

BELLCOMM, INC.

1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: Drop Sonde and Photo Sinker Probes
for a Manned Venus Flyby Mission
Case 710

DATE: May 7, 1968

FROM: R. N. Kostoff

MEMORANDUM FOR FILE

I. INTRODUCTION

Both the Drop Sonde and Photo Sinker are similar (see Figure 1) bomb-shaped, well-instrumented atmosphere traversing probes which measure the state of selected regions of the Venus atmosphere. In addition, the Photo Sinker has the capability of taking TV pictures of the surface and near-surface region. More detailed objectives of the Drop Sonde are listed in Table I, and those of the Photo Sinker are listed in Table II. In the context of this study, the probes are delivered from a manned flyby spacecraft.

II. Mission Profile (See Figure II)

Both probes are separated from the manned flyby vehicle and are given velocity increments (ΔV) sufficient in both magnitude and direction to place them on the desired trajectory. Separation times are of the order of a few days prior to manned vehicle periapsis. Lead times for the Drop Sondes are about 15 hours, and for the Photo Sinker are about 1 1/2 hours. After the separated probes have traveled about half the distance from separation to the planet surface, they are given a midcourse correction, if required. (Optimal separation and midcourse correction times are discussed more fully in Reference 2, for the case of Mars). Then, their engines are jettisoned.

During the course of flight from separation to atmospheric entry, the probe is tracked by radar, so that its distance from the manned vehicle is known.

At a distance of about 2000 km from the planet surface the Langmuir probe, free-molecule pressure probes, and mass spectrometer begin operation. Continuous transmission of data occurs until the probe encounters the initial portion of the sensible atmosphere ($\sim 200 \pm 50$ km). Then, communications are temporarily disrupted during this high-heating regime, due to the formation of a plasma sheath about the vehicle. In this high-deceleration phase, accelerometer readings are taken. This data is stored,

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ABSTRACT

System requirements for two similar classes of Venus atmosphere traversing probes, Drop Sondes and Photo Sinkers, are presented. Emphasis is placed on the selection of a well balanced experiment payload. In comparison with similar type probes suggested for Mars,⁽¹⁾ it is seen that probe descent time for Venus is increased by about two orders of magnitude, but entry deceleration and heating loads also rise.

and is transmitted after the communications blackout ceases. Because the probe is not tracked during the blackout phase, trajectory information is obtained from multiple integration of the accelerometer data. When communications have resumed and probe heating has decreased considerably (deceleration is also negligible), the heat shield (including the Langmuir probe and free molecule pressure probes, which are built into the heat shield) is jettisoned. The jettisoning process, which is initiated by a low g sensing switch, consists of two steps. First, the heat shield is cut in half by strategically placed charges, with the cutting plane containing the axis of the entry cone. Then the two cone halves are spring-ejected to the side, so that they will not interfere with the vehicle. After this, the vehicle enters its terminal flight phase (~60 km). During this regime, the probe descends at its local terminal velocity, all the while taking continuous atmosphere measurements and relaying the data to the manned flyby vehicle. In addition, the Photo Sinker takes TV pictures of the surface region and transmits them to the manned vehicle. All experiments are considered terminated when the probe impacts with the surface, and its transmission ceases.

Constraints on Drop Sonde targeting may be briefly summarized as follows. For the nominal (15 hour) lead time, the area available for targeting purposes is the conical region shown in Figure 3-A with cone angle C. This constraint occurs due to the limited coverage of the manned vehicle trajectory by the probe antenna beam, with the cone angle C necessarily being equal to the probe antenna beam width (50°).

In the case of a shorter lead time (~7 hours), the reduction in free-space communication losses allows use of an omnidirectional antenna. Here, nearly the full half-planet seen by the manned vehicle is available for targeting (3-B).

On the assumption that any ΔV required for a probe direction change should be no larger than the ΔV necessary for a 15 hour lead time, the probe may be separated no less than 20,000 km from its hypothetical periapsis point (Figure 3-C).

