# Reports

## The VEGA Venus Balloon Experiment

R. Z. Sagdeev, V. M. Linkin, J. E. Blamont, R. A. Preston

**In June 1985, two instrumented balloons were placed in the atmosphere of Venus as part of the VEGA mission. Each balloon traveled about 30 percent of the way around the planet at a float altitude near 54 kilometers. In situ sensors measured pressure, temperature, vertical wind velocity, cloud particle backscatter, ambient light level, and frequency of lightning. A ground-based network of 20 radio antennas tracked the balloons by very long baseline interferometry (VLBI) techniques to monitor the Venus winds. The history, organization, and principal characteristics of this international balloon experiment are described.**

Last June, the two Soviet VEGA spacecraft each inserted a meteorological balloon with an instrumented gondola into the atmosphere of Venus. Each balloon remained aloft and transmitted data to Earth for a period exceeding 46 hours. Before this mission, all the in situ observations of this atmosphere had been obtained by a series of 15 probes (11 Soviet and 4 American) that collected data for a period of up to 1 hour as they descended to the planet's surface. Unlike these earlier probes, the VEGA balloons provided a platform capable of sampling a selected range of altitudes for an extended period of time and therefore provided the first opportunity to observe the temporal behavior and detailed horizontal structure of the Venus atmosphere at these levels.

The concept of a balloon experiment on Venus was first proposed in 1967 by J. Blamont and was studied jointly during the 1970's by the Space Research Institute (IKI) of the U.S.S.R. and by the French space agency, the Centre National d'Etudes Spatiales (CNES). The studies were further refined by IKI, and, in 1980, R. Sagdeev and V. Linkin introduced the concept of the present VEGA balloon experiment devoted to investigation of the dynamics of the Venus atmosphere. This experiment was then defined by an international scientific team, with V. Linkin, J. Blamont, and R. Preston leading the Soviet, French, and American groups, respectively. The balloon experiment was officially included in the VEGA mission payload in 1981, with the U.S.S.R. developing the flight hardware. The experiment was organized formally as a cooperative effort of Intercosmos, the Soviet organization responsible for international space experiments, and CNES, with NASA assisting CNES. A principal responsibility of CNES was to organize an international network of radio telescopes to track the motion of the balloons.

The VEGA mission consists of two identical and independent space probes that were launched from Baykonour, U.S.S.R., on 15 and 21 December 1984. On 11 and 15 June 1985 the probes reached Venus, where each separated into two modules. One of the modules entered the Venus atmosphere and the other swung by the planet on a trajectory that will lead it to a flyby of comet Halley in March 1986.

Each entry module separated into two parts. One of them was a descent probe similar to the previous Venera landers, and the other was a canister containing a balloon. During the descent, the balloon was inflated to a pressure slightly greater than that expected at the float altitude (superpressurized) with a predetermined quantity of helium from tanks that were then jettisoned at an altitude of about 50 km. Figure 1 describes the deployment and inflation sequence.

Each balloon had a nominal diameter of 3.4 m and supported a total mass of 21 kg, including a 6.9-kg gondola. The balloons floated in a region of the clouds identified as convective (*1*) at an initial equilibrium float altitude of 53.6 km, corresponding to a pressure of 535 mbar and a temperature of 305 K. This altitude was chosen partially because of the relatively benign temperature and pressure.

Both balloons were inserted near Venus midnight at 2 hours universal time (U.T.) on their respective encounter dates and at a Venus longitude of about 180°. The VEGA-1 balloon entered 7° north of the equator, and the VEGA-2 balloon entered 7° south of the equator. They drifted westward with the predominant zonal wind and were expected to follow closely a parallel of latitude (Fig. 2). Each balloon was tracked over a distance of more than 11,000 km, encountering dawn about 33 hours (8,000 km) after injection and then penetrating far into the daylit hemisphere. Details of the balloon tracks are given in Table 1 of the companion paper by Preston and colleagues (*2*). It is assumed that the float time was longer than the 46 hours of transmission for each balloon, which was limited by battery lifetime. The capacity of the batteries restricted the effective earthward radiated power to 2 to 4 W, depending on the position of the balloon. As a consequence, it was necessary to use exceptionally sensitive receiving stations in the terrestrial tracking network.

