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FINAL REPORT
BUOYANT VENUS STATION
FEASIBILITY STUDY

Volume I - Summary and Problem Identification

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FOREWORD

This final report on the Buoyant Venus Station Feasibility Study is submitted by the Martin Marietta Corporation, Denver Division, in accordance with Contract NAS1-6607.

The report is submitted in six volumes as follows:

Volume I - Summary and Problem Identification;

Volume II - Mode Mobility Studies;

Volume III - Instrumentation Study;

Volume IV - Communication and Power;

Volume V - Technical Analysis of a 200-lb BVS;

Volume VI - Technical Analysis of a 2000- and 5000-lb BVS.

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FINAL REPORT

BUOYANT VENUS STATION FEASIBILITY STUDY

VOLUME I - SUMMARY AND PROBLEM IDENTIFICATION

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SUMMARY

Future NASA planetary exploration may require an unmanned capsule to probe the Venusian atmosphere. This capsule could be released from a spacecraft orbiting Venus in a manner to enter the atmosphere. The orbiting spacecraft could then serve as a communication link with Earth. The high temperatures of Venus tend to make difficult the direct exploration of this planet by standard probes. However, the concept of a buoyant station placed in the atmosphere in a condition of equilibrium (with a degree of mobility) at the higher and cooler altitudes could lead to the acquisition of detailed scientific information about the Venusian atmosphere. In addition, from such a station, descent and impact probes may be released to obtain information on lower atmosphere and surface conditions.

The acquisition of this information could lead to the formulation of subsequent experiments of a more definitive nature and would assist in furnishing environmental design criteria for subsequent more sophisticated mission systems.

The objective of this study was to determine the feasibility of using inflatable buoyant devices as mobile Venus atmospheric stations. The feasibility was investigated by establishing the scientific objectives, and identifying and comparing alternative station modes together with associated operational and system design characteristics.

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

1) The orbiter spacecraft shall serve as a relay station for transmittal of data to Earth, and shall be assumed to possess all required receiving, storage, and transmitting capabilities;

2) The nominal orbit shall be assumed to have a periapsis altitude of 1000 km and apoapsis altitude of 10 000 km;

3) The three NASA Venus model atmospheres as delineated in NASA SP-3016 shall be used;

4) The initial conditions at inflation of the buoyant device(s) shall be assumed to be consistent with a subsonic velocity above the visible cloud layer for the three Venus model atmospheres;

5) Consideration shall only be given to mission modes using the buoyant station concept;

6) The mission modes investigated shall be consistent with the sampling times and coverage required for the experiments; the communication time required to transmit data; and the limitations of instruments, materials, and systems;

7) No consideration shall be given to survivable landing of the buoyant station on the Venusian surface;

8) The buoyant station may serve as a mobile platform for the release of probes to investigate the lower atmosphere and surface conditions;

9) Total station(s) weight at the inflation initial conditions shall not exceed 5000 lb;

10) The station shall include engineering instrumentation to monitor all significant events and the operational status throughout the mission;

11) The station measurements to be considered shall include as a minimum the following classes and quantities:

Class of measurement	Measurement quantity
Position	Altitude above terrain Absolute altitude Horizontal position
Ambient environment	Pressure Temperature Density Composition Particles Electromagnetic fields Gravitation Radiation Winds
Below station	Radiation from surface Surface characteristics Cloud top height(s) Cloud particles

12) The station to orbiter communications system shall be assumed not to require directional orientation of antennas or high-gain antennas.

The above technical guidelines served to focus the effort on the fundamental problem -- the feasibility of the buoyant station concept as deployed in the atmosphere -- without considering the overall mission problem.

Although all of these constraints were observed during the study, the emphasis was modified part way through the program to include a "small" station considered to be compatible with an early (1972 and 1973) mission employing an Atlas/Centaur as a launch vehicle.

The milestone schedule under which the program was controlled is as follows.

	Task	1	2	3	4	5	6	7	8	9	10
		Months after go-ahead									
Contractor tasks											
Mode mobility studies	4.1	█	█	█	█	█					
Instrumentation studies	4.2	█	█	█	█	█					
Communication studies	4.3				█	█					
Power system studies	4.4				█	█					
Mission mode tradeoff/studies	4.5						█	█	█	█	
Problem area identification	4.6		█	█	█	█	█	█	█	█	
Documentation											
Oral presentation						△					
Final oral report										△	
Monthly progress reports			△	△	△	△	△	△	△	△	
Monthly financial reports			△	△	△	△	△	△	△	△	
Informal letter reports			△	△	△	△	△	△	△		
Final report (approval copies)										△	
Final report (approved)											△

As part of the midterm oral presentation recommendations were made to concentrate the remainder of the effort on two configurations of approximately 200 and 2000 lb, respectively. This course was followed for the remainder of the program.

The complete final report is presented in six volumes as follows:

- Volume I - Summary and Problem Identification;
- Volume II - Mode Mobility;
- Volume III - Instrumentation;
- Volume IV - Communication and Power;
- Volume V - Technical Analysis of a 200-lb BVS;
- Volume VI - Technical Analysis of a 2000- and 5000-lb BVS.

INTRODUCTION

At this writing, the generally accepted models of Venus describe a surface too hot for a lander to survive (for a significant time) and a cloud cover too dense to "see" through. Above the surface, however, the environment is moderate over a wide range of altitudes and the atmosphere is dense enough to support a balloon with a generous payload. This is the buoyant Venus station (BVS) concept.

The main features of this approach are:

1) The environment for the station is moderate;
2) The duration of the mission is not limited;
3) There is an inherent mobility over the surface;
4) Means can be devised to probe toward the surface as desired.

In many ways, this concept is more attractive than that of a survivable lander. Aside from the lack of mobility, the lander will have to cope with (at this point) an undefinable surface. For earlier missions, the buoyant station appears to be a very desirable adjunct, or later alternative to, the basic nonsurviving probe.

This report is intended to summarize the results of this study and particularly to list the problem areas, or areas requiring accelerated development, that have been identified.

SYMBOLS

BPS	bits/second
BVS	buoyant Venus station
FSK	frequency shift key
LRC	Langley Research Center
PBI	polybenzimidazole
PSK	phase shift key
RTG	radioisotope thermoelectric generator

MODE MOBILITY STUDY (TASK 4.1)

The first task of this study was to determine the feasibility of a balloon system to operate in the atmosphere of Venus. For this purpose the mission was considered to start with the balloon undeployed, but separated from the aeroshell, in a subsonic condition above the cloud tops. (Whether this condition could be achieved with the existing atmospheric models was not investigated.) After this, the stages of operation can be roughly divided into (1) chute deployment, (2) balloon deployment/inflation, (3) achievement of equilibrium condition, and (4) altitude cycling. The approach to the study is indicated in figure 1. Several station deployment methods were considered based on experience to date with air-deployed balloon systems. This is identified as a fundamental area where accelerated development will be required. In particular, it is recognized that the deployment must be restricted to a relatively narrow range of altitude (pressure).

Four methods of altitude cycling a balloon were initially identified (table 1 -- gas dump and makeup, gas dump and ballast drop, pump and dump atmospheric gases, and heat cycling). The first three methods proved feasible and permitted cycling to a selected minimum altitude. Gas dump and makeup and gas dump and ballast drop allow for three or four cycles for the nominal 2000-lb station. Atmospheric pump and dump allows for an unlimited number of cycles and permits dwelling at altitudes below the station equilibrium altitude. Heat cycling was found to require a prohibitive heating rate or balloon insulation thickness and was discarded. The comparative efficiencies of the three methods are shown in figure 2.

A survey of government agencies and industrial suppliers by Raven Industries, Inc., determined that materials exist or are in development that can be considered for balloon and decelerator use for this type mission. The survey was made using the material requirements generated for this mission from fabrication and test through the launch and transit phases, Venus atmospheric entry, deployment, and mission in the atmosphere. The materials investigated are shown in table 2. Of these, the three materials selected as most promising are Mylar (acceptable for the noncyclic station), Kapton (Polyimide), and PBI (polybenzimidazole) film and fiber.

Five inflation gases were investigated as summarized in table 3. For the small station, hydrogen transported as a high-pressure gas is the lightest system providing the maximum gondola weight of 70 lb for the 200-lb station. It is followed by hydrazine, decomposed with the spontaneous catalyst, and helium transported as a high-pressure gas. For the large stations (2000 to 5000 lb), cryogenic hydrogen becomes the most efficient gas system resulting in gondola weights of 800 to 2800 lb, respectively. For the cyclic station using the gas dump and makeup mode, the cryogenic hydrogen initial inflation with the cycle gas of decomposed hydrazine is the most efficient system, resulting in the maximum gondola weight of 545 to 2000 lb for the 2000- and 5000-lb stations, respectively.

It is the conclusion of this task that the basic approach of a balloonborne Venus station is feasible, including the concept of altitude cycling. Specific areas requiring accelerated development are identified later in this report.

Mode mobility is reported in detail in Volume II of this report.

INSTRUMENTATION STUDIES (TASK 4.2)

Part of the overall question of feasibility of the BVS is whether the scientific mission is significantly enhanced by the balloon approach. For this reason, one of the first tasks of the program was to investigate the instrumentation that might be carried. The objectives of this study are summarized as follows:

1) Establish scientific objectives;
2) Investigate experiments for possible use on BVS,
    a) Compile list of experiments and instruments for BVS,
    b) Establish priorities on basis of scientific merit and compatibility with BVS,
    c) Investigate detailed characteristics of experiments;
3) Establish a reference coordinate system;
4) Investigate instrumentation for position determination;
5) Establish engineering measurements and instrumentation.

The approach (fig. 3) was to first appraise the present knowledge of Venus (and what is likely to be known in the near future), to compile a list of desirable measurements that would answer the present questions concerning Venus, and to arrange this list in order of priority. Experiments to perform these measurements which were compatible with the BVS concept were then arranged into suitable complements for each of the various sized stations.

The present knowledge of Venus is summarized in table 4. In this list there is a degree of controversy on many items, which suggests that even a very simple scientific mission into the atmosphere would greatly increase our understanding of the planet.

The factors leading to the selection of experiments for the buoyant station mission are as follows:

1) SSB/NAS-recommended space program objectives,
    a) Origin and evolution of life,
    b) Origin and evolution of solar system,
    c) Dynamic processes that shape planetary environment;
2) Venus objectives, initial exploration,
    a) Investigation of atmosphere and constraints on life,
    b) Surface and body characteristics,
    c) Direct search for life;
3) Experiment selection criteria,
    a) Relevant to general objectives above,
    b) Test validity of models,
    c) Compatible with BVS concept;
4) Ground rules,
    a) Measurements to be made in early stages of exploration,
    b) Emphasis on BVS ambient environment and below,
    c) Include measurements of questionable feasibility.

The emphasis on early stages of exploration should be noted. This was done partly to conform to the mid-1970s constraint of the study, but more specifically to avoid speculation on the nature of second generation experiments. (Note that the larger 2000- and 5000-lb stations have generous capability to support these as yet undefined experiments.)

An objective of the study was to create a priority list of experiments and instruments. A breakdown into three or four general categories into which all measurements might be arranged was feasible. As a result of discussions with Dr. G. Ohring of GCA, it was decided that both Martin Marietta and GCA would make parallel attempts at such a grouping and to make the final ordering after an analysis of both lists. A list of priorities was also compiled by Mr. R. Henry of LRC. In general all three groupings were similar to within ± 1 category.

The priorities, table 5, are based mainly on the contribution to increased knowledge that the measurement of a particular parameter would make. In our approach to the assignment of ratings we have assumed that the most important parts of the Venus environment are the clouds and lower atmosphere. By defining these parts of the environment, other parts, such as the upper atmosphere and hard body of the planet could be inferred. The reverse is not necessarily true. Thus, emphasis has been placed on lower atmosphere parameters, and such parameters generally received high ratings.

Table 5 also indicates the experiment complements used for the two baseline stations of this study. The smaller payload (for the 200-lb station) covers all of the Priority 1 and some of the Priority 2. This complement would weigh about 23.5 lb including two drop sondes.

The larger payload (for the 2000-lb station) would weigh about 137 lb and covers all of the instrumentation that could reasonably be identified at this time. Recognizing that such identification is difficult and likely to prove incomplete, an additional 58 lb was added for "undefined" experiments. To this was added 105 lb of drop sondes to make a total baseline payload of 300 lb. Note that this does not use the total capability of the 2000-lb station described in this study.

The payloads for the two stations are shown in tables 6 and 7. Typical drop sondes are described in figures 4 and 5 and tables 8 thru 10.

Because of the desirability of knowing the position of the station over the surface, both to identify the location at which measurements are made and as a basic determination of wind pattern, a method of locating the station by ranging from the orbiter is suggested (fig. 6). Further consideration of this approach must be made when integration of the orbiter into the overall mission is undertaken.

Table 5 compares the two experiment payloads on the basis of their contributing to the desired objectives. As can be seen, both payloads contribute to all of the Priority 1 measurements (with the exception of cloud composition in the small BVS) and many of the Priority 2 measurements. Thus, the small station answers the most urgent questions about the Venus atmosphere while the large station answers those and most of the other questions we can intelligently ask about Venus. In fact, since so little is known at present about Venus, it becomes difficult to use the full capability of the larger station in an optimum manner and the selection of one experiment over another becomes somewhat fanciful for the early missions.

We conclude that an early BVS mission of the Atlas/Centaur launch vehicle class can answer the most important scientific questions we have about Venus while the larger, Voyager-class BVS (cyclic or with drop sondes) appears to have the capability for answering all of the questions that might be asked about the Venus atmosphere and general surface characteristics. The investigation of the body and detailed surface characteristics will, of course, require a vehicle to be landed on the surface. The design of such a vehicle, however, will require a detailed investigation of the surface and near surface conditions that only a large BVS can conduct.

The drop sondes are a necessary adjunct to any BVS, cyclic or noncyclic. Indeed, their versatility makes the concept of cycling the station somewhat questionable from the scientific point of view.

