The *Vega* balloon experiments

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A brief review is given of the development of the *Vega* balloon probes, together with basic data on the experiment, the instrumentation on board, and the ground radio telescope network.

The global circulation of planetary atmospheres can adequately be studied only if abundant experimental information is available, covering different parts of the planet for prolonged intervals of time. On the earth, a huge amount of material has been gathered that bears on atmospheric dynamics; yet many fundamental questions remain. No wonder, then, that the dynamics of the Venus atmosphere, for which the data are incomparably scarcer, continues to pose a number of unresolved puzzles. One of these, the superrotation of the atmosphere — the rapid zonal flow that occurs at all latitudes — represents a most interesting problem, both as a physical process and as a factor affecting the climate on Venus.

Prior to the Vega flights direct measurements in the Venus atmosphere had been made by eleven Soviet landing craft in the Venera series and four American atmospheric probes. For each of these the data transmission was limited to an interval of roughly one hour. With the deployment of balloon platforms, Project Vega has initiated a radically new phase in research on the dynamics of the Venus atmosphere.

Freely floating balloon stations can measure atmospheric parameters for several days at a time; in due course perhaps the span can be extended to a few weeks. Drifting in the regular zonal wind flow, balloons can survey extensive regions of the planet. Moreover, certain phenomena of importance for our understanding of the atmospheric dynamics will become accessible to study only from aboard drifting balloon probes.

The first proposals to use balloons for investigating the Venus atmosphere dynamics were made by one of the authors (Jacques Blamont) in 1967. From 1974 to 1980 a cooperative Soviet-French program was

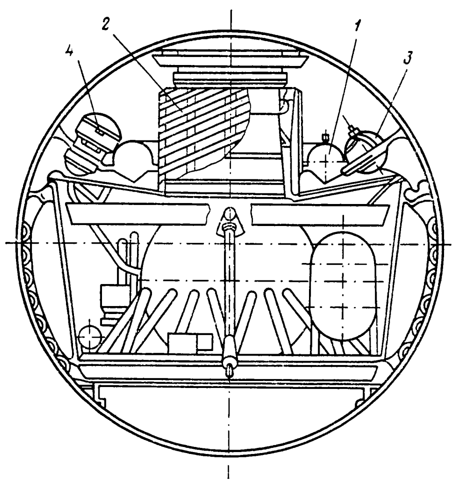

Fig. 1. Arrangement of the balloon-probe payload in the upper part of the Vega landing capsule. 1) Toroidal balloon compartment; 2) lander transmitting antenna; 3) one of the helium pressure vessels; 4) parachute compartment.

