Modeling the Attitude Determination and Control Subsystem (ADCS) for Pointing

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Introduction

Attitude control—controlling the orientation of an object in space relative to a frame—is an important component of spacecraft. The stabilization and control of a satellite's orientation is necessary to point an antenna and relevant scientific instruments towards Earth so that accurate, interpretable data is collected for onboard experiments. In the case of one of the lab's satellite missions (the Multi-view Onboard Computational Imager, or MOCI) where reconstructed models of surface landmarks must be derived from images taken at near-perfect angles using a Structure-from-Motion (SfM) pipeline, attitude control is especially critical. The CubeSat must be able to determine its attitude from sensors accurately, derive the error given the measured attitude and the desired attitude, and apply torques using actuators– such as magnetorquers and reaction wheels– to minimize the error and reorient the spacecraft. This research aims to model MOCI'S ADCS through computer simulations in order to understand the algorithmic and mechanical constraints for pointing configurations and determine data needed for the mission's pointing budget calculations. Configurations, such as pointing (idle, nadir, and detumbling) and point tracking are described and proven given the developed model and other unit parameters.

Pointing Requirements

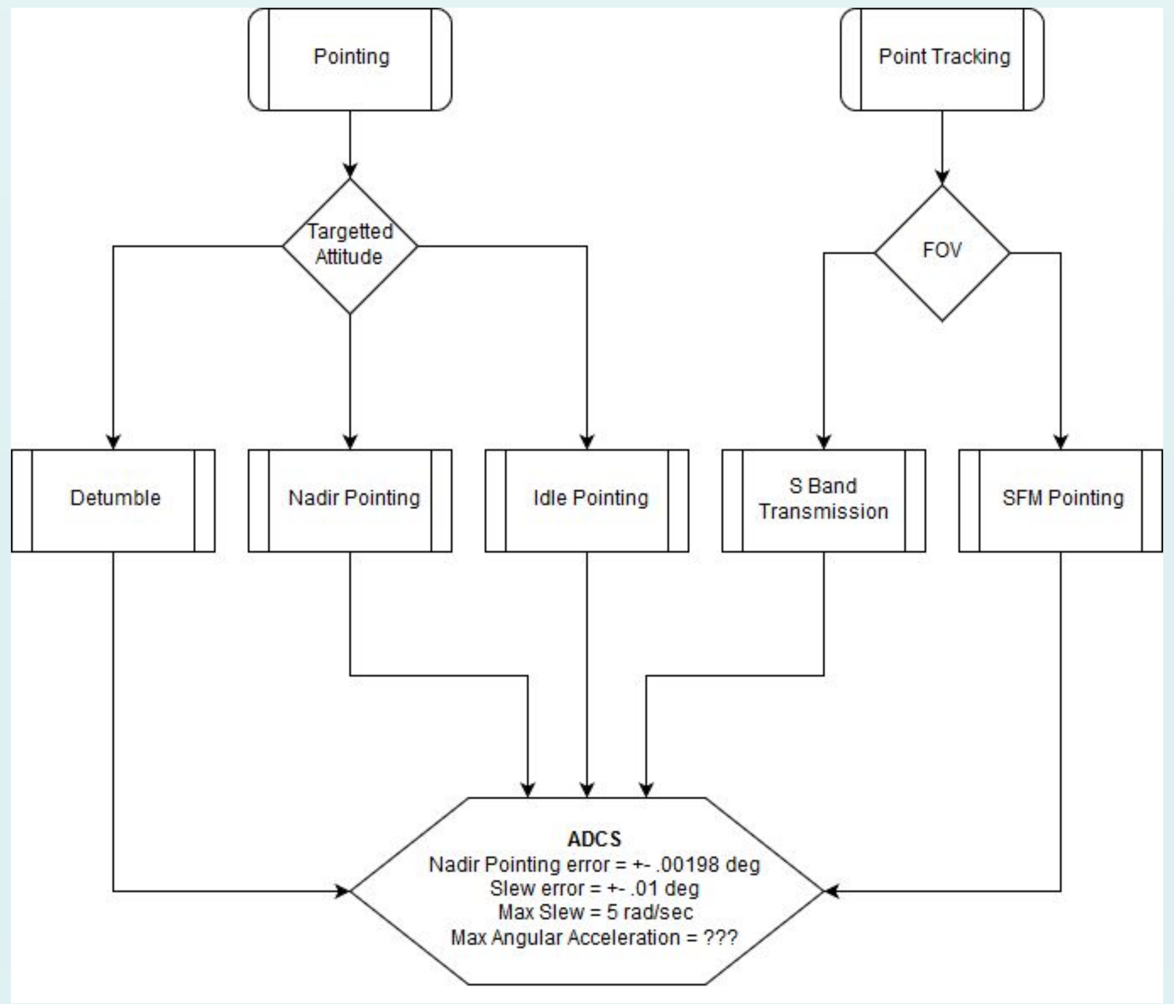

Figure 1

Before determining the capabilities of the attitude determination and control system and if those capabilities can meet mission objectives, we must define those mission objectives and the necessary pointing configurations. For the MOCI mission, simple pointing and point tracking are needed: these configurations include detumbling, idle, nadir, SFM pointing, and S-Band transmission, as Figure 1 illustrates. Parameters dependent on the ADCS such as slew rate, angular acceleration, and pointing accuracy, in addition to flight requirements, constrain these configurations (i.e. transitioning