N75 20375

PIONEER VENUS PROBE DESIGN

L. J. Nolte
HUGHES AIRCRAFT COMPANY

Strictly speaking, I don't belong here because I am going to talk about a set of probes designed to explore an inner rather than an outer planet, and designed to survive to 100 bars rather than 10 bars. Nevertheless, they represent a detailed look at what it takes to fly the complement of instruments that we have been talking about here today, and they will probably be the first such set that flys. We thought you might be interested in hearing where Pioneer-Venus stands at the moment.

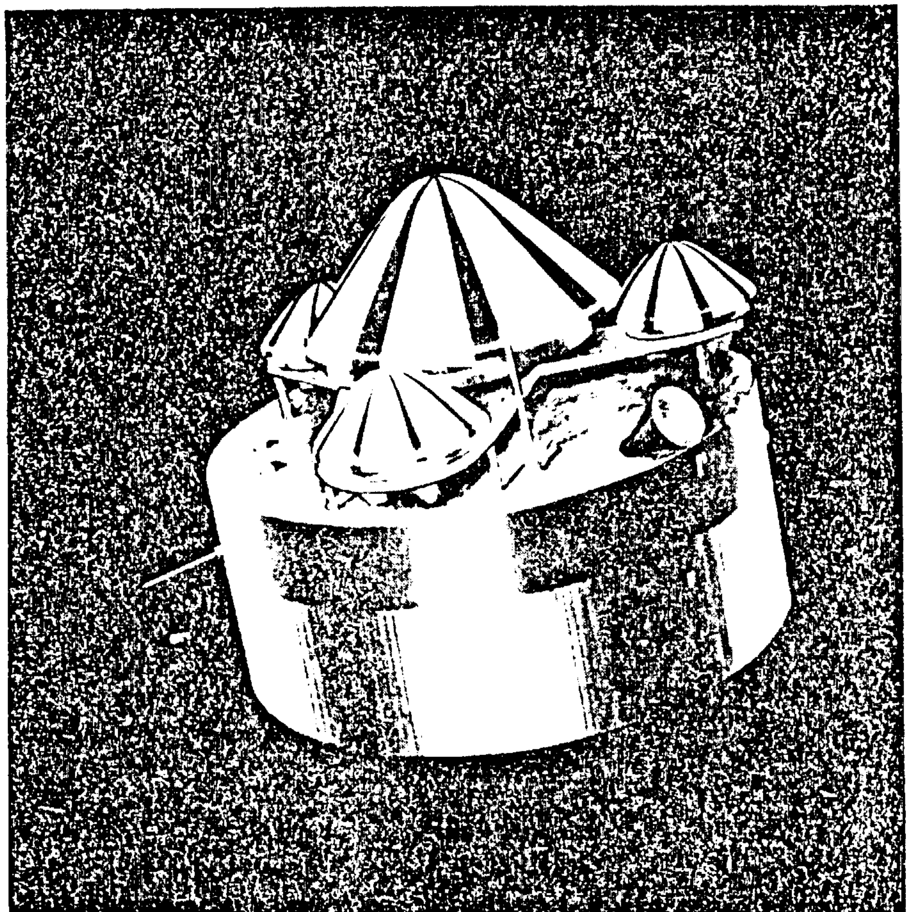
Before starting, I would like to note that all the view graphs in this presentation are marked with the Hughes logo. This is somewhat misleading because the probes in this mission are really a joint venture between Hughes and the General Electric Company; Dave Stephenson, the General Electric Program Manager, is with us today.

Figure 4-19 shows the probes, one large and three small, mounted on a bus that transports them from here to Venus. The whole system, as you can see, weighs 1760 pounds, of which a little over 600 pounds is invested in the large probe and about 160 pounds in each of the three small probes. The heart of the problem is going to be the integration of 33 separate instruments into those packages. This may be one of the highest number densities of instruments that has ever been flown. The large probe will carry 77 pounds of instruments, 12 in number. This includes the basic payload that was described this morning, the optional payload, plus a wind-drift radar and a spin-scan photometer. Each of the small probes contain pressure and temperature sensors, an accelerometer, a nephelometer, and a net flux radiometer.

Figure 4-20 addresses the question of where we are going. Simply stated, the basic requirements in probe targeting are

PIONEER VENUS MULTIPROBE SPACECRAFT

HUGHES
HUGHES AIRCRAFT COMPANY



46072-13

- **SIZE**

WIDTH :	8 FT , 4 IN.
HEIGHT :	11 FT

- **WEIGHT**

PROBE BUS :	677 LB
LARGE PROBE :	605 LB
SMALL PROBES :	160 LB EACH
TOTAL :	1760 LB

- **POWER :** 225 W
- **DATA :** 11 TO 2816 BPS
- **SCIENTIFIC PAYLOAD**

PROBE BUS :	40 LB, 6 INSTRUMENTS
LARGE PROBE :	77 LB, 12 INSTRUMENTS
SMALL PROBE :	5 LB, 5 INSTRUMENTS
TOTAL :	132 LB, 33 INSTRUMENTS

