ROTATIONALLY STABILIZED MULTI-SENSOR PACKAGE FOR A SOUNDING ROCKET

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Nicholas Roder, William Ryan

Overview

- Team Overview
- Mission Overview
- Design Review
- Testing
- Safety
- Societal Impact
- Completed Project
- Schedule
- Budget
- Conclusions

Team Overview

- Students
  - Charles Galey (Team Leader)
    - Programming, Data Analysis and Testing
  - Peter Jay
    - Structural Analysis/Model and Testing
  - Nicholas Roder
    - Camera Board Testing, Bread-boarding, System Testing
  - William Ryan
    - PCB Layout, Bread boarding, Circuitry
  - Harish Muralidhara
    - Programming and Circuitry

- Faculty Advisors
  - Dr. Paul Johnson (Physics Dept.)
  - Dr. David Walrath (ME Dept.)
  - Dr. Barrett (EE Dept.)

Project Overview

- Rocksat
  - Originally a faculty outreach program
  - NASA's low cost option for student access to space
  - Each project is given a canister
  - 3rd year of the program
  - UW's second year of participation

Mission Overview

- Standards and Compliance
  - Colorado Space Grant
    - Payload required strict compliance
    - Specific mission requirements
    - Bi-weekly updates and reporting
  - NASA
    - Wallops compliance reviews
    - International Traffic in Arms Regulations (ITAR)

Mission Overview

- Shared Canister
  - Reason
    - Collaboration
    - Cost reduction
  - Can shared on a 50/50 Volume basis
    - Sharing with University of Minnesota
  - Payload Orientation:
    - Minnesota will occupy the top 50%
    - Wyoming will occupy the bottom 50%
  - Access Ports
    - Wyoming will share photographs with Minnesota
    - Minnesota will share atmospheric data

Mission Overview

Type	Quantitative Constraint
Physical Envelope	Cylindrical: Diameter: 9.3 inches Height: 4.75 inches
Mass	Payload = 6.5 lbm
Center of Gravity	Lies within a 1x1x1 inch envelope of the RockSat payload canister's geometric centroid.
Ports	Customer shall provide drop down tubing for atmospheric plumbing. Plumbing must terminate with a male ¼" NPT connector. Additionally, the customer shall design in a redundant valve to protect the payload at splash down.
Power	The payload shall have full compliance with Wallop's 1 SYS.2 preflight requirement and G-switch payload activation.

Mission Overview

- Experimental Ideas
  - Temperature and humidity sensors
  - Pressure sensors
  - Magnetic sensors / Power Generation
  - Ozonesondes
  - Infrared spectroscopy
  - Relativity
  - Biological experimentation

Mission Overview

- Objectives / Goals
  - Measure rocket speed and spin rate
  - Determine the rocket’s motion and flight path
  - Design a stable platform to achieve clear images during flight
  - Successfully retrieve the flight data wirelessly (post-flight)
  - Obtain basic knowledge and understanding of the design requirements and obstacles in real world applications

Mission Overview

- Objectives / Goals
  - 3 Accelerometers to determine spin and motion
  - A GPS unit will log position and altitude
  - Stepper motor will rotate camera plate
  - Bluetooth will send data after splashdown

Mission Overview

- Success Criteria
  - No electrical system failure
  - No structural failure
  - Stable platform achieved
  - Flight data retrieved and stored correctly in system
  - Obtain reliable data wirelessly (post-flight)

Mission Overview

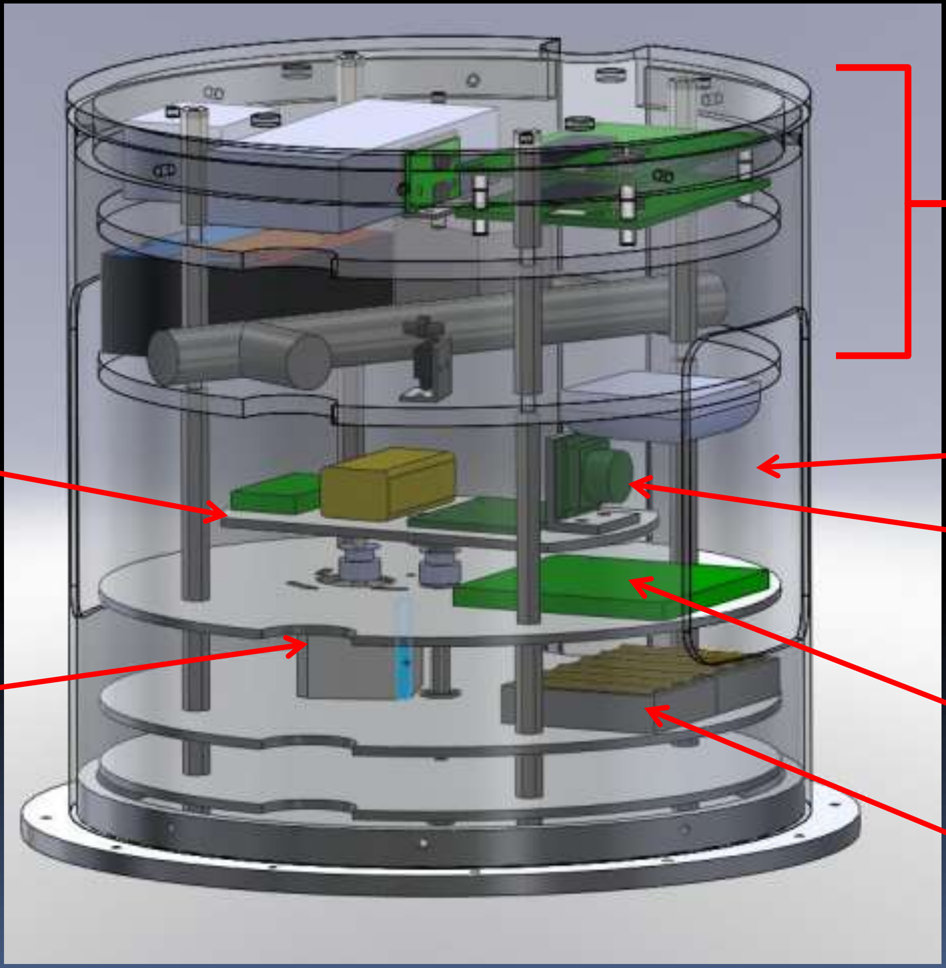
- Benefits
  - Provide Future Rocksat Groups:
    - Stabilization system for experiments
    - Accurate data of flight parameters
    - High quality clear images for future flights
  - Allow expansion for wireless transmission data post-flight

