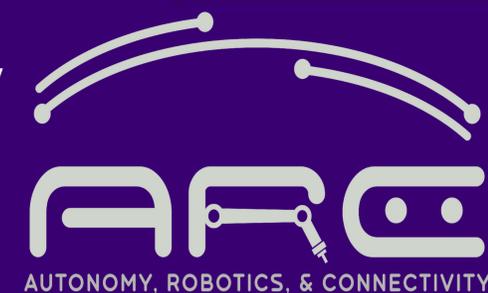# SHIELD: Smart Hardware Inspection for Early Latency Detection

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Motivation

Sensors in embedded systems are used across a many different industries, such as aerospace, robotics, industrial automation, and healthcare. As more autonomous systems are developed, the reliability of sensor data becomes increasingly important. For example, the Boeing 737-Max accidents in 2018 and 2019 were largely caused by a single angle-of-attack sensor. SHIELD aims to monitor sensor behavior and predict failures early enough to mitigate them.

The plane's sensors took different readings
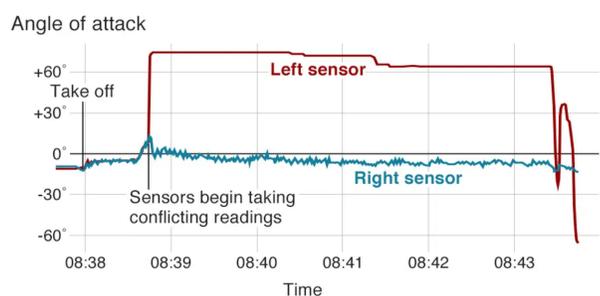
Source: Ethiopian Aircraft Accident Investigation Bureau

"Boeing 737 Max: What went wrong?" BBC. https://www.bbc.com/news/world-africa-47553174 (accessed February 8, 2026).

Data Collection

We are currently obtaining data from Inertial Measurement Units (IMUs), pressure sensors, and temperature sensors.

In addition to publicly available degradation datasets, our research also involves gathering data for failing sensors. There are two ways this can be achieved:
1. Failure can be artificially inserted (Fault Injection)
2. The sensor hardware can be damaged intentionally

Data is recorded on different models for each sensor modality

Different Sensor Models
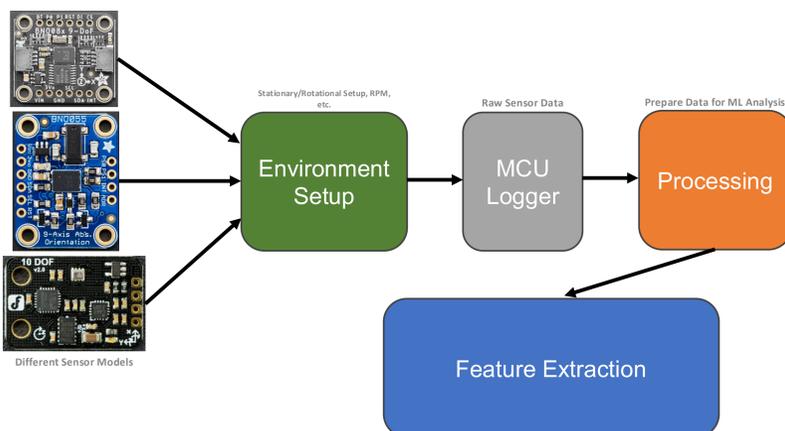
Approach

- Sensor-agnostic signal characterization: Wavelet-based decomposition extracts features to classify modality and assess early degradation.
- Hybrid anomaly detection: Isolation Forest, a convolutional autoencoder, and EWMA/CUSUM drift detectors run in parallel and fuse into a unified health index.
- Lightweight forecasting: Wavelet features and residuals feed a quantized LSTM
- Decision logic for early warnings: Threshold-based alerts trigger actions
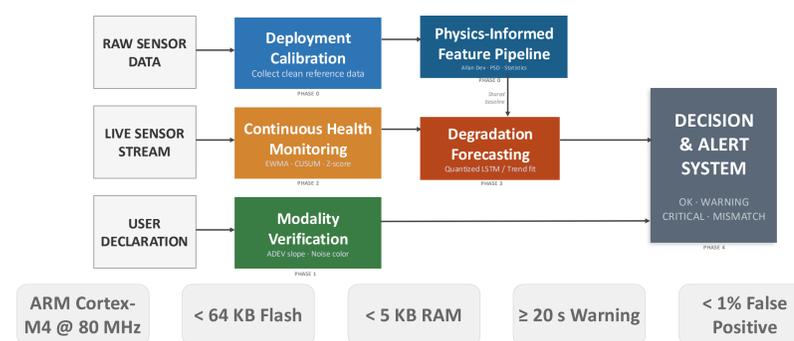
| ARM Cortex-M4 @ 80 MHz | < 64 KB Flash | < 5 KB RAM | ≥ 20 s Warning | < 1% False Positive |

Results

Sensitive features respond strongly to both noise and environmental changes, while stable features remain consistent—enabling separation of true degradation from operating-condition effects.

