

# Low-Cost Satellite Attitude Determination and Control System

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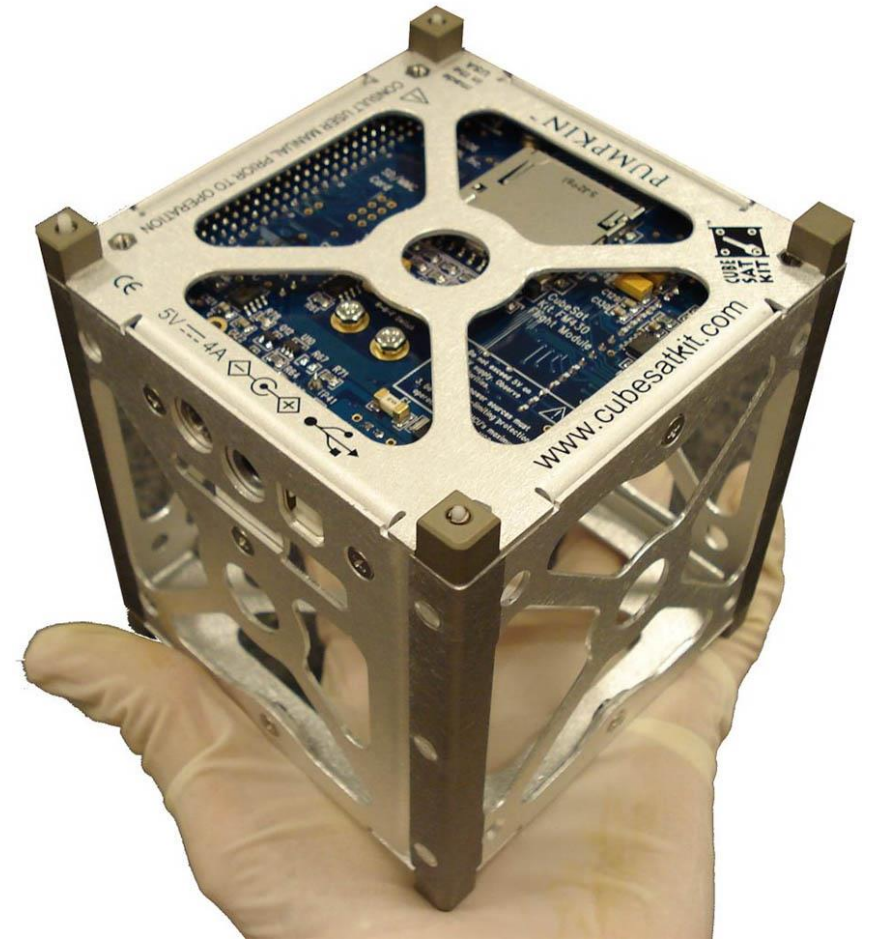


University  
of Idaho



# What is a CubeSat?

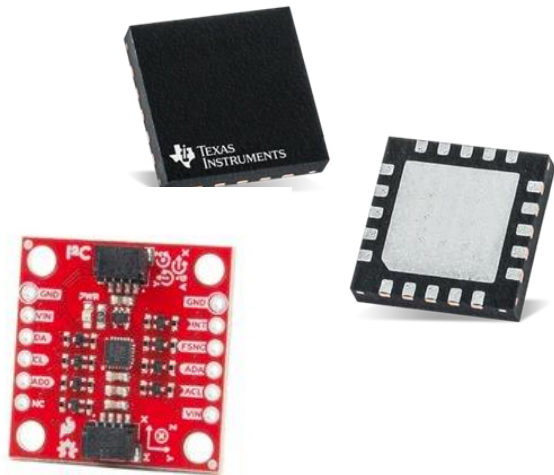
- "Nanosatellites" - small satellites sent up with other missions
  - Made of units called "U"s, 10 cm on each side
- Reduce cost of space research
  - Used by academics, college groups, and even high schoolers
- Examples of Research
  - Used to monitor vegetation on coastlines
  - Infrared imaging to improve climate change models
  - Map neutrons and solar radiation
  - Testing novel propulsion techniques, like solar sails
- Have been used to orbit Earth, Mars, and are being considered for Saturn and Jupiter missions



