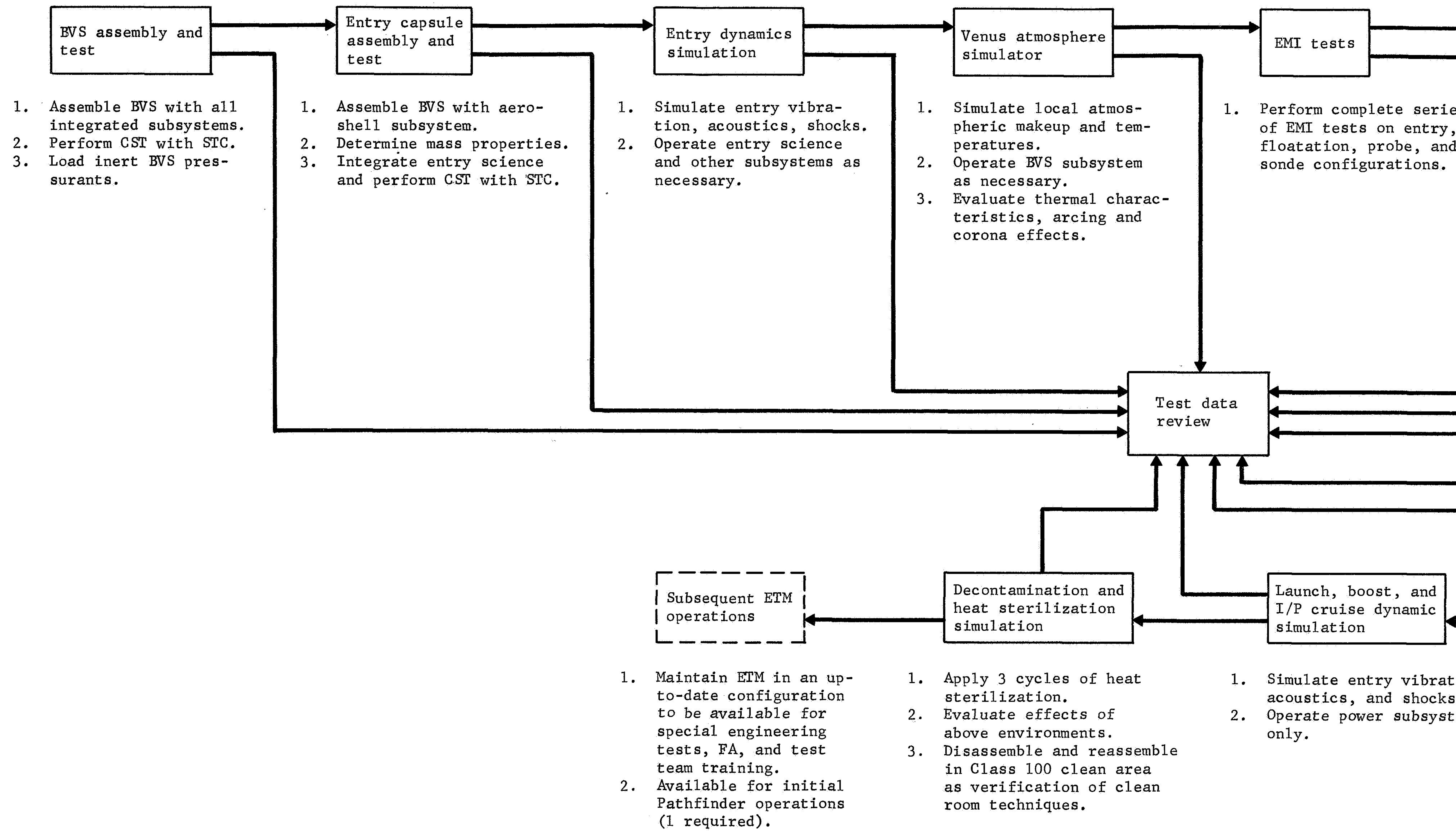


BVS assembly and test
1. Assemble BVS with all integrated subsystems.
2. Perform CST with STC.
3. Load inert BVS pressurants.
Entry capsule assembly and test
1. Assemble BVS with aeroshell subsystem.
2. Determine mass properties.
3. Integrate entry science and perform CST with STC.
Entry dynamics simulation
1. Simulate entry vibration, acoustics, shocks.
2. Operate entry science and other subsystems as necessary.
Venus atmosphere simulator
1. Simulate local atmospheric makeup and temperatures.
2. Operate BVS subsystem as necessary.
3. Evaluate thermal characteristics, arcing and corona effects.
EMI tests
1. Perform complete series of EMI tests on entry, floatation, probe, and sonde configurations.
Test data review
Subsequent ETM operations
1. Maintain ETM in an up-to-date configuration to be available for special engineering tests, FA, and test team training.
2. Available for initial Pathfinder operations (1 required).
Decontamination and heat sterilization simulation
1. Apply 3 cycles of heat sterilization.
2. Evaluate effects of above environments.
3. Disassemble and reassemble in Class 100 clean area as verification of clean room techniques.
Launch, boost, and I/P cruise dynamic simulation
1. Simulate entry vibrati
acoustics, and shocks.
2. Operate power subsyste
only.