For the nominal Photo Sinker mission (1 1/2 hour lead time) the targeting area is again the conical region shown in Figure 3-A. If it is desired to have nearly the full half-planet seen from the manned vehicle available for targeting purposes, while keeping the bit rate constant, then the lead time may be reduced to 3/4 of an hour, and an omnidirectional antenna may be employed. Because of the fact that the probe descent time is nominally 1/2 hour, but subject to large uncertainties, usage of the 1 1/2 hour lead time provides a better guarantee that communications will be maintained for the complete descent.

One additional constraint, due to photographic requirements, is that the descent through the lower atmosphere should be on the sunlit portion of the planet.

III. Experiments Subsystem

Table III-A lists the major instruments on board the Drop Sonde, while Table III-B lists the instruments on board the Photo Sinkers. All the instruments on the Drop Sonde are included in the Photo Sinkers complement. Specific instrument functions will now be briefly described.

- 1) Langmuir Probe - Obtains electron and ion densities in upper atmosphere from measurements of electron and ion fluxes (200→2000 km).
- 2) Free-Molecule Pressure Probe - Obtains neutral particle densities in upper atmosphere from measurements of neutral particle stagnation pressures (200→500 km).
- 3) Accelerometers - Obtain probe trajectory in high-deceleration regime from double integration of deceleration readings (60→200 km).
- 4) Mass Spectrometer - Obtains atmospheric composition from measurements of charged particle and neutral particle concentrations. Instrument requires pumping at inlet in high pressure region (terminal flight phase) (0→500 km).
- 5) Temperature Sensors - Obtain ambient static temperatures from measurements of local total temperatures (0→60 km).
- 6) Pressure Sensors - Obtain ambient static pressures by direct measurements (0→60 km).
- 7) Photometers - Obtain transmissivity of atmosphere for visible radiation (light) from measurements of visible light level (0→60 km).
- 8) Disdrometer - Obtain particle size and density in lower atmosphere from observation of light scattering (0→60 km).
- 9) α -Densitometer - Obtain lower atmospheric density from measurements of α -particle absorption by the atmosphere (0→60 km).

- 10) β -Densitometer - Obtain lower atmospheric density from measurements of β -particle absorption by the atmosphere. Complements and serves as a check on the α -densitometer experiment (0-60 km).
- 11) Radar Altimeter - Obtains probe altitude, after blackout, from range measurements (0-60 km).
- 12) Impact Accelerometer - Obtains surface property information from deceleration measurements at surface impact.
- 13) Rate Gyro - Obtains atmospheric turbulence data from measurements of vehicle angular velocity (0-60 km).
- 14) Television Camera - Obtains surface features from photographs taken during terminal descent. Pictures are taken every ten seconds from 100,000 ft altitude until impact. Initial pictures have a surface resolution of 360 ft, and a coverage of 70,000 ft x 70,000 ft. Final picture would have a surface resolution of 15 ft, and a coverage of 3,000 ft x 3,000 ft. Total picture content is 10^6 bits of information (per picture).
- 15) IR Radiometer - Obtains infrared emission over field of view of TV camera. Allows assignment of gross average temperatures to photographed regions (0-30 km).
- 16) Gas Chromatograph - Obtains lower atmosphere composition. Complements mass spectrometer results (0-60 km).

IV. Communications Subsystem

A. Drop Sonde

Due to relatively long lead times considered for some Drop Sondes (~15 hours) communication ranges of about 600,000 km have to be considered.

The required information rate can be estimated at 300 bits per second for the transmission of both real time data acquired after exit from blackout and concurrent readout of the data accumulated during blackout. Taking into account the communication capabilities foreseen for the manned vehicle, i.e., utilization of S-band frequencies, a twenty foot diameter antenna, and a three hundred watt transmitter, it is found that the gain requirement of the probe antenna for the command link manned vehicle-to-probe is satisfied by a 7.5 inch diameter conical horn antenna.

Choosing this conical horn antenna in turn determines the power requirement of the probe transmitter for the probe-to-manned vehicle data transmission link. The required transmitter power output is 6.3 watts.⁽³⁾ With a transmitter efficiency of 10%, the required power input is 63 watts. A bandwidth of about 500 hertz should be adequate.

B. Photo Sinker

Maximum transmitted bit rate is governed by the TV experiment. It is felt that six pictures per minute, or 10^5 bits per second, over a maximum range to the manned vehicle of 60,000 kilometers, will be adequate. With the same 7.5 inch diameter conical horn antenna, facing rearward, a transmitter output power of sixty watts (input power ~200 watts) is sufficient,⁽³⁾ while the transmission frequency is selected to be S-band.