The primary objective of the balloon mission was to obtain information about the large- and small-scale motions, structure,

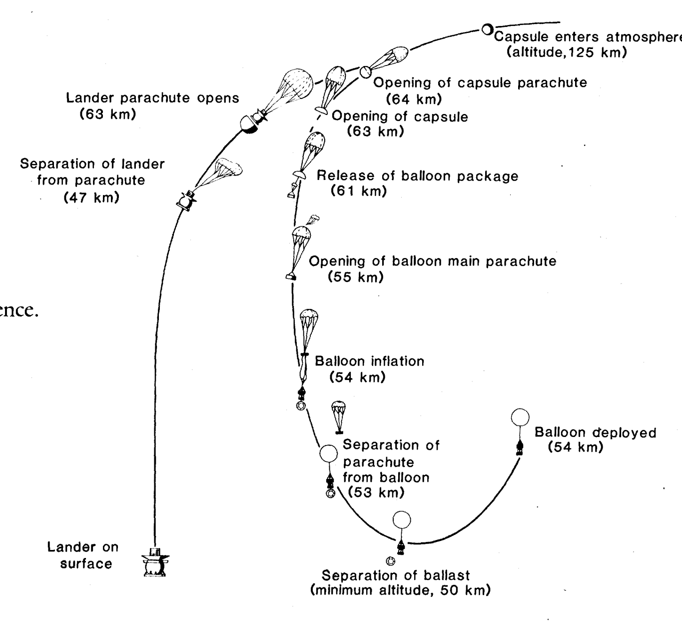


Fig. 1. Balloon entry sequence.

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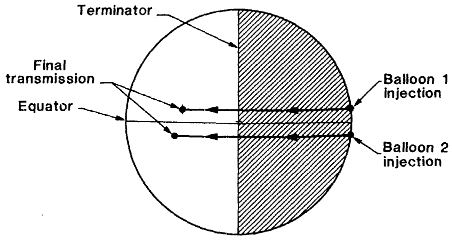


Fig. 2. Track of balloons across the face of Venus as viewed from Earth.