1

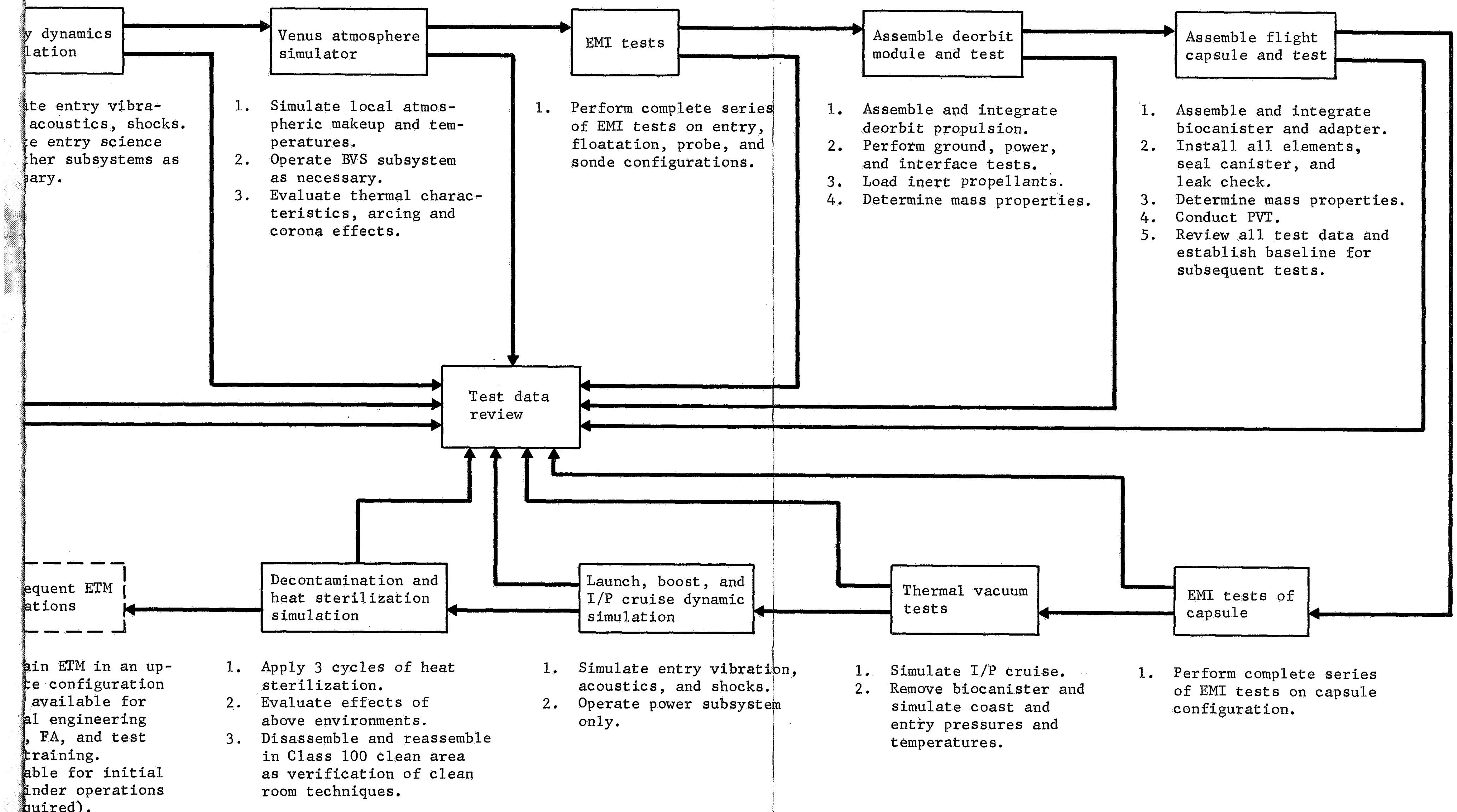
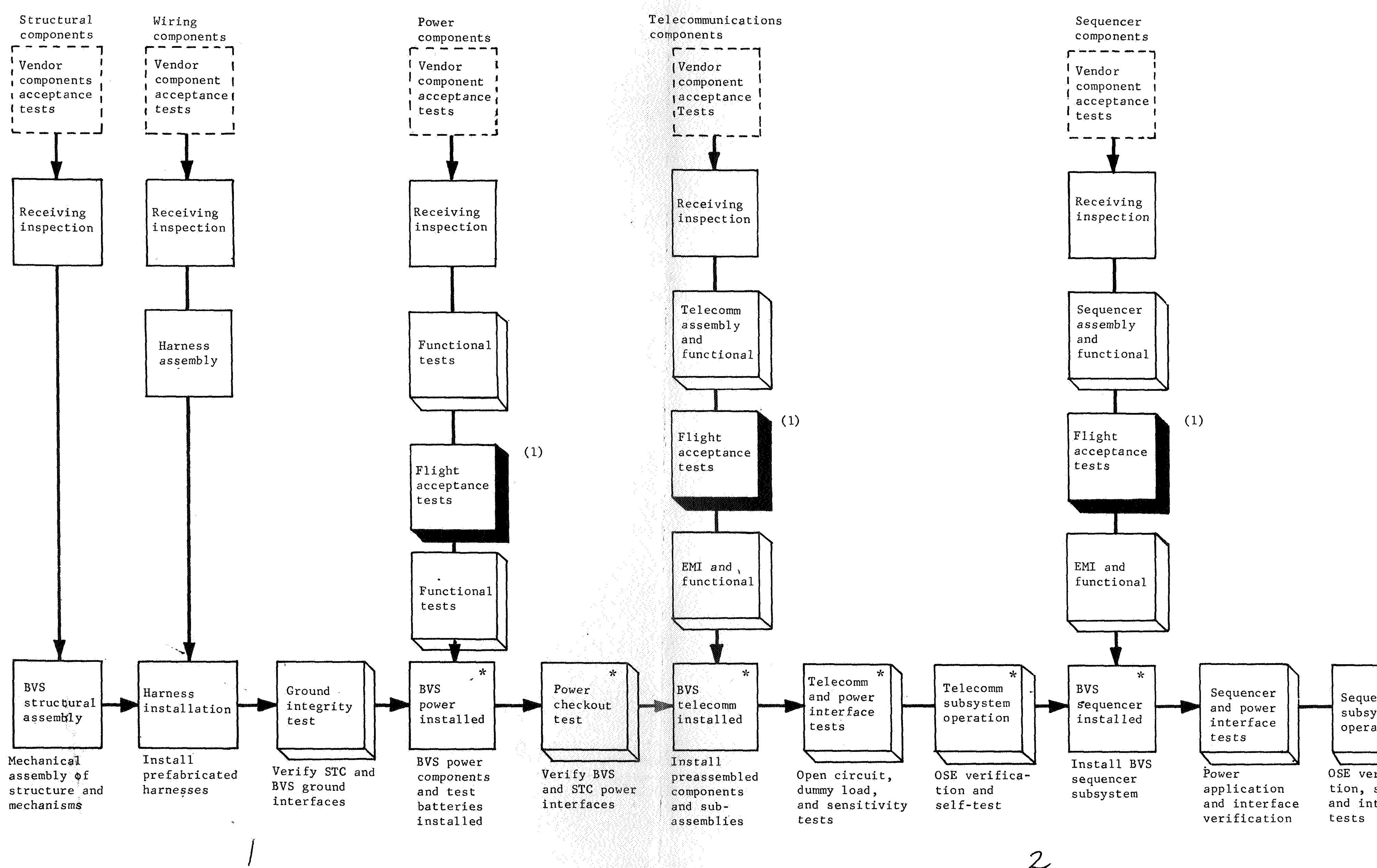
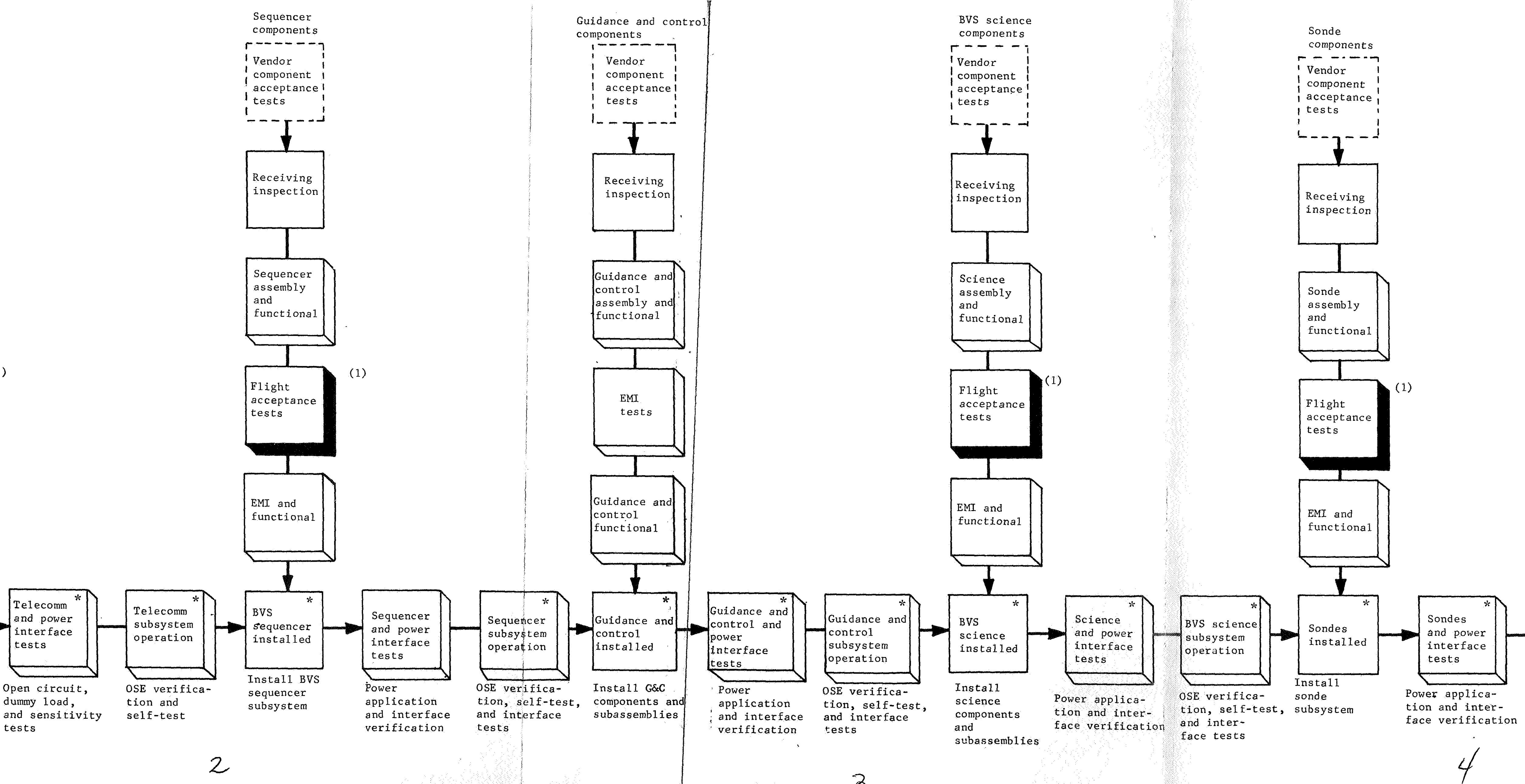
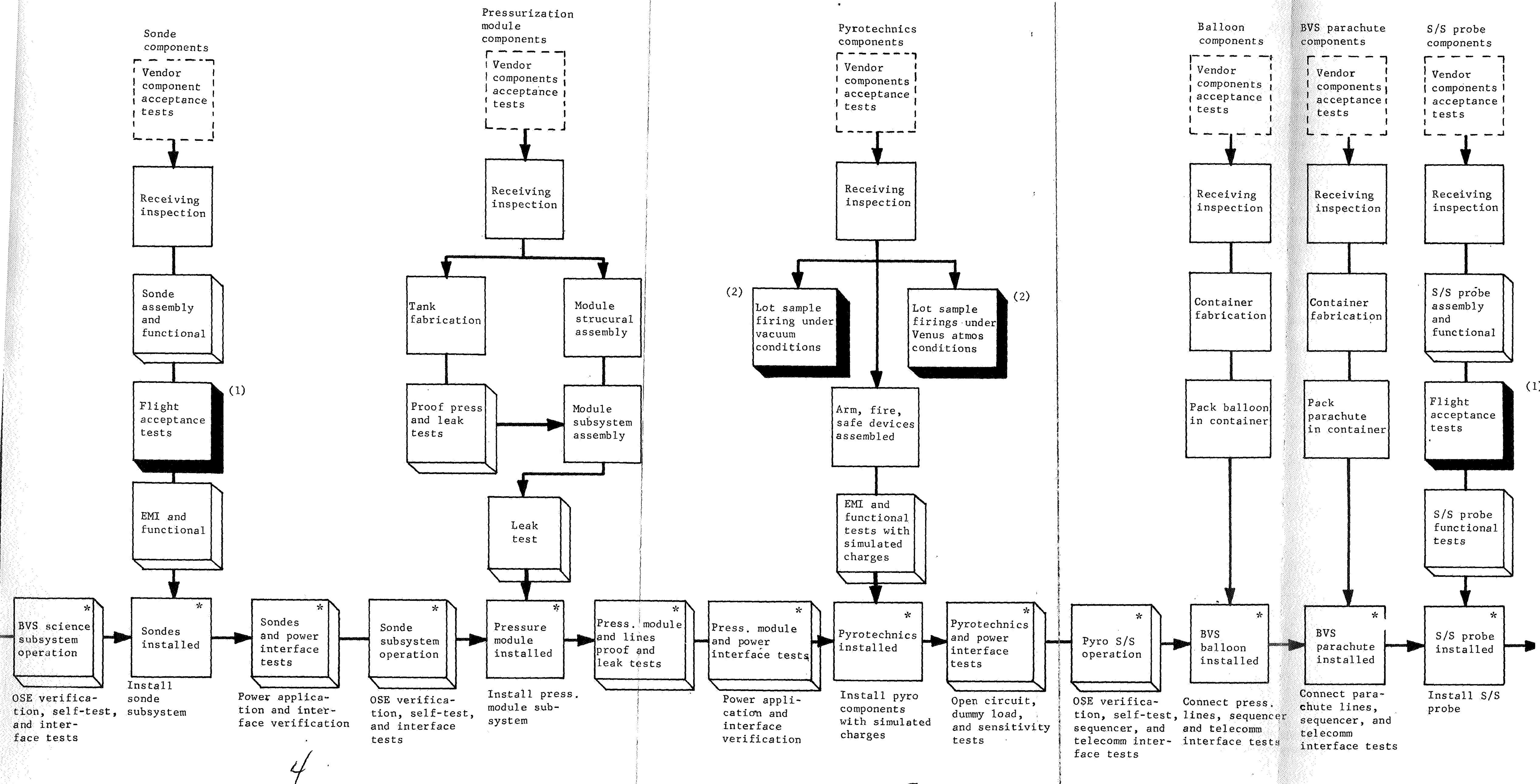