between modes, how well tracking operation). Additionally, the two point tracking configurations, SFM and S-Band, are also reliant on the Field of Views (FOV) of the imaging sensor and the S-Band transmitter. Normal point modes are, while required to be less accurate, are expected to be maintained for longer periods of time, whereas point tracking modes require high accuracy in order to point to something on ground, such as a target or our ground station. SFM tracking is constrained with optics with a FOV of 4.89° and requires that the vehicle slew 30° starting from 15° off nadir while pointing at the target, and end at 15° from nadir. Each image, ideally, has at least 50% overlap with the next image for a total of 30 images. For S-Band pointing, used for downlinking science data, the FOV is 60° at a constrained altitude and time of 1000 km and 15 minutes, respectively (the ideal/required conditions for transmission). Additionally, while performing these maneuvers, care must be given to avoid blinding the onboard star tracker and that slews begin early, so as to not introduce significant jitter into the system, which can impact the quality of images.

Figure 2

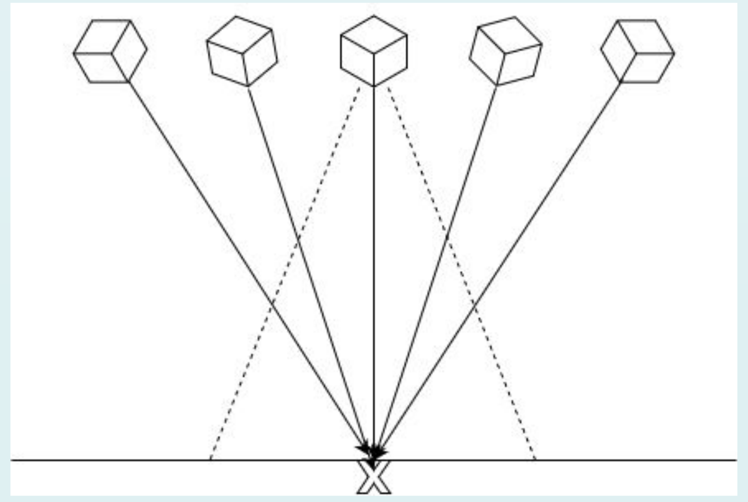

Figure 3

Methods and Approach

Given the maximum slew rate, reaction wheel torque, and momentum storage from the manufacturer, and error values from non-negligible sources, we can compute the expected slew rate and the maximum angular acceleration, which helps model the system better and adjust the pointing objectives accordingly if needed. Next, we need to simulate the system incorporating the computed characteristics/parameters using NASA's in-house 42 simulation software, which will allow us to determine nuances of the system and retrieve attitude representations of the satellite that can be used to input parameters into software during flight. Additionally, we will also use the manufacturer's Dynamic Simulation package in order to use their implemented pointing determination and control modes to further investigate the system's capabilities and refine the pointing budget.

