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System of Systems Engineering for low-cost CubeSat Development

An OpenOrbiter Project Update

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Presentation Overview

- System of Systems Engineering
  - Electrical Power System
  - Attitude Determination and Control System
- Low-Cost Fabrication Methods
  - Successes and Challenges

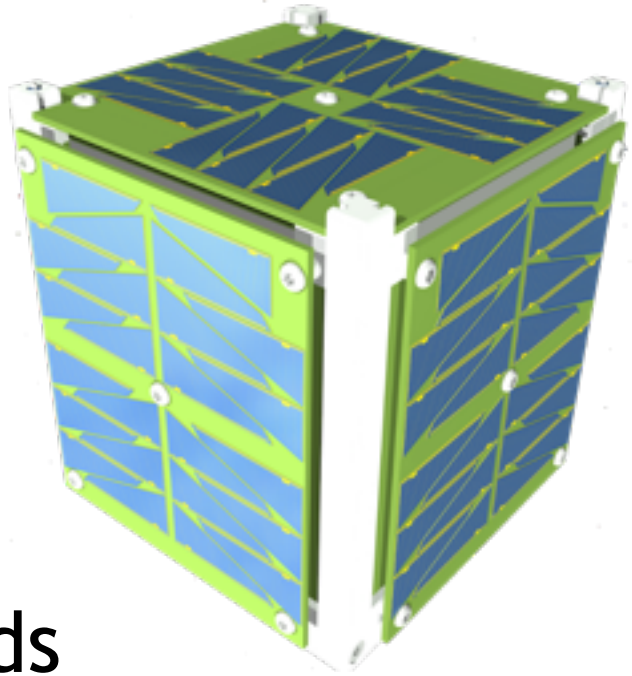

Fig. 1 OpenOrbiter 1U CubeSat Renderin

OPEN Project

- **O**pen **P**rototype for **E**ducational **N**anosatellites
  - Started in 2012
  - Student Led

- Project Goals
  - Low-cost
  - Versatile Framework
  - Open-Source Designs

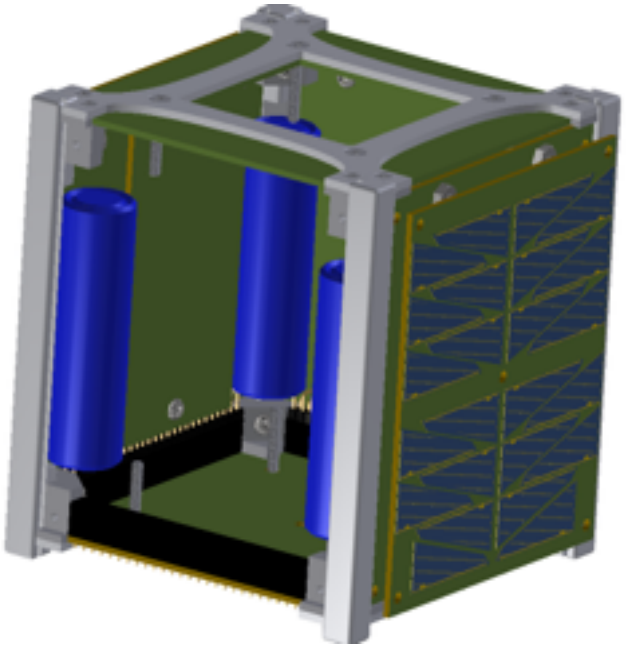

Fig. 2 Cutaway Model of OpenOrbiter

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System of Systems Engineering Design

- System of Systems Engineering (SoSE)
  - "Systems managed for their own purpose rather than the purposes of the whole."
  - Hierarchical
  - Black Box Design
- Why an SoSE approach for OpenOrbiter?
  - Separate systems allow for greater flexibility
  - "Plug-and-Play"
- Implementation
  - Standard Interface for board connection
  - Individual Subsystem Microcontroller
  - Ethernet & I2C Communication Protocols