# What is an ADCS?

## Attitude Determination & Control System

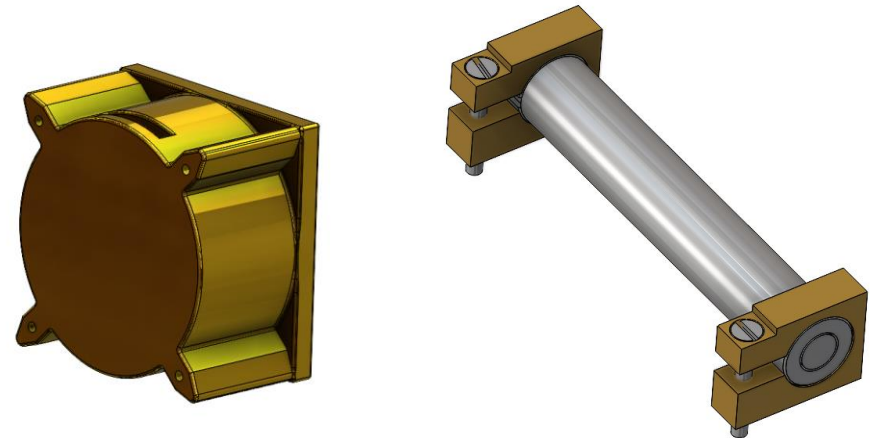
- Detects where satellite is
  - Relative to sun (sun sensor)
  - Relative to earth (magnetometer)
- Changes position of satellite
  - Using a flywheel
  - Using magnetic fields