Figure A7.- Engineering Test Model Test Program

2


Structural components
Vendor components acceptance tests
Receiving inspection
BVS structural assembly
Mechanical assembly of structure and mechanisms
Wiring components
Vendor component acceptance tests
Receiving inspection
Harness assembly
Harness installation
Install prefabricated harnesses
Ground integrity test
Verify STC and BVS ground interfaces
Power components
Vendor component acceptance tests
Receiving inspection
Functional tests
Flight acceptance tests
(1)
Functional tests
BVS power installed *
BVS power components and test batteries installed
Power checkout test *
Verify BVS and STC power interfaces
Telecommunications components
Vendor component acceptance Tests
Receiving inspection
Telecomm assembly and functional
Flight acceptance tests
(1)
EMI and functional
BVS telecomm installed *
Install preassembled components and sub-assemblies
Telecomm and power interface tests *
Open circuit, dummy load, and sensitivity tests
Telecomm subsystem operation *
OSE verification and self-test
Sequencer components
Vendor component acceptance tests
Receiving inspection
Sequencer assembly and functional
Flight acceptance tests
(1)
EMI and functional
BVS sequencer installed *
Install BVS sequencer subsystem
Sequencer and power interface tests
Power application and interface verification
Sequer subsys operat
OSE ver tion, s and int tests
1
2


Sequencer components
Vendor component acceptance tests
Receiving inspection
Sequencer assembly and functional
Flight acceptance tests
(1)
EMI and functional
Guidance and control components
Vendor component acceptance tests
Receiving inspection
Guidance and control assembly and functional
EMI tests
Guidance and control functional
BVS science components
Vendor component acceptance tests
Receiving inspection
Science assembly and functional
Flight acceptance tests
(1)
EMI and functional
Sonde components
Vendor component acceptance tests
Receiving inspection
Sonde assembly and functional
Flight acceptance tests
(1)
EMI and functional
Telecomm and power interface tests *
Open circuit, dummy load, and sensitivity tests
Telecomm subsystem operation *
OSE verification and self-test
BVS sequencer installed *
Install BVS sequencer subsystem
Sequencer and power interface tests
Power application and interface verification
Sequencer subsystem operation *
OSE verification, self-test, and interface tests
Guidance and control installed *
Install G&C components and subassemblies
Guidance and control and power interface tests *
Power application and interface verification
Guidance and control subsystem operation *
OSE verification, self-test, and interface tests
BVS science installed *
Install science components and subassemblies
Science and power interface tests *
Power application and interface verification
BVS science subsystem operation *
OSE verification, self-test, and interface tests
Sondes installed *
Install sonde subsystem
Sondes and power interface tests *
Power application and interface verification
2
3
4



Sonde components
Vendor component acceptance tests
Receiving inspection
Sonde assembly and functional
Flight acceptance tests
(1)
EMI and functional
Pressurization module components
Vendor components acceptance tests
Receiving inspection
Tank fabrication
Module strucural assembly
Proof press and leak tests
Module subsystem assembly
Leak test
Pyrotechnics components
Vendor components acceptance tests
Receiving inspection
(2)
Lot sample firing under vacuum conditions
Lot sample firings under Venus atmos conditions
(2)
Arm, fire, safe devices assembled
EMI and functional tests with simulated charges
Balloon components
Vendor components acceptance tests
Receiving inspection
Container fabrication
Pack balloon in container
BVS parachute components
Vendor components acceptance tests
Receiving inspection
Container fabrication
Pack parachute in container
S/S probe components
Vendor components acceptance tests
Receiving inspection
S/S probe assembly and functional
Flight acceptance tests
(1)
S/S probe functional tests
* BVS science subsystem operation
OSE verification, self-test, and interface tests
* Sondes installed
Install sonde subsystem
* Sondes and power interface tests
Power application and interface verification
* Sonde subsystem operation
OSE verification, self-test, and interface tests
* Pressure module installed
Install press. module subsystem
* Press. module and lines proof and leak tests
* Press. module and power interface tests
Power application and interface verification
* Pyrotechnics installed
Install pyro components with simulated charges
* Pyrotechnics and power interface tests
Open circuit, dummy load, and sensitivity tests
* Pyro S/S operation
OSE verification, self-test, sequencer, and telecomm interface tests
* BVS balloon installed
Connect press. lines, sequencer and telecomm interface tests
* BVS parachute installed
Connect parachute lines, sequencer, and telecomm interface tests
* S/S probe installed
Install S/S probe
4
5