The instrumentation study is discussed in more detail in Volume III of this report.

COMMUNICATIONS STUDIES (TASK 4.3)

Communication to and from the station is an important part of the feasibility of the buoyant station concept. The problem is unique in that, because of the drift of the station over the surface, the station/orbiter geometry is variable and to some extent unknown for an extended mission. This raises the problem of adapting the system to a variable situation and also creates the need for a position determination as a valuable addition to the scientific information to be obtained. (For this study a concept of ranging from the orbiter is suggested, see Volume III.)

The communications task required the consideration of four separate functions in addition to defining data storage and handling concepts. These are telemetry link, command, ranging, and communication with the drop sondes.

The technical guidelines established by the contract statement of work that have a direct bearing on the communications study are:

1) An orbiter shall serve as a relay station for transmittal of data to earth, and shall be assumed to possess all required receiving, storage and transmitting capabilities;
2) The nominal orbit shall be assumed to have a periapsis altitude of 1000 km and apoapsis altitude of 10 000 km;
3) The station-to-orbiter communications system shall be assumed not to require directional orientation of antennas or high-gain antennas.

Parametric bounds on the communications variables were established as an initial step in the study and modified as required as information on station data acquisition rates became available. These bounds are:

1) Communications range, 1000 to 14 000 km;
2) Communications period available, 5 to 105 min;
3) Radio frequency range, 200 to 400 MHz;
4) Antenna gain product, 3 dB minimum;
5) Antenna look angles (station to orbiter), 20° above horizon (minimum desired elevation);
6) Modulation techniques, FSK or PSK/PM;
7) Transmitter power, 40 W (maximum);
8) Data rates (station to orbiter), 30 to 1000 BPS.

Typical variations in communications period as functions of the station location in the orbital plane and station antenna half power beamwidth are shown in table 11. From this, it was established that the time that could be allowed for both communication and ranging would have to be restricted to the order of 5 min for certain station locations.

Factors in selection of the frequency band are shown in table 12.

The final selection will, of course, require consideration of minimum modification to the orbiter.

Two modulation techniques were considered for the station-to-orbiter telemetry link -- frequency shift key (FSK) of the carrier and phase shift key (PSK) using a data and a sync subcarrier to phase-modulate a carrier. The latter method requires a frequency search mode to acquire and track the carrier; hence a pseudorandom sync code was not used to obtain sync data for telemetry because the sync signal energy would fall in the search frequency band.

A comparison of effective radiated power required for the two methods shows the coherent system with a carrier search mode to have a distinct advantage over the FSK approach. This is particularly true when one attempts to integrate the command, telemetry, and turnaround ranging system because an FSK link does not lend itself to use in the ranging mode. Further, use of FSK for the larger station unduly restricted the data rate.

Frequency shift key was the only modulation approach considered for the drop sonde-to-station link -- drop sonde transmitter power requirements never exceeded 12 mW for the maximum data rate requirement of 25 BPS.

The command control technique chosen for the station is as follows:

1) Earth commands stored in orbiter and updated as required;
2) Station commanded from orbiter's command storage programer;
3) Station handles real-time commands only;
4) Station transmitter turned on when receiver locks onto orbiter command carrier;
5) Station transmitter turned off by station programer (after fixed transmission period);
6) Two-way carrier lock (orbiter/station) before commanding;
7) Transmitter can be commanded off.

Station data storage capacity requirements for the 200-lb station amounted to approximately 4000 bits. For the 2000-lb station, the required storage capacity was held to approximately 160 000 bits by the use of an assumed data compression ratio of 5 to 1 on picture and scanning-type instrument data. Without data compression, either a tape recorder must be used or the data acquired per orbit by the station science instrumentation must be reduced. The capacities cited above are based on communicating on each orbit for periods of at least 5 min.

For long missions (several weeks), the possibility of the station drifting out of communications range is apparent especially if the initial station location with respect to both the orbiter's orbit and the anticipated wind pattern is not carefully selected.

See Volume IV for a more detailed description of the study approach and results. Details of the 200-lb station and the larger stations are given in Volumes V and VI.

POWER SYSTEM STUDIES (TASK 4.4)

The missions for the buoyant station dictated that the capability of several types of power systems be investigated to meet these needs. For the buoyant station itself, batteries, radioisotope thermoelectric generators (RTGs) and solar cells were examined. Substantial sterilization efforts are underway on only the nickel-cadmium and the silver-zinc batteries. These efforts have given an energy density of 10 Wh/lb for the nickel-cadmium battery and promise to give,in the near future, an energy density of 25 Wh/lb for the silver-zinc battery.

The nickel-cadmium battery is well-suited for use as an energy storage device to provide for power peaks when used in conjunction with a prime power source such as an RTG, while the silver-zinc battery with its high-energy density is preferred when a battery is selected for the primary source.

For powering, the drop sonde batteries and wind-driven turbines were considered. Two batteries appear to be candidates -- the silver-zinc, when sterilization is accomplished, and the reserve magnesium perchlorate battery. The latter is currently being developed for ground communications and has an energy density of 38 Wh/lb. It appears amenable to sterilization, although no effort is presently underway.

Studies for the wind-driven turbine indicate that to obtain 5 W for the small sonde, 67.6 W must be available in the intercepted airstream. This compares with the limits of 80 and 1360 W being expended to the atmosphere at terminal velocity for limiting ballastic coefficients of 0.1 and 5 slug/ft^2. Since the energy extracted by the turbine should be only a fraction of that available, ballistic coefficients lower than 0.5 should be avoided for a sonde equipped with a wind-driven generator.

Studies for the two buoyant stations, the 200 and the 2000 lb, showed that a battery system is lighter in weight than an RTG for periods up to 5 days, when only electric power aspects are considered.

For extended periods of operation, an RTG is advantageous because its waste heat can be used for thermal control. Since battery temperature needs to be maintained at a minimum of 278°K (40°F), even though a minimum atmospheric temperature of 195°K (-110°F) may be encountered, auxiliary heat is necessary. For a battery system, a chemical system employing dissociation of a monopropellant, combination of two reactants, or burning of a fuel such as beryllium metal powder in the Venusian atmosphere should be considered. These release energy ranging from 0.4 to 7.5 kcal/g. This area requires further investigation on prototype burners and selection of reactants whose products would not contaminate the scientific samples being analyzed.

MISSION MODE TRADEOFF STUDY (TASK 4.5)

200-lb Station

One of the recommendations for further consideration during the mission mode tradeoff studies was a minimum size (200-lb) buoyant station. This vehicle is intended to be compatible with an Atlas/Centaur launch in 1972 or 1973.

The mission defined for this station is summarized in figure 7. A duration of seven days was selected, during which four sets of measurements of the atmosphere to the surface will be accomplished, initially by the descending aeroshell, twice by drop sondes, and finally by allowing the entire station to descend.

The buoyant station itself is shown in figure 8. The 25-ft-diameter balloon is inflated to a 6 mb superpressure with hydrogen to float at 57 km above the surface (assuming the mean atmosphere). Since the temperature at this altitude is moderate (~225 °K), the balloon is constructed of Mylar, which is widely used in the balloon industry. Figure 9 indicates the subsonic deployment sequence for the station to the point of inflation tank separation.

The constraints and performance requirements to which this configuration was created are as follows:

1) 225-lb launch vehicle compatibility;
2) Sterilization considerations;
3) NASA SP-3016 atmospheres;
4) Float at cloud tops;
5) Relay communications, no directional antennas;
6) 1000 by 10 000 km orbit;
7) Probe to surface with two sondes and final descent;
8) Science measurements,
    a) Temperature,
    b) Pressure,
    c) Density,
    d) Composition,
    e) Horizontal position;
9) Onboard sequencing with command as backup;
10) 7-day mission;
11) Transmission during deployment;
12) Adaptability to environment.

The science payload, weighing 13.5 lb, covers the fundamental parameters desired to be measured. The inclusion of a small radar altimeter would also be desirable if available at a low weight.

Table 13 summarizes the telecommunications system. This is based on the 1000 by 10 000 km orbit specified for the study, which has a period of 3.86 hr. Approximately 10 000 bits of data are transmitted during each orbit in addition to performing the ranging function (from the orbiter) for position determination. This orbit and the ground track of the station drifting in the predicted wind pattern are indicated in figure 6.

Figure 10 shows the 200-lb station inside the contour of the spacecraft dynamic envelope of the Atlas/Centaur shroud. Interfacing with an orbiter was not within the scope of this study.

Potential features of this mission compared with a hypothetical simple probe to the surface alone are suggested in table 14. Based on this study, it is concluded that a small station of this size class is feasible and should be considered further as a desirable adjunct to the early missions to Venus.

This configuration is described more fully in Volume V of this report.

2000/5000-lb Station

The large class stations selected for further study in Task 4.5 are compatible with a Voyager-class spacecraft in the mid-1970s. Two general types of missions were investigated for these stations: cyclic and noncyclic. Emphasis was given to the 2000-lb station whereas the 5000-lb station was studied only to the extent of assigning weight allocations to subsystems.

The mission defined for the noncyclic station is summarized in figure 11. A mission duration of 100 days was selected during which six sets of atmospheric profile measurements to the surface are made -- the aeroshell, four drop sondes and the final descent of the station. Based on the wind model constructed in this study, 100 days allows the station to float from near subsolar to the vicinity of antisolar point by way of the pole.

The station is shown in figure 12. The 56.6-ft-diameter balloon is inflated to a 6-mb superpressure with hydrogen to float at 57 km in the mean atmosphere (40 and 79 km in the lower and upper atmospheres, respectively). The moderate ambient temperature range, 195 to 287°K, allows for use of Mylar, which is well-defined and used extensively throughout the balloon industry. Figure 13 shows the subsonic deployment sequence for the stations, which is identical for both the cyclic and noncyclic missions.

The mission for the cyclic station is summarized in figure 14. Again a mission duration of 100 days was selected during which five drop sondes are released and a minimum of three altitude cycles are accomplished. The method of cycling can be any of three: gas dump and makeup, gas dump and ballast (science packages) drop, and pump and dump atmospheric gases. The first two limit the number of possible cycles to low altitudes to three: pump and dump of atmosphere allows for a large number of cycles, limited by compressor power available and allows for dwelling at intermediate altitudes. Cycling to 10 km appears feasible for the cyclic station.

The station, floating at equilibrium altitude of 57 km in the mean atmosphere is shown in figure 15. The balloon is inflated with hydrogen gas to 6 mb superpressure and is constructed of a high-temperature polymer, PBI (polybenzimidazole) film. A hydrazine gas makeup cycle system is shown for three cycles. Each cycle tank is dropped after the hydrazine, decomposed by a spontaneous catalyst into hydrogen, nitrogen, and trace amounts of ammonia, is exhausted into the balloon. Cycle times of approximately 4 hr are required to descend to 10 km and return to approximately 57 km in the mean atmosphere.

The constraints and performance requirements to which the large station was created are as follows:

1) 5000-lb BVS limit;
2) Sterilization considerations;
3) NASA SP-3016 atmospheres;
4) 1000 by 10 000 km orbit;
5) Relay communications, no directional antennas.

The science payload of 300 lb, shown in table 15, includes all of the science identified with experiments in the instrumentation study (Task 4.2) plus five drop sondes and an allocation of 58 lb for undefined science. Four of the drop sondes are approximately 25 lb each and are shown in figure 16. A 5-lb drop sonde is also included.

Table 16 summarizes the telecommunications system, which is shown as a block diagram in figure 17. For the 1000 by 10 000 km orbit specified for this study, approximately 300 000 bits of data are transmitted for each orbit in addition to performing the ranging function from the orbiter for determining station location. The command system included 36 commands for the cyclic station and 31 commands for the noncyclic station. Approximately 65 engineering measurements were identified.

The power subsystem is shown in schematic form in figure 18. A 40 W (electrical) RTG is required for this mission duration and power requirement. A battery is provided for peak loads and is charged from the RTG.

Figure 19 indicates a single 2000-lb station in the Voyager capsule envelope and Mars aeroshell. Figure 20 illustrates a 5000-lb station located within the Voyager envelope. The use of cryogenic hydrogen transport is shown, which produces the largest payload of the gases investigated.

PROBLEM AREA IDENTIFICATION (TASK 4.6)

An important task of the study was to identify items or technical areas that require accelerated development and to determine their impact on the feasibility of the buoyant Venus station.

It was recognized early in the study that with almost no exceptions, specific hardware developed and tested for the environment and other requirements of this mission was not available. Examples of such requirements are sterilization and the entry deceleration into the atmosphere of Venus.

General Problem Areas

Four general problem areas were pursued in this study only as far as a unique significance to the feasibility could be established. These four areas are:

1) Atmospheric uncertainties,
   a) Cloud top heights,
   b) Temperature, pressure, density,
   c) Wind shears, storm, vertical drafts;
2) Orbiter interface,
   a) Communication systems interface,
   b) Communication systems geometry;
3) Sterilization,
   a) Tankage,
   b) Balloon materials,
   c) Batteries/RTGs;
4) General development,
   a) Entry deceleration,
   b) Sterilization.

Atmospheric uncertainties. - NASA SP-3016, which was used as a model for this study, presents a wide spread of conditions for the Venus atmospheres. (In other literature even further extremes have been suggested.) In this study, the approach was taken to design to be adaptable to the extremes of this specified atmosphere.

For early missions in particular, it is desirable to deploy the station at or near the cloud top where the atmosphere is best defined. In the model used for this study, the cloud tops are very broadly defined referenced to the surface. This creates an uncertainty as to whether the balloon would float above or in the clouds.

To be conservative, in these designs, the balloon was assumed to be below the cloud tops, precluding the use of sun or star sensors. Solar cells were not considered as a source of power for the same reason, and the gas inflation system and thermal control were designed to operate without benefit of solar radiation. These conservations represented a significant penalty to the several design concepts considered.

