INC03

HOLLOW SPHERE PLATFORM FOR ATTITUDE CONTROL TESTING OF CUBESAT

CONTROL SYSTEMS AND INSTRUMENTATION ENGINEERING

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Abstract

This project focuses on developing a ground-based test platform for the Attitude Determination and Control System (ADCS) of CubeSat satellites. By integrating a spherical structure with an air-bearing unit, the system simulates near-microgravity conditions and 3-axis rotation (Roll, Pitch, and Yaw) to facilitate the testing of attitude control algorithms. The system utilizes an ESP32-based architecture equipped with a BNO055 IMU for orientation tracking. Rotational torque is generated by DC motor-driven reaction wheels, while a stepper motor and lead-screw mechanism provide precise mass balancing. Experimental results confirm the successful integration of the prototype; although full levitation is currently limited by air compressor constraints, the system effectively reduces friction for smooth rotation. This platform establishes a functional testbed, providing a foundation for future satellite control research and optimization.

Objectives

1. To design and develop a hollow spherical platform with an air-suspension system for ground-based testing of the Attitude Determination and Control System (ADCS) and orientation control of small satellites.
2. To develop an air-bearing system that enables near-frictionless rotational motion in three axes.
3. To establish the platform as a learning and research tool in space engineering, particularly for applications related to microgravity simulation and hardware testing.

Problem

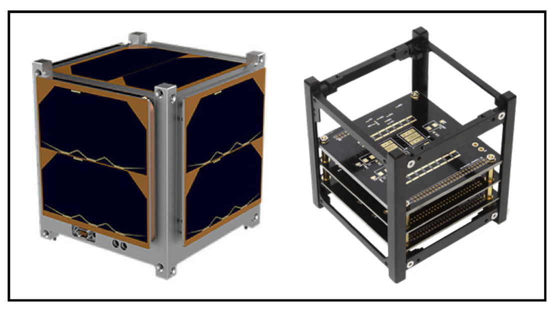
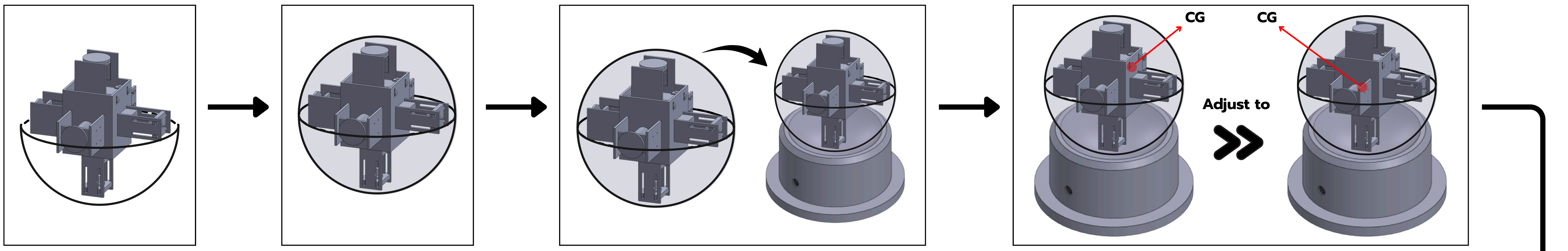


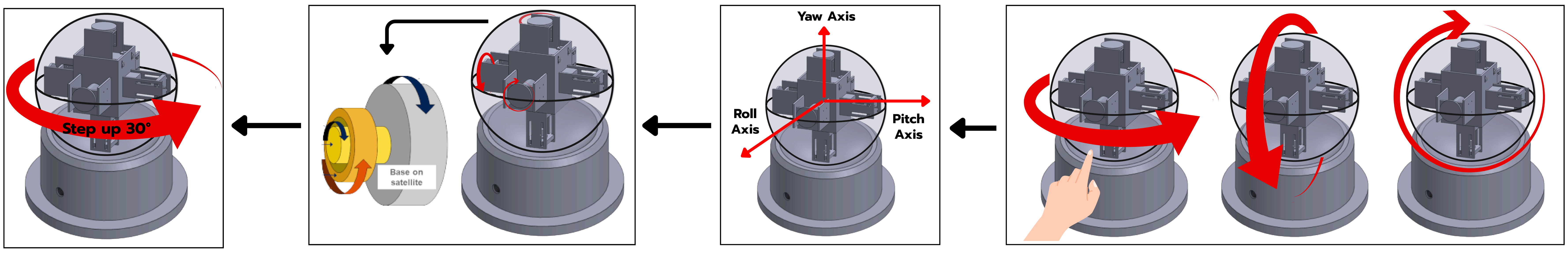
Figure 1 : CubeSat 1U

CubeSat attitude control systems must be tested before deployment, but real space testing is expensive and risky. On Earth, gravity and friction make it difficult to reproduce satellite rotational motion. This project therefore develops a low-friction hollow sphere testbed to simulate CubeSat attitude motion and evaluate ADCS performance in a laboratory environment.

System Overview



Install CubeSat in shell → Assemble sphere halves. → Mount on air-bearing base. → Adjust the CG to align near the center of rotation.