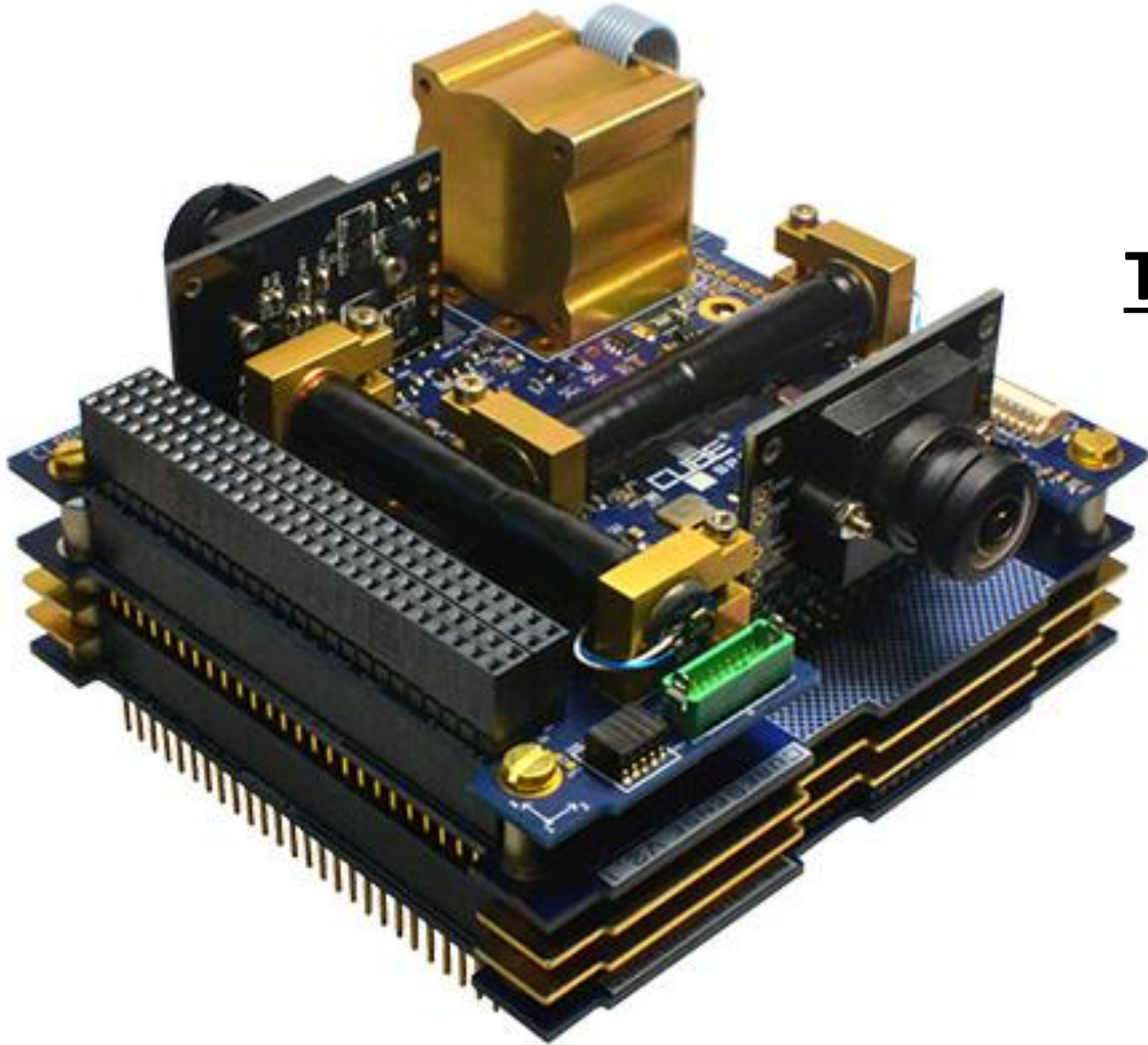
The Brains



The Eyes



The Brawn



## The Problem:

- ADCS units are expensive
  - Retail from \$25,000 to \$100,000
- ADCS units take a long time to manufacture and ship

Our Solution: Reduce cost of CubeSats by integrating commercially available orientation control and communication systems.

Team Objective: To identify components and manufacture a unit ready for vibration testing.

# Project Requirements

## Resources

- Budget of \$3,000.00.
- Close mentorship working alongside NASA Ames Nano-Orbital Workshop.

## Timeline and Objective

1. Deliver unit to NASA for Vibration Testing.
2. System to be improved based on testing results.
3. Future system to be used for Cubesat space exploration.

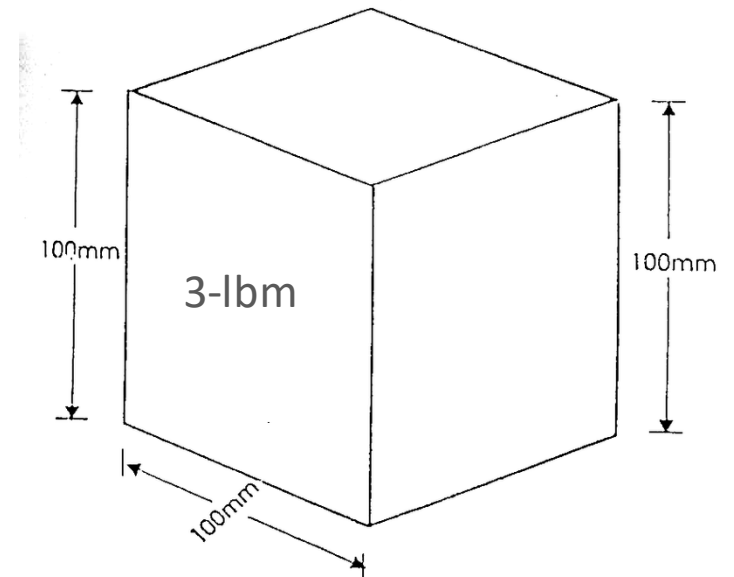
# Mechanical Requirements

## System Properties:

- Operable within a Vacuum
- Withstand High level of Radiation
- Function within a broad temperature range: -10 to 40°C

## Form Factor:

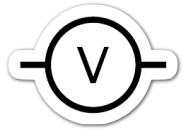
- Fits within 1 U (10x10 cm)
- Weigh in under 3-lbm





# Electrical Requirements

## System Properties:



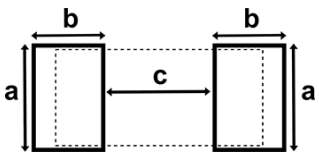
- Function off a voltage at or under 9V.



- Process sensor data.



- Drive any motors and other control units.



- Remain compact and modular to work alongside satellite design.