Mission Overview: Subsystems

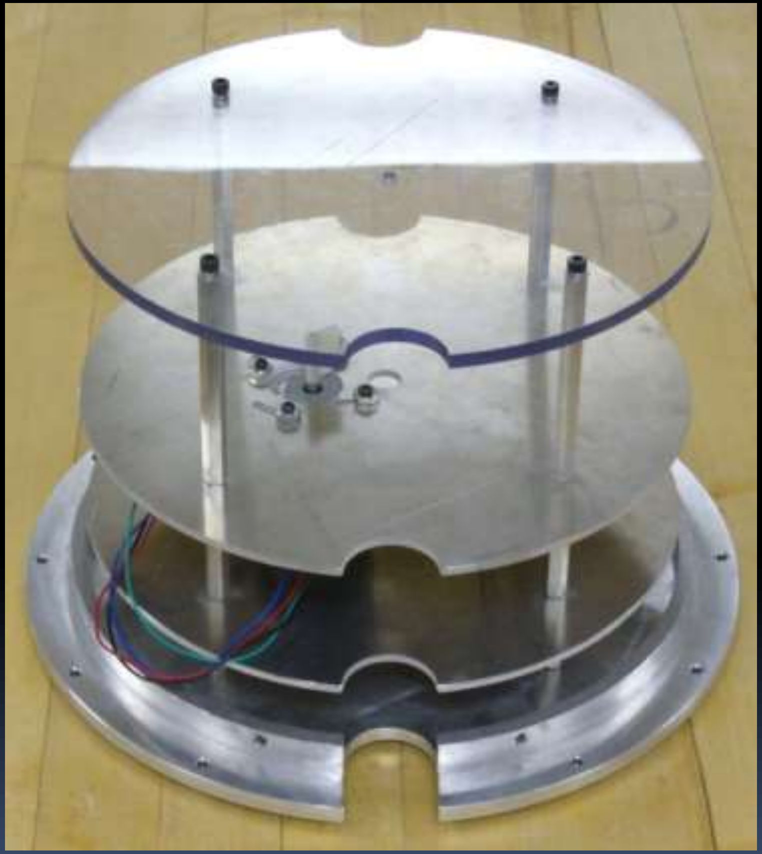
- Mechanical
  - Structure
  - Drive Train
- Electrical
  - Power
  - Camera
  - Control
  - Software
  - Sensors

Design Overview: Mechanical

Solid Works model of both UW and UM payload system

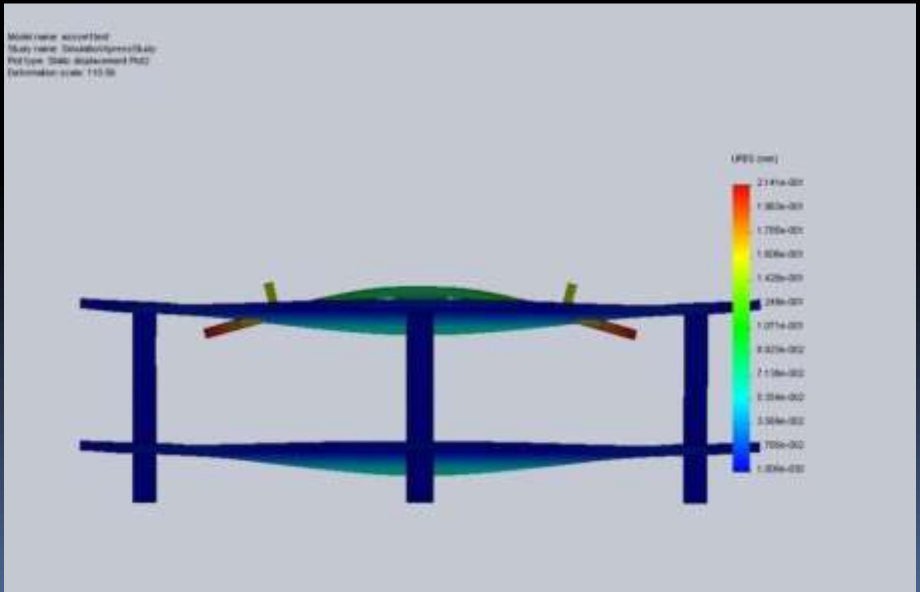


Design Review: Structure



Design Review: Structure

- Design and Testing:
  - Based on last year
  - Solidworks Analysis
  - Planned Vibrations Testing



