Project ELSA

Europa Lander for Science Acquisition

Manufacturing Status Review

Team: Darren Combs, Gabe Frank, Sara Grandone, Colton Hall, Daniel Johnson, Trevor Luke, Scott Mende, Daniel Nowicki, Ben Stringer

Customer: Joe Hackel (Ball Aerospace)

Advisor: Dr. Robert Marshall

Agenda:

- Project Overview
- Schedule
- Budget
- Manufacturing & Status
- Conclusion

Project Overview

Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

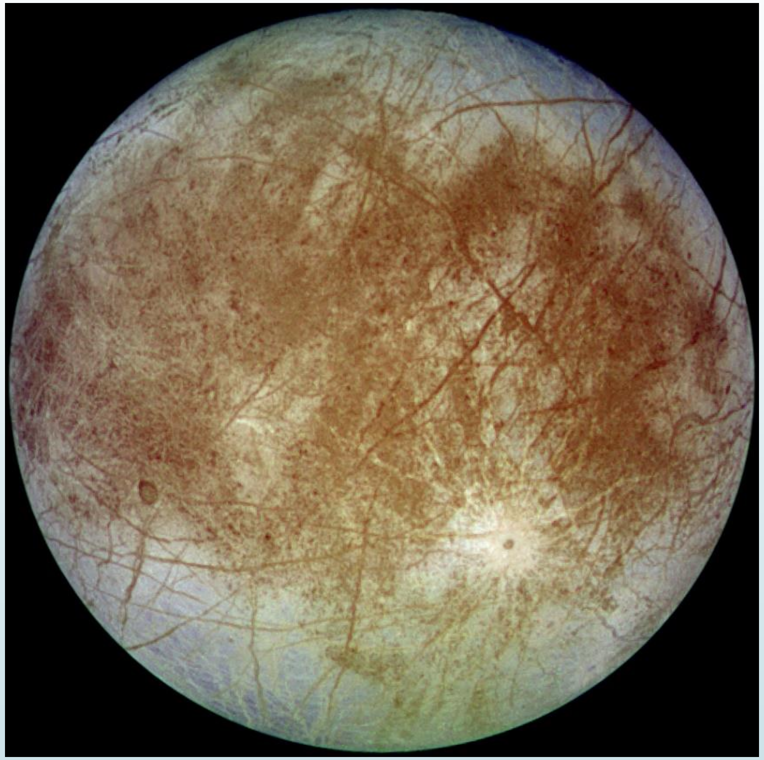
Project Statement

The ELSA team will **design and build a probe (the NeoPod) to collect, store, and transmit data via RF** to a Ground Station.

The NeoPod will operate in a stationary position for a **100 hour mission lifetime in a laboratory environment on Earth**, with a short distance between the NeoPod and the Ground Station.

Motivation for Project: Europa Mission

- Moon of Jupiter **(85 hour orbit)**
- Icy surface with an active geology and possibility of subsurface ocean
- Identified by NASA as a "High Priority Target" for its potential to support life
- **Ball Aerospace has developed a concept for a mission to Europa**
    - Polar orbiter (100 km, 95° inclination) deploys probe to surface
    - Probe collects data and then transmits it back during every pass



ELSA Mission Objectives

"Do science, get it back."

-Joe Hackel (Customer)

- **SCI 0:** *NeoPod shall collect scientific data relevant to the study of Europa*
- **COM 0:** *NeoPod shall communicate with the Ground Station*
- **INT 0:** *NeoPod shall integrate with existing mission architecture*

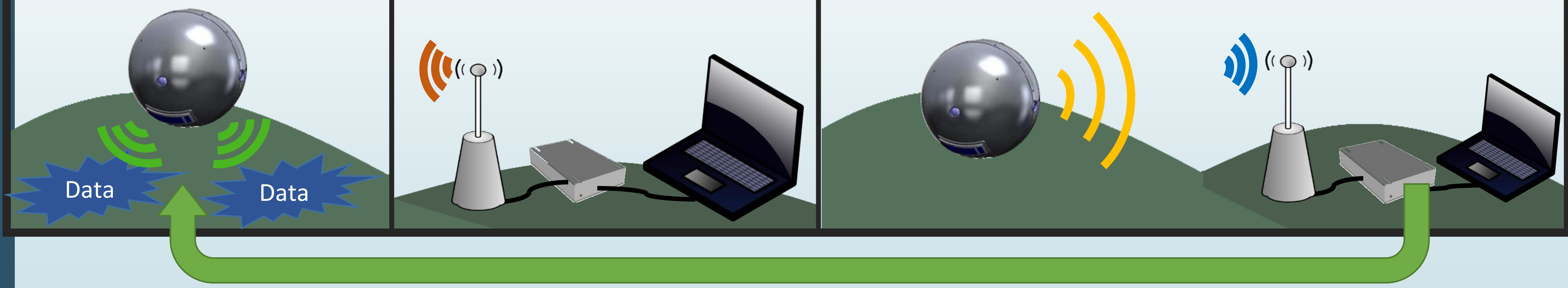
ELSA CONOPS

Collect & Store (2hr)
NeoPod is powered on and begins collecting and storing science data