System of Systems Engineering Design

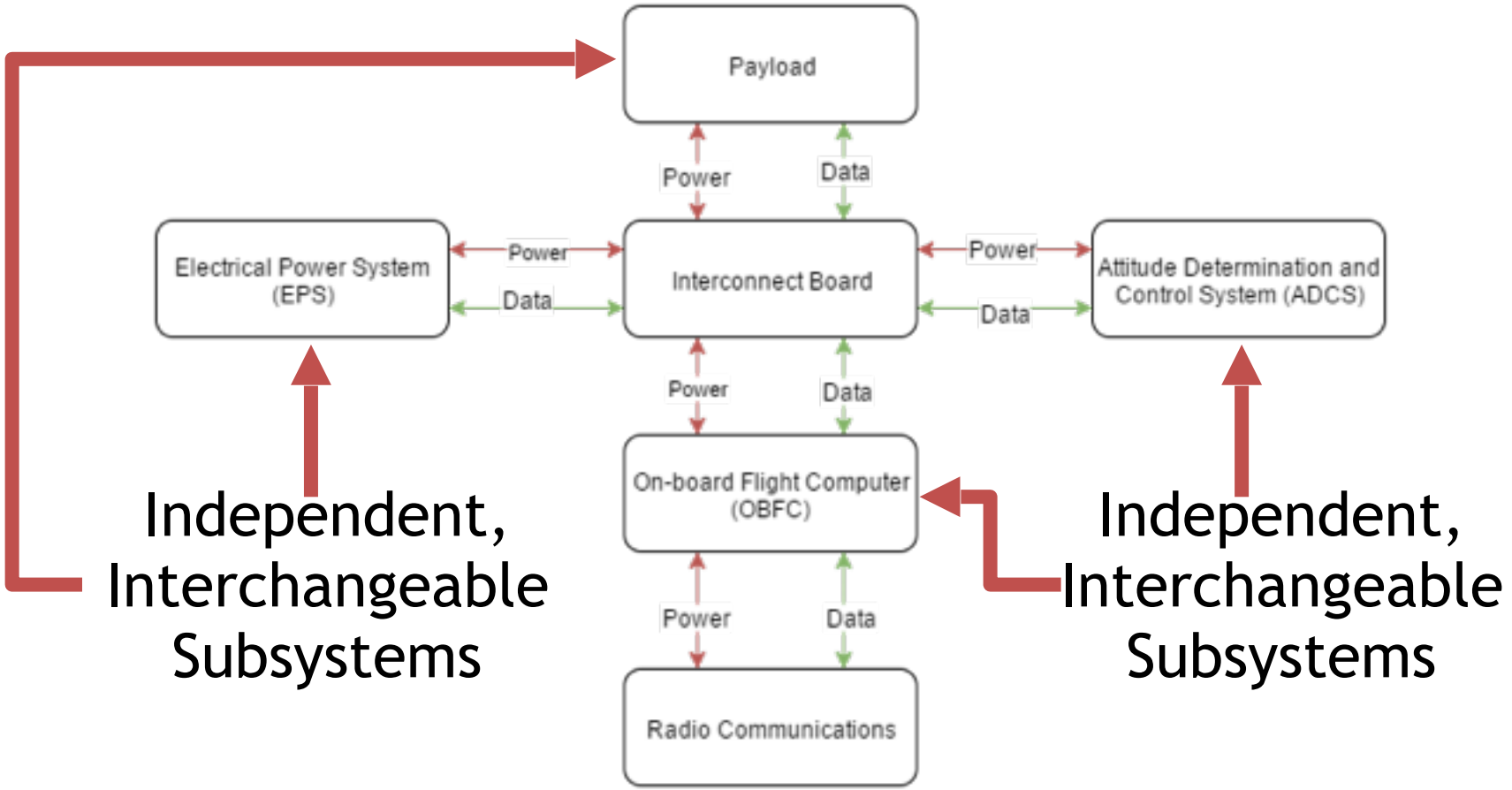

Fig. 3 OpenOrbiter System Block Diagram

SoSE: Electrical Power System

- Challenges of Monolithic Designs
  - Trouble diagnosing complications
  - Division of Labor
  - Learning Curve

