March 11, 2015

Hardware Design for an Intelligent Attitude Determination and Control System (ADCS)

Michael Wegerson
Matt Partridge
Nathan Crocker
David Schindele
Broc Friend, et al.

Available at: https://works.bepress.com/jeremy_straub/248/
Hardware Design for an Intelligent Attitude Determination and Control System (ADCS)

Michael Wegerson1, Matt Partridge1, Nathan Crocker2, David Schindele3, Broc Friend1, Levi Lewis1, Ben Johnson1, Jeremy Straub1, Ronald Marsh1
1Department of Electrical Engineering, University of North Dakota
2Department of Computer Science, University of North Dakota

Introduction
Cubesat spacecraft have been shown to provide significant cost [1], research [1] and educational benefits [2]. Prior work at UND has demonstrated the efficacy of this form factor of craft for asteroid assessment activities [3] and onboard image processing [4]. Work is also ongoing to develop a low-cost framework [5] for Cubesat development to enable activities at UND and at other locations.

To aid this effort, numerous subsystems are being designed and developed. This poster focuses on the Attitude Determination and Control System (ADCS) for a 1-U Cubesat (10 cm x 10 cm x 10 cm, 1.33 kg) [6]. The ADCS is critical to spacecraft operations as it is required to allow the spacecraft to sense and control its orientation while in orbit. This is essential to communications, imaging, thermal control and other activities.

The ADCS is designed around an onboard intelligence paradigm: inputs are assessed and control decisions are made onboard.

Project Goals
Active/Passive Hybrid Design
- Designed to use both magnetorquers and reaction wheels interchangeably depending on mission parameters.

Low-Cost
- Consumer off the shelf (COTS) parts.
- In-house fabrication of magnetorquers.

Low-Power
- Component choices based on power efficiency and current rating.

Attitude Sensing
- 9 axis Inertial Measurement Unit (IMU).
- Accelerometer; Relative to previous orientation.
- Magnetometer; Relative to Earth’s magnetic field.
- Gyroscope; Relative to Earth’s gravitational field.

Attitude Control
- Reaction Wheels; DC brushless motors that rotate a mass to counteract rotation.
- Electronic Speed Controllers (ESC); DC controller for motor.
- Pseudo-Passive Magnetorquers; Drain stored rotational energy from reaction wheel.

Figure 1. High-Level Design of Hybrid ADCS.

Figure 2. Process Flowchart of Hybrid ADCS.

Figure 3. A motor being considered for the active attitude control subsystem [7]. This brushless motor requires 12v and less than 0.12A. It includes hall sensors that will determine the motor rotational characteristics.

Work To-Date
Current ADCS development began with breaking the overall ADCS into subsections for concurrent development. These subsections include the IMU, microcontroller, active stabilization, and pseudo-passive stabilization. Figure 1 shows the division between the sub-projects for ADCS system development. At present, development is ongoing with core system design (shown in Figure 2) completed, board design underway and component orders pending.

Specific challenges faced to-date include the determination of the length, width, wire-thickness, and loop count for the in-house development of magnetorquer units. These values have been calculated across multiple voltage and current levels to ascertain the most power efficient method to create the pseudo-passive magnetic control. Characteristics for the microcontrollers have been determined. The microcontroller will include I2C channels for IMU communications and PWM output for motor and magnetorquer control.

Future Work
Currently, work is progressing towards the completion of the circuit designs for the individual components. Shortly, the circuit designs will be integrated together, a PCB designed and externally fabricated. Local component population of the circuit board will be performed. Software is being developed for intelligently characterizing and controlling system performance. Extensive testing will be performed before the system is considered space ready.

Several challenges must still be solved. The level of isolation of the magnetometer from the magnetorquer required to mitigate potential data manipulation is being assessed. The specific design and placement of the magnetorquer’s third axis is also an area of active work.

Conclusion
Development of the Hybrid Active/Passive Attitude Determination and Control System is progressing. Completion to a point of testing readiness is planned by the end of June of 2015. When complete, this highly-accurate and adaptive system will facilitate low-cost missions in support of various technology development, science and other goals.

Acknowledgement
Dr. Naima Kaabouch and the UND Departments of Electrical Engineering and Computer Science are gratefully acknowledged for providing facilities and equipment that have been used for performing this work. Thanks are given to Dr. Hossein Salehfar for advice on motor selection.

References