Command
Ground Station sends command to NeoPod to begin transmission of data

Transmit (8 min)
NeoPod begins to transmit stored data

Record
Ground Station receives and records data

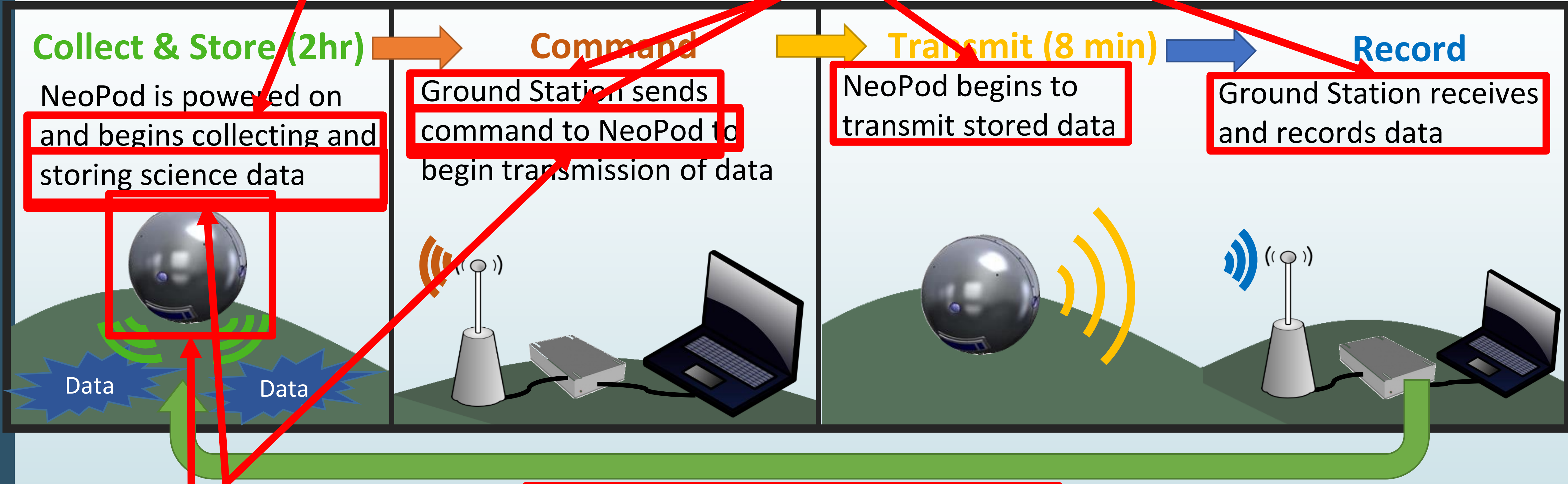


Total: 100 hour mission timeline

Levels of Success

Ground Station Communications

PAYLOAD



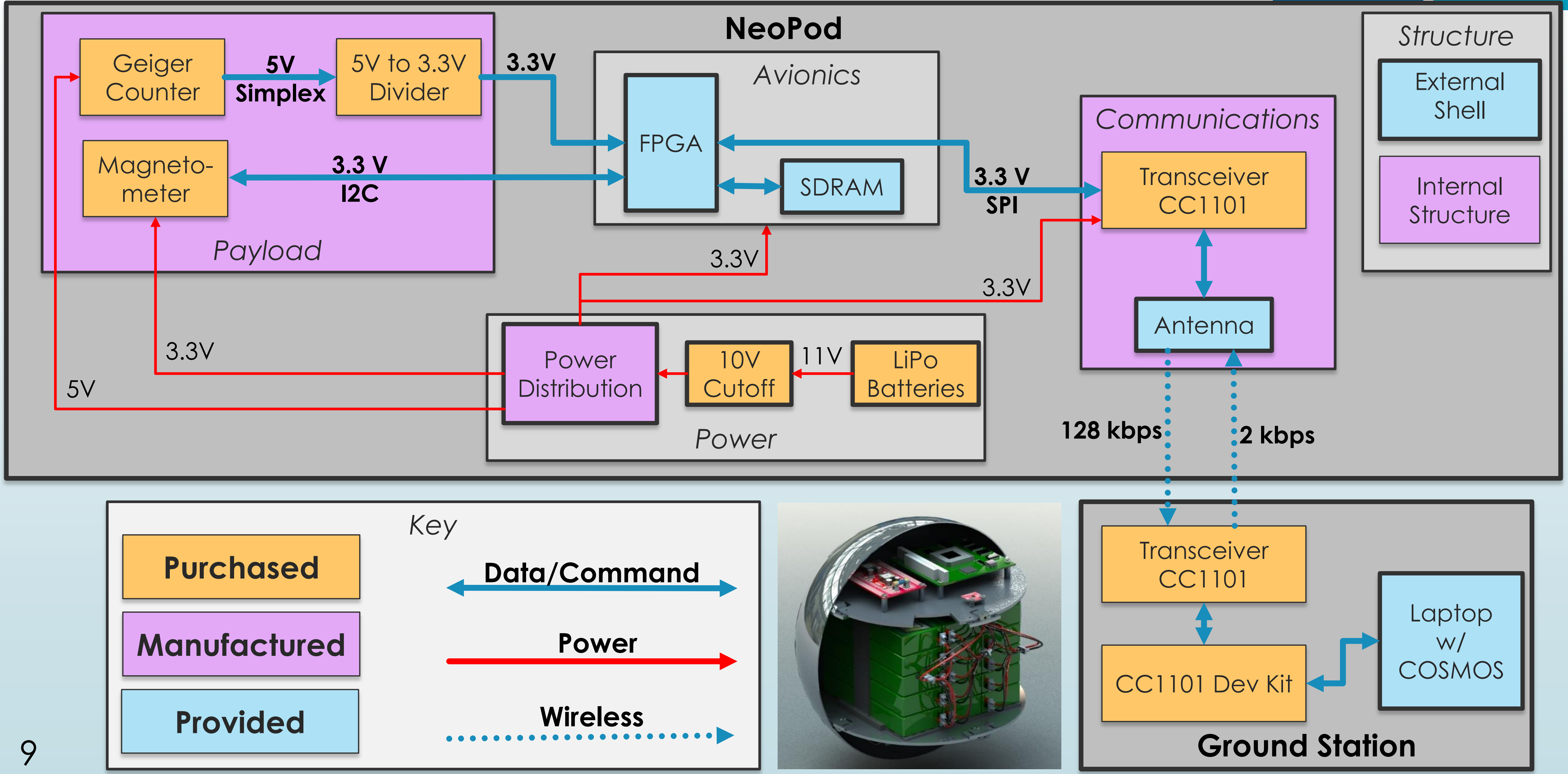
AVIONICS

Total: 100 hour mission timeline

Power

Structure

FBD of ELSA System

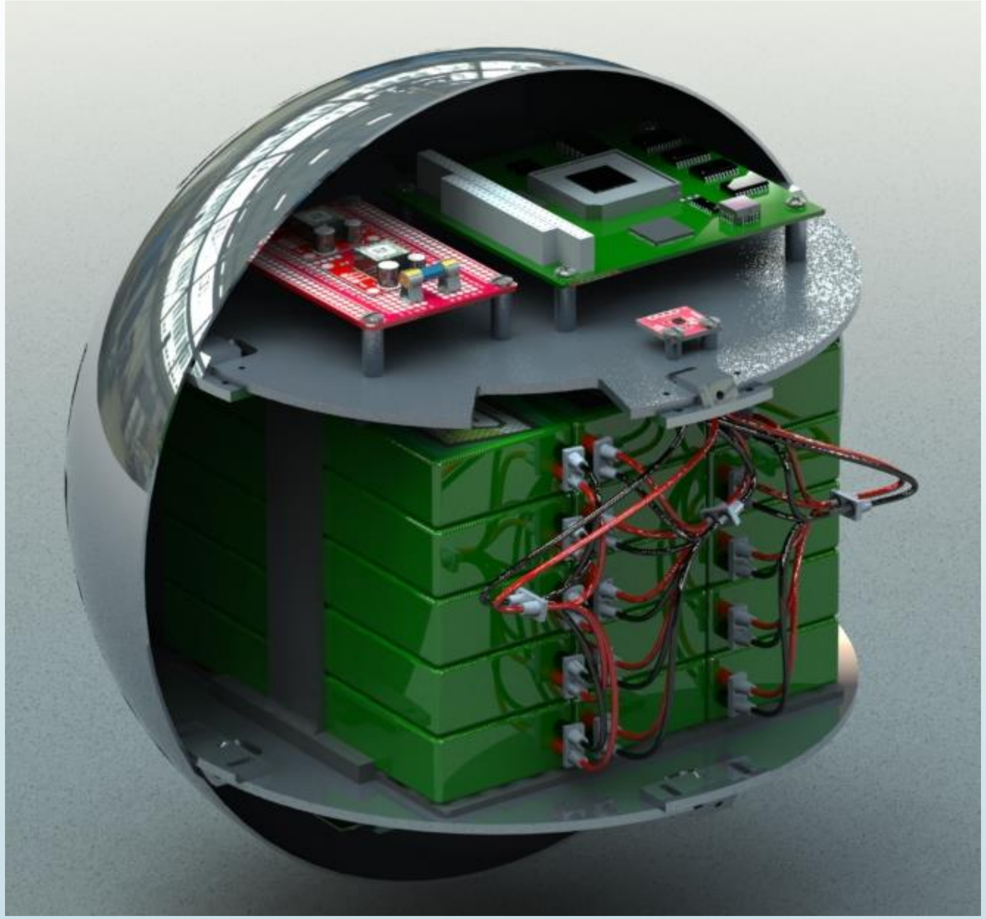


Critical Project Elements

Designation	CPE	Description
CPE-1	Avionics Hardware Integration and FPGA Software	Avionics Board must **interface** with **all components** and **structures**. Lack of previous team FPGA experience.
CPE-2	Communications System Design	**Two-way** communication between **NeoPod** and **Ground Station**. Multiple data types.
CPE-3	Powers System Design	Accurate **models** to ensure **power is supplied** for **100 hour** mission lifetime. **Custom PCB** and circuit design necessary.
CPE-4	Mechanical Integration	All components **must** satisfy mass and volume requirements. Internal components must **not** exceed **thermal tolerances**.

Executive Summary

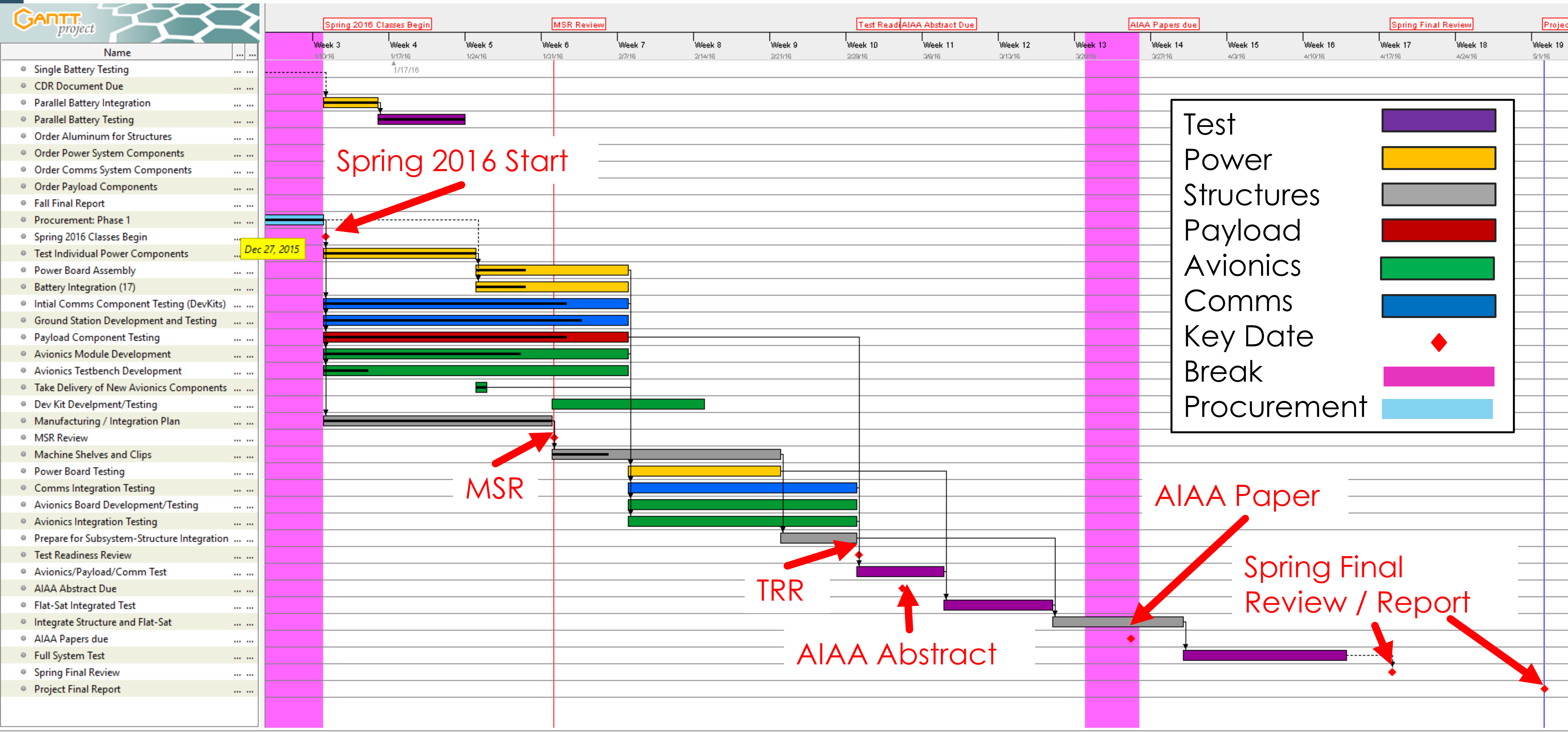
- Changes from CDR
  - Battery strap to 3D printed casing
  - Slight Structure Modifications (Wiring Locations)
  - **Minimal effect on schedule and budget**
- Schedule
  - Communications, Payload **ahead of schedule**
  - Structures, Power **on schedule**
  - **Avionics behind schedule (Mitigation Discussed Later)**
- Budget
  - Majority of procurements acquired: **~$3000 remaining**
  - 100% margin on budget – **No Budget Concerns**



