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A guide to selecting an ADCS for a small satellite mission

Make humankind interplanetary.

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Objectives of Engineers

- Accomplish mission goals with minimum cost and time
- Balancing from reliability, cost, and development time
- Suggestion: Focus on the payload and how to extract value from a mission

How to define pointing requirement for a CubeSat mission?

- **Criteria include** 1) pointing knowledge of individual components; 2) pointing knowledge of the whole ADCS; 3) absolute pointing accuracy; 4) relative pointing accuracy (jitter) & 5) slew rate.
- **Remote Sensing Satellites with a narrow field of view (FOV) requires a better absolute pointing accuracy; for wide FOV remote sensing satellites, relative pointing accuracy would be more important.**
- **Communication Satellites using** 1) UHF-band omnidirectional antenna usually not care about the pointing accuracy; 2) 4 deg of the pointing error can cause 0.1 dB of the loss on X-band antenna; 3) 0.1 deg of the pointing error can cause 0.1 dB of the loss on Ka-band antenna.
- **CubeSats with deployable solar panels need to make sun acquisition.**

Methods of building ADCS

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Past days:
the space agency driven time

(Arrow of time)

Nowadays:
the commercial space driven time

In our investigation, >75% of the commercial CubeSat adopt this method in 2020

1. Design & build every component & system integration by the satellite owner
2. Purchase COTS components and integrate the system by the satellite owner
3. Purchase integrated ADCS subsystem, and the satellite owner integrate the system into their satellite
4. Contracting to a professional satellite integrator. These integrators might build their own components or purchase from their trusted suppliers.

Things engineers should keep in mind while adopting method 2

- **Which spec should I care about except max. angular momentum storage capability & max. torque while choosing a reaction wheel?**
  - Magnetic disturbances
  - Static & Dynamic imbalance of the reaction wheel rotor
- **What limits the bandwidth and pointing accuracy of an ADCS?**
  - Usually the attitude sensors, especially the image-based one.
- **System error: component frame misalignment; Random error: the nature of components; Gross error: algorithm implementation error**
- **The development of attitude determination & control algorithms- with the help of SIL (software in the loop simulation) & HIL (hardware in the loop simulation)**

Pros and Cons of adopting method 3

- **Pros:** w/ the same configuration of actuators & sensors, they usually cost 20~50% more than method 2. However, if count in the manpower, time, and equipment required to develop a reliable ADCS, they are cheaper in fact.
- **Cons:** Less level of customization; or it may cost more.
- **Costs of different grades of integrated ADCS for 3U CubeSat**

Attitude actuator	Torquer	Reaction wheels*3 + torquers*3	Reaction wheels*3 + torquers*3
Attitude sensor	Coarse sun sensors and mag-meters	Coarse/fine sun sensors, magnetometers, and gyro	Coarse/fine sun sensors, mag-meters, gyro, and image-based sensors
Absolute pointing accuracy	5~15 deg	0.1~3 deg	1~0.01 deg
Cost of method 2	~8k USD	30k~80k USD	50k~100k USD
Cost of method 3	~10k USD	35k ~ 80k USD	50k~150k USD

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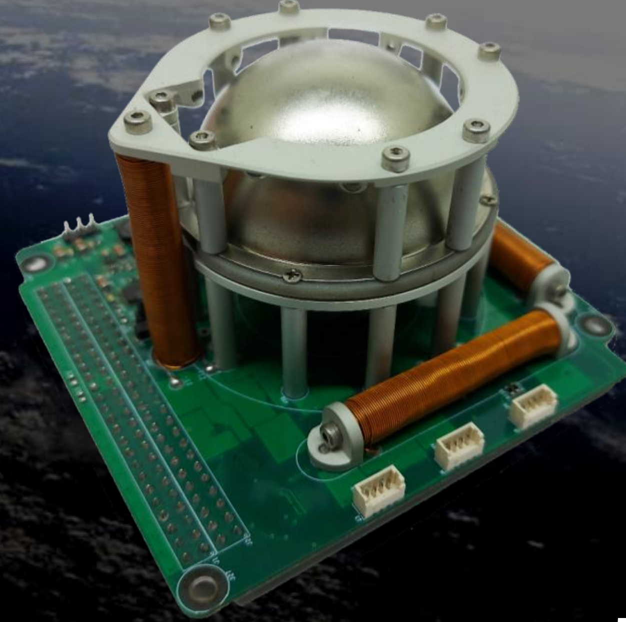
Trends on satellite ADCS

- Mass properties determination after the satellite is deployed to orbit
- Agile satellites- ADCS with a higher slew rate. Some of them are using Control Moment Gyro(CMG) to achieve a better torque-to-power ratio
- Better components- e.g., higher update rate attitude sensors; spherical-motor-based CMGs for SmallSats



Thanks for your time!

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