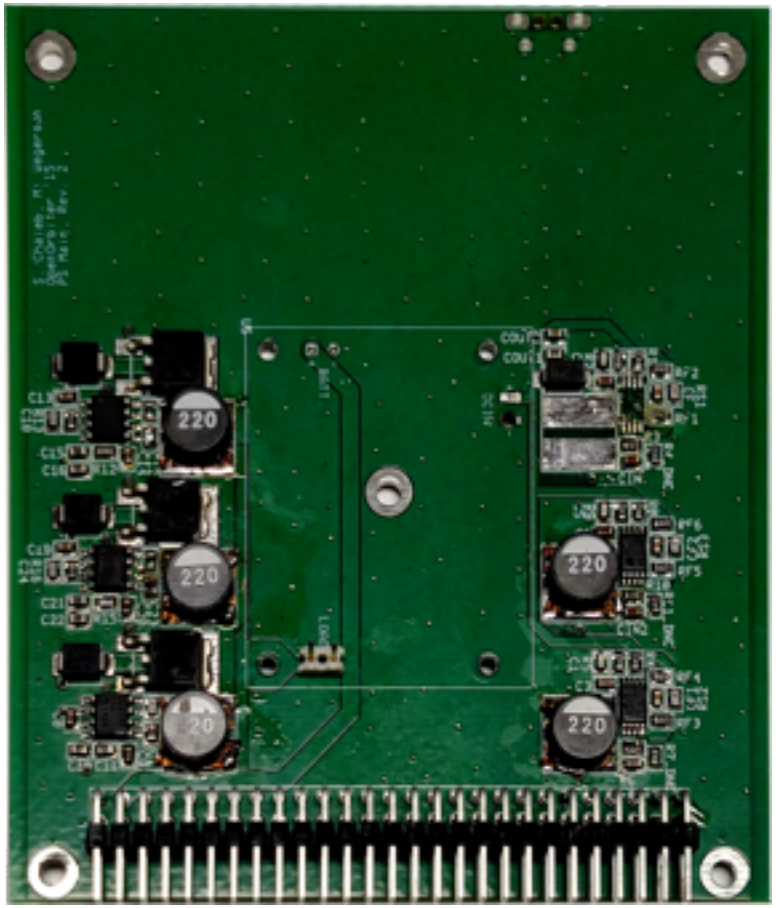

Fig. 4 Electrical Power System PCB, Revision 2

SoSE: Electrical Power System

- Implemented SoSE in EPS Revision 3
  - Modules vs Monolithic PCB
  - Flexible Development