# Conceptual Development

Fall

- Researched Components of ADCS systems

Winter

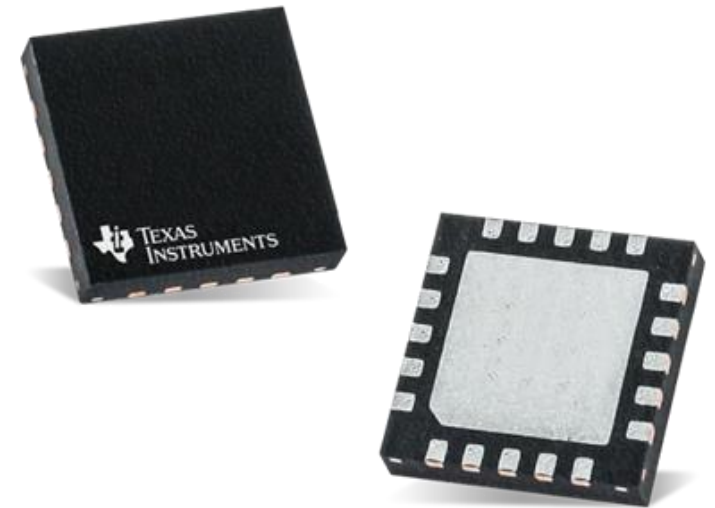
- Evaluated components on cost, precision, and flight history