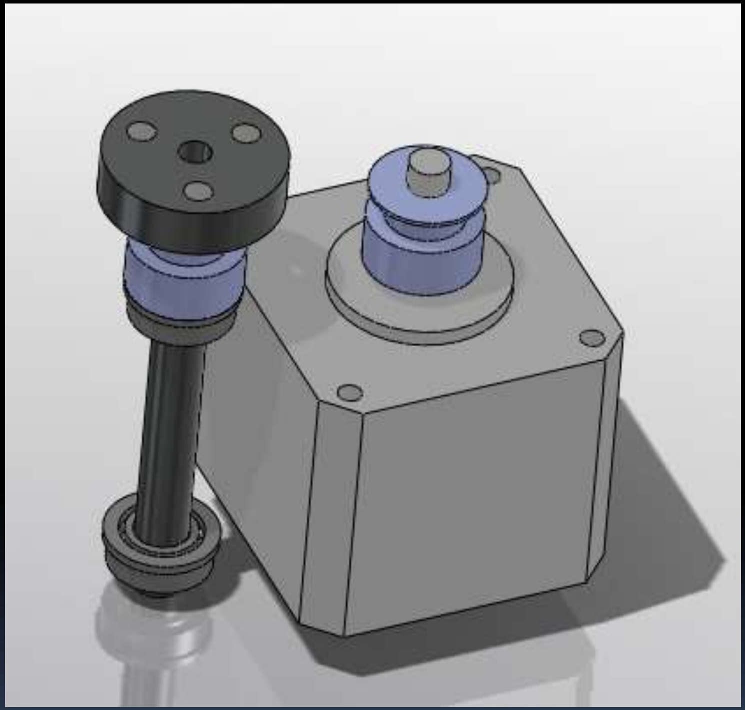
Structure deformed under 25g vertical load

Design Review: Drive Train

- Motor Selection
  - Requirements
    - 7.2 oz-in torque
    - 5V-12V
    - ~1 A
  - Jameco 237-490 Stepper Motor
    - 25 oz-in torque at 5V
    - Running Conditions
      - 12V
      - 1A-.4A

Design Review: Drive Train

- Shaft Design
  - 9 lbf max bending load
  - FS of 16
- Bearings
  - Radial
    - 243 lb max
    - FS 40+ (1.5 lb side force)
  - Thrust
    - 50lb max load
    - FS of 2 (25 G acceleration)
- Pulleys
  - 15 tooth
  - 1:1 gear ratio
- Belt
  - Timing belt



Fabrication: Mechanical

Design Overview: Electrical

Wallops Compliance

Design Review: Power

- Wallops Compliance:
  - 1.SYS.2
    - Early activation
  - RBF pins
- Power Pack
  - Requirements
    - 1.2 A peak current
    - 12V requirement
    - 1 hour flight time

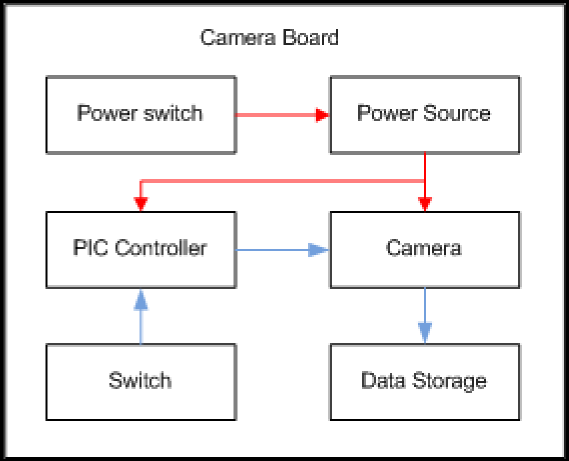
    } 1200 mAh peak required
  - 8 AA Batteries
    - 1.5 V Each
    - 2250 mAh
    - Predicted to last 3x flight duration

Design Review: Camera

- Requirements
  - Low power consumption (5v or less)
  - Fast shutter speed (1-4 sec)
  - High Resolution (>3 Megapixels)
  - Low Cost (<$100)
- DSV 675
  - 5 MP
  - 4 sec trigger speed
  - Trigger ,time and video modes

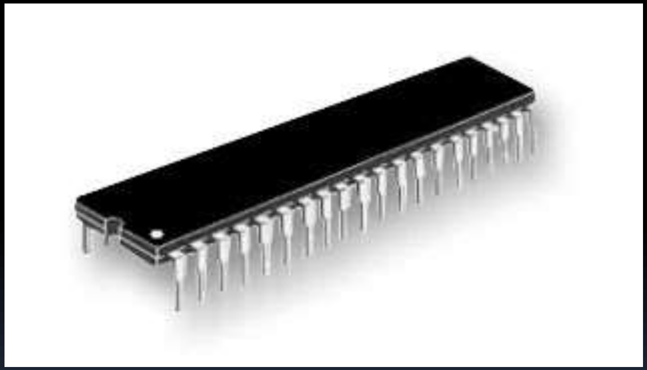
Design Review: Camera

- Control
  - PIC 16F84A
  - Phototransistor trigger(s)
  - 4 GB SD Card
  - Picture every 4 seconds
  - 0.75 MB per picture (600 total)
- Separate Power
  - Phototransistor for Wallops compliance
  - 270 mA peak current
  - 9V battery will last 45 min
  - Tested to 50 min



