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EXPERIMENT PAYLOADS FOR MANNED ENCOUNTER MISSIONS TO MARS AND VENUS

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ABSTRACT

Trajectory opportunities have been identified for free return manned flyby, or encounter, missions to Mars and Venus. Using Saturn V launch vehicle technology and assuming the development of a manned planetary spacecraft with two year capability, missions to these planets with experiment payloads of 50,000 lbs are possible.

Selecting as a design reference mission a triple planet (Venus-Mars-Venus) flyby with a 1977 Earth launch date, a possible experiment program is outlined which employs unmanned probes to explore Mars and Venus during the planetary encounter phase. To complement this a program of space science and astronomy experiments is carried out during the remaining portion of the mission.

A precursory unmanned program of orbital reconnaissance missions with small atmospheric and survivable surface impacter probes is assumed for both planets. Based on this the prime objective of the manned encounter mission at Mars is surface sample return for life detection experiments. Samples from three different selected areas could be recovered during the Mars encounter phase of the mission. Four types of probes are considered for Venus. A meteorological balloon probe deploys a distribution of weather balloons to record atmospheric data. A companion orbiter serves as a balloon tracking and data relay station. Also considered are slow descent, non-survivable impacter probes which might take TV pictures of the surface from below the cloud layer and survivable impacting lander probes to investigate surface properties.

Several en route experiments have been identified which take particular advantage of the trajectory of the design reference mission. These include optical observations of Zodiacal light, several known asteroids, Mercury, and the moons of Mars. Radio observations of Jupiter and the sun made in conjunction with an earth-based station would also be of interest.

EXPERIMENT PAYLOADS FOR MANNED ENCOUNTER MISSIONS TO MARS AND VENUS

1.0 INTRODUCTION

The U.S. program of planetary exploration through space flight missions is still in its early stages. Missions ranging in technical complexity from today's unmanned Mariner flyby probes through possible manned Mars landings in the 1980's are being studied. It appears that a planetary program covering that spectrum of missions could achieve many of the scientific, technological and national prestige objectives associated with one of the major goals of our national space program--the exploration of the solar system.

Assuming that manned planetary exploration in the late 1970's is a possibility, this paper postulates a planetary program concept and illustrates the roles fulfilled by unmanned precursory and manned encounter missions. In particular, the possible contribution of the experiments payload of the latter class of missions to our knowledge of the solar system is described.

2.0 PROGRAM CONCEPT

2.1 Exploration Objectives

One of the major goals of our national space program is the exploration of the solar system. General objectives which may be cited in the pursuit of this goal are the advancement of science and technology, with implications bearing on our national image.

The scientific objectives, as stated by the Space Science Board of the National Academy of Sciences,(1) are summarized as follows.

A. The Origin and Evolution of the Earth, Sun, and Planets

Pertinent questions relate to the source of the material and mechanism of formation of the visible objects of the solar system, the time scale of the major events which have occurred and are occurring in the solar system, and the physical processes responsible for the principal energy release of the sun.

B. The Origin and Evolution of Life

Problems include the examination of what constitutes life, the search for recognizable life elsewhere in the solar system, the possibility of living systems based on other than hydrogen-carbon chemistry, and an examination of the likely conditions necessary for the origin of primitive life.

C. The Dynamic Processes that Shape Man's Terrestrial Environment

One facet of this objective involves the examination of other bodies of the solar system which are either quite different from Earth or, if similar, are at different stages of geologic evolution, to stimulate increased understanding of the evolution and present physical state of the Earth itself. A second facet is the application of our knowledge of the terrestrial environment to the explanation of observed properties of planetary atmospheres, surfaces, and interiors.

The technological objectives, although not necessarily independent of the scientific objectives, are focused on stimulating a wide spectrum of scientific and engineering disciplines in the nation and providing the capability to continue manned and unmanned exploration of space.

Prestige objectives focus on the potential enhancement of national power and position which can be accrued by demonstrating technological leadership through being first in important new accomplishments.

Particular scientific, technological, and prestige objectives which may be pursued through a planetary program are summarized as follows:

<u>Scientific</u>

- Search for extraterrestrial life in the recovered Mars surface sample and in situ on the Mars surface.
- Mapping and reconnaissance of Mars and Venus to understand the current physical state of the planets and their history.
- Measurement of the atmospheric properties of Mars and Venus, especially the dynamics of the Venus atmosphere.

- Optical observations of Mercury, light scattered from interplanetary dust, the satellites of Mars, and selected asteroids which cannot be made from Earth orbit.
- Radio observations of Jupiter and the sun which cannot be made from Earth orbit.
- Increase in our understanding of Mars and Venus to a level where full use can be made of the exploration potential of the succeeding generation of manned planetary orbiting and landing missions.

Technological

- Utilization of the existing technological capability for manned exploration of space.
- Utilization of the existing capability for development of unmanned probes, instrumentation, and data processing.
- Acquisition of engineering design input data on the planets and interplanetary space for application to future systems.
- Definition of the requirements on technology for the exploration of the entire solar system.

Enhancement of National Prestige

- Manned planetary encounter mission.
- Mars surface sample return.
- Unmanned spacecraft rendezvous with an asteroid.
- Unmanned spacecraft rendezvous with a comet.
- Manned planetary landing.

Objects of Investigation

The selection of Mars and Venus as the prime areas of investigation in the early phases of planetary exploration is a reflection of the fact that they are not only highly interesting bodies which will provide new data bearing on the scientific objectives of solar system exploration, but they are also the near-Earth planets with higher likelihood of yielding early results. A listing of the priorities of solar system exploration, exclusive of the sun and the Earth, which reflects a consensus within the scientific community,(1) is:

1. Mars, Venus
2. Moon
3. Major planets
4. Comets and asteroids
5. Mercury
6. Pluto
7. Interplanetary dust

2.2 Flight Opportunities

Table I outlines possible unmanned flyby missions to Mars and Venus in terms of the Earth departure energy requirements, C_3, and the hyperbolic excess velocities at planetary encounter, V_∞. Of particular interest is the fact that the V_∞ values all lie within the relatively low range of 2.4-5.6 km/sec.

The parameters of representative manned Mars and Venus encounter missions are set forth in Table II. They are low-energy trajectories of a free-return type, i.e., only minor trajectory corrections are necessary to achieve Earth entry following the initial planetary injection maneuver in Earth orbit. The missions include single planet exploration, as well as dual and triple planet flights.

2.3 Precursory Program

It is expected that the planetary program of the next decade would pave the way for continued achievement of our national space objectives through manned planetary orbiting and landing missions. The time scales for carrying out the more advanced missions are difficult to forecast, but a reasonable planning assumption is that their accomplishment would be feasible in the 1980's. This timing suggests that an initial manned planetary encounter mission be conducted in the late 1970's and that it be preceded by (1) a manned Earth orbital program aimed specifically at the development of a capability for long duration flight and (2) an unmanned program to provide early data on the planets through the mechanism of Earth-launched probes.

This assumption is one of several that could be made at this time. Although partially based on optimism toward what might be done, it was chosen to permit the selection of an illustrative manned encounter mission as the basis for a conceptual design of an experiment payload. The system, mission and program details described should be considered as illustrative of feasibility rather than as a plan for the future.

Achievement of a long duration spacecraft would undoubtedly require a major new start in the manned space flight program. It is envisioned as having a versatile, flexible capability built around a "standardized" module which can provide at least two years of life support independent of external sources. The following precursory needs of the manned planetary program should be provided in the manned Earth orbital program:

Determination of Crew Capability

- Maintenance and repair
- Experiment operation and data analysis

Development of Technology

- Long-duration subsystems
- Experiment subsystems, particularly a large optical telescope

Development of Operational Techniques

- Orbital assembly and launch
- Experiments probe deployment and control

Figure 1 outlines a possible program which would use existing capabilities for unmanned exploration and provide a sound scientific base on which to proceed with the manned encounter mission. The four basic types of probes considered are orbiters, atmospheric probes, survivable surface impacters, and soft landers.

Early orbiter probes are desirable to provide reconnaissance data useful in the targeting of later probes such as soft landers. Furthermore, as a comparison of Tables I and II indicates, the passage velocities at both Mars and Venus are in general less when the probe is launched directly from Earth, thereby reducing the propulsion requirements for planetary orbit injection.

Small atmospheric probes in the 50-200 lb class could be delivered to different regions of the atmospheres of both planets by being deployed from a parent orbiter spacecraft either before or after the orbital injection maneuver. Data on the atmospheric structure provided by these probes would be used in the mission planning for lander probes targeted to specific surface sites and would provide preliminary meteorological data.

Impacting lander probe technology for Venus has already been tested by the Russians (Venus 4 spacecraft). Atmospheric braking without retropropulsion is sufficient, and the technology is available for short term surface missions at the high temperatures which are believed to exist. Such a probe would probably communicate through its parent orbiter.

JPL has studied short term (∿1 day) survivable impact probes for Mars which could be delivered by a Mariner flyby spacecraft.(2) Having a gross weight of 350 lbs, this probe would land about 13 lbs of scientific instruments and transmit 600 bits of data directly to Earth. Such a probe should also be deliverable from an orbital spacecraft. By instrumenting the entry shell of this type of probe, the function of the atmospheric probe could be performed on the same mission. This is the mode assumed in Figure 1.

Soft lander precursory probes have been studied for Mars, but without satisfactory solution. Candidate concepts are the Saturn V Voyager and the Titan III/Centaur lander. The latter concept is adopted for the purposes of Figure 1, with future study required to determine the exact nature of the lander. An appropriate resolution of this matter may be that the Titan III/Centaur probe include a second generation Mars orbiter spacecraft (the first generation being, perhaps, a Mariner derivative) and a large survivable impact probe, with soft landing probes left to the manned program.

Soft lander probes for Venus were not considered because it was felt that there is insufficient data on the surface environment to support the design of such probes.

A parallel program of flyby missions to comets and asteroids in the late 1970's would capitalize on Mariner spacecraft technology and require only the Atlas/Centaur launch vehicle.(3) Another program of flyby missions to Jupiter and the major planets in the middle and late 1970's would serve as the focal point of new technology in the unmanned program which would carry over into the 1980's when manned systems are expected to provide the major means of exploring Mars and Venus.

2.4 Mission Selection

Evaluation of the relative merits of the manned missions outlined in Table II reveals that the 1977 triple planet encounter is the most attractive for purposes of this analysis. In addition to being sufficiently late to permit a suitable unmanned precursory program and to afford a reasonable period for development and test of the long duration spacecraft, that mission appears to win most of the trade offs in system requirements.

Discounting the one year 1975 Venus encounter, the 1977 mission competes favorably with regard to mission duration. In particular, it is superior to the 1978 and 1981 triple planet flights, each of which requires in excess of two years. This mission also has the lowest Earth entry velocity of all the missions. It should be noted, though, that all the Earth entry velocities shown are in a range (12.0-14.9 km/sec) that can be accommodated by Apollo techniques and technology. The space environment through which the flight would pass is also favorable since the spacecraft would not enter the asteroid belt and would not come closer to the sun than Venus.

While the encounter geometry and parameters are short of being ideal, they are no worse than, and in some cases better than, those of the other triple planet flights. The combination of encounter velocities appears to be the best; periapsis velocities of approximately 12.0 km/sec at Venus are comparable to those of other missions, and the low velocity (5.6 km/sec) at Mars not only affords greater time in the vicinity of the planet, but also reduces the ΔV requirements on experiments probe delivery and retrieval systems. The periapsis altitudes are not as low as the 300-500 km range of the single planet missions; however, they are generally more suitable to reconnaissance of the planet from the flyby vehicle than those of the other triple planet flights. Also, during each planetary approach better than half of the planetary area projected on the "plane-of-the-sky" is illuminated by the sun.

The principal drawback of the mission is its high Earth departure velocity. In the family of 1977 free return opportunities there are other missions with significantly lower injection energy requirements. These, however, generally require orbital plane changes en route to the planets and have Earth entry velocities that are outside the range cited above. There are also non-ballistic flights with lower initial velocity requirements. The 1977 flight of this class which has been studied requires an impulsive maneuver of approximately 0.2 km/sec at the first Venus encounter.

3.0 SPACE VEHICLE CONFIGURATION AND MISSION PROFILE

3.1 Space Vehicle Configuration

To provide a basis for sizing the experiment payload to be carried on the design reference mission, an estimate of the system capability necessary to meet performance requirements within the constraints of the mission has been made, using the results of analyses conducted within NASA and Bellcomm and by other contractors. Studies have shown that a crew size of between four and six will be needed to conduct this class of mission. Exclusive of experiments payload, the spacecraft weight for a four-man crew would be in the range of 145-150,000 pounds, and increasing the crew to six would entail a weight penalty of 20-25%. The use of Saturn V technology reflecting improvements possible in the next decade should permit injection of a total payload weight of 240,000 pounds into the interplanetary trajectory.

3.2 Mission Profile

Spacecraft injection takes place late in January, 1977. The first Venus encounter occurs on the 149th day of the mission, the Mars encounter on the 345th day, and the second Venus encounter on the 574th day. Earth entry takes place in January, 1979, just short of two years after Earth departure. The geometry of the spacecraft solar orbit is shown in Figure 2.

The mission is a single-impulse flight which makes hyperbolic encounters with each planet and provides a free return to Earth for entry at a velocity of 12.0 km/sec. Midcourse corrections are made as necessary during the interplanetary phases.

The two Venus encounters have a number of similar features. The angles of inclination to the Venus orbit plane are 80.4° and 80.5°, respectively, and both flights pass over the south polar region. On the first encounter periapsis occurs on the sunlit side of the planet at an altitude of 680 km, and for the second, on the dark side at 700 km. The Mars encounter has a periapsis altitude of 3960 km on the dark side of the planet, with the flyby plane inclined 29.7° to the Mars equatorial plane.

4.0 EXPERIMENT PROGRAM FOR A TRIPLE PLANET ENCOUNTER MISSION

4.1 Mission Objectives

The experiment program for the triple planet encounter mission can be divided into three distinct categories, namely, experiments performed at Mars, experiments performed at Venus, and en route experiments. Each of these categories has a specific set of objectives.

Mars

The available experimental data on Mars suggest an environment which would be relatively hospitable to soft landing spacecraft. The atmosphere is thin compared to the Earth's, containing a small amount of haze which does not seem to preclude good photography of the surface. It is capable of providing a substantial amount of aerobraking, thereby decreasing the total thrust required from a descent propulsion system. Our current understanding of this atmosphere appears sufficient to successfully design entry shells and retropropulsion systems for unmanned spacecraft, although additional data from atmospheric entry probes would lead to a higher confidence in these designs.

The Mars surface has been photographed to a resolution of several kilometers and appears "moon-like."(4) In the absence of strong physical evidence to the contrary we can assume that this surface is landable in the same sense that the lunar surface is landable to a Surveyor or Apollo spacecraft. Here again, higher resolution imagery of the surface is desirable before attempting to land any probes.

One objective of the manned encounter program should be to provide planning data for the next major step, a manned Mars landing. The function of this data should first be to confirm that manned landing is a worthwhile goal, and then to provide environmental data which will affect the descent, surface, and ascent strategy and hardware design of the landing mission.

A second objective is to extend the scientific investigation of Mars beyond the point reached in the precursory program. Consistent with the plan outlined in Section 2.3, it is assumed that the manned encounter mission will be preceded by a program of orbital reconnaissance, in situ measurements of the atmosphere, and measurements at the planet surface.

A common focus for both of these objectives is the return of a sample from the surface of Mars. The search for extraterrestrial life is one of the most challenging scientific problems of the planetary program, and it seems that sample return should be the next step after accomplishing a soft landing by unmanned probes. The difficulty in defining a finite set of experiments to detect life and to adequately characterize it, once having been detected, suggests sample return as a reasonable course of action.

The immediate bio-analysis of part of a sample of Mars in a laboratory on board the manned spacecraft by a well trained analyst, coupled with a more detailed analysis of the remainder of the sample in earth-based laboratories, appears to be the most promising approach to the search for life on Mars. There is no guarantee that this approach would lead to a successful identification of life - or proof of its absence. However, this approach does have the advantage of permitting scientists to exhaust their imaginations and reflect what they learn in the definition of additional experiments to perform on the samples. On the other hand, the approach of placing a package of experiments on the surface of Mars by an unmanned landing probe would only produce definitive results if a positive identification and characterization occurred.

Forward contamination of Mars is an obvious problem if the search for life is pursued. While adequate sterilization can be approached for an unmanned probe, it can never be a guarantee for a manned system. The risk of an accident on the surface which would expose an unsterilized astronaut could bring the search for life to a rapid conclusion. It therefore seems reasonable to try to solve the question of life on Mars before attempting a manned landing. Sample return, we feel, offers the best chance for meeting this goal.

There is also the related question of back-contamination of the Earth. In the flyby sample return mode to be discussed in Section 4.3, a sterilized probe retrieves the sample, which is subsequently transferred behind a biologic barrier for further handling by the astronauts. Before this spacecraft reenters the Earth's atmosphere, it must be determined by analysis that there is no risk due to known pathogenic organisms. Furthermore, if the question of pathogenic organisms were to exist at the time of a proposed manned landing, the sum total of the constraints this might place on the surface systems and operational plan could be sufficient to compromise the landing mission.

Venus

The physical picture of Venus is quite different from that of Mars. The recent Russian probe(5) has confirmed earlier speculation as to the high surface pressure, revealing it to be some 15-22 Earth atmospheres. This probe recorded the surface temperature on the dark side to be approximately 280°C, and temperatures on the sunlit side are probably higher. However, except for the surface temperature, which has also been estimated from the radio emission brightness, and an average surface dielectric constant which has been measured by earth-based radar, physical properties of the surface are largely unknown. Aspects of the surface environment of interest to the spacecraft designer are whether it is solid or liquid, the topography, and the nature of the near surface winds. The Russian Venus 4 probe apparently did not survive the landing, and one can only speculate as to the nature of the surface which caused its demise.

The visible picture of Venus as seen from Earth is that of a planet covered by clouds. Photographs of the Earth from space lead us to speculate that the Venus cloud cover may be intermittent with regions through which the surface might be viewed. Unlike Mars, however, Mariner photography has not been attempted for Venus, so its visible appearance must be based on rather crude evidence.

A gross characterization of Venus, then, is that it is a cloud-covered planet with a dense atmosphere and a hot surface. Also, it is roughly the size of the Earth with a Venus day being equal to about 120 Earth days. This sort of picture is not readily conducive to thoughts of a manned Venus landing. Instead, the reaction is one of probing the environment more thoroughly to understand the basic physics and chemistry (and possibly biology) of the planet.