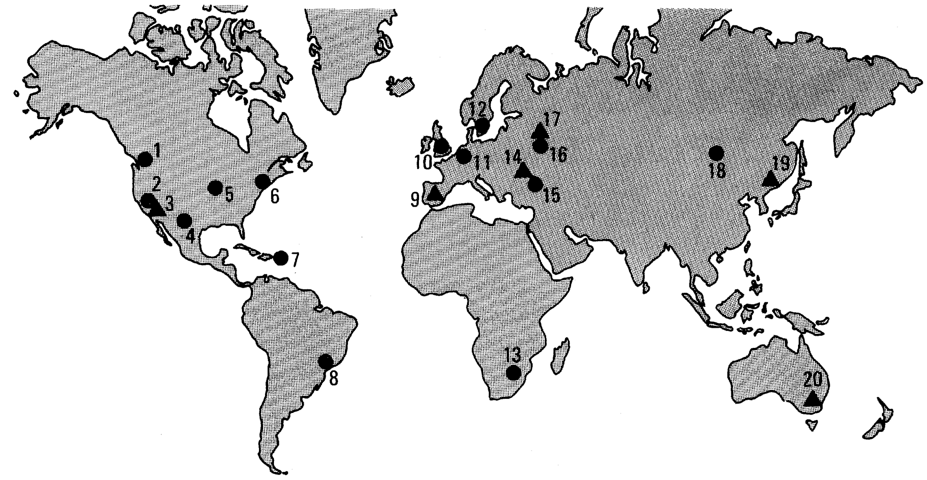

Fig. 3. The balloon-tracking network. Symbols: (●) VLBI data; (▲) VLBI and telemetry data. Key: (1) Penticton, British Columbia (dish diameter, 26 m); (2) Big Pine, California (40 m); (3) Goldstone, California (64 m); (4) Fort Davis, Texas (26 m); (5) North Liberty, Iowa (18 m); (6) Westford, Massachusetts (37 m); (7) Arecibo, Puerto Rico (213 m); (8) Atibaia, Brazil (14 m); (9) Madrid, Spain (64 m); (10) Jodrell Bank, England (26 m); (11) Effelsberg, Federal Republic of Germany (100 m); (12) Onsala, Sweden (26 m); (13) Hartebeesthoek, South Africa (26 m); (14) Eupatoria, U.S.S.R. (70 m); (15) Simeiz, U.S.S.R. (22 m); (16) Pushino, U.S.S.R. (22 m); (17) Medvezhi Ozera, U.S.S.R. (64 m); (18) Ulan-Ude, U.S.S.R. (25 m); (19) Ussurisk, U.S.S.R. (70 m); and (20) Canberra, Australia (64 m).

and cloud properties of the Venus atmosphere at the float altitude. It was expected that new insight would be gained into such phenomena as turbulence, eddy motions, waves, meridional flow, and heat and momentum transport. Two types of measurements were planned: in situ measurements transmitted by telemetry, and ground-based determination of balloon motion by differential very long baseline interferometry (VLBI) between each balloon and its associated flyby. Both types of measurements were provided by signals transmitted directly from the balloons to Earth at 1667 MHz. Because of Earth's rotation, continuous reception of telemetry data required the use of antennas widely distributed in longitude. In addition, the VLBI measurements required a high density of antennas widely spaced in both longitude and latitude. Therefore, the tracking network consisted of an array of 20 antennas distributed over the globe (Fig. 3). These stations were organized in two separate but coordinated networks: the Soviet network (6 antennas), coordinated by IKI and composed of existing antennas on Soviet territory and a new 70-m antenna at Ussurisk, U.S.S.R., that was constructed for this experiment; and an international network (14 antennas), coordinated by CNES and composed of the 3 sensitive NASA 64-m antennas together with 11 radio astronomy observatories.

The float altitude, signal strength, and balloon lifetime were very close to planned values. All 20 ground tracking stations performed well. In situ sensors returned data on pressure, temperature, vertical wind velocity, cloud particle backscatter, ambient light level, and frequency of lightning. Initial results from this pioneering balloon experiment in the atmosphere of another planet are presented in the following reports.

REFERENCES AND NOTES

1. A. Seiff *et al.*, *J. Geophys. Res.* **85**, 7903 (1980).
2. R. A. Preston *et al.*, *Science* **231**, 1414 (1986).
3. Supported in part by NASA at the Ames Research Center and the Jet Propulsion Laboratory, California Institute of Technology.

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# VEGA Balloon System and Instrumentation

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**The VEGA Venus balloon radio transmissions received on Earth were used to measure the motion of the balloons and to obtain the data recorded by onboard sensors measuring atmospheric characteristics. Thus the balloons themselves, the gondolas, the onboard sensors, and the radio transmission system were all components of the experiment. A description of these elements is given, and a few details of data sampling and formatting are discussed.**

The Venus-Halley (VEGA) mission included the deployment of two balloon and gondola systems into the Venus atmosphere (*1*) to investigate the characteristics of the atmosphere at altitudes from 53 to 54 km. The principal experiments conducted involved (i) radio tracking to measure the motion of the balloons as tracers of the winds and (ii) in situ sensors to measure atmospheric temperature and pressure, vertical wind, cloud density variations, light intensity variations, and possible lightning events.

The balloon was a spherical, closed, superpressure structure fabricated from a specially woven Teflon plastic cloth matrix coated with Teflon plastic, reinforced and stiffened mechanically at critical points. The diameter of the helium-filled balloon at a nominal superpressure of 30 mbar was 3.54 m, and the total weight of the balloon-gondola system was nominally 21 kg (12 kg for the balloon structure, reinforcements, and so forth, 2 kg of helium gas for inflating the balloon, and 6.9 kg of gondola and instrument payload). Tests of the balloon

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