Design Review: Processor

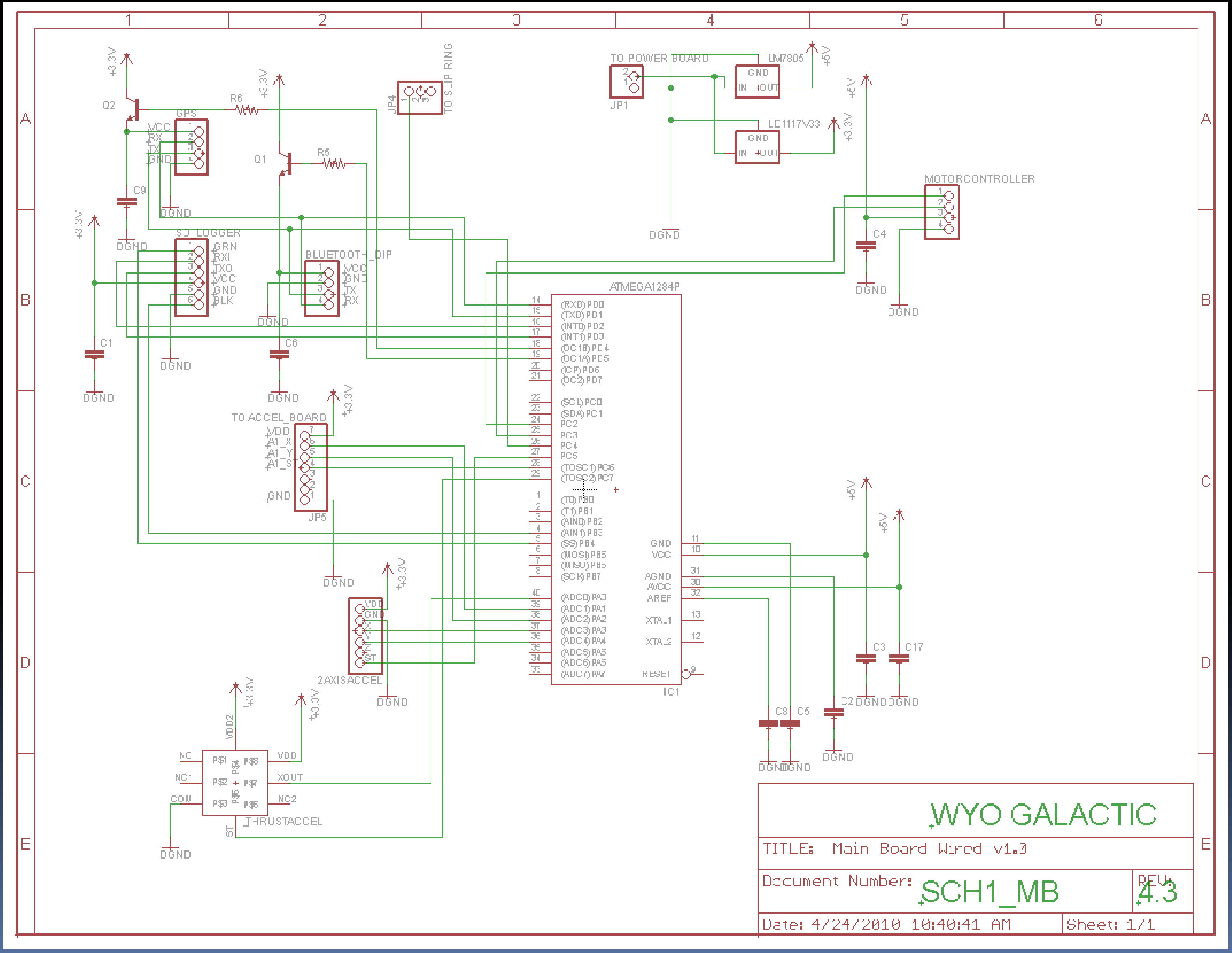
- Processing
  - Requirements
    - 2 (3 preferred) serial connections
    - A/D converter
    - 3 timers (2 16bit)
    - 16kB/s bandwidth
  - ATMEL 1284p Processor
    - 64k SD-RAM
    - 128k Programming memory



Design Review: Motor Control

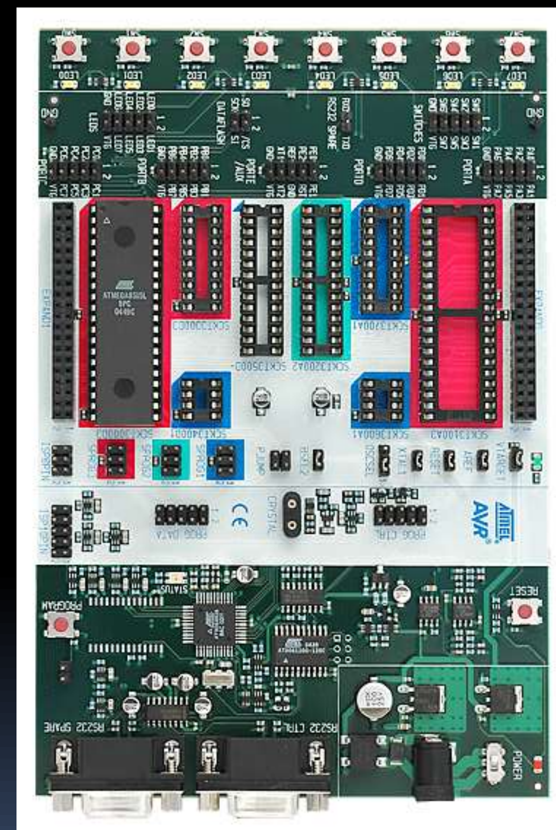
- Requirements
  - Power a 2 coil stepper motor
  - Variable voltage (5-27V)
  - Step division
  - Variable current
- EasyDriver v4.0
  - Internal voltage regulation
  - Step and Direction inputs

Design Review: Main Board



Design Review: Software

- Programming
  - 4 Phase plan
    - Phase 1
      - Single accelerometer
      - Motor Control
      - Mission Clock
    - Phase 2
      - SD Logger circuit
    - Phase 3
      - Additional accelerometers
      - GPS
    - Phase 4
      - Bluetooth
  - Phase 2 Complete



Design Review: Software

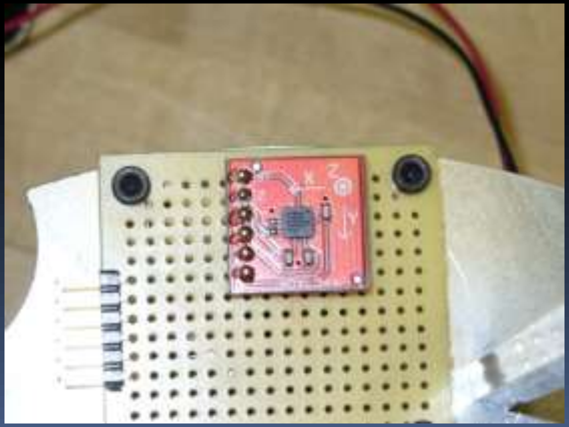
- Plate Stabilization:
  - Data is extracted from two peripheral accelerometers
  - Acceleration data is converted to velocity via the trapezoid rule
  - The processor then compares current and new rocket velocities
  - Velocities are converted to steps per second and transmitted to the motor controller

