QuaSAR: Quantum Sensing Aerial Reporting

Problem

Modern aviation maintenance methods rely on labor-intensive, reactive inspections that typically identify structural damage only after cracks have already formed. Meanwhile, the shrinking workforce of certified technicians struggles to keep pace with the maintenance demands of a rapidly expanding global fleet. The current reliance on reactive scheduling leads to unsustainable costs and frequent, unnecessary groundings.

Innovative Solution

A Nitrogen-Vacancy (NV) Quantum Sensor utilizes atomic defects in a diamond lattice to detect minute magnetic field variations that indicate structural fatigue at the molecular level.

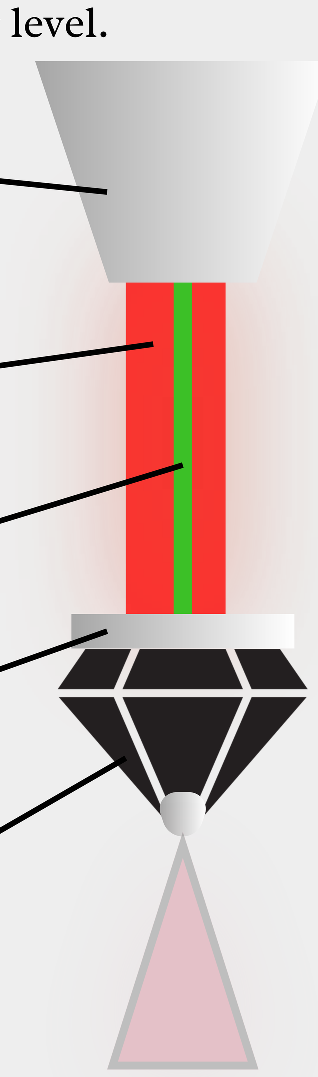
The Photodiode is a high-sensitivity semiconductor that coverts the captured fluorescence light into an electrical signal that allows the system to read the exact level of material fatigue

The Fluorescence is the red light emitted by the diamond's nitrogen-vacancy centers that changes in intensity to provide a visual map of the magnetic fields within the aircraft's surface.

The Green Laser is a 532 nm beam used to excite the nitrogen-vacancy centers and initialize their quantum state for sensing.

The Lens focuses the laser onto the diamond crystal and collects the resulting light emission for high-precision data acquisition.

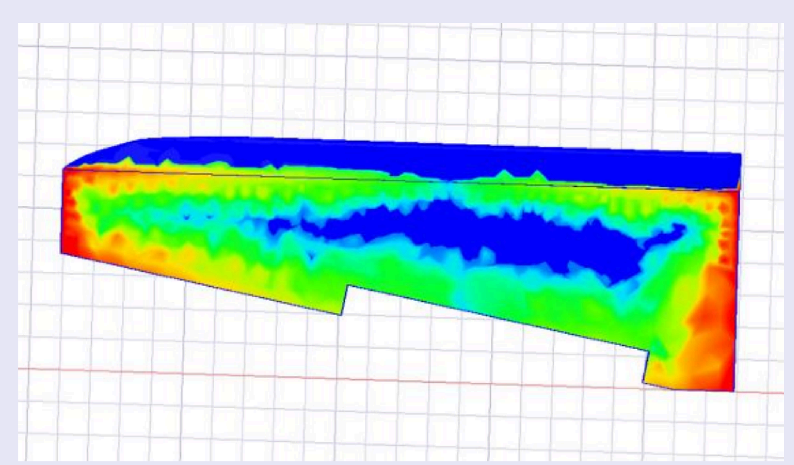
The NV Diamond serves as the quantum transducer that alters its fluorescence intensity in response to local atomic-level magnetic fields.



Deployment

The drones are deployed onto pre determined paths where the sensor probe performs high-precision scans of aircrafts inside hangars. The tilt-rotor and gimbal help maintain a constant 1–5 mm distance to capture atomic-level magnetic data while remaining immune to the high-frequency vibrations of the flight system.