The range of the atmospheres, and the method of definition in terms of altitude above an unknown surface, also creates a situation where subsonic deployment above the clouds may be impossible to achieve in all cases. This difficulty might be avoided by a redefinition of the atmospheres from the cloud tops down.

The subjects of wind shears, vertical drafts and storms in general can only be subjects for speculation at this time.

Orbiter interface. - The scope of the study did not permit definition of the physical or functional interfaces between the buoyant station and the orbiter/bus. This is particularly significant in the communication system areas. No attempt has been made to define "modification" to the orbiter that might be required.

In addition, it is apparent that the selection of the orbit in relation to the anticipated path (due to winds) of the BVS over the surface is critical to the mission.

Sterilization. - Sterilization problems unique to the buoyant station have been identified in the areas of tankage and balloon materials. The tankage weight would be increased significantly if sterilization in the filled condition were required. For this reason the approach of sterilizing the empty tankage was assumed. Mylar is likewise assumed to be sterilizable.

In addition, information on the sterilizability of the other equipment, where available, was considered, particularly in the areas of batteries and RTGs, where appropriate weights were used.

In other areas, however, the problem is one that the buoyant station has in common with other planetary vehicles and was considered to be beyond the scope of this study.

General development. - It is recognized that few of the systems or components required exist as off-the-shelf hardware. Specifically, this is true with regard to sterilization and the anticipated entry decleration requirements. The approach has been taken to avoid requirements far beyond the state of the art, and, in general, this was possible.

Specific Development Areas

Problem areas specifically identified within the scope of this study are as follows:

1) Relief valve;
2) Sensing for balloon deployment;
3) Balloon deployment;
4) Kapton or PBI fabrication;
5) Vaporization of cryogenic hydrogen;
6) Inflation gas temperature control;
7) Gas transport;
8) Heat source for thermal control;
9) Variable communication parameters;
10) Lightweight antenna design;
11) Station position determination;
12) Wind pattern uncertainties;
13) Cloud sampling;
14) Gas sampling;
15) Atmospheric contamination;
16) Instrumentation view angles;
17) Drop sondes.

In each case, a need was demonstrated that appeared to be unique to the buoyant station concept and that appears to be beyond the scope of "routine" design and development.

Relief valve. - Initially for the small station, a design was attempted wherein the balloon was inflated in one step by opening a valve from the high-pressure tank after which the balloon was sealed permanently and the tankage dropped. This simple approach required no sensing of balloon pressure, etc., and required only one opening into the gas bag. Analysis, however, indicated that the penalties in balloon weight to survive possible overpressure conditions were prohibitive, and a method of releasing pressure was required.

Sensing for balloon deployment. - On entering the atmosphere, it is necessary to deploy the balloon under precise conditions. Too early deployment (low ambient pressure) will result in excessive superpressure or loss (by venting) of gas. Deployment below equilibrium altitude will require an excess of gas to produce sufficient buoyancy to reverse the station velocity in the presence of higher atmospheric pressure. This study concluded that the most likely approach was to sense directly the ambient pressure.

Balloon deployment. - Few applicable data are available on the reliable deployment or mechanics of failure of a balloon under these conditions. This gray area is the source of the most serious of uncertainties of the BVS feasibility uncovered during this study.

Kapton or PBI balloon fabrication. - High-temperature materials must be used for the cyclic station. Both Kapton and PBI have a desirable operating temperature range with good physical properties. However, neither has been applied to balloon design or fabrication. The pertinent properties of these materials must be established, and then designs must be tested by fabricating test specimens.

Vaporization of cryogenic hydrogen. - Balloon inflation rates of approximately 1 lb/sec are desired for the large stations. This requires that a high rate of heating for a short period be available for vaporizing and superheating the cryogen. Several methods are available such as oxygen or fluroine use as oxidizer for the heat source. The method must be efficient, lightweight, and reliable.

Inflation gas temperature control. - It is highly desirable to inflate the balloon and drop the tankage with no additional gas required or lost after establishing station equilibrium. This requires that the bulk temperature of the inflation gas be controlled to near the local ambient temperature.

Gas transport. - Tankage weight is one of the critical items for the samll station. Projected technology for the 1970 time period suggests a ratio to 11 lb/lb based on a filament-wound (glass or boron) nickel-lined concept. However, this has not yet been achieved.

Heat source for thermal control. - The station must be designed to survive the extreme temperature of 195°K in the upper density model. This requires that a heat source be provided to maintain batteries and other equipment at a minimum temperature of 278°K. For the small station, this must be highly efficient, controllable, lightweight, and reliable.

Variable communications parameters. - The variable communications period which is a function of station location with respect to the orbit creates an operational problem in programing the second ranging measurement.

Ideally the second ranging measurement should be made immediately preceding loss of contact with the station to provide range measurements from 2 points (on the orbit) as far apart as possible; however, the contact time can vary from 5 to 106 min depending on whether the station is under the periapsis or under the apoapsis.

The problem is in predicting the correct interval and maintaining an up-to-date program in the orbiter.

Lightweight antenna design. - An integrated design is required for the main communications antenna for the samll (200-lb) concept that provides nearly hemispherical coverage, particularly for communication during deployment, with a minimum weight penalty.

Station position determination. - Accurate determination of position by ranging from the orbiter will require further integration with the orbiter systems, particularly in the area of resolving the ambiguity of position to the right or left of the orbit. Further consideration of devices such as sun sensors should be given after the cloud level question has been resolved. In addition, an inertial platform may prove feasible for the larger station concepts.

Wind pattern uncertainties. - While a theoretical model has been assumed for calculating the BVS trajectories and flight times, very few experimental data exist to substantiate either the general pattern or the magnitude of the wind velocities used.

Cloud sampling. - There are two major problem areas in designing a system to present cloud samples to an analyzing instrument. The first is the separation of the sample in the form of particulates (e.g., solidified gases, dust) or liquid droplets from the atmosphere. The second is the concentration and conversion of the sample into a form suitable for analysis.

The collection of solid particulates can be accomplished with filters and blowers or electrostatic precipitators. The collection of liquid droplets is somewhat more difficult and may require a filter similar to a chromatograph column.

After the sample is collected, it must be presented to the analyzing instrument in a suitable form and concentration. The solidified gas particles and liquid droplets can be vaporized easily and presented to a gas chromatograph or mass spectrometer for analysis. The dust particles (e.g., quartz) may require "wet" chemical analysis.

Gas sampling. - A gas sampling system is required to reduce the high pressure of the ambient atmosphere (without affecting the composition) to a value compatible with the inlet system of a mass spectrometer (to prevent the vacuum pumps from becoming saturated). Even with a suitable gas sampling system to prevent immediate saturation of the pumps, a high capacity electronic vacuum pump (e.g., a sputter ion pump) must be developed if the mass spectrometer is to function over long periods.

Atmospheric contamination. - The contamination of the atmosphere in the vicinity of the gondola by gases leaking from the balloon is an apparent problem.

Instrumentation view angles. - The proximity of the gondola to the balloon prevents experiments from viewing in directions above the balloon. This may necessitate placing an auxiliary experiment package at the apex of the balloon introducing problems in balloon deployment and of supplying power to the experiments.

Drop sondes. - The design and development of small drop sondes to survive and collect data in the high temperatures and pressures of the lower atmosphere presents a problem that must be solved. The sensing of some atmospheric constituents (e.g., water vapor) and surface composition is complicated by the high temperatures and pressures to which the experiments themselves must be exposed.

CONCLUSIONS

This study originally posed two fundamental problems with regard to the buoyant station concept:

1) Do anticipated scientific missions exist that would be significantly enhanced by the buoyant station approach?

2) Is a balloon system feasible with regard to payload capability and most particularly with regard to potential reliability?

The first of these questions was answered in the first phase of the study. It is very evident that the ability to survive for (relatively) long periods in the atmosphere, to sample over vertical profiles (more than one) in the atmosphere and to move (drift) over the surface is almost a necessity for all but the earliest scientific missions and that even the simplest missions are enhanced sufficiently to justify further consideration of this approach. Priorities of experiments and instrumentation are suggested in Volume III of this report as well as specific payloads.

The second question relating to balloon system feasibility could be answered only in part. It became apparent early in the study that above a certain size system (in the range of 200 pound weight at deployment) a significant usable payload could be supported. Larger sizes permitted consideration of more sophisticated missions such as cycling the entire station up and down through the atmosphere. The fundamental technology -- materials, tank design, etc. -- is available, and designs were conceived. A gap exists, however, in actual experience within the industry in deploying and controlling buoyant vehicles of this nature and developing the background in design and test necessary to achieve and demonstrate the necessary reliability. The conclusion was reached that the approach is feasible, but that a significant development program will be required.

Communication (including ranging for position determination purposes) presents only one fundamental problem, that of losing line-of-sight contact with the orbiter as the station drifts over the surface with the prevailing wind patterns. In this report, missions of from 7 to 100 (Earth) days are suggested. The problem is, of course, aggravated by the longer missions. Additional study with more optimum orbits will be required.

Energy requirements for electric power and thermal control (i.e., heating the station in ambient environments as low as 195°K) are likewise increased for longer missions. Chemical storage of energy becomes difficult for missions of more than 4 or 5 days. The most appropriate solution, particularly for the large (2000-lb) station is the radioisotope thermoelectric generator that has an output of both heat and electrical energy in usable proportions and a modest weight over an indefinite life.

The output of this study has been the development of design concepts for the use of the buoyant station approach in two distinctly different situations.

The 200-lb station concept is appropriate for an early mission into the atmosphere of Venus. Without this technique, such a mission would be limited to a single profile of measurements to the surface with no choice of location and a life limited to a few hours at most.

The station, as presented herein, has a complement of 16 lb of experiments/instruments, a life of seven days, a potential over the ground range of 5400 km, and the potential of making profile measurements to the surface at the beginning and end of this track and at two discretionary points in between. Table 14 compares this capability with that of a simple probe alone.

The 2000-lb station conceived in this study is representative of the type of vehicle that will be required for later missions to Venus. In this regard it will fill the corresponding slot to the (Mars) Voyager lander. For Venus exploration, actual landing with the intent of surviving for a significant period will be extremely difficult, if at all possible. A properly mobile balloon, however, can fill the gap and actually exceed the lander in desirability in many respects. For example, relatively simple drop sondes with limited on-the-surface survival ability can collect data at many locations with a much reduced communication problem.

The 2000-lb size was selected originally to permit consideration of two such vehicles with each Voyager bus. This study has demonstrated, however, that there are no unique limitations associated with size above the few hundred pound vehicle.

Martin Marietta Corporation
Denver, Colorado
May 15, 1967

TABLE 1. - ALTITUDE CYCLE METHOD SUMMARY

Method	Practical limitations	Number of cycles feasible	Number of functions required	Sensitivity to extreme atmospheres
Gas dump and makeup	Amount of makeup gas carried as payload	3	6	Insensitive except for ascent and descent rates
Gas dump and ballast drop	Ballast should be usable Instrumentation	3	6	Insentitive except for ascent and descent rates
Pump and dump atmosphere gases	Balloonette volume and compressor ratio	Limited by available power	9	Sensitive to molecular weight and temperature; determine ballast added; has dwell capability

TABLE 2. - MATERIALS SELECTION SUMMARY

Material trade name and/or generic name	Usable	Needs study	Not usable
Polyester film	X		
Viton ® elastomer			X
Perfluoronated elastomer		X	
Pyre-M.L. ® polyimide			X
Kapton ® polyimide	X		
Parylene ® poly-paraxylylene		X	
Polysulfone			X
Perfluoroalkyl triazine elastomer			X
PPO ® polyphenylene oxide			X
Silicone rubber		X	
PBI film	X		
Carbon and graphite			X
Glass			X
Titanium wire		X	
304 stainless wire		X	
Polyimide		X	
BBB		X	
PBI fiber	X		

TABLE 3. - BALLOON INFLATION GASES

Gas	Method of transport	Advantages	Disadvantages
Helium	Gas	Low molecular weight, inert, experience, no fire hazard	Leakage problems, high tank weight
Hydrogen	Gas	Lowest molecular weight, less leakage problem	Tankage volume, tankage weight, explosion hazard
	Cryogenic	Minimizes tankage volume	Thermal isolation during transit (boiloff losses) and vaporization requirement
Methane	Cryogenic	Minimizes tankage volume	High molecular weight, boiloff losses, and energy required for vaporization
Hydrazine	Liquid	Minimum tankage weight and volume, uses a spontaneous catalyst	High temperature dissociation
Ammonia	Liquid	Minimum tankage weight and volume, low molecular weight is disassociated	Extreme energy required to dissociate

TABLE 4. - PRESENT KNOWLEDGE OF VENUS

Surface temperature	500 to 800°K bright side average 430 to 600°K dark side average 260 to 470°K poles
Atmospheric temperature	234°K at cloud tops
Atmospheric pressure	2 to 200 atm at surface 2.6×10^{-3} mb at 60 km above clouds
Atmospheric composition	CO_2 5 to 20% H_2O, HCℓ, HF, very little Major constituent: N_2, Ne, He Other gases: A, CO, N_2, O_2, N_2O_4, NH_3, CH_4, C_2H_4, N_2O, NO_2, HCHO
Cloud composition	Ice crystals 10 μ diam Others: quartz dust, formaldehyde, carbon suboxide polymers
Winds	Upper clouds turbulent General flow from subsolar to antisolar V = 1 cm/sec to 33 m/sec (~5 m/sec average)
Particles and haze above clouds	Thin layers confined to 5 km above cloud tops
Cloud top heights	From 30 to 90 km above surface Visible diameter: 12 400 to 12 300 km Radio diameter: 120 km smaller than visible diameter
Surface characteristics	Generally smoother than the moon Five rough areas located by radar
Rotation rate	-243 days retrograde
Magnetic fields	Dipole moment less than 1/10 to 1/20 Earth's
Mass	.81485 mass of Earth ± .015%