The precursory program can make a good start on this. Orbital reconnaissance should provide visible imagery of the cloud patterns and microwave imagery of the surface. Atmospheric probes can measure thermodynamic properties along their descent paths through the atmosphere. Short term survivable lander probes may be able to provide early data on the properties of the surface.

The objective of the manned Venus encounter experiment program, then, is to extend these precursory investigations of the Venus environment a step further, hopefully to also define the nature of a follow-on program. Three particular types of experiments are felt to be a key part of this extension.

First, there is strong scientific interest in understanding the meteorology of the Venus atmosphere. Factors such as the length of the Venus day, the density of the atmosphere, and the planet's proximity to the sun may lead to quite a different system than we have observed on Earth. A network of weather balloons is envisioned as the means of carrying out this experiment.

Secondly, it is possible that the planet has a permanent cloud cover which still transmits enough light to illuminate the surface below - much like a cloudy day on Earth. In this case it would be valuable to have visible photographs of the surface taken from beneath the cloud layer. A Ranger-type TV system could provide this data, with several of these probes being deployed to different parts of the sunlit side of the planet on a single flyby.

And thirdly, it seems worthwhile to extend the exploration of the surface, albeit with short-term probes, to examine the range of surface properties at places such as the sub- and anti-solar points and the poles.

There are at least two possible probe concepts which should be considered for a follow-on program. One is a buoyant laboratory station designed to float in the atmosphere and make detailed composition and thermodynamic measurements, observe the surface, and possibly even search for life in the more temperate regions of the atmosphere. Such a probe would probably have the capacity for a several hundred pound science payload, at the same time providing a controlled environment in which the experiments could be operated. The weather balloon experiment is a necessary precursor to this probe in gathering data on wind circulation patterns, atmospheric turbulence, and temperature and pressure profiles.

A second follow-on probe might be a long-life surface lander. Part of the task of the short-life landers considered for the first encounter mission would be to determine whether there is a need for the advanced lander, and if so, to provide those design criteria which are dictated by the environment.

En Route Experiments

The en route experiments program has two prime objectives: (1) to carry out a biological analysis of the sample material collected from the Mars surface and (2) to take advantage of the encounter mission trajectory to perform experiments in space science and astronomy which cannot be done equally well at the Earth's surface or in Earth orbit. Several of these experiments which are particularly suited to manned operation involve extensive observations with a large optical telescope. These include observations of Mercury, certain asteroids, the satellites of Mars, and faint stars and galaxies. Additional experiments would be the use of a passive microwave receiver to record radio emission from Jupiter and the sun in conjunction with a similarly equipped station at Earth, and a small hand-held camera to record the intensity of Zodiacal light at points removed from the Earth.

4.2 First Venus Passage

The geometry of the first Venus passage of the triple planet encounter mission is shown in Figure 3 (in the flyby vehicle plane) and Figure 4. Four types of probes and several experiments on board the flyby vehicle are considered especially compatible with the experiment objectives outlined in Section 4.1.

Meteorological Balloon Probe System

The primary objectives of the meteorological balloon system are: (1) to determine the gross atmospheric circulation patterns by tracking balloons from an over-flying orbiter, and (2) to gain a general understanding of existing atmospheric conditions from the balloon sensor payloads.

The balloons are delivered to the atmosphere by two separate probes, each containing six balloons, to be deployed at altitudes of 45, 40, 30, 25, 10 and 5 km. A shallow entry path angle of about 12 degrees is selected as a reasonable compromise between the total heat load, maximum heating rate, and maximum deceleration experienced by the probe.

The two target areas for the first passage are shown in Figure 5. These areas nominally lie near the terminator about 12 degrees from the limb, separated by 156 degrees of central angle. Since for tracking purposes the targets must lie close to the orbital plane, a near polar orbit requirement for the tracking orbiter is established. Although somewhat arbitrary at this time, the targeting strategy adopted permits the acquisition of atmospheric information from two widely separated regions of the planet. Precursory data from the reconnaissance orbiters and atmospheric probes should provide better guidelines on where to target the meteorological balloon probes.

The six altitudes at which balloons are deployed were chosen to provide a means of investigating the low, intermediate and high altitude domains of the atmosphere. Deployment at altitudes of 5 and 10 km is suggested to cover the near surface region of the atmosphere. Specification of 25 and 30 km intermediate altitudes covers the domain in which a buoyant laboratory station might be deployed. These balloons would probably operate inside the clouds. The two high altitude balloons at 40 and 45 km are expected to yield data on the conditions above the clouds, probably in the region of the tropopause. Earth-based observations indicate that very high wind velocities parallel to the equator may be encountered at these altitudes.(6) The balloons were designed using a model atmosphere based on data from both the Soviet Venus 4 mission and brightness temperature data obtained from earth-based observations.(7) Nominal balloon lifetime is one month.

Figures 6 and 7 indicate the balloon probe conceptual design, while Figures 8 and 9 show aspects of the mission profile.

The payload subsystem carried by each of the meteorological balloons will include a pressure gauge, three mutually orthogonal accelerometers, a sferics detector, and a thermistor for ambient temperature measurement. The pressure and temperature gauges will be designed to operate within ranges appropriate to the altitude of deployment. In addition, each balloon will be equipped with a humidity gauge.

The accelerometers will measure the gross effects of wind gusts and turbulence on the balloon motion. To reduce power dissipation and the associated thermal control requirement the acceleration data would be collected for three minutes in every fifteen. During these periods a record would be made of the number of occasions upon which the vector sum of the three accelerations exceeded a preset threshold, and also of the integrated length of time for which this occurred. The complete record would, in addition, contain the maximum acceleration experienced in each of the three directions during the data collection period. It is expected that knowledge gained from the analysis of the acceleration data will be applied to the design of larger and more complex buoyant Venus probes.

Suitable temperature measurements can be made with ceramic thermistor devices in the form of beads and thin wires. As each balloon floats in the atmosphere at a known constant density, measurement of temperature allows the ambient pressure to be calculated. However, since the redundancy of a pressure measurement requires only a small weight penalty, it is considered worthwhile to make this measurement as a means of checking the temperature record. Within the range of pressures that will be encountered up to an altitude of 45 km the performance of conventional aneroid gauges will be quite adequate. Simultaneous pressure and temperature measurements would be taken every 15 minutes.

The sferics detector carried by each balloon will enable observations to be made of the general electrical activity of the atmosphere. The detector, consisting of a small whip antenna and a broad-band radio receiver, will operate continuously and will count the number of discrete electrical discharges which produce sufficient electromagnetic radiation for detection. From the analysis of this data a general picture of the electrical activity of the Venus atmosphere will be obtained. It should be possible to detect any correlations between such activity and position on the planet.

Direct spectroscopic observations have shown that water vapor exists above the clouds covering Venus,(8) and it is possible that the clouds themselves are partly composed of ice crystals. It is, therefore, considered desirable to equip the balloons with humidity detectors. Such a detector, consisting of an electrically conducting chemical film, registers changes in humidity by its change in resistivity at 15 minute intervals.

The balloon tracking and data relay orbiter is deployed several days before flyby vehicle periapsis. Immediately after separation from the manned vehicle the orbiter performs a preprogrammed velocity correction to adjust its periapsis passage altitude to 4000 km. At periapsis it is deboosted via a two stage retro system into a circular orbit with about a 3 hour period. Figure 10 shows the orbiter spacecraft design concept.

The balloon tracking and data communications system employs a square array antenna with a 27° half angle. The orbital tracking geometry is shown in Figure 11. The orbiter measures the angle and range to each balloon within its field of view on every orbit. It also interrogates each balloon for the atmospheric data it has in on-board storage. The position of the orbiter relative to the planet is established by tracking from Earth. The latitude and longitude of each balloon can be determined to an uncertainty of about 100 km. This is not a serious error since the objective is to determine atmospheric circulation patterns on a planetary scale. Balloon altitude will be calculated by comparing the on-board pressure and temperature measurements with atmospheric profile data collected by the photo sinker, lander, and atmospheric probes.

Each balloon is programmed to transmit some 800 bits per orbit when interrogated. Consequently, the orbiter can accumulate as many as 9,600 bits per orbit. This data is relayed to Earth through an omnidirectional command data link at a 5 bit/second rate, requiring 120 watts of input power. The solar array power supply was sized for 265 watts continuous. Attitude control consists of horizon scanners and a cold gas system to keep the tracking antenna pointed along the gravity gradient.

The propulsion system was sized for a total ΔV of 6.25 km/sec (approximately 0.25 km/sec to change the periapsis altitude from that of the nominal flyby path and for mid-course maneuvers, with the remaining 6 km/sec for circularization and plane changes). The total ΔV is divided equally between two stages, with stage I being used both for periapsis altitude adjustment and deboost. Table III summarizes the subsystem weight breakdown for the orbiter probe.

Photo Sinker Probe

This probe is essentially an atmospheric drag probe instrumented to take TV pictures below the Venus cloud layer. If the precursory program establishes that the surface is not visible from orbit, but there is sufficient light below the clouds for illumination (photometer measurement), this type of probe might provide the only large area coverage of the surface in the visible range. The utility of the encounter mission is that it can deliver several probes on a single passage to provide a good statistical sample. If the surface visibility is not uniformly good for photography, multiple probes will provide a better chance of locating a single good area. If the visibility is uniformly good over the sunlit side of the planet, multiple probes will provide a statistical sample of terrain over different regions of the planet. Knowledge of the visibility conditions would influence the experiment selection and mission plan for the floating laboratory station, which might be a second generation atmospheric probe.

In addition to TV this probe carries a complement of atmospheric experiments to measure temperature, pressure, composition, light level and altitude. All experiments cease to function when the probe impacts the surface. Prior knowledge of probe descent times gained from the precursory program will permit accurate timing so that the photographic readout from the sinker probe occurs when the flyby vehicle is in the optimal range position.

Pictures are acquired every 10 seconds from an altitude of about 30 km. Initial pictures have a resolution of approximately 120 meters and a coverage of 500 km^2. A maximum transmission range of 60,000 km is adequate for this experiment.

The design concept for this probe is shown in Figure 12 and its mission profile in Figure 13. Probe power is supplied by batteries, and thermal control is by insulation with an internal coolant such as ice.

This probe can be targeted for atmospheric entry angles ranging from vertical incidence to 25° off vertical. This latter constraint is the half angle of the communications antenna which is aligned with the spacecraft spin axis. The only other targeting requirement is impact on the sunlit side. Precursory data is expected to contribute to the targeting strategy.

Venus Lander Probe

The lander probe is designed to impact the Venus surface and survive for one hour. During this time it collects data on the surface environment, including a panoramic television scan, and transmits the data directly to the manned flyby vehicle. The objective of this probe is to find out whether surface operations on Venus are feasible and to indicate which areas are more suitable for landing. This requires the use of several lander probes. The large payload capacity of the manned vehicle makes it possible to investigate eight surface locations on a single mission.

Figures 14 and 15 illustrate the probe mission profile and conceptual design, respectively. The lander probe is designed for entry at angles ranging from vertical incidence to about 78° off vertical, which is the skip out angle. It can also take TV pictures in the dark, as it carries its own illumination system.

As this probe is the subject of a companion paper(9), it will not be discussed further here.

On Board Experiments

A variety of remote sensor experiments might be usefully carried out on board the manned vehicle during Venus encounter. In particular, a one meter diffraction-limited telescope which is proposed for en route astronomy (see Section 4.5) could be used for photography and spectral measurements of Venus during the approach and periapsis passage phases.

Some of the most comprehensive imagery of the surface might be obtained from a radar imagery experiment conducted at periapsis passage.

4.3 Mars Passage

The geometry of the Mars passage is shown in Figures 16 and 17. Only one type of probe for investigating Mars is included in the probe complement of this mission. The Mars Surface Sample Recovery (MSSR) probe collects samples of the Martian surface material and transports them via a rendezvous rocket to the manned flyby vehicle, returns full color photographs taken on the surface, and emplaces long term experiments on the surface. Three MSSR probes are used to increase the likelihood of successful sample return and hopefully to return samples from different areas.

Figure 18 shows the significant events in the MSSR mission profile. Prior to deployment, the three MSSR probes are encased in individual sterilization canisters and stored in the probe compartment of the flyby vehicle. Deployment occurs about 5 days before flyby vehicle periapsis passage (M-5 days) and consists of ejecting the probes from the flyby vehicle and separating the sterilization canisters in such a way as to prevent contamination of the probes.

The injection propulsion maneuver, which is started as soon as deployment is complete, causes the probes to intercept the planet from 2 to 4 hours prior to flyby vehicle periapsis passage. Following two midcourse maneuvers and jettisoning of the rocket, the probes enter the atmosphere at a height of 220 km and an entry angle of 19° below the local horizontal. These entry conditions constrain the touchdown points to a locus of about 11° behind the limb of Mars as viewed from the approaching manned vehicle. Figure 19 shows the approximate landing geometry. Since the planet rotates approximately 14° per hour, it takes almost an hour after landing for the MSSR probes to establish line-of-sight communications with the manned vehicle.

A 60° half-angle sphere-cone shaped aeroshell equipped with an ablative heat shield protects the probe during entry. The relatively low ballistic coefficient of about 0.7 slugs/ft^2 causes the velocity to be reduced to about 2000 fps at an altitude of 20,000 feet. At this point, landing rockets are ignited to slow the vehicle further.

Gimbaled, variable thrust landing rockets and attitude control rockets are used to achieve low velocity landing through the use of range and Doppler radar and an autopilot system similar to that of Surveyor. After the velocity has been reduced to about 1000 fps the aeroshell is separated from the landing vehicle and the landing legs are extended. Touchdown occurs at a vertical velocity of about 5 fps.

The landing points of the three MSSR probes were chosen so that they would all be rotated into the flyby plane for launch about 6 minutes prior to manned vehicle periapsis passage, as shown in Figure 20. The variation in arrival time allows flexibility in the probe landing location. Figure 21 shows the early arrival times required to properly position the MSSR in the flyby plane at launch as a function of landing latitude.

Shortly after landing the probes begin programmed pre-launch surface operations. The equipment doors are unfolded as shown in Figure 22, and the high gain antenna is deployed. Sample collection is begun using a rock drill to collect sub-surface material and an aerosol filter to collect samples of material suspended in the atmosphere. As soon as communications are established with the manned vehicle, a panoramic television picture is transmitted to enable the astronauts in the flyby vehicle to select the most interesting areas for surface sample collection. Since it is necessary to collect surface samples at least 100 feet from the landed MSSR probe to minimize contamination by rocket exhaust gases, the surface sample acquisition devices are propelled radially outward by mortars remotely aimed in the favorable directions. Drag buckets or vacuum cleaner type samplers, or a combination of these, are used to collect samples of the surface material. The entire sample acquisition procedure and other interactions of the probe with the surface, such as footpad penetration and rocket cratering, are photographed in color. The film is placed in the rendezvous rocket along with the surface samples and the probe is readied for launch.

On command from the manned vehicle the antennas and cameras on the MSSR are then retracted. The conical structural shells which surround and support the rendezvous rocket during the entry and landing are folded outward over the equipment doors. This frees the rocket for launch and protects the equipment from damage by the rocket exhaust. On further commands from the manned vehicle the three rendezvous rockets are launched nearly simultaneously. Inertial guidance is used to control the rockets as they accelerate to the speed of the flyby vehicle. The terminal maneuvers are made using the small attitude control rockets on the rendezvous vehicle. Rendezvous and docking are accomplished using command guidance under optical and radar observation from the manned vehicle. Docking and transfer of the payload from the three rendezvous rockets to the flyby vehicle are done in a manner which prevents contamination of the payload and back-contamination of the flyby vehicle.

Post-launch surface operations begin soon after launch of the rendezvous rockets and continue for the life of the probe - nominally two years. A 180-pound geophysics laboratory containing nine experiments including a television camera is included in the landed payload. An additional 100 pounds of landed payload for exobiology experiments or more geophysics is provided in the weight estimate shown in Table IV. These experiments are supplied power from the MSSR power subsystem and transmit data over the probe communication subsystem. When the increasing distance to the departing flyby vehicle reduces the transmission rate below that of a direct Mars-Earth link, the MSSR antenna acquires the Earth and communicates directly for the remainder of its mission.

So far as on-board experiments are concerned, optical photography and spectroscopy using the one meter telescope may be acquired during the approach and departure phases of the mission, but infrared and radar imagery would have to suffice at periapsis passage, since this is a darkside flyby of Mars.

4.4 Second Venus Passage

The geometry of the second Venus passage is shown in Figures 23 and 24. The objective is to repeat the type of experiment program carried out on the first passage in the different planet geometry. Figure 5 illustrates possible target areas for the meteorological balloon probes. A large portion of the data collected on the first passage will have been analyzed to provide clearer direction to the experiment and probe mission planning. In this strategy the second generation class of surface or atmospheric probes could be carried on some later mission.

By the time of this passage all of the earlier balloon probes would have exceeded their design lifetime. To insure a successful mission for the new meteorological balloon probes, a separate tracking and relay orbiter would be provided for the second passage experiment program. However, if the first orbiter were found to be still operational, the second could be used to provide additional spatial coverage for the new balloon probes. The location of this orbit (still circular at 4000 km altitude) would be selected after examination of the first passage balloon tracking data.

4.5 En Route Experiments

A number of particularly rewarding experiments which take advantage of the orbital geometry of the flyby mission are suggested. In general these experiments cannot be done equally well in Earth orbit, although in some cases similar measurements made simultaneously in Earth orbit would enhance their total value.

Zodiacal Light

Zodiacal light is the faint scattering of sunlight from interplanetary dust and gas in the ecliptic plane back to Earth. The distribution of this dust in space cannot be resolved solely with earth-based measurements. Of particular concern is the question of whether this dust is uniformly distributed around the sun, or whether there is a local concentration in the vicinity of the Earth, giving rise to the enhanced scatter from the anti-solar direction known as gegenschein (see Figure 25).(10) Observations from the manned vehicle en route to and from the planets could provide useful data in determining the distribution of this dust. Using a small hand-held camera with a wide field of view (at least 10°), a record of the changing intensity, and possibly polarization, of Zodiacal light in various directions as the spacecraft moves away from Earth should provide key data for the analysis of this problem. Simultaneous measurements of light intensity from Earth orbit would be required to compensate for any possible time variations in intensity.