Stable vs Sensitive Features — Degradation Detection vs Environment Sensitivity
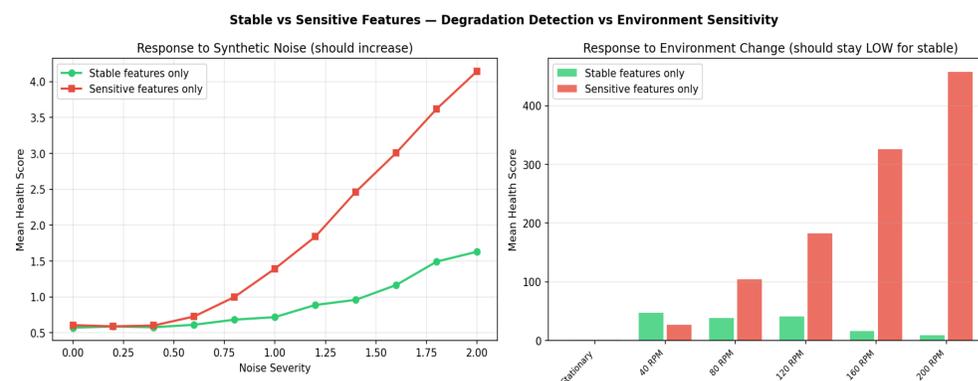
The health score rises steadily as both noise and bias drift increase, showing that the quality vector is sensitive to multiple forms of synthetic degradation.

Quality Vector Response to Synthetic Degradation
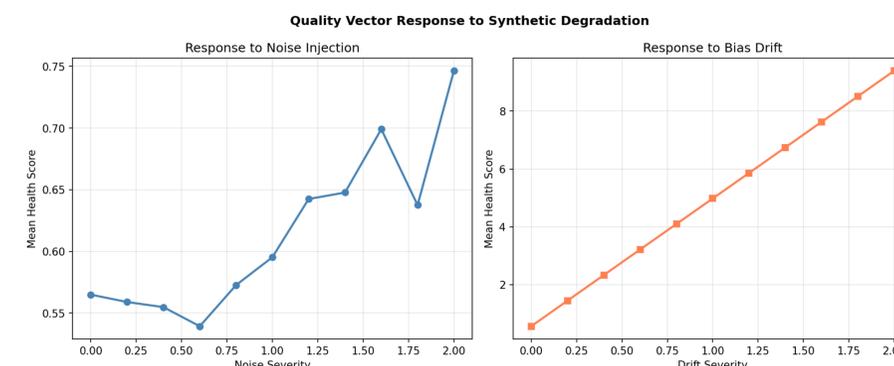
Challenges

This project presented several key challenges across data collection, modeling, and evaluation

- The same type of sensor could be used in a variety of environments, i.e. a gyroscope will have vastly different readings depending on if it is on a plane, car, or person. This makes it difficult for the model to predict if the device is faulty or the state had changed
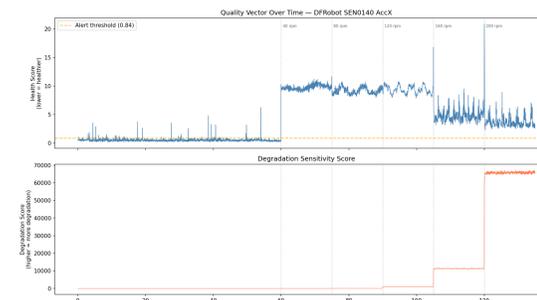
- Ensuring the framework is truly sensor-agnostic would be challenging to implement and test, as there is an extensive set of sensors with different capabilities

Future Work

- Additional testing must be done with different sensors, environments
- Framework to be implemented on embedded platforms
- Papers to be published on data collection process, sensor modality and degradation detection
- Study commercialization, patent possibilities

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