TABLE 5. - EXPERIMENT PRIORITY

Measurement	200-lb BVS	2000-lb BVS
Priority 1		
Pressure	X	X
Temperature	X	X
Composition	X	X
Surface temperature	X	X
Cloud composition		X
Circulation	X	X
Priority 2		
Cloud structure		X
Temperature variations	X	X
Pressure variation	X	X
Microwave emission		X
Trace constituents	X	X
Nature of surface		X
Particulates		X
Surface insolation		X
Priority 3		
Albedo		X
Outgoing thermal radiation		X
Atmospheric insolation		X
Atmospheric thermal radiation		X
Magnetic fields		X
Gravity		
Winds - small scale		
Precipitation		
Topography		X
Priority 4		
Seismic activity		
Volcanic activity		
Surface radioactivity		
Life detection		X
Ionizing radiation		X

TABLE 6. - EXPERIMENTS FOR 200-LB BVS

	Weight, lb	Power, W	Data per measurement, bits	Range of measurement	Data acquisition
4 platinum resistance temperature sensors	1.0	.8	14	200 to 500°K 450 to 800°K	Three times per orbit; every 1.25 hr except during acquisition of drop sonde data
6 pressure sensors	3.0	.6	14	6 ranges: 10^{-1} to 10^{4}	Measure every 13.3 sec during descent
Composition:					
H_2O	1.5	1.0	7	.01%	
N_2	1.0	1.0	7	1%	
O_2	1.5	1.0	7	.01%	
A	1.5	1.0	7	.01%	
CO_2	1.0	1.0	7	1%	
Acoustic transmission line	3.0	4.0	28	10^{-2} to 10^{-5} g/cm^3	
Drop sondes (2)	10 (5 each)	5	28 (3192 Total)	Station to surface	On command
Total weight:	23.5 (including two 5-lb drop sondes)				

TABLE 7. - 2000-LB BVS EXPERIMENTS

No.	Experiment	Weight, lb	Power, W	Data acquisition
1	Temperature sensors (4)	2	.8	Two 7-bit words/measurement (range switched electronically)
2	Pressure sensors (10)	5	1.0	Four 7-bit words/measurement (2 ranges - 2 sensors/range)
3	Acoustic transmission	3	4	Four 7-bit words/reading Three readings/sample = 84 bits
4	Mass spectrometer (atmospheric gases)	10	10	4000 bits/analysis, 60 sec/analysis
5	Pyrolysis/gas chromatograph/mass spectrometer (cloud, dust composition)	15	15	10 000 bits/analysis, 1 hr/analysis
6	Dust/cloud particle collector for 5	2	10 peak .5 cont	Status only
7	Vidicon microscope (dust and biota)	15	8	255 000 bits/picture, 20 pictures/sample = 5.1×10^6 bits
8	Minimum bio lab	20	10 peak	100 hr/analysis, 13 500 bits/analysis
9	Dust collector for experiments 7 and 8	2	.5	Status only
10	Ion chamber and Geiger tube	3	.5	14 bits - ion chamber 21 bits - GM tube every 10 sec for 60 sec
11	Ultraviolet radiation flux	2	1.5	Six 7-bit words/measurement
12	Visible/near-IR flux	3	2.3	25 7-bit words/measurement
13	Altimeter/radar scatterometer	15	30	10 000 bits/10-sec scan 14 bits - altitude
14	Microwave scanner/spectrometer	25		100 000 bits/image 10 000 bits/scan, 4 wavelengths
15	IR scanner/spectrometer	10	4	255 000 bits/image 10 000 bits/scan, 4 wavelengths
16	Light backscatter from aerosols	5	5	10 7-bit words/sec
	Weight	137		

TABLE 8. - DROP SONDE EXPERIMENTS

	Weight, lb	Power, W	Data
Platinum resistance temperature sensor	.25	.2	7 bits every 30 sec
Pressure sensors (2) (wide range)	.75	.2	14 bits every 30 sec
Water vapor detector	.5	.5	7 bits every 30 sec
Totals	1.5	.9	28

TABLE 9. - 5-LB DROP SONDE WEIGHT AND POWER ALLOCATIONS

	Weight, lb	Power, W
Experiments	1.5	.9
Telemetry	1.5	2.0
Batteries	.25	---
Structure, wires	.5	---
Thermal insulation	.85	---
Parachute	.4	---
Totals	5	2.9

TABLE 10. - LARGE SONDE EXPERIMENT COMPLEMENT

Experiment/instrument	Range of measurement	Weight, lb	Power, W	Bits/ measurement	Data acquisition
Temperature sensing, A_1	200 to 500°K	.25	.2	7	One measurement every 10 sec
Temperature sensing, A_2	200 to 500°K	.25	.2	7	One measurement every 10 sec
Temperature sensing, B_1	450 to 800°K	.25	.2	7	One measurement every 10 sec
Temperature sensing, B_2	450 to 800°K	.25	.2	7	One measurement every 10 sec
Pressure-static, A	0 to 10 mb	.5	.1	7	
Pressure-static, B	0 to 10^2 mb	.5	.1	7	One measurement every 10 sec (only two ranges read out)
Pressure-static, C	0 to 10^3 mb	.5	.1	7 (14 for pressure-static A to D together)	
Pressure-static, D	0 to 10^4 mb	.5	.1	7	
Pressure-impact	0 to 20 mb	.5	.1	7	One measurement every 10 sec
Pitot tube		.5			
Impactometer		.5	.5	2-sec pulses on carrier frequency	At impact only
Photometers and filters looking up	CO_2, H_2O absorption bands	6.0	3.0	Six 7-bit words	One measurement every 10 sec
Mass spectrometer (MS)	H_2O, N_2, O_2, A, CO_2 gases or scan 10 to 50 amu	10.0	10.0	497	One measurement every 6 minutes. 1 minute/analysis. First measurement at 1 minute
Cloud sampler for MS	Heat cloud sample	2.0	2.0	497	Present vaporized cloud to MS. One analysis every 6 minutes. 1 minute/analysis. First measurement at 4 minutes
Totals		22.5	16.8		

TABLE 11. - AVAILABLE COMMUNICATION PERIODS, STATION TO ORBITER

True anomaly from periapsis, θ, deg	Maximum communications periods for various station antenna half-power beam widths		
	90°, min	100°, min	140°, min
0	3.1	3.2	5.3
45	8.0	13	20
90	22	23	40
135	29	55	84
180	69	78	106

TABLE 12. - FACTORS IN SELECTION OF FREQUENCY BAND

Critical frequency - ionosphere	Estimated to be 2 to 20 MHz
Attenuation (moderate rain)	At 3000 MHz 1 x 10^{-4} dB/km (negative slope with frequency)
Attenuation (sleet, snow)	Less than rain
Therefore:	200 MHz to 3000 MHz; good from standpoint of above
Doppler and frequency instability plus desire for solid state	Reduce above to 200 MHz to 400 MHz
Transmitter weight and efficiency	High efficiency and low weight desired

TABLE 13. - TELECOMMUNICATIONS SYSTEM SUMMARY

Telemetry link - station to orbiter	
Frequency	200 MHz
Modulation	2 subcarrier PSK/PM
Transmitter power	5 W (3 dB antenna gain product)
Data rate	30 BPS
Maximum range	10 000 km
Command link	
Frequency	230 MHz
Modulation	2 subcarrier PSK/PM
Transmitter power	10 W (3 dB antenna gain product)
Data rate	30 BPS
Turnaround ranging	
Modulation	Pseudonoise ranging code (use subcode elements)
Orbiter transmitter power	10 W at 230 MHz
Station transmitter power	5 W (3 dB antenna gain product)
Drop sonde link	
Frequency	300 MHz
Data rate	1 BPS
Transmitter power	9 MW (minus 6 dB antenna gain product)

TABLE 14. - POTENTIAL MISSION FEATURES

	Direct probe alone	Direct probe with BVS
Number of probes to surface	1	4
Communications opportunities	1 (½ to 2 hr) on entry	1 (½ to 2 hr on entry) + 40 (10 min to ½ hr) to orbiter
Location	1 - dictated by entry conditions	Covers a ground track of 1800 miles over surface
Time span over which measurements may be taken	½ to 2 hr	~7 days
Mission flexibility	Limited	Essentially unlimited possibilities to command mission modifications over several days
Wind pattern measurements	Limited	By tracking from orbiter

TABLE 15. - 2000-LB BVS EXPERIMENTS

No.	Experiment	Measurement group	Data acquisition
1	Temperature sensors (4)	I, IV	Two 7-bit words/measurement (range switched electronically)
2	Pressure sensors (10)	I, IV	Four 7-bit words/measurement (2 ranges - 2 sensors/range)
3	Acoustic transmission	I, IV	Four 7-bit words/reading, three readings/sample = 84 bits
4	Mass spectrometer (atmospheric gases)	II, IV	4000 bits/analysis, 60 sec/ analysis
5	Pyrolysis/gas chromato-graph/mass spectrometer (cloud, dust composition)	II	10 000 bits/analysis, 1 hr/ analysis
6	Dust/cloud particle collector for 5	--	Status only
7	Vidicon microscope (dust and biota)	II, IIA	255 000 bits/picture, 30 pictures/sample = 5.1×10^6 bits
8	Minimum bio lab	IIB	100 hr/analysis, 13 500 bits/ analysis
9	Dust collector for experi-ments 7 and 8	--	Status only
10	Ion chamber and Geiger tube	I, IV	14 bits - ion chamber 21 bits - GM tube every 10 sec for 60 sec
11	Ultraviolet radiation flux	I, IV	Six 7-bit words/measurement
12	Visible/near-IR flux	I, IV	25 7-bit words/measurement
13	Altimeter/radar scatterometer	I/III, IV	10 000 bits/10-sec scan, 14 bits - altitude
14	Microwave scanner/spectrom-eter	III	100 000 bits/image, 10 000 bits/ scan, 4 wavelengths
15	IR scanner/spectrometer	III, IV	255 000 bits/image, 10 000 bits/ scan, 4 wavelengths
16	Light backscatter from aerosols	IV	10 7-bit words/sec

TABLE 16. - 2000-LB BUOYANT VENUS STATION, COMMUNICATIONS LINKS SUMMARY

Telemetry Link - station to orbiter	
Frequency	400 MHz
Modulation	2 subcarrier PSK/PM
Transmitter Power	40 W (3 dB antenna gain product)
Data rate	1000 BPS
Maximum range	14 000 km
Command link	
Frequency	370 MHz
Modulation	2 subcarrier PSK/PM
Transmitter power	20 W (3 dB antenna gain product)
Data rate	50 BPS
Turnaround ranging	
Modulation	Pseudonoise ranging code (use of subcode elements)
Orbiter transmitter power	40 W at 370 MHz
Station transmitter power	40 W at 400 MHz
Drop sonde link	
Frequency	300 MHz
Data rate	25 BPS
Transmitter power	12 MW at 100 km range

