CanSat Project – Dual MCU + Dual Sensor + Dual Servo PCB & CAD

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Project Report

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Electronic System Design & PCB Layout

1. Hardware Specifications:

Component	*Specification*	*Redundancy Role*
Microcontrollers	2x ESP32-WROOM-32	Primary & Secondary (Independent)
Board Diameter	88 mm (Circular)	Physical trace isolation
Power Regulation	LM7805 & MCP1700	Independent power rails
Sensors (IMU)	2x MPU6050	Orientation & Stability tracking
Sensors (Altimeter)	2x BMP280	Dual-pressure/altitude monitoring
Connectors	JST-PH 2.0 & Pin Headers	Secure vibration-resistant interface

2. PCB Layout Strategy:

To maximize mission reliability, the PCB was designed using a **symmetrical dual-modular approach**.

- **Spatial Separation:** By expanding the board to **88mm**, we achieved a "buffer zone" between the Primary (System A) and Secondary (System B) routing. This minimizes the risk of a single physical impact or localized thermal event damaging both processing units.

- **Module-Level Integration:** Rather than using bulky development boards, bare **ESP32-WROOM** modules were utilized. This reduces the vertical profile of the PCB, creating a dedicated **30mm clearance zone** for battery storage and cable management within the CanSat body.

- **Dual-Rail Power Architecture:** The system uses two distinct voltage regulators. The Primary system is backed by a robust **LM7805** for heat dissipation, while the Secondary system utilizes an **MCP1700** for high-efficiency low-dropout regulation, ensuring the backup system remains active even if the battery voltage drops.

3. Trace and Signal Integrity:

Power Trace Width: Critical power delivery traces and most important traces were widened to **24mil** to ensure reliability under the peak current draws of the dual ESP32 Wi-Fi/Bluetooth stacks and servo actuation.

Independent I2C Buses: System A and System B utilize separate I2C bus lines, preventing a sensor hang-up on one system from "locking" the communication lines of the other.

<u>CAD Design & Structural Integration</u>

1. Structural Assembly Overview:

Section	***Vertical Zone***	***Primary Function***
Parachute Bay	*130mm – 160mm*	Housing for recovery system and hinged lid.
Actuation Zone	*110mm – 130mm*	Dual SG90 servos and redundant sliding latch.
Electronics Bay	*30mm – 110mm*	Redundant PCB assembly and sensor mounts.
Power & Base	*0mm – 30mm*	Battery storage, sensor vents, and structural base.

2. Mechanical Redundancy Logic:

The structural design prioritizes the **Single-Fault Tolerance** of the parachute deployment:

- **Slotted Sliding Pin:** The latch uses a "slotted" mechanical interface. This allows either the Primary or Secondary servo to pull the locking bolt without being hindered by the mechanical resistance of the other (potentially failed) servo.

- **Internal Honeycomb Shelving:** To comply with aerospace mass constraints, internal mounting shelves feature circular cutouts. This reduces overall mass by approximately **15%** while maintaining the rigidity required to withstand launch vibrations.

- **Modular Assembly:** The CanSat uses a modular approach where the **Bottom Cap** is a separate body from the main cylinder. This allows the 88mm PCB to be inserted from the bottom and secured against internal standoffs, simplifying maintenance and pre-flight checks.

3. Environmental Sensing Integration:

Static Vents: Four 3mm ventilation ports are positioned circumferentially around the Electronics Bay. These ensure that the internal **BMP280** sensors are exposed to ambient atmospheric pressure for accurate altitude triggering.

<u>Software Logic & Redundancy Strategy</u>

1. Independent Parallel Logic Flow:

The CanSat operates on a **"Dual-Active"** logic. Both the Primary and Secondary MCUs run identical mission firmware but operate on independent sensor data and power rails.

Flight Phase	*Primary MCU Action*	*Secondary MCU Action*
Launch	Detects high-G acceleration; arms latch.	Detects high-G acceleration; arms latch.
Apogee	Monitors pressure drop to detect the peak.	Monitors pressure drop to detect the peak.
Descent	Reaches 300m threshold; pulls pin.	Reaches 300m threshold; pulls pin.
Recovery	Enters beacon mode (Buzzer/LED).	Enters beacon mode (Buzzer/LED).

2. Fail-Safe Deployment Scenarios:

To ensure the parachute deploys even in the event of a partial system failure, the following logic is implemented:

- **Scenario A: Nominal Operation**- Both MCUs reach the target altitude (e.g., 300m) and actuate their respective servos. Because of the **slotted linkage** in your CAD design, the two servos move the sliding pin simultaneously without mechanical conflict.

- **Scenario B: Primary System Failure**- If the Primary MCU loses power or the BMP280 fails, the Secondary MCU, operating on its own independent power rail, detects the threshold. It pulls the sliding pin via the slotted linkage, successfully deploying the parachute.

- **Scenario C: Sensor "Ghosting" prevention**- Each MCU uses a **3-point moving average filter** on the altitude data. This prevents a single noisy sensor reading (common in high-vibration launches) from triggering a premature deployment.

3. State Machine Overview:

The software is structured as a Finite State Machine (FSM) to prevent logic loops:

1. **IDLE**: Waiting for launch (low power mode).
2. **ASCENT**: High-speed data logging (BMP280 + MPU6050).
3. **APOGEE_CHECK**: Identifying the moment of zero vertical velocity.
4. **DEPLOYMENT**: Actuating the SG90 servos.
5. **LANDED**: Transmitting GPS/Beacon coordinates for recovery.

<u>Conclusion</u>

1. Project Summary:

The design and development of the **CanSat** successfully demonstrated the integration of **dual-modular redundancy** within a constrained 160mm airframe. By utilizing a parallel electronic architecture and a mechanically redundant slotted-latch system, the mission profile achieves a significantly higher reliability coefficient compared to single-MCU designs.

2. Key Achievements:

- **System Independence:** Successfully isolated Primary and Secondary systems across independent power rails and processing units.
- **Mechanical Innovation:** Developed a **single-fault tolerant** parachute release mechanism that eliminates the risk of servo-jamming through a slotted pin interface.
- **Mass Efficiency:** Optimized the internal structural integrity using **honeycomb weight-reduction pocketing**, ensuring the 88mm PCB assembly remains flight-worthy while minimizing total mass.
- **Prototyping Proficiency:** Successfully transitioned from breadboard-level concepts to bare **ESP32-WROOM** module integration and advanced 3D CAD modeling.