Design Review: Software

- Data Logger
  - Requirements
    - Use compact media (micro-SD)
    - High capacity (2 GB or more)
    - Simple interface (USART)
  - OpenLog
    - Log on power up mode
    - Accepts micro-SD
    - 2 GB max capacity
    - Simple ASCII over USART interface

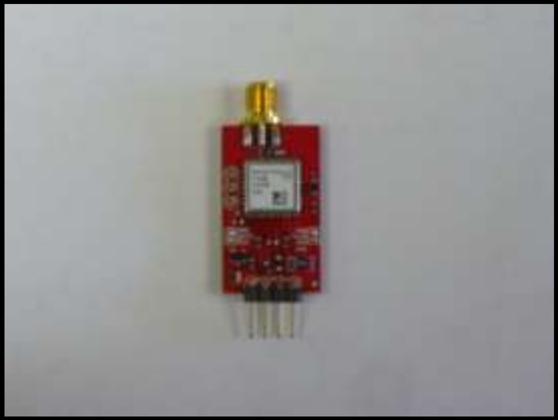
Design Review: Sensors

- Accelerometers
  - 2 +/-18 G 2-Axis accelerometers
    - Based on limited knowledge of flight characteristics
    - Complete flight data is unavailable
  - 1 +/-30 G thrust Axis accelerometer



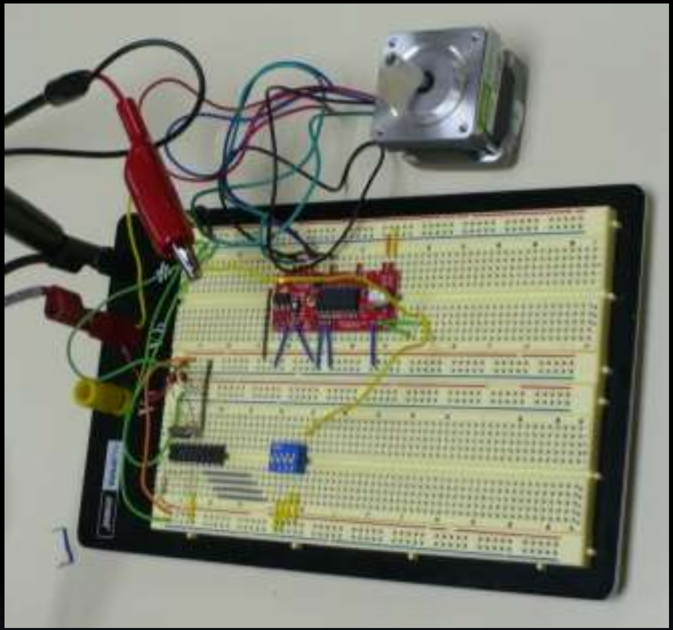
Design Review: Sensors

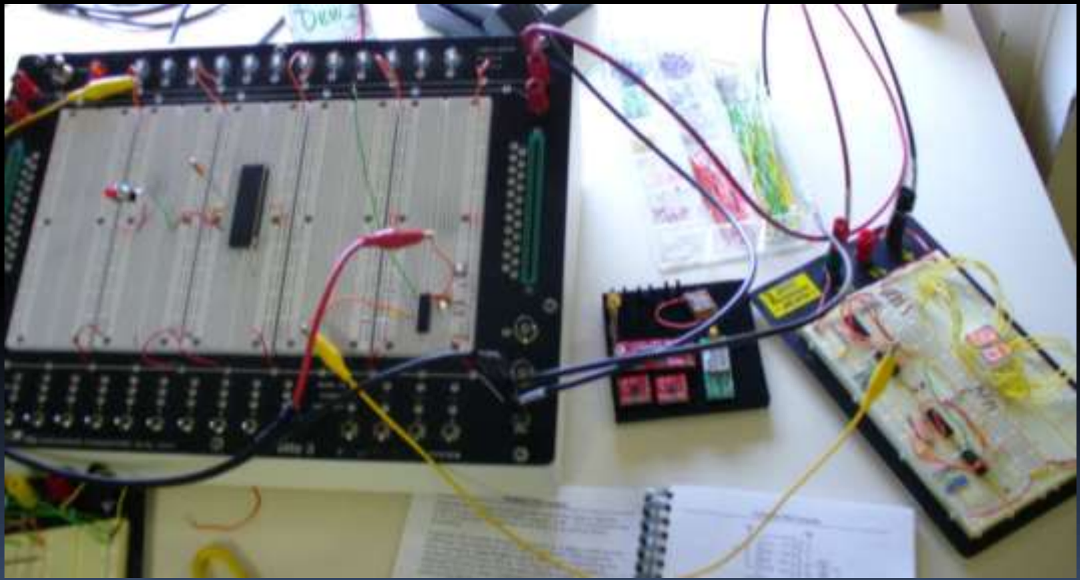
- GPS (mini-GPS)
  - Requirements
    - Fast cold start time (<40 sec)
    - Rapid acquisition (<20 sec)
    - External antenna



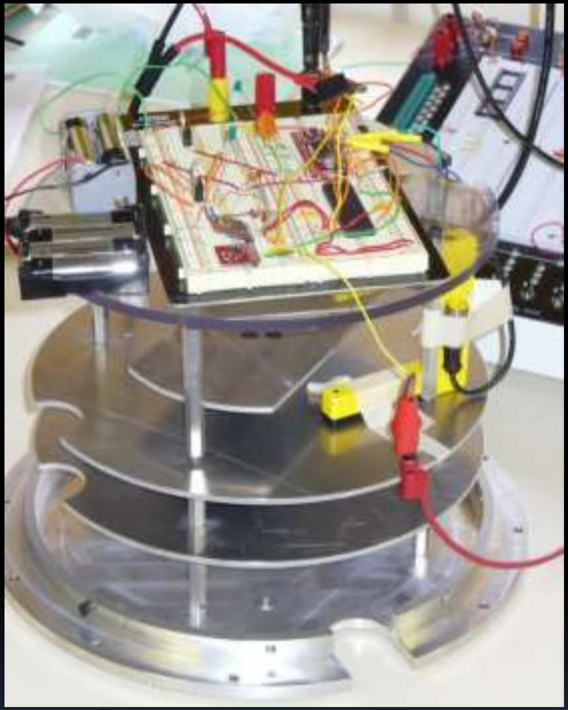
- Bluetooth (bluSMiRF)
  - Requirements
    - Long range (>20m)
    - High data rate (>250 kB/s)