Rotate each axis manually to verify free motion. → Activate ADCS System. → Use reaction wheels to stabilize the platform. → Rotate as Commanded

Method

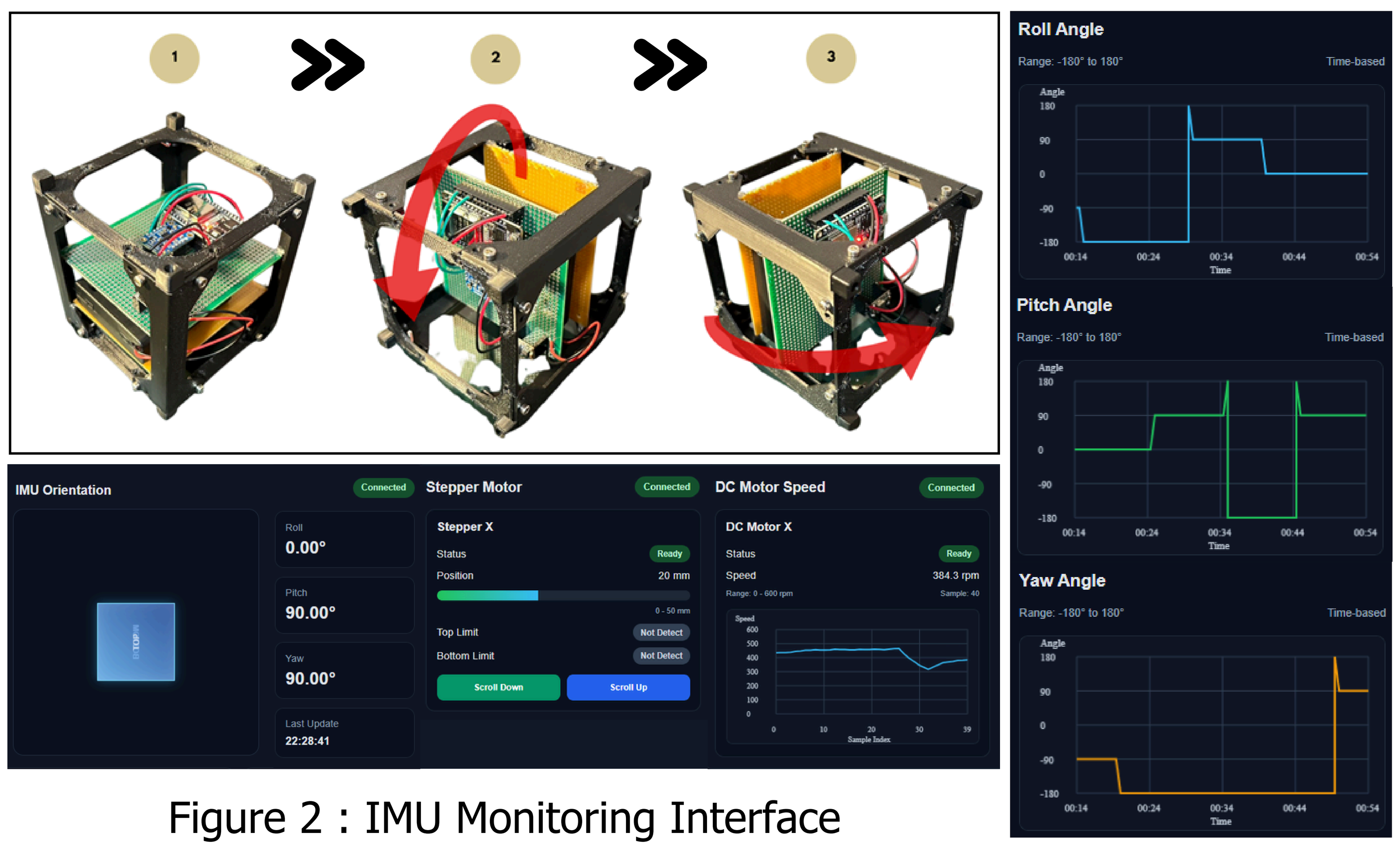


Figure 2 : IMU Monitoring Interface

The IMU measures roll, pitch, and yaw angles and displays them on the web interface in real time. The interface also controls the stepper motor for CG adjustment and monitors motor status.