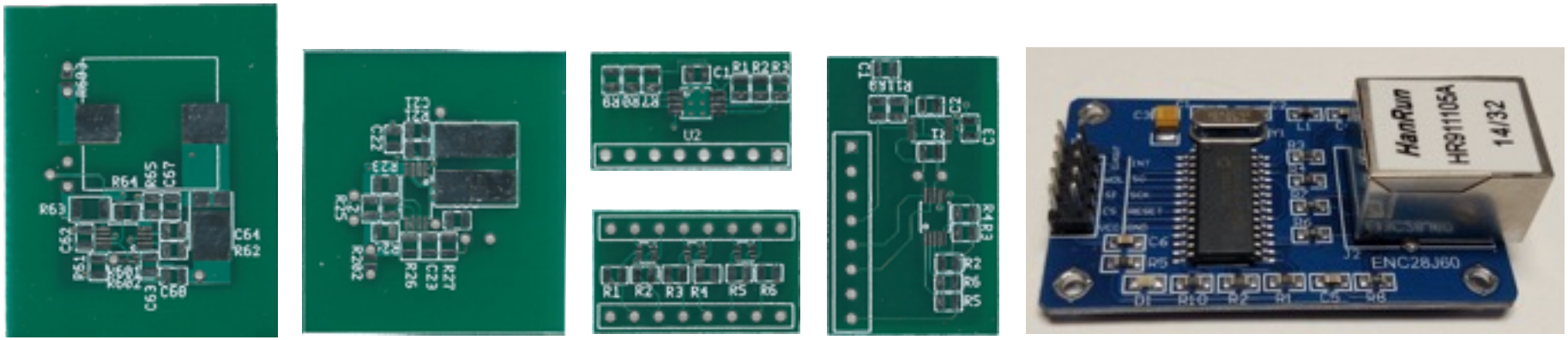

Fig. 5 EPS Rev.3 Prototyping Modules: (left to right) Output Conditioning, Solar input conditioning, Temperature Sensor (top), System Toggle Circuit (bottom), Current/ Coulomb ICs, SPI-to-Ethernet Communication Adapter.

Attitude Determination and Control

- Low-Cost, SoSE Approach
- Description of Concept
- Benefits of this approach
  - Changing Fuel Model
  - Patent Pending
- Direction Forward

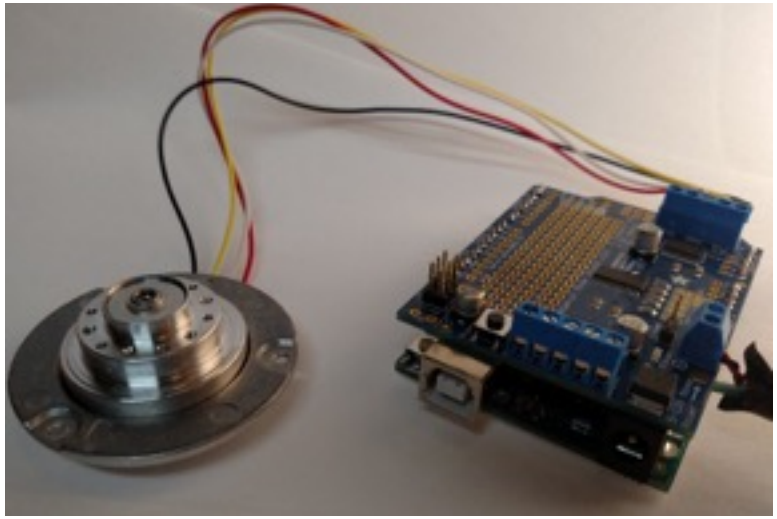

Fig. 6 Reaction Wheel Initial Test using Arduino Controlle

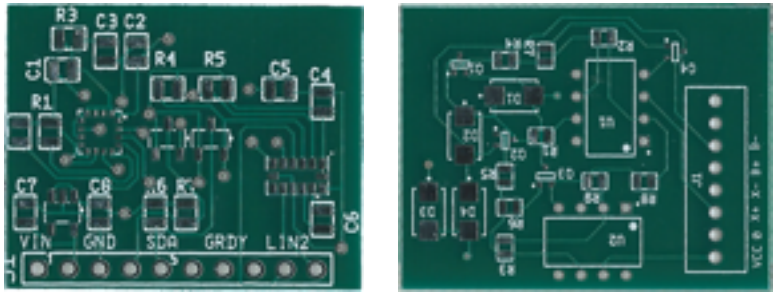

Fig. 7 IMU (left) & Magnetorquer (right) PCBs

In-house Fabrication Methods

- Prove efficacy of low-cost production techniques
- Electrical Design
  - PCB Milling
  - Fabrication
  - Testing
- Mechanical Design
  - Structure Milling
  - Frame Anodizing

