NASA Ames Flight Instrument Group - MARS Exploration Efforts Overview

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Brief Presenter Biography: Dr. Vandana Jha is a planetary scientist at NASA Ames Research Center. She works with the Flight Intrument Group developing new instruments. She supports Volatile Investigation Polar Exploration Rover (VIPER) Mission Operations as the payload operator for the (Near Infra-red Volatile Spectrometer System (NIRVSS) instrument and also assists as an integration and test engineer.

Introduction: Flight Instrument Group (FIG) MARS Mission Overview: The NASA Ames Flight Instrument Group (FIG) MARS development activities include Aeolus, an integrated multi-probe mission to observe surface and atmospheric forcing and general circulation of Mars; the Mars Sonic Anemometer (MSA), a sonic-based, in-situ wind measuring instrument and the Saltation Sensor to detect the critical wind stress threshold for sand motion, which is believed to be a key aspect of dust lifting at Mars.

These efforts are readying the instruments to fly, and their measurements are regarded as data of high scientific priority for future flight missions. Each of these efforts focuses on addressing a measurement or capability considered critical within the Agency and traceable to the decadal survey and MEPAG Goals. As we elevate the Technology Readiness Level (TRL) of these instruments to 6 through rigorous environmental testing, and participate in forming mission concepts, we make them viable for inclusion in flight mission proposals. Below, we outline FIG's highest priority advancements for Mars exploration.

Aeolus: The Aeolus mission concept (in some versions) includes a set of landed probes, dubbed Javelins, These probes are responsible for deploying and facilitating surface operations for the Aeolus surface sensor suite. Developed in collaboration with NASA Glenn Research Center as part of the Compass study effort, the current design is illustrated in Figure 1. The Javelin features a forward payload compartment, a drag skirt, and a rear sensor mast. This solar-powered probe is engineered to function across all longitudes and within a latitude range of +/- 45 degrees.

The drag skirt serves as a deployable system, enabling compact storage before deployment. Its front side is designed to withstand entry pressures and heating, while the backside is equipped with flexible solar panels for power generation. The estimated mass of each probe is 10.5 kg. The power system was sized to allow operations day and night at any day of the year for latitudes within +/-45 deg.

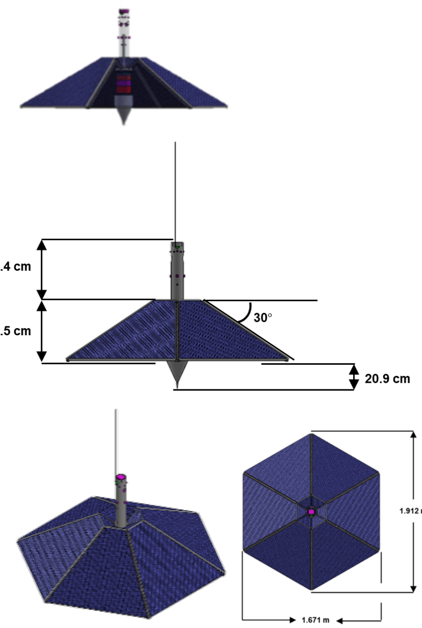

Figure 1 Concept drawing of the descent and landed Javelin probe configurations.

Mars Sonic Anemometer: The Mars Sonic Anemometer represents a cutting-edge sonic-based wind measuring instrument designed for in-situ deployment [1]. Utilizing ultrasonic transducers, the MSA emits 'chirps' into the atmosphere, enabling precise measurement of wind direction, speed, and temperature based on the travel times of these chirps when received by a corresponding transducer (see figure 2). This method facilitates rapid sampling of wind at frequencies up to 20 Hz, surpassing the capabilities of current Mars wind sensors and capable of detecting significantly gentler wind speeds down to approximately 0.01 m/s [2].

The MSA not only advances research into Mars' surface-to-atmosphere dynamics but also offers durability exceeding that of recent Mars wind sensors. Its implications extend beyond Mars, with potential applications in validating surface-atmosphere interactions on various celestial bodies including Titan, Earth, Venus, Saturn, Uranus, and Neptune. The MSA has attracted interest from a prospective Venus discovery mission, NASA's Scientific Ballooning Program, and infrasound detection initiatives by Sandia. Moreover, it can be repurposed as a hydrogen ortho/para fraction and Helium abundance sensor for deployment in giant planet descent probes.