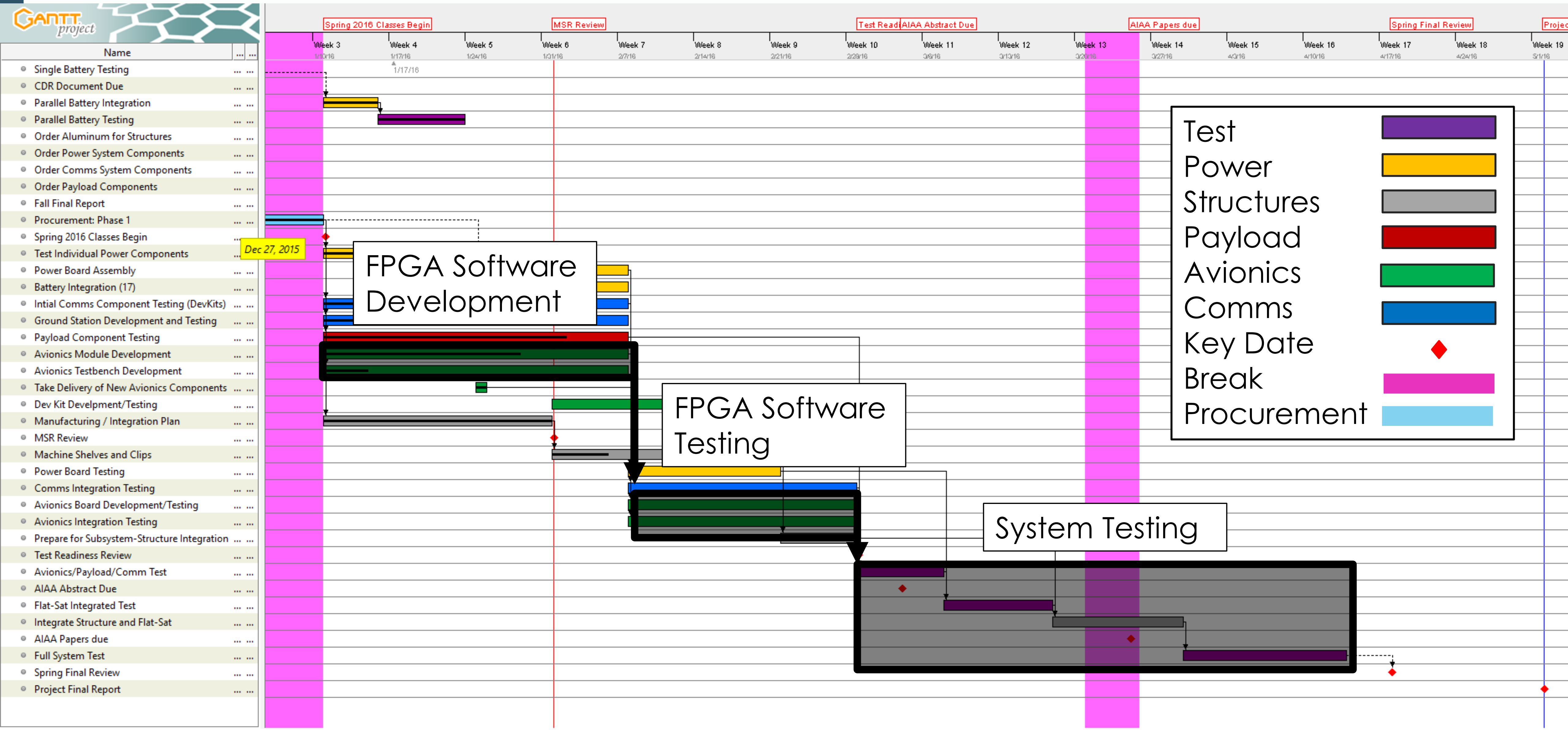
Schedule

Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

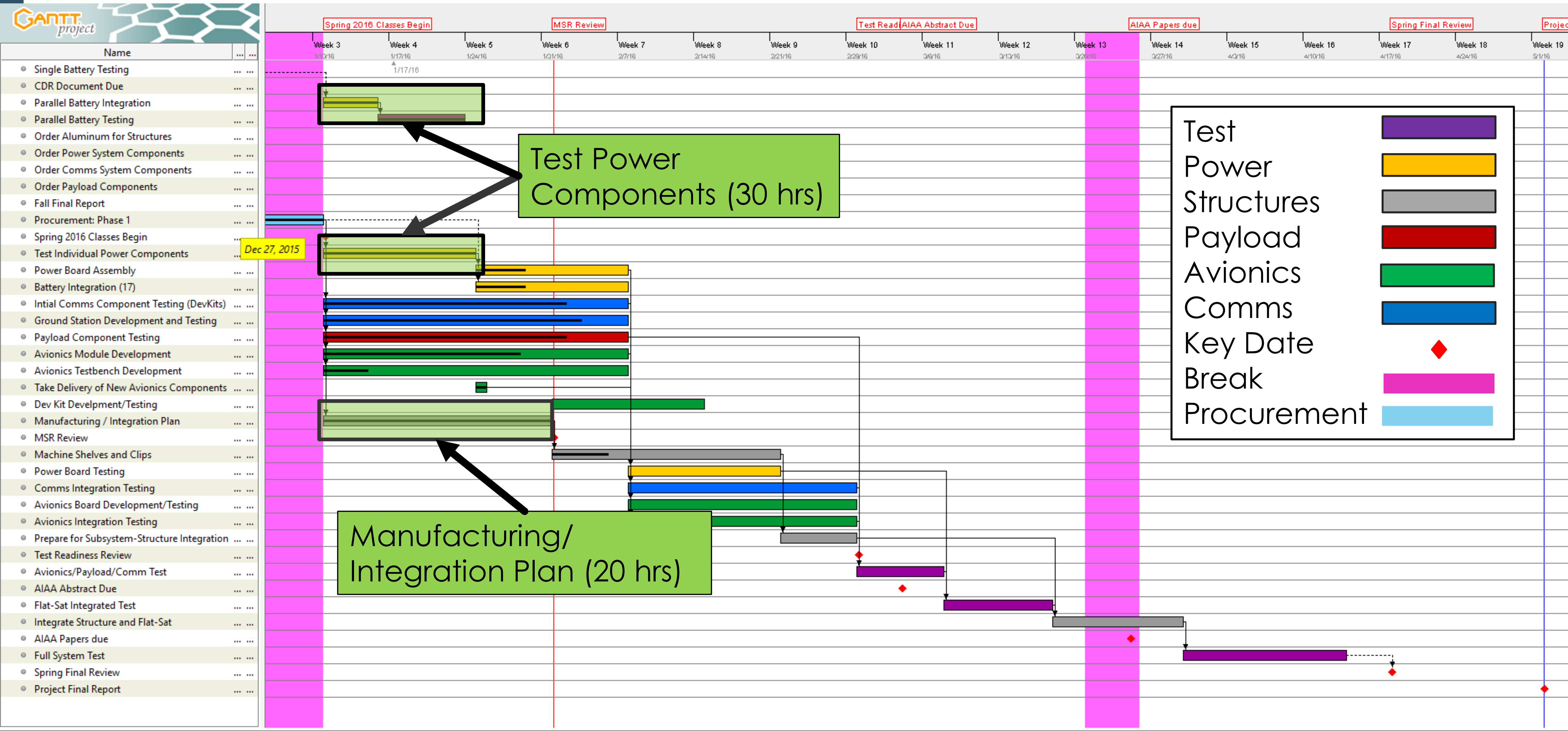
Spring Semester Schedule



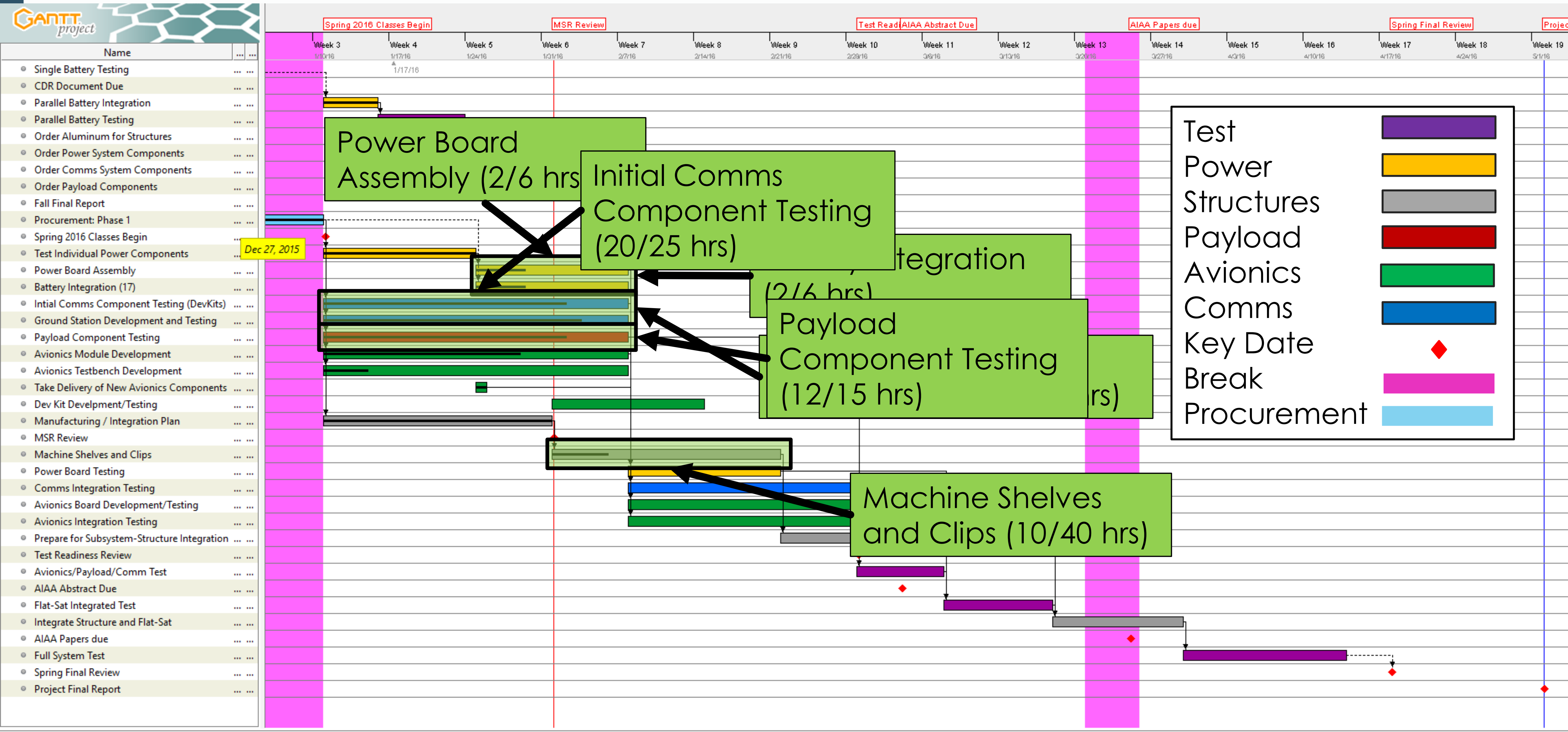
Spring Critical Path



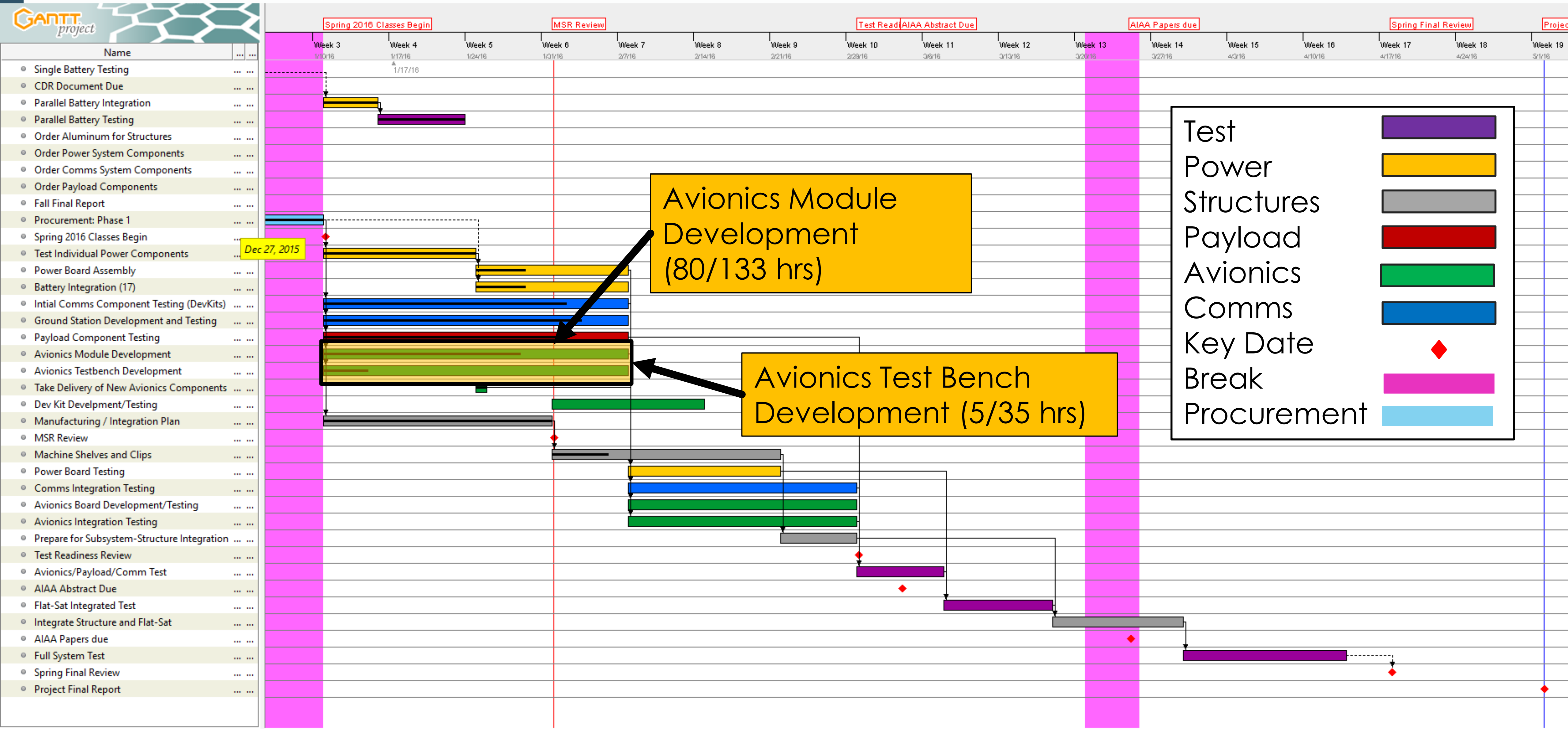
Completed Tasks:



Tasks Ahead of Schedule:



Tasks Behind Schedule:



Budget

Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

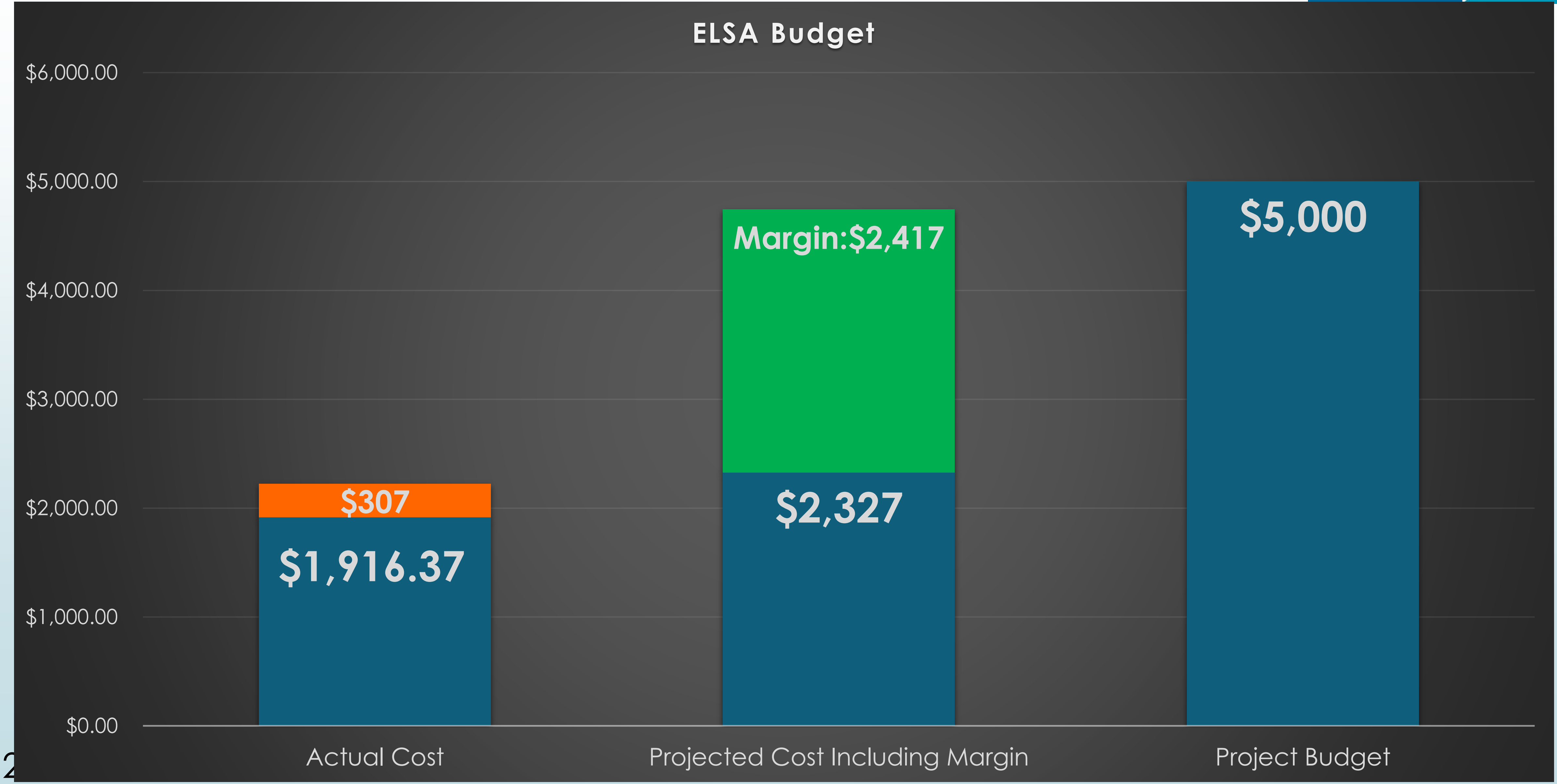
Procurement Status

- Ball Avionics Board: **DELIVERED**
- Subsystem Primary Procurement: **COMPLETE**
  - All items specified as needed in FFR have been delivered

- **Future Procurements (Total: $307)**
  - PCB's Revision 2 ~ $66
  - Logic Step Down PCB Rev. 1 ~ $66
  - ESD Ionizing Fan ~ $150
  - Standoff Screws ~$20

No Budget Risk to Project

Budget Status



Budget Status

Part	Projected Cost	Actual Cost	Difference	Projected + Margin
Batteries (x20)	$640.00	$404.88	$235.12	$768.00 (4 Batt.)
CC1101 Transceiver Kit	$500.00	$471.42	$28.58	$1000.00 (100%)
Wires, Connectors, Cables	$400.00	$206.6	$193.4	$1200.00 (200%)
Testing Equipment	$240.00	$236.35	$3.65	$265.00 (10%)
Metals and Fasteners	$177.00	$135.56	$41.44	$531.00 (200%)
Sensors	$165.00	$179.85	$14.85	$330.00 (100%)
Printed Circuit Boards	$100.00	$102.38	$2.38	$400.00 (300%)
Avionics Programmer	$50.00	$51.25	$1.25	$100.00 (100%)
DC/DC and Logic Converters	$35.00	$65.8	$30.8	$70.00 (100%)
Power Safety Devices	$20.00	$40.45	$20.45	$80.00 (300%)
Miscellaneous	-	$21.83	$21.83	-
Total:	**$2327**	**$1916.37**	**$410.63**	**$4744**