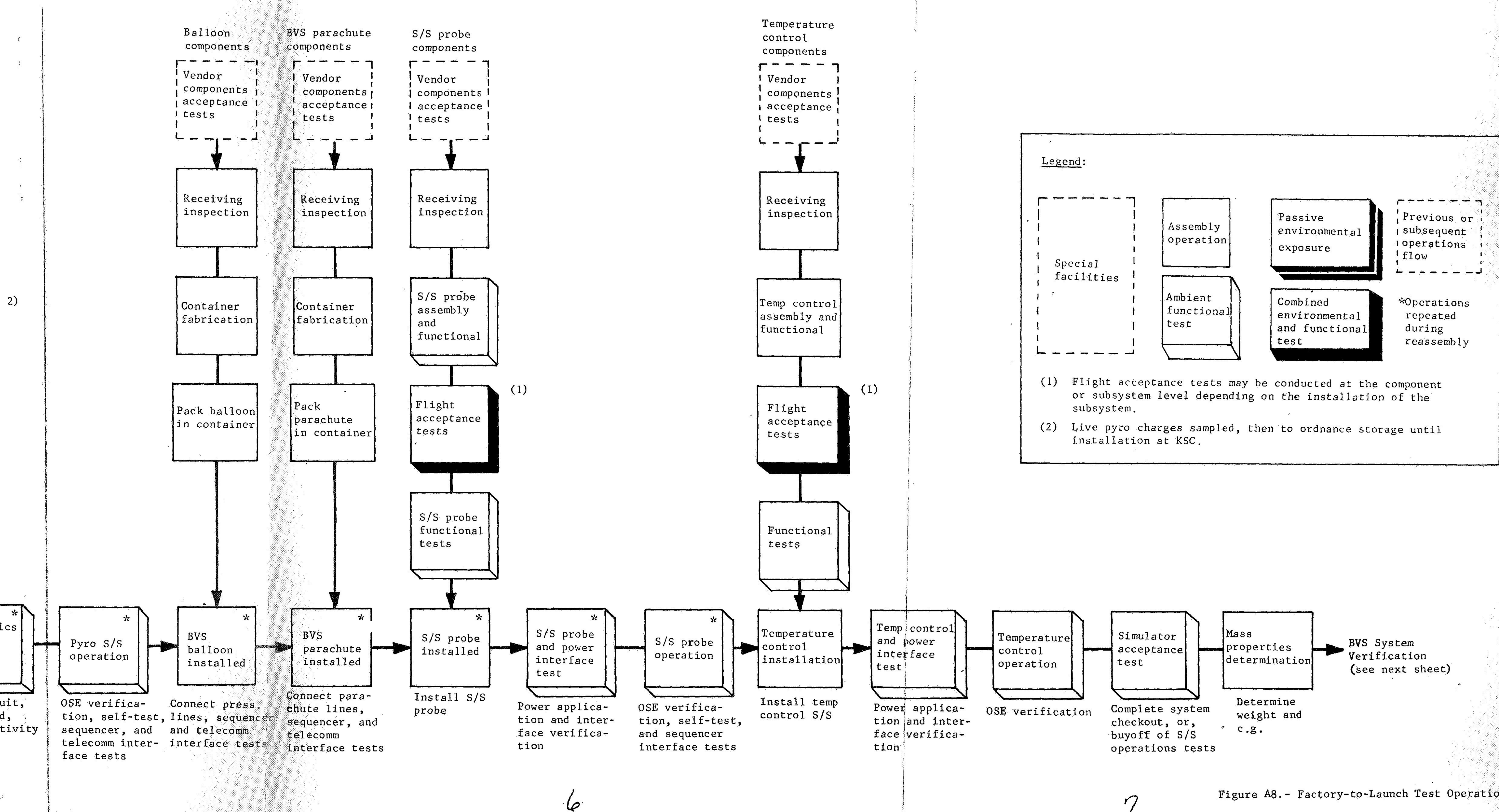
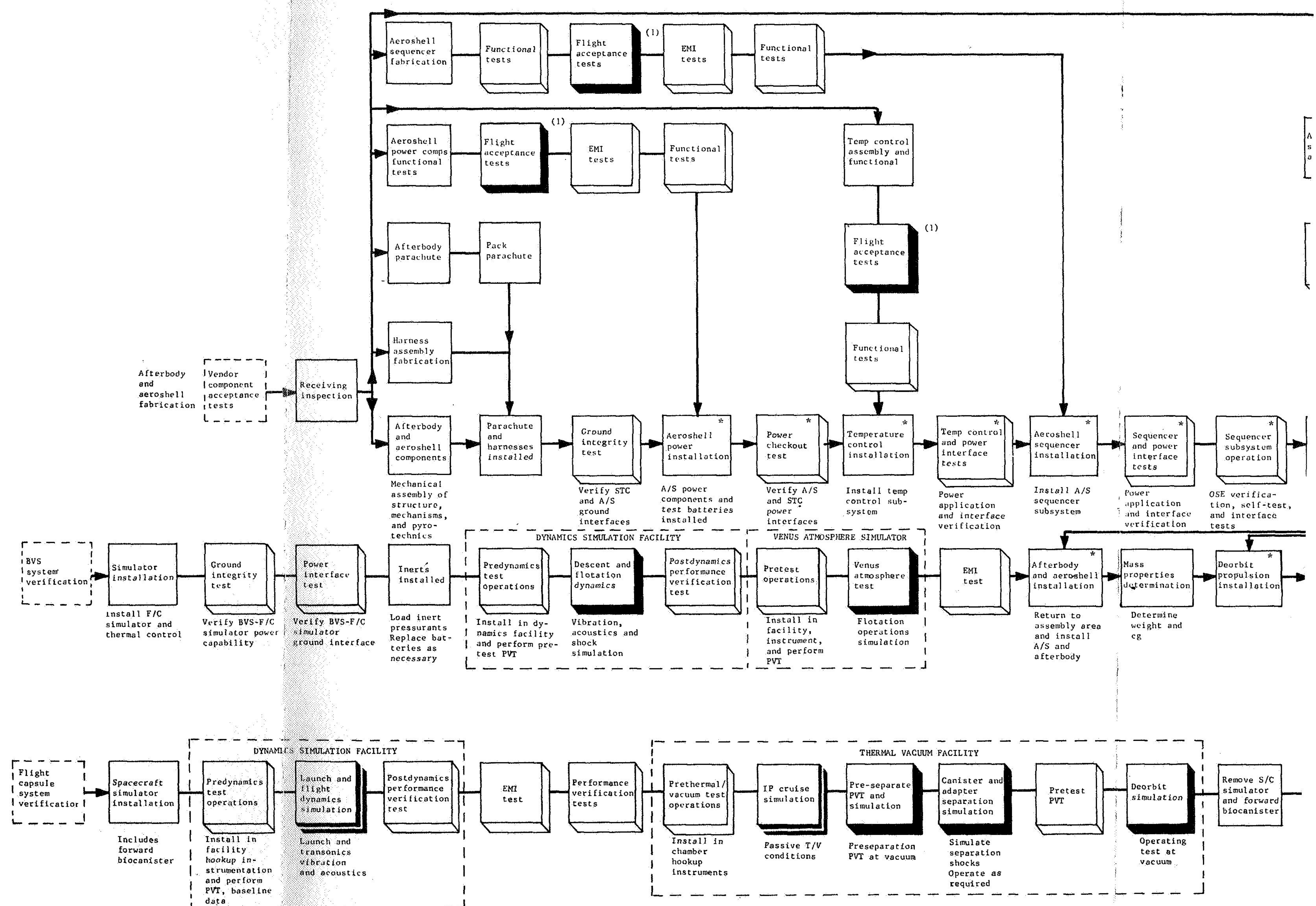