The performance of the MSA under Mars-like conditions, operating at 6 mbar CO2 and 20 Hz, was rigorously validated at the Danish Mars Wind Tunnel [3]. The transducers successfully passed an Ames random vibration test according to APR 8070.2/GEVS standards and a JPL 2000-g impact test as part of the SHIELD lander development. Data collected from a prototype during a NASA stratospheric balloon flight further demonstrates its capabilities.

We expect this sensor to fully reach TRL6 around the time of the workshop, placing our innovative wind sensor for Mars ready for selection on upcoming flight opportunities.

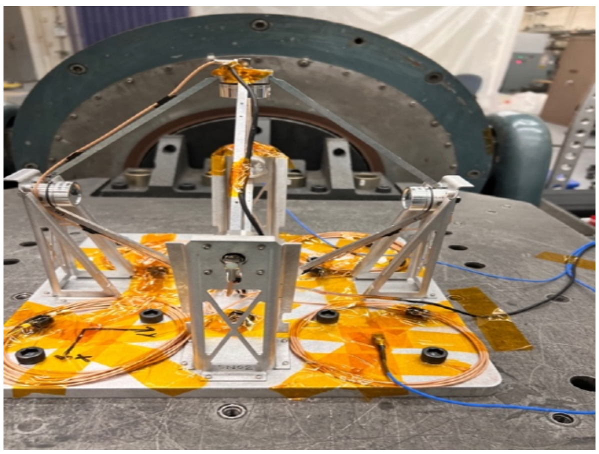

Figure 2: Mars Sonic Anemometer, including three orthogonal pairs of transducers, during successful vibration test in the Engineering Evaluation Lab at NASA Ames.

The Saltation Sensor: Saltation is believed to be a dominant factor in dust lifting, important to Mars climate and geology, with impacts to the safety of human exploration. Existing terrestrial instrumentation to detect the impacts of sand grains have not been hardened for flight and moreover they are not optimized to return sufficiently rich data for robotic remote science investigations. The Saltation sensor (figure 3) addresses all of thes shortcomings of existing instrumentation by detecting not only the timing of grain impacts, but also their speed, impact mass, and the height of the impact. Additionally, because saltation is inherently a wind-driven process, the Saltation sensor has been developed to use the same instrument back-end as the Mars Sonic Anemometer, allowing direct detection of the critical wind stress threshold for sand motion. The basic performance of the Saltation Sensor has been demonstrated in the lab, detecting grain impacts in typical Mars particle size range (100um-1mm), resolving impact size, speed, and height at impact rates up to ~1000/second. The plan is to mature these capabilities from a lab prototype to an Engineering Test Unit using similar architectures to the Mars Sonic Anemometer. The field prototype will be characterized in the lab with well-defined impacts before being tested in an active dune field, alongside state-of-the-art (but notably less capable) commercial instrumentation. Our MatISSE funded sensor will reach TRL 6 in 2025.

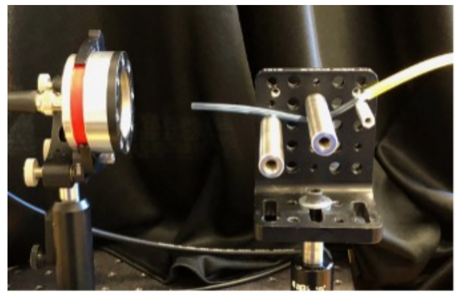

Figure 3: Saltation sensor showing the ambient pressure grain air gun to the right and a capacitive transducer target at left.

References:

[1] Banfield, D., A. Simon, R. Danner, D.H. Atkinson, K. R. Reh, 2017. SPRITE: A Saturn Probe New Frontiers Mission, *IEEE Aerospace Conference Proceedings*, paper 2871.

[2] Banfield, D., D.W. Schindel, S. Tarr, R. Dissly, 2016. A Martian Acoustic Anemometer. *J. Acoust. Soc. Am*., 140, 1420. doi:10.1121/1.4960737

[3] White. R. D et al. (2024), *Aviation Flow Testing of a Digital Sonic Anemometer for Martian and Stratospheric Environments" submitted to AIAA Aviation, 2024. Submitted December 12, 2023, under review.*