MARS BOUNDARY LAYER SOUNDING BALLOON: SCIENTIFIC AND TECHNICAL CONCEPT.

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Brief Presenter Biography:

Lars Witte is a senior researcher at German Aerospace Center's (DLR) Institute of Space Systems and head of the Landing & Exploration Technology department. He was involved in several DLR planetary missions and instrument contributions.

Introduction: The Mars Exploration Program Analysis Group (MEPAG, [1]) has identified measurements of the state and the variability of the Martian atmosphere as high priority investigations for the upcoming years. Balloon-borne instruments could bridge the gap in both temporal and spatial resolution in mesoscale distances between local, stationary landers and global orbiter observations. The idea to use a balloon system for such purposes is not new in essence and has been proposed already in past decades. While those concepts considered an aerial deployment during entry and descent, the concept outlined in this abstract revisits a launch off the payload deck of a lander from the Martian surface. This deployment option profits today mainly from the technological advance in micro-electronics and sensor miniaturization which enables designing a balloon-probe significantly smaller than earlier proposed systems.

Concept of Operations & instrumentation: The investigated experiment concept responds to the afore mentioned MEPAG [1] high level investigations with its following instrument objectives:

1. Observe the interaction of the atmosphere with the surface with simultaneous measurements of radiative heat and turbulent fluxes and hence the forcings and effects of the transportation process of dust and other aerosols from the ground into the atmosphere.
2. Monitor the magnitude, spectrum and spatial extent of turbulent zones caused by convective instabilities and vertical shear of the horizontal wind.
3. Provide temporally and spatially highly resolved data usable for validation and improvement of yet numerical model-based predictions of mesoscale phenomena and for validation of orbiter global observational data by measurements of synoptic-scale circulation.

The associated scientific concept of operations is illustrated in Figure 1. Measurements of upwelling radiation ①, using DLR's radiometer technology [2] flown on the InSight mission, are performed in the 7 to 16 µm wavelength range to determine soil surface temperature, the temperature of the air column underneath the gondola, and the aerosol (dust) content. Onboard humidity and temperature sensors [3] measure the relative humidity at the balloon altitude. The entire balloon system acts as a wind sensitive probe ② to detect vertical wind velocity components. The vertical wind component and turbulence spectra are measured by baro-integrated inertial data and differential air data around the gondola with a constant temperature anemometer [4], respectively. Large scale horizontal wind components are deduced from the balloon trajectory obtained from radio tracking ③. Balloon position allows correlation of measurements to orographic features and thermo-physical surface properties ④. Altogether, these measurements allow a simultaneous monitoring of key driving forces – thermal gradients, orography – and the magnitude of resulting vertical turbulent fluxes.

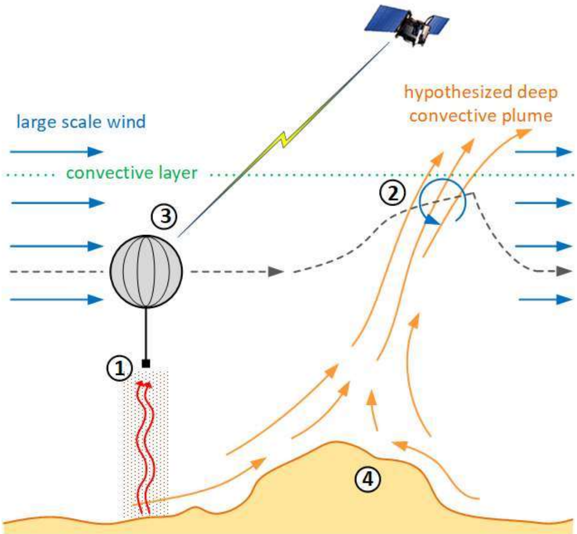

Fig. 1 *Illustration of the scientific concept of operations for a probe drifting within the planetary boundary layer*

The probe shall have a lifetime of at least two Martian days to ensure that repeated diurnal effects can be observed, a diversity of topographic features is crossed and large-scale wind patterns can be resolved. Furthermore, the trajectory shall probe the daytime convective layer which requires a cruising altitude of less than 5000 m above ground level.