Figure A8.- Factory-to-Launch Test Operations

1

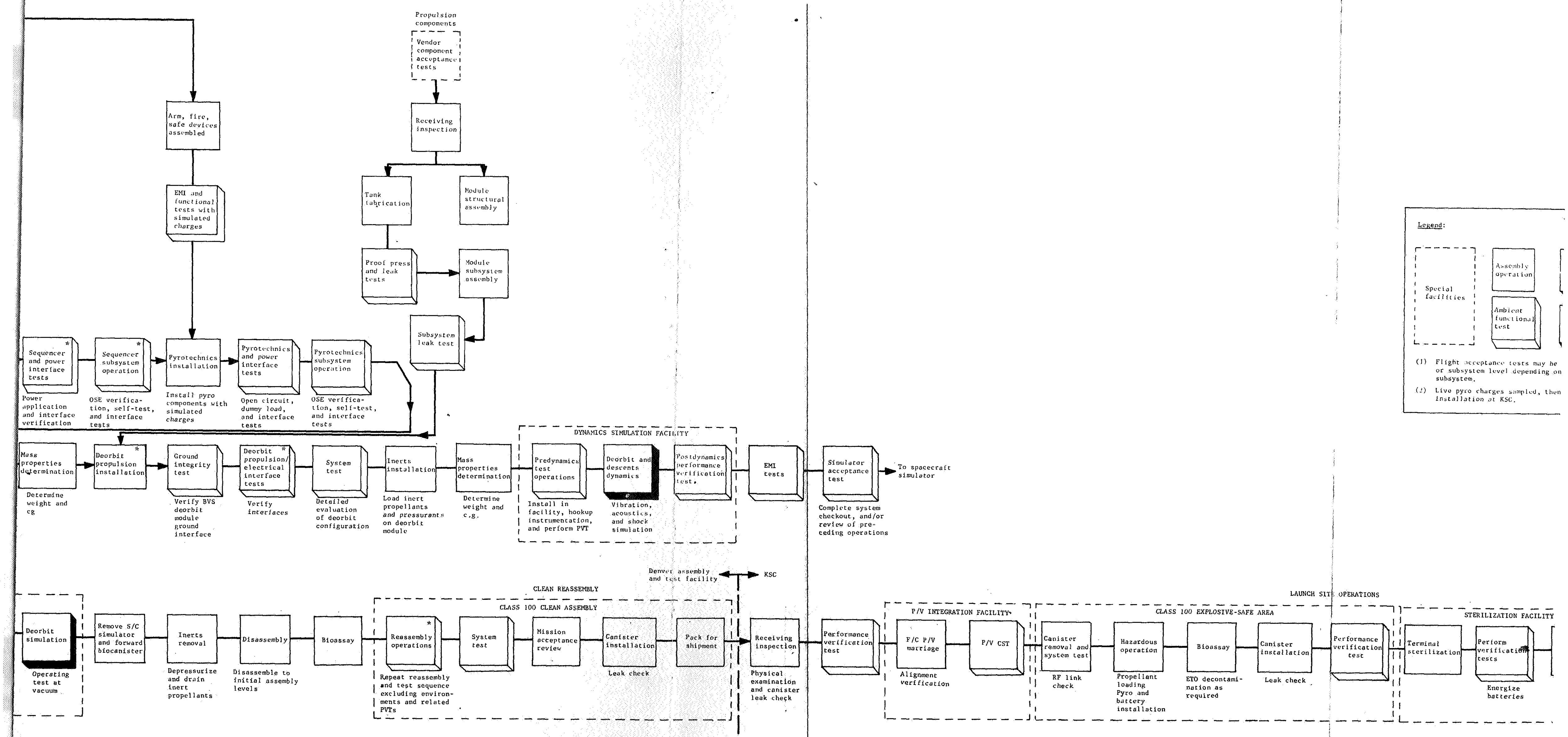
2



Aeroshell sequencer fabrication
Functional tests
Flight acceptance tests
(1)
EMI tests
Functional tests
Aeroshell power comps functional tests
Flight acceptance tests
(1)
EMI tests
Functional tests
Temp control assembly and functional
Flight acceptance tests
(1)
Functional tests
Afterbody parachute
Pack parachute
Harness assembly fabrication
Afterbody and aeroshell fabrication
Vendor component acceptance tests
Receiving inspection
Afterbody and aeroshell components
Mechanical assembly of structure, mechanisms, and pyro-technics
Parachute and harnesses installed
Ground integrity test
Verify STC and A/S ground interfaces
* Aeroshell power installation
A/S power components and test batteries installed
* Power checkout test
Verify A/S and STC power interfaces
* Temperature control installation
Install temp control sub-system
* Temp control and power interface tests
Power application and interface verification
* Aeroshell sequencer installation
Install A/S sequencer subsystem
* Sequencer and power interface tests
Power application and interface verification
* Sequencer subsystem operation
OSE verification, self-test, and interface tests
BVS system verification
Simulator installation
Install F/C simulator and thermal control
Ground integrity test
Verify BVS-F/C simulator power capability
Power interface test
Verify BVS-F/C simulator ground interface
Inerts installed
Load inert pressurants Replace batteries as necessary
DYNAMICS SIMULATION FACILITY
Predynamics test operations
Install in dynamics facility and perform pre-test PVT
Descent and flotation dynamics
Vibration, acoustics and shock simulation
Postdynamics performance verification test
VENUS ATMOSPHERE SIMULATOR
Pretest operations
Install in facility, instrument, and perform PVT
Venus atmosphere test
Flotation operations simulation
EMI test
* Afterbody and aeroshell installation
Return to assembly area and install A/S and afterbody
Mass properties determination
Determine weight and cg
* Deorbit propulsion installation
Flight capsule system verification
Spacecraft simulator installation
Includes forward biocanister
DYNAMICS SIMULATION FACILITY
Predynamics test operations
Install in facility hookup instrumentation and perform PVT, baseline data
Launch and flight dynamics simulation
Launch and transonics vibration and acoustics
Postdynamics performance verification test
EMI test
Performance verification tests
THERMAL VACUUM FACILITY
Prethermal/vacuum test operations
Install in chamber hookup instruments
IP cruise simulation
Passive T/V conditions
Pre-separate PVT and simulation
Preseparation PVT at vacuum
Canister and adapter separation simulation
Simulate separation shocks Operate as required
Pretest PVT
Deorbit simulation
Operating test at vacuum
Remove S/C simulator and forward biocanister

