TechThrive 2.0 – Idea Submission Template (Phase 1)

Theme: Innovating for a Better Tomorrow

1. Team Details

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Team Name

TechMavu

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Team Members

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2. Problem Statement

Structural failures in bridges, buildings, and infrastructure often occur due to undetected micro-cracks, material fatigue, or stiffness degradation. Traditional Structural Health Monitoring (SHM) systems rely on expensive sensors, specialized equipment, and complex installations, making them inaccessible for widespread or low-cost monitoring.
In developing regions and smaller municipalities, continuous monitoring of infrastructure is rarely implemented due to high costs and technical barriers. As a result, early warning signs of structural weakness go unnoticed, potentially leading to catastrophic failures, economic loss, and risk to human life.

There is a need for a low-cost, accessible, and scientifically reliable structural monitoring solution that can detect early-stage integrity loss without requiring specialized hardware.
SIL (Structural Integrity Lab) addresses this gap by transforming a standard smartphone into a precision vibration analysis tool capable of detecting structural micro-shifts using advanced signal processing techniques.

3. Proposed Solution

SIL is a low-cost Structural Health Monitoring system that:

- Uses smartphone motion sensors to capture vibration data
- Performs real-time spectral analysis
- Detects natural frequency shifts
- Calculates an Integrity Score
- Provides scientific error margins using CRLB (Cramér-Rao Lower Bound)

By analyzing frequency shifts ($f \propto \sqrt{k}$), SIL detects reductions in structural stiffness — an early indicator of cracks, fatigue, or damage.

The system combines:

- Digital Signal Processing (detrending, filtering)
- Welch's Power Spectral Density (noise-reduced frequency estimation)
- Statistical confidence analysis

All through a user-friendly real-time dashboard.

4. Innovation Aspect

Novelty

- Converts a smartphone into a scientific SHM instrument
- Uses Welch's PSD (Power Spectral Density) instead of basic FFT (Fast Fourier Transform) for more accurate frequency detection
- Applies Cramér-Rao Lower Bound (CRLB) to calculate theoretical minimum variance
- Provides quantifiable confidence instead of just visual analysis

Uniqueness

- No expensive accelerometers required
- Web-based architecture (React + FastAPI)
- Real-time structural integrity scoring
- Practical, scalable, and deployable in resource-limited environments
- Combines structural mechanics + DSP + statistical modeling

5. Technology Stack

Languages & Frameworks:

- TypeScript
- Python
- HTML
- React
- FastAPI
- Tailwind CSS
- Vite

Tools & Hardware:

- Bun (package manager)
- Uvicorn (ASGI server)
- Smartphone (used as vibration sensor via DeviceMotion API)

APIs:

- Web DeviceMotion API (to capture real-time acceleration data from smartphone sensors)
- REST API (FastAPI backend for spectral analysis processing)

6. Feasibility & Expected Impact

Feasibility

- Uses existing smartphone sensors (no additional hardware required)
- Real-time vibration capture via Web DeviceMotion API
- FastAPI backend performs efficient spectral analysis (Welch's PSD)
- Lightweight full-stack architecture (React + Python)

Expected Impact

- Early detection of structural damage through frequency drop analysis
- Affordable alternative to traditional SHM systems
- Improves public infrastructure safety
- Suitable for rural and resource-limited regions
- Scalable to smart city and IoT monitoring systems