V. Power Subsystem

A. Drop Sonde

In this case, zinc-silver batteries may be used to supply power for operation of all vehicle components (probe instrumentation, communication and data handling, propulsion, and avionics). According to Reference 4, for slow drain time, these batteries may be expected to yield 30 watt-hours per pound, so that three pounds of batteries are quite adequate.

B. Photo Sinker

For this probe, approximately 240 watt-hours of energy are necessary. Thus, eight pounds of the above mentioned zinc-silver batteries are required.

VI. Structural Subsystem

Figure 1 shows a cross-section view of the Drop Sonde. The main difference between the Drop Sonde and Photo Sinker is the presence of a viewing window at the forward region of the Photo Sinker. Both probes are bomb-shaped and have stabilizing fins on the rear. Each probe is contained in a cone-shaped heat shield, with the cone angle ideally selected to minimize combined radiative and convective entry heating. A small cone angle minimizes radiative heating, while a large cone angle minimizes convective heating. The front portion of the probe

contains the scientific payload, while the rear section holds the data handling and communication subsystem. Behind the main body of the probe is the propulsion system, which is jettisoned after the midcourse maneuver.

Reference 5 describes the thermal control suggested for each probe. Briefly, the probe shell is heavily insulated such that its contents do not thermally interact with the environment during descent. Also, to remove the energy generated within the probe, a heat sink (such as ice, with heat of liquefaction of 40 watt-hours/lb) is provided. About six pounds of ice are necessary for the Photo Sinker, while two pounds of ice should be adequate for the Drop Sonde.

The relative weight of structure to payload (instruments, communications, coolant) will change for different entry angles. For shallow entry ($<30^\circ$), the growth factor (ratio of total vehicle weight at entry to payload weight) is about 1.6, while for steep entry, it is approximately 2.5⁽⁶⁾.

VII. Propulsion System

A liquid fuel engine is selected due to the arbitrary requirement that the same engine be refired for midcourse maneuvers. The engine thrust is 50 pounds, its nominal specific impulse is 300 seconds, and the mass fraction for the entire engine subsystem is 0.7. Once midcourse corrections are made, the engine is jettisoned.

VIII. Sterilization Subsystem

The sterilization canisters, which contain the probes until their separation times, and which are hermetically sealed until this time, perform two distinct functions:

- 1) Protection of the probe and its associated propulsion subsystem from recontamination with micro-organisms subsequent to the terminal sterilization process (the main function); and
- 2) Facilitation of the thermal control of the probe during the period of storage aboard the manned vehicle.

The pressurized canisters are constructed to allow venting at any desired time.

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Attachments

Tables I, II, III-A, III-B
Figures 1-3

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4. Koelle, H. H., Editor, "Handbook of Astronautical Engineering," Chapter 15, McGraw-Hill Book Co., Inc., New York, 1961.
5. "Venus Probe Analysis and Design," Volume VI, NASA C7-73008, AVCO AVSSD-0047-66-RR.
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TABLE I - DROP SONDE OBJECTIVES

General Objectives

Detailed Objectives

I) Atmospheric Properties

Physical

Pressure, temperature, neutral
density, electron density

Chemical

Mass spectrum

Circulation

Turbulence

Clouds

Particle size

Transmission

Radio frequency (communications band)
and light attenuation

II) Surface Properties

Physical

Radar reflectivity

Optical

Illumination

III) Biological Properties

Environmental

Atmospheric conditions

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TABLE II - PHOTO SINKER OBJECTIVES