3

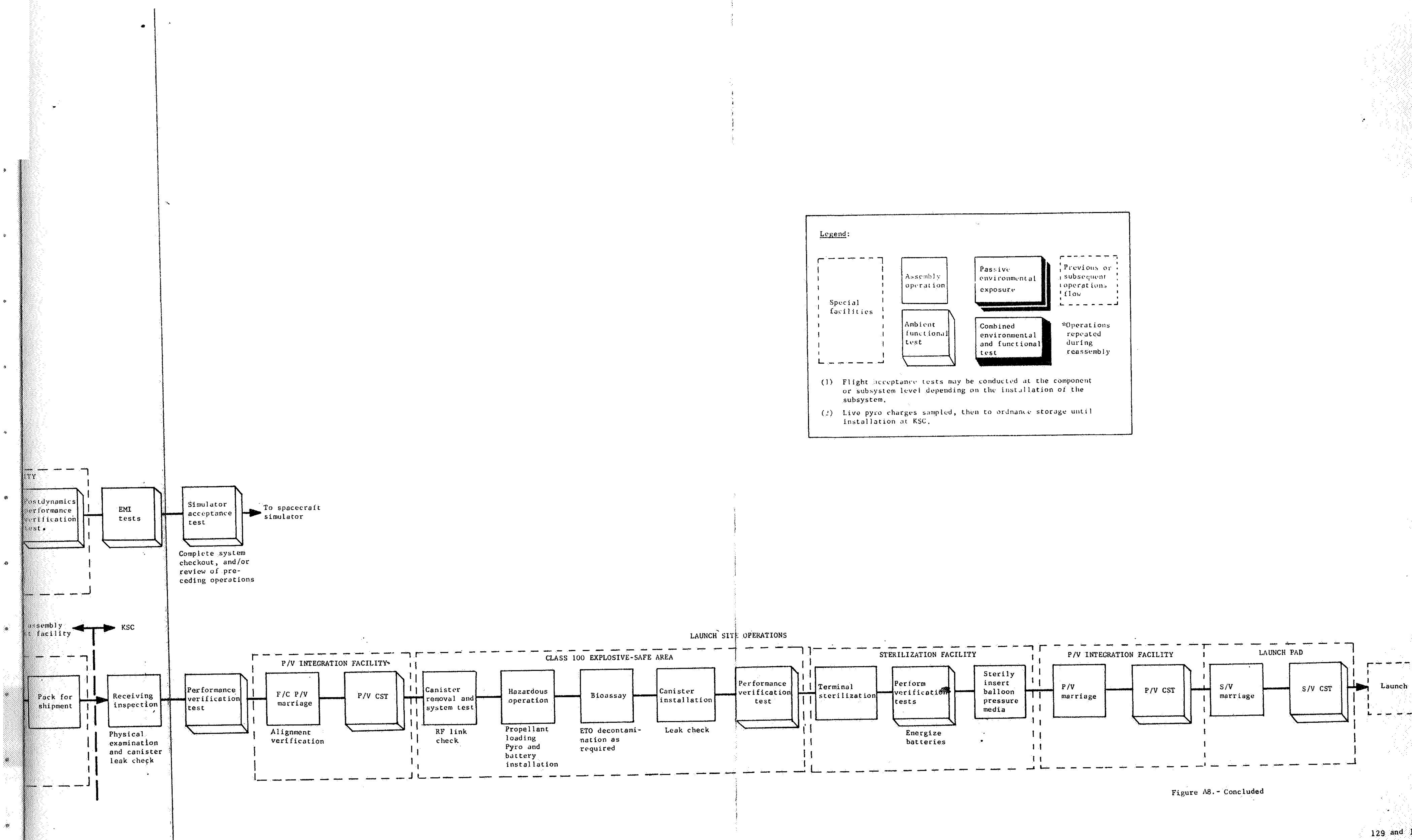
4



Propulsion components
Vendor component acceptance tests
Receiving inspection
Tank fabrication
Module structural assembly
Proof press and leak tests
Module subsystem assembly
Subsystem leak test
Arm, fire, safe devices assembled
EMI and functional tests with simulated charges
Sequencer and power interface tests
Power application and interface verification
Sequencer subsystem operation
OSE verification, self-test, and interface tests
Pyrotechnics installation
Install pyro components with simulated charges
Pyrotechnics and power interface tests
Open circuit, dummy load, and interface tests
Pyrotechnics subsystem operation
OSE verification, self-test, and interface tests
Mass properties determination
Determine weight and cg
Deorbit propulsion installation
Ground integrity test
Verify BVS deorbit module ground interface
Deorbit propulsion/electrical interface tests
Verify interfaces
System test
Detailed evaluation of deorbit configuration
Inerts installation
Load inert propellants and pressurants on deorbit module
Mass properties determination
Determine weight and c.g.
DYNAMICS SIMULATION FACILITY
Predynamics test operations
Install in facility, hookup instrumentation, and perform PVT
Deorbit and descents dynamics
Vibration, acoustics, and shock simulation
Postdynamics performance verification test.
EMI tests
Simulator acceptance test
Complete system checkout, and/or review of preceding operations
To spacecraft simulator
Deorbit simulation
Operating test at vacuum
Remove S/C simulator and forward biocanister
Inerts removal
Depressurize and drain inert propellants
Disassembly
Disassemble to initial assembly levels
Bioassay
CLEAN REASSEMBLY
CLASS 100 CLEAN ASSEMBLY
Reassembly operations
Repeat reassembly and test sequence excluding environments and related PVTs
System test
Mission acceptance review
Canister installation
Leak check
Pack for shipment
Denver assembly and test facility
KSC
Receiving inspection
Physical examination and canister leak check
Performance verification test
LAUNCH SITE OPERATIONS
P/V INTEGRATION FACILITY
F/C P/V marriage
Alignment verification
P/V CST
CLASS 100 EXPLOSIVE-SAFE AREA
Canister removal and system test
RF link check
Hazardous operation
Propellant loading
Pyro and battery installation
Bioassay
ETO decontamination as required
Canister installation
Leak check
Performance verification test
STERILIZATION FACILITY
Terminal sterilization
Perform verification tests
Energize batteries
Legend:
Special facilities
Assembly operation
Ambient functional test
(1) Flight acceptance tests may be or subsystem level depending on subsystem.
(2) Live pyro charges sampled, then installation at KSC.

4

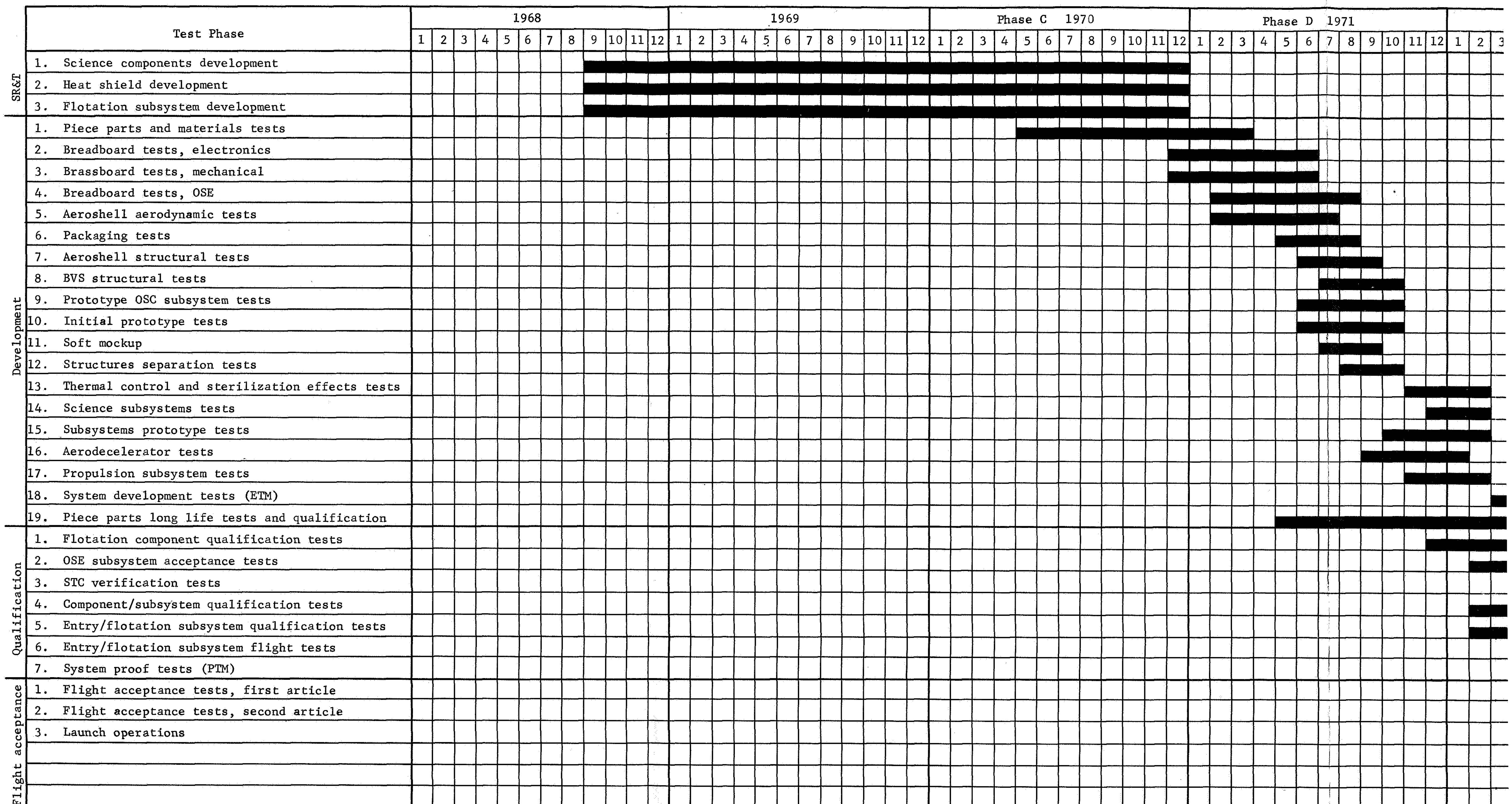
5



(1) Flight acceptance tests may be conducted at the component or subsystem level depending on the installation of the subsystem.