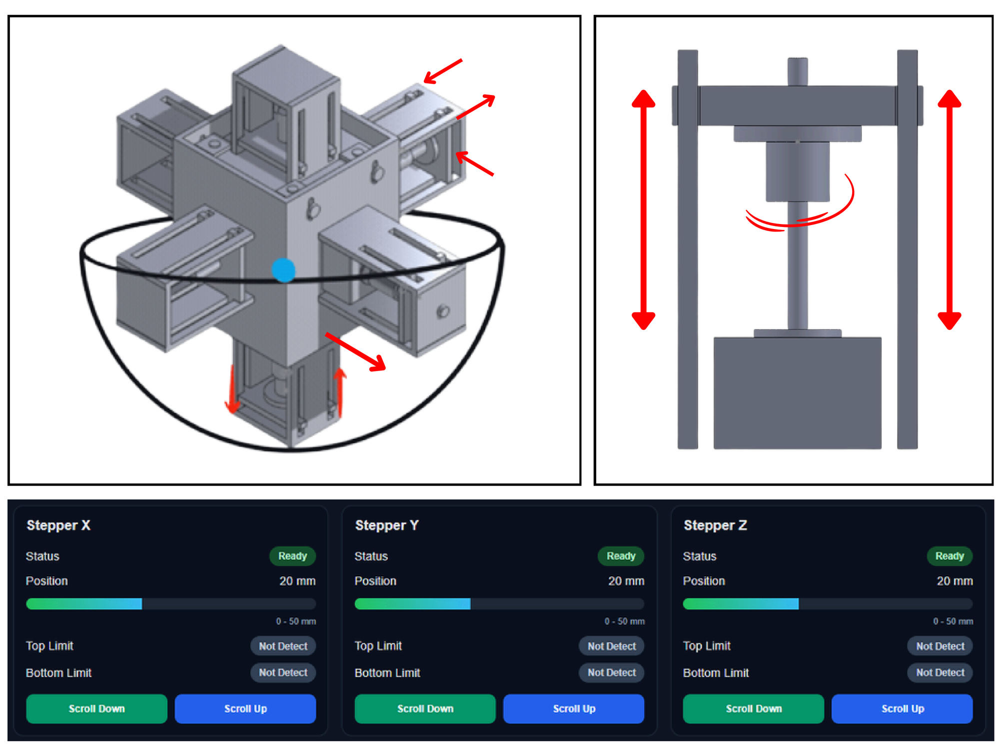


Figure 3 : CG Adjustment Mechanism

Stepper motors were integrated as a mass-balancing mechanism to adjust the internal mass position and align the center of gravity near the center of rotation before attitude control testing.

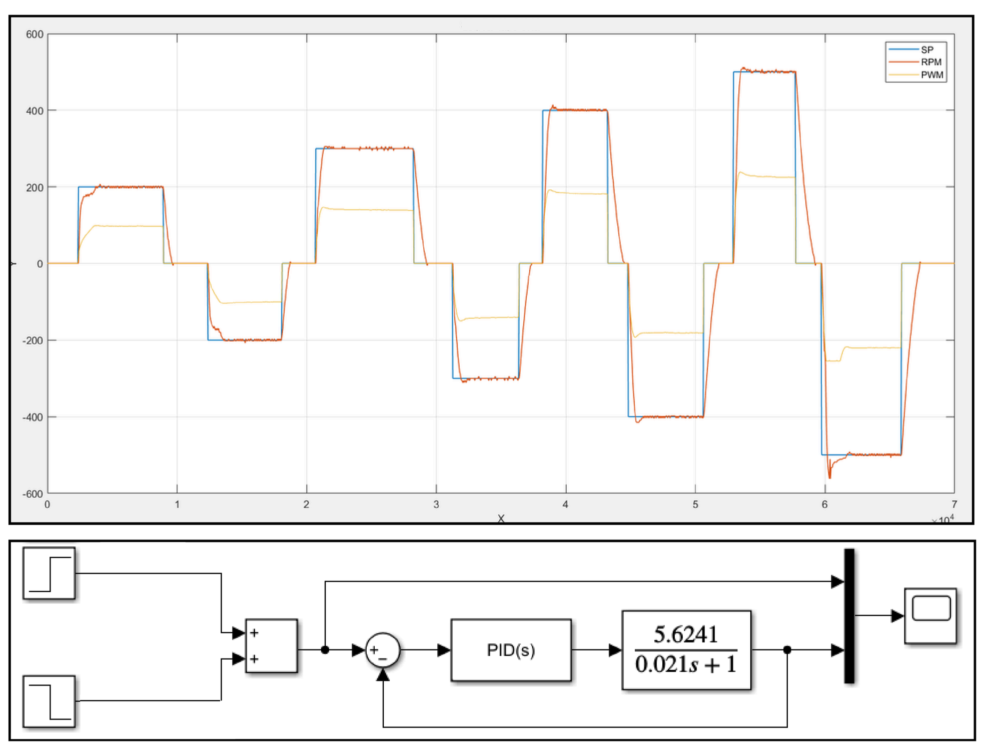


Figure 4 : Speed Control for Reaction Wheel

The DC motor drives the reaction wheel for control torque generation. Experimental data were used for transfer function identification, PID tuning, and speed response evaluation.

Reference

1. Faisal, M., Wolz, F., Dengel, F., & Montenegro, S., 2021, "A Testbed for a Three Dimensional Pico–Sphere Satellite–Simulator (T3Dpilare)", IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), 2021, No. 4067-7, pp. 1–6.

Conclusion

This project developed a hollow sphere platform for CubeSat attitude control testing. Although fully free rotation was limited by the platform weight and air supply capacity, the single-axis control concept was successfully validated. Future work should focus on weight reduction and air-bearing improvement for smoother rotational motion.