Asteroid Observations

Many hundreds of asteroids with sizes estimated to range from a fraction of a kilometer to several hundred kilometers are in orbit about the sun, mostly between the orbits of Mars and Jupiter.(11) Little is known of the physical properties of these objects. During the 1977 flyby mission the manned spacecraft comes reasonably close to four of these asteroids, as shown below.*

Asteroid	Encounter Distance (AU)	Date
Icarus	.048	5-11-77
Aethra	.387	12-5-77
Icarus	.670	8-5-78
Prisma	.532	4-14-78
Alinda	.124	4-25-78

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*Data is courtesy of Dr. D. F. Bender of North American-Rockwell, Inc.

Using a one meter diffraction-limited telescope, the size of asteroids with diameters greater than 160·R kilometers, where R is the distance to the asteroid in AU, could be measured. Knowing the diameter, the asteroid albedo could be determined. Only four asteroid albedos are known to date, making it difficult to determine whether there are several classes of asteroids differing in composition and structure.

Another useful observation which could be made during the encounter mission would be a measure of asteroid reflectance and polarization as a function of phase angle. For most asteroids, phase angle data obtained from Earth is limited to a maximum of 27°; this could be increased to 40° or 50° by observing from the flyby spacecraft near its aphelion position.

Stellar and Galactic Astronomy

A large aperture diffraction-limited telescope may be used to advantage during the flyby mission to obtain long exposure photographs to search for faint stars and galaxies. Using a one meter diffraction-limited telescope able to point within about 0.04 arc seconds of a given direction for exposure periods of 10 to 40 hours, an improvement in the detection of faint sources of several stellar magnitudes should be possible compared with the present detection limit of the 200 inch Mt. Palomar reflector. By proper selection of the orbit inclination, comparable exposure periods could be obtained for selected regions of the sky from Earth orbital spacecraft. However, in this mode of operation thermal problems may be introduced by the passage from sunlight to darkness on each orbit. There could also be an advantage to the flyby mode if it is determined that the Zodiacal light background is reduced by moving the telescope away from the Earth.

A sky survey should be made to count faint stars in our own galaxy and the average number of galaxies as a function of distance (determined by the red shift). Once the sky survey is recorded on film, the sources of interest would then be calibrated photoelectrically by counting photons from the source region and comparing this level with the neighboring sky background.

A possible extension of the faint source detection experiment is the measurement of the spectra of these sources. One advantage in making these measurements in space is the absence of an airglow spectrum of the night sky which provides an effective noise background at Earth. Spectral data could be used to correlate velocities of distant galaxies (red shift measurement) with apparent magnitudes (as a measure of distance) to further test Hubble's law. Also stellar spectra in the near infrared and ultraviolet are of interest in determining stellar structure and composition.

Another advantage of the flyby-based telescope is the possibility of uninterrupted observation of variable sources. This is especially true for quasar intensity fluctuations, where several days of uninterrupted observation at several wavelengths may shed new light on the structure of these objects.

Observations of Mercury

As it is the closest planet to the sun, information on Mercury is important to our understanding of the solar system. In addition, the unusual relationship between its period of revolution and its spin period leads to a substantial amount of uneven heating of the surface. It has been estimated that the total energy absorbed at the perihelion subsolar point is 2.5 times greater than the point 90° away on the equator,(12) this difference having been maintained for perhaps a considerable fraction of the planet's history. This may have led to permanent changes in the surface properties, as a function of longitude, which may be observed optically or in the infrared.

Unfortunately Mercury is a very difficult planet to observe from Earth. As it never gets more than 28° from the sun, optical observations from the Earth's surface are handicapped either by daylight viewing for small zenith angles, or by extreme atmospheric distortion for nighttime viewing. (At times when the sun is below the horizon and Mercury is still in sight, it must be viewed through the equivalent of several Earth atmospheres.)

Observations from Earth orbit would provide a considerable improvement, as there is no atmospheric distortion. Arbitrarily assuming that the telescope line of sight is kept at least 10° from the Earth-sun line (to minimize the scatter of sunlight down the telescope barrel), the minimum distance to Mercury is about 0.54 AU, although at this time the phase angle (sun-Mercury-observer) is nearly 160°. For a phase angle of 90° the minimum distance is about 0.87 AU. Figures 26 and 27 illustrate the observation geometry of Mercury from the flyby spacecraft during the two passages of Venus on the 1977 encounter mission, and Table V tabulates the pertinent data. So that this data may be compared with the Earth orbital observations, an optical resolution figure of merit is indicated in the far right column. With the same telescope in Earth orbit, this figure of merit would be

1.58 when Mercury is closest to Earth, with a minimum value of about 0.87. In other words, there are periods on the flyby mission when the best linear resolution obtainable at the surface of Mercury would be approximately a factor of two better than could be achieved from Earth orbit, i.e., a figure of merit as low as 0.44.

Infrared observations would also be valuable, and again approximately a factor of two improvement in linear resolution could be achieved. In particular, on J.D. 2443276.5 Mercury is at a minimum range of 0.3 AU with nearly the full disk in darkness. The comparable range from Earth orbit is 0.54 AU.

The Natural Satellites of Mars

The diameters of Phobos and Deimos have been estimated at 19 and 10 kilometers, respectively, based on a measured brightness and an assumed albedo, since they cannot be resolved optically from Earth. Phobos is the only observed satellite in the solar system whose orbital period is shorter than the spin period of its primary. Its large angular momentum suggests that it is a captured asteroid. High resolution photographs of Phobos could be compared with similar photos of known asteroids to search for similarities.

The geometry of the nominal encounter during the 1977 flyby mission is shown in Figure 28. In this configuration both satellites would be seen from the dark side. However, by delaying the encounter time by approximately one hour, both satellites would have moved into extremely favorable viewing positions. Types of observations which could be made include gross optical features such as shape, diameter, and albedo, and possibly the cooling rate if the satellite is eclipsed by Mars. It should also be noted that there may be additional satellites of Mars which have not been detected.

Decameter Radio Emission from Jupiter

Decameter radiation (5-40 Mcps) in short, intense bursts which seem to be confined to cones of about 10° half-angle has been observed coming from Jupiter. More specifically, it has been observed that the satellite Io seems to affect both the probability that emission will be received at Earth and the spectral character of the emission above about 20 Mcps.(13) Apparently the emission phenomenon depends on the favorable positioning of both Io and the Jovian longitude as seen from Earth. Observations of the emission from two different positions would allow a determination of its changing character as the Io-Jovian longitude geometry changes. The geometry of the

1977 encounter mission provides the opportunity to carry out such an experiment. In particular, at the time of Mars passage the spacecraft-Jupiter-Earth angle is approximately 20°. The radiometer equipment used for this experiment could have several alternate uses, such as simultaneous decameter observations of the sun from the flyby spacecraft and the Earth.

Objects of Opportunity

The sudden appearances of comets or asteroids near us in the solar system, and novae or supernovae in our own or other galaxies, provide a good secondary reason for having an observatory available to look in any direction on short notice. In addition, it would be interesting to return photography of the Earth, Mars and Venus taken from distances ranging from a few thousand miles up to an Astronomical Unit to compare their appearances at different distances.

5.0 PAYLOAD SELECTION AND MISSION RETURN

5.1 Payload Selection

Study has shown that experiment payloads on the order of 50,000 lbs can be effectively utilized on a manned planetary encounter mission. This payload weight is compatible with estimates of allowed payload assuming a Saturn V technology based program. Consistent with the scientific objectives and probe deployment strategy outlined earlier, the following preliminary payload selection is made.

	First Venus Passage	Weight
(2)	Meteorological Balloon Probes (6 Balloons each)	3280 lbs
(1)	Balloon Tracking and Data Relay Orbiter	5750 "
(4)	Venus Lander Probes	3600 "
(4)	Photo Sinker Probes	1532 "
	Total	14,162 lbs

Mars Passage	Weight
(3) Mars Surface Sample Recovery Probes (Each establishing a remote geophysics and biologic station in addition to returning surface material)	14,151 lbs
Second Passage	
Same as First Passage	14,162 lbs

Assuming a 50,000 lb experiment payload capability, this leaves about 7,500 lbs for experiments on board the flyby vehicle. Major items here include the one meter diffraction-limited telescope, the biological laboratory, and a microwave mapping radar system.

5.2 Mission Return - Scientific

Origin and Evolution of the Earth, Sun, and Planets

Inferences as to the origin of the Earth and planets are based on extrapolation from knowledge of their present physical and chemical states. Important properties of the various solar system elements which will be investigated by the flyby experiment program include the appearance of Mars, its moons, Venus, Mercury, and the asteroids; composition of the Mars surface and the atmospheres of Mars and Venus; possible distribution and density of interplanetary dust; and the state of the Mars interior, as determined by surface and orbital geophysics measurements. Knowledge of these parameters, in particular the similarities and differences between the new bodies under investigation and the Earth, provides important constraints which the various hypotheses of planetary origin and evolution must satisfy. Astronomical observations of other stars at different stages of development will aid in understanding the origin and history of the sun.

The Origin and Evolution of Life

Samples returned from several areas on the Mars surface will be investigated for life forms; these could be current or fossil life. The results of this investigation, carried out both on board the manned spacecraft and, subsequently, in an earth-based laboratory, should establish the existence or absence of life on Mars. Supplementary measurements to establish the present, and perhaps past, chemical and physical aspects of the biologic environment (chemical composition, temperature, etc.) should shed new light on the mechanism of life development on Earth and the possibilities for similar (or dissimilar) development elsewhere in the solar system.

Dynamic Processes that Shape Man's Terrestrial Environment

One of the primary forces affecting our everyday lives is the weather, which can be described as the interaction between solar radiation and the Earth's atmosphere, with perturbing effects due to the Earth's surface (continents and oceans). Understanding features of this weather phenomenon, perhaps to the point of accurate prediction and limited control, would certainly be a considerable achievement. While much experimental and theoretical work remains to be carried out on our own weather system, it is probable that the study of the rudimentary aspects of a radically different weather system, as quite likely exists on both Mars and Venus, will provide new insight into the working of our own atmosphere. Obvious parameters of importance that are varied by studying Mars and Venus are solar energy flux, mass and composition of the atmosphere, rotation rate of the planet, and physical nature of the surface.

The investigation of another planet at a different stage of geologic evolution, with different degrees of both internal and external activity, serves to isolate and emphasize the role various factors play in their complex interaction on Earth. For example if it were found that Venus had a molten core but no magnetic field, this would certainly provide new insight into the dynamo-type magnetic field generation we believe takes place within the Earth. Such a situation could call for a reappraisal of current theories. The results would, in general, be applicable to all the planets.

5.3 Mission Return - Technological

The technological application of data derived from the Mars encounter mission has two related functions: first, to verify that manned Mars landing is a feasible goal; and second , to determine the physical aspects of the planet environment which will affect the planning and performance of such a mission. The successful performance of the MSSR probe should demonstrate manned Mars landing feasibility. Environmental data collected by the precursory unmanned program, coupled with the encounter mission soft lander experiments and sample return, should provide an adequate characterization to proceed with the follow-on program.

In the case of Venus the complexity of the environment, combined with our lack of sufficient data to describe it, suggest that the role of the technological return will be to determine just what shape the subsequent course of manned exploration should actually take. In the event that manned landing is ruled out for some time to come, the data gathered during the encounter mission will probably be used to determine the design and performance parameters for second generation probes which might work in conjunction with a manned Venus orbiter mission.

Technological return bearing on the overall mission may be considered in terms of two very general but interrelated areas: first, an evaluation of the performance of both man and the spacecraft (including all subsystems) as a measure of the technological requirements to continue and extend our space exploration capabilities; and second, an evaluation of the manned encounter (flyby) mission as a competitive mode of planetary exploration. Specific points related to the first area cited above include the physiological and pyschological effects of long term exposure to zero gravity and confinement when no longer in Earth orbit and the performance of the spacecraft with regard to general reliability and repairability effectiveness. Regarding the second area, the importance of evaluating encounter (flyby) as a mode of exploration can be appreciated when it is realized that as our solar system exploration program develops, there will be an increasing number of objects which man will wish to investigate closely without ever committing himself to an orbit or landing mode.

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Attachments:
References
Tables (5)
Figures (28)

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TABLE I

UNMANNED PLANETARY FLYBY MISSION PARAMETERS

MISSION	EARTH DEPARTURE C_3 (km^2/sec^2)	PLANET ENCOUNTER V_∞ (km/sec)
1971 MARS (I)	8.2 - 9.6	2.8 - 2.9
1972 VENUS (I)	13.3 - 29.1	3.8 - 5.6
1973 MARS (I)	15.0 - 21.5	2.4 - 3.0
1973 VENUS (I)	14.0 - 21.6	3.0 - 4.4
1973 VENUS (II)	7.7 - 9.0	4.5
1975 MARS (I)	21.0 - 26.0	2.4 - 3.6
1975 MARS (II)	13.6 - 19.3	2.4 - 2.9
1975 VENUS (I)	7.0 - 12.5	3.0 - 3.4
1975 VENUS (II)	6.8 - 12.1	3.0 - 3.7
1977 MARS (I)	20.0 - 29.0	2.4 - 3.6
1977 MARS (II)	11.0 - 13.6	2.4 - 2.6
1977 VENUS (I)	7.9 - 9.4	4.1 - 4.6

NOTES: (1) IN THE MISSION COLUMN, "I" AND "II" IDENTIFY TYPE I AND TYPE II TRAJECTORIES, RESPECTIVELY.

(2) THE DATA ARE BASED ON PERIAPSIS ALTITUDES OF 1000 km AND 2000 km AT MARS AND VENUS, RESPECTIVELY.

TABLE II- MANNED PLANETARY ENCOUNTER MISSION PARAMETERS

Mission	Duration (days)	Earth Departure C3 (km^2/sec^2)	Earth Entry Velocity (km/sec)	Aphelion/ Perihelion (AU)	Planet Encounter				
					Planet	V_∞ (km/sec)	Periapsis Velocity (km/sec)	Periapsis Altitude (km)	Planet Illumination On Approach*
1975 Mars Encounter	648	34.9	14.9	2.3/1.0	Mars	8.6	10.0	300	Sunlit
1975 Venus Encounter	368	10.5	13.5	1.2/0.7	Venus	4.6	10.9	500	Sunlit
1977 Triple Planet	716	40.8	12.0	1.6/0.7	Venus Mars Venus	6.7 4.4 7.1	11.8 5.6 12.0	680 3960 700	Sunlit Sunlit Sunlit
1978 Dual Planet	645	27.8	13.7	1.7/0.5	Venus Mars	10.5 5.4	14.1 7.3	1170 200	Sunlit Dark
1978 Triple Planet	800	26.3	13.1	1.6/0.6	Venus Mars Venus	10.3 4.9 6.5	13.7 5.9 11.1	1750 4670 1910	Sunlit Dark Sunlit
1979 Mars Encounter	686	32.4	14.4	2.4/0.9	Mars	10.6	12.0	300	Sunlit
1981 Triple Planet	790	45.4	12.5	1.6/0.5	Venus Mars Venus	6.0 7.6 10.9	8.8 8.4 13.3	9270 2990 5060	Sunlit Dark Dark

*The criterion is that a planet is considered "Sunlit" if approximately half or more of the area projected on the "Plane-of-the-Sky" is illuminated by the sun.

TABLE III

BALLOON TRACKING AND DATA RELAY ORBITER SUBSYSTEM WEIGHT BREAKDOWN

ORBITAL SPACECRAFT			510 LBS
POWER SUBSYSTEM		180 LBS.	
COMMUNICATION SUBSYSTEM		150	
ATTITUDE CONTROL		80	
STRUCTURE		65	
EQUIPMENT		35	
PROPULSION STAGE II			1200 LBS
PROPELLANT	(I_{sp} 325 SEC)	1065	
INERT WEIGHT		135	
PROPULSION STAGE I			4040 LBS
PROPELLANT	(I_{sp} 325 SEC)	3590	
INERT WEIGHT		450	
			5750 LBS

TABLE IV

MSSR PROBE SUBSYSTEM WEIGHTS

RENDEZVOUS ROCKET	910
SAMPLE ACQUISITION SUBSYSTEM	88
GEOPHYSICS EXPERIMENTS	180
ADDITIONAL EXPERIMENTS	100
FLIGHT CONTROL SENSORS AND ELECTRONICS	60
RADARS	43
COMMUNICATIONS INCLUDING ANTENNAS	70
DATA HANDLING	30
POWER	243
ATTITUDE CONTROL PROPULSION	50
CABLING	80
SPACEFRAME	760
LANDING PROPULSION	900
AEROSHELL	578
INJECTION PROPULSION	380
STERILIZATION CANISTER	405
GROSS WT.	4717 LBS

TABLE V

OBSERVATIONAL GEOMETRY FOR MERCURY

1977 TRIPLE PLANET ENCOUNTER

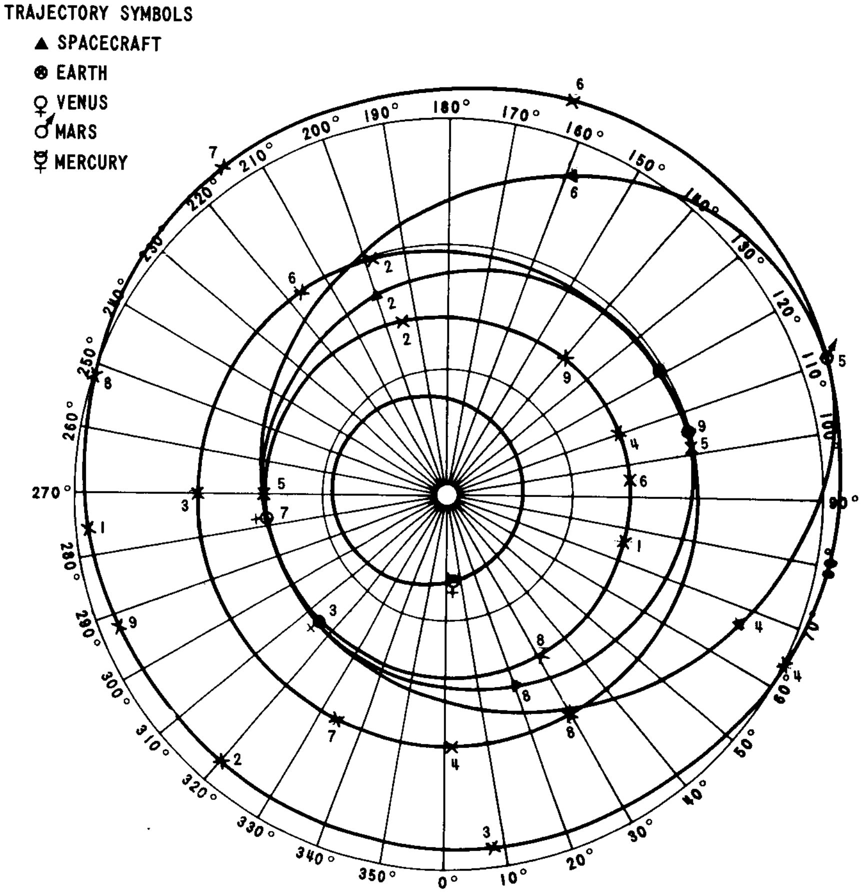
EARTH LAUNCH - J.D. 2443166.00
VENUS ARRIVAL- 3315.66
MARS ARRIVAL - 3511.15
VENUS ARRIVAL- 3739.99
EARTH ARRIVAL- 3882.00

DATE	LATITUDE OF MERCURY (DEGREES)	SEPARATION DISTANCE (AU)	SUN-MERCURY-SPACECRAFT ANGLE (ψ) (DEGREES)	OPTICAL RESOLUTION FIGURE OF MERIT*
1977 TRIPLE PLANET ENCOUNTER TRAJECTORY - EARTH TO VENUS LEG				
J.D. 2443252.5	+5.2	.55	119	.63
3260.5	+2.3	.4	141	.64
3268.5	-0.6	.35	163	1.21
3276.5	-3.2	.3	168	1.43
3284.5	-5.3	.3	145	.53
3292.5	-6.7	.35	128	.44
3300.5	-6.9	.5	106	.52
3308.5	-4.9	.6	92	.60
1977 TRIPLE PLANET ENCOUNTER TRAJECTORY - MARS TO VENUS LEG				
J.D. 2443692.5	+5.2	.7	138	1.04
3700.5	+2.3	.5	160	1.47
3708.5	-0.6	.4	168	1.91
3716.5	-3.2	.4	142	.65
3724.5	-5.4	.5	122	.59
3732.5	-6.7	.5	109	.53

*FIGURE OF MERIT = SEPARATION DISTANCE DIVIDED BY COS $(\psi - \frac{\Pi}{2})$, WHICH IS PROPORTIONAL TO THE BEST LINEAR RESOLUTION OBTAINABLE ON THE ILLUMINATED PORTION OF THE SURFACE.

