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ANOMALOUS BEHAVIOR OF THE PIONEER VENUS ENTRY PROBES DURING LOWER DESCENT

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SUMMARY

Four Pioneer Venus Probe spacecraft entered the Venusian atmosphere on December 9, 1978, and descended to the surface while making in situ measurements of chemical composition, structure, and radiative balance. In the lower Venusian atmosphere, a number of anomalous events were noted in some of the scientific instruments and Probe engineering data. Many of these anomalies occurred on each of the Probes at approximately the same altitude.

The anomalies are thought to be the result of some unexpected electrical interaction between the Probes and the Venusian atmosphere. This conclusion is based on analysis and testing of similar Probe hardware on the ground. However, the possibility that some anomalies were a result of latent design or manufacturing flaws cannot be ruled out.

INTRODUCTION

Four Pioneer Venus Probe spacecraft entered the Venusian atmosphere on December 9, 1978, and descended to the surface while making in situ measurements of chemical composition, structure, and radiative balance. In the lower Venusian atmosphere, a number of anomalous events were noted in some of the scientific instruments and Probe engineering data. Many of these anomalies occurred on each of the Probes at approximately the same altitude.

The first indication of anomalous behavior came when the Atmosphere Structure Experiment (LAS/SAS) temperature sensors on each of the four Probes suddenly failed at approximately 640 K, which corresponds to an altitude of about 12.5 km (ref. 1). It was then observed that the Net Flux Radiometer's (SNFR) external sensors on the North, Day, and Night Probes suddenly failed at about the same altitude (ref. 2). A close examination of the data received from the other scientific instruments and Probe housekeeping measurements uncovered additional anomalies that occurred prior to, during, and following the aforementioned sensor failures.

ANOMALIES

The following anomalies were common to the North, Day, and Night Probes. There was an apparent failure of the SNFR fluxplate and SAS temperature sensors. There were also abrupt changes and spikes in the SAS pressure and sensor data and in the SNFR maximum and minimum flux data. The SAS and SNFR boom deployment status changed from deployed to stowed. Other anomalies included erratic data from the two thermocouples embedded in the heat shield (at the stagnation point and frustum) and from the thermistor measuring the junction temperature of the heat-shield thermocouples. Finally, there were slight variations in the power bus current and voltage levels and slight offsets or jumps in the values for Probe internal pressure and forward and aft shelf temperatures.

On the Sounder Probe, the following events were observed. There was an apparent failure of the Atmosphere Structure (LAS) temperature sensors along with abrupt changes and spikes in the LAS pressure sensor data. Abrupt changes occurred in the Cloud Particle Size Spectrometer (LCPS) laser alignment monitor as well, and the LCPS return laser beam intensity decreased. On the other hand, there was a steady increase in the Infrared Radiometer (LIR) flux readings and the LIR flux data were "Noisy." Other events include spikes in the Mass Spectrometer (LNMS) analyzer ion pump current monitor and in the receiver automatic gain control (AGC); an abrupt decrease in the power bus current; and jumps in the receiver (transponder) static phase error. Finally, values appeared for the heat-shield thermocouple measurements whose leads were severed when the heat shield was separated from the pressure vessel.

DISCUSSION

It is important to note that on each Probe several seemingly unrelated events occurred simultaneously. For example, on the North, Day, and Night Probes, the apparent failures of the SAS and SNFR temperature sensors occurred within a few minutes of each other. The failed sensors were each different, the SAS being a platinum resistance device and the SNFR being a thermistor. The electronics for these sensors were electrically isolated from each other; however, they both were mounted on booms that extended from opposite sides of the Probe. On the Sounder Probe, jumps occurred in the LAS pressure data when the heat-shield thermocouple values changed or when the LNMS analyzer ion pump indicated current spikes, yet the LAS sensor, heat-shield thermocouple, and the LNMS electronics were electrically isolated from each other. During this time the thermocouple electronics were attached to two severed (nonconnected) former thermocouple leads.

It was first suspected that the SAS and SNFR temperature sensor failures were the result of a partial or catastrophic failure of the external harness or pressure vessel feed-through connectors. Extensive analysis and environmental testing of the harness materials and connectors had been conducted during the Probe development and qualification test program. Additional tests were conducted after the flight to determine the combined effects of sulfuric acid, pressure, and temperature on these components. None of these revealed any material or design deficiencies.