FIGURE 4-19

LARGE & SMALL PROBE TARGETING

HUGHES
HUGHES AIRCRAFT COMPANY

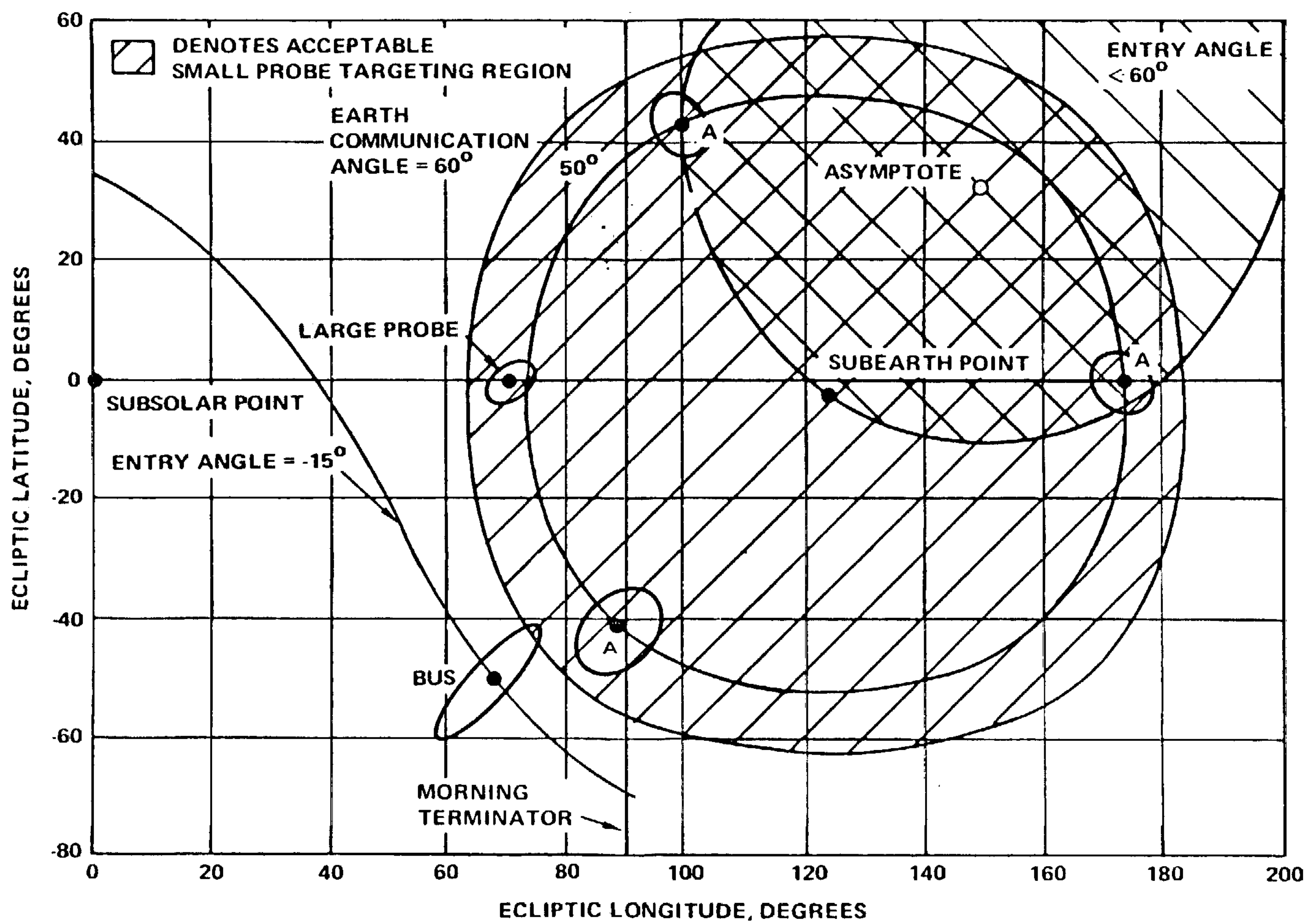


FIGURE 4-20

these: the large probe wants to look at the clouds; it wants to know what their composition and characteristics are. It wants to make a detailed analysis of the composition of the atmosphere all the way to the surface. It wants to look at the interaction of light and re-radiation at all altitudes. Consequently, it wants to be placed on the daylight side of the terminator, which in this plot is at 90 degrees longitude.

The small probes targeting requirements might be summarized by saying that they want to be as far apart as possible; that is, they want to be widely spread in longitude and in latitude. The objective is to construct a three-dimensional picture, instantaneous, if you will, of the large-scale motions of the atmosphere.

The other lines in this busy figure have to do with non-science constraints. For instance, the specified entry angle design limits of 15 degrees and 60 degrees (down from horizontal) are shown. The cross-hatched circle represents permissible communication angles, and angle between local vertical and the earth line, and we would rather not go below about 60 degrees. Thus, the permissible targeting area for the probes lies in this circle as vignetted by the 60-degree entry angle. (We have chosen to increase the design capability of the small probes so that they are capable of entering at 90 degrees entry angle, and the vignetting is not as severe as represented here.) A possible set of small probe impact locations is indicated by points "A" in the figure.

How do we get there? Figure 4-21 considers that problem. The large probe is carried in the middle of the spacecraft; it is held in place by three explosive bolts and is spring-separated. The three small probes are carried in circular clamp mechanisms, shown in their open position here, and they are targeted on the planet simply by aiming the bus at the center of the targeting area and releasing the latch mechanisms.