LAUNCH YEAR	MARS ♂	VENUS ♀
1969	(2) MARINER FLYBYS ATLAS/CENTAUR	
1970		
1971	ORBITER + IMPACT LANDER PROBE TITAN III	
1972		ORBITER + ATMOSPHERIC PROBE TITAN III
1973	ORBITER + IMPACT LANDER PROBE TITAN III	VENUS/MERCURY SWINGBY + VENUS IMPACT LANDER PROBE TITAN III
1974		
1975	ORBITER + LANDER PROBE TITAN III/CENTAUR	ORBITER + LANDER PROBE TITAN III/CENTAUR
1976		
1977	MANNED TRIPLE PLANET ENCOUNTER MISSION SATURN V	

FIGURE I - PRECURSORY UNMANNED PLANETARY PROGRAM



POSITION	DAYS INTO MISSION	DATE
1	0	JAN. 23, 1977
2	74	
3	149 (VENUS ENCOUNTER)	JUNE 21, 1977
4	245	
5	345 (MARS ENCOUNTER)	JAN. 3, 1978
6	459	
7	574 (VENUS ENCOUNTER)	AUG. 20, 1978
8	645	
9	716 (EARTH ENTRY)	JAN. 9, 1979

FIGURE 2 - 1977 TRIPLE PLANET MISSION SOLAR ORBIT GEOMETRY

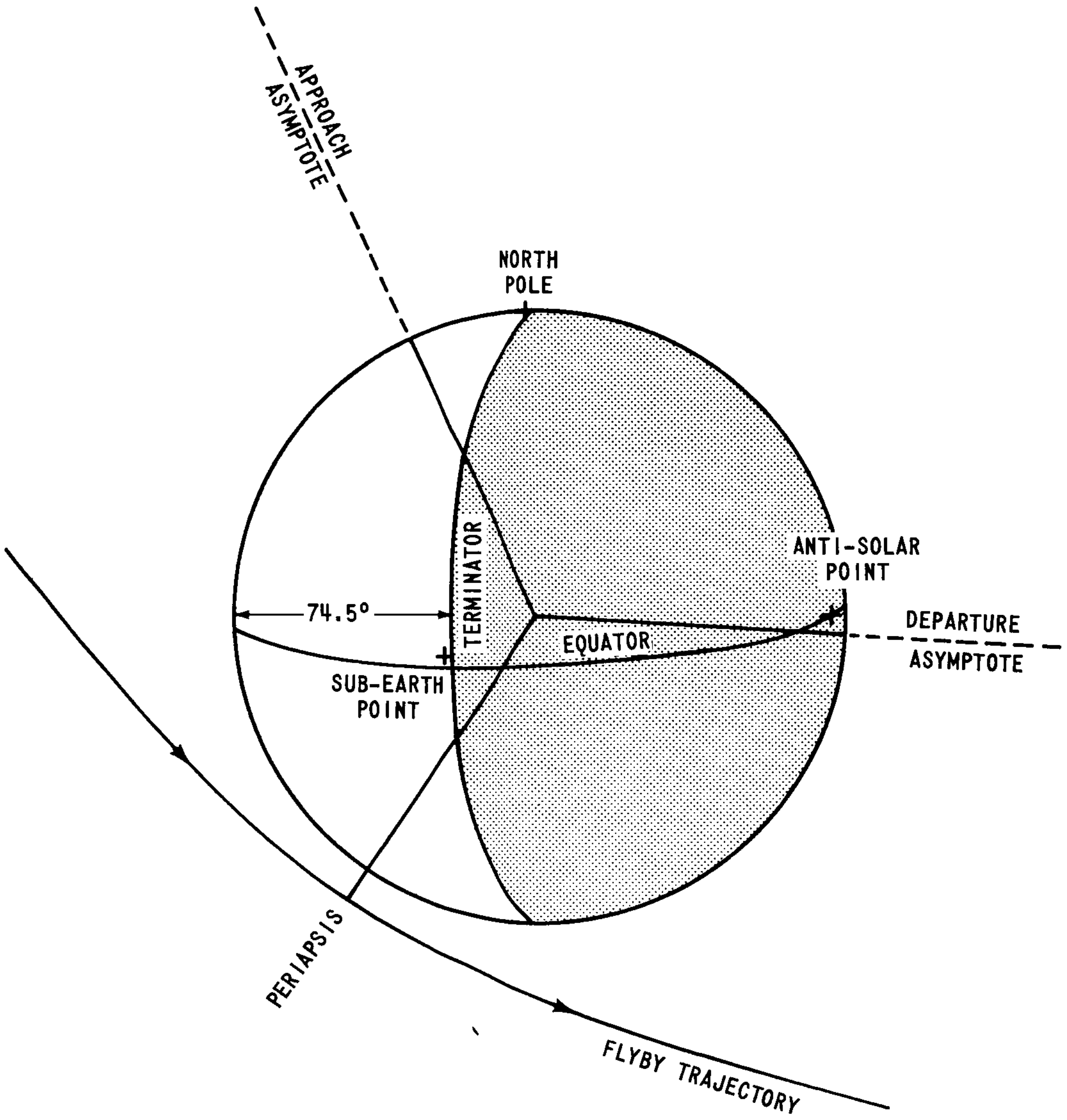
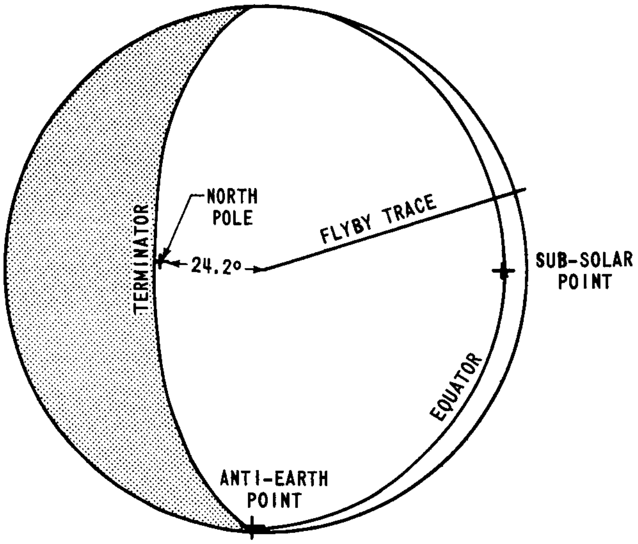
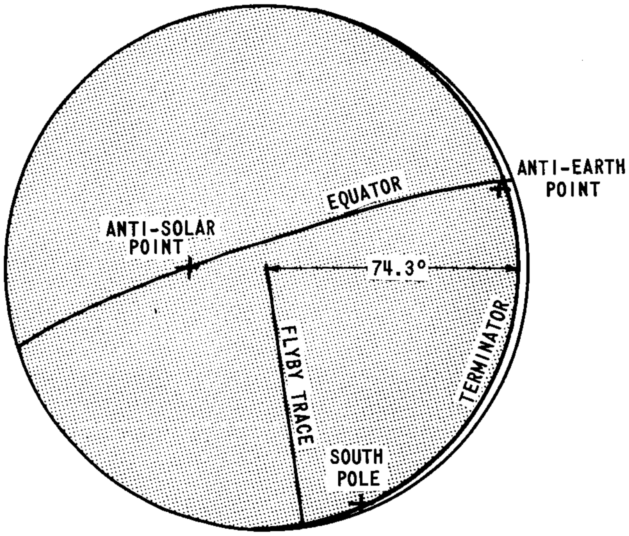


FIGURE 3 - FIRST VENUS ENCOUNTER - PROJECTION IN THE FLYBY PLANE

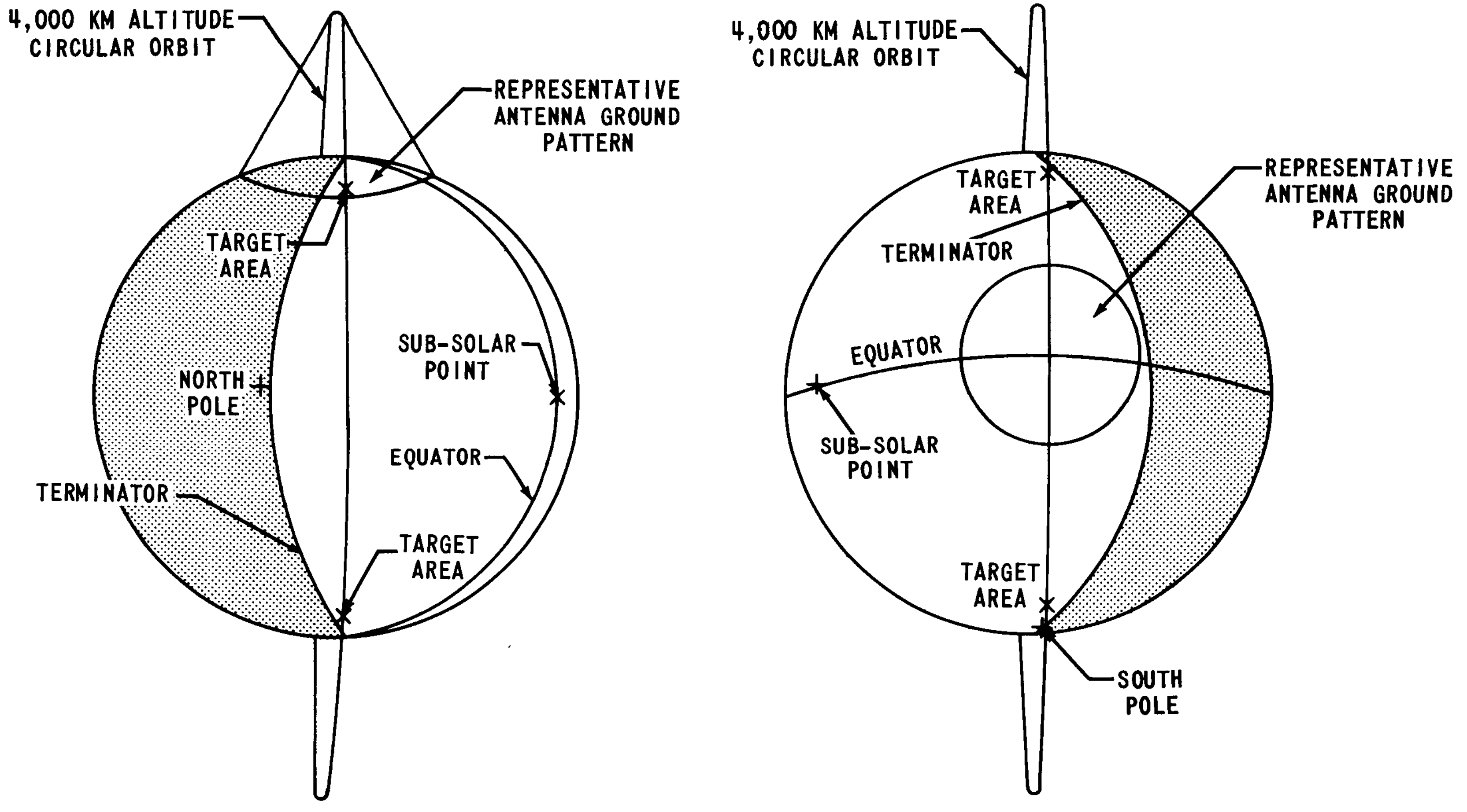


VIEW ON ARRIVAL



VIEW ON DEPARTURE

FIGURE 4 - FIRST VENUS ENCOUNTER - VIEW ON ARRIVAL AND DEPARTURE



FIRST VENUS ENCOUNTER

SECOND VENUS ENCOUNTER

FIGURE 5 - METEOROLOGICAL BALLOON PROBE TARGET AREAS AND INITIAL ORBIT OF RELAY SATELLITE

GENERAL PROBE CHARACTERISTICS:

1. WEIGHT AT SEPARATION = 1,640 LBS
2. 30° SPHERE - CONE ENTRY SHELL
3. BALLISTIC COEFFICIENT: .50 (LOW ALT.) $\leq \frac{M}{C_D A} \leq$ .90 (HIGH ALT.)

WEIGHT SUMMARY: (LBS.)

BALLOON SYSTEM WEIGHTS:		
45 KM ALT.	=	81
40 KM ALT.	=	70
30 KM ALT.	=	81
25 KM ALT.	=	80
10 KM ALT.	=	165
5 KM ALT.	=	188
TOTAL BALLOON SYS. WT.	=	665
ENTRY SYS. WT.	=	400
PROBE WT. AT ENTRY	=	1,065
PROPULSION SYS. AND SUPPORT STRUCTURE WT.	=	222
STERILIZATION CAN. WT.	=	353
PROBE WT. AT SEP.	=	1,640

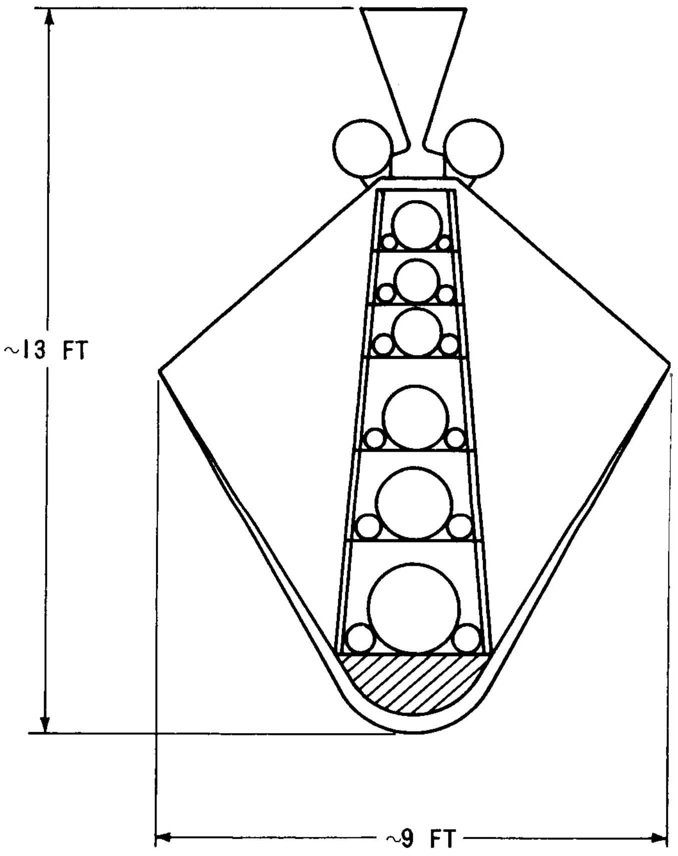
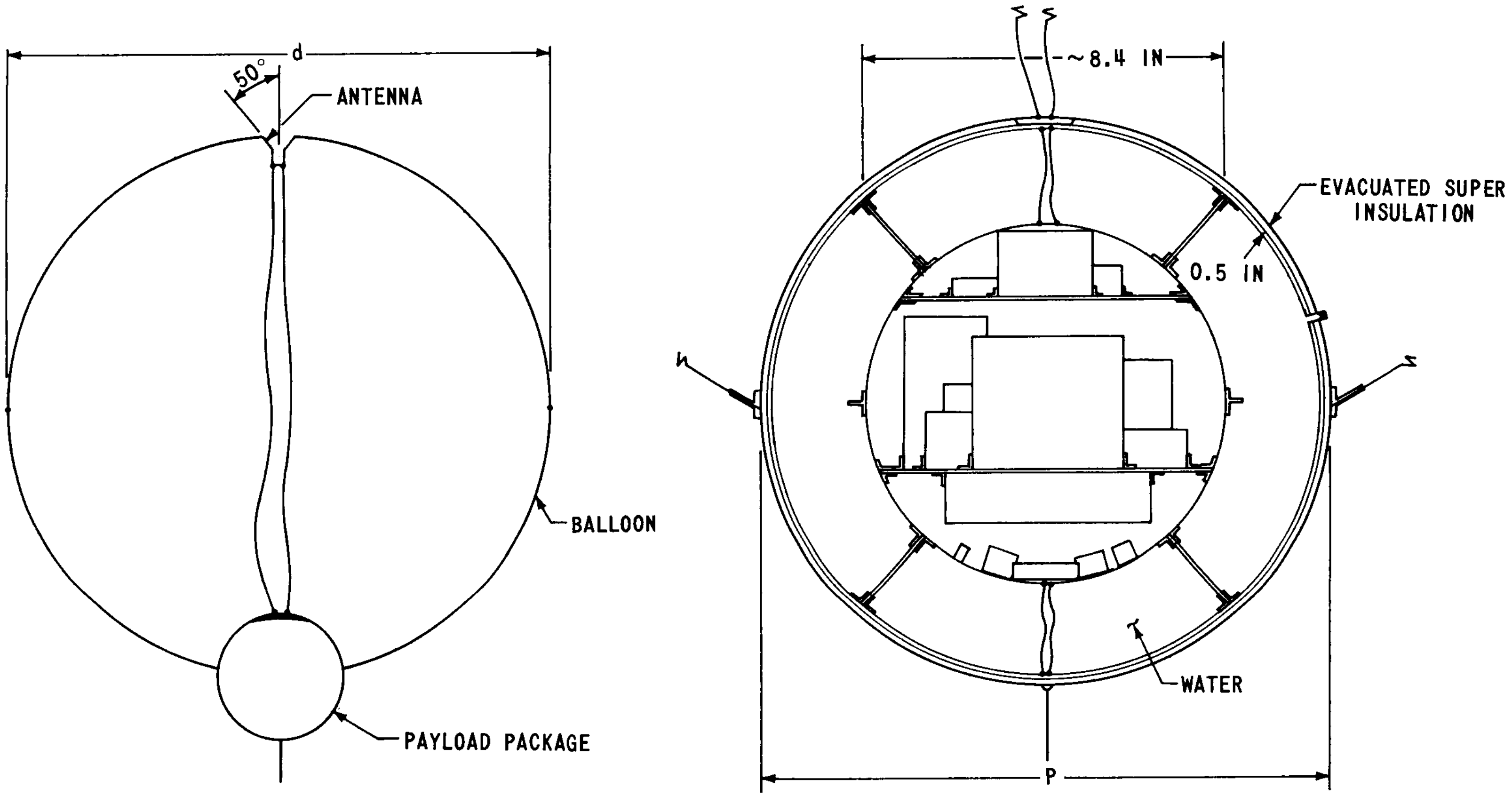


