Low-Cost Balloon Missions to Mars and Venus

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Though numerous planetary balloons ideas were around for a long time, the 1985 Russian-French-US Venus VEGA balloons were the only ones, which have been actually launched and successfully performed. Growing costs, limited number of planetary missions opportunities and increasingly high science competition make difficult to get a dedicated planetary balloon mission even of moderate cost. One of the reasons is that planetary balloons have still been considered as an immature and high-risk technology.

Balloon performance at float altitude can be well understood and modeled to the degree of knowledge of ambient and radiative environment both of which are quite well known for Mars as for Venus. Aerial deployment and inflation of the balloons is much less deterministic process that was studied with much less degree of certainty and for a long time it was considered as the high-risk element. VEGA balloon experience is not directly applicable because much heavier (10-20 times) fabric material was used.

The recent first successful flight demonstration of aerial deployment of Mars balloon prototypes and, earlier, of Venus balloon prototype deemed to be a turning point in the risk assessment of balloon missions. These flight tests as well as preceding development, simulations and tests brought understanding of major influencing factors and proved feasibility of the concept.

The low-cost dedicated or piggyback mission could be the first opportunity. The key is to decrease size and mass of the entry vehicle that contain the balloon with all associated hardware to be carried by any major planetary mission without a burden or to be launched by a small LV or as an auxiliary payload on a larger LV. At the present level it is possible to realize a scientifically meaningful balloon mission on Mars or Venus with the entry vehicle mass of 45-60 kg only. Lightweight balloon films, small highly integrated payloads, lightweight inflation, deployment and parachute systems are essential elements of design.

A number of mission concepts have been proposed in the last several years that could fit to low cost cap. Rarified Martian atmosphere limits low-cost missions to long-duration superpressure spherical or superpressure balloons equipped with magnetometers, cameras and atmospheric instruments, and solar montgolfiere balloon serving as a lightweight decelerator for landing a surface module as, subsequently, a hot-air balloon with science payload.

Deep atmosphere of Venus provides more options for balloon missions. They may include: superpressure balloons to study atmosphere at fixed altitude levels at different latitudes, including polar regions, zero-pressure or superpressure balloons for high-resolution surface imaging in infrared, zero-pressure sounding balloons to study vertical structure of the Venus mesosphere. Both zero-pressure and superpressure balloons can drop sondes and relay data from them including high-resolution images of the surface. Eventual Venus surface sample return will require a high-temperature balloon that will bring the return rocket with sample or the sample canister to the altitude 55-65 km from where this rocket can be launched. Technology demonstration prototype of such balloon can be realized in low cost mission. Less distant *in situ* surface sample analysis would benefit from balloon that will bring the sample to the altitude where moderate environment would allow to analyze it in much more details than in harsh environment of the Venus surface.

The technology for many of these missions is either well developed or does not have major showstoppers and we hope that this decade will see the long-waited mission that will engage all balloon community.