HUGHES

HUGHES AIRCRAFT COMPANY

PROBE SEPARATION

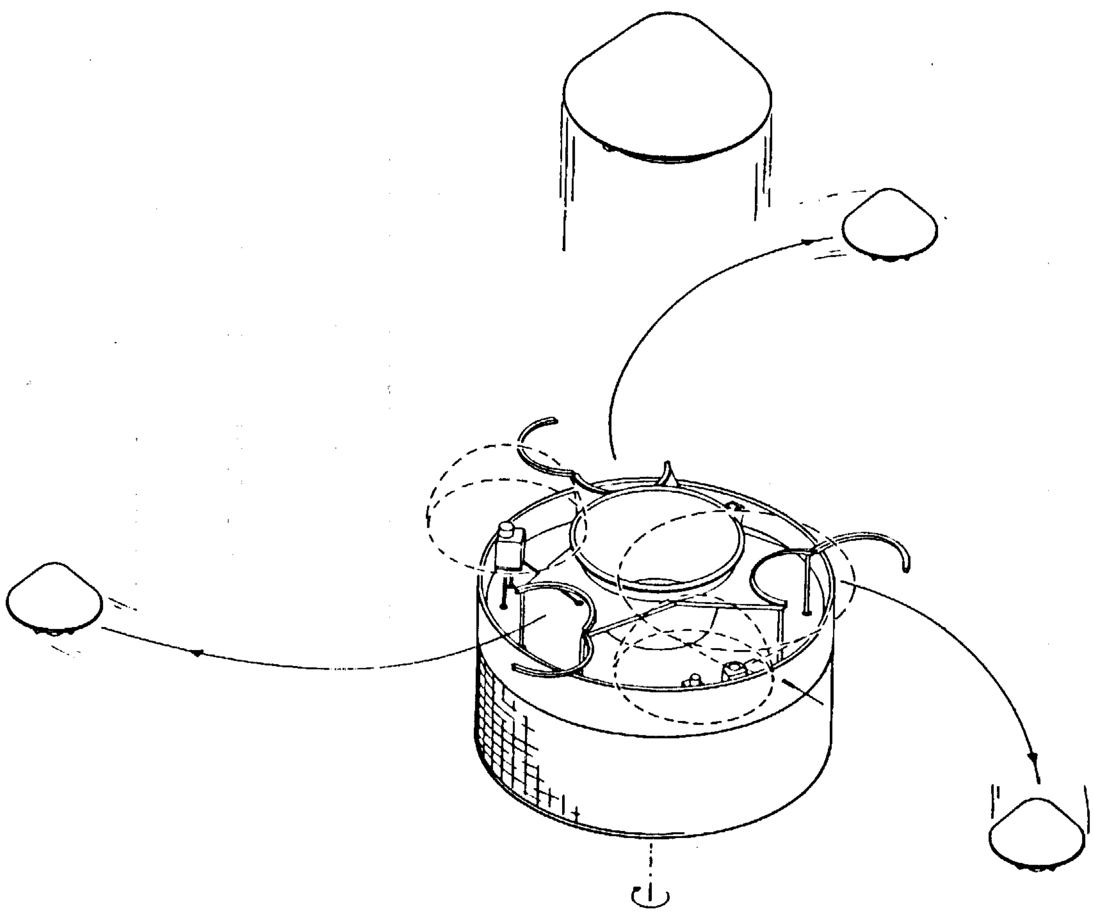


FIGURE 4-21

36254 2

The sequence is illustrated in Figure 4-22. About 24 days before encounter, the bus is oriented so that the large probe will enter at zero angle of attack and the large probe is released. About one day later, the bus is retargeted for the small probes, and three days after that it is spun up to about 40 RPM (it had been spinning at 15 RPM in the interplanetary cruise period). About 20 days away from the planet the latches shown in the previous figure are released and the small probes move laterally away from the bus. Two days later, the bus, which is actually a fifth probe, is retargeted so that it will impact the atmosphere at a shallow entry angle, allowing it to explore the upper reaches of the atmosphere before burnup.

Figure 4-23 shows the sequence of events as the large probe descends through the atmosphere. The entry configuration appears in detail 1. At about 68 and 1/2 kilometers above the surface of the planet, the mortar which deploys the pilot chute is fired. The pilot chute removes a cover from the back side of the entry vehicle which, in turn, pulls the main parachute out of its housing. The pilot and main parachutes are both fairly conventional designs: conical ribbon, disc-gap-band configurations, respectively.

The main parachute is attached to a pressure vessel carried inside the entry vehicle. Once it is stabilized, the restraining bolts that tie the pressure vessel to the aeroshell are fired and the aeroshell is jettisoned.

The system configuration remains as shown in detail 5 from 67 kilometers down through most of the clouds to about 44 kilometers above the surface. Here the main parachute is jettisoned and the system falls to the surface in the configuration of detail 7.

Figure 4-24 is a graphical presentation of the large probe descent sequence. The descent requires an hour from the point of initial chute deployment to the surface of the planet, 25 percent of which is spent in the last ten kilometers. The altitude

