Precision Pointing Requirements

Trade Study: A0001

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Purpose of Trade Study (Foresee)

The attitude determination and control system, maintains, corrects and determines the attitude of the space craft. Trade study A0001 shall focus on using the pointing requirements derived from Payload team's trade study Y0005. Using the data obtained, this study aims to integrate the spacecraft configuration & orientation with pointing requirements to determine the pointing capability required on the 3-axis of the spacecraft. The result of this study shall then be used to determine the type of ADCS (active or passive) needed.

Investigation

Trade study A0001 commences by exploring two possible spacecraft configurations and their implications. It is known that the mission definition requires the spacecraft to be NADIR pointing while it is mapping. Orbital trade study O0001 provides us the necessary orbital metrics and tangential velocity (v_{tan}) of the spacecraft. Let h_{alt}, be the altitude of the spacecraft above the surface of earth and R_{Earth} be the radius of the earth. We can now determine the rate at which the spacecraft revolves around the Earth in LEO. To do this:

$$\omega_{rev} = \frac{v_{tan}}{(R_{Earth} + h_{alt})} \tag{1}$$

To satisfy the NADIR pointing requirement, the spacecraft should maintain an angular velocity of ω_{rev} about its pitch axis while in mapping mode. Essentially, the angular velocity of the spacecraft about its pitch axis, should be the same as its velocity about the center of the Earth.
Having determined the spacecraft's angular velocity, we now explore the two choices of orientations of the spacecraft and its implications.

Long axis perpendicular to orbit (Z-face NADIR pointing):

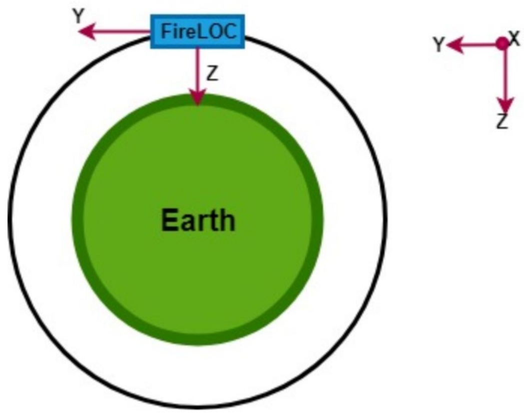

Figure 1. Long axis perpendicular to orbit

In this configuration, the +Z-face is NADIR pointing. Therefore, the X,Y & Z axis are the pitch, roll and yaw axis of the spacecraft. Further, the spacecraft will be pitching constantly at a rate of ω_{rev} *rad/s* while mapping. The IR payload shall be aligned with the z-axis, which results in the following ascending precision requirement: Z < Y <= X.
In case a passive system is possible, our choice would be to use the aerodynamic properties of the spacecraft to perform attitude control to fulfil the NADIR pointing requirement. Further, to control the torques about the pitch and roll axis, we may explore active systems or other passive systems depending on the degree of pointing accuracy.
In case an active system is necessary, there is a diverse array of devices that we may use for attitude control and the choice would depend on the pointing accuracy metrics obtained from Y0005.

Long axis aligned with orbit (z face NADIR pointing):

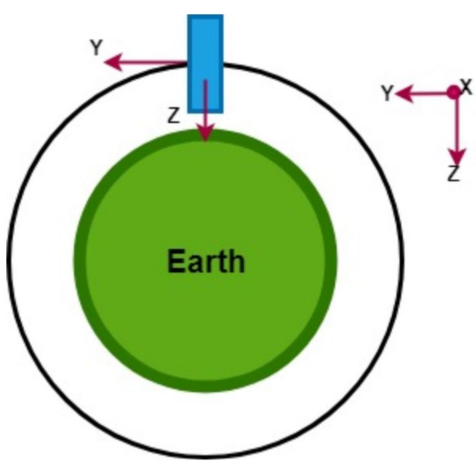

Figure 2. Long axis parallel to orbit

In this configuration, the +Z face is NADIR pointing, which results in the x,y and z axis to be the pitch, roll and yaw axis. Again, the spacecraft is required to pitch at a rate of ω_{rev} *rad/s*, while mapping. The IR payload shall be aligned with the z-axis, which results in the following ascending precision requirement: Z < Y<= X.
In case a passive ADCS is possible, the most favorable would be a gravity gradient based system. Further, to control the torque about the roll axis, other active or passive systems may be explored.
Lastly, similarly to the previous configuration, in case an active system is necessary, there is a diverse array of devices that we may use for attitude control and the choice would depend on the pointing accuracy metrics obtained from Y0001.

In this section of our investigation, we shall organize our spacecraft pointing accuracy determined by the choice of payload and orbital metrics. It was determined by the payload team in study Y0001, the pointing accuracy required very closely matched the accuracy obtained in using *Blue Canyon's XACT-50*[2] ADCS. Using the enlisted trade studies, we have the following pointing requirement metrics for our configurations defined above:

Table 1. 3-axis pointing accuracy requirement based on payload & orbit

	NADIR Pointing Req.	Orbit Normal Pointing Req.	Third Axis Pointing Req.
400 km	± 0.0699°	± 27.74"	± 30.94"
500 km	± 0.0699°	± 23.01"	± 24.75"
600 km	± 0.0699°	± 19.58"	± 20.63"
700 km	± 0.0699°	± 17"	± 17.68"

Record

Having defined specific cases and requirements for our ADCS, in this section we shall define constraints and using their implications, conclude this trade study by laying a framework for our future trade studies to make a choice between the various ADCS configurations and devices that may be used.
A study[1] conducted on Aerodynamic stabilization for satellites operating in LEO, describes the possibility of using aerodynamic drag on CubeSats operating below 500 km. Considering the orbital altitude range determined in Orbital study O0001, the 500 km threshold is right in the middle of the range, hence using this method of stabilization shall be determined by the exact orbital altitude of CubeSat as well as whether this method is capable of producing the level of pointing accuracy listed in table 1.
The use of gravity gradient stabilization has gained a lot of popularity in recent times. Along with the option of using a completely passive system, it is also worthwhile to explore a semi-passive system consisting of magnetorquers along with a gravity gradient boom, to damp the residual

error as described by a study conducted by researchers from Utah State University[3]. However, this would increase the mass of the system and occupy more volume. Further, it will still be imperative to compare the pointing accuracy obtained by using such a system with the requirement.

These systems shall be discussed and/or simulated in later trade studies to determine the exact specification of ADCS to be used in the FireLOC CubeSats.

Execute

This section subjects the supervisor of the trade study to peer review. Here the trade study supervisor, sub team liaison, and team lead must approve and sign-off at the conclusions reached. Once a FIRE document has been signed off, the trade study is considered complete. If rejected by any party for any reason, the supervisor must revisit and fix the corrections or expand on the trade study.

Signatures:

Trade Study Supervisor: ____

Sub-team Liason(s):____

Team Lead: ____

References:

[1] Aerodynamic Stability for CubeSats at ISS Orbit
https://www.jossonline.com/wp-content/uploads/2014/12/0201-Aerodynamic-Stability-for-CubeSats-at-ISS-Orbit.pdf

[2] XACT-50- Blue Canyon Technologies: http://bluecanyontech.com/xact-50/

[3] A STUDY FOR SEMI-PASSIVE GRAVITY GRADIENT STABILIZATION OF SMALL SATELLITES
https://digitalcommons.usu.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2348&context=smallsat