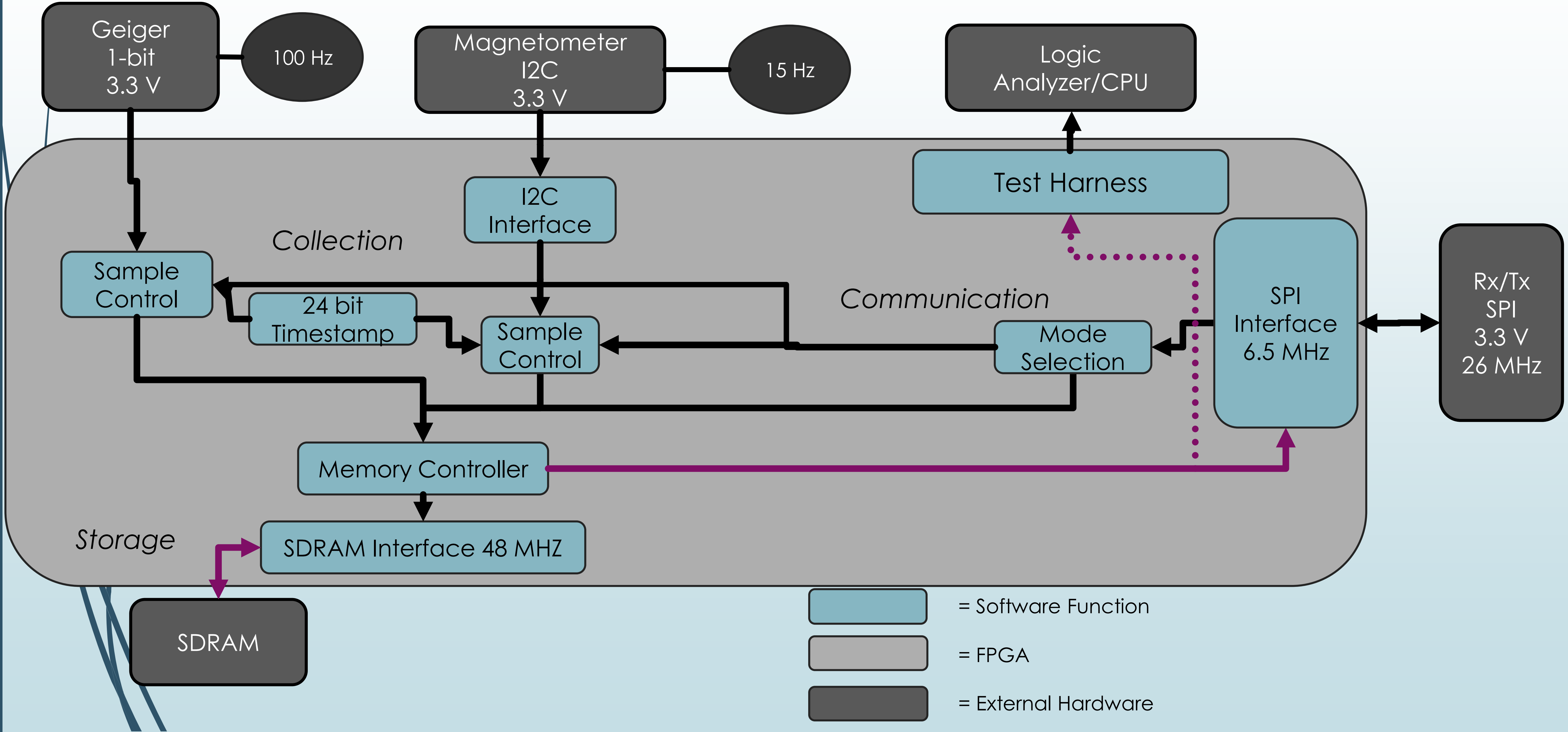
Manufacturing & Status

Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

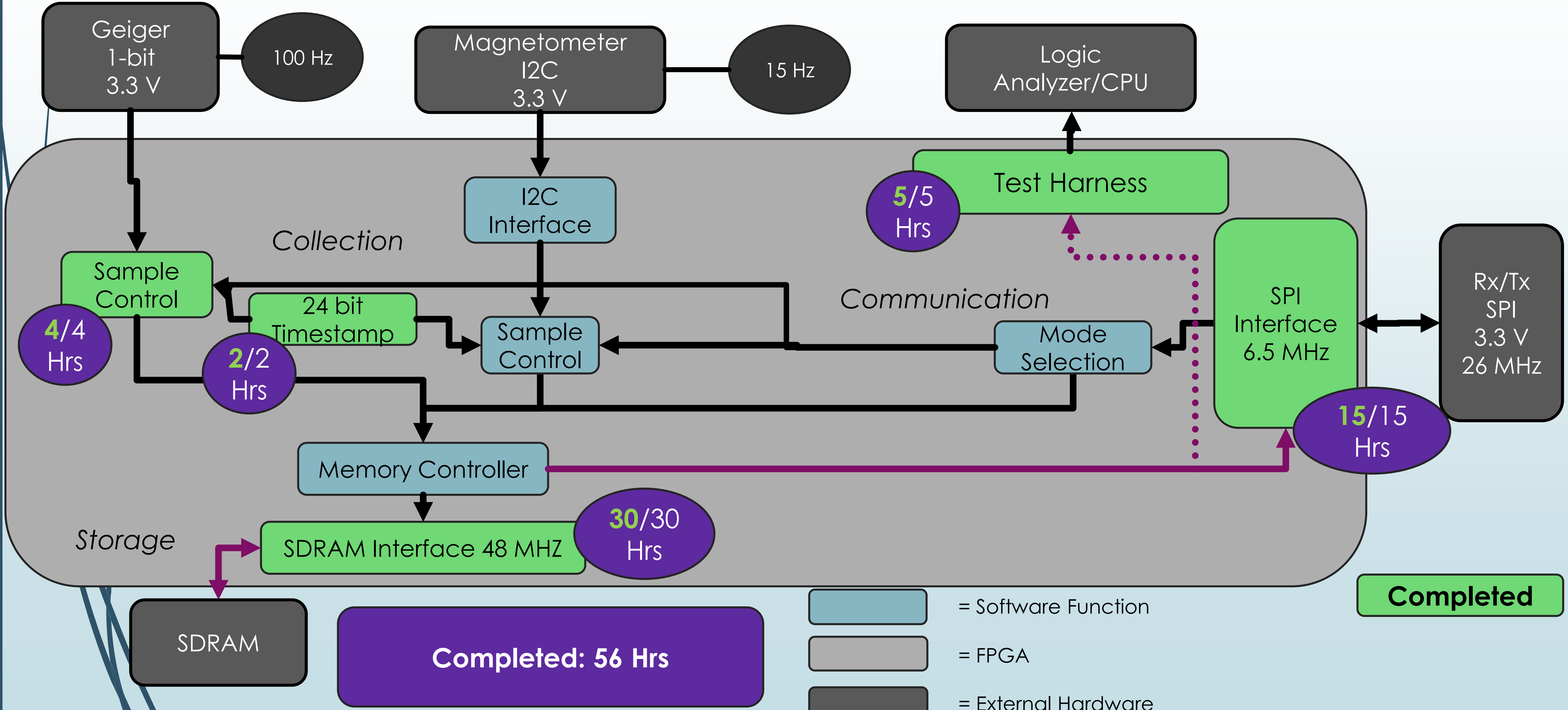
Avionics Software

Critical Project Element 1: Avionics Hardware Integration and FPGA (Field Programmable Gate Array) Software

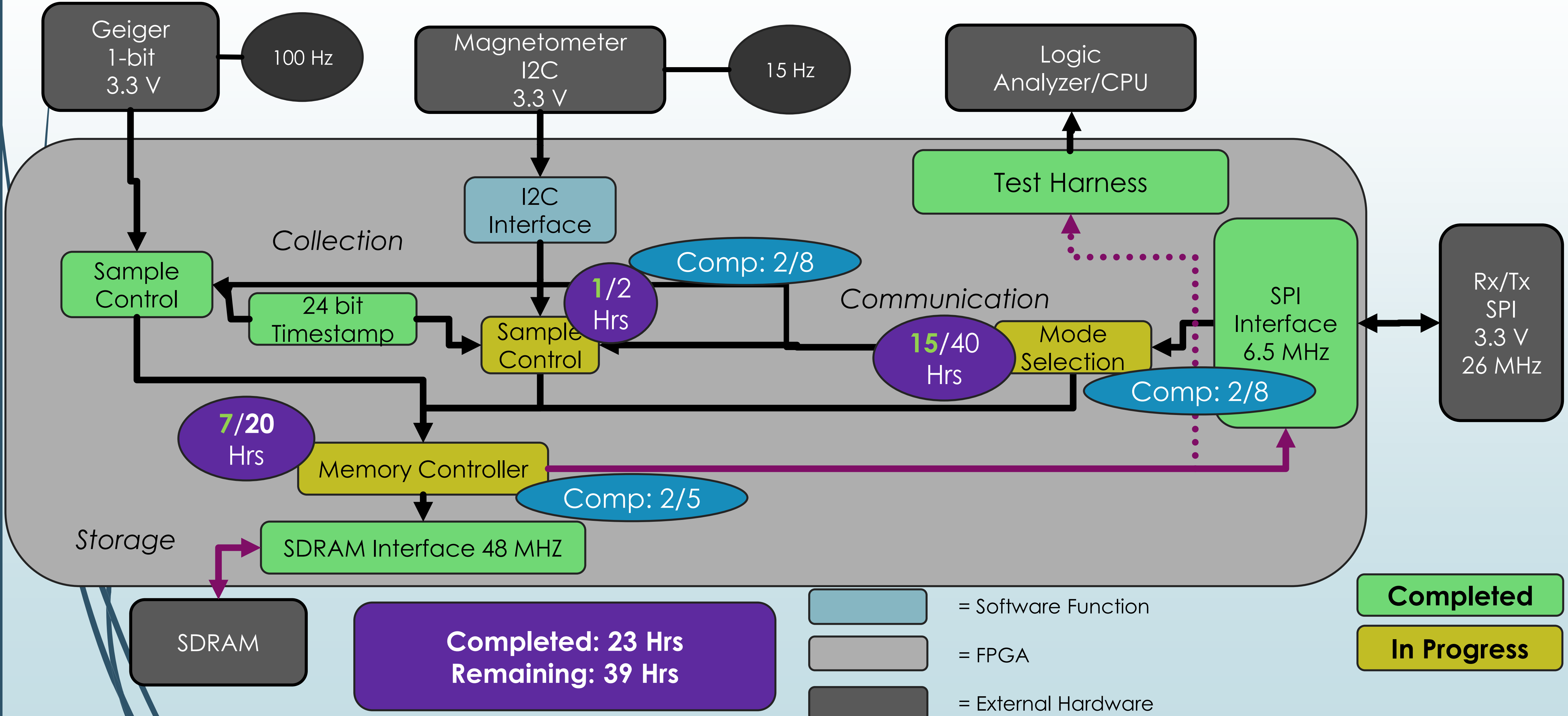
Avionics Software



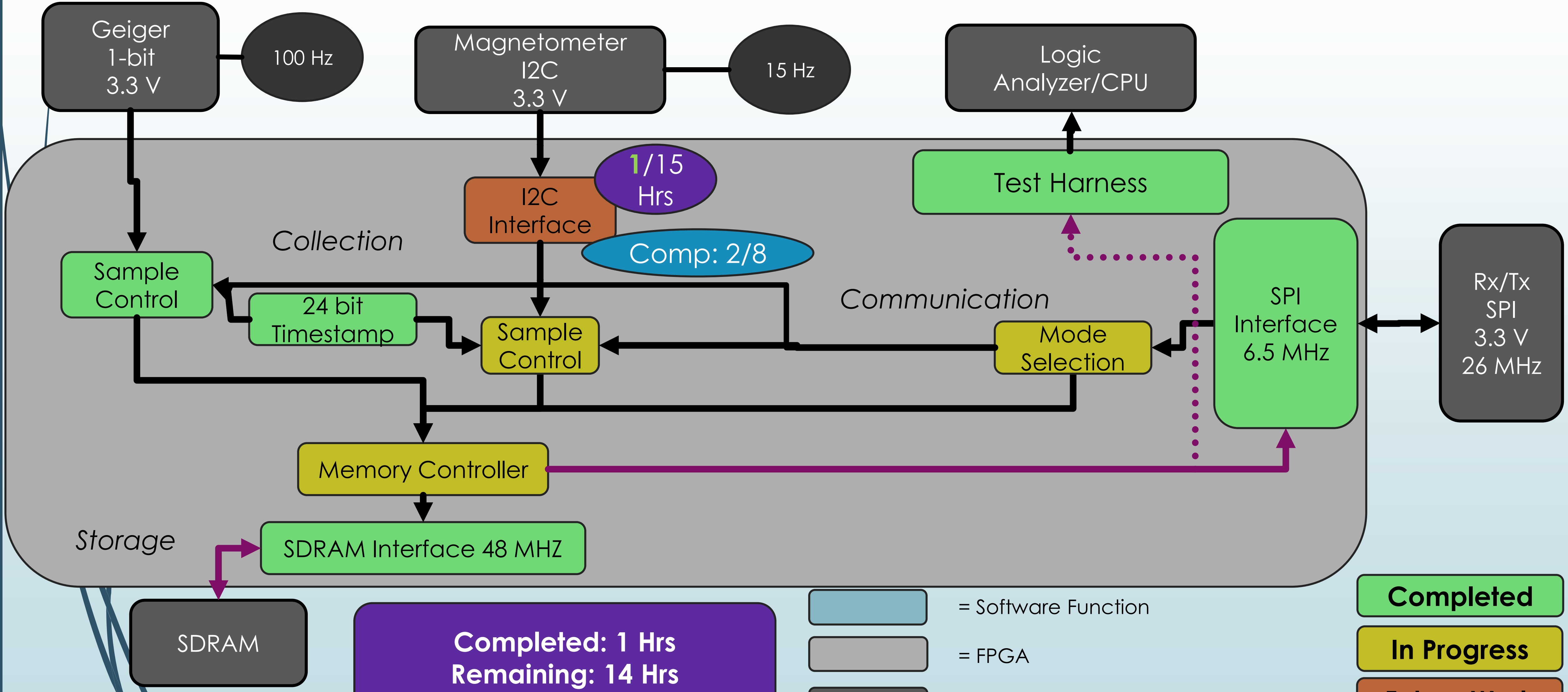
Module Completion Status



Module Completion Status



Module Completion Status



Completed: 1 Hrs
Remaining: 14 Hrs

= Software Function

= FPGA

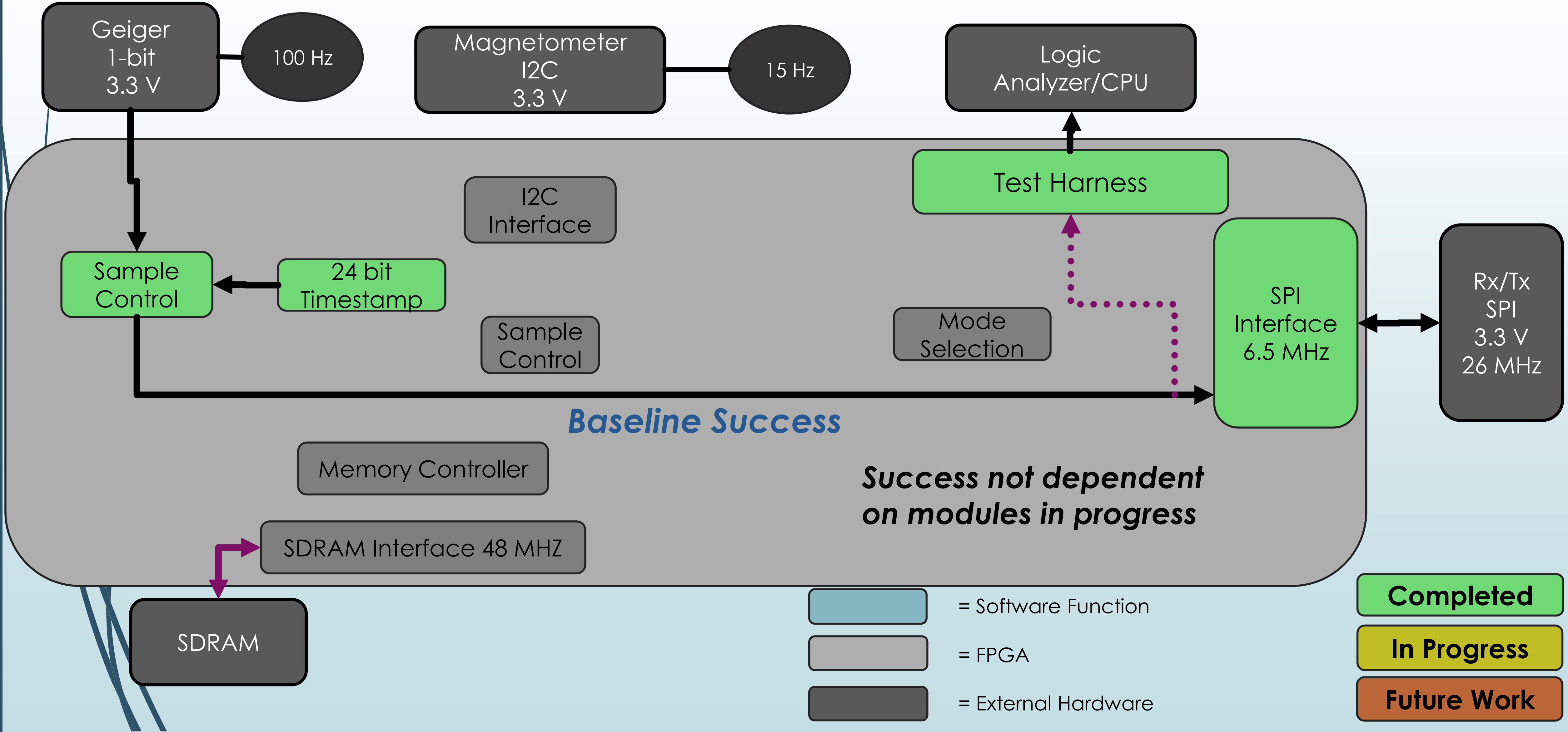
= External Hardware

Completed

In Progress

Future Work

Module Completion Status



Progress and Path Forward

Mitigation:

