Active vs Passive ADCS

Trade Study Number – A0002

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Purpose of Trade Study (Foresee)

The purpose of this trade study is to use the framework laid down in A0001, along with orbital parameters from O0005**,** to determine and concretize the requirements of the ADCS system and use that to design or select viable candidates from the available COTS instrumentation. Based on the choice of instrumentation and constellation metrics, we shall determine the total cost of ADCS parts for the Fire-LOC constellation.

Investigation

The payload trade study Y0005 laid out stringent requirements for 3-axis stabilization of the CubeSat's to achieve the required pointing accuracy. The IR payload chosen, requires pointing accuracy to the measure of 0.0064 degrees about the orbit normal axis, greater than 0.0069 degrees about the third axis and 0.069 degrees about the NADIR pointing axis considering orbital altitude of 500 km.

The following table lists the maximum pointing accuracy that may be obtained by various ADCS (passive and active). This list acquires data from a study included in the NASA ADCS archives[1][3]**.**

Table 1. Attitude control: Passive and Active

Type	Pointing Options	Maneuverability	Typical Accuracy
Gravity-gradient	Earth Local Only	Very Limited	5 degrees (2-axis)
Gravity-gradient + momentum bias	Earth Local Only	Very Limited	5 degrees (3-axis)
Zero momentum (3-wheels)	Any	No constraints	0.003 degrees (3-axis)
XACT-50	Any	No constraints	0.003 degrees (3-axis)

Taking these metrics into consideration, it is straightforward to conclude that even state of the art passive attitude stabilization methods are not capable or proving this level of pointing accuracy, considering the highest accuracy which can be achieved with gravity gradient methods is around the 5 degree metric while the aerodynamic methods tend to achieve somewhere around the 3 degree mark.

The high accuracy pointing provided by reaction wheels needs to be supplemented by high accuracy determination system. The NASA State of the Art of Small Spacecraft Technology handbook lists state of the art guidance, navigation and control COTS parts. It is evident from table 1, that reaction wheels would be required to provide the needed pointing accuracy. Further, magnetorquers need to be used for momentum dumping and/or to provide a damping effect. Lastly, star trackers, as shown in the table below, provide the minimum pointing knowledge required by the control system[4].

Table 2. Attitude determination systems

Type	Performance	TRL
Star tracker	25 arcsec pointing knowledge	9
Sun sensor	0.1 degree accuracy	9
Earth Sensor	0.25 degree accuracy	9

Hence, there are two options that may be looked at- integrated ADCS or piece-wise part integration. In case of integrated system, it might be easier for installation considering there is a constellation of satellites and piece-wise integration may introduce variables and create room for error. However, cost would be a major driving factor, if a large number of CubeSats are to be deployed.

Record

Having considered the various factors driving the choice of ADCS, we may safely conclude the need for 3-axis stabilization using reaction wheels. We plan to use a system consisting of 4 reaction wheels, one for each axis and a fourth one for redundancy. Further, a magnetorquer will be used for momentum dumping. Lastly, star trackers provide the required attitude determination knowledge for the control system.

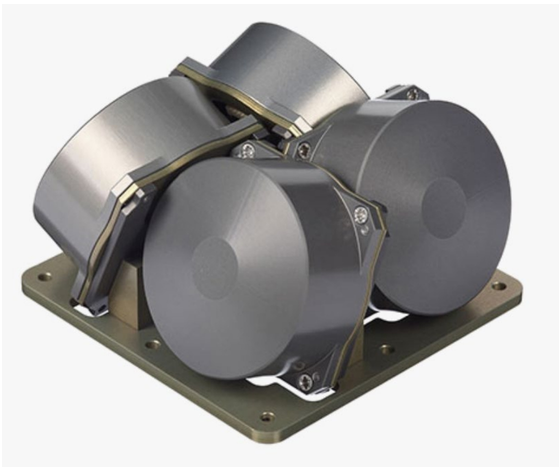

Figure 1. 4-reaction wheel configuration

Execute

Signatures:

Trade Study Supervisor: ____

Subteam Liason(s): ____

Team Lead: ____

References

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