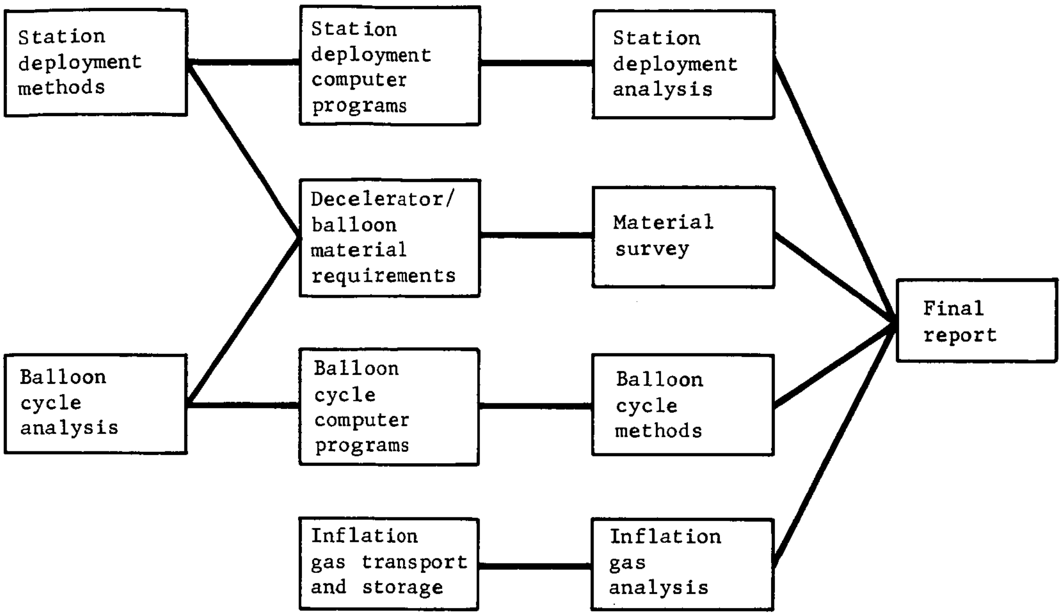


Figure 1. - Mode Mobility Flow Diagram

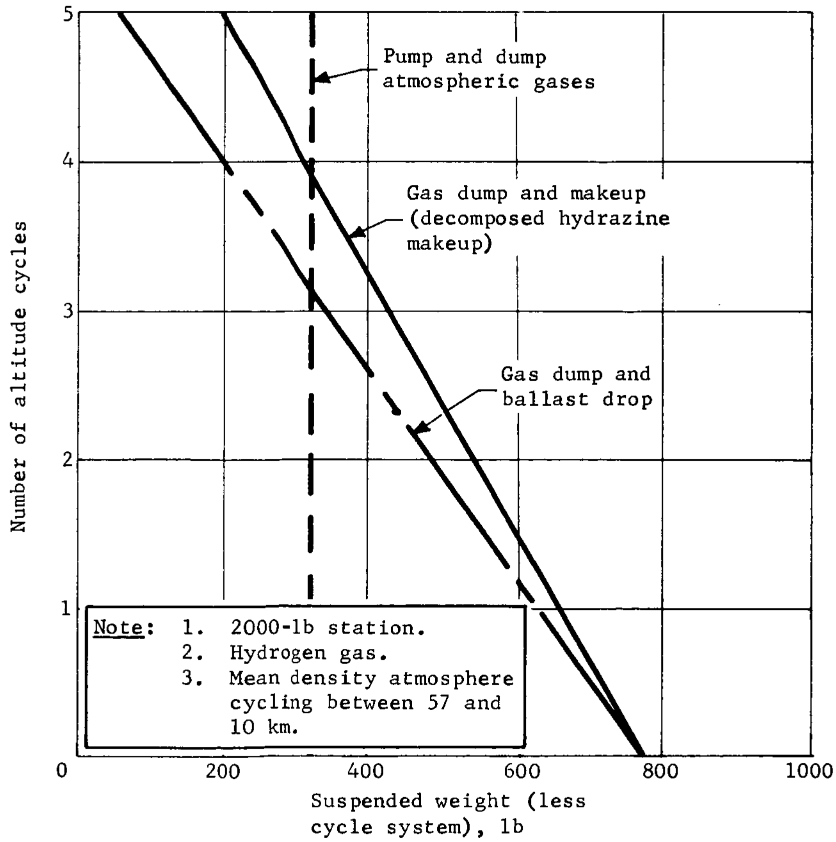


Figure 2. - Cyclic Mode Efficiencies

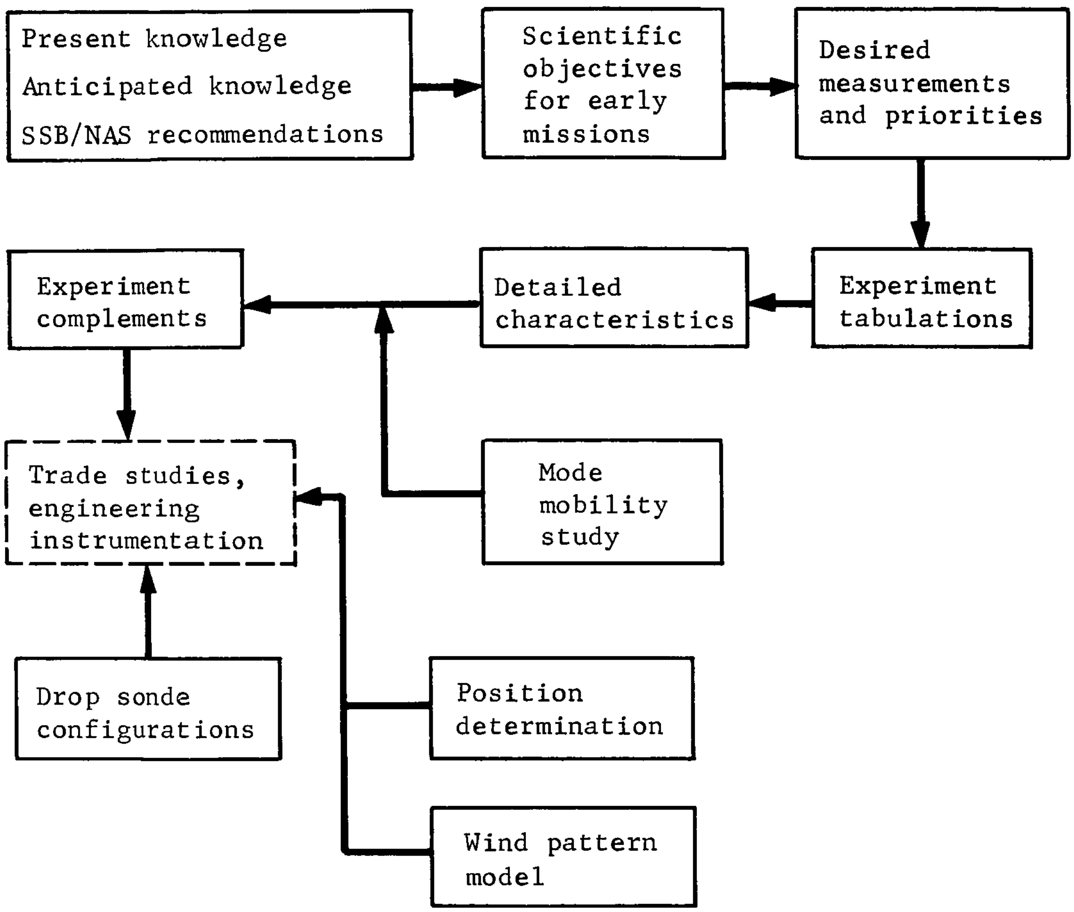


Figure 3. - Instrumentation Studies Flow Chart

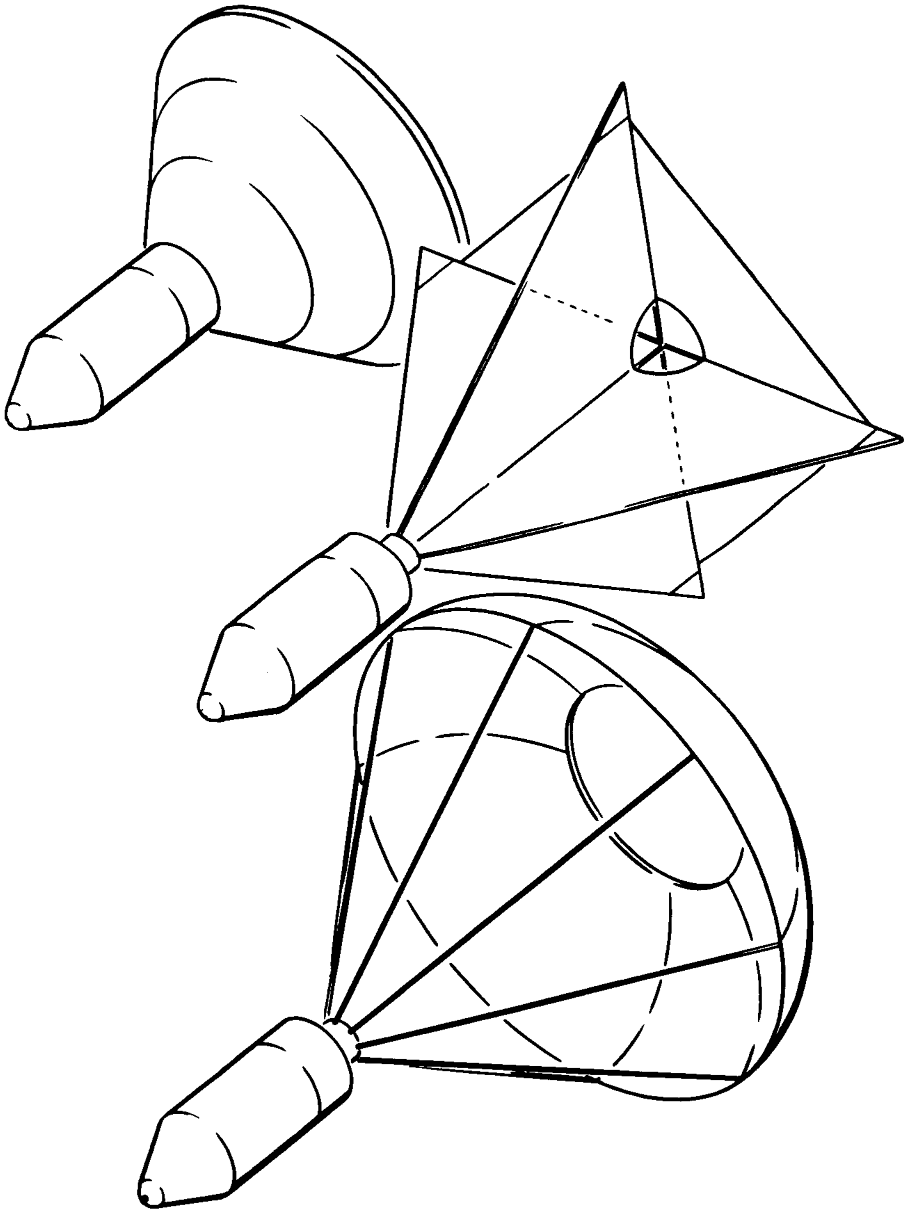


Figure 4. - Drop Sonde Decelerator Concepts

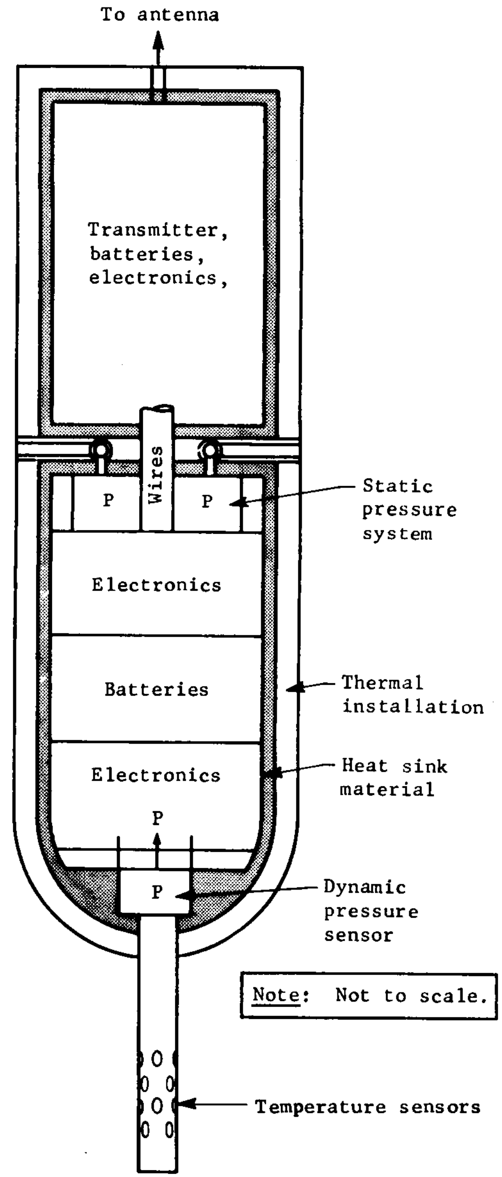


Figure 5. - Schematic of Small Sonde

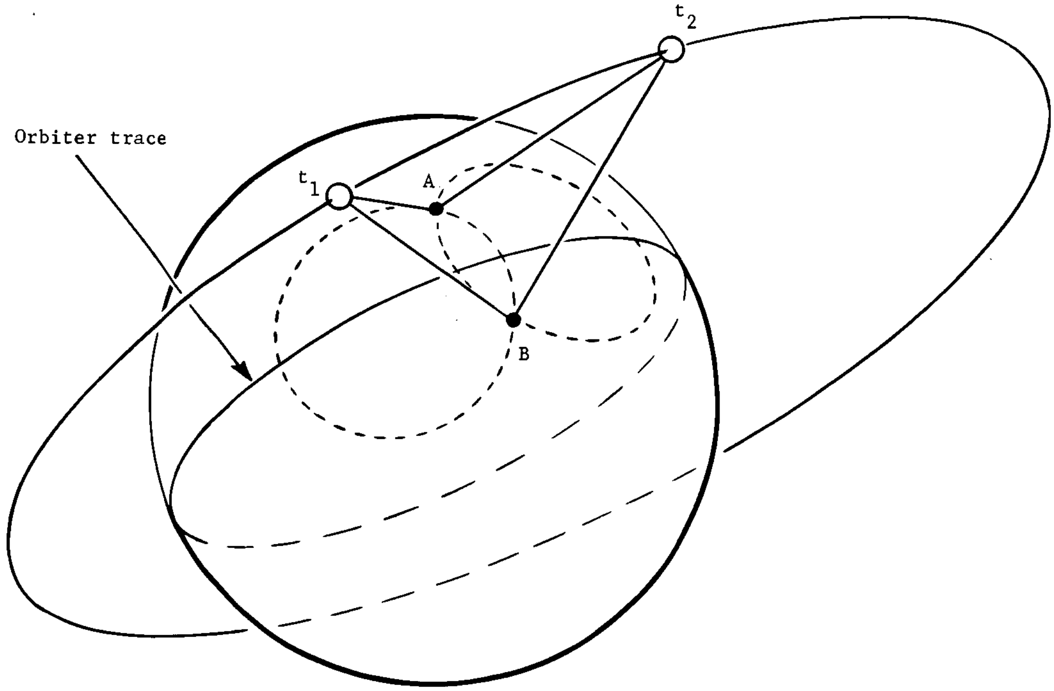
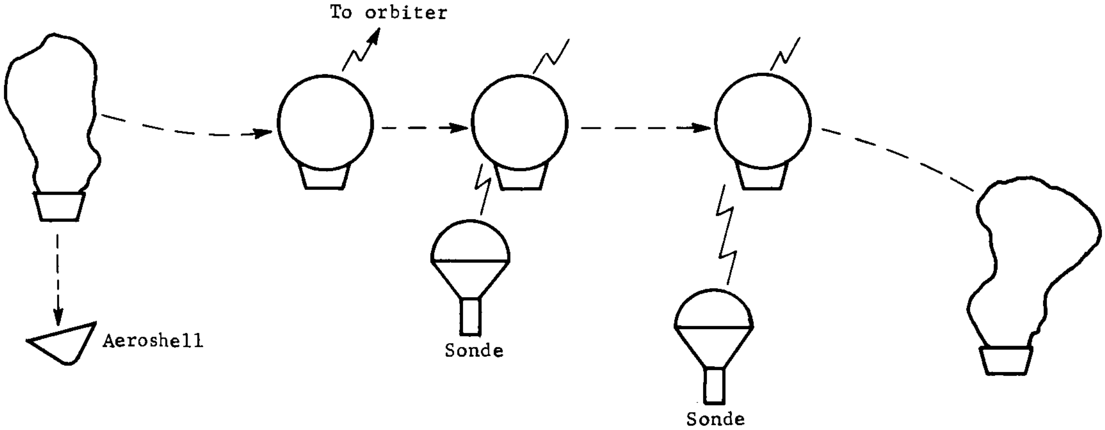