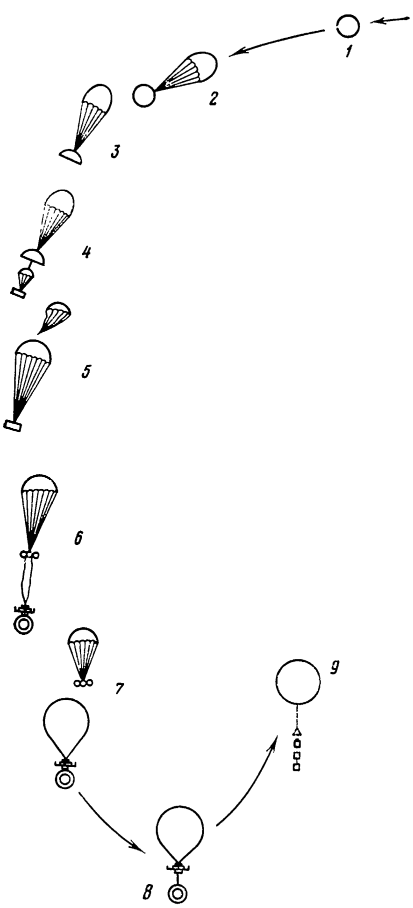

FIG. 2. The balloon-deployment sequence: 1) Venus atmosphere entry (H = 125 km, v < 11 km/sec, θ = −19°; 2) parachute attached to cap of landing craft opens (t = 38 sec, H = 64 km); 3) cap withdrawn (t = 30 sec, H = 63 km); 4) balloon probe released (t = 70 sec, H = 61 km); 5) second parachute opens deploying furled balloon (t = 200 sec, H = 55 km); 6) balloon unfurls and inflates (t = 300 sec, H = 54 km); 7) parachute and inflation system jettisoned; 8) ballast jettisoned as trajectory reaches its lowest point (H = 50 km); 9) balloon rises to its drift level (t = 15-25 min, H = 53-54 km).

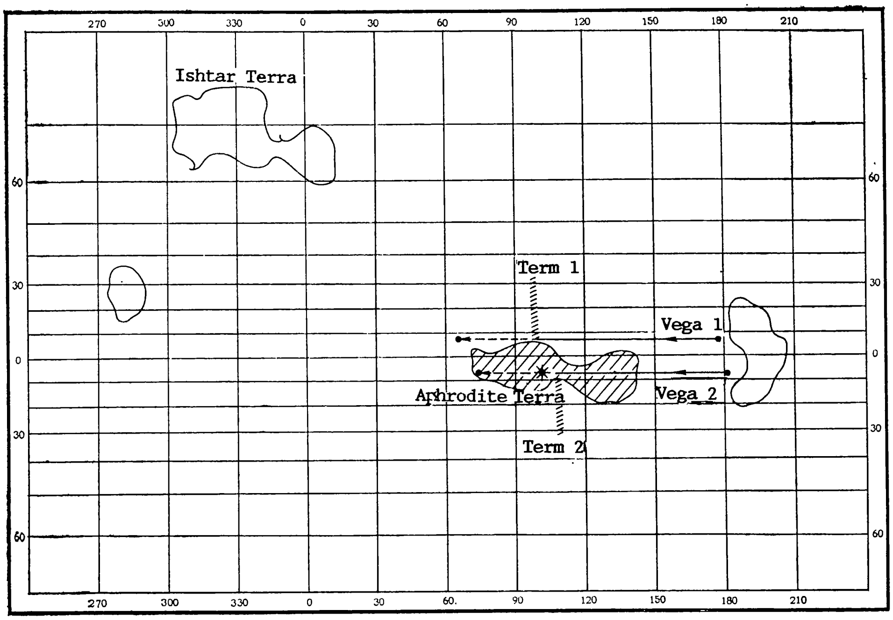

FIG. 3. Vega 1 and Vega 2 balloon flight paths. The bands Term 1, 2 indicate the morning terminator positions for Vega 1, 2; dashed lines, portion of trajectory of Venus dayside. Asterisk, a mountain 5 km high.

carried on by the Intercosmos Council, USSR Academy of Sciences, and the Centre National d'Etudes Spatiales; engineering designs were worked out for a balloon instrument package that would conduct in situ physical, chemical, and meteorological measurements inside the Venus cloud deck and would relay information to earth via a spacecraft orbiting the planet. To implement this plan each balloon station and each orbiter would have had to be delivered by a separate carrier.

At the suggestion of two of us (Roal'd Sagdeev, Vyacheslav Linkin), however, a new approach was adopted in the balloon program: instead of the orbiter relay, all the telemetry data were sent directly to earth, using a low-power transmitter and high-sensitivity receiving antennas which at the same time could measure the balloons' coordinates and velocity by very long baseline radio interferometry. This procedure much diminished the weight of the balloon equipment while allowing most of the scientific experiments to be retained.

In approving this project the Intercosmos Council stipulated several main goals: to trace the large- and small-scale motions over time intervals of up to 2 days, to measure the turbulent heat and momentum flow in the cloud layer, and to determine the physical parameters of the Venus atmosphere in the balloon flight regions. The balloon probes were developed in the USSR.

