Aircraft sensor for detecting particle hazards

Community Partner: COffee And Telesensing Lab (COATL)

Background and Motivation

Particles in the atmosphere, such as volcanic ash, mineral dust, and wildfire smoke, pose significant challenges to aviation safety and performance. Silicate particles like volcanic ash and mineral dust are particularly hazardous when ingested by an engine, clogging components, eroding turbine blades, and potentially leading to engine failure. The acute hazards to aviation are perhaps best exemplified by the so-called Jakarta incident. In 1982, British Airways flight 009 (flying from Kuala Lumpur, Malaysia, to Perth, Australia) inadvertently entered the ash cloud from an eruption of Mount Galunggung (West Java, Indonesia). As the Boeing 747 plunged into the plume, all four engines flamed out after ingesting the ash. While less dramatic, suspended particles ("dust") also present long-term challenges to aviation. Components on aircraft flying in and out of airports with high atmospheric dust loads (like the Middle East) tend to degrade more rapidly than their counterparts operating in clean air environments.

Figure 1: Artist rendition of a British Airways 009 (Boeing 747) flying through a volcanic ash cloud, leading to engine failure. Ash does not readily shown up on weather RADAR and pilots were not aware of the hazard. Luckily, the aircraft performed an emergency landing and no one was harmed.

Objective

This capstone project aims to construct an electrostatic dust analyzer (EDA) to detect when an aircraft has entered a particle cloud. The sensor will use the fact that most atmospheric dust is electrostatically charged. As such, the sensor will detect particles by measuring the currents charged particles induce on a set of electrodes (see Figure 2). Running continuously during a flight, the EDA will provide real-time information about the particle environment surrounding the aircraft. A sudden rise in particle counts, for instance, could reveal the presence of insidious hazards like volcanic ash or wildfire smoke, complementing remote or relayed data. The immediate availability of such information would enhance the decision-making capability of pilots in situations similar to the Jakarta incident. Outside of emergency conditions, the data collected by a multitude of EDAs aboard hundreds of flights would yield invaluable insights into the current state and evolution of atmospheric dust content.

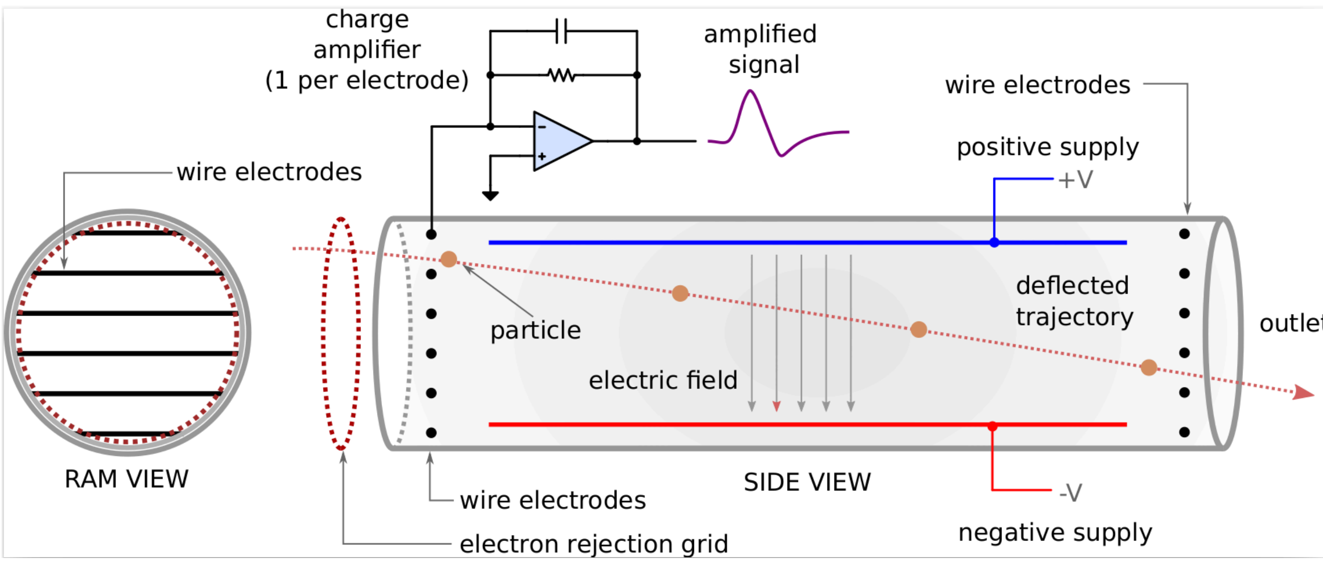

Figure 2: A conceptual schematic of an EDA consisting of a narrow, open-ended tube with arrays of wire electrodes at both the inlet and outlet. Mounted on the aircraft much like a pitot tube, the EDA samples the air as the plane is in flight. Charged particles entering the EDA will induce currents on two wire electrodes in both arrays. These signals can be used to infer the charge and size of particles.

Requirements

- Must
    - 🌕 Detect a flow of dust particles

    - Be sensitive to electrostatic charge
- Should
    - Be small and low power
    - Be able to determine the size of particles

Suggested Skills

The student team will need a mix of skills, including analog electronics, mechanical CAD design, board layout and fabrication, and 3D printing. Additional valuable skills include familiarity with machine learning algorithms, mixed-signal electronics, and basic machining.

Deliverables

Besides the course deliverables, students will deliver:

- Must
    - A prototype capable of detecting particles with diameters in the range of 50-500 microns and with charges of at least 10 fC.
- Should
    - Include hardware to digitize analog signals from sensors
    - Include software to compute particle sizes digitized signals