MULTIPROBE MISSION RELEASE AND ENTRY

HUGHES
HUGHES AIRCRAFT COMPANY

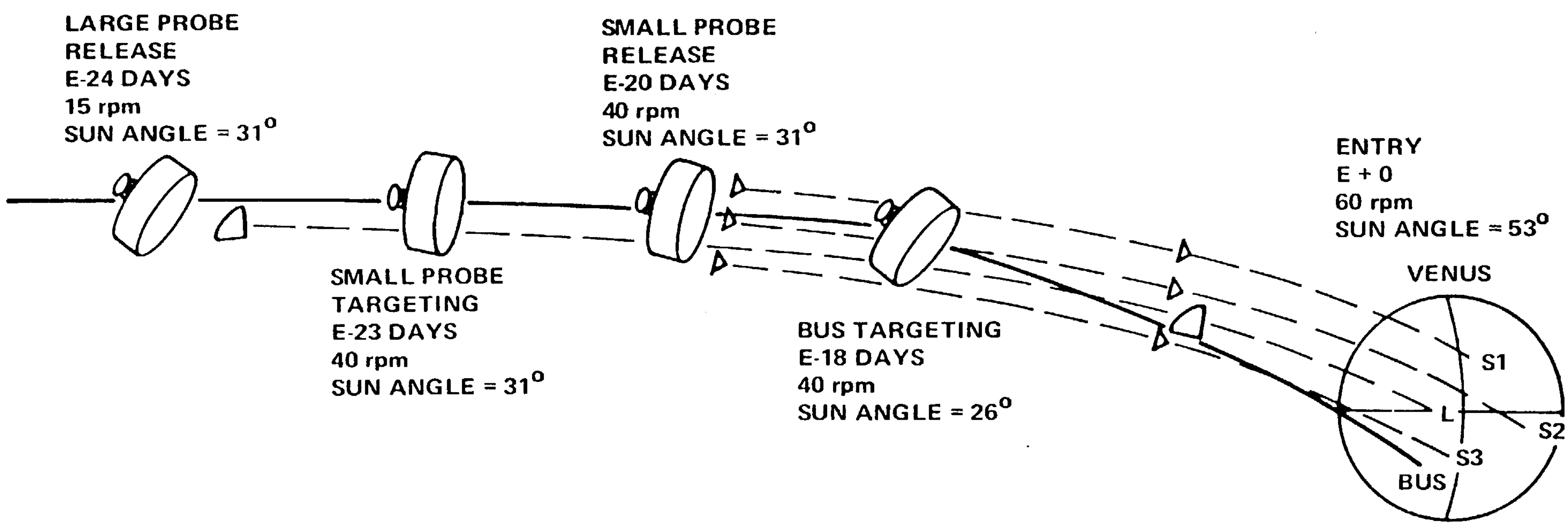


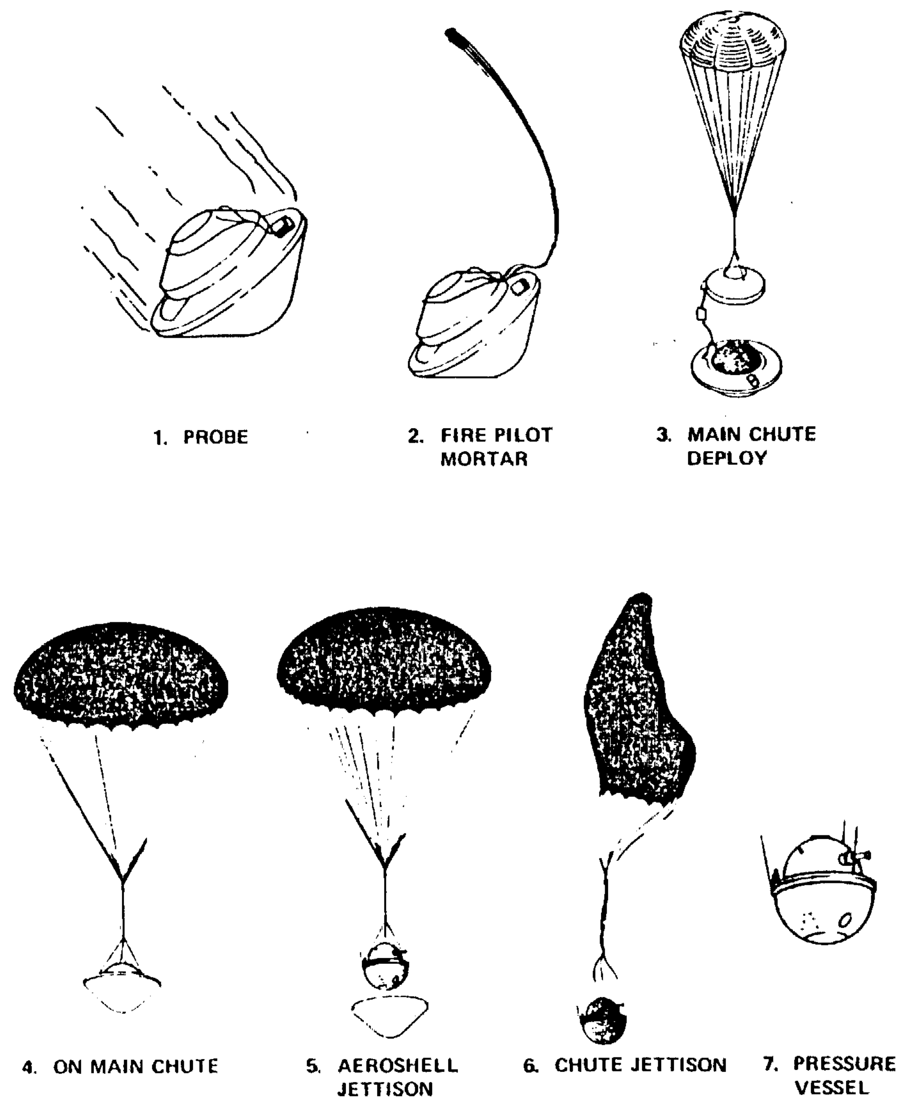
FIGURE 4-22

30243 710111

HUGHES

HUGHES AIRCRAFT COMPANY

PARACHUTE DEPLOYMENT SEQUENCE- LARGE PROBE



36254-1

FIGURE 4-23

NOMINAL LARGE PROBE DESCENT PROFILE

HUGHES
HUGHES AIRCRAFT COMPANY

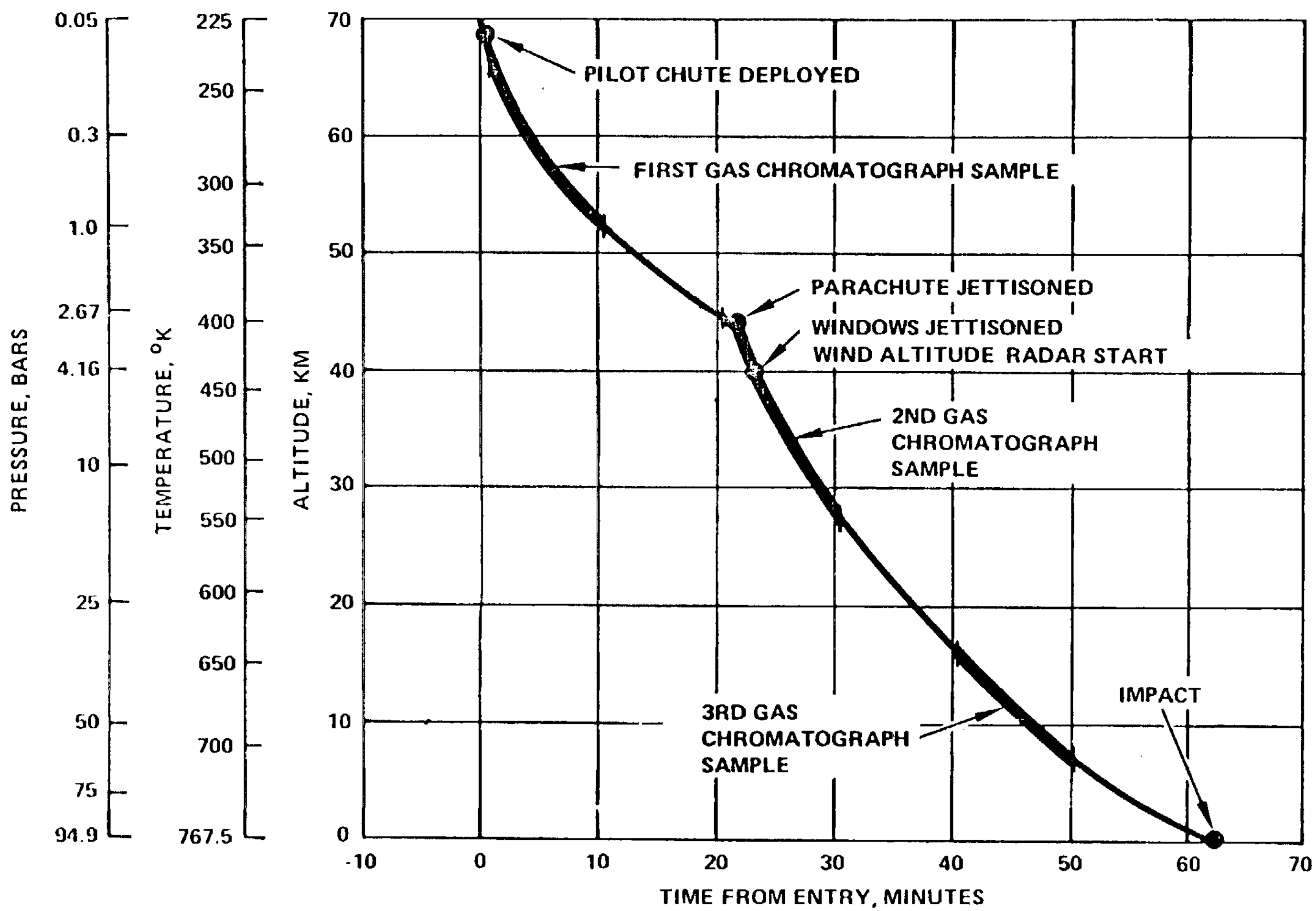


FIGURE 4-24

at which the parachute is jettisoned is a result of a complex trade involving just about every housekeeping subsystem in the probe: data, communications, power, and thermal. It provides the minimum weight mechanization which satisfies the instrument data rate requirements.

Figure 4-25 illustrates similar trajectories for the small probes. Time is taken relative to large probe entry, so that the figure may be compared with the preceding one. The variation in time at which the small probes pass through any given altitude is seen to be of the order of ten minutes. Note that data rate is changed from 64 to 16 bps at 30 KM altitude. This is consistent with instrument requirements because of the large percentage of time spent at the lower altitudes. This could not be done on the large probe because of the staging at 44 KM.

Figure 4-26 begins to show the hardware involved. It is a blowup of a large probe, which comprises a 57-inch diameter, 45-degree half-angle conical entry vehicle and a spherical pressure vessel. The aeroshell is an aluminum monocoque structure protected by a carbon phenolic heat shield. Carbon phenolic was chosen because it is the best characterized material which gives the minimum amount of uncertainty in final shape and base area. The aeroshell, heat shield, aft cover and the parachutes will be built by General Electric Company.