General Objectives

Detailed Objectives

I Atmospheric Properties

Physical

Pressure, temperature, neutral
density, electron density

Chemical

Mass spectrum

Circulation

Turbulence

Clouds

Shape, temperature, particle size

Transmission

Radio frequency (communications band)
and light attenuation

II Surface Properties

Physical

Radar reflectivity, cohesiveness
temperature, topography

Optical

Illumination, albedo

III Biological Properties

Environmental

Atmospheric conditions, surface
temperature

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TABLE III-A DROP SONDE SUBSYSTEM WEIGHT BREAKDOWN

<u>Subsystem</u>		<u>Weight (Lbs)</u>	<u>Totals</u>
1)	Scientific Instrumentation		
	Langmuir Probe	2	
	Accelerometers	2	
	Mass Spectrometer	7	
	Temperature Sensors	2	
	Pressure Sensors	2	
	Photometer	2	
	Disdrometer	2	
	α and β Densitometers	2	
	Free Molecule Pressure Probe	2	
	Radar Altimeter	10	
	Impact Accelerometer	1	
	Engineering Instruments	13	47
2)	Communications and Data Storage	15	15
3)	Power	3	3
4)	Propulsion		
	Avionics, Support Structure	6	
	Δ V Engines and Propellant		
	1977*	128	134
	1977**	186	192
	1978***	281	287

* A 1977 Venus-Mars-Venus flyby mission, first Venus passage

** A 1977 Venus-Mars-Venus flyby mission, second Venus passage

*** A 1978 Venus Mars flyby mission, Venus passage

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TABLE III-A (CONT'D)

<u>Subsystem</u>	<u>Weight (Lbs)</u>	<u>Totals</u>
5) Vehicle Structure, Heat Shield, Thermal Insulation	117	117
6) Sterilization Canister	75	75
7) Coolant & Support Structure	7	7

VEHICLE WEIGHTS AFTER STERILIZATION CANISTER SEPARATION

<u>Mission</u>	<u>Weight (Lbs)</u>
1977 (first passage)	323
1977 (second passage)	381
1978	476

The following assumptions have been used in weight calculations:

Drop Sonde lead times - 15 hours

Photo Sinker lead times - 1 1/2 hours

Growth factor - 2.5

Fuel Specific Impulse - 300 seconds

Mass Fraction - 0.7

Canister Material - Aluminum

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TABLE III-B PHOTO SINKER SUBSYSTEM WEIGHT BREAKDOWN

<u>Subsystem</u>	<u>Weight (Lbs)</u>	<u>Totals</u>	
1) Scientific Instrumentation			
Drop Sonde Instrumentation	47		
TV Camera	10		
Beacons	4		
IR Radiometer	5		
Gas Chromatograph	13	79	
2) Communications and Data Storage	25	25	
3) Power	8	8	
4) Vehicle Structure, Heat Shield, Insulation	158	158	
5) Sterilization Canister	75	75	
6) Coolant & Support Structure	12	12	
7) Propulsion			
Avionics, Support Structure	6		
	1977 (first passage)	16	22
ΔV Engine and Propellant	1977 (second passage)	20	26
	1978	26	32

VEHICLE WEIGHTS AT SEPARATION

<u>Mission</u>	<u>Weight (Lbs)</u>
1977 (first passage)	304
1977 (second passage)	308
1978	314

WEIGHT BREAKDOWN

SCIENTIFIC INSTRUMENTATION	47 LBS
COMMUNICATIONS AND POWER	18 LBS
PROPULSION	192 LBS
STRUCTURE AND HEAT SHIELD	117 LBS
COOLANT	7 LBS
STERILIZATION CANISTER	75 LBS
TOTAL	456 LBS

NOTE:

