ANTARCTIC FIELD-TESTS OF A MARS BOUNDARY LAYER SOUNDING BALLOON.

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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: Measurements of the state and the variability of the Martian atmosphere are high priority investigations for the upcoming years [1]. Balloon-borne instruments could bridge the gap in both temporal and spatial resolution in mesoscale distances between local, stationary landers and global orbiter observations. Although ballon concepts are not new in essence, related developments profit today mainly from the technological advance in micro-electronics and sensor miniaturization which enables designing a balloon-probe significantly smaller than earlier proposed systems [2]. The balloon probe uses an automatic launch off a lander payload deck (a feature which was not part of the analogue test campaign). A development model of the balloon probe and its sensor suite has been built and tested in an analogue environment in Antarctica. The scientific concept of operations, the flight test hardware and field test realization are described subsequently.

Concept of Operations & instrumentation: The studied Mars Boundary Layer Explorer (MABLE) experiment responds to the high level [1] 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 and spatial extent of turbulent zones caused by convective instabilities and wind shear.
3. Provide temporally and spatially highly resolved data usable for validation and improvement of numerical model-based predictions of mesoscale phenomena, and for validation of orbiter global observational data.

The associated scientific concept of operations is illustrated in Figure 1. Measurements of upwelling radiation (① in Fig. 1), using DLR's radiometer technology to determine soil surface temperature, the temperature of the air column underneath the gondola, and the aerosol (dust) content. Onboard humidity and temperature sensors measure the relative humidity at the balloon altitude. The entire balloon system acts as a wind sensitive tracer ② to detect vertical wind velocity components. The vertical wind component and turbulence spectra are measured by air data around the gondola with a constant temperature anemometer, 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.

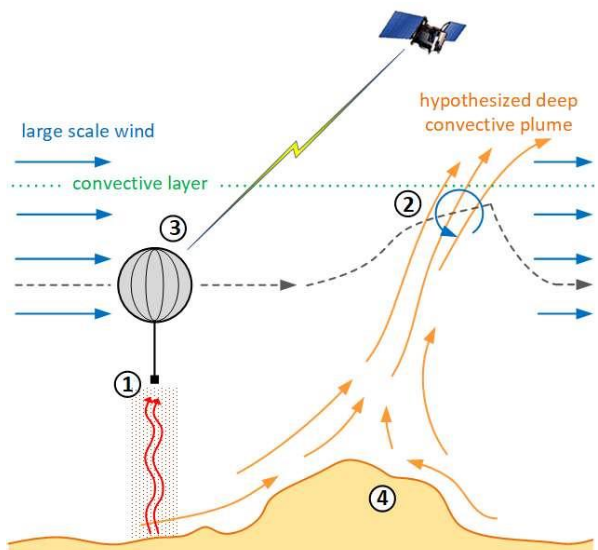

Fig. 1 *Illustration of the scientific concept of operations for a probe drifting within the planetary boundary layer*

Field test flight hardware: The primary objective of flying a development model in a field test is to put its integrated sensor suite into a full-scale operational context. Focus is therefore on the combined instrument performance. For the field tests, five flight units have been prepared which are: (a) two units with basic meteorological (pressure, temperature, humidity, PTH) sensors, balloon hull state monitoring and Iridium satellite data link. Its 3.25 m hull enables flight altitude up to 20 km (flights HA1 and HA2). (b) two units with PTH sensors, radiometer (only surface temperature in terrestrial test), camera and anemometer and short-range UHF-data link. Its 1.65 m hull enables flight altitude up to 8 km (flights LA1 and LA2). (c) one unit with avionics similar to (a) but an anemometer for high altitude calibration, flying with a conventional rubber balloon hull (HA3, ~30 km altitude). Figure 2 shows the flight hardware built for the field test.

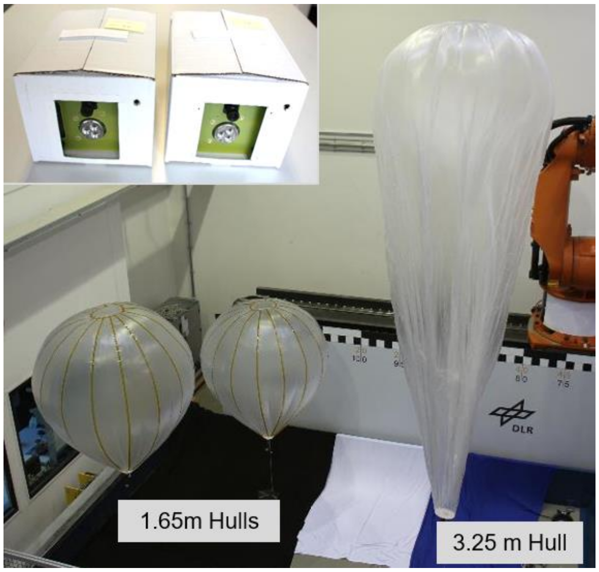

Fig. 2 *Balloon hulls during check-out in DLR's Landing and Mobility Test Facility. Image inset: Integrated avionics and sensor suite with nadir-looking radiometer and camera*

Antarctic test campaign: Antarctica provides a cold, arid, in some regions hyper-arid, climate and a high similarity to certain Martian environments [3]. Particularly the Transantarctic Mountains feature regions, which for these reasons have a heritage for use as Mars-analogues. The flight trials for this experiment took place in November 2025 in the Terra Nova Bay area in the northern Victoria Land / East Antarctica. The campaign was part of the German Antarctic North Victoria Land Expedition (GANOVEX 16) led by the Federal Institute for Geosciences and Natural Resources (BGR). All five flights have been successfully flown their mission during this period on different sites. Particularly the site 'Tarn Flat' (Fig. 3) was thereby the closest Mars-analogue with regard to its geomorphologic surface properties and was used as test area for flight LA2 (Fig. 4) with focus on terrain-atmosphere interaction. Snow ablation from catabatic winds formed this mostly snow- and ice-free area, whose dark, rocky surface is comparatively warm compared to its icy vicinity. The probe experienced significant wind shear during its flight. The data acquired from all flights are used for the further development of this probe experiment and contributes to the meteorological characterization particularly of Tarn Flat as Mars analogue site.

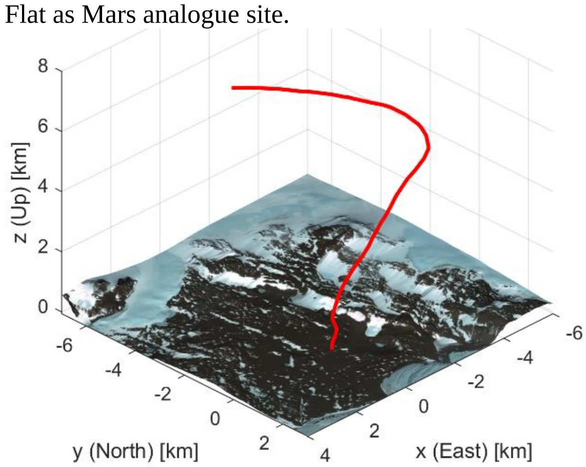

Fig. 4 *Flight trajectory of flight LA2 registered in a high-resolution digital terrain model of the Tarn Flat site. (ENU-coordinate system centered at 74.97550°S, 162.54623°E, view into south-western direction)*

References: [1] Banfield, D. et al. (2025) MEPAG
[2] Witte L. et al. (2022) Aerospace 9, 136
[3] Marchant D., Head J. (2007) Icarus, Vol. 192, Iss. 1

Fig. 3 *Panorama view of site 'Tarn Flat' showing the Mars-analogue geomorphology. Image inset: launch of flight LA2*