(2) Live pyro charges sampled, then to ordnance storage until installation at KSC.

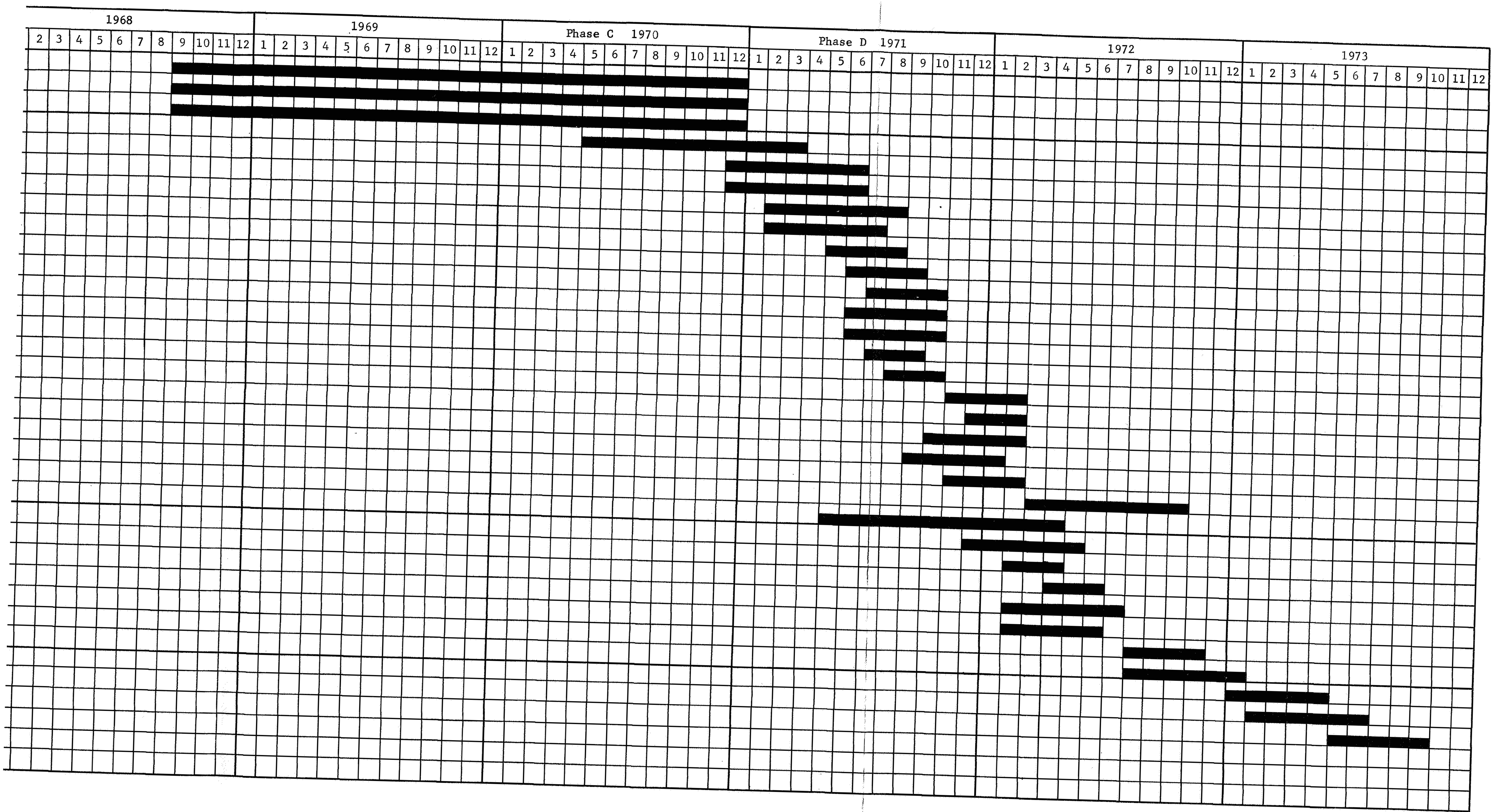
Figure A8.- Concluded



Test Phase
1968
1969
Phase C 1970
Phase D 1971
1 2 3 4 5 6 7 8 9 10 11 12
SR&T
1. Science components development
2. Heat shield development
3. Flotation subsystem development
Development
1. Piece parts and materials tests
2. Breadboard tests, electronics
3. Brassboard tests, mechanical
4. Breadboard tests, OSE
5. Aeroshell aerodynamic tests
6. Packaging tests
7. Aeroshell structural tests
8. BVS structural tests
9. Prototype OSC subsystem tests
10. Initial prototype tests
11. Soft mockup
12. Structures separation tests
13. Thermal control and sterilization effects tests
14. Science subsystems tests
15. Subsystems prototype tests
16. Aerodecelerator tests
17. Propulsion subsystem tests
18. System development tests (ETM)
19. Piece parts long life tests and qualification
Qualification
1. Flotation component qualification tests
2. OSE subsystem acceptance tests
3. STC verification tests
4. Component/subsystem qualification tests
5. Entry/flotation subsystem qualification tests
6. Entry/flotation subsystem flight tests
7. System proof tests (PTM)
Flight acceptance
1. Flight acceptance tests, first article
2. Flight acceptance tests, second article
3. Launch operations

1

2



2

3

Figure A9.- BVS 1973 Orbital Test Schedule

Figure A9 also shows the test and checkout operations performed at KSC to verify that the capsule, as it moves through space system assembly, is physically and functionally capable of performing its mission. Included are combined system tests with the spacecraft and specified planetary quarantine operations. Examples of the latter are controlled access clean area canister-off activities, decontamination, and terminal sterilization. Subsystem test activities range from the development of breadboard circuits through detailed qualification to flight acceptance testing.

The assembly level at which subsystems are tested is constrained by the packaging method used. Integrally packaged subsystems are treated as entities while dispersed subsystems are tested at component or subassembly levels.

The purpose of subsystem development testing is to identify and resolve as early as possible all potential design problems. This is accomplished through the application of a broad spectra of nominal environmental and functional tests that determine worst-case conditions of environmental level and duration, sequence, and operative state.

At the conclusion of subsystem development, engineering drawings are formally released, and the fabrication of flight subsystems initiated. First flight-article components are allocated to qualification that formally demonstrates that the final design configuration can perform its required functions under simulated mission conditions.

System level tests are conducted during development, qualification, flight acceptance, and launch operations. During development and qualification, full-scale models are used. These include the following:

1) Soft mockup - This mockup, based on initial engineering layouts, is used to refine component and subsystem configurations and locations and to develop piping and cable sizes and routing;
2) Engineering test model (ETM) - This is a fully functional model assembled with operational prototype hardware. It is mated to the prototype system test complex (STC) to provide for a functional evaluation of the complete capsule design;

3) Proof test model (PTM) - This is the initial capsule built to release engineering. It is used to formally qualify the BVS/entry vehicle system.