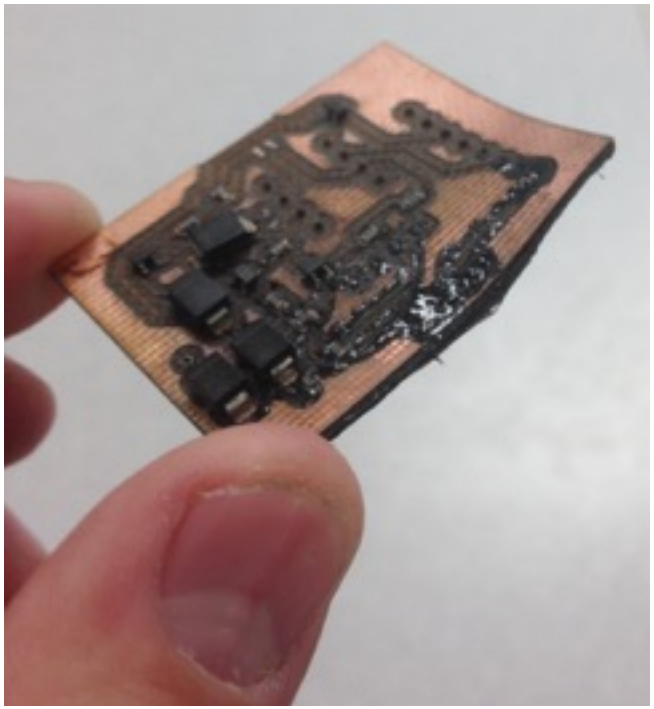

Fig. 8 Less than successful PCB Fabrication…

In-house Fabrication: Electrical

- Reflow Soldering Process

Fig. 9 High-Tech Solder Reflow Oven with added Temperature Monitor

In-house Fabrication: Electrical

- Reflow Soldering Process

Fig. 10 PCB in the Reflow Soldering Process

In-house Fabrication: Mechanical

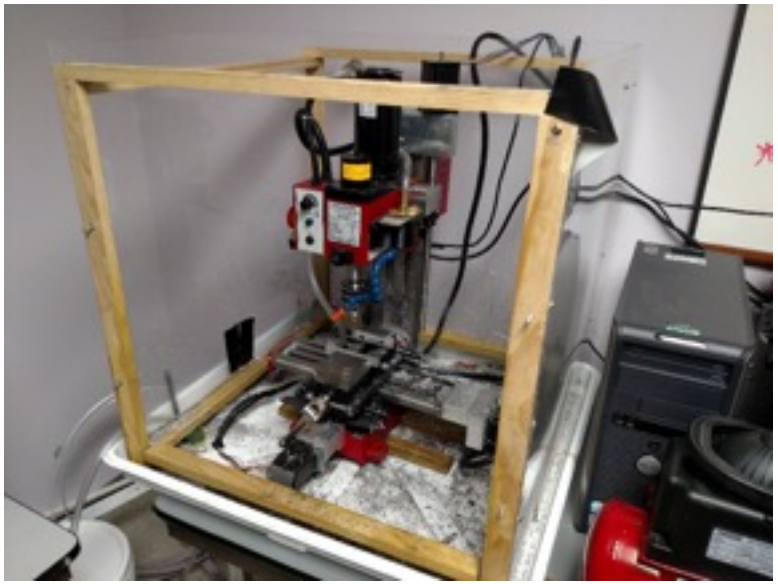

Fig. 11 Custom CNC Drill for Aluminum Frame Milling

Fig. 12 Test Milling of Aluminum CubeSat Post

Conclusion

- SoSE Design Method
  - Easy for Universities
  - Rapid Development
  - Interchangeability
- In-house Fabrication
  - Successes
  - Challenges
  - Space-rated?
- Project Timeline
  - Completion of Satellite Subsystems (June)
  - Testing and Verification (August)
  - Open-source Publication (September)
  - Hand-over (October)
  - Launch! (December)

Questions?

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More Information?
Open Orbiter Small Satellite Development Initiative
openorbiter.und.edu

Special Thanks to the University of North Dakota's Intercollegiate Academics Fund for providing resources for attending this conference.

References

1. Kading, B., Straub, J., & Marsh, R. (2015). Open Prototype for Educational NanoSats CubeSat Structural Design. In *University of North Dakota School of Graduate Studies Scholarly Forum*.
2. S. Chaieb, M. Wegerson, B. Kading, J. Straub, R. Marsh and D. Whalen, "The OpenOrbiter CubeSat as a system-of-systems (SoS) and how SoS engineering (SoSE) Aids CubeSat design," *System of Systems Engineering Conference (SoSE), 2015 10th*, San Antonio, TX, 2015, pp. 47-52.