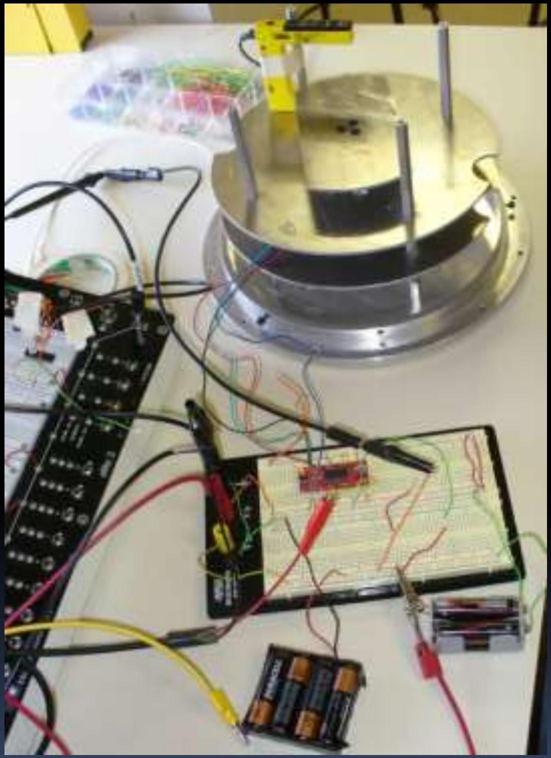
Fabrication: Electrical



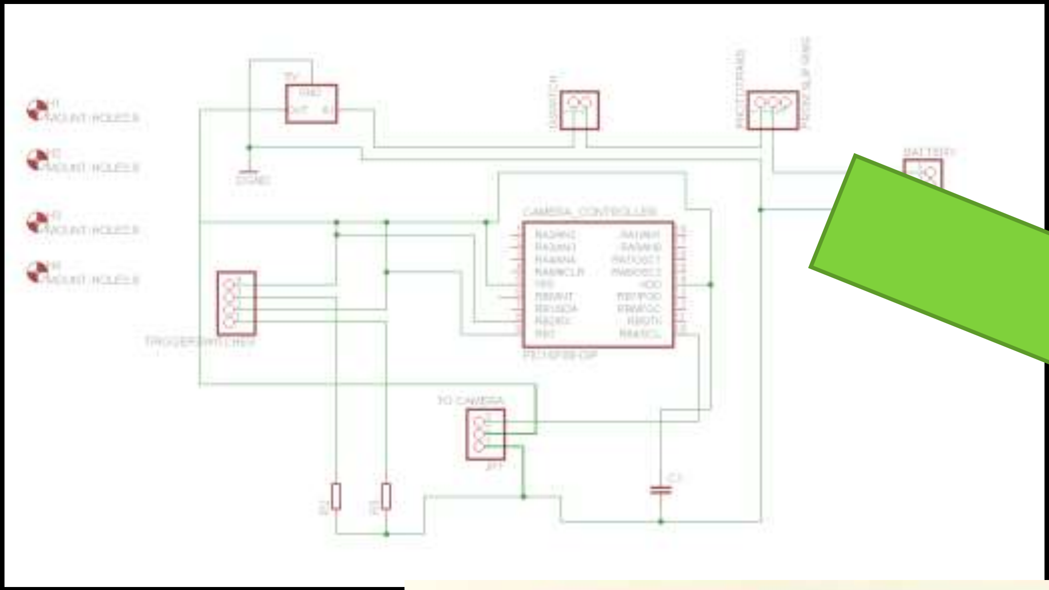


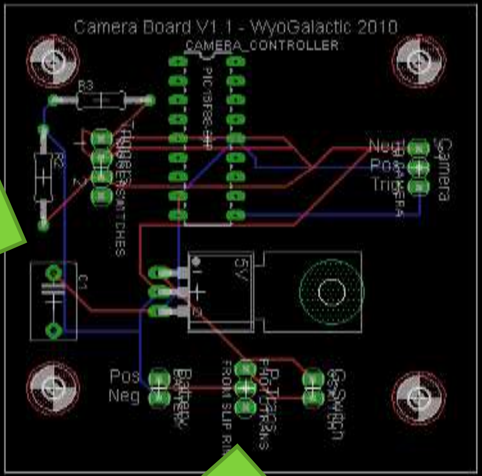
Fabrication: Electrical

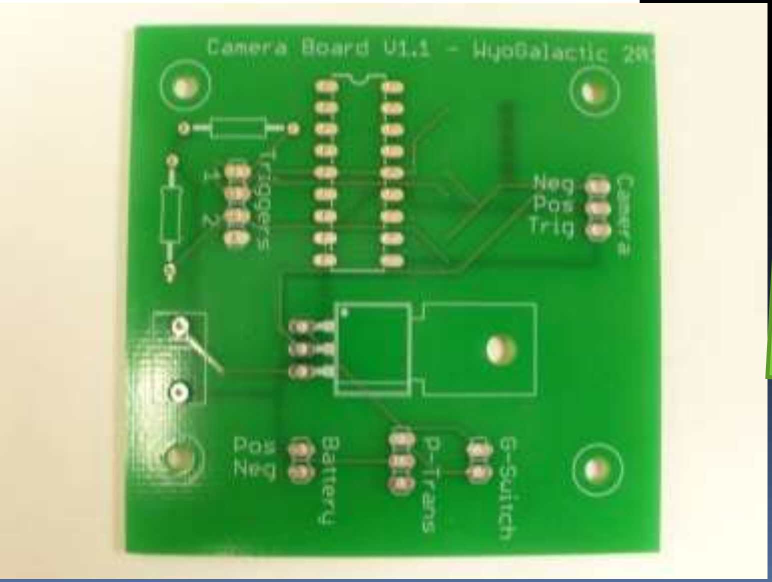




Fabrication: Electrical



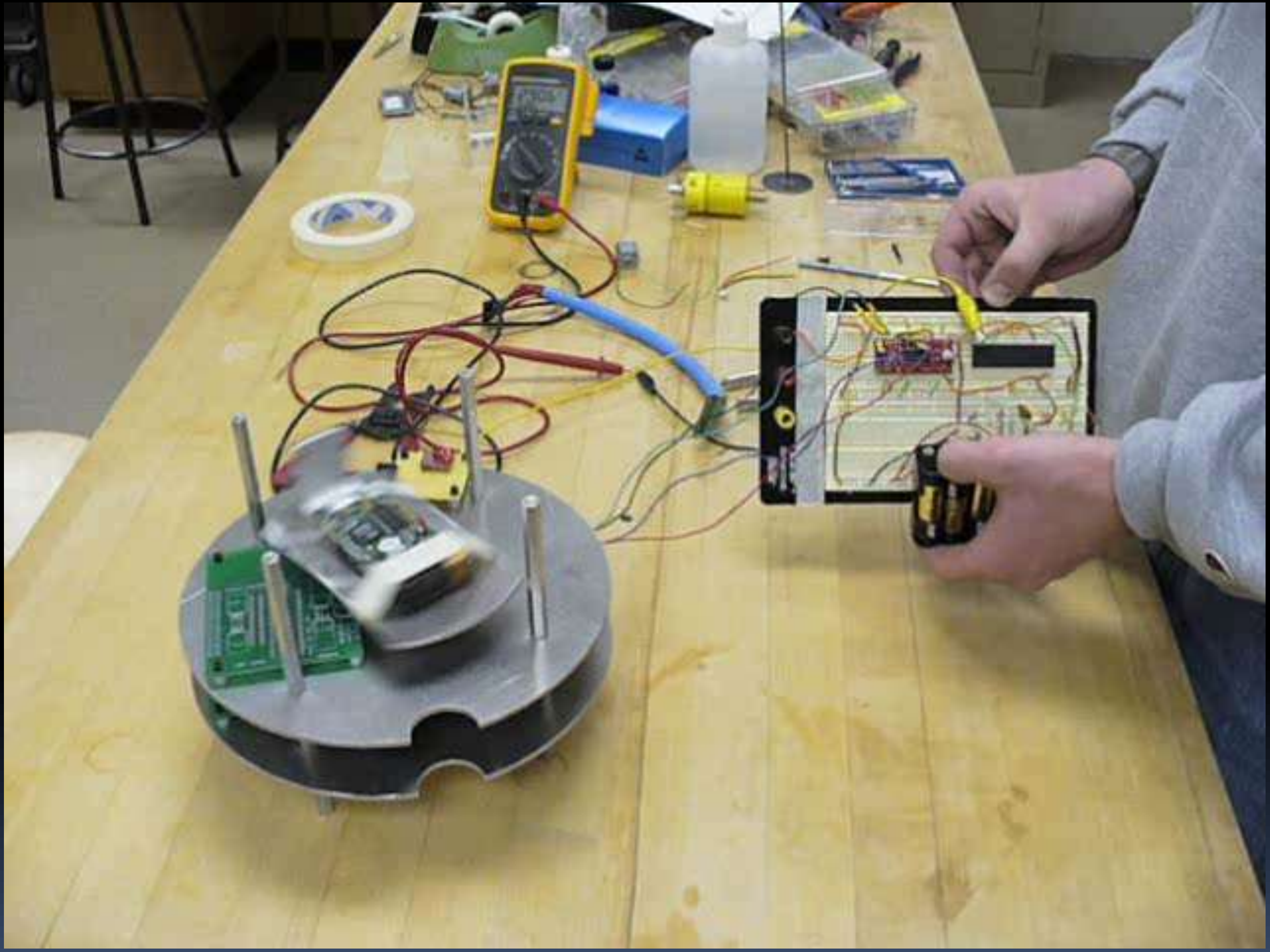




Testing

- Electrical
  - Code verification will be completed in the AVR Studio Development Environment
  - Test camera and plate control system on turntable
- Structure
  - Determine the canister and payload's natural frequency
  - Determine the center of mass
  - Test plate control system on turntable

Testing



Testing

- Potential Points of Failure
  - Electrical
    - Electrical connection breakage during high G's
    - Unforeseen code interruption due to interference
    - Creating own circuit board
  - Mechanical
    - Vertical supports buckling
    - Platter or camera platform malfunction

Safety

Hazards:

- Sharps – Level 3
- Electrical Hazards – Level 1
- Pinch Points – Level 3
- High Speed Rotating Machinery – Level 3
- High Speed Lateral Moving Machinery – Level 3
- High Pressure Hydraulic Lines – Level 4

