MABVAP: ONE STEP CLOSER TO AN AEROBOT MISSION TO MARS V.V.Kerzhanovich[1], J.A.Cutts[1], A.D.Bachelder[1], J.M.Cameron[1], J.L.Hall[1], J.D.Patzold[1], M.B.Quadrelli[1], A.H.Yavrouian[1], J.A.Cantrell[2], T. T. Lachenmeier[3], M.G.Smith[4], [1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [2] Space Dynamics Laboratory, Utah State University, Logan, UT; [3] GSSL, Inc., Hillsboro, OR; [4] Raven Industries, Sulphur Springs, TX

Lighter-than-air planetary missions continued attract growing interest in Mars exploration due to unique combination of proximity to the surface and mobility that far surpasses capability of surface vehicles.
Following the experience with the Sojourner rover and subsequent development of powerful rovers for Mars 2003 and 2005 missions it became clear that on Mars surface rover mobility is quite restricted. Realistic travel distances may be limited to tens of kilometers per year on relatively obstacle-free plains and a few kilometers or less on the more rugged terrains. Many areas on Mars will be inaccessible to rovers.

Several concepts for a Mars aerobot (robotic balloon) mission have been pursued in the last decade: Russian-French Mars Aerostat Project (1987-1995)[1], Mars Aerial Platform Discovery Proposal (1994)[2], Mars 2001 Aerobot/Balloon Study (1996)[3]. The Mars Aerostat was a full-scale mission (~600 kg entry mass) with a payload of 15 kg and 15 kg of the “snake” guiderope. The aerostat floated at an altitude of ~ 4km during the day, when it was slightly overpressured, and descended to the surface during the night when the envelope cooled using a guiderope to prevent the envelope contacting the surface. The expected lifetime was < 7 days. The two other concepts used superpressure balloons providing lifetimes of the order of 90 days with potentially extended lifetime and were to be launched on dedicated Delta II class rockets. The MABS study conducted in collaboration with Goddard Space Flight Center, led to the concept of an Ultra-Long Duration Balloon (ULDB), a 100 day scientific stratospheric “balloon-craft” that has recently become NASA’s Olympus program.

In 1997, JPL was requested by NASA to develop a concept for an aerobot mission a factor of 5 to 10 smaller in size than MAP and MABS and conceived as a technology demonstration similar to the rover Sojourner. The Mars Aerobot Technology Experiment (MABTEX) could be launched as a piggy-back mission on the 2003-2005 mainstream mission or as an Ariane 5 ASAP payload.

MABTEX would employ a ~10-m spherical superpressure balloon with 2.5-3 kg payload providing a lifetime in excess of 1 week and possibly much longer. Recent progress in microminiaturization - Sojourner(10 kg) and Muses-C(1.2 kg) rovers, DS-2 Mars Microprobes(3.5 kg) - proves that this payload can serve not only as a technology demonstration but alos can provide a significant opportunity for new types of scientific measurements. High spatial resolution measurements of the remanent magnetic field on Mars, high-resolution imaging and sub-surface radar/electromagnetic survey are among the prime instrument candidates.

During development of the Mars Aerostat in France in the early 1990s, the major technical challenge identified was aerial deployment and inflation of the thin-film envelopes in the Martian environment. Shocks to the balloon envelope during deployment shocks and various aerodynamic instabilities that acted on the envelope during inflation were never satisfactorily controlled. After an extended development effort, the project was terminated without successful demonstration of aerial deployment and inflation. This has cast a shadow over subsequent proposals for light-gas Martian aerobots as well on concepts for advanced lighter-than air vehicles with altitude or trajectory control. Thus validation of the aerial deployment and inflation of thin-film light-gas balloon in Martian-like environment was established as the primary objective of the Mars Balloon Validation Program (MABVAP) initiated in August 1997.
We consider MABVAP as the technology program enabling a new generation of missions for exploration of Mars and of the other planets and satellites with atmospheres including Venus and Titan.

The MABVAP development program includes laboratory, wind tunnel, vacuum chamber tests of the system components and tropospheric tests culminating in stratospheric flight tests of deployment and inflation of light-film balloons in a simulated Martian environment.

To achieve our goal of completing MABVAP in two years it was necessary to use of proven balloon materials or their combinations and established balloon fabrication technologies and processes. A particular area of concern was evacuation of gas from the balloon prior to packaging and the design of a balloon container capable of storing the balloon over a wide range of ambient pressures. During the deployment process several considerations come into play: mitigation of forces on the balloon during deployment; a safe deployment process without impacts on the balloon envelope which could tear the balloon; and avoiding subsequent instabilities of the balloon including helium gas bulb propagation inside the balloon. Other key design issues include the necessity for a reefing mechanism for ensuring stable and predictable inflation of the balloon and the choice between top and bottom inflation.

Tests that have been made at JPL and at the Vertical Wind Tunnel at NASA Langley Research Center clarified many of the first order issues discussed above and lead to the selection of a bottom inflation configuration without a reefing mechanism. In this configuration the system of parachute and balloon is stable during the most critical part of inflation process. Although oscillations may develop when the balloon is filled to more than ~60% in volume the bottom inflation configuration ensures that these do not damage the balloon by impingement on the inflation hardware. Free drop tests of the inflated balloon at LARC and at JPL confirmed stability in the free flight. To avoid possible damage of the balloon during inflation. a special diffuser/windsock was designed to operate at high inflation rates. The system has been validated by inflating both 12.5 mk and 8.5 mk 10-m diameter balloons in the vacuum chamber at 5 mbar ambient pressure.

A series of free flight tests of a brassboard deployment module from an altitude of 1.5 km have been conducted with the payload dropped initially from a hot air balloon and in later flights from a helicopter. These tests were successful and demonstrated the shock mitigation approach and the stability of inflation of the balloon from gas cylinders beneath the balloon. These tests have validated the bottom inflation approach for aerial launch of a balloon in dense atmospheres such as those of Titan and Venus.

The first stratospheric test with simulation of Martian environment using a carrier balloon to raise the deployment module to ~35 km was performed in March 1999. A 10 m balloon was deployed and inflated to 90% of its planned gas mass capacity and video data acquired to characterize the deployment. However, the balloon separated frorn from the deployment module at the end of the inflation process. This was most likely the result of a mechanical defect at the bottom fitting; there was no evidence of the aerodynamic instabilities during the inflation that could have contributed to.

Plans are being initiated for further tests of a miniaturized system that would be compatible with the payload envelope for a Mars Micromission launched by Ariane 5 and would incorporate the results from the firs stratosperic test. Development and stratospheric test of this miniaturized system could be conducted during the remainder of 1999. A Mars Aerobot Micromission capability should be ready in ample time for the 2005 launch opportunity.

References

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