Mission: Mars – Emergency Reaction Wheel Redesign

Problem Statement

You are part of a Mars-bound mission aboard the spacecraft **Aether-1**. Midway through the journey, the spacecraft begins to tumble — your primary reaction wheel has failed. With communications lag increasing and ground support limited, it's up to **you and your onboard engineering team** to save the mission.

Luckily, you have access to a 3D printer, circuit fabrication tools, and embedded computing modules. Your task is to **design, power, and control** a brand-new reaction wheel system that can stabilize the spacecraft before it drifts off-course permanently.

Be sure to check the required values and constraints given at the end of this document.

Task 1: CAD Design of the Reaction Wheel

Objective:
Design a **3D printable reaction wheel** suitable for spacecraft attitude correction. The design should:

- Include the motor mount, flywheel, shaft, and housing.
- Be compact, mass-efficient, and mechanically balanced.
- Be printable on a 3D printer using available materials.

Deliverable:

- A CAD file (e.g., `.STEP` or `.STL`) of the complete reaction wheel assembly, along with a short description of design decisions.

Task 2: Power System Design (KiCad / Proteus)

Objective:
Design the power electronics circuit required to drive the reaction wheel motor. The design must:

- Support a brushless DC (BLDC) or stepper motor.
- Include a motor driver, voltage regulation, and protection circuitry.
- Be energy-efficient, using spacecraft-standard DC input.
- Include optional feedback sensors (Hall, temperature, etc.) if needed.

Deliverable:

A circuit schematic and PCB layout (in KiCad or Proteus), with a short explanation of how your circuit supports the reaction wheel's operation in a low-power environment.

Task 3: Control System Design – PID Algorithm

Objective:
Stabilize the spacecraft using a PID-controlled reaction wheel system. Your algorithm should:

- Use gyroscope feedback to measure angular velocity.
- Tune the PID constants (`Kp`, `Ki`, `Kd`) for smooth correction.
- Implement the algorithm in pseudo-code, Python, or C/C++.

Deliverable:
A block diagram of your control system and the PID algorithm implementation with comments explaining each section.

Evaluation Criteria:

Your solution will be evaluated based on:

- **Mechanical feasibility** of the CAD design.
- **Electrical robustness** and efficiency of the circuit design.
- **Stability and responsiveness** of your PID controller.
- **Creativity**, **clarity**, and **technical soundness**.

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Tech Stack Required

Task 1: CAD Design

- **Software:**
  - SolidWorks, Fusion 360, or FreeCAD
  - MATLAB(for inertia, torque, and flywheel calculations)

Task 2: Power System Design

- **Software:**
  - KiCad (preferred, open-source) or Proteus

- **Components:**
  - BLDC motor / Stepper motor

  - Motor driver IC (e.g., DRV8833, L298N, or ESC for BLDC)
  - Voltage regulator (e.g., LM2596, LM317)
  - Passive components (resistors, capacitors, diodes)
  - Sensors (optional: Hall sensor, thermistor)

- **Deliverables:**
  - Schematic (.sch) and PCB layout (.kicad_pcb / .dsn)

Task 3: Control System (PID)

- **Programming Languages:**
  - *Python*, *C*, or *C++*

- **Simulation Tools:**
  - *MATLAB/Simulink*, *Python (Matplotlib + control systems library)*, or *Arduino IDE*

Data/Constraints of Satellite to be taken under consideration:

Parameter	Value
Max mass of satellite	3 kg
Internal dimensions	10 cm × 10 cm × 22 cm
Moment of inertia (I)	0.0195 kg·m² (along longitudinal axis)
Initial angular velocity	5°/s (≈ 0.087 rad/s)
Target angular velocity	≤ 0.5°/s (≈ 0.0087 rad/s)
Detumbling time window	120–300 seconds
Volume allowed for reaction wheel assembly	<=250 cm³
Centre of mass	At the geometric center of the satellite

Evaluation Criteria

Component	Weightage
Mechanical design of gyro (CAD, mass balance, feasibility)	**25%**
Control loop & PID code accuracy and performance	**30%**
Power efficiency & compactness of circuit design	**25%**
Technical report and presentation clarity	**20%**