Figure 6. - Locating the Station by Ranging from the Orbiter



Deployment	Horizontal mobility	Drop sonde 1	Drop sonde 2	Descent of buoyant station
Aeroshell acts as a direct probe and transmits data to buoyant station	Collect and transmit data at equilibrium altitude Location determination from orbit Wind Earth-based data analysis	On command drop sonde at selected locations Earth-based data analysis	On command at selected location Earth based data analysis	By natural loss of gas By command

Figure 7. - 200-1b Station Mission

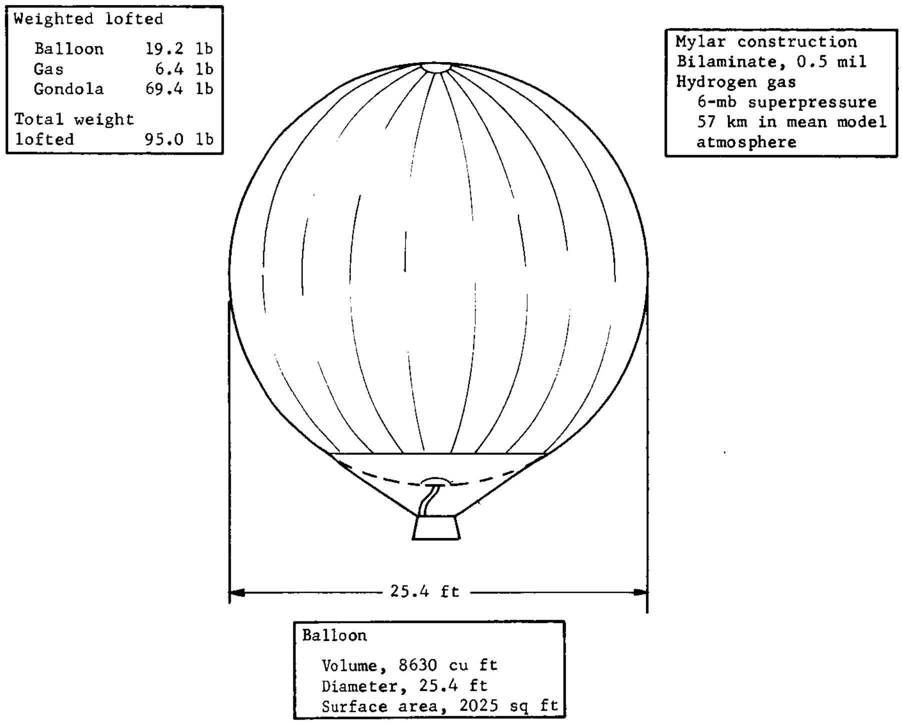


Figure 8. - Nominal 200-lb Station

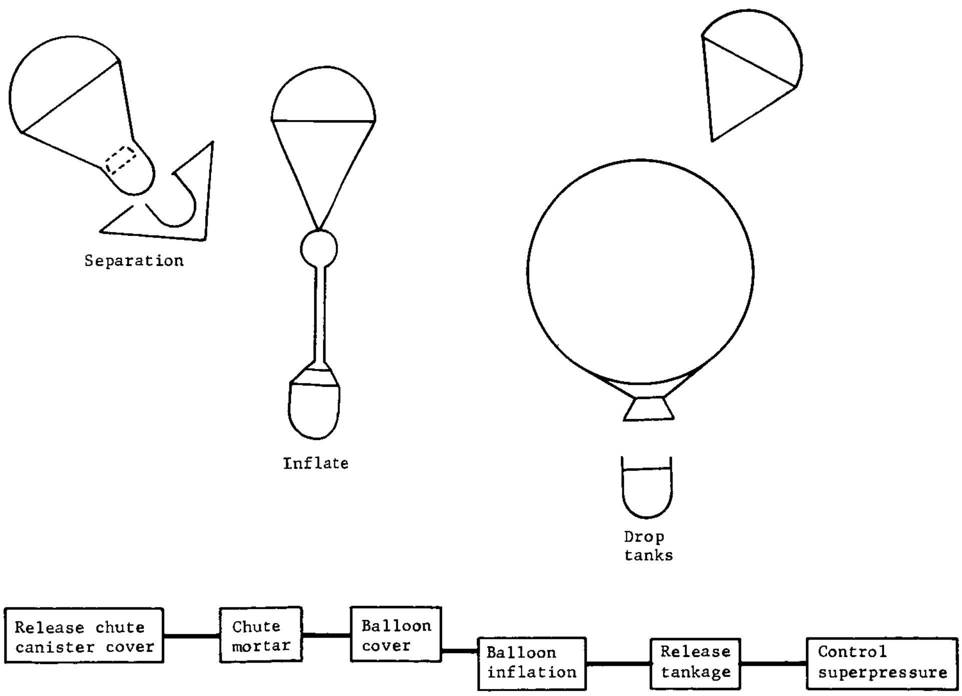


Figure 9. - Balloon Deployment Sequence

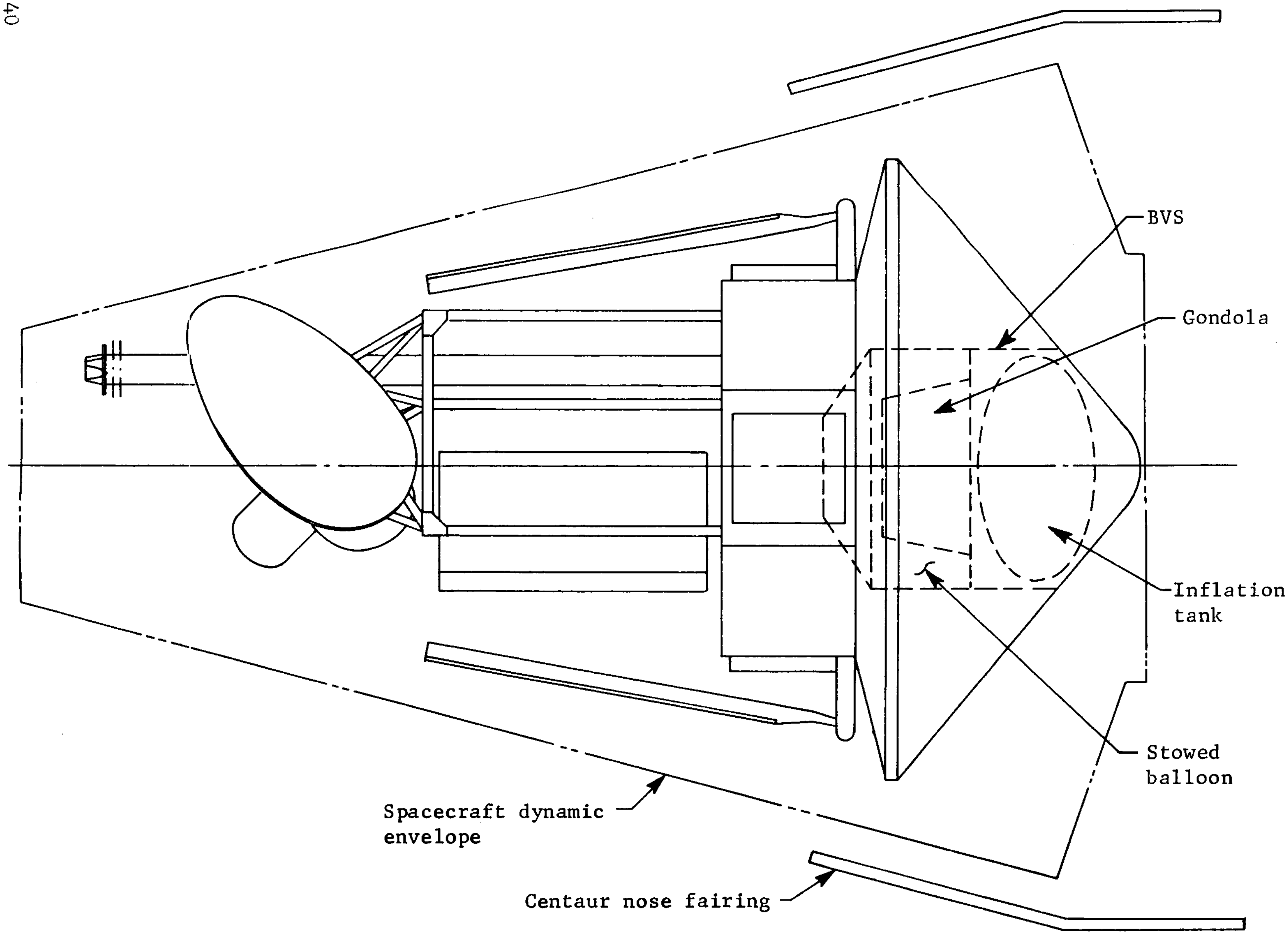


Figure 10. - 200-1b Buoyant Venus Station in Atlas/Centaur Shroud

