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Phosphine and Trace Gas Measurement Instrument Design in the Earth's Troposphere and Stratosphere.

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The detection of phosphine (PH_3) gas in the atmosphere of Venus [1] started intense speculation about whether PH_3 could be produced by anaerobic bacterial life on Venus as it may do on Earth. They utilized the James Clerk Maxwell Telescope (JCMT) in Hawaii and the Atacama Large Millimeter Array (ALMA) in Chile, to verify their detection. While this discovery has been contentious in the scientific community (the original study [1] have since reduced their PH_3 estimates and two other studies [2,3] refute their results), it alerted us to the lack of research on PH_3 in the stratosphere of Earth. Our instrument design [Figure 1] aims to improve this lack of data.

The easiest locations to obtain phosphine data in any planetary atmospheres are the Earth's troposphere and stratosphere. On Earth, PH_3 is thought to be a metabolic product of bacteria in anaerobic environments and is also produced anthropogenically via industrial processes. Trace amounts are contained within the Earth's atmosphere in the ppq to ppb range.

In addition to PH_3, our instrument detects 3 additional trace gasses - sulfur dioxide (SO_2), hydrogen sulfide (H_2S) and ammonia (NH_3) using precise pre-calibrated electrochemical sensors. Oxygen (O_2) is also measured to allow for instrument calibration. We are interested in discovering whether PH_3 in different layers of the Earth's atmosphere correlate with altitude or vary with other trace gasses. Secondary pressure, temperature, VOC and UV sensors allow comparison with our trace gas measurements. Our instrument will launch on a commercial weather balloon and spend four hours in the stratosphere (75,000 feet). Throughout the flight, measurements will be relayed to the main circuit board every 60 seconds. A secondary circuit board will interpret the data from each sensor, and the data will then be directed to a Metro M4. All the mounts and part trays are 3D-printed and mounted using a combination of bolts, cyanoacrylate, and epoxy adhesive. Once the experiment is recovered, the saved data will be analyzed.

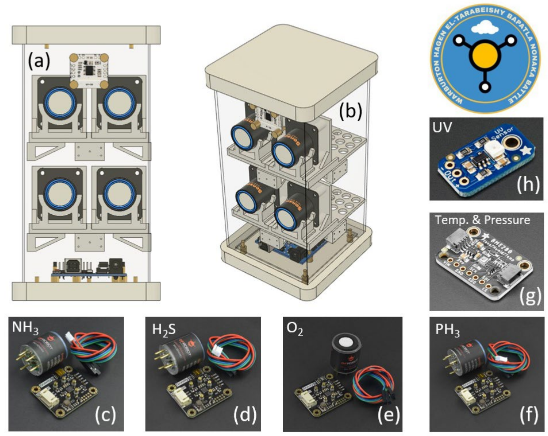

Figure 1: 3D Fusion 360 instrument design renderings of the flight box's exterior and interior design [a,b]. The blue ellipses represent the location of the protruding sensors. All the electronics including the buck converters, the data registration board and sensor hardware are located behind the trace gas sensors. At the top there is a payload interface board that connects our experiment to the telemetry of the flight vehicle. The main Metro M4 board is located at the bottom of the flight box. Figures [c-f] show the four electrochemical trace gas sensors. The circuit board we will be using to take non-trace gas measurements such as humidity, temperature and pressure [g] and UV [h] is located at the top of the instrument [a].

References

[1] Greaves et al. (2020), *Nature* 5 (7), 655-664.
[2] Villanueva et al. (2021), *Nature* 5, 631-635.
[3] Cordiner et al. (2022), *Geophysical Research Letters*, 1-9.