Spring

- Focused on manufacturing the flywheel component in-house



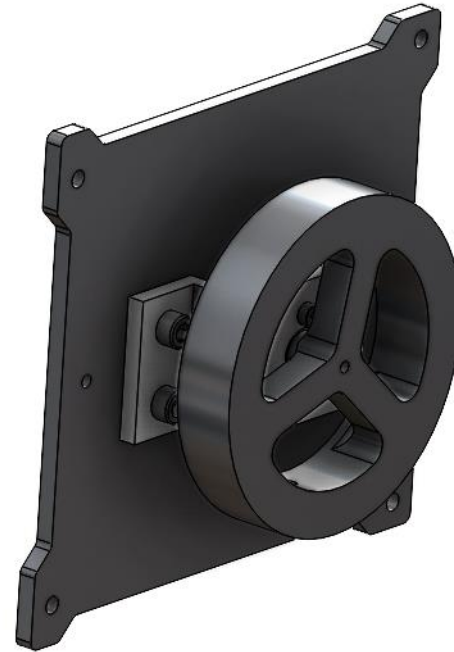
ICM-20948, the highest ranked IMU



Texas Instruments DRV425-Q1, the highest ranked magnetometer

# Mechanical Design

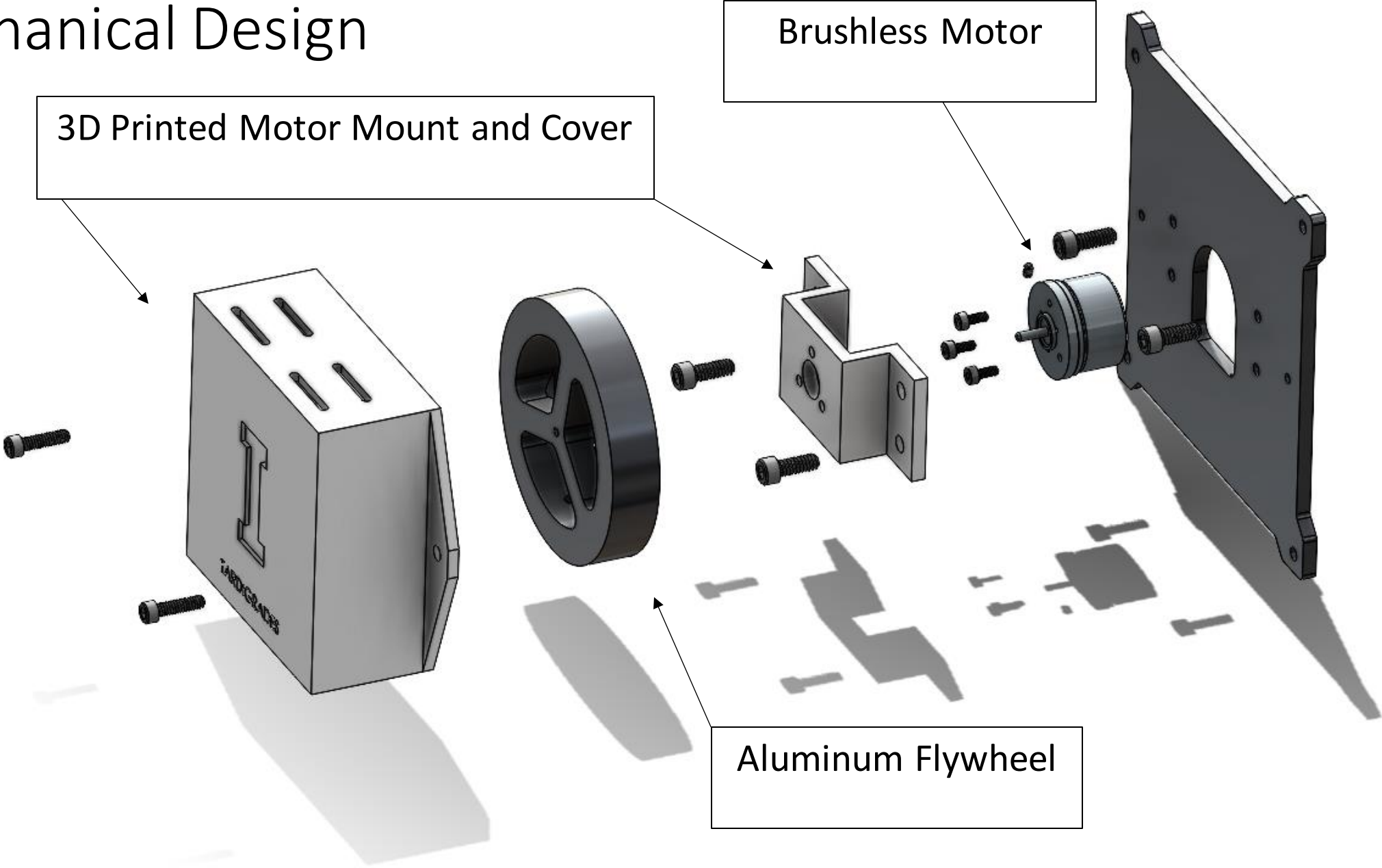
- Works on the principle of the Conservation of Angular Momentum
  - Like a figure skater spinning
  - If wheel starts spinning up one way, the satellite rotates in the opposite direction
- Dimensions are 3.5 in. by 3.75 in. for the base plate.
- Total Assembly is 1.25 in. tall