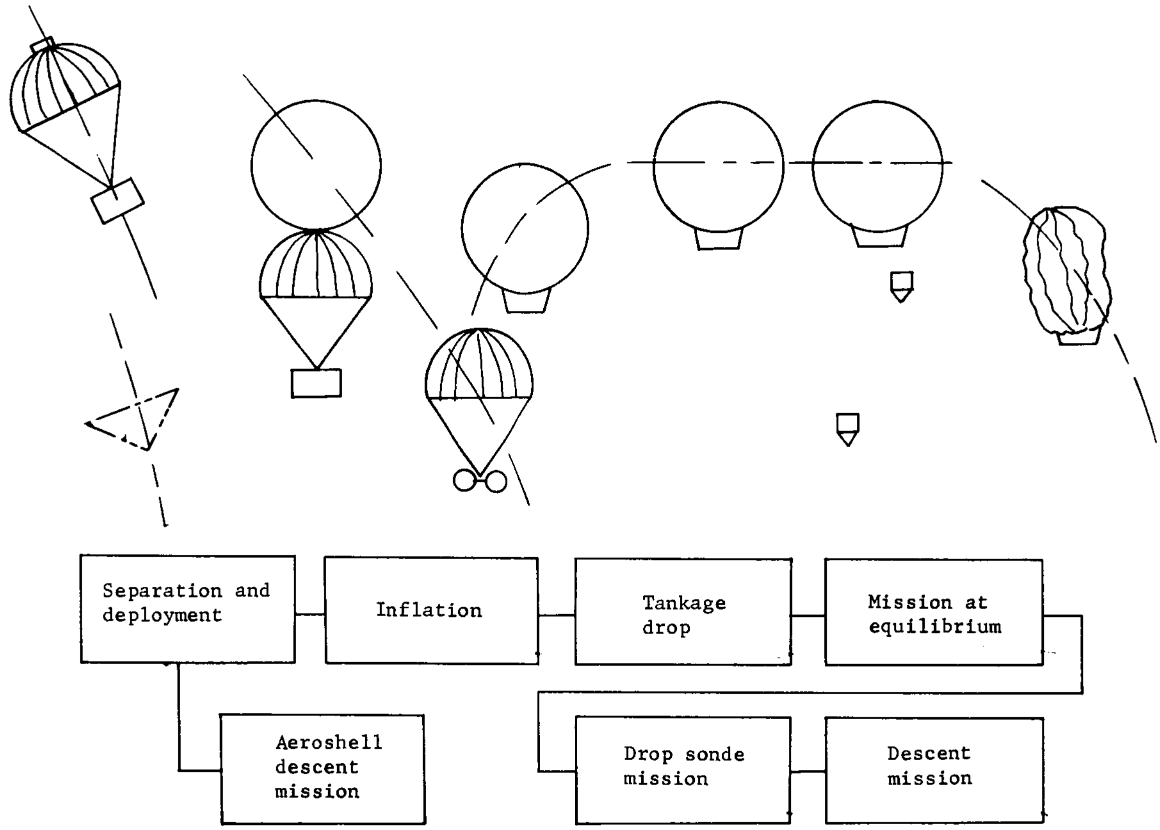


Figure 11. - Mission without Altitude Cycling Capability

Subsystem	Weight, lb
Parachute	106
Balloon	274
Inflation	850
Gondola	770

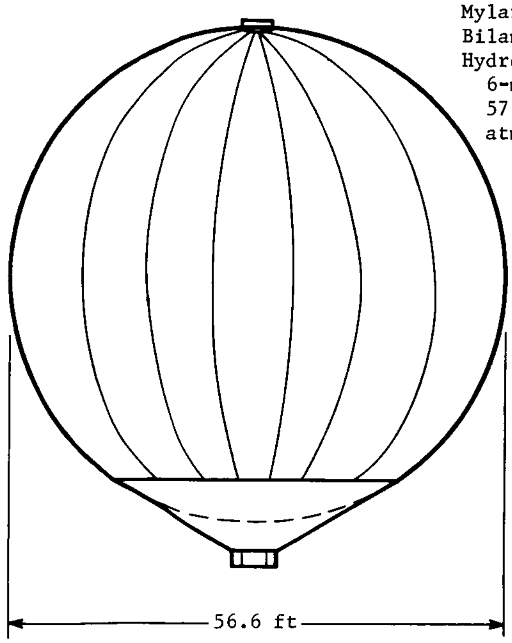


Figure 12. - Noncyclic 2000-lb Station

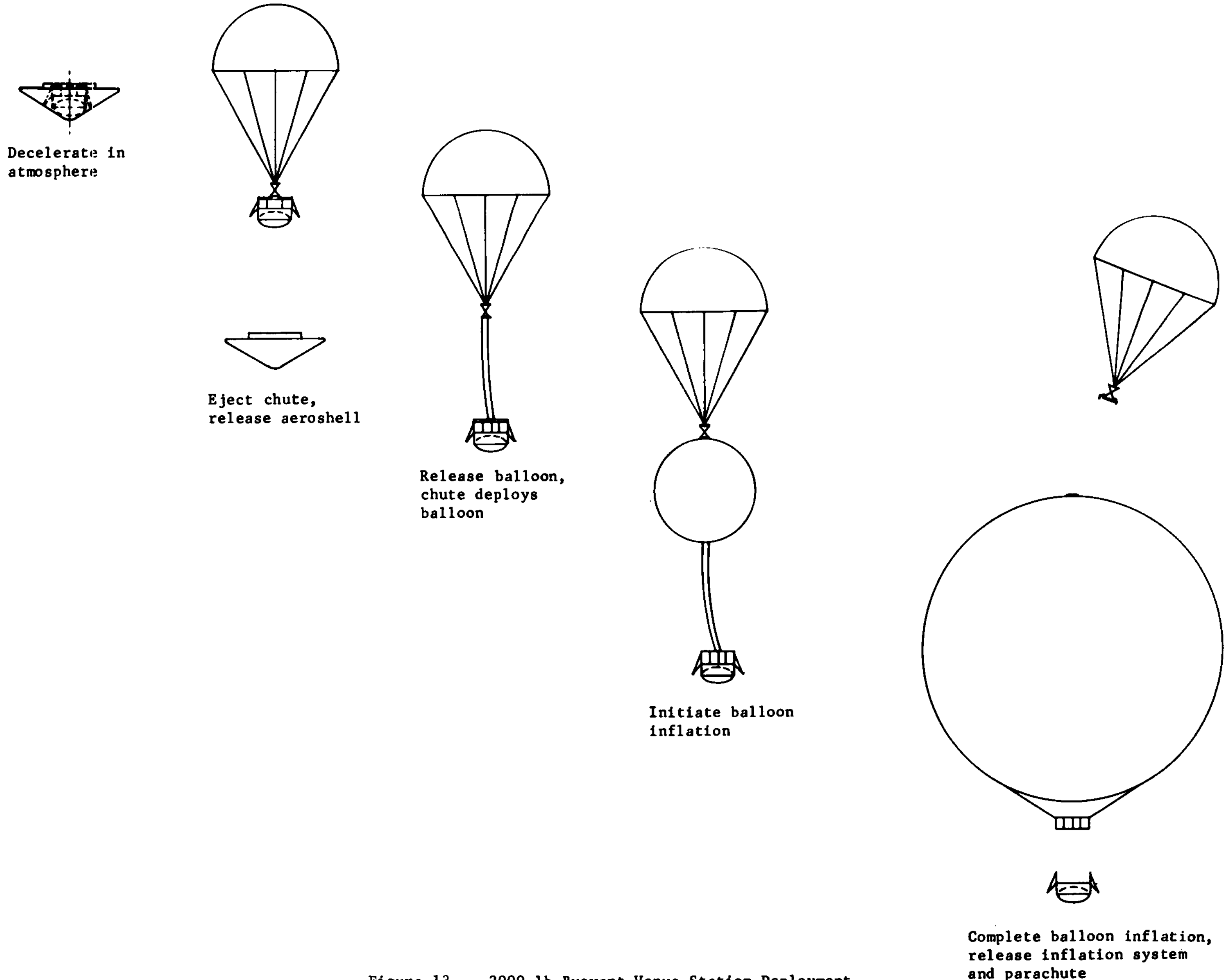


Figure 13. - 2000-lb Buoyant Venus Station Deployment

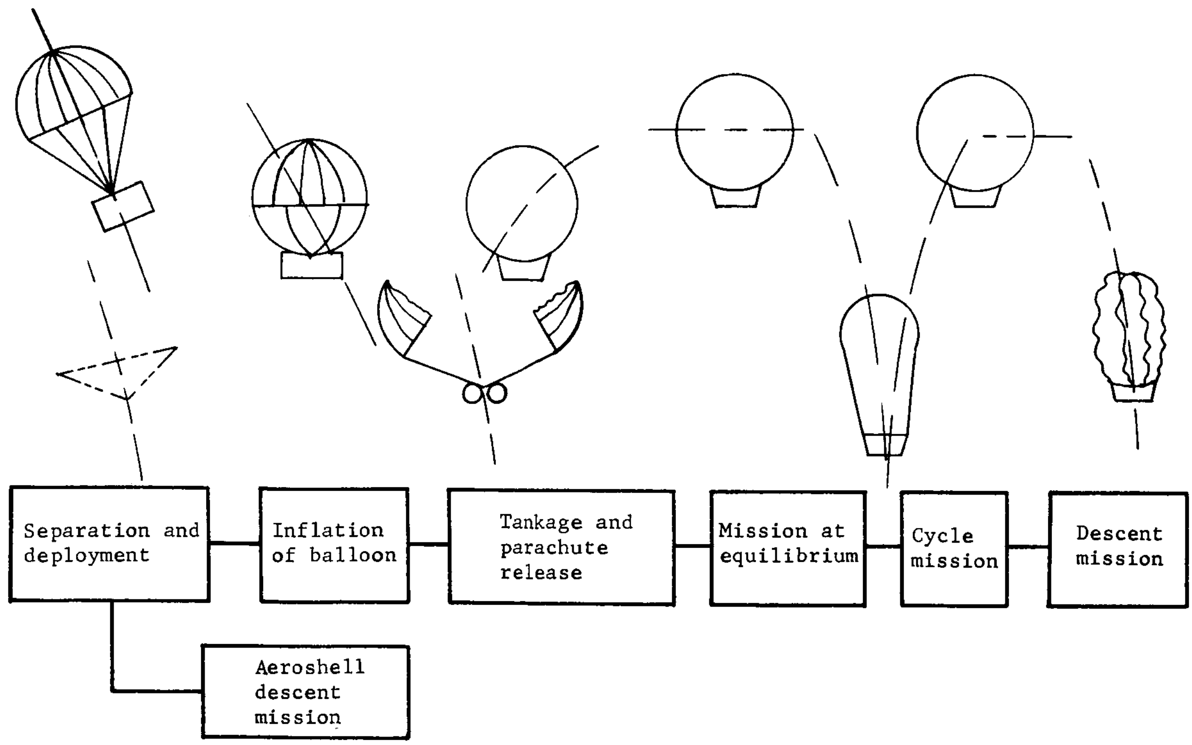
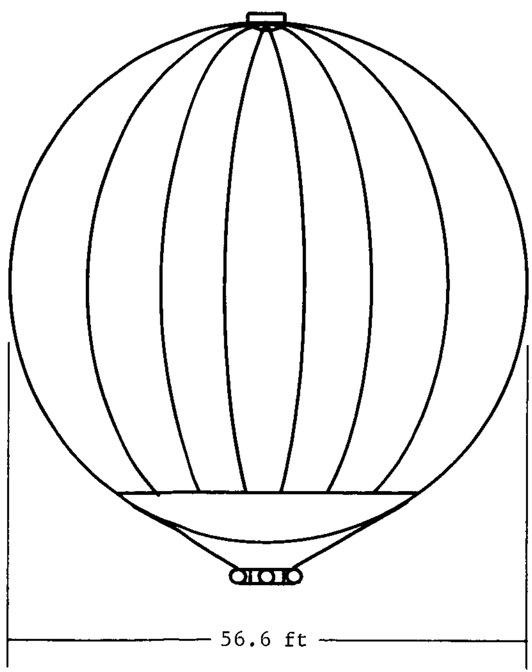


Figure 14. - Mission with Altitude Cycling Capability

Gas dump and makeup
3 cycles
Hydrogen inflated
Decomposed hydrazine
cycle gas system

PBI film
Bilaminate, 1.25 mil
6-mb superpressure
57 km in mean model
atmosphere

Subsystem	Weight, lb
Parachute	106
Balloon	261
Inflation	850
Cycle	236
Gondola	547