FIGURE 6 - METEOROLOGICAL BALLOON PROBE



PAYLOAD PACKAGE DETAIL

BALLOON ALT. (KM)	DEPLOYED WT. (LBS)	WALL MATERIAL	d(FT)	P(IN)
45	50	MYLAR	21.8	10.6
40	44	MYLAR	15.0	10.8
30	46	KAPTON	9.7	11.4
25	50	KAPTON	8.5	12.4
10	109	STEEL WEAVE	7.1	14.6
5	122	STEEL WEAVE	7.0	15.7

FIGURE 7 - DEPLOYED METEOROLOGICAL BALLOONS

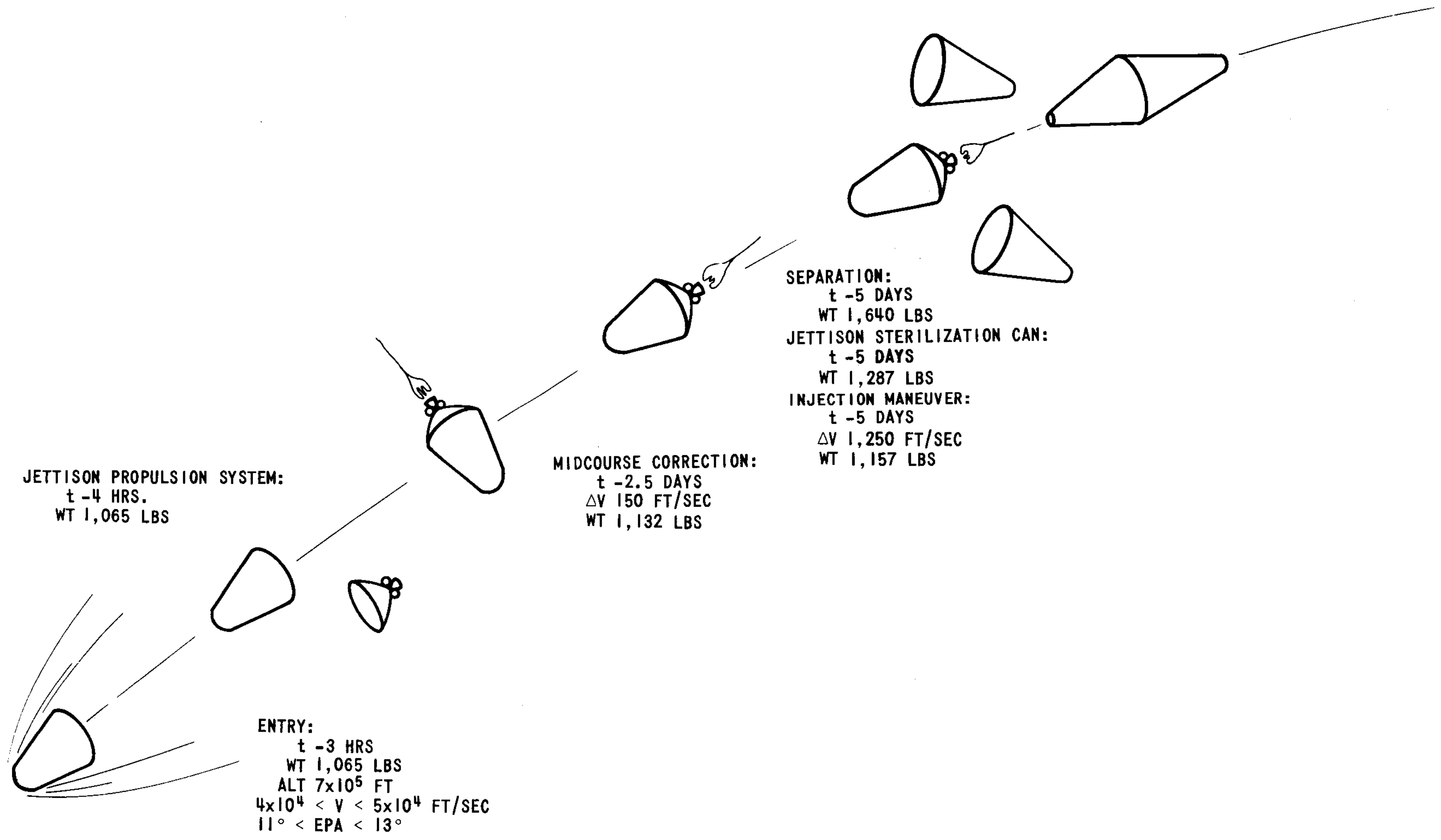
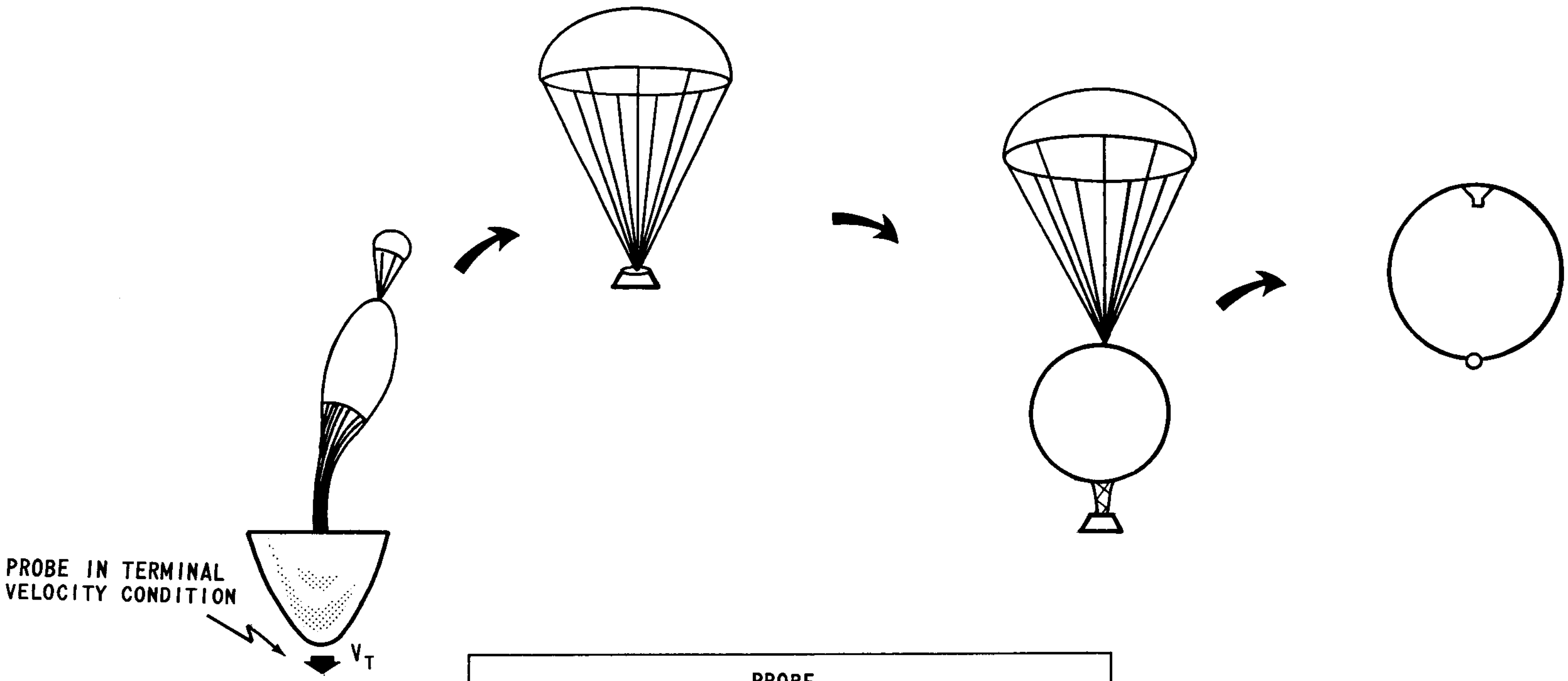


FIGURE 8 - METEOROLOGICAL BALLOON PROBE: SEPARATION TO ENTRY MISSION PROFILE



	PROBE			
DEPLOYMENT ALTITUDE (KM)	M/C_DA (SLUGS/FT^2)	V_T (FT/SEC)	q (LB/FT^2)	PARACHUTE DIAM.^{1,2} (FT)
45	.90	350	23	14.3
40	.85	280	24	13.9
30	.80	120	23	13.5
25	.70	95	20	15.0
10	.60	40	17	SEE NOTE 3
5	.50	30	15	SEE NOTE 3

NOTES:

1. PARACHUTE DIAMETERS ARE SIZED TO MAINTAIN $q \sim .75$ LB/FT^2 DURING "MYLAR" AND "KAPTON" BALLOON INFLATION.
2. TYPE OF PARACHUTE IS "SOLID FLAT".
3. ONLY A SMALL STABILIZATION CHUTE IS NEEDED SINCE A HIGH "q" ENVIRONMENT IS ACCEPTABLE DURING INFLATION OF A "STEEL WEAVE" BALLOON.

FIGURE 9 - DEPLOYMENT AND INFLATION OF METEOROLOGICAL BALLOONS

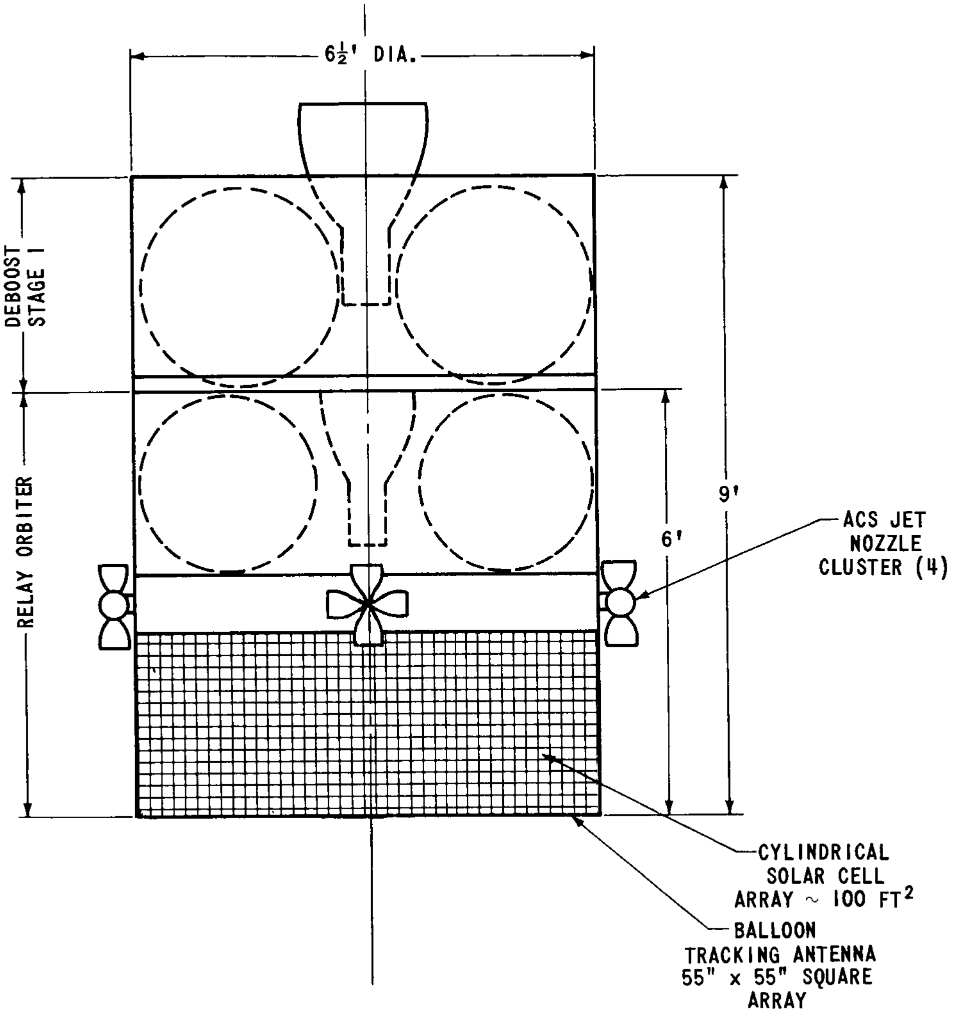


FIGURE 10 - BALLOON TRACKING AND DATA RELAY ORBITER

ALTITUDE = 4,000 KM
ORBIT RADIUS = 10,050 KM
PERIOD = 3.08 HRS.
ORBITAL VELOCITY = 5.65 KM/SEC

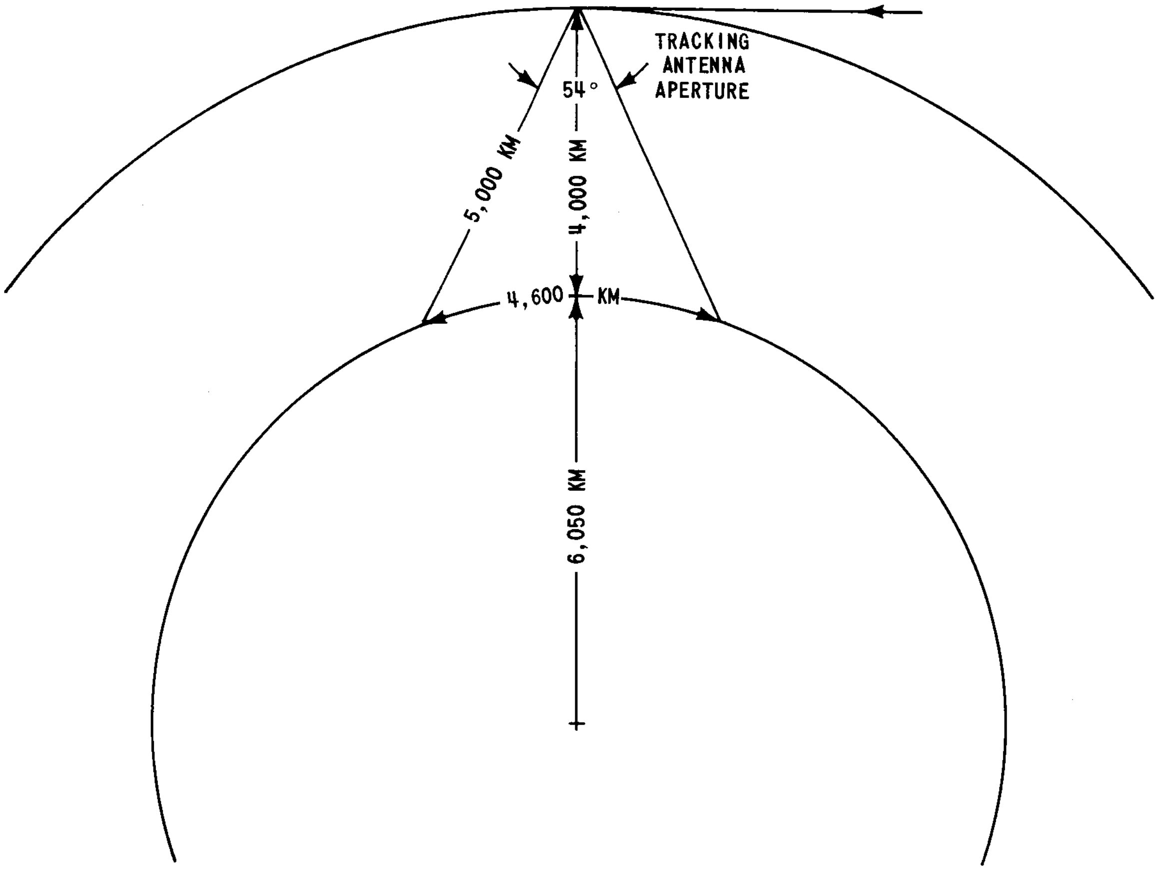


FIGURE 11 - BALLOON TRACKING AND DATA RELAY ORBITER TRACKING GEOMETRY

WEIGHT BREAKDOWN

SCIENTIFIC INSTRUMENTATION	79 LBS
COMMUNICATIONS	33 LBS
PROPULSION	26 LBS
STRUCTURE	158 LBS
COOLANT	12 LBS
STERILIZATION CANISTER	75 LBS
TOTAL	383 LBS