PHOTO SINKER
HAS VIEWING
WINDOW IN THIS
REGION

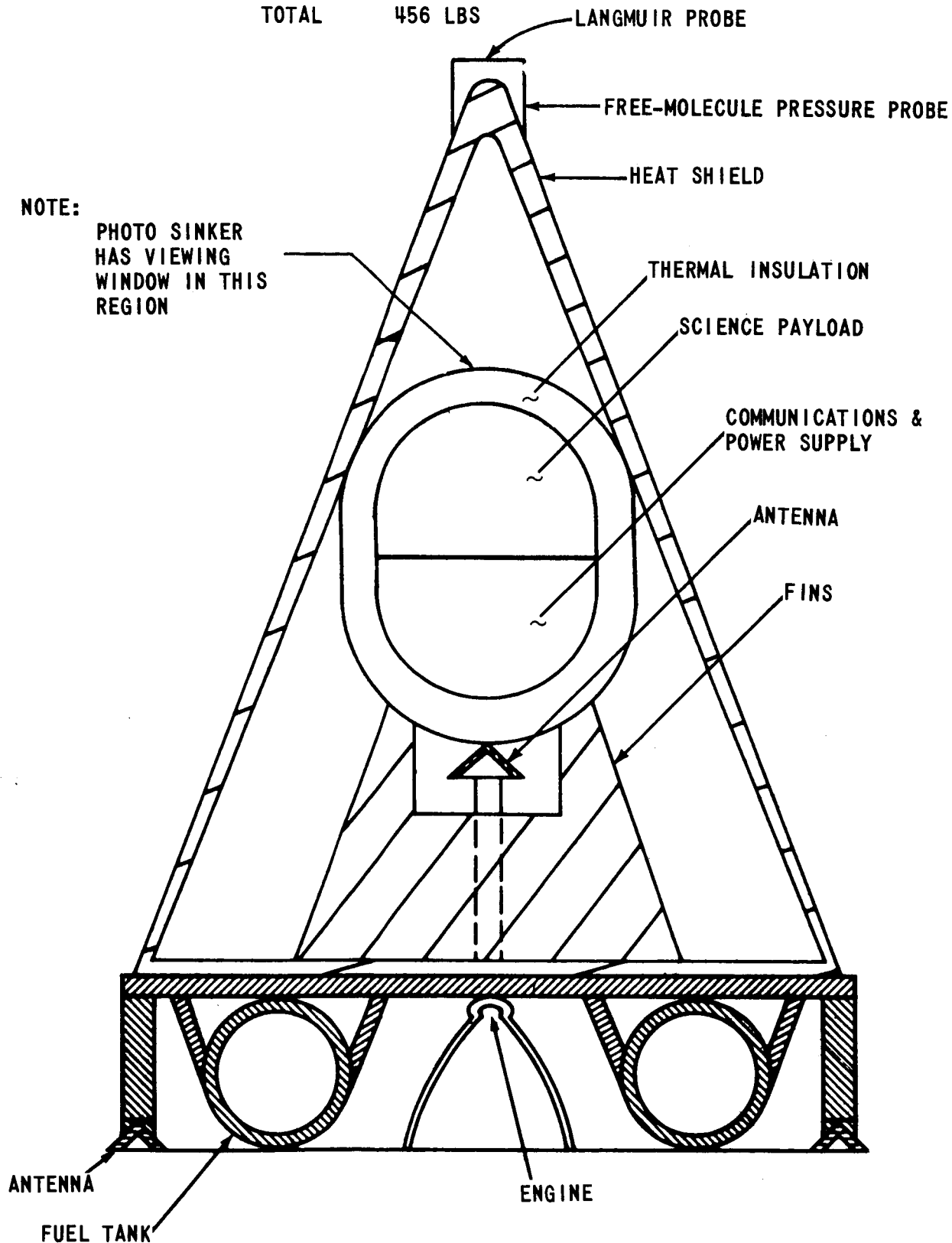


FIGURE 1 - OUTLINE OF DROP SONDE