Total deployed
weight of 1040 lb

Figure 15. - 2000-lb Cyclic Station

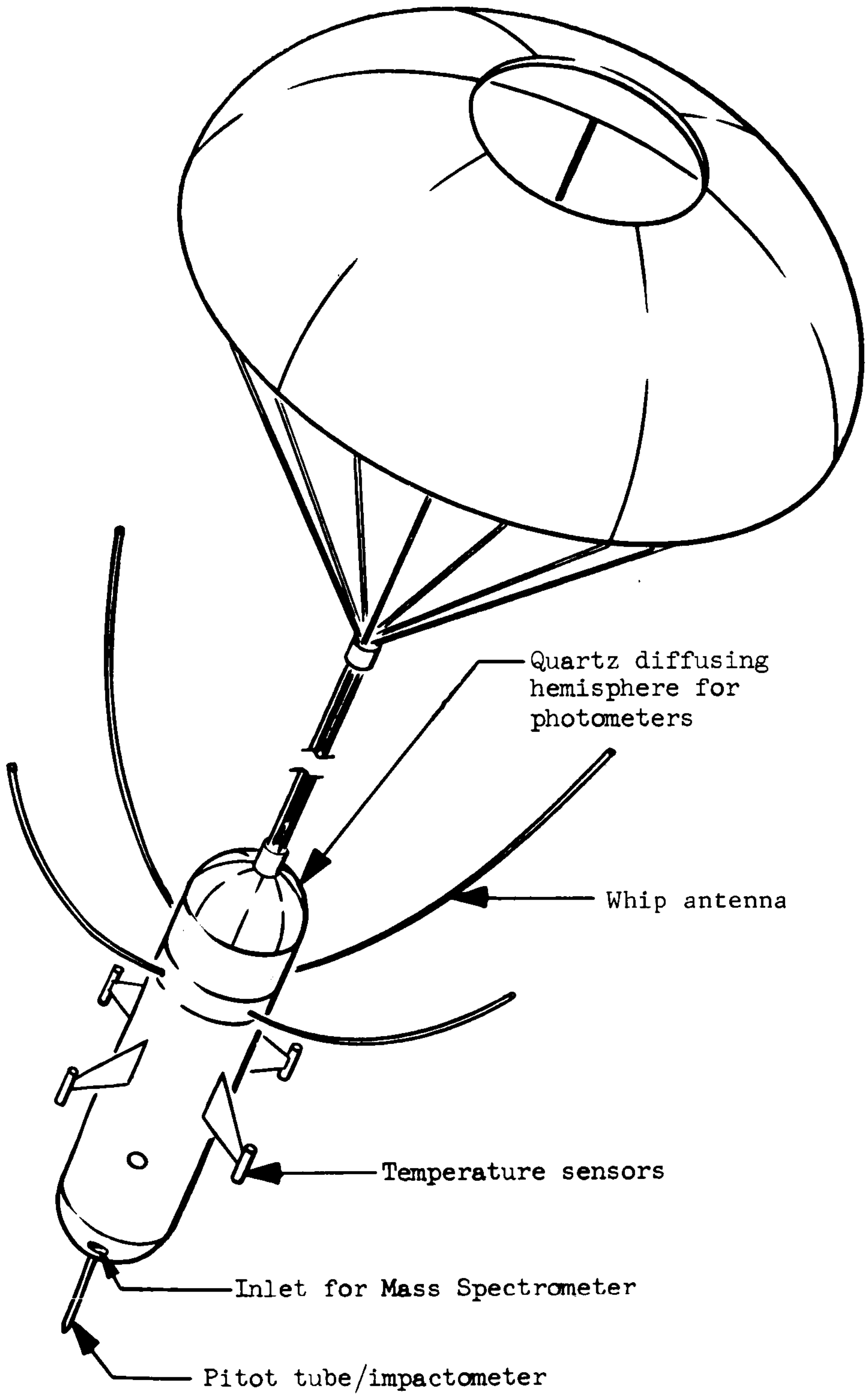


Figure 16. - Large Sonde Suspended from Parachute

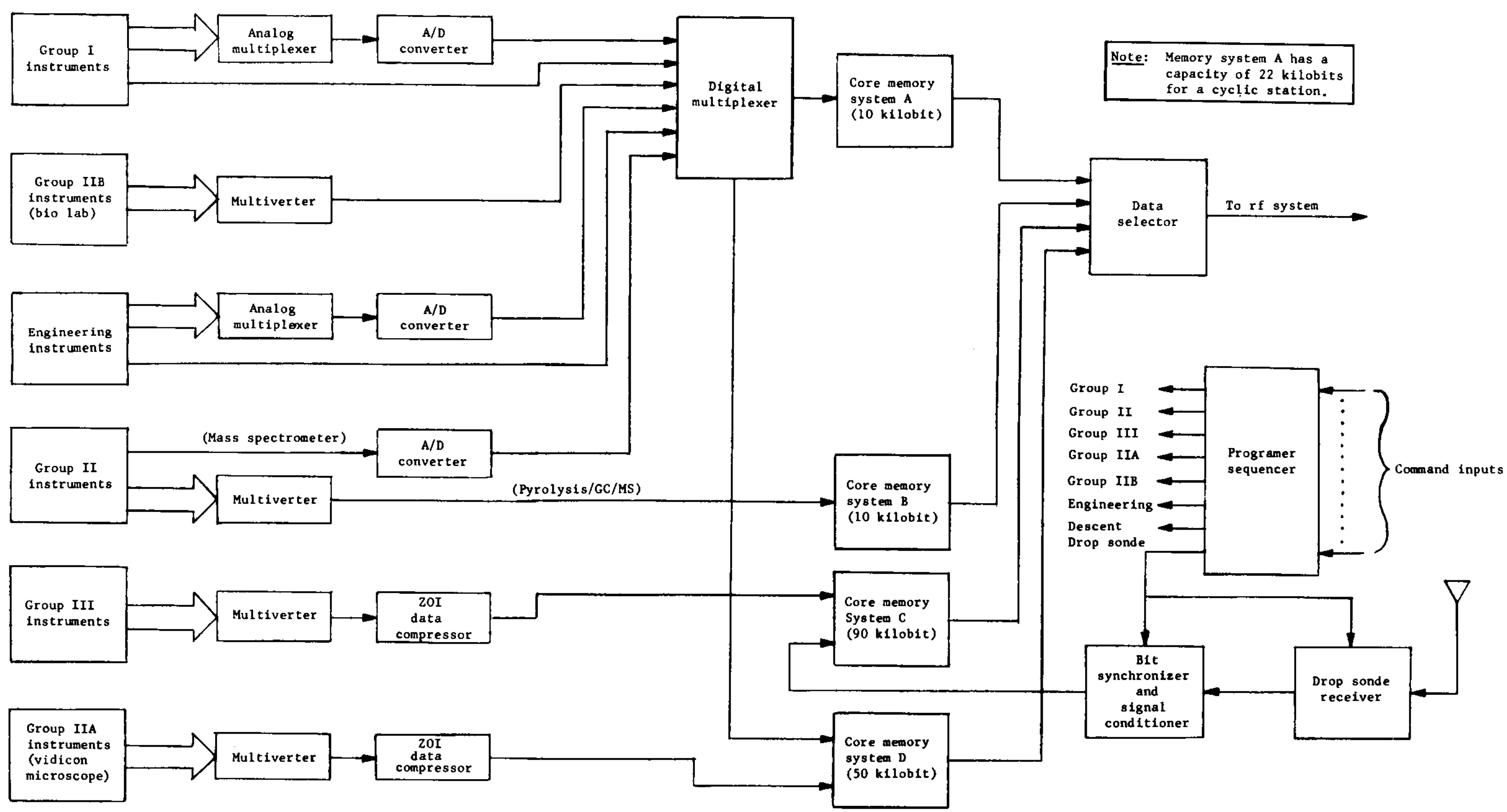


Figure 17. - Data Management Block Diagram, 2000-lb Station

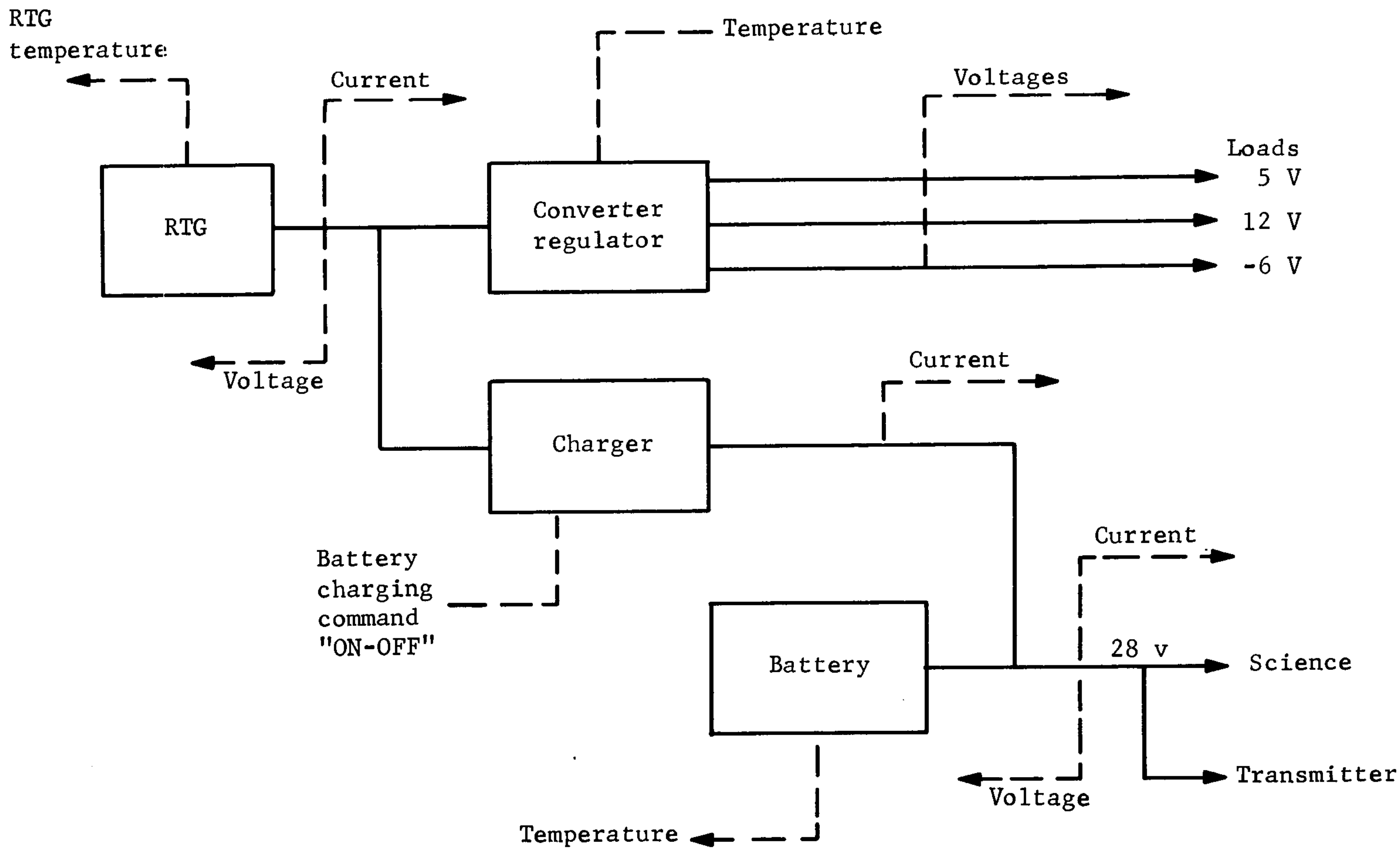
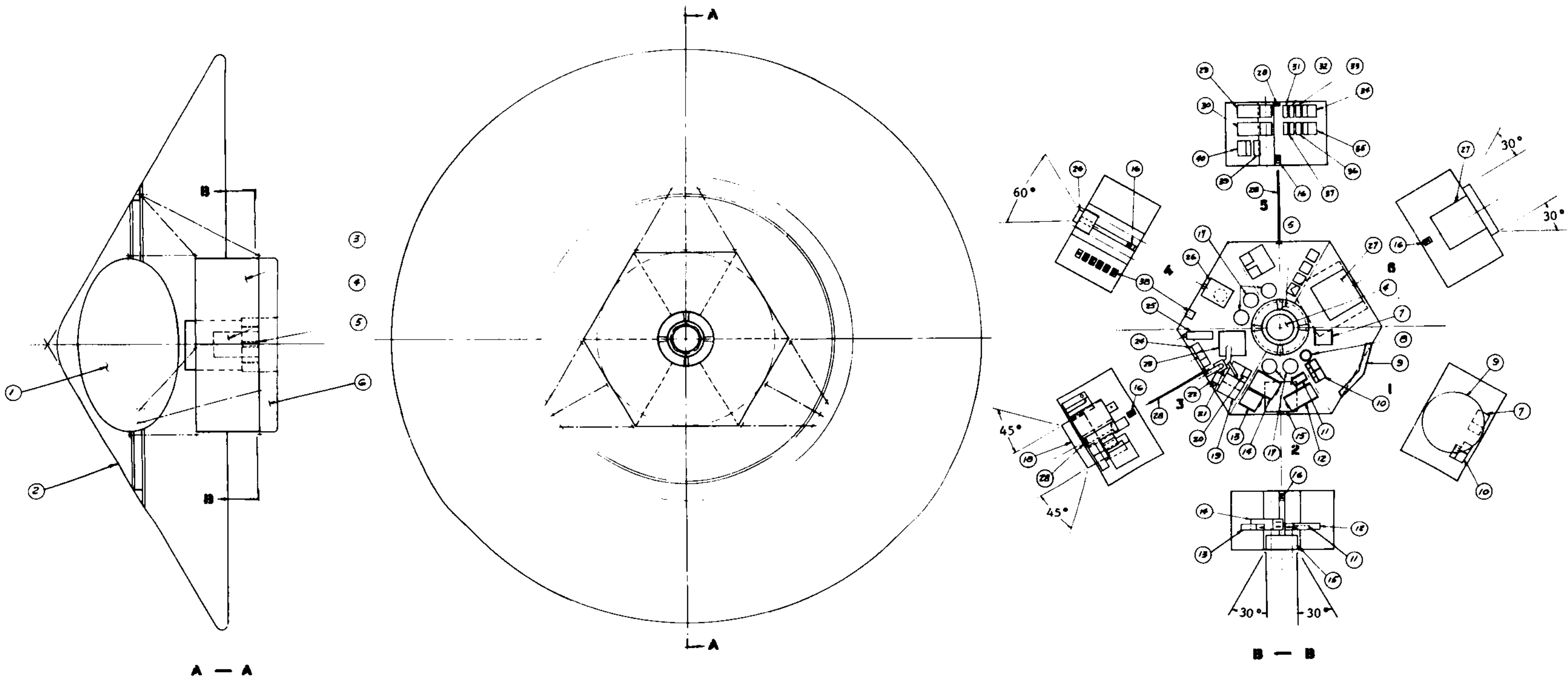


Figure 18. - Power System Block Diagram



Legend:

1. Inflation tank
2. Voyager Mars aeroshell (19-ft diam)
3. Gondola
4. Stowed parachute
5. Phased array antenna
6. Stowed balloon
7. Battery
8. Balloon inflation hose
9. RTG power supply
10. Junction box, switches, and relays
11. Diplexer
12. Transmitter
13. Command receiver
14. Command decoder
15. Radar altimeter
16. Pressure sensor (total 10 req)
17. Drop sonde tubes (total 5 req)
18. Drop sonde antenna
19. Gas chromatograph
20. Vidicon microscope
21. Dust-sampler (for vidicon microscope)
22. Sampler (atmosphere and clouds)
23. Micro-biology laboratory)
24. Mass spectrometer
25. Acoustic densitometer
26. IR scanner/spectrometer
27. Microwave spectrometer/scanner
28. Temperature sensors-boom mounted (2 req)
29. Group III/DS memory
30. Group IIA memory
31. Data package 1
32. Data package 2
33. Data package 3
34. Data selector
35. Programer/sequencer
36. Group I memory
37. Group II memory
38. Aerosol detectors
39. Drop sonde receiver
40. Drop sonde bit synchronizer and signal conditioner

Figure 19. - 2000-1b Buoyant Venus Station

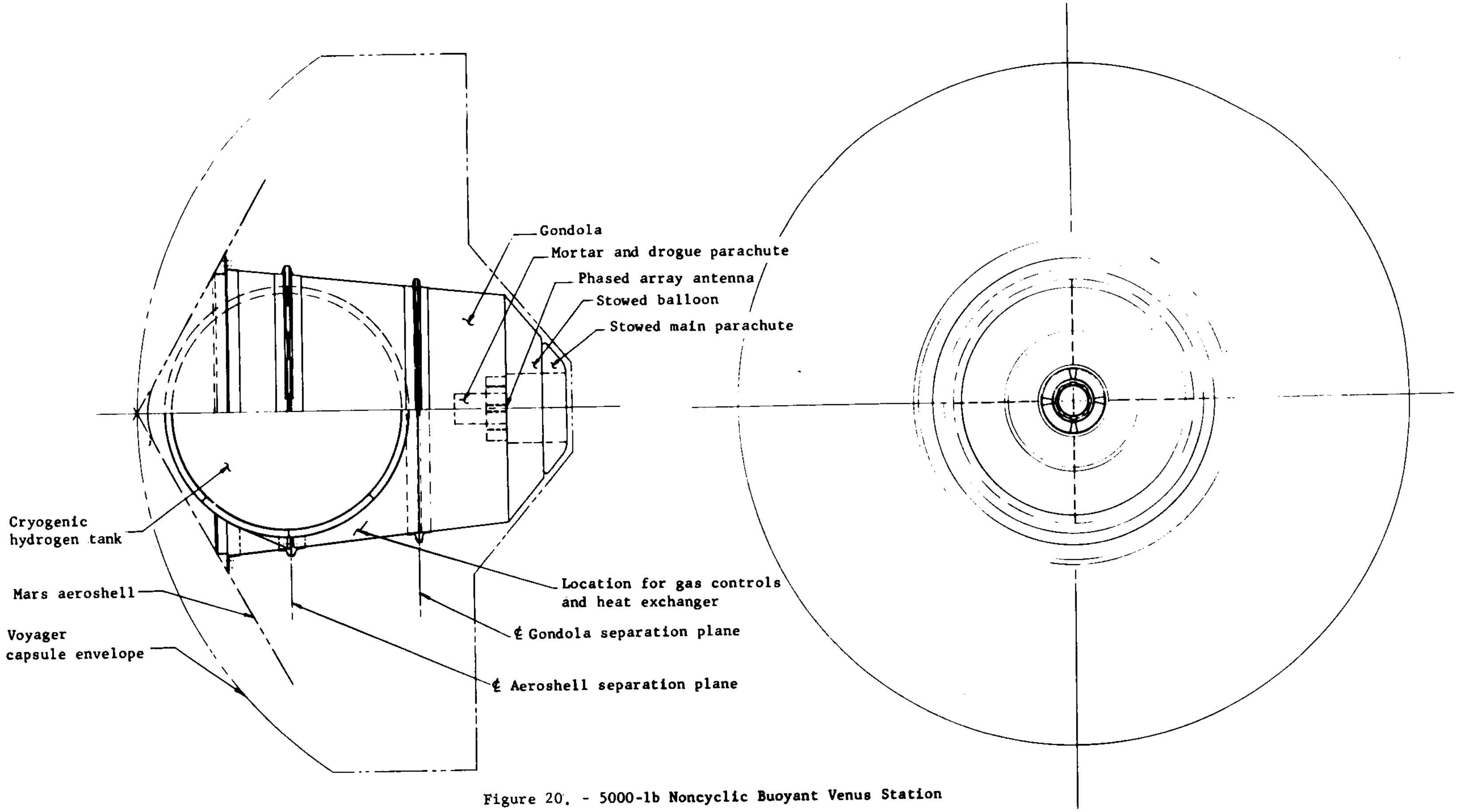


Figure 20. - 5000-lb Noncyclic Buoyant Venus Station

NASA CR-66404
National Aeronautics and Space Administration.
FINAL REPORT, BUOYANT VENUS STATION FEASIBILITY STUDY, VOL I - SUMMARY AND PROBLEM IDENTIFICATION. J. F. Baxter. July 1967.
48 pp.

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