The pressure vessel contains all of the scientific instruments and it is shown exploded in Figure 4-27.

The pressure vessel mounts all of the instruments and housekeeping equipment on two heatsink shelves, of which only the top one is visible. They are mounted together and supported from the spherical pressure shell on a flange located just below the lower shelf. Both are thermally isolated from the pressure shell.

The shell itself is steel, and 28.8 inches in diameter. It is exposed to the atmosphere and consequently is always nearly

NOMINAL SMALL PROBE DESCENT PROFILE

HUGHES
HUGHES AIRCRAFT COMPANY

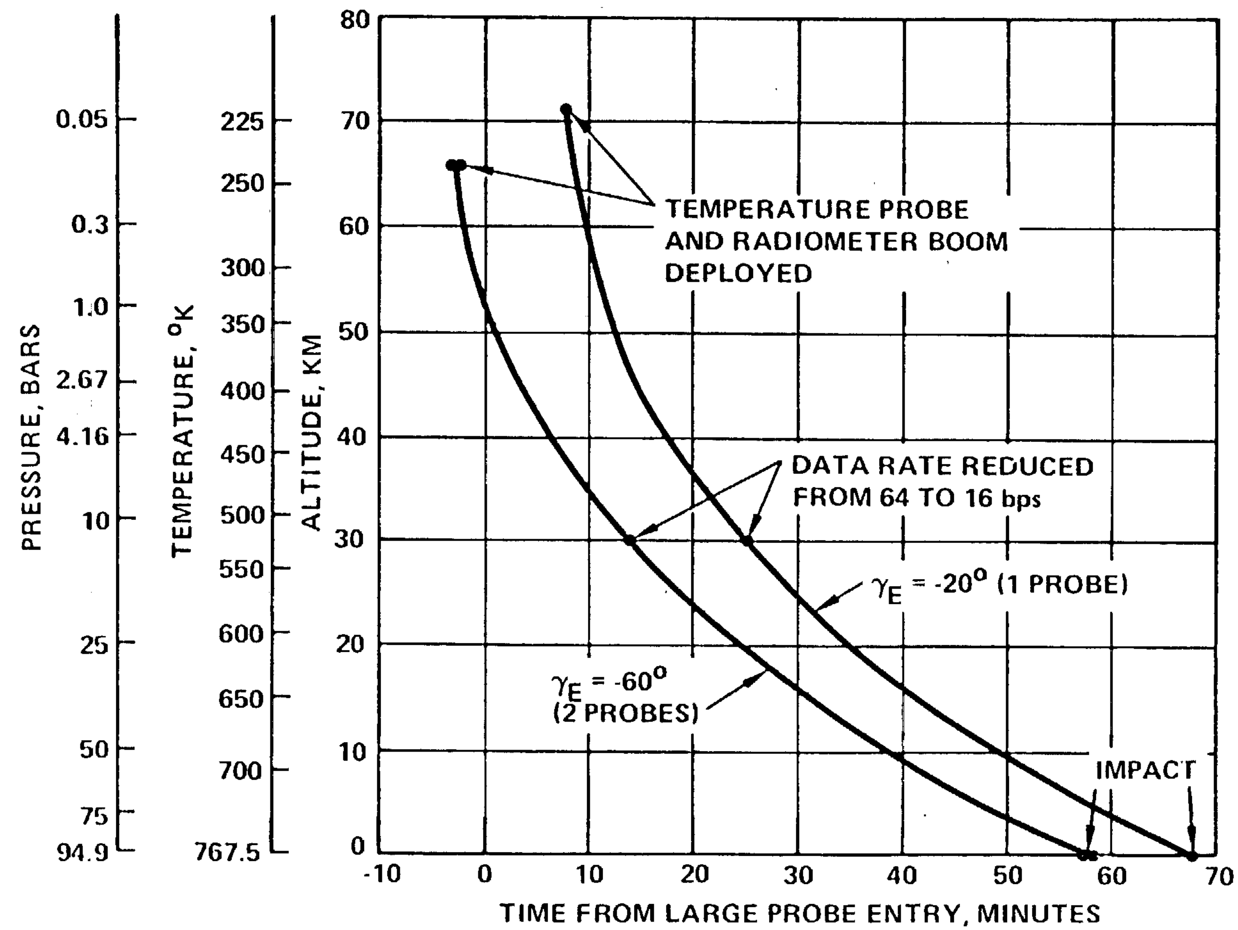
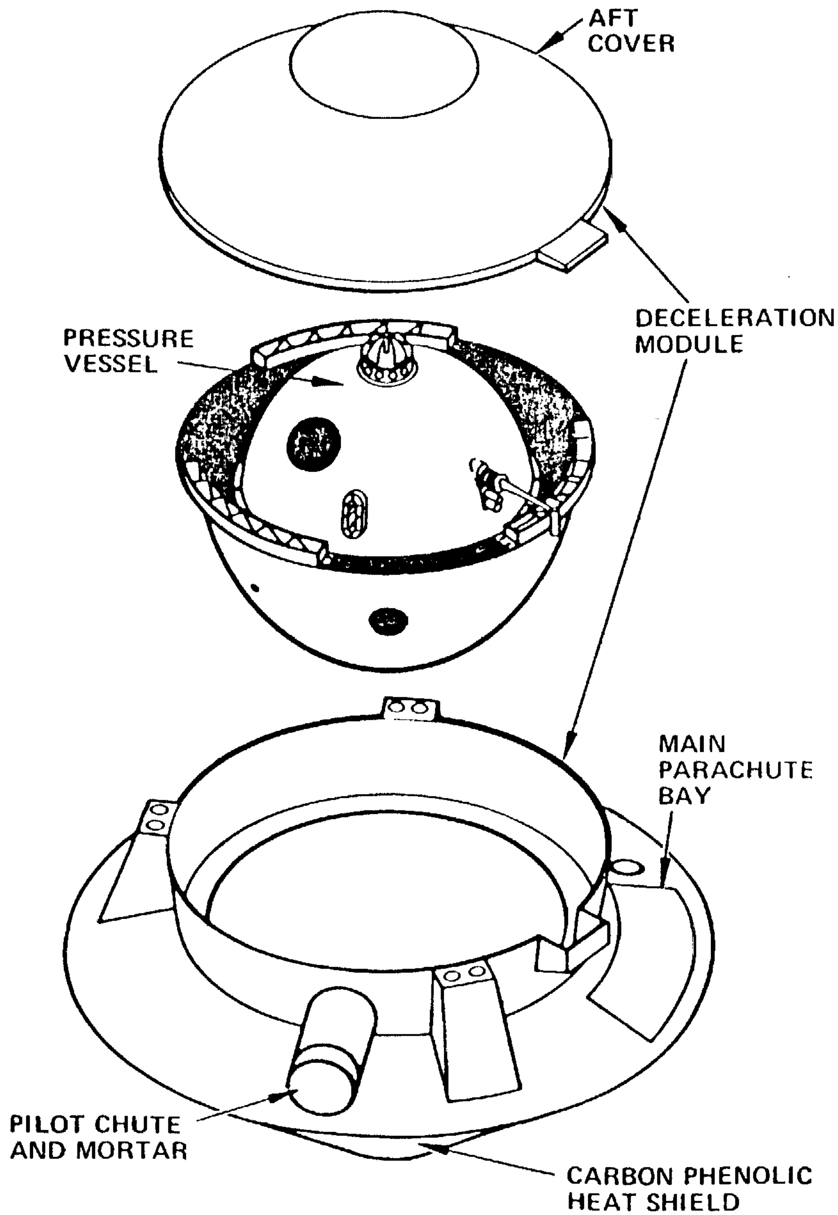


