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TSYP13

TECHNICAL CHALLENGE

TECHNICAL REPORT

ASTRA

Artificial Supervision & Time-Critical Recovery Automation

A Distributed AI Architecture for CubeSat Resilience

2025

1. High Risks

Power System: Overcharging of the battery, undervoltage, degradation of the solar panel, and energy waste (communication components remain active even though ground communication occurs only 7–10 minutes per 45-minute orbit).

Thermal Control System: Overheating caused by radiation failure or internal heat buildup.

On-Board Computer (OBC): Memory corruption, watchdog resets, software hang-ups, and excessive temperature levels on the OBC.

2. Idea

The proposed solution introduces a **distributed autonomous monitoring architecture** based on **AI fragmentation across two electronic boards** to guarantee **ultra-fast response** and **continuous mission safety** for CubeSats as long as a **mutual supervision** via a close feedback loop between the two boards(if one board fails, the other automatically activates a backup process to maintain operation stability). The system operates as a lightweight orchestrator, coordinating the detection, detection of anomalies, fault isolation, and recovery of the subsystem in real time while respecting the strict power and computational constraints of a 3U CubeSat.

An **economic subsystem** will be integrated to assist the Electrical Power System (EPS) in managing power by placing the CubeSat in an **economy mode**. In this mode, only essential components (OBC and sensors) remain active, while communication components are powered only during ground contact. An **impulse testing system** will also be implemented to verify the health state of certain circuits when necessary. In addition, **watchdogs** will be used to automatically recover from software hang-ups.

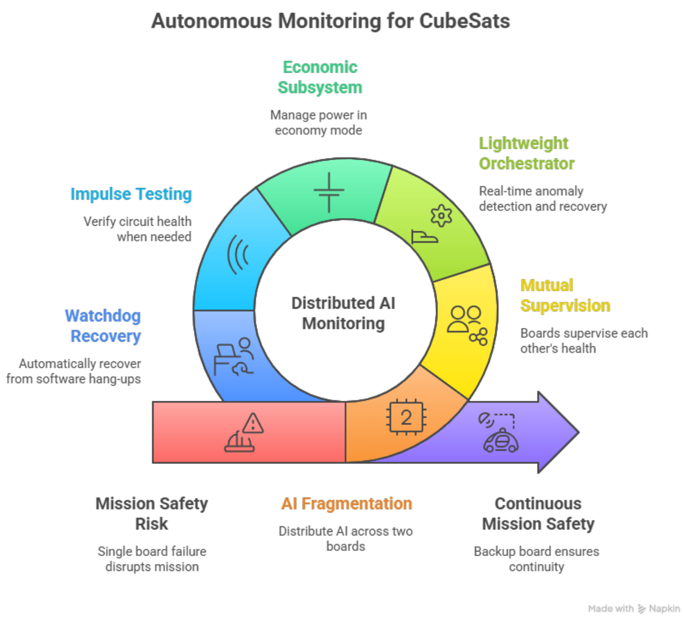

Figure 1: System architecture diagram illustrating the distributed AI monitoring process.

3. Electronic Components

Component	Qty	Performance	Cost & Business Justification
STM32H7A3RITx	2	ARM Cortex-M7 (280 MHz)	High processing power for embedded AI at low energy and cost; supports distributed AI computation across two boards.
FPGA	1	Parallel logic (ns scale)	Ultra-fast, reconfigurable, and reliable for real-time anomaly mitigation, reducing long-term costs.
INA226	1	140 µs conversion	Precise current measurement via I^2C with low power and PCB simplicity.
LM35	1	10 mV/°C sensitivity	Affordable, accurate temperature sensor with minimal calibration needs.

4. Artificial Intelligence

First AI Moddel prediction of anomalies (STM32_1): STM32_1 processes input data using a 1D-CNN model trained on datasets of average temperature, voltage, and current patterns. The model output is a matrix containing confidence levels for the classes: `obc_normal`, `obc_anomaly`, `pdu_normal`, and `pdu_anomaly`.

Second AI Model – GXROOT (STM32_2): STM32_2 processes the confidence rates of the classes as long as inputs datat about the state of the OBC and the PDU to predict the cause of the anomaly (thermal instability , voltage sag , solar flare interference , sensor drift , voltage fluctuation overheating) . Then it performs specific corrective actions (throttle CPU frequency to lower power dissipation , stop non critical tasks to reduce heat geaneration , trigger software watchdog ...) according to the cause of the anomaly via FPGA.

5. Space Environment Protection

To prevent **Single Event Upsets (SEUs)** — bit flips caused by high-energy particles such as cosmic rays striking sensitive electronic nodes — a **Triple Modular Redundancy (TMR)** scheme will be implemented in critical areas. This ensures that corrupted data is automatically discarded while maintaining reliable system operation in harsh radiation environments.