A post-flight analysis was also conducted to reexamine the implications of an uncovered Probe/Bus Interface Disconnect (IFD) containing the power data and command lines between the Probe and the Bus spacecraft on each of the Probes and the potential effects of the cable-cutter severance of the Probe/heat-shield IFD harness carrying the power and signal lines between the heat shield and the pressure vessel on the Sounder Probe. This analysis considered the effects of shorts (caused by the presence of sulfuric acid or conductive debris) across the IFD socket contacts or the severed IFD harness wires. The analysis revealed that even if such shorts occurred, no damage or adverse performance would result. The possibility of electrical shorts or arcing across the pins of the pressure vessel feed-through connectors carrying the power and signal lines between the externally mounted sensors and window heaters and the inside of the Probe was also considered. Shorts and arcing could occur only if the feed-through and its mating external harness connector were not fully engaged, an unlikely situation to occur on all four Probes. The likelihood of conductive debris or sulfuric acid entering the gap between partially mated connectors is remote, because of their mechanical configuration. The low voltage on the pins (28 VDC maximum) and the high atmospheric pressure rule out the possibility of arcing. Thus, there is no possibility of a feed-through connector failure causing the observed events. However, there is evidence that several Probe failures did occur. The first was observed on the Sounder Probe shortly after the LAS temperature sensor failure, when the Probe bus current dropped 2.1 A (from 15.4 A). Simultaneously, the LIR flux data indicated a change. It was verified that the current drop exactly matched the current normally supplied to the LIR window heater. The construction of this heater is different from the other window heaters in that its outer sheath is made from tantalum (the others are Kovar). One suggested failure mechanism is that the tantalum reacted with the sulfuric acid and the atmospheric CO_2, creating holes in the outer sheath. These holes then permitted the insulation to become contaminated, thus forming conductive paths between the heating element and ground (sheath). This short caused the heater fuse to blow. The change in the LIR flux data was most likely a response to the rapid change in the diamond window temperature when the heater failed.

A second failure was noted on each of the small Probes when the SAS and SNFR sensor boom status changed from deployed to stowed at about the same time the SAS and SNFR temperature sensors failed. Unfortunately, this status was only sampled once every 512 sec. Thus, precise knowledge of when the status changed is impossible. Since it was mechanically impossible for the booms to re-stow themselves, failure of the boom status switch was suspected. Post-flight testing of identical switches indicates that the switches most likely failed as a result of the atmospheric temperature and pressure.

The anomalies in the Probe housekeeping data are more difficult to explain, since no spare hardware was available for testing. The most interesting anomalies are those associated with data from each Probe's heat-shield thermocouple and thermistor. Each Probe heat shield was instrumented with two thermocouples: one in the nose cap (stagnation region) and the other in the aft end of the forebody (frustum region) (ref. 3). These thermocouples were installed to obtain heat-shield performance data during entry. Each set of thermocouple leads was routed to a terminal board located on the inside of the heat-shield support structure. Here the thermocouple wires were terminated into copper Probe harness wires that were then routed into the pressure vessels through feed-through connectors. A thermistor was mounted on each terminal board to monitor the temperature of the thermocouple lead/copper wire junction.

On the North, Day, and Night Probes, during the period immediately following the failures of the SAS and SNFR temperature sensors, the outputs of the terminal board thermistors dropped from their saturated value of 305 K. These sensors then returned to their normal saturated value after about 10 min. During this same interval, the thermocouple produced anomalous readings. One suggested cause of these anomalies is that the external harnesses or connectors failed, but as previously noted, this possibility is ruled out. The data could also be explained by an atmospheric temperature inversion that the Probe passed through; however, there is no evidence to support this assumption. The only remaining suggested possibility is that the Probe was covered with a plasma. Just how a Probe could pick up a plasma sheath is unknown.

On the Sounder Probe, the leads to the thermocouples and the terminal board thermistors, along with other wires, were severed by an anvil-type cable cutter just before the separation of the pressure vessel from the heat shield. About 2 min before the loss of the LAS temperature sensors, the readings for the thermocouples changed from an "open" value to a value equivalent to a 0.2-mV output between the severed thermocouple leads. The readings from these leads occasionally changed (up and down) during the remainder of the descent. Again, a possible explanation for this behavior is a failure of the external harness or feed-through connectors. A tantalizing possibility, however, is that the open leads were acting like a Langmuir Probe in a plasma. The other anomalies observed were power variations, jump increases in each of the Probe's internal pressure and temperature readings, and changes in the Sounder Probe's transponder static phase error (SPE) and receiver automatic gain control (AGC). Although not the prime candidates for cause, each of these anomalies could have resulted from the effects of static discharge within or outside of the Probe.

CONCLUSIONS

An analysis of the Probe anomalies suggests that they are the result of an unexpected electrical interaction between the Probes and the Venusian atmosphere. The source of the electrical energy for such an interaction is unknown. Further analysis of the instrument anomalies and the scientific data obtained in lower altitudes may offer more clues. However, the possibility that some anomalies were a result of latent design or manufacturing flaws cannot be ruled out.

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