Baseline Design: The sensor suite is controlled by a system-on-chip onboard computer. Data transmission uses a UHF radio and the CCSDS Proximity 1 Link protocol to enable data relay and tracking by the fleet of Martian orbiters. The avionic is powered by a primary battery, sized to support >50 h of operations. Altogether, the integrated gondola has an estimated mass of ~600 g. A 7 m diameter super-pressure sphere is selected to provide a floating altitude of about 2000 m above the MOLA datum. The intended automatized inflation and lift-off sequence requires a hull packing technique which avoids unintended contact with the surface or surrounding spacecraft structure. Hence, any folding pattern which would require unpacking before inflation is unsuitable. In this application, a technique is employed which unfolds the hull during its inflation according to the amount of lifting gas being filled in. This underlying folding pattern uses an 'inverted-cone' fold, originally developed as optimized packing for automotive airbags [5]. Figure 2 shows the instrument configuration (a) with its main components, including the instrument support system, (b) accommodation on a notional lander deck with balloon inflated to a 'ready for launch' state, and (c) the fully inflated balloon probe at ceiling altitude. The instrument design and the mission and trajectory analysis are described in more detail also in [6].

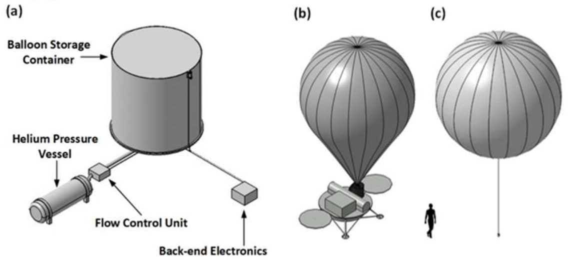

Fig. 2 Principal instrument layout and balloon in launch and flight configuration

Testing: The primary components have been subject to testing to demonstrate and mature the concept's critical functions. Particularly, the hull inflation was tested with a subscale model in the low speed wind tunnel (Figure 3) to determine the hull's aerodynamic properties in ground proximity and inflation characteristics under wind load. A (near) half-scale hull (Figure 4) was used to establish folding and packing procedures. The basic avionic and sensor package has been flown as radiosonde payload (Figure 5).

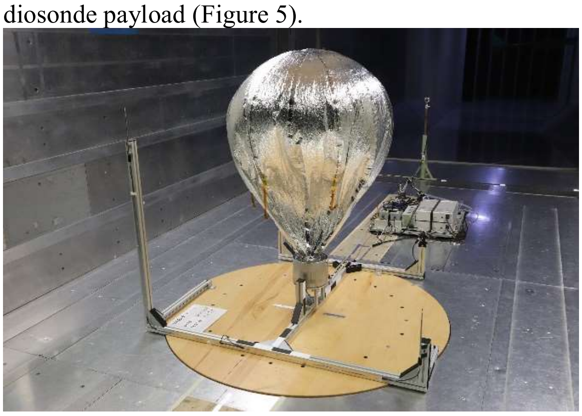

Fig. 3 *Wind tunnel test set-up in the German-Dutch (DNW) low speed wind tunnel*

Fig. 4 *A 3.25 m test sphere in DLR's Landing and Mobility Test Facility*

Fig. 5 *First core avionic and basic instrumentation tests in free-flight conditions over Northern Germany*

References: [1] Banfield, D. et al. (2018) MEPAG [2] Grott M. et al. (2017) Space Sci Rev 208, 413–431 [3] Lorek A. et al.; (2018) Sensors, 18, 2615 [4] Theuerkauf A., (2011) Atmos. Meas. Tech., 4, 55–66 [5] Bruton J.T.et al. (2016) R. Soc. open sci., 3, 160429 [6] Witte L. et al. (2022) Aerospace 9, 136