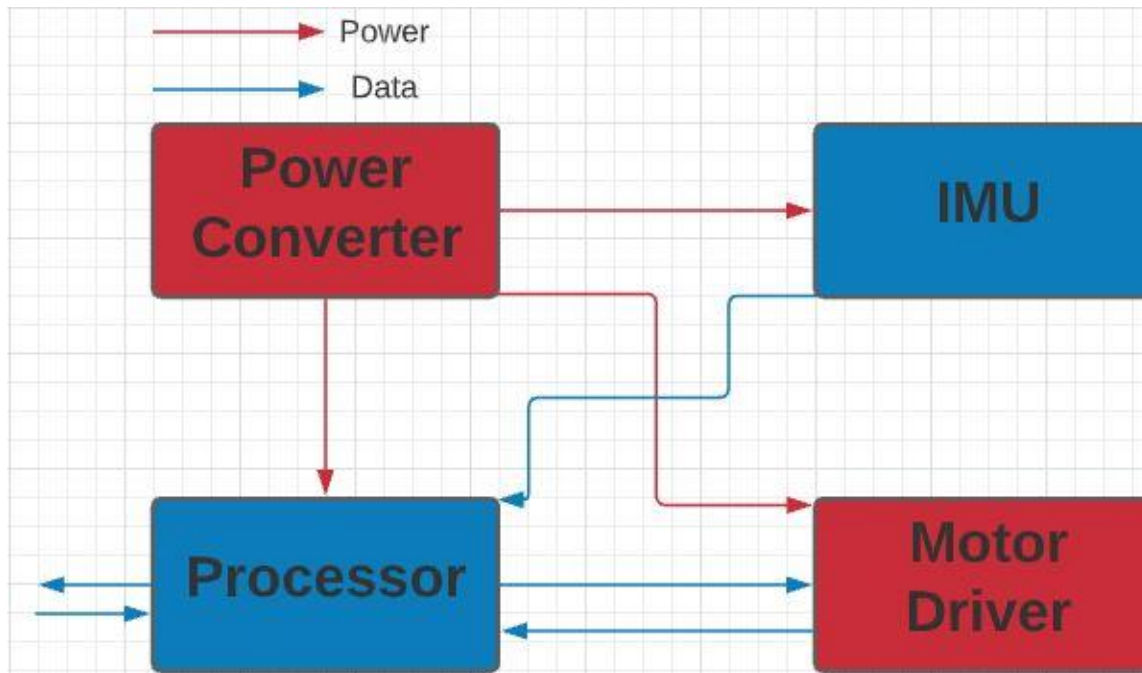
## Quick Wheel Stats

- Weight: 46.6 grams (0.1 pounds)
- CNC Machined 7075 Aluminum
- Maximum angular momentum imparted to satellite: 0.8018 revolutions/min

# Mechanical Design



# Final Design - Electrical

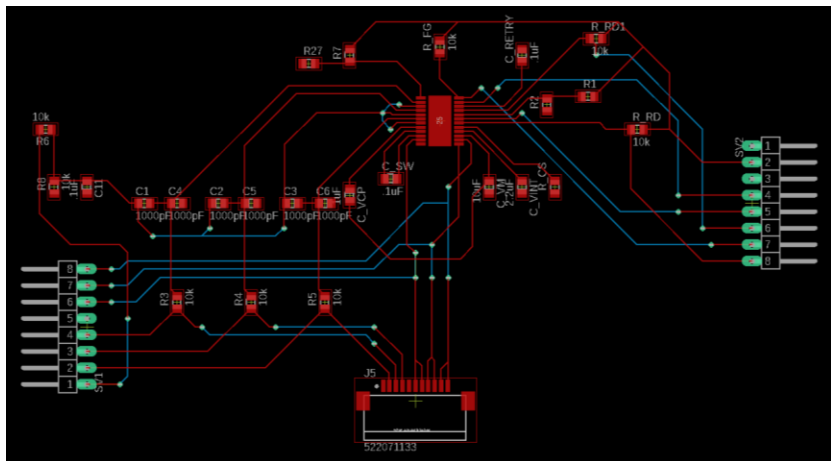


- Main Components of Electrical System
- Power Converter
  - Supplies power to all components
- Processor (SAM21)
  - Processor is the brains of the electrical control system
- Accelerometer (IMU)
  - Measures and sends movement information to processor
- Motor Driver
  - Spins the motor at the desired speed

# Final Design - Electrical

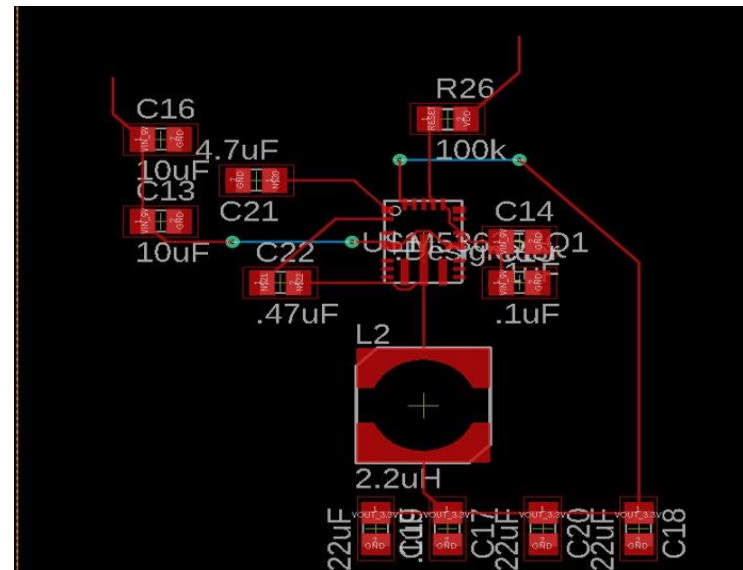
## Motor Driver

- Receives command from processor and executes it by spinning the motor at the proper speed and direction
- Provides feedback about speed and direction to the SAMD21



## Power Converter

- Receives 9V from the satellites power system
- Outputs 3.3V to be used by other components on the board