The final step in capsule development is to evaluate the total system. This is done in two phases. The first involves the final verification of the physical configuration, with primary concern directed at packaging, routing, fitting, and other physical interfaces; the second involves complete functional tests of all interconnected subsystems and the operation of the total system. Figure A9 shows how these operations, including prelaunch, are combined into an integrated test program.

Launch site operations are a continuation of those acceptance test activities initiated during capsule assembly and test at the contractor facility. These operations are primarily concerned with the preparations and tests necessary to assure that the capsule is in a launch-ready state. The flow at the bottom of figure A9 indicates the sequential flow of launch site operations for a typical capsule.

Program Schedule and Model Requirements

Schedule requirements, BVS 1973. - The overall schedule necessary to accomplish the BVS 1973 orbital mission up to and including KSC operations is shown in figure A10. There are four distinct phases of testing required:

1) SRT - To allow those subsystems requiring technology development to be initiated well ahead of normal program subsystems;

2) Development - The normal flow of tests from the initial circuit and mechanical design of components up to and including system tests;

3) Qualification - The normal flow of tests from component qualification through system qualification. Also includes a test of entry/flotation subsystems;

4) Flight acceptance and launch operations - Includes all operations from initial component assembly through launch.

A summary of model requirements and usage is shown in table A1.

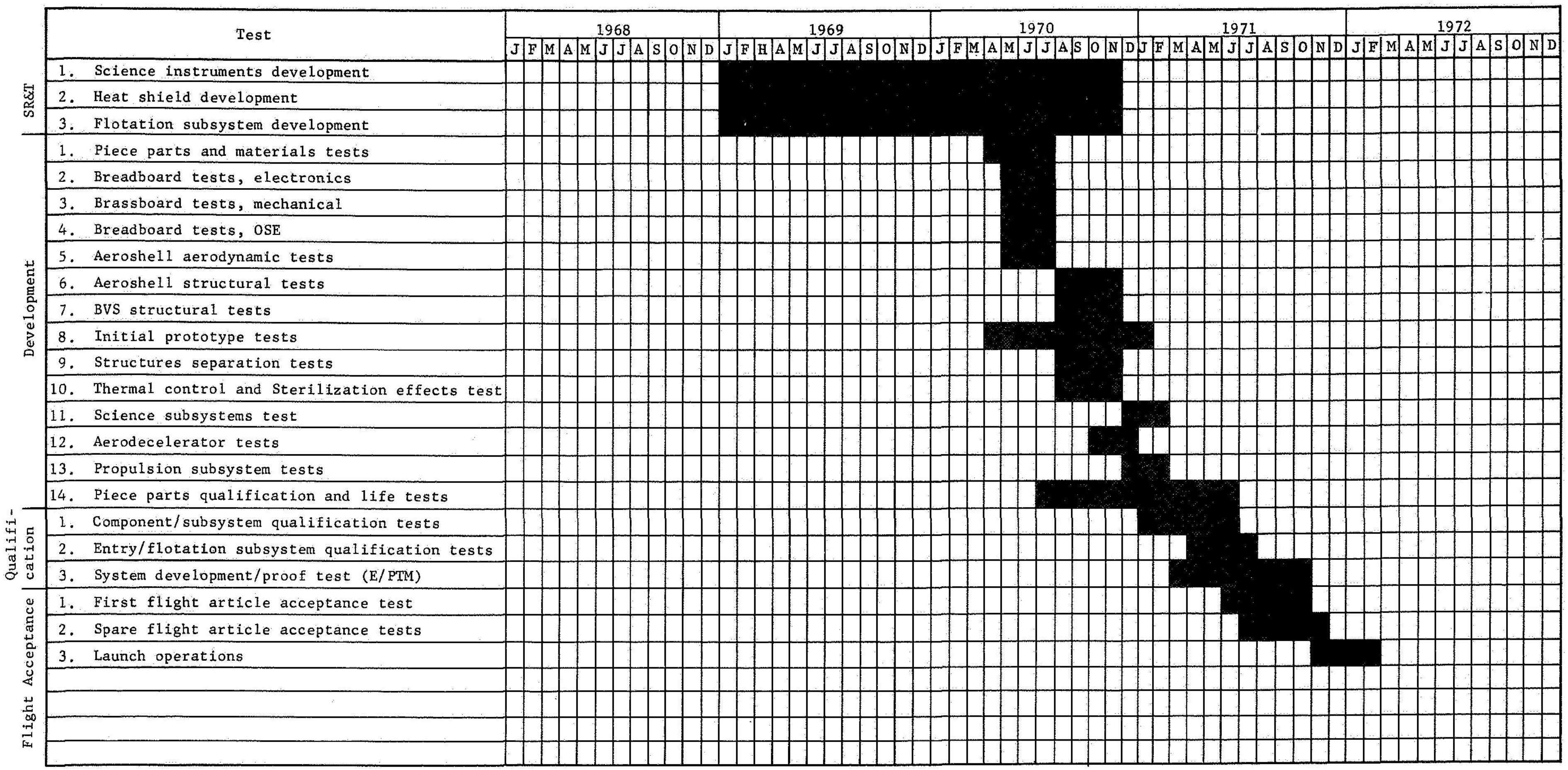


Figure A10.- 1972 BVS Flyby Mission Test Schedule

TABLE A1.- PROGRAM MODEL REQUIREMENTS

Major subsystem / Test phase	Breadboard and/or brassboard tests	Initial prototype tests	Flotation subsystem low-altitude tests	Structural tests	Structures separation tests	Thermal control and sterilization effects test	Subsystem prototype tests	Prototype STC tests	System development tests (ETM)	Entry/flotation subsystem qualification tests	OSE subsystem acceptance tests	Component/subsystem qualification tests	STC acceptance tests	Entry/flotation subsystem flight tests	System proof tests (PTM)	Total No. of models requirements	Remarks
OSE	a	1					1	1	1		2		2			2	Model 1 to support ETM, then flight article #1 Model 2 to support PTM, then flight article #2
Power																	
A/S	a	1			1	1	2		2			3		4	3	4	
BVS	a	1			1	1	2		2			3		4	3	4	
Sonde	a	1			1	1	2		2			3		4	3	4	
Subsonic probe	a	1			1	1	2		2			3		4	3	4	
Telecommunications																	
A/S	a	1					1		1			2		3	2	3	
BVS	a	1					1		1			2		3	2	3	
Sonde	a	1					1		1			2		3	2	3	
Subsonic probe	a	1					1		1			2		3	2	3	
Thermal control	a	1				1	2		2			3			3	3	
Flotation subsystem																	
Balloon	a	1	1		1	1			2	3				4	3	4	
Inflation	a	1	1		1	1			2	3				4	3	4	
Aerodeceleration																	
Aeroshell	a	1			1	1	2		2	3		3		4	3	4	
BVS	a	1			1	1	2		2	3		3		4	3	4	
Structures																	
BVS				1	2	2			2					3	4	4	
A/S	a			1	2	2			2					3	4	4	
Biocanister				1	2	2			2					3	4	4	
Sonde				1	2	2			2			3		4	3	4	
Subsonic probe				1	2	2			2			3		4	3	4	
Guidance, control, and navigation	a	1				1	2		2			3		4	3	4	
Pyrotechnics	a	1			1	1	2		2			3		4	3	4	Numbers refer to circuitry only, not charges. Approximately 1000 line charges will be required for the program.
Propulsion	a	1			1	1	2		2			3			3	3	Model 3 fired in vacuum chamber.
Heat shield	a	a		a	1	1	2		2	a				4	3	4	

[a]Denotes engineering models which are supplied by engineering.

Note: 1. Numbers in blocks denote the model number being used, not quantity. The total column lists the total number of models required to complete the program through qualification.
2. Two additional models will be required for Flight Articles except for OSE.

REFERENCES

1. J. F. Baxter: Summary and Problem Identification, vol. I, Final Report Buoyant Venus Station Feasibility Study, NASA CR-66404.

2. Space Science Board, Planetary Exploration 1968-1975, Report of a Study by the Space Science Board, June 1968, NAS-NRC.