FIGURE 4-25



HUGHES

HUGHES AIRCRAFT COMPANY

LARGE PROBE EXPLODED VIEW

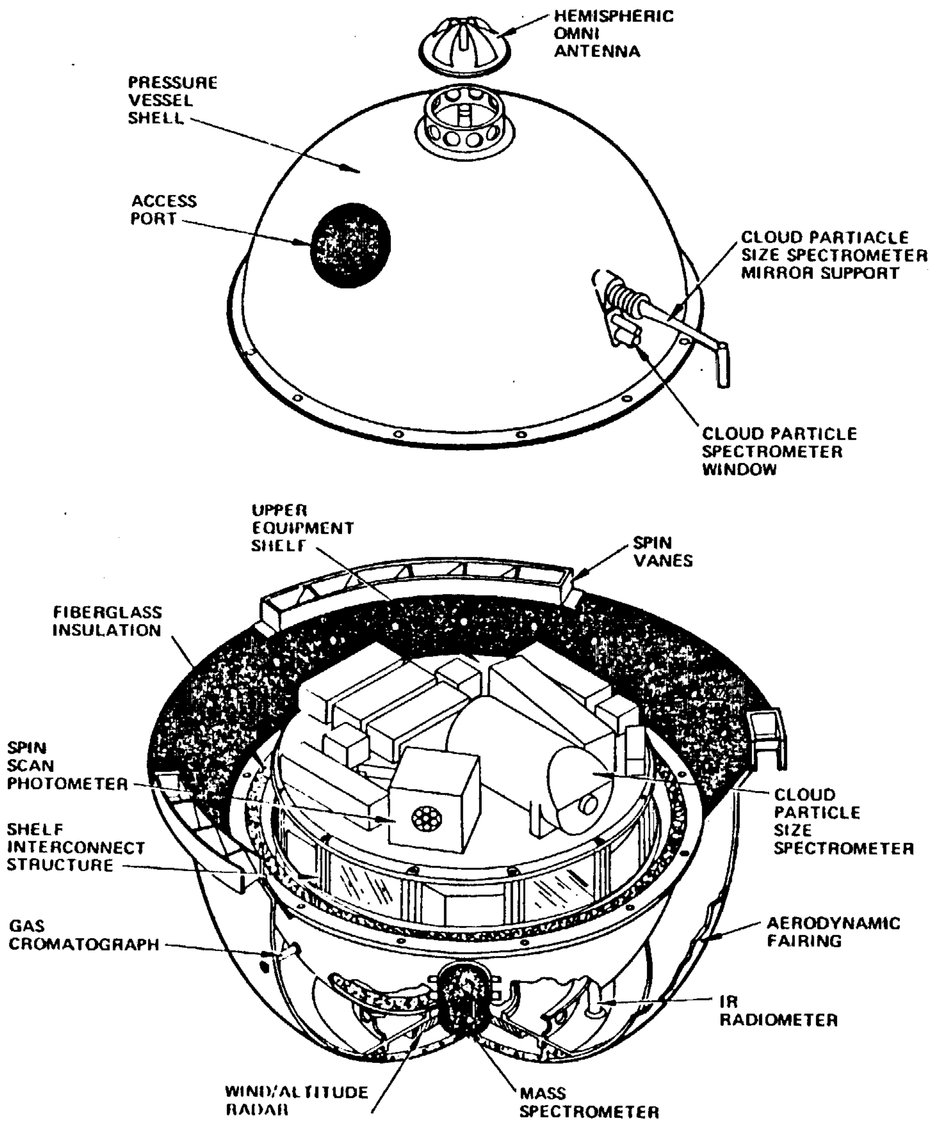
36254 G

FIGURE 4-26

HUGHES

HUGHES AIRCRAFT COMPANY

PRESSURE VESSEL EXPLODED VIEW



36254 5

FIGURE 4-27

ORIGINAL PAGE IS OF POOR QUALITY

at atmospheric temperature. The equipment is protected by a fiberglass insulation system. One of the objectives of the Pioneer Venus Program is that cost be minimized, and this is one way in which the low-cost philosophy has entered into the design. This is, in our opinion, a more inexpensive way to handle the problem of thermal control than with an external insulation system because it minimizes developmental and system test complexities.

Around the outside of the probe is an aerodynamic fairing. The aerodynamic fairing was necessitated by parts of instruments that must be mounted externally, notably a wind/altitude radar which has a large planar array antenna which wants to be at the stagnation point. For reasons of aerodynamic stability, the antenna is covered by the fairing which contains a radome at its forward end.

Stabilization is further enhanced by separating the flow with a ring just aft of the pressure vessel equator. The ring contains slots in it and the slots contain fins to rotate the probe as it descends.

Figure 4-28 is somewhat redundant with the previous one, but was included because it shows an exploded view of a small probe. The small probe is 28 inches in base diameter and has exactly the same forbody configuration and heat shield as the large probe. The structural and thermal design and materials of the pressure vessel are identical with those of the large probe, and indeed the principal difference between the two is that the small probe aeroshell is retained to the surface.

Figure 4-29 (2 pages), summarizes details of probe subsystems. Note that high degree of commonality between the two vehicles, a feature of the low-cost design approach.