1) **4th Team Member allocated to Avionics**
2) **14 days of Remaining Margin**

COMPLETED:

1) Data In/Out Modules
2) SDRAM Interface
3) SPI Interface
4) Test Harness

Future Work:

1) Memory Traversal: 2/5
2) **Mode Control and Transceiver Control: 2/8**
3) **Initial Dev. Kit Testing / On Hardware Testing: 2/4**
    1) Logic Analyzer Testing: 2/4

Module Work Completed: 80 Hrs

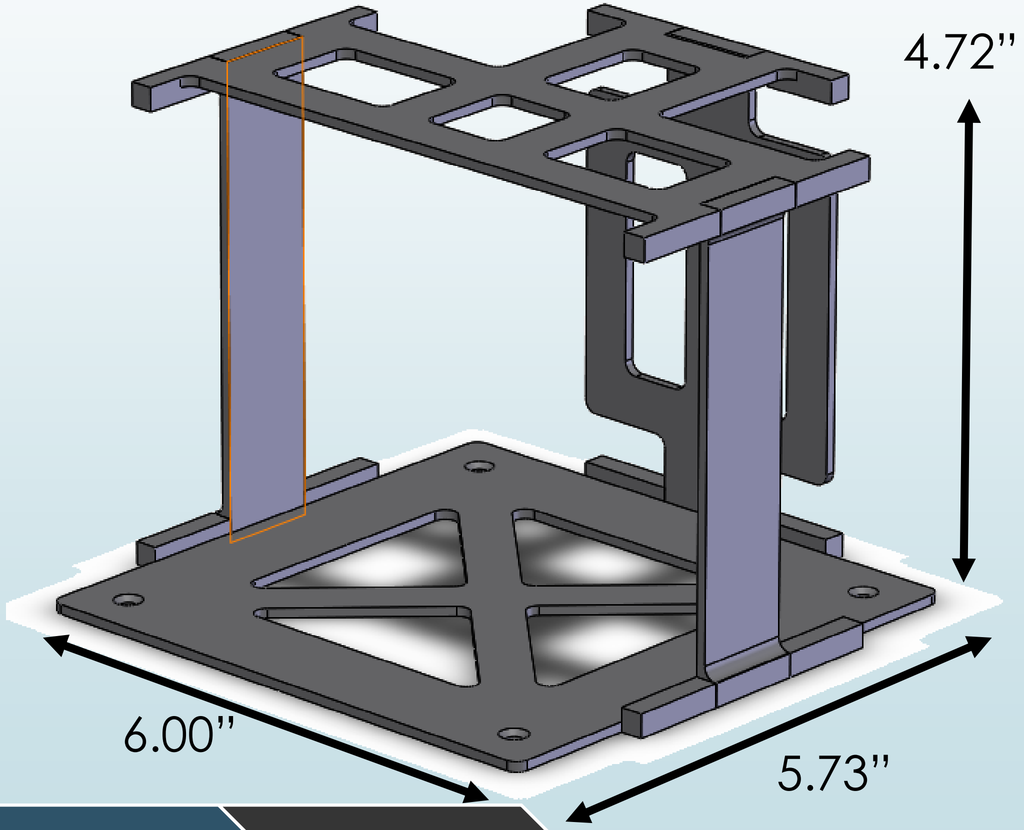
Module Work Remaining: 53 Hrs

Structures & Manufacturing

Critical Project Element 4: Mechanical Integration

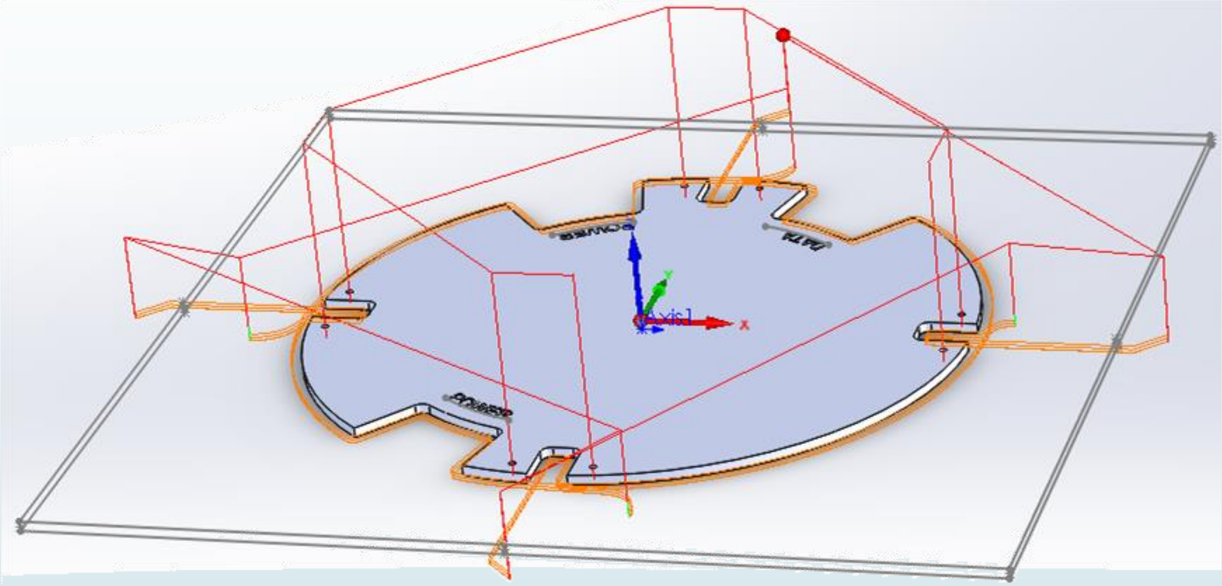
Structural Design Updates

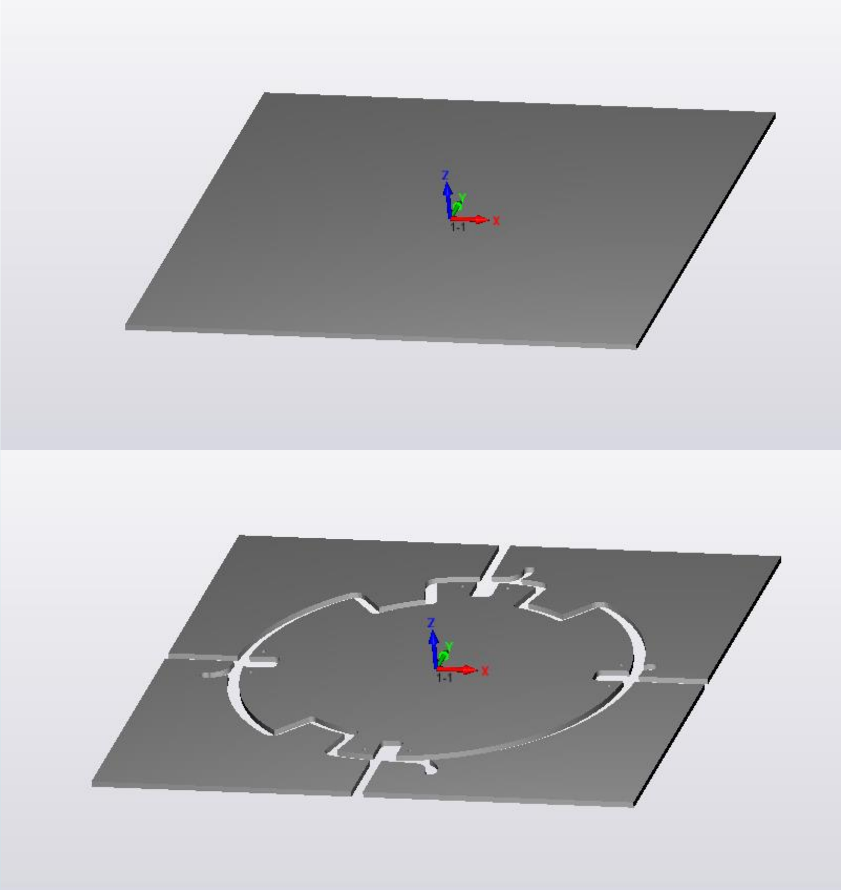
- Designed **3D printed case structure for batteries** (PLA)
  - Replaces battery strap
- **Modified wiring holes/paths** in both plates
- Changed **size of drill holes -> more accessible screws**
- **Added two Printed Circuit Boards** inside structure
- **15 battery** design
  - Down from 17 batteries at CDR



Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

Shelf Machining Process



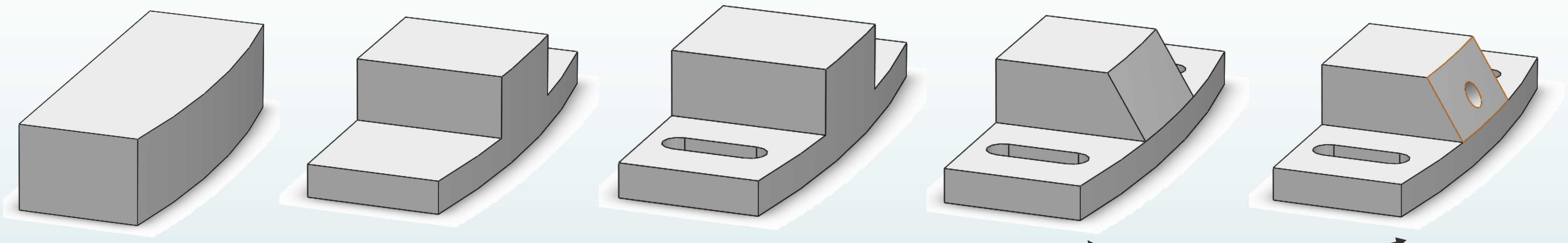


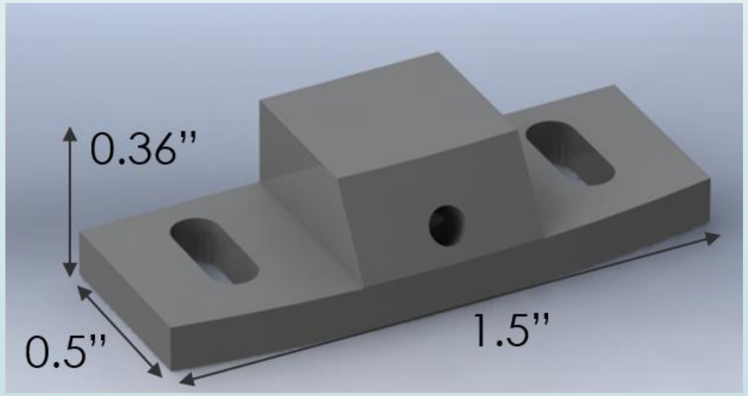
Top Shelf: Machining Completed

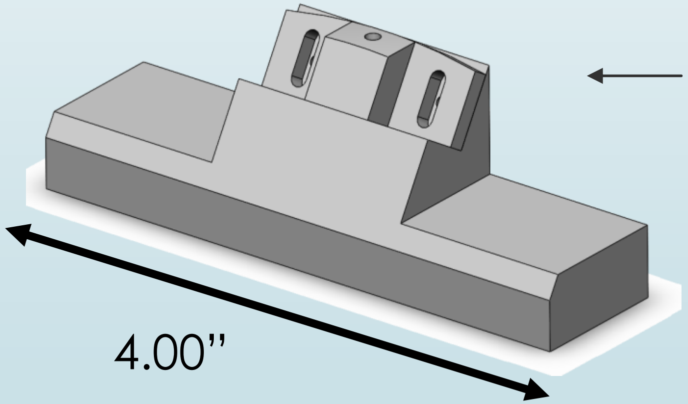
Bottom Shelf: Machining Completed

Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

Clip Machining Process





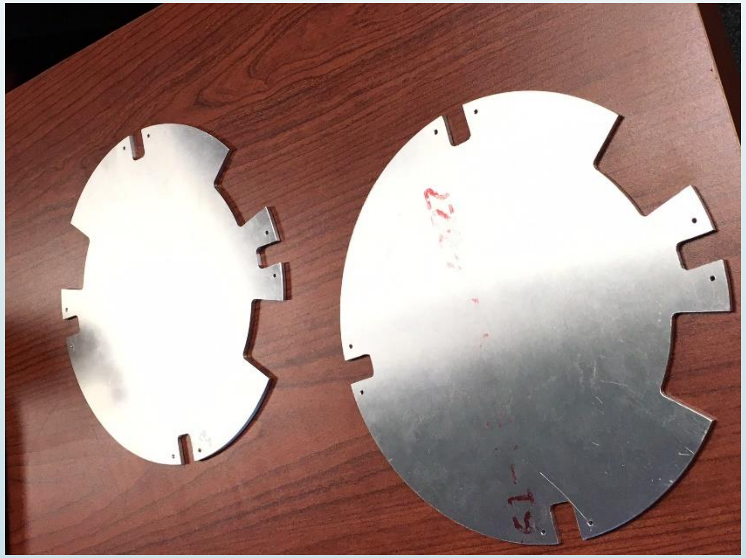


Operations will be performed using custom designed fixture

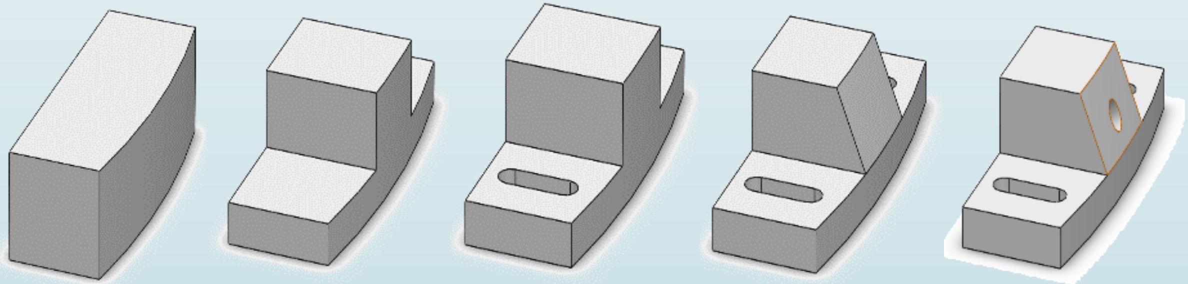
Expected Completion: 02/12/16

Structures Summary

- **Work Completed:**
  - Both shelves are machined
  - Tool paths for machining completed
  - CAD model for 3D print complete
  - All metal has been acquired



- **Future Work:**
  - Thread holes in shelves – Week of 2/1 (3 hours)
  - **Buy PLA material and 3D print battery case** – Week of 2/1 (3 days)
  - **Machine 8 shelf clips** – Week of 2/8 (15 hours)
  - Physically integrate components inside ball – Week of 2/15 (5 hours)



Communications System

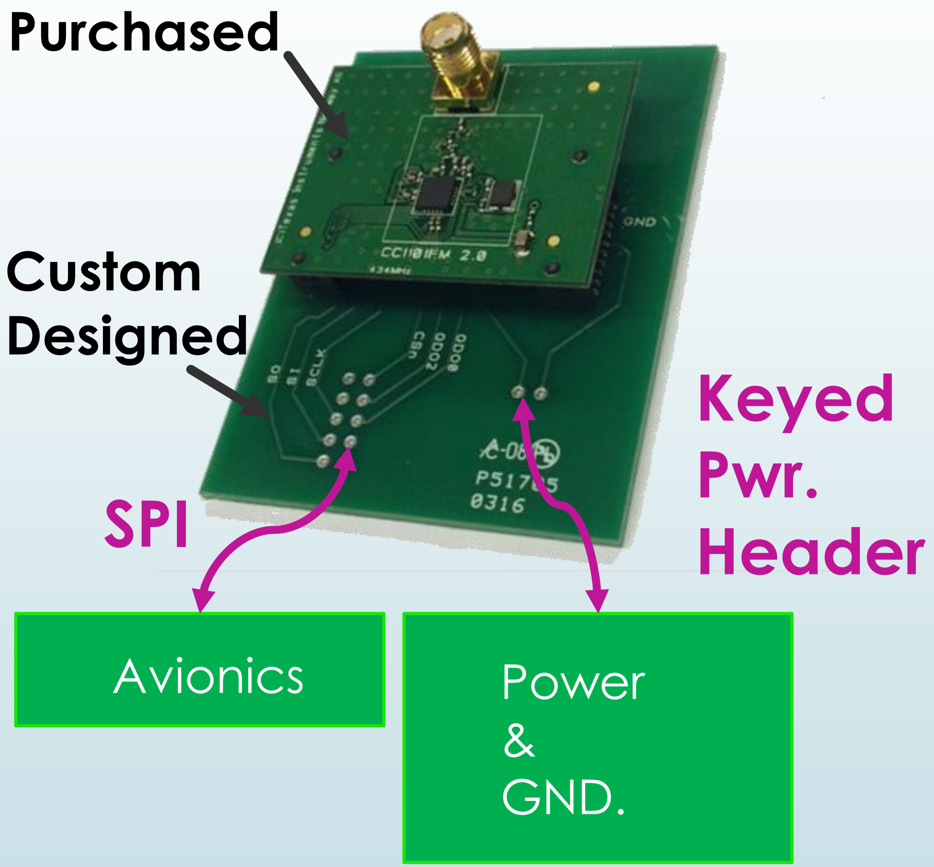
Critical Project Element 2: Communications System Design

Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

NeoPod Inner Comms. System

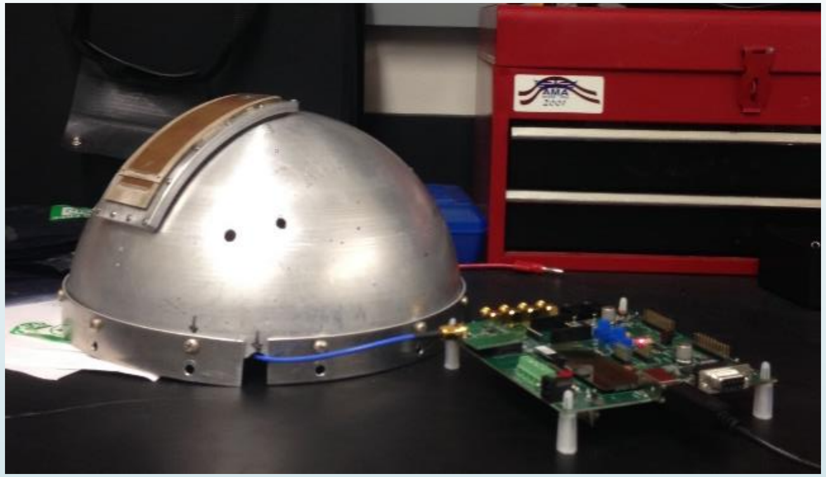
- **Successfully** mechanically mated with CC1101 Transceiver headers
- Continuity has been **tested and approved**
- Standoffs and avionics/power headers **will be** added on
- SPI Functionality **will be** tested by attaching PCB and CC1101 to PIC18 dev. Kit **provided by University of Colorado** for rent

