CubeSat Dual Axis Solar Articulation

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Introduction

CubeSats are small-scale satellites originally developed for academic use, but have seen broad research and commercial application since their invention in 1999. As CubeSat missions expand beyond the congested LEO regime into polar orbits and deep space exploration, power generation is critical. Most CubeSats with articulation use single axis motion to improve solar energy capture - dual axis could offer even more.

Design Objective

Compare power generation benefits between body fixed, fixed deployed, single axis articulated, and dual axis articulated solar systems **at the CubeSat scale**.

Mechanical Design

CubeSat Configuration

Designed to fit within 3U CubeSat dimensions, protyped with laser-cut acrylic and 3D-printed components. Panel housing includes 4 rows of three solar cells, placed to mimic COTS, space-ready panel architecture.

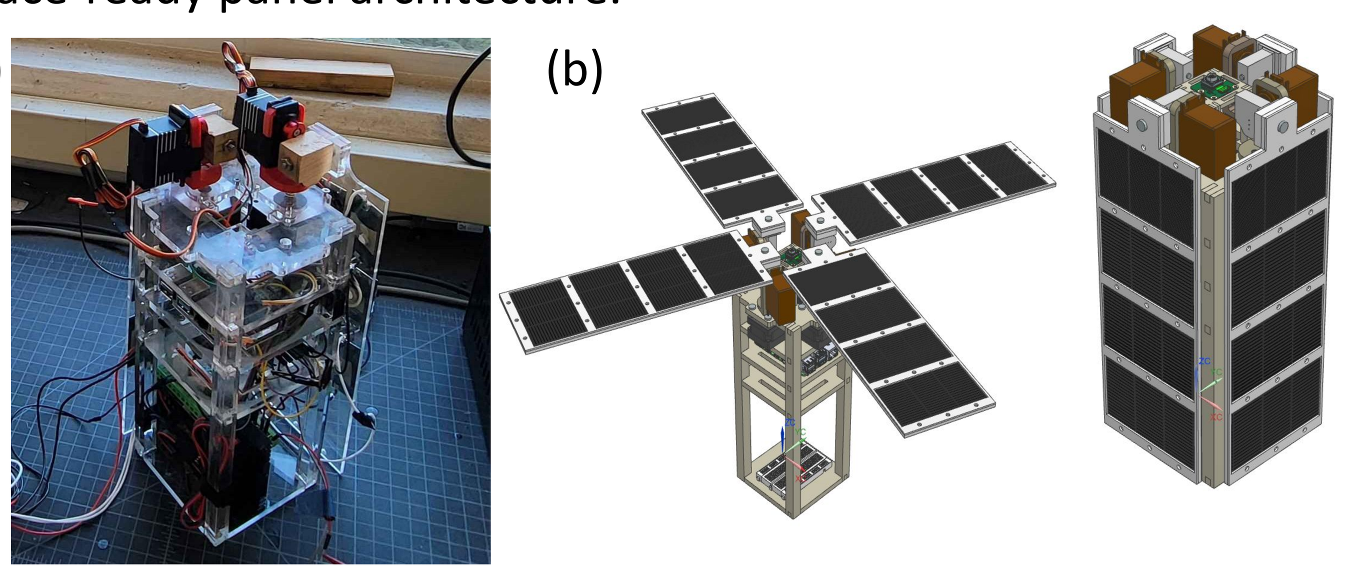

Figure 1: (a) Model CubeSat with articulation system and (b) CAD-modeled assembly

Launch configuration must be compact to fit within standardized CubeSat P-Pods. When deployed, its configuration must maximize surface area normal to light source. The motors provide articulation about the yaw and pitch axis of the panel housing.

