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Preventing Mission Failure Without Ground Control for CubeSats

IEEE IES Tunisia Section Chapter & IEEE AESS Tunisia Section Chapter

TSYP13 TECHNICAL CHALLENGE

SCOPE & TOPIC:

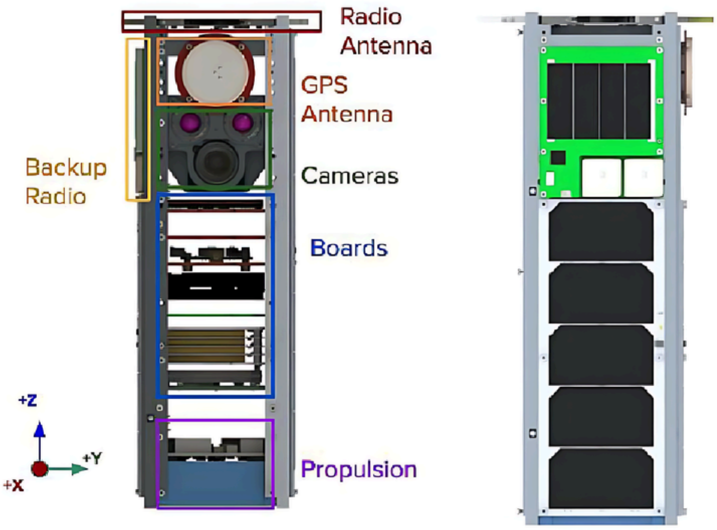
This challenge addresses the critical need for **advanced autonomous monitoring** systems that leverage AI to prevent mission-critical failures in CubeSats operating beyond ground control reach, thereby enhancing mission success rates and advancing space technology capabilities. Participants must research the most important parts of a standardized **3U CubeSats** and design a 24/7 electronic monitoring system that applies industrial predictive maintenance principles to space hardware. Solutions must operate within CubeSat resource constraints, using existing electronic boards (Arduino, Raspberry Pi, FPGAs) or custom PCBs, and leverage AI-driven decision logic to autonomously detect subsystem anomalies and trigger hardware corrections without ground intervention.

Problem Statement:

CubeSats operate in environments where ground control is either impossible or too slow to prevent irreversible failures. Communication blackouts, orbital latency, and limited bandwidth mean critical anomalies must be resolved onboard within seconds to minutes. CubeSats suffer irreversible mission failures when minor electronic or mechanical anomalies escalate during orbital periods with no ground contact. Historical failures prove that even non-catastrophic electronic or mechanical glitches when unaddressed in real time trigger total mission loss, with anomalies like thermal runaway or attitude oscillations propagating faster than ground communication cycles.

Challenge Goal:

Create a validated autonomous electronic subsystem that continuously monitors empirically high-risk CubeSat subsystems, uses AI to detect pre-failure signatures in real-time sensor data, and executes immediate interventions to prevent anomaly escalation into mission-critical failures, all while operating within 3U CubeSat resource constraints and proving effectiveness against historical mission failure scenarios. The system must operate exclusively through electronic components and demonstrate capability to function reliably in space without ground support or manual intervention.



Instructions and delivrables:

- **Phase 1: Ideation & Report Evaluation**
  - **Deadline: 10 November 2025**
  - **Instructions:**
- **1. Subsystem Analysis**
  - Research high-risk CubeSat subsystems (based on failure databases & mission history).
  - Justify choices with empirical evidence.
- **2. Electronics Implementation**
  - Use only electronic components (PCBs, MCUs, FPGAs).
  - Guarantee responses at electronic speeds.
  - Provide infrastructure for AI model deployment + real-time data processing.
- **3. AI Integration**
  - Develop anomaly detection & autonomous response system.
  - Continuously process sensor data to identify pre-failure signatures.
  - Trigger immediate corrective actions at

hardware level.
  - Include adaptive logic for hybrid failure cases
- **4. Space Environment Readiness**
  - Fit within 3U CubeSat volume, mass, and power limits.
  - Ensure resilience to thermal cycling, radiation, and vacuum.
  - Design for autonomous operation without ground support.
- **5. Validation & Testing**
  - Create protocols simulating space conditions (radiation, EMI, thermal).
  - Demonstrate AI accuracy + latency under fault scenarios.
- **6. Documentation & Repository**
  - Provide clear documentation of circuits, AI algorithms, and test results.
  - Maintain a structured GitHub repo with specs, code, and procedures.
- **7. System Integration**
  - Ensure interoperability with standard CubeSat subsystems.
  - Manage resources efficiently under strict power and computational limits.
- Delivrables:

All participants are required to submit **two items**:
- **1. GitHub Repository Link**
  - Repository should contain:
    - Hardware/electronics design files (schematics, RTL, firmware snippets, PCB layouts if available).
    - AI integration artifacts (models, datasets, inference pipeline code).
    - Clear folder structure and a **README.md** explaining how everything fits together.
- **2. Small Report (PDF, max 3 pages)**
  - Summarize:
    - **System Architecture** – electronic implementation + AI integration.
    - **Key Design Choices** – components, methods, constraints.
    - **Verification Evidence** – latency results, power/thermal budget, anomaly detection tests.
  - The report should serve as a high-level overview that complements the repository.

=> submit via this link.

- **Phase 2: Final Presentation & Prototype Evaluation**
  - **Deadline: 11 December 2025**
  - **Deliverables:**
    - Final Presentation
    - Prototype showcase

Rules & Criteria:

This challenge is for Student Branches (SBs) only, any SB can participate in this challenge represented by one team of 5 members (maximum).

=>Any deliverables submitted must remain anonymous.

Pitching Duration:

5 minutes

Pitching Language:

English

Scoring:

- **First phase :[50 points]**
  - **Non-Technical Criteria:(10 points)**
    - Respect rules & scope (**5 points**)
    - Creativity & innovation (**3 points**)
    - Clarity of short report (**2 points**)
  - **Technical Criteria (25 points)**
    - Focuses on engineering depth, feasibility, and technologies used.
    - Subsystem analysis & AI logic relevance (**5 points**)
    - Effectiveness of autonomous correction + integration with CubeSat systems (**5 pts**)
    - Implementation realism: hardware suitability, AI/ML methods, repo (**10 pts**)
    - Consideration of space environment readiness (**5 pts**)
  - **Bonus Points (15 points)**
    - Broader Impact & Real-World Relevance (**10 points**)
    - Application in commercial or institutional missions (up to 5 points)
    - Scalability, cost-awareness, or market relevance (up to 5 points)
    - Extra WOW Factor / Exceptional Effort (up to **5 points**)
      - Judges' discretion for standout submissions that go beyond expectations(e.g., testing in real environments, creative simulations, unique partnerships, advanced validation methods)
- **Final Phase: 30 points**
  - Quality of Pitching and Presentation (**10 points**)
    - Clarity, engagement, structure, and visual aids.
  - Prototype / Virtual Prototype + Documentation (**17 points**)
    - Prototype (**12 points**)
    - Documentation (**5 points**, using provided template, max 2 pages)
  - Bonus (**3 extra points**):
    - At least one IEEE AESS member- **1 point**
    - At least one IEEE IES member- **1 point**
    - At least one IEEE YP member- **1 point**

Please contact us through the following email address **ies@ieee.tn** or **aess@ieee.tn** for any inquires or clarifications.