Preliminary Results

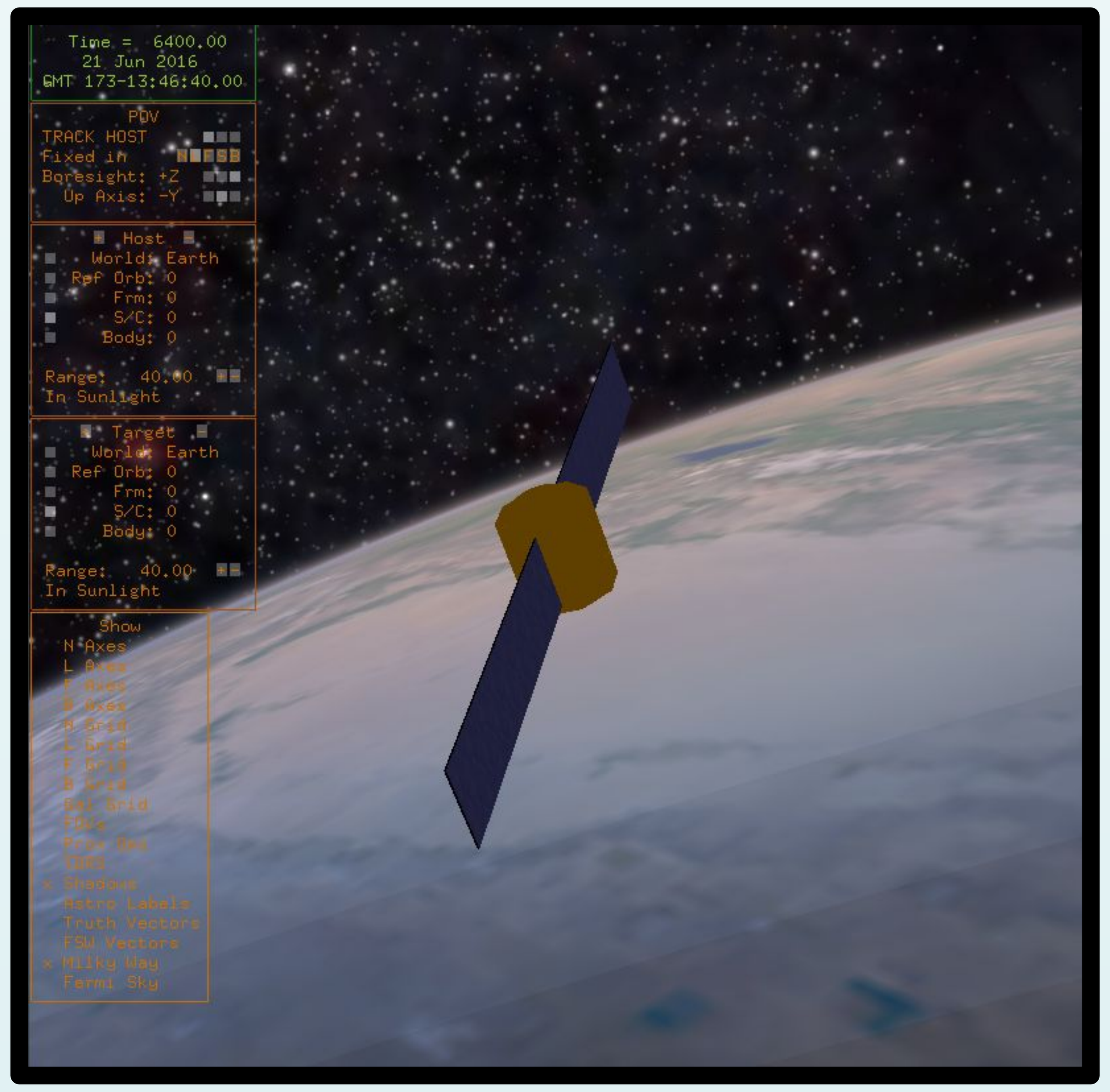

Figure 4

The maximum angular acceleration and their corresponding slew rates were able to be computed and were input into 42. With a simulation time of 10000 seconds and an altitude of 450 km (within the specified range), the output attitudes and velocities demonstrated that the vehicle was capable of nadir pointing fairly rapidly. Additional simulations will need to be performed to demonstrate mission objective point tracking capability.

References

Parker, J., Hevert, M., Heavner, N."MOCI Pointing Budget Document". 2019, Deliverable

Jensen, K., Vinther, K. "Attitude Determination and Control System for AAUSAT3". Aalborg University, Denmark. 2009. Thesis

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