Articulation System

- Stepper Motor (NEMA 17-39): Placed inside frame, less restrictive on weight and size; responsible for yaw
- Servo Motor (MG995): Limiting factor being size, need sufficient torque and loading current to lift and maintain panel's position; responsible for pitch
- Servo Limits: 0° to 120°, Stepper Motor Limits: -30° to 30°; serves to avoid collisions with other panels/ hardware
- Sensor: Raspberry Pi Camera Module 3 Wide

Sun-Seeking Algorithm

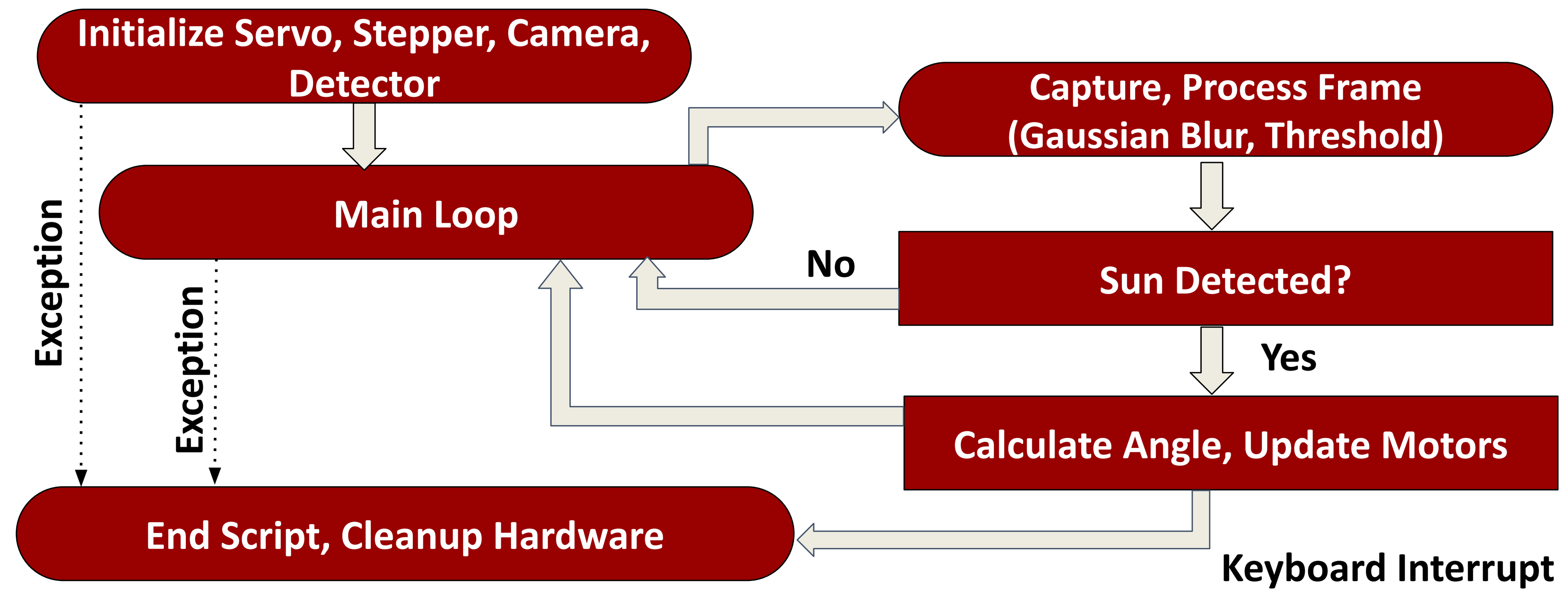

Figure 2: High-level flowchart depicting sun-seeking control algorithm. Sun tracking is implemented using OpenCV with real-time motor control achieved via multithreading.

OpenCV

Results

Table 1: Initial voltage results at sample 60° and 80° orientations

System	60°	80°
Body Fixed	0.32 ± 0.08 V	0.26 ± 0.05 V
Static Deployed	0.95 ± 0.3 V	1.08 ± 0.3 V
Dual Axis	1.9 ± 0.2 V	1.8 ± 0.2 V

Dual axis generally performed better than deployed for both panels. Voltage output by deployed is comparable to dual axis system for panel 1 (closer to light source). The static deployed and dual axis systems outperform body fixed in every case. Voltage output are lower than anticipated due to use of artificial light.

