Project Brief: CubeSat 3-Axis Attitude Control Simulation

Objective:
The goal of this project is to develop a numerical simulation of a 3-axis attitude control system for a 1U CubeSat. The simulation will model the spacecraft's rotational dynamics using Euler's equations of motion and implement a feedback control law. This feedback control law is foreseen to initially be a Proportional-Integral-Derivative (PID) controller, to stabilize the CubeSat's orientation after an external disturbance. The final deliverable will include a visualization of the CubeSat's attitude response, quantitative performance metrics, and a GitHub repository containing well-documented code, figures, and reports.

Motivation:
Precise attitude control is essential for modern small satellites, enabling tasks such as imaging, communications, and scientific observation. CubeSats, due to their small size and low inertia, are particularly sensitive to environmental torques from sources like solar radiation, magnetic fields, and residual angular momentum from deployment.
By modeling a simplified 3-Axis control system, this project aims to capture the essence of spacecraft attitude dynamics and demonstrate control design principles in a compact, replicable simulation.

The project, I believe, provides a foundation that can be extended toward more advanced methods. Such as optimal control, reaction-wheel modeling, or magnetorquer actuation for future academic or research applications.

Scope & Framework:
The simulation will assume a rigid, symmetric 1U CubeSat with known principal moments of inertia. The dynamics will be expressed in body coordinates and integrated numerically. A three-axis control law will compute corrective torques to minimize the orientation error with respect to an inertial reference frame.
Key Components include:
1. Modeling: Euler rotational dynamics with quaternions or Euler Angles
2. Control: PID attitude stabilization with adjustable gains.
3. Simulation: Numerical integration (e.g., Runge-Kutta 4) in MATLAB or Python.

4. Visualization: Plots and 3D animation showing the CubeSat's re-orientation over time
5. Performance Evaluation: Settling time, steady-state error, and control torque effort.

Deliverables:

- Source Code: MATLAB or Python files implementing dynamics and control.
- Plots and Animations: Angular velocity, orientation, and control torque responses.
- Documentation:
  - CubeSat_Dynamics.pdf: Derivation of equations of motion and control laws.
  - README.md: Concise project summary, results, and instructions.
- One-Page summary: Visual overview of results for presentation or mentorship outreach.
- GitHub Repository: Publicly available with organized structure and reproducible results.

Expected Outcome:
By the end of the 10-Day Project, the completed simulation will demonstrate a clear understanding of spacecraft attitude dynamics, control theory, and numerical implementation. The project serves as a stepping-stone toward more advanced research in autonomous systems, spacecraft guidance, and control optimization. These are all fields that align closely with the expertise of UC San Diego's Control and Robotics Faculty.