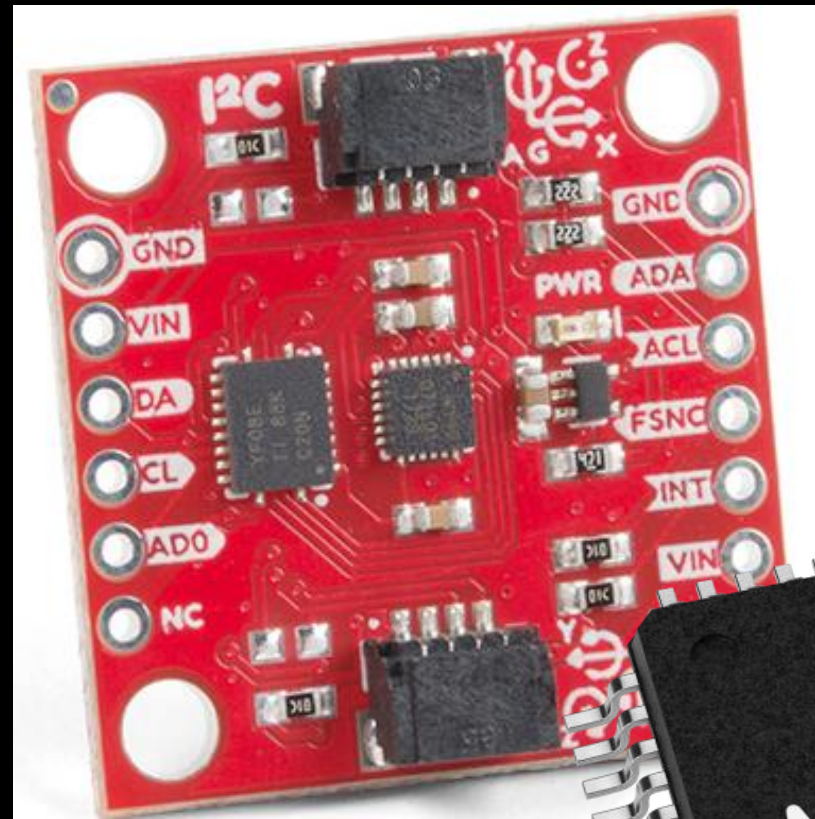
# Final Design - Electrical

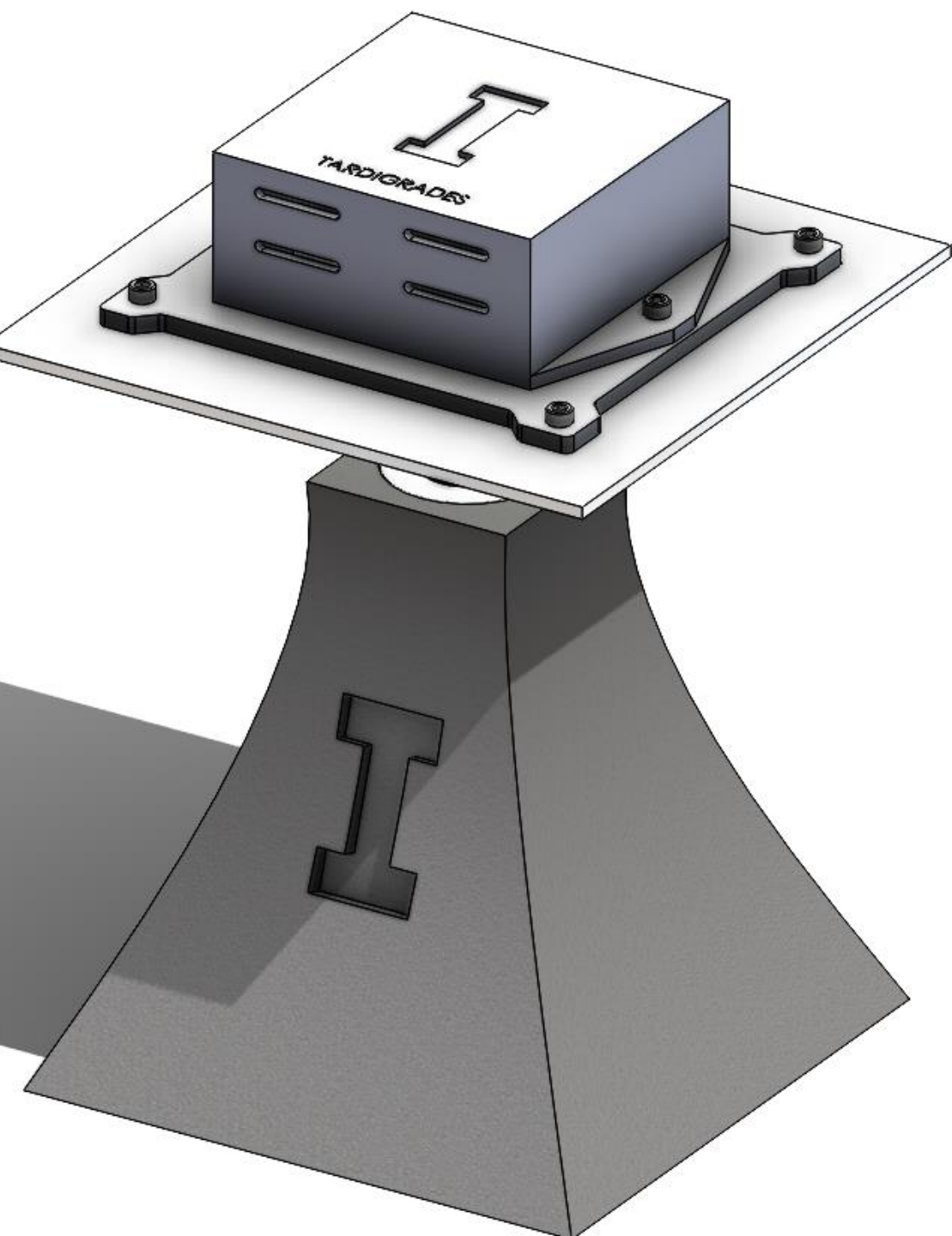
## IMU – Inertial Measurement Unit

- Measure's speed, direction, acceleration and angular rates of the satellite
- Sends data to processor

## SAMD – Processor

- Receives speed and direction command to be executed to the motor
- Processes data from IMU
- Sends command to motor driver





# Test Stand – Continuing Development

## Flywheel

- 3D printed test stand and motor mount allowing uniaxial rotation
- Allows testing of motor-flywheel assembly and observation of counter-rotation of the plate

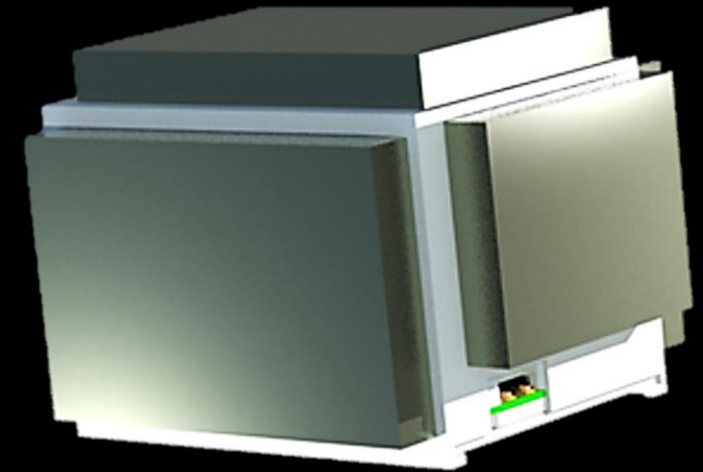
## Controls

- Once the board is manufactured verify it can spin the motor in the correct direction and speed
- Check that it is supplying correct voltage to all component of the board



# Radiation Shielding

- Objective: Shield graphics processing unit (GPU) from radiation damage
  - Radiation can corrupt logics processing, memory, and shorten working life of the GPU
- Value Proposition: Enable graphics processing with advanced GPUs on satellites
  - Star tracking for attitude determination
  - Exoplanet detection
- Conceptual Development: Identifies materials capable of shielding gamma rays and neutrons/ions
- Final Design
  - Composite box of 3D printed boron-rich filament
    - Neutron & ion shielding
  - Either W-Cu metal matrix composite or tungsten impregnated resin
    - Gamma & X-ray shielding
    - Depends on vaporization data



# Recommendations for Future Work – Goals for the Flight Unit

## Mechanical

- Increase compactness of design
- Adjust wheel geometry based on desired rotation

## Electrical

- Integrate motor driver and power converter circuit board with processor and accelerometer circuit board design
- Consolidate circuit board design to fit on the mounting plate if necessary
- Configure communication pins between processor, accelerometer, and motor driver