Safety

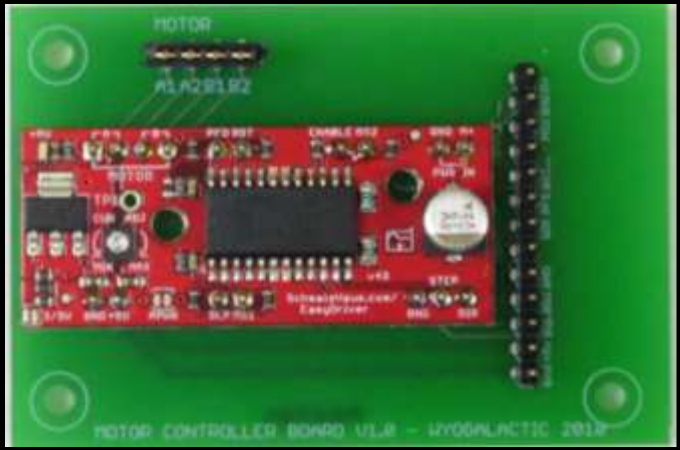
In order to mitigate these hazards:

- At least two people were to be present
- All hydraulic lines and fittings were inspected
- Hearing protection was used
- All machinery was used in accordance rules and guidelines.
- Testing was done according to set procedures
- No horseplay was allowed

Societal Impact

- Positive
  - Space exploration
  - Payload/Rocket reusable
  - Made of recyclable materials
- Negative
  - Pollution from launch

Completed Payload



Completed Payload

- Mechanical
  - Mission Ready
  - Awaiting electrical for full simulations
- Electrical
  - Power complete
  - Camera complete
  - Phase 2 software implemented

To-Do List

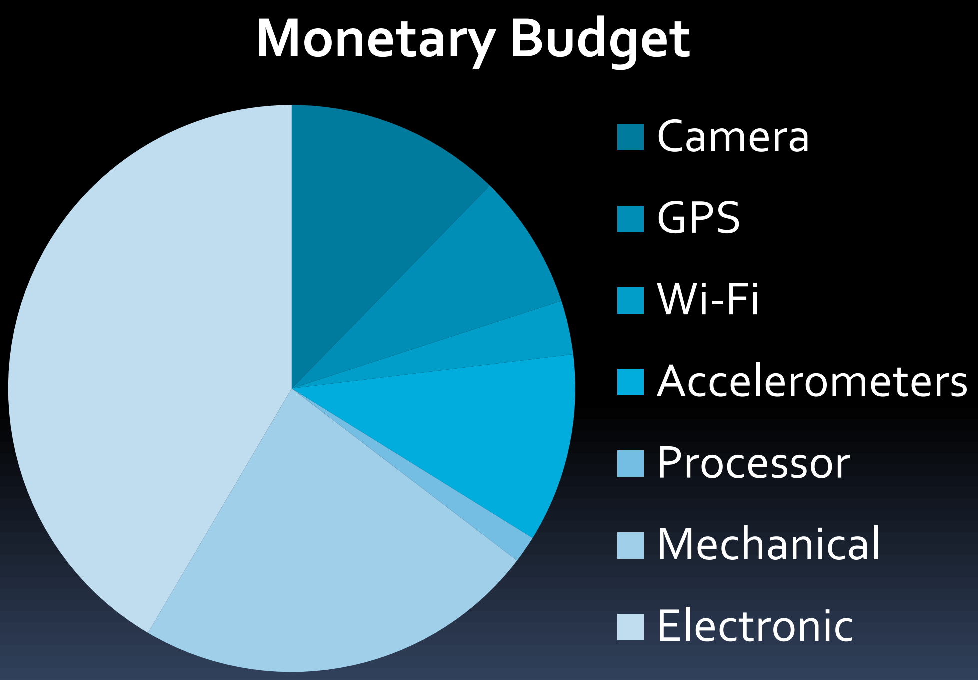
- Electrical (Software)
  - Calibrate control system
  - Vibration and turntable testing
  - Camera delay calibration
  - Implement Bluetooth/GPS software

Scheduling

- Today — Present Research and Project
- May 7 — Rough Draft of the Post Flight Final Wallops Report
- May 8 — Final Flight Simulation
- May 12 — Full Mission Simulation Test Report
- May 14 — Presentation of Full Mission Simulation Test
- June 17 — To Wallops
- June 24 — 6:00 AM Launch Rocket
- June 24 — Analyze Data Received from Launch
- July 14 — Final Report for Wallops

Budget

- Mass of Payload
  - Platform system~ 3.2lbs
  - Electronics~ 0.8lbs
- Money
  - Canister~ $7,000
  - Parts~ $650
  - Travel~ $3,250
  - Total~$10,900



Budget

- Simulated real world budget

Budget Senior Design					
Salaries		Per Hour	Hours a Week	Weeks	Per Year
Engineers:	Charles Galey	$30.00	20.00	38	$22,800.00
	Peter Jay	$30.00	20.00	38	$22,800.00
	Nick Roder	$30.00	20.00	38	$22,800.00
	Will Ryan	$30.00	20.00	38	$22,800.00
Consultants:	Dr. Johnson	$45.00	1.00	38	$1,710.00
	Dr. Barrett	$45.00	3.00	19	$2,565.00
	Dr. Walrath	$45.00	2.00	38	$3,420.00
Sub Total:					$98,895.00
Fringe Benefits 41%					$40,546.95
Entry Fee (Canister)					$7,000.00
Indirect Costs 41%					$60,041.20
Total Project					$206,483.15

- Spring Semester
  - ~751 man hours

Lessons Learned

- What did we learn from this experience:
  - Do not procrastinate
  - Contact is key for a smooth payload integration
- Words of wisdom for next year's groups:
  - Start early
  - Keep constant communication with other group(s) in canister to clarify ideas and models
- Hardest part:
  - Coordinating presentations and reports for both groups
  - Programming
  - Integrating systems together
- What would we change:
  - Less electrical integration

Conclusion

- Interfacing the components was one of the setbacks
- Learning new programming language and debugging the program was more difficult than anticipated
- We learned a lot during the course of this project
- Excited to finish the project and see the launch results from Wallops

Special Thanks

- CEAS Machine Shop
- Wyoming Space Grant Consortium
- Physics Department
- Mechanical Engineering Department
- Dr. Steven Barrett
- Harish Muralidhara

QUESTIONS?