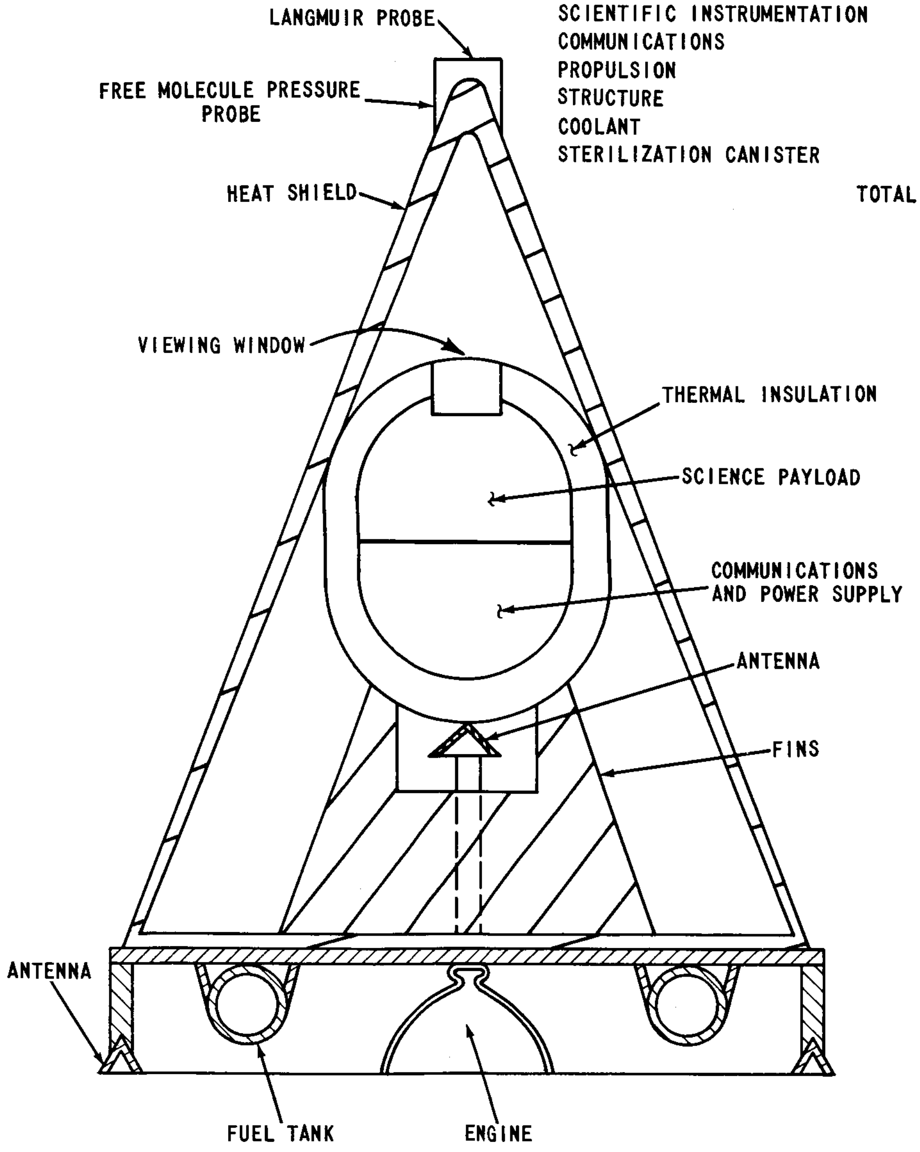


FIGURE 12 - OUTLINE OF PHOTO SINKER PROBE

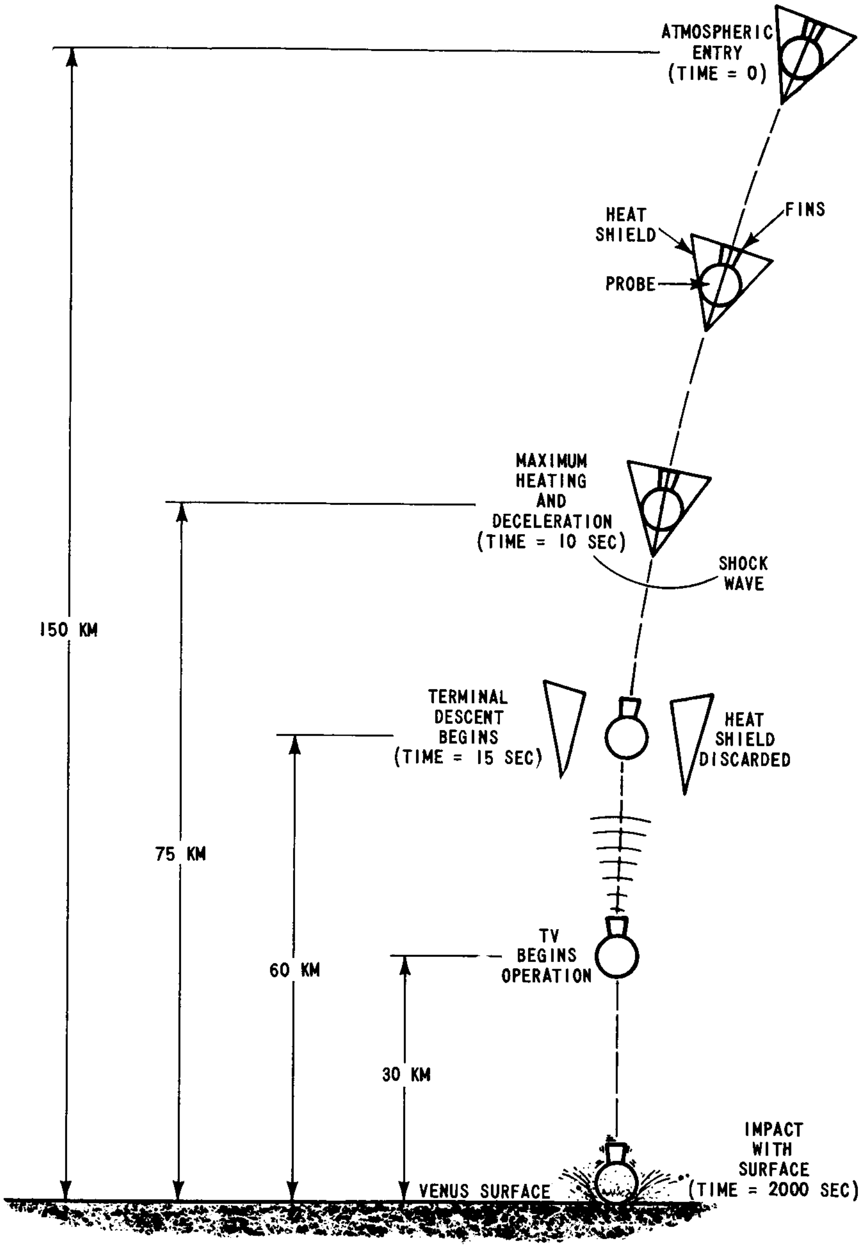


FIGURE 13 - PHOTO SINKER MISSION PROFILE

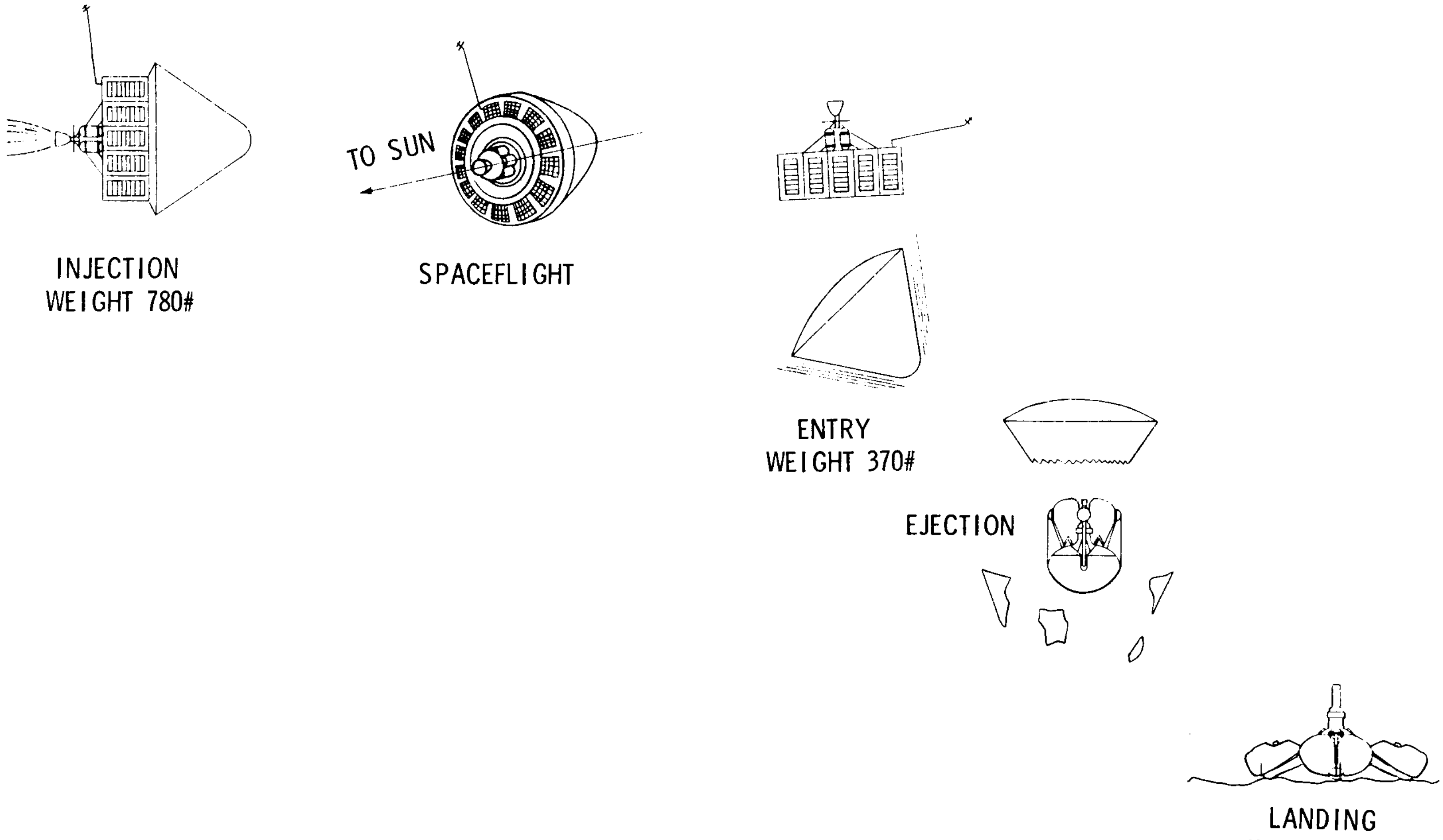


FIGURE 14 - VENUS LANDER PROBE MISSION PROFILE

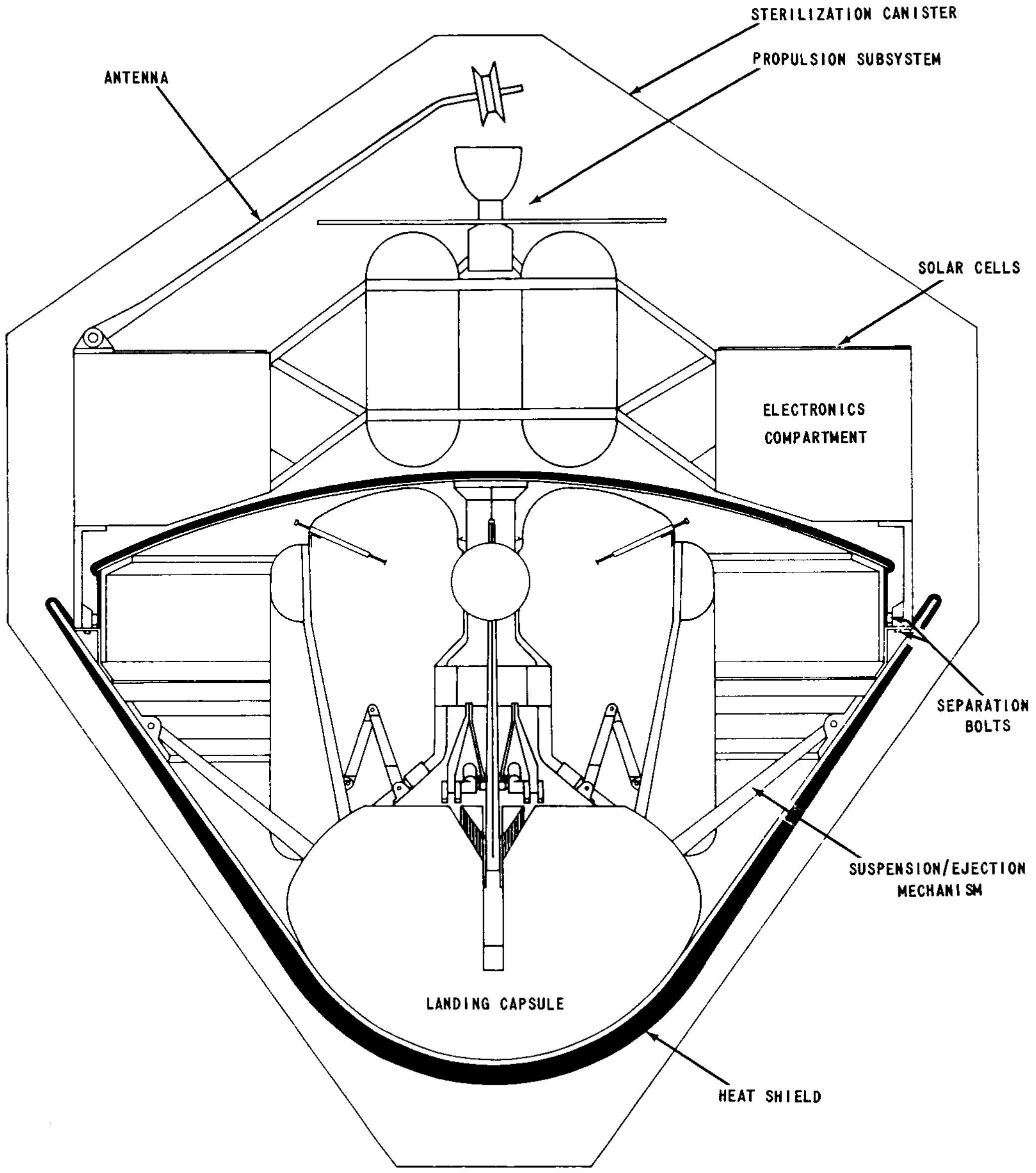


FIGURE 15 - VENUS LANDER PROBE GENERAL ARRANGEMENT

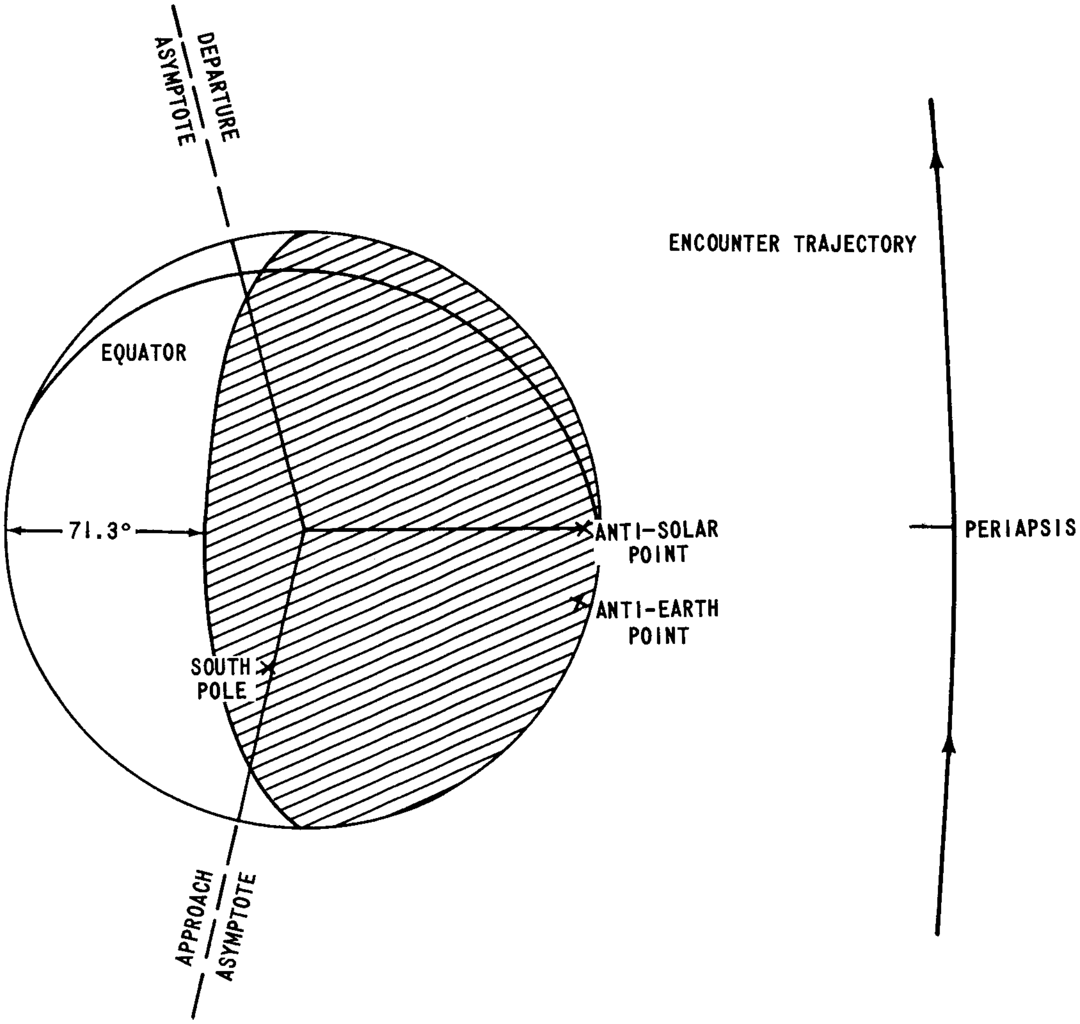
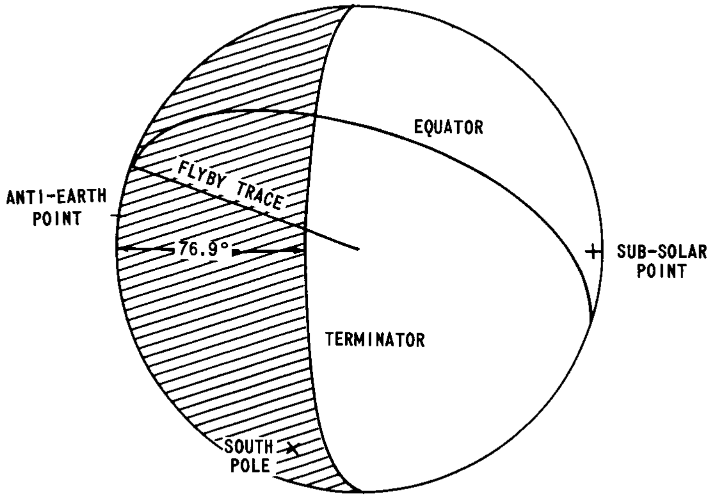
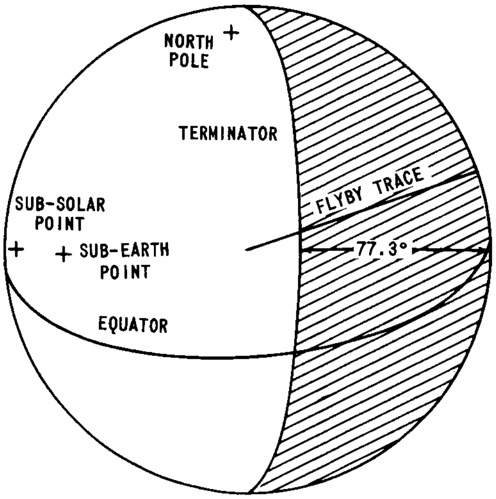