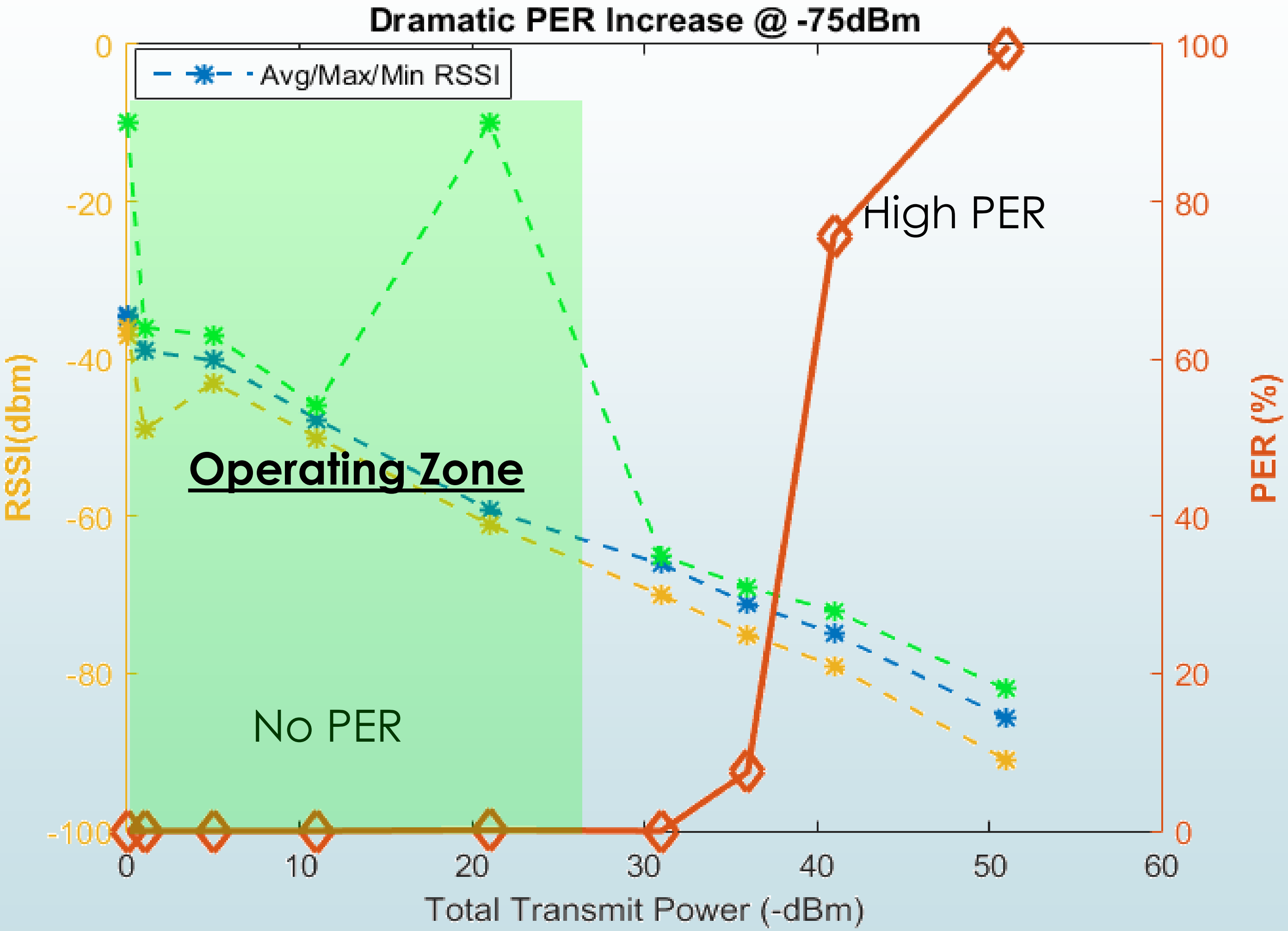
Expected Completion Date: 02/08/16



Antenna Characterization Test

- 1.8 m transmit distance (Lab Environment)
- 3 Packet Errors out of 21,000
- Packet Error Rate (PER) begins to **significantly increase at -70dBm** RSSI





Conclusion: A PER of **<u>0.005%</u>** is achievable

Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

Communication Summary

- **Work Completed:**
  - Antenna functions with transceiver
  - Nominal PER is achievable
  - Groundstation is capable of real-time data display as well as automated commands

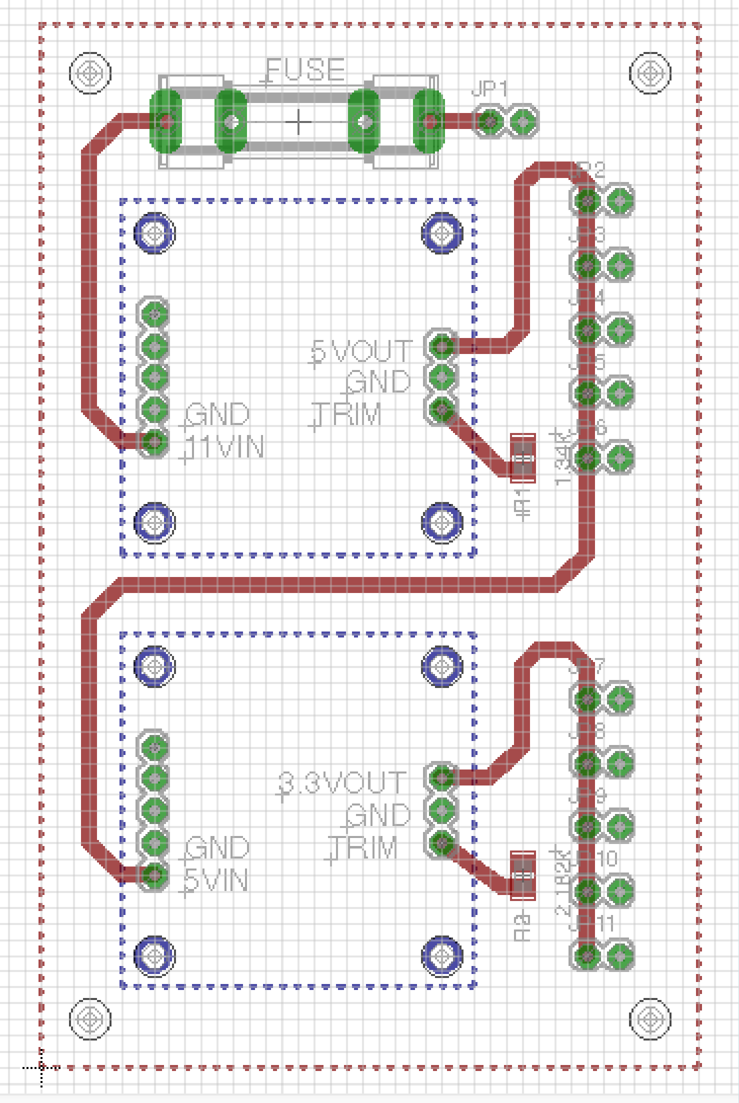
- **Future Work:**
  - Custom PCB will be further proven by interfacing with a PIC18 dev. Kit
  - Groundstation mission specific software will be finalized by 2/5
  - Communications is **on schedule and will not require future purchases**

Power System

Critical Project Element 3: Powers System Design

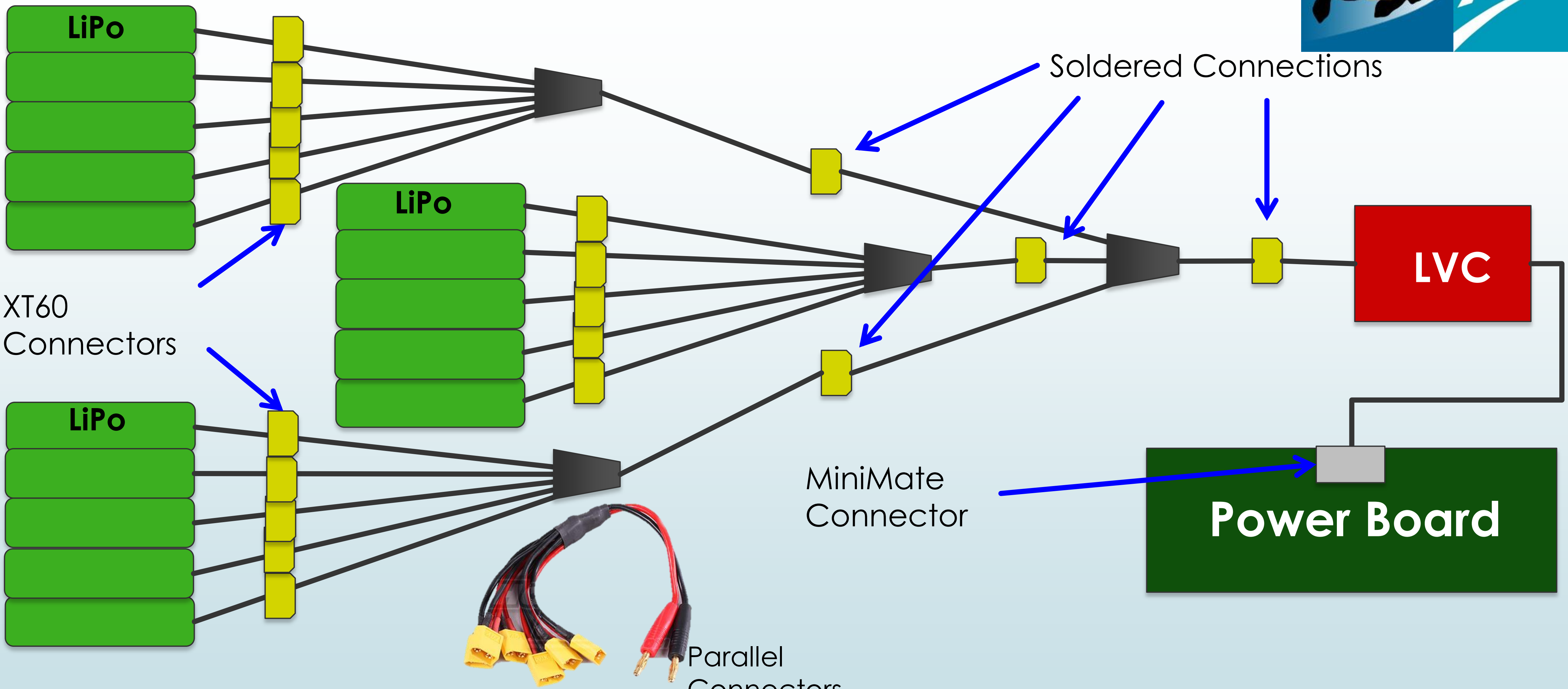
Power Distribution Board

- First version of the printed circuit board has been **received**.
- The board will be constructed and tested.
- The components that must be soldered are:
  - Fuse clips: procured
  - Connector headers: procured
  - Board-to-board clips: procured
  - Resistors: ordered



Power Board Rev 0 has been procured

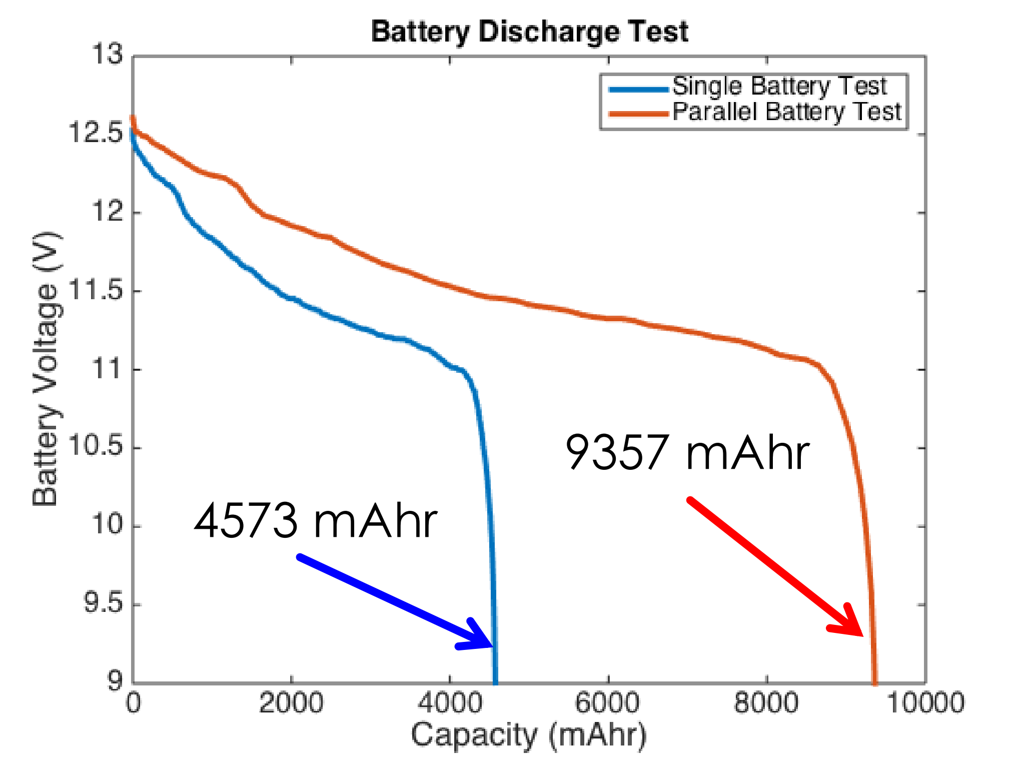
Battery Integration Plan