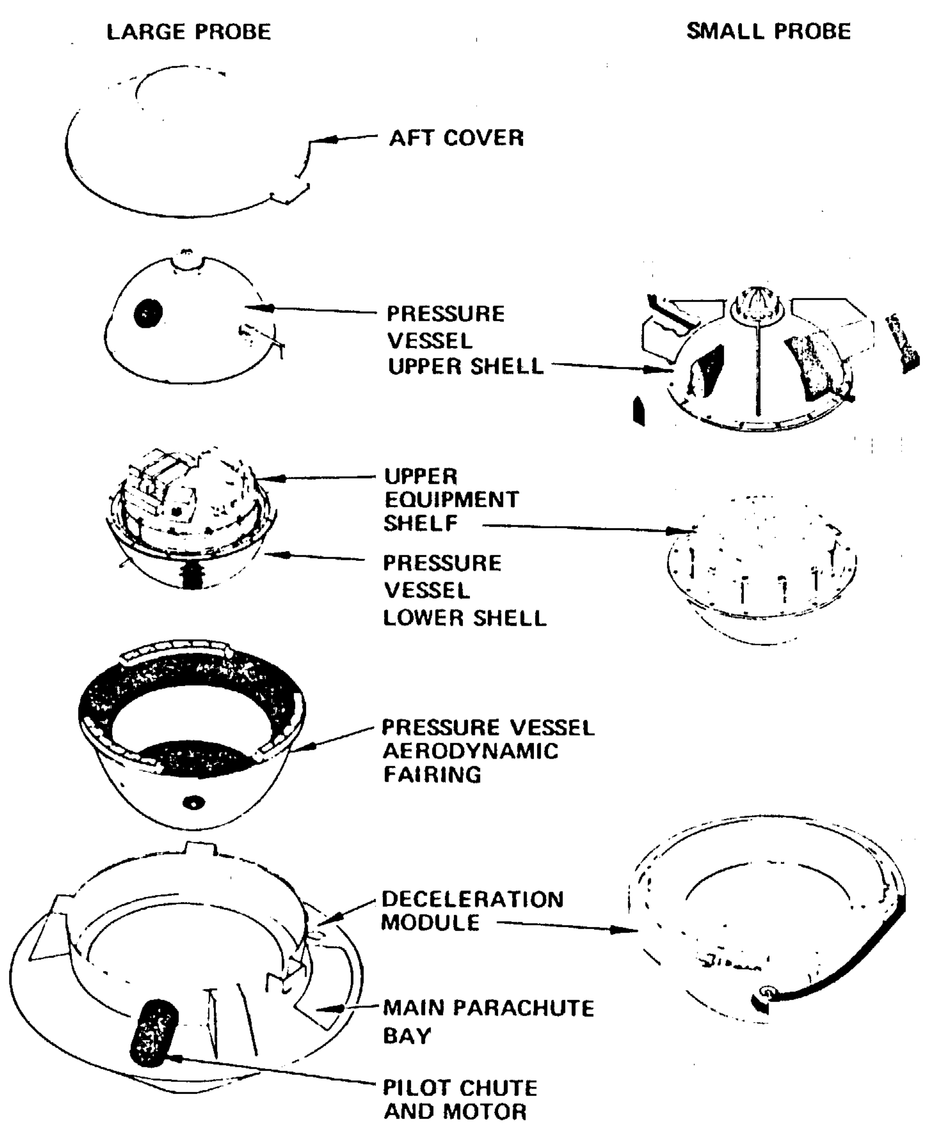


FIGURE 4-28

HUGHES

HUGHES AIRCRAFT COMPANY

EXPLODED VIEWS OF LARGE & SMALL PROBES

NOT TO SCALE – LARGE PROBE ACTUALLY TWICE SIZE OF SMALL PROBE

36254-4

ORIGINAL PAGE IS OF POOR QUALITY

PROBE CHARACTERISTICS AND PERFORMANCE SUMMARY

HUGHES
HUGHES AIRCRAFT COMPANY

SUBSYSTEM	LARGE PROBE	SMALL PROBE
GENERAL	OVERALL HEIGHT: 37.9 IN. DIAMETER: 57 IN. TOTAL WEIGHT: 605.4 LB PRESSURE VESSEL WEIGHT: 401.8 LB SCIENCE: 77.2 LB RELIABILITY: 0.9231	OVERALL HEIGHT: 22 IN. DIAMETER: 28 IN. TOTAL WEIGHT: 159.1 LB PRESSURE VESSEL WEIGHT: 91.5 LB SCIENCE: 5.3 LB RELIABILITY: 0.9438
DECELERATION MODEL	45^{o} BLUNT CONE AEROSHELL W/C_DA: 32.4 LB/FT^2 CARBON PHENOLIC HEAT SHIELD ALUMINUM MONOCOQUE SUB-STRUCTURE 15 FT DISK GAP BAND MAIN PARACHUTE 2.75 FT CONICAL RIBBON PILOT CHUTE	45^{o} BLUNT CONE AEROSHELL W/C_DA: 34.4 LB/FT^2 CARBON PHENOLIC HEAT SHIELD STAINLESS STEEL SUBSTRUCTURE
PRESSURE VESSEL	INSIDE DIAMETER: 28.8 IN. MARAGING STEEL SPHERE PRESSURE VESSEL STABILIZATION-PERFORATED RING WITH SPIN VANES INTERNAL FIBERGLASS INSULATION	INSIDE DIAMETER: 17 IN. MARAGING STEEL SPHERE INTERNAL FIBERGLASS INSULATION

46271-1

FIGURE 4-29

PROBE CHARACTERISTICS AND PERFORMANCE SUMMARY (CONT)

HUGHES
HUGHES AIRCRAFT COMPANY

SUBSYSTEM	LARGE PROBE	SMALL PROBE
RADIO	2295 MHz TRANSMIT 40 W RF POWER TWO-WAY DOPPLER TRACKING	2295 MHz TRANSMIT 10 W RF POWER ONE-WAY DOPPLER TRACKING
ANTENNA	0 DBI HEMISPHERICAL OMNI 180° BEAMWIDTH	→ →
DATA HANDLING	CONVOLUTIONAL ENCODING 256 BPS DATA RATE PCM/PSK/PM MODULATION 2048 BIT SEMICONDUCTOR MEMORY FOUR DATA FORMATS	→ 64/16 BPS DATA RATES → → →
COMMAND	64 COMMANDS FROM PROBE BUS NO GROUND COMMANDS AFTER SEPARATION COMMAND EXECUTIONS: SEQUENCER: 128 MASS SPECTROMETER: 16 22 SEC/24 DAYS CLOCK ACCURACY	22 COMMANDS FROM PROBE BUS → → → →
POWER	26.5 ± 1 VDC BUS 605 W-HR AG-ZN BATTERY 307 W PEAK POWER	→ 176 W-HR AG-ZN BATTERY 66 W PEAK POWER

46271-2

FIGURE 4-29 (Cont'd)

Figure 4-30 attempts to rebridge the gap between the Pioneer Venus probes and the outer planet probes. The latter have been for the most part conceptually designed to survive to the order of 10 bars pressure. We thought that it might be interesting to work our problem backwards, if you will, to see what it costs (in weight) to survive to the surface of the planet, i.e., to about 100 bars, rather than to 10 or 20 bars pressure. This figure illustrates the results for a small probe. It indicates a weight increase of the order 25 pounds to survive to the surface compared to the weight if the probes were designed for, say, ten or twenty bars. This is about 5 times the weight of the instrument payload. Another way of interpreting the figure is to note that there is essentially no pressure-induced weight penalty for survival to 10 bars.