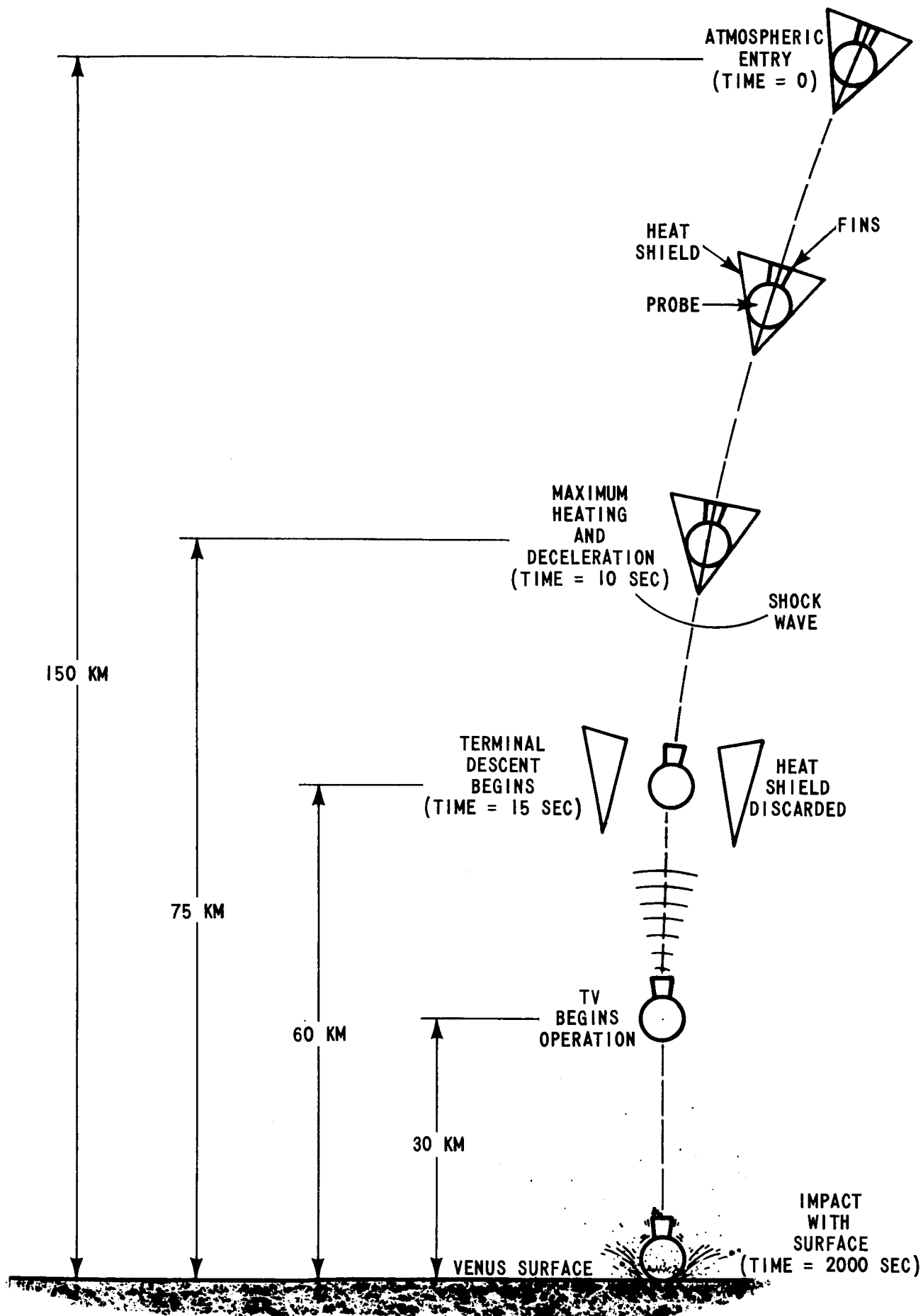
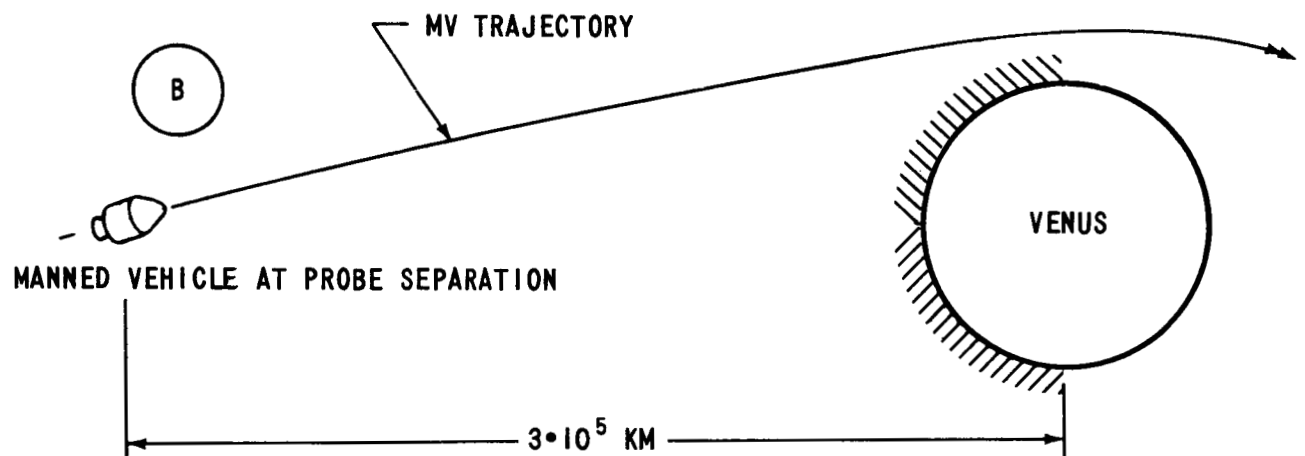
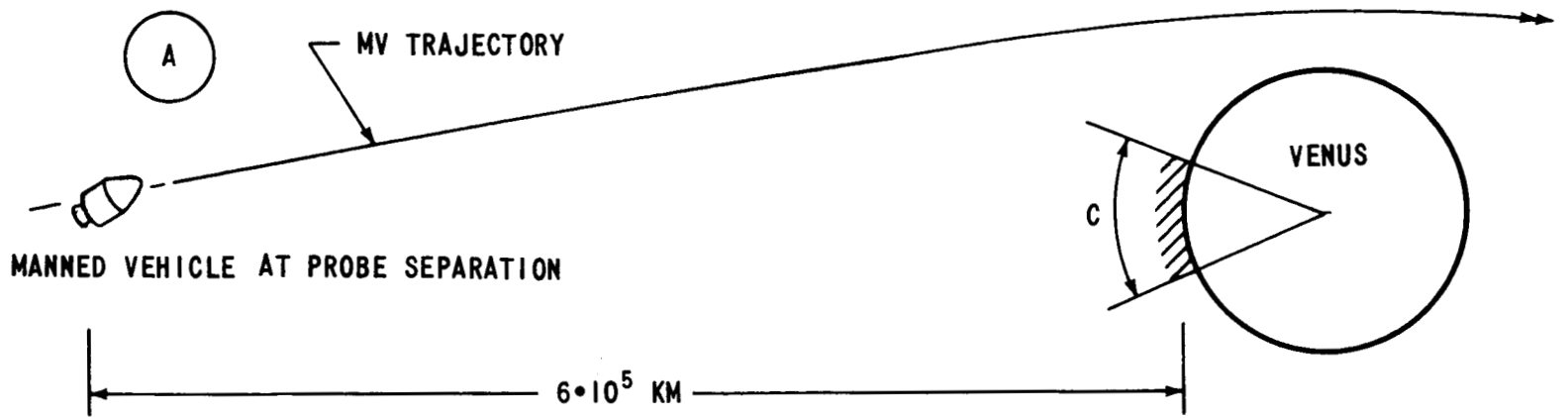