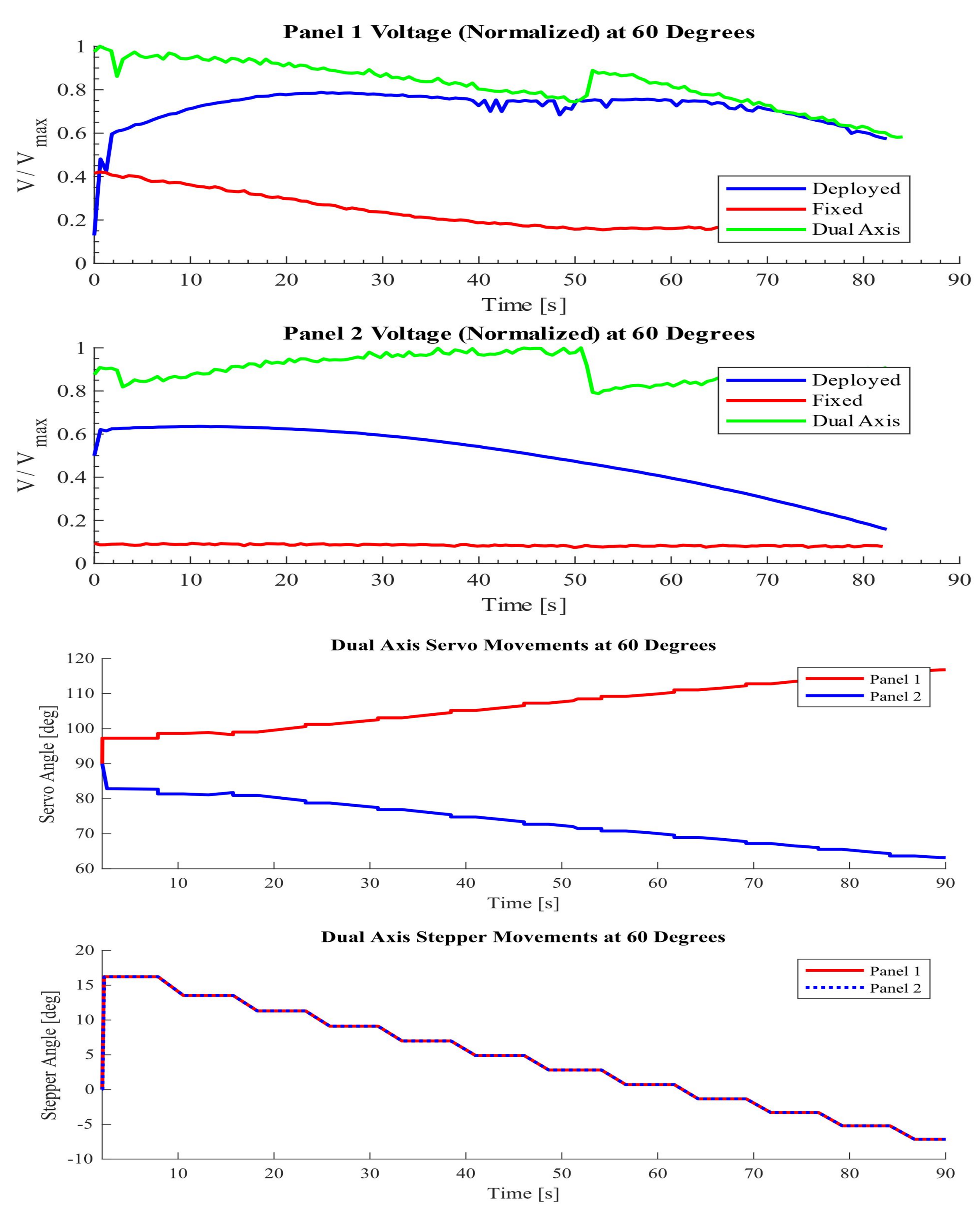

Figure 3: Motor angle and voltage output, 60°

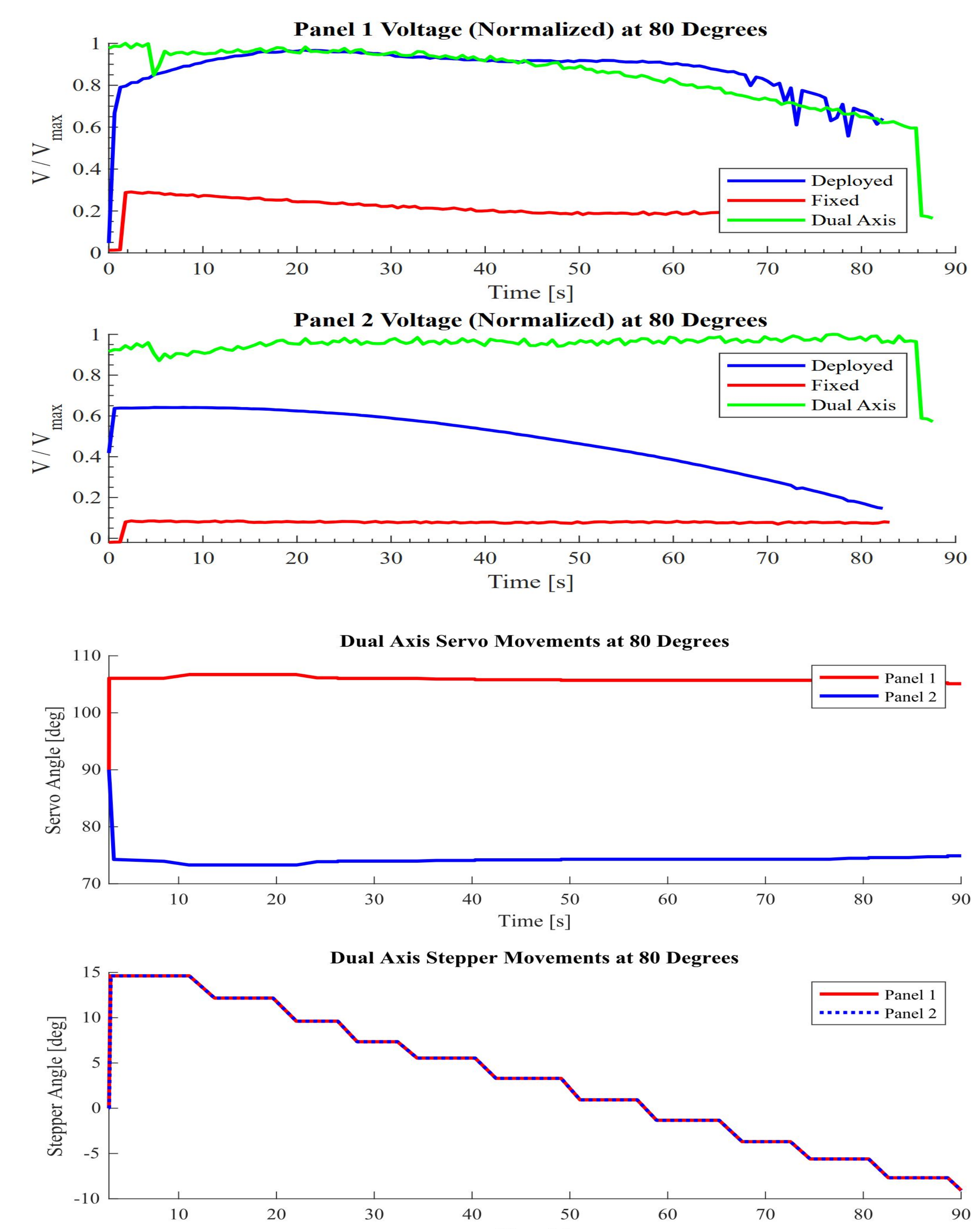

Figure 4: Motor angle and voltage output, 80°

Experimental Design

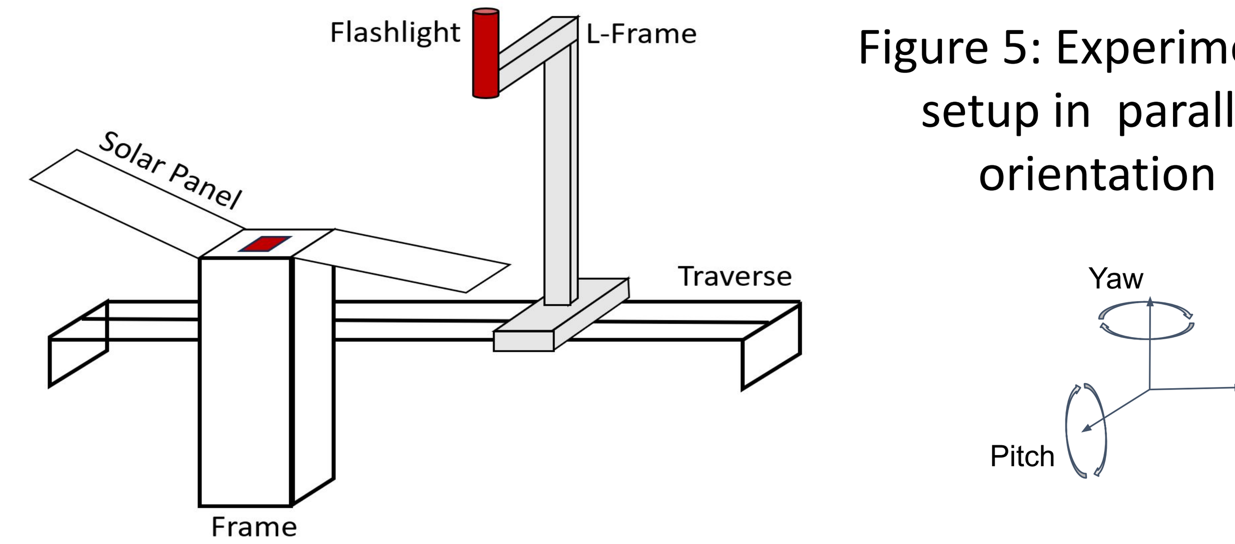

Figure 5: Experimental setup in parallel orientation

Setup features a LabView-operated traverse system equipped with an L-shaped attachment made from 8020 beams and aluminum brackets. A flashlight is positioned 42 cm above IR camera when directly overhead. Mechanism is driven by a stepper motor to translate the attachment across the frame and safeguarded by limit switched. This allows for different incidence angles from the point of view of the camera, ensuring absolute positioning and repeatability.

Conclusion

The data highlights a practical solution for increasing energy generation in CubeSats. Every orientation showed that dual axis performed equal to or better than the static deployed and fixed systems. Across the normalized voltage output tests, **dual axis articulation improved output by 48 ± 7%.**

Direct comparison between single and dual axis output **was not achieved** due to limitations of the experimental design. The linear motion of the flashlight did not motivate significant differences between the motion of a single axis vs dual axis system, rendering their voltage output indistinguishable.

Future Work

- Specializing design for CubeSats in polar orbit regimes or deployed for interplanetary missions
- Reassignment of control to a different axis (yaw to roll)
- Scaling to smaller or larger CubeSat configurations (1U, 6U)
- Integrating all four panels to demonstrate full capability
- Evaluating mechanical design with space-ready components

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