I would like to make one final point. Although I didn't stress the low cost aspects of the Pioneer Venus Program, they are extremely important for program survival. If the outer planet missions are going to be low-cost missions, or moderate cost missions, and the indications would be that they have to be, then this concept must be factored into your planning now. It is not too early.

MR. CANNING: Any questions?

MR. HERMAN: You are treating the bus as a Kamakazi vehicle. How long do you expect it to survive?

MR. NOLTE: Thatis a good question. It may survive to the order of 120 kilometers.

MR. HERMAN: It is certainly not aerodynamically designed.

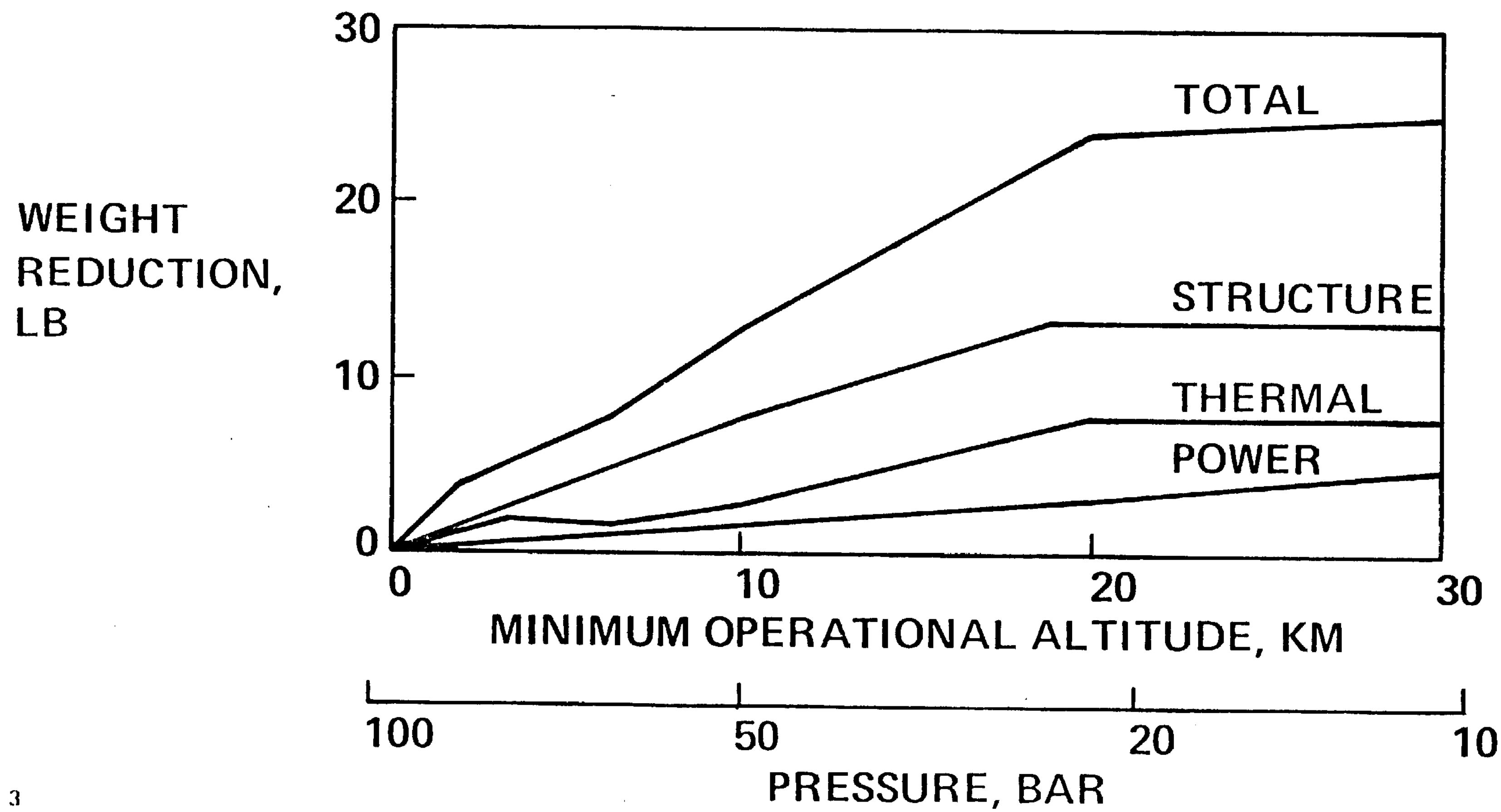
MR. NOLTE: No, it is not aerodynamically designed.

UNIDENTIFIED SPEAKER: I think the time involved is of the order of ten or twelve minutes.

MR. CANNING: I think we will count ourselves very lucky if we get data below about 135 kilometers that is not dirtied up with ablation products from the thermal control system or blackout.

WEIGHT REDUCTION FOR LIMITED OPERATIONAL ALTITUDE -SMALL PROBE

HUGHES
HUGHES AIRCRAFT COMPANY



46271 3

FIGURE 4-30

(INAUDIBLE QUESTION)

MR. NOLTE: The question is how sulphuric acid-proof is the parachute. That really depends on the abundance of the acid. Although the parachute is not acid-proof, the sulphuric acid content of Venus atmosphere is probably less than that of Earth in some locales. This is a design problem which is shared by every exposed component.

UNIDENTIFIED SPEAKER: Are any of the probes sterilized?

MR. NOLTE: None of them are sterilized.

MR. SEIFF: Is it atmospheric attenuation that forces the communication bit rate down from 64 to 16?

MR. NOLTE: Yes

MR. SEIFF: Is it pure absorption of what?

MR. NOLTE: Yes, it is absorption.

MR. CANNING: Sixteen bits per second is also adequate.

MR. NOLTE: Adequate in terms of bits of data per kilometer because you are going so slow, obviously.

MR. SEIFF: You can live with it?

MR. NOLTE: Yes.

MR. CANNING: I would now like to introduce Mr. Kane Casani; Mr. Casani will speak on the subject of "Probe Interface Design Considerations." Mr. Casani is the Section Manager of the Spacecraft System Design and Integration Section of the Jet Propulsion Laboratory. He has participated in the design of many of the Mariner Spacecraft and over the past ten years has been actively involved in every capsule or probe design activity conducted at the Jet Propulsion Laboratory.