MARS BALLOON SCIENCE. A. Wolf[1], L. Beegle[1], C. Raymond[1], J. Plaut[1], B. Pollard[1], Y. Gim[1], X. Wu[1], J. Hall[1] [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA 91109

Introduction: Balloons provide an excellent vantage point for scientific observations over regional scales at altitudes lower than orbit but higher than the surface. Balloons have been flown in Mars-relevant atmospheric conditions on Earth, and two balloons have flown at Venus during the 1985 VEGA mission [1]. Mars balloon missions have been proposed to NASA in the past. Balloon platforms can offer unique benefits for both Mars science and the human exploration program. When flying a smaller payload (few kg) a balloon is small enough to fly as a secondary payload on a larger Mars orbiter or lander mission. Some applications of Mars balloon platforms are discussed below.

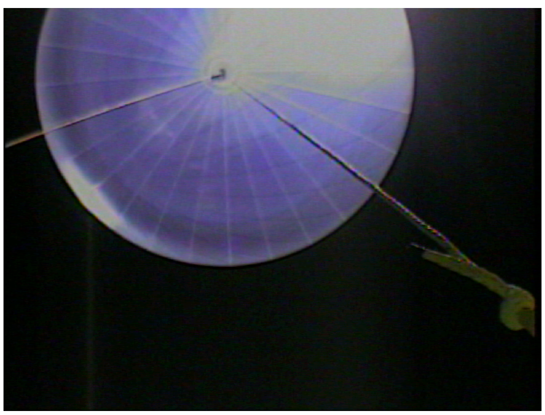

Fig. 1: Prototype Mars balloon flying at 30 km altitude on Earth.

Sounding radar for 3-D mapping of Martian Subsurface: Layered subsurface structure, including interfaces between ice or other volatailes and bedrock, could be mapped using a sounding radar similar to MRO's SHARAD [2] or the MARSIS [3] instrument flying aboard Mars Express. The size and location of subsurface ice deposits have implications for life detection and the water history of Mars, and are also important for in-situ resource utilization (ISRU) for future human exploration. Potential targets include the shallow arctic ground ice studied by Phoenix, deeper pervasive ice in areas such as Arcadia Planitia [4], Dorsa Argentea [5] and the remnant glaciers of Deuteronilus and East Hellas [6, 7]. The 3-D mapping radar would use a very wide band of 40 MHz at a center frequency of 70 MHz, thus enabling a **vertical resolution of 2.5 meters in ice, a factor of four improvement over SHARAD.** By forming a synthetic aperture, we could achieve a horizontal resolution of 10 m at an altitude of 5 km; such a 3-D mapping technqiue was recently demonstrated with an aircraft radar sounding system [8]. The mass of the proposed balloon-borne radar would be 10-20 kg, similar to SHARAD, with power consumption of ~20W. A high-resolution 3-D subsurface map to a depth of 1 km could be paired with high-resolution images of terrain from MRO's HIRISE camera for surface and subsurface characterization of a potential site for a human base. (A balloon could carry its own camera for additional surface imaging.)

Near surface hydrogen: The Gamma Ray Spectrometer onboard the Mars Odyssey spacecraft has measured the near surface hydrogen content over the entire surface of Mars. The results indicate that many near-equatorial regions have a hydrogen content on the order of 8% by volume, which raises the possibility that water based ISRU is possible. However, the orbital measurements have a spot size of ~200 km and do not differentiate between ice and hydrated minerals. In order to take advantage of subsurface hydrogen for ISRU, the exact nature of the hydrogen needs to be better defined in both spatial scale and form. **A moving aerial platform instrumented with a Gamma Ray Spectrometer and with a visible camera could better correlate locations of near-surface hydrogen deposits (0- 2 meters depth) to geologic formations so that optimal landing sites for future human missions can be identified and explored.** The spatial resolution of the measurement would depend on ground speed neutron flux and detector size, but would expected to be <10 km. Mass of the gamma ray spectrometer would be <5 kg with power consumption <10 W. Finally, Gamma ray spectrometers have the ability to detect other elemental abundances beyond hydrogen as demonstrated by the lunar prospector mission that constructed maps of over 20 different elements [9]. Identification of other elemental deposits can answer many scientific and human exploration related issues.

Remanent magnetism in the crust: The history of the Martian dynamo is recorded in the magnetization of the Martian crust. The crustal magnetism also reflects the evolution of the Martian crust, including aqueous alteration. High-resolution magnetic-field measurements enabled by a balloon platform are critical to understanding the time history of the field via correlations with surface geology and the magnetization of craters [10]. The strongest magnetic fields are encountered in the southern highlands, but significant but weaker magnetism is likely ubiquitous. **Observations are needed at low altitudes to resolve the full spectrum of magnetic field variations to understand their implications for the Martian dynamo, and the volcanic and climate history of Mars.** Additionally, there may be some benefit to choosing a future human landing site in regions of strong crustal magnetization, which could shield the surface from harmful radiation. A magnetometer system flown in a gradiometer configuration would have very low mass and power (< 2kg and < 1W).

Meteorology: Improved knowledge of Martian winds and weather is of scientific interest and is also critical for future human missions to Mars. **Improved wind knowledge, particularly between ~10km altitude and the Martian surface in regions of interest for future Mars landing, is particularly useful to EDL and improving landing accuracy.** Wind error is the "tall pole" to address in pinpoint / precision landing [11]. Measurements of wind and other atmospheric properties in this altitude range are needed to validate existing models. Orbital measurements from the Mars Climate Sounder [12] on MRO have a resolution of 5km from the surface to 80km.

Atmospheric properties: Better understanding of electrostatic properties of the Martian atmosphere is needed specifically for EDL, ascent, and future human exploration; a small, lightweight balloon-mounted Langmuir probe or probes could yield relevant measurements. In addition, better **understanding of Martian atmospheric chemistry, particularly in the boundary layer (1–4km altitude) is needed to predict long-term degradation of materials and dust accumulation on Mars.** A balloon-mounted tunable laser spectrometer could answer questions about chemistry of specific species in the boundary layer

Mars balloon state of the art: Terrestrial helium superpressure balloons have achieved over two year flight durations, and the expectation is that this technology could yield at least multi-month flights at Mars, enabling coverage over ground tracks of thousands of km.. Figure 1 shows a prototype 12 m diameter Mars superpressure balloon successfully flying in the stratosphere of Earth at 30 km altitude [13], where the atmospheric density is comparable to that of Mars at altitudes of a few km. A superpressure balloon at Mars would float at an altitude of ~5 – 6 km.

The likely mission implementation would feature aerial deployment and inflation of the balloon upon arrival at Mars, similar to the technique used for the VEGA superpressure balloon mission at Venus. While there has been some success deploying 10 m scale balloons in the stratosphere [14], the scaling to deployment of larger balloons remains incomplete. However, the recent successful flight experiment of Venus superpressure balloon [15] suggests that the controlled deployment strategy employed for that test would also work for Mars balloons and thereby solve the scaling problem.

Conclusions: Balloons are uniquely suitable platforms for some observations important for Mars science and future human exploration. They are technologically within reach, and are small enough to be packaged as secondary payloads.

References:

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