To receive the information telemetered from the balloon stations and to measure their coordinates and velocity throughout their periods of operation, a worldwide network of antennas was required. At the behest of the Intercosmos Council, CNES organized and coordinated this international radio telescope network, which was under the scientific direction of two of the authors (Blamont and Robert Preston).

Along with six Soviet radio telescpes, including the large 70-m antennas at Evpatoriya on the west Crimean coast and Ussuriisk north of Vladivostok as well as the 64-m antenna at the Medvezh'i Ozera (Bear Lakes) station near Moscow, the balloon transmitter signals were received by another fourteen tracking stations in nine countries around the globe. In fact most of the world's largest radio telescopes took part in the balloon experiments, such as the three 64-m antennas of the Jet Propulsion Laboratory's Deep Space Network, located at Goldstone, California, Madrid, and Canberra.

Each of the two Vega balloon probes was deployed in the Venus atmosphere concurrently with the landing craft. The balloon and its gondola were stowed in a toroidal enclosure surrounding the lander's transmitting antenna (Fig. 1). Attached to the top of this torus were the high-pressure vessels containing the helium to fill the balloon, the housing for the balloon-probe parachute, a timing device programmed to release the balloon package, and pyrotechnics with their electric power supply.

The total weight of the balloon payload, including all the accompanying instrumentation for deploying the probe in the Venus atmosphere (Fig. 2), was 120 kg.

Both balloons were released on the planet's nightside, timed near local midnight, at the following positions:

	Latitude	Longitude
Vega 1	+8°.1	176°.9
Vega 2	−7°.5	179°.8.

A 53-54 km balloon drift height was selected in the dense cloud layer near the convection zone in an effort to bring out more clearly the influence of the mechanisms keeping the atmosphere in rapid motion from east to west — the superrotation. After they were released the balloons drifted westward in the zonal wind flow (Fig. 3). Each probe functioned for 46 h in the Venus atmosphere, Vega 1 on 1985 June 11-13 and Vega 2 on June 15-17. Along their flight tracks the balloon probes measured the temperature, pressure, vertcal wind-velocity component, backscatter coefficient, and mean solar illuminance, and they monitored the fluctuations of the illuminance in the cloud layer. The highly stable generators on board enabled informative Doppler measurements to be made, providing initial data on the balloon trajectories.

The balloon-probe signals recorded by the various radio telescopes are now being processed and will yield the wind velocity vector during each interval of transmitter operation. The drift trajectories will then be reconstructed from sets of three measurements.

According to the telemetry data and the Doppler tracking, the balloons drifted latitudinally in the Venus atmosphere about one-third the way around the planet at an average speed of 69 m/sec (Vega 1) and 66 m/sec (Vega 2), maintaining practically the nominal height of 53-54 km. They crossed the terminator 34^h (Vega 1) and 32^h (Vega 2) after deployment, their operation ending on the dayside when then sun was at a zenith distance of about 60°-55° (Fig. 3). The 46^h duration of the balloon telemetry was limited by the electric energy supply in the batteries. By the close of the operating sessions the balloons had dropped about 500 m due to escape of some of the helium. On the dayside, however, the solar heating of the helium in the balloons offset the loss in height through diffusion, so the probes presumably continued their drift motion even after they were no longer transmitting signals to earth.

The 20 radio telescopes in the VLBI network acquired the Vega 1 and Vega 2 balloon signals and recorded them with a high signal/noise ratio. Over the four days of the two experiments the network gathered data from about 1200 individual measurement sessions, and the total file of information recorded amounts to some $1.5 \cdot 10^{12}$ bits. We are hopeful that the magnetic tapes will have been fully processed by late 1986, giving the actual fight trajectories and velocities of the balloon probes in the Venus atmosphere. Preliminary results of the analysis, as well as the measurement techniques and system parameters, are set forth in a number of communications appearing in this issue of Soviet Astronomy Letters.

These Vega balloon experiments could not have been conducted successfully without extensive international collaboration, a direct role being played by staff members from many organizations and radio astronomy observatories. We would express our most sincere thanks to all.