FIGURE 16 - MARS ENCOUNTER - PROJECTION IN THE FLYBY PLANE



VIEW ON ARRIVAL



VIEW ON DEPARTURE

FIGURE 17 - MARS ENCOUNTER - VIEW ON ARRIVAL AND DEPARTURE

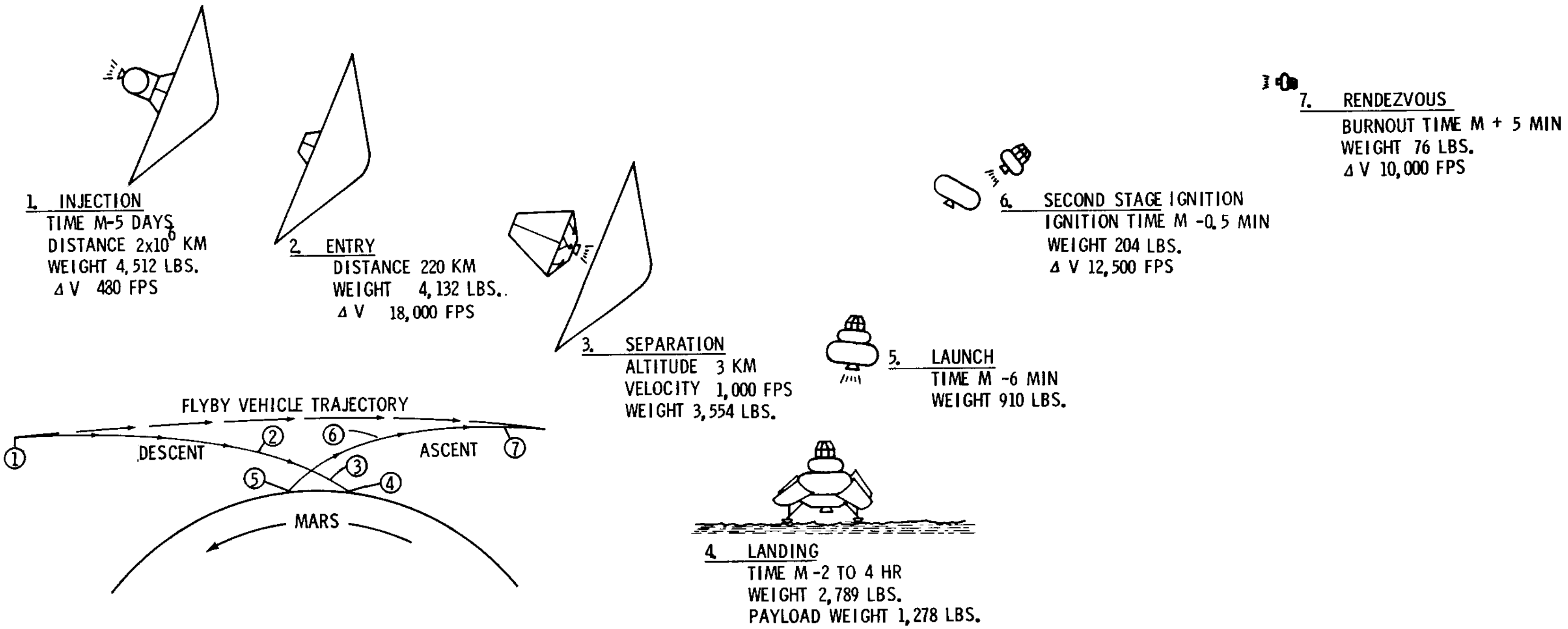


FIGURE 18 – MSSR MISSION PROFILE

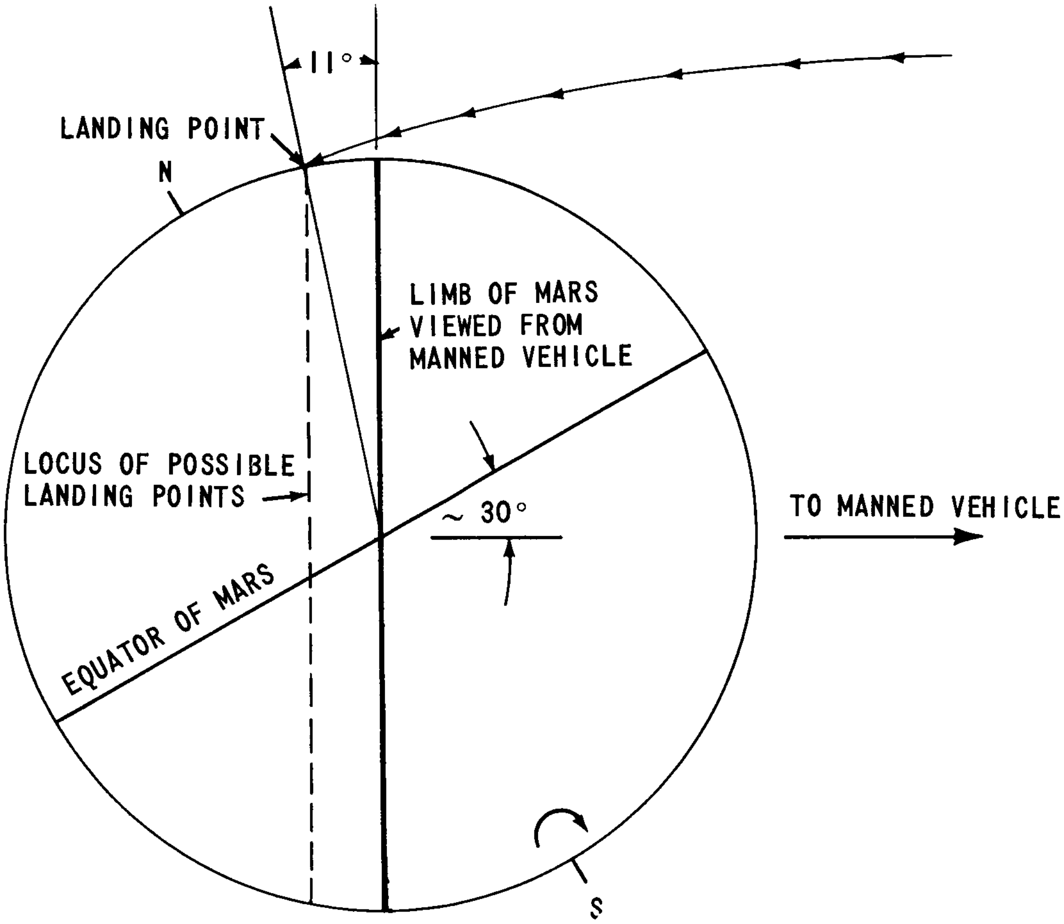


FIGURE 19 - MSSR ENTRY AND LANDING GEOMETRY

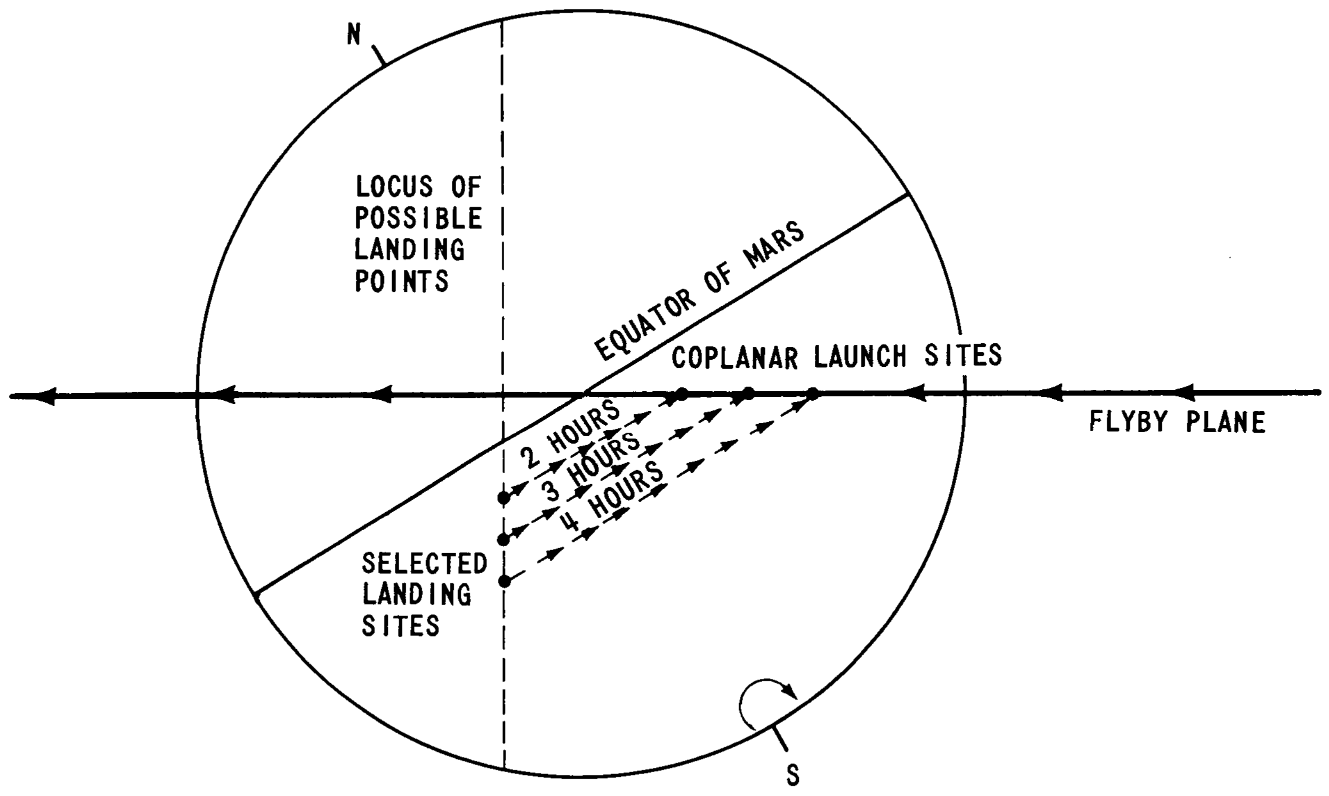


FIGURE 20 - MOTION OF LANDED MSSR PROBES DURING STAY TIME

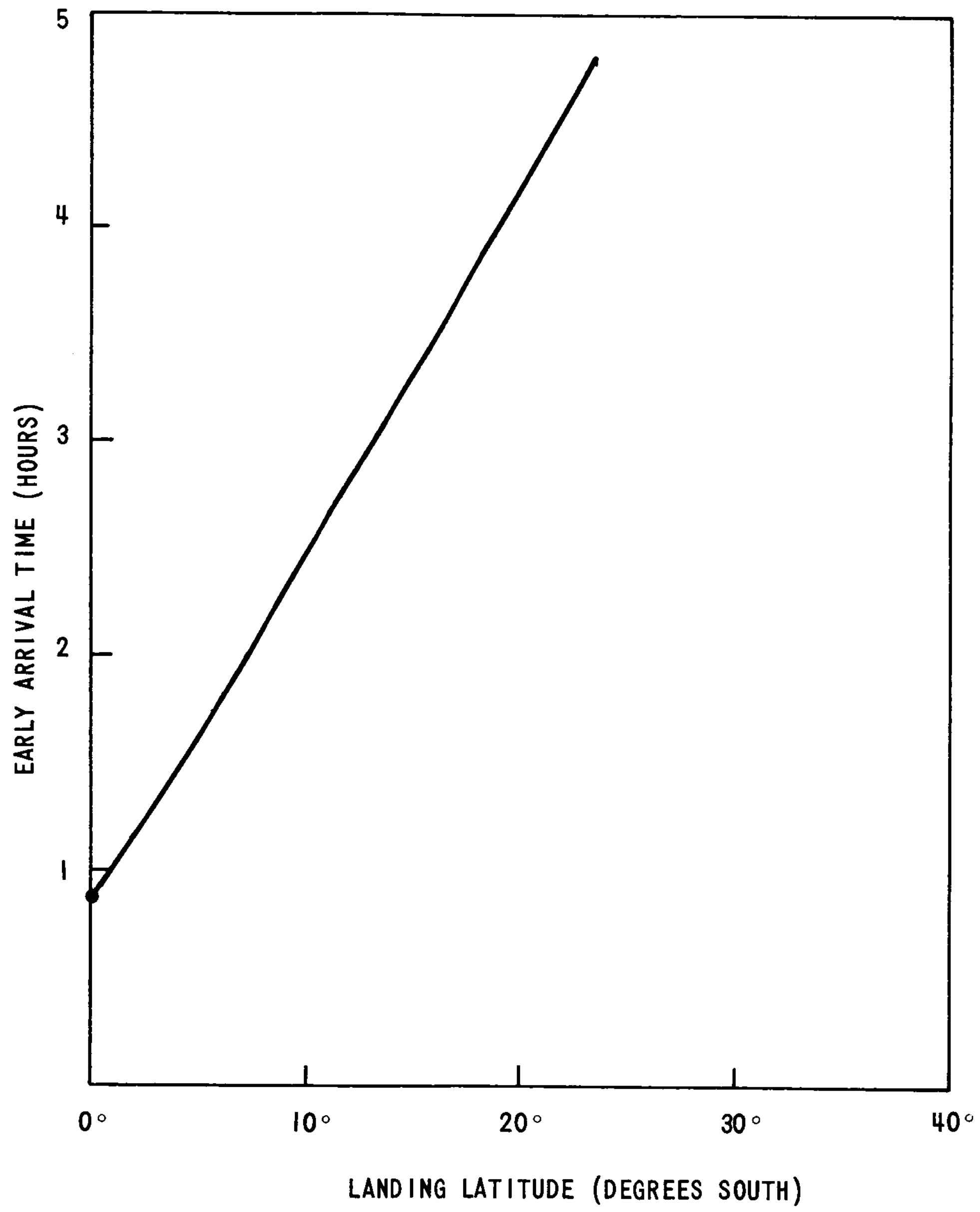


FIGURE 21 - MSSR TARGETING

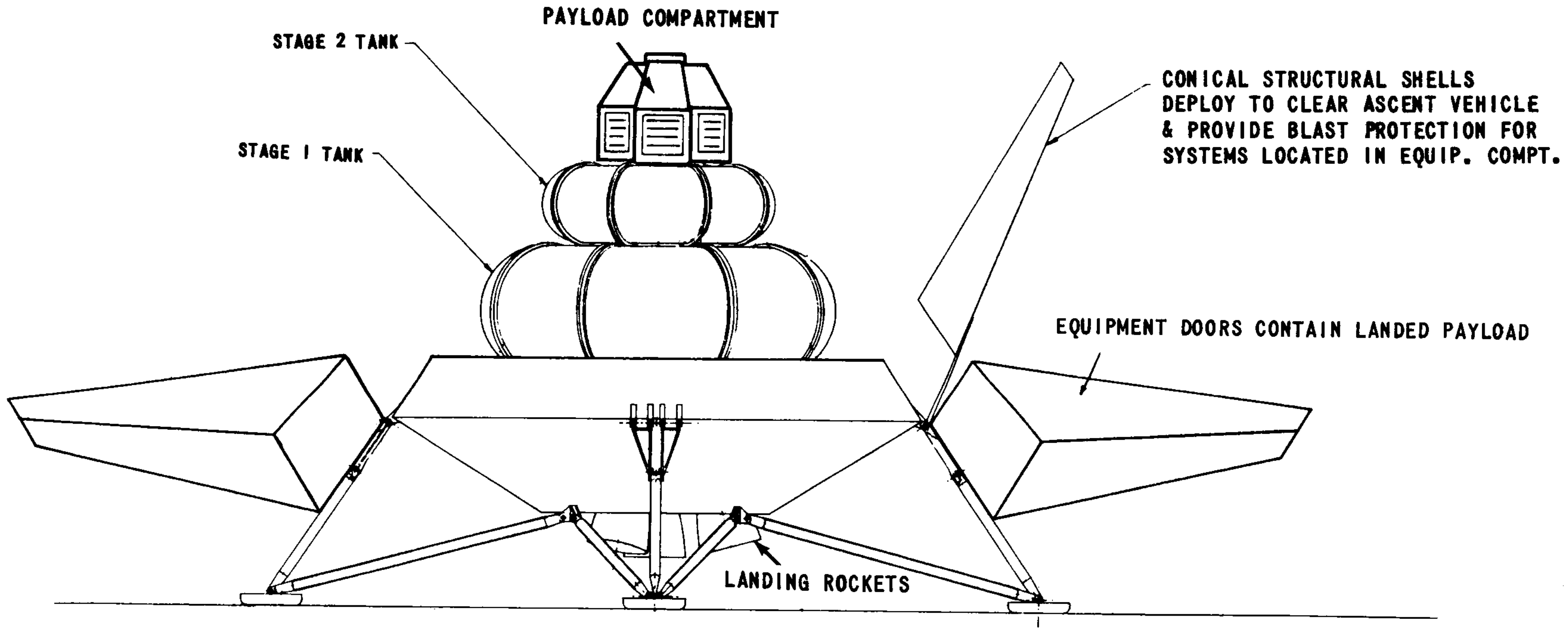


FIGURE 22 - MSSR PROBE (LANDED CONFIGURATION)