FIGURE 2 - PHOTO SINKER MISSION PROFILE




 DENOTES AVAILABLE AREA

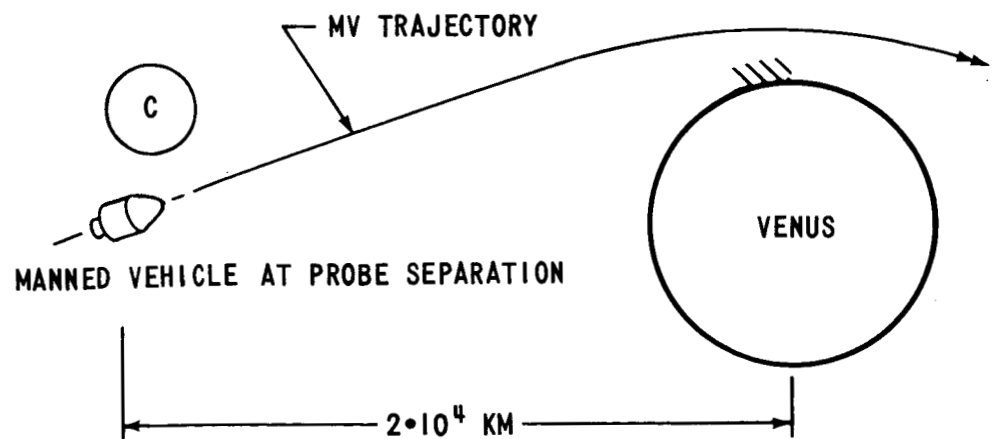


FIGURE 3 - AVAILABLE TARGETING AREAS FOR PROBES