Long duration autonomous balloon platform for Mars exploration. A. Pankine[1], [1]Space Science Institute, 4750 Walnut Street, Suite 205, Boulder, Colorado 80301, apankine@spacescience.org.

Introduction: At the center of this mission concept is the long-duration (10-30 days) autonomous balloon platform deployed in the atmosphere of Mars. Such a platform combines long-range mobility with opportunity to take in situ and high spatial resolution remote sensing measurements on regional to global scales. The concept is responsive to the scientific goals identified by the Decadal Survey and MEPAG, and can be tied to the Challenge Area 1: Investigative Approaches.

Overview: Balloons have been long recognized as unique, low-cost scientific platforms due to their relatively low cost and low power consumption. Indeed, the successful Venera-Vega Project [1] demonstrated technical feasibility of deploying a balloon at another planet and performing scientific observations from it. Concepts and technologies enabling planetary balloon exploration of Mars, Venus, Titan and the Outer Planets have been developed [2-6].

The spacecraft mass budget and the associated launch vehicle for this concept could be similar to those of the Mars Exploration Rovers (MER). The balloon inflation takes place during spacecraft entry and descent in the Martian atmosphere. The entry and descent phases would be very similar to previous Mars lander missions. A heat shield reduces the interplanetary velocity and absorbs the heat generated by passing through the atmosphere. The aft cover is released and a supersonic parachute is deployed at a Mach number of ~2. As the system approaches terminal velocity on the parachute, the inflation phase commences. The gondola and attached equipment are lowered, and the weight is used to stretch out the balloon envelope vertically. The inflation equipment is mounted below the balloon, and will be jettisoned when the inflation of the balloon is complete. An inflation tube is used to carry the gas up to the initial inflation bubble towards the upper end of the balloon and could also to support the deployment shock. Once the balloon has reached a size comparable to the parachute, the parachute will be cut away. Upon completion of inflation, the inflation hardware will be released, and the system will ascend towards an equilibrium float altitude.

The superpressure balloon proposed for this concept is not connected with atmosphere and maintains constant shape and volume due to the gas pressure inside the envelope being slightly higher than the ambient pressure. The balloon platform remains in the constant density height in the atmosphere and is carried around the planet by the prevailing winds. Depending on the season and location on Mars, the floating altitude of the balloon can range from 4 to 10 km above the surface.

Instrumentation. The balloon platform can carry a useful payload of 10 to 30 kg. This payload can include a camera with a relatively small telescope. The balloon platform is about 20 times closer to the surface than an orbiter, resulting in the corresponding improvement in spatial resolution. Imaging of surface targets a resolution of ~1 cm would be possible with a relatively small telescope, - on global spatial scales.

In situ lightweight instruments based, for example, on Tunable Laser Spectrometry approach can provide a wealth of information on abundances of atmospheric trace gases (including methane) on a global scale.

Since the balloon is carried by the winds, tracking the position of the balloon provides information on winds. A lightweight 1 km- long tether with several humidity and temperature sensors can be lower from the gondola and provide measurements on the vertical structure of the atmosphere.

Magnetometers and gravimeters measure spatial variations in the magnetic and gravity fields with a resolution proportional to the height from which the observation is made. Observations from a balloon at the height of 5-10 km will improve orbital observations by an order of magnitude.

A thermal emission spectrometer, either near-infrared or thermal infrared, can provide high-spatial resolution observation of surface mineralogy and of atmospheric abundances of dust, water vapor and water ice aerosols.

Communications. The balloon platform carries a UHF antenna and communicates with a relay orbiter once or twice a day. Between the communication passes the collected data is stored in onboard data storage.

Navigation and science planning. The balloon trajectory is uncontrolled, but can be forecasted daily with good accuracy using the Mars Global Circulation Models. Several approaches will be used simultaneously to determine the balloon position on Mars. During the night the onboard star tracker periodically images the stars in the sky and calculates the shift in the position of the platform. During the day the camera periodically images the underplaying terrain and the horizon and uses image recognition software to match the topography to the topographic maps stored in the onboard computer. The final determination of the balloon position and orientation is done by the operator on Earth using the information collected by the start tracker, topography features identification and trajectory prediction from circulation simulations. Onboard actuators provide information on platform tilt and rotation.

The following approach to data collection can be envisioned. The camera and the spectrometer are in a nadir pointing configuration continuously collecting imagery and spectra of the surface underneath the balloon platform. The data are tied to the geo-spatial information off-line after the data and the auxiliary information are uploaded to Earth during a relay orbiter pass. The camera and the spectrometer also perform periodic scans from nadir to above horizon for the purposes of atmospheric studies and providing the location information. In situ instruments also operate continuously.

Mobility. The predicted wind speeds during summer months in the lower atmosphere of Mars are such that a balloon platform floating with the winds will circumvent midlatitudinal region of Mars in about 7-10 days. A long-duration 30 day mission, feasible with the currently available composite balloon skin materials, can accomplish 3-4 circumnavigations, sampling geologically diverse regions of the planet.

Relevance to Science and Programmatic objectives: The proposed Mars balloon platform will enable investigations and novel exploration approaches that address the Goals and Objectives of Mars exploration as outlined in the Decadal Survey and in the MEPAG reports. Specifically, it addresses Goal II: Understanding the processes and history of climate on Mars - by providing a platform for characterizing current Martian atmosphere with in situ and remote sensing instrumentation at unprecedented spatial resolution and at different locations across the planet; Goal III: Determine the evolution of the surface and interior of Mars – by providing a platform for high spatial resolution observations of gravitational and magnetic fields, which are relevant for investigations of evolution of Martian crust.

The concept also addresses the objectives of the Strategic Knowledge Gaps n the Human Exploration of Mars by providing a platform for high-resolution measurements of surface characteristics such as composition and morphology of multiple possible landing sites (near-term Challenge Area 1); by providing a platform and a concept for measurements of lower atmosphere winds and densities, either globally or at specific sites to support future landing systems (mid-term Challenge Area 1).

References:

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