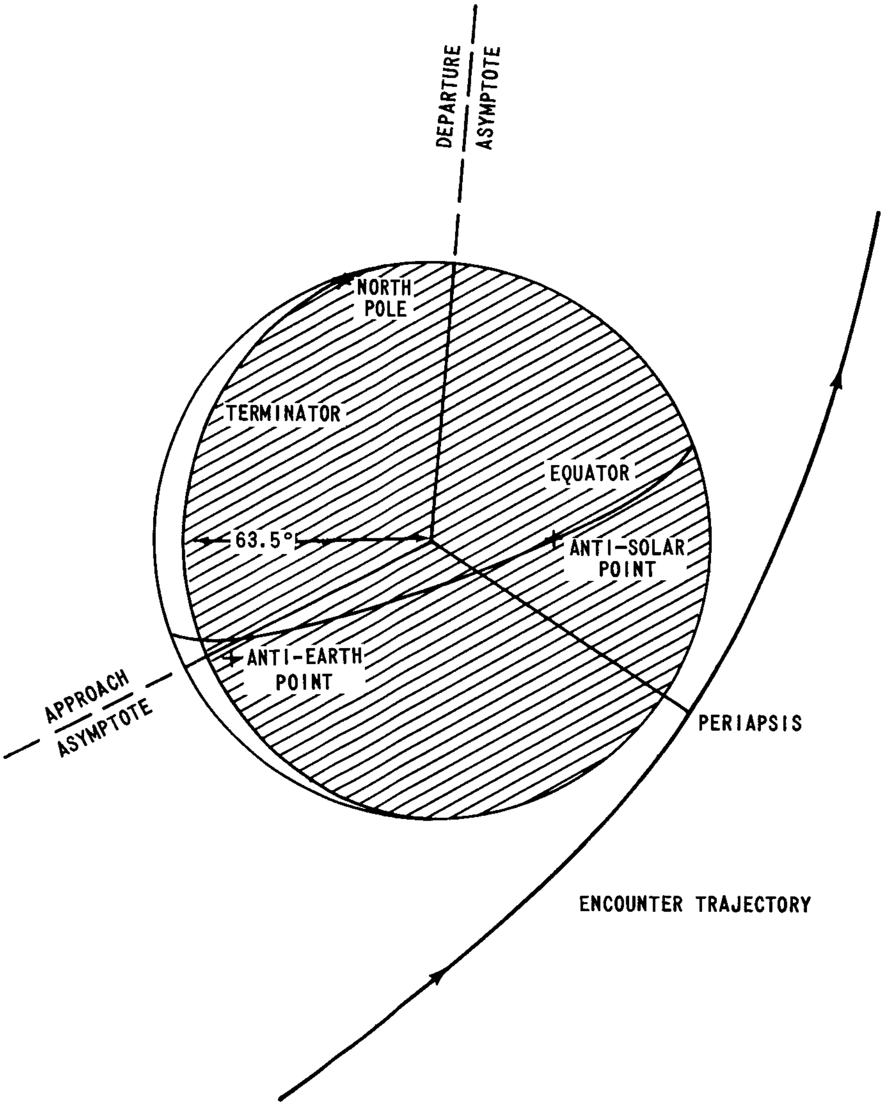
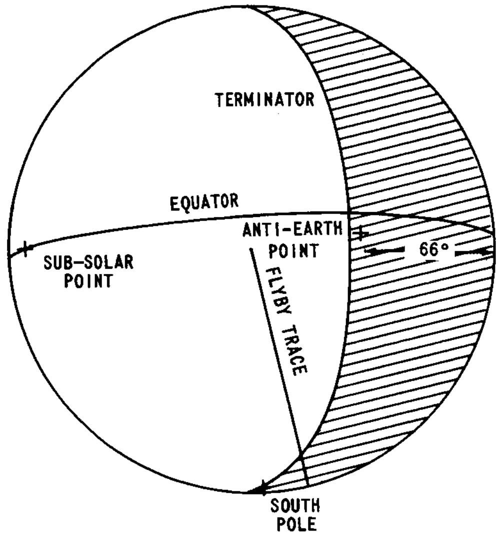
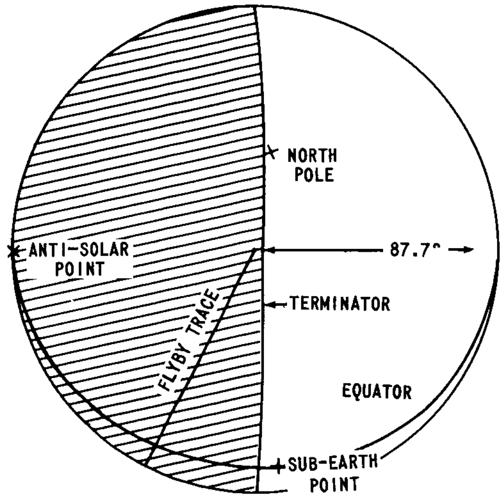


FIGURE 23 - SECOND VENUS ENCOUNTER - PROJECTION IN THE FLYBY PLANE



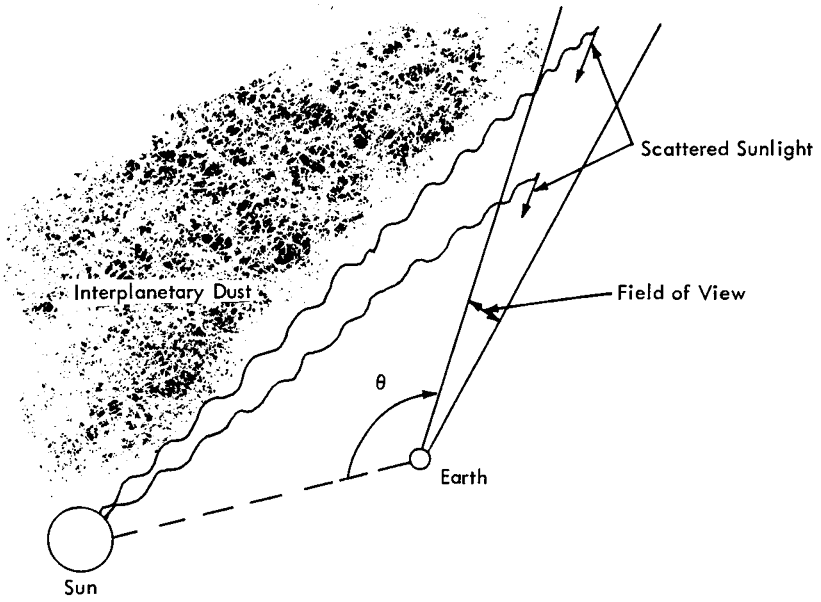
VIEW ON ARRIVAL



VIEW ON DEPARTURE

FIGURE 24 - SECOND VENUS ENCOUNTER - VIEW ON ARRIVAL AND DEPARTURE

The Zodiacal Light
(The drawing is in the plane of the ecliptic)



Light Intensity of the Sky Background in Space vs. θ (Schematic)

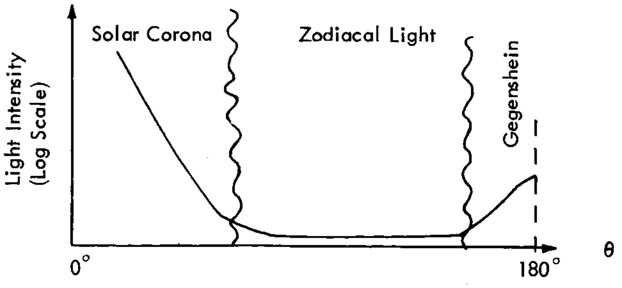


FIGURE 25 - ZODIACAL LIGHT

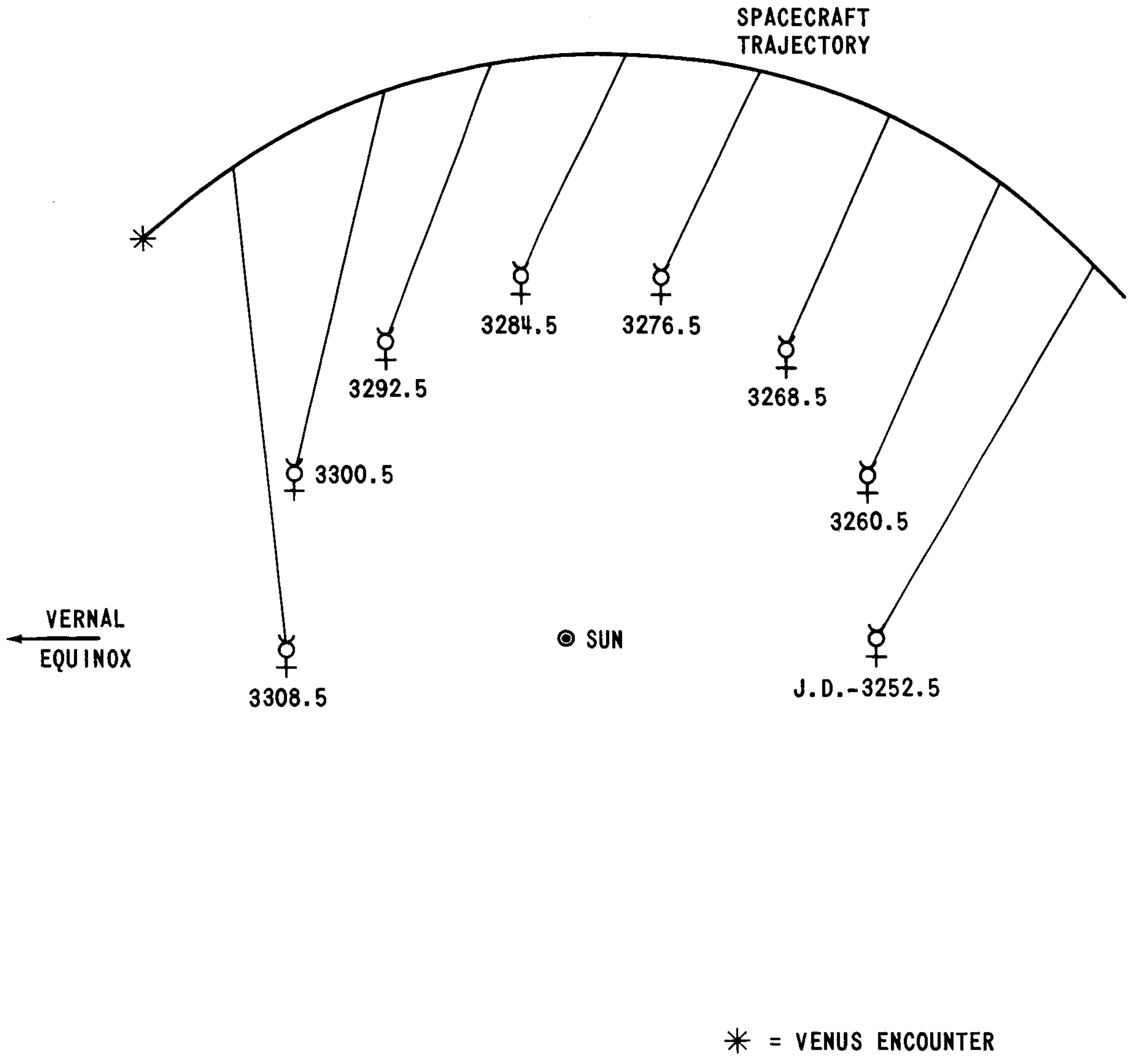


FIGURE 26 - SUN-MERCURY-SPACECRAFT GEOMETRY ON FIRST VENUS PASSAGE

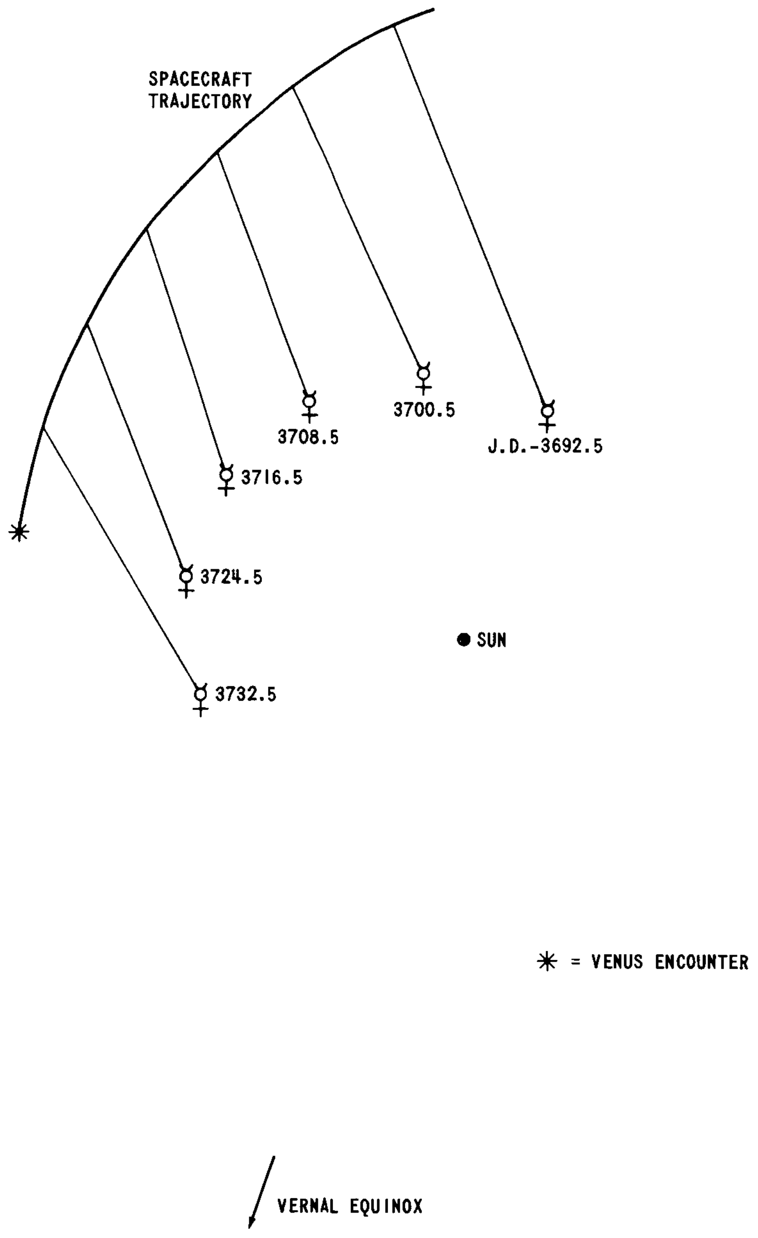


FIGURE 27 - SUN-MERCURY-SPACECRAFT GEOMETRY ON SECOND VENUS PASSAGE

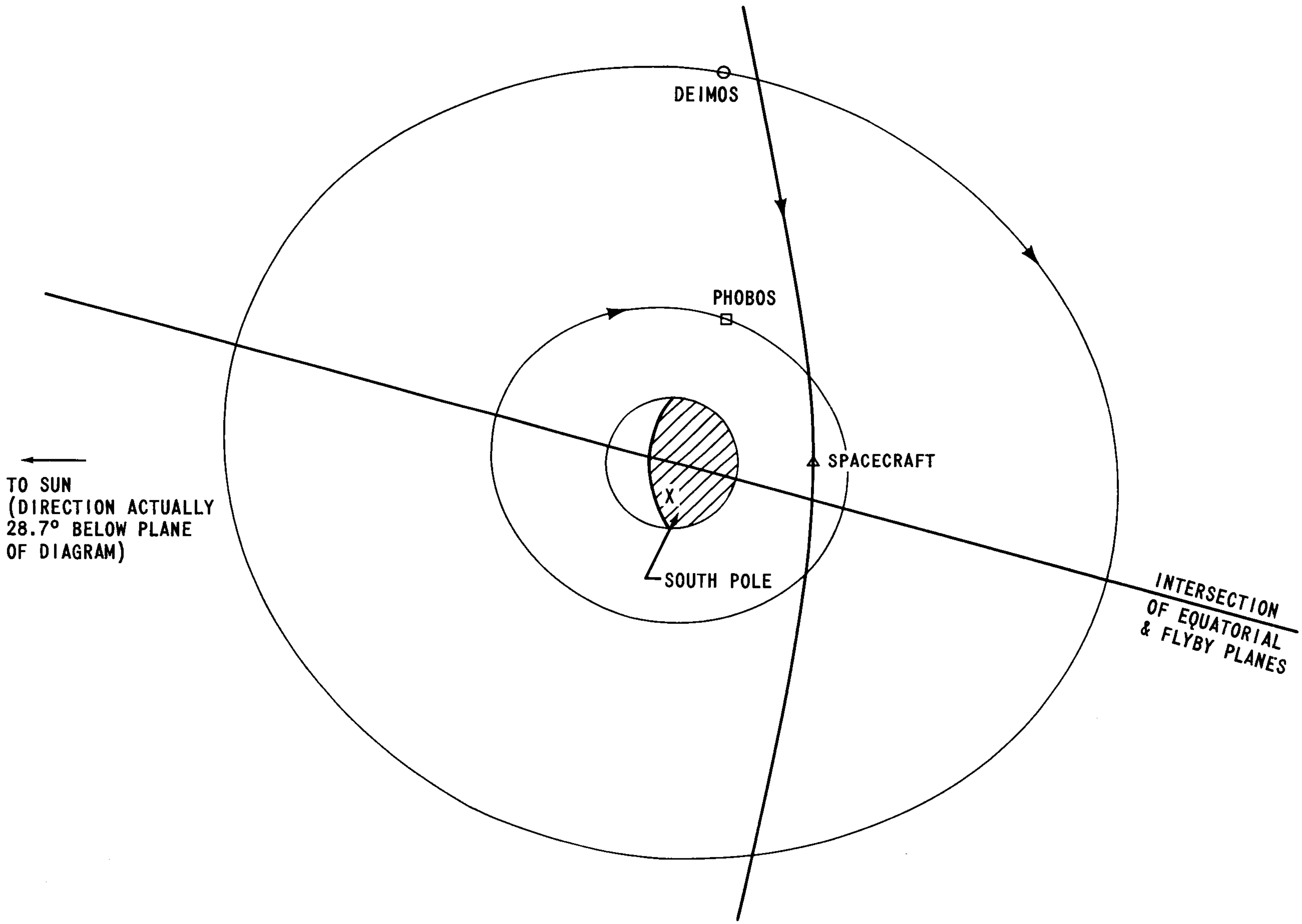


FIGURE 28 - POSITIONS OF PHOBOS AND DEIMOS ON THE 1977 TRIPLE PLANET FLYBY

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