Data Analysis



The system collects data by scanning surfaces with the NV Quantum Sensor by measuring changes in the flourescence intensity of nitrogen vacancy centers. The optical signals are converted into magnetic field maps that show the material stress and fatigue within the aiframe structure. The data is gathered and processed in real time within the hangar by having the data sent over to computers in which further analysis can be made

Maintenance

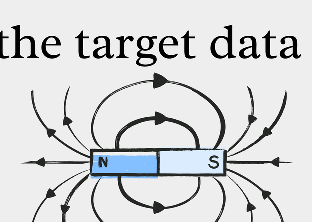
Once the stress maps are analyzed and the progression of the material fatigue is assessed, a maintenance crew can begin repairs. Over time, automated alerts can be made based on predicted structural health. This allows airlines and maintenance bays to optimize supply chains and reduce the unnecessary grounding time by scheduling ahead with earlier thresholds from the data obtained by the quantum sensor

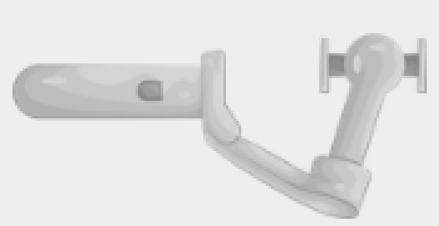
Timeline

- **2026** — Project concludes its initial design phase by validating the vibration, optical path and control systems.
- **2028** — Integration and testing phases end with the successful quantum scans and the establishment of sensitivity benchmarks.
- **2030** — Refined prototypes are deployed at maintenance facilities to compare scan data with findings from active testing methods.
- **2032** — The system preforms testing inside commercial hangars to confirm reliable operation.
- **2034** — Final FAA certification as a supplemental inspection tool is secured.
- **2036** — Commercial availability, system integrated into standard predictive maintenance workflows across the aviation industry.

Challenges

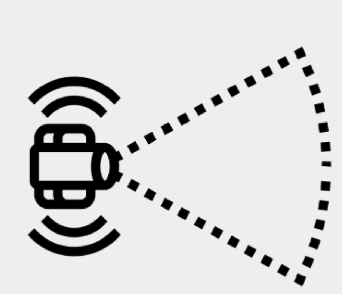
Magnetic Noise: External magnetic fields from the drone's system can cause interference and affect the magnetic readings . The solution to this is the use of a bias magnet to filter background noise and isolate the target data



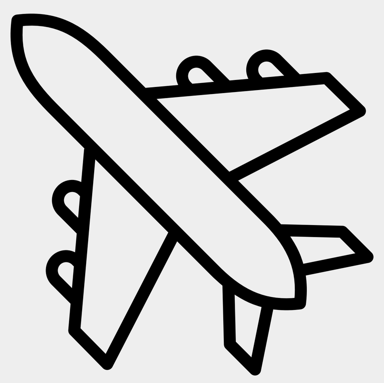


Vibrational Noise: External vibrations from the drone's systems can cause a disruption between the laser and diamond. This is solved throught the use of a motorized rotor arm and a 3 axis gimbal to provide stability.

Precision: The quantum sensor requires a constant 1-5mm distance from the surface to capture accurate data. This is solved throught the use of a LiDAR feedback loop that allows the flight controller to make adjustments in real time.

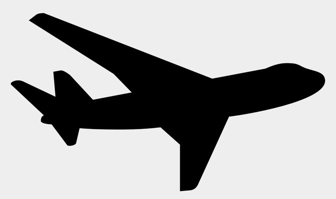


Impact



Safety: The use of quantum sensors would reveal atomic-level fatigue long before physical wear appears, this provides a critical early warning system comparable to current methods. This approach allows maintenance teams to address potential problems instead of reacting to visible damage.

Efficiency: Automating inspections drastically reduces inspection times compared to traditional methods. This lowers the aircraft on ground time significantly improving fleet avilability.



Sustainability: Using this condition based maintenance model the operational lifespan of airframes can be extended which reducses the demand for new manufacturing. The commercial aircraft industry would see less industrial waste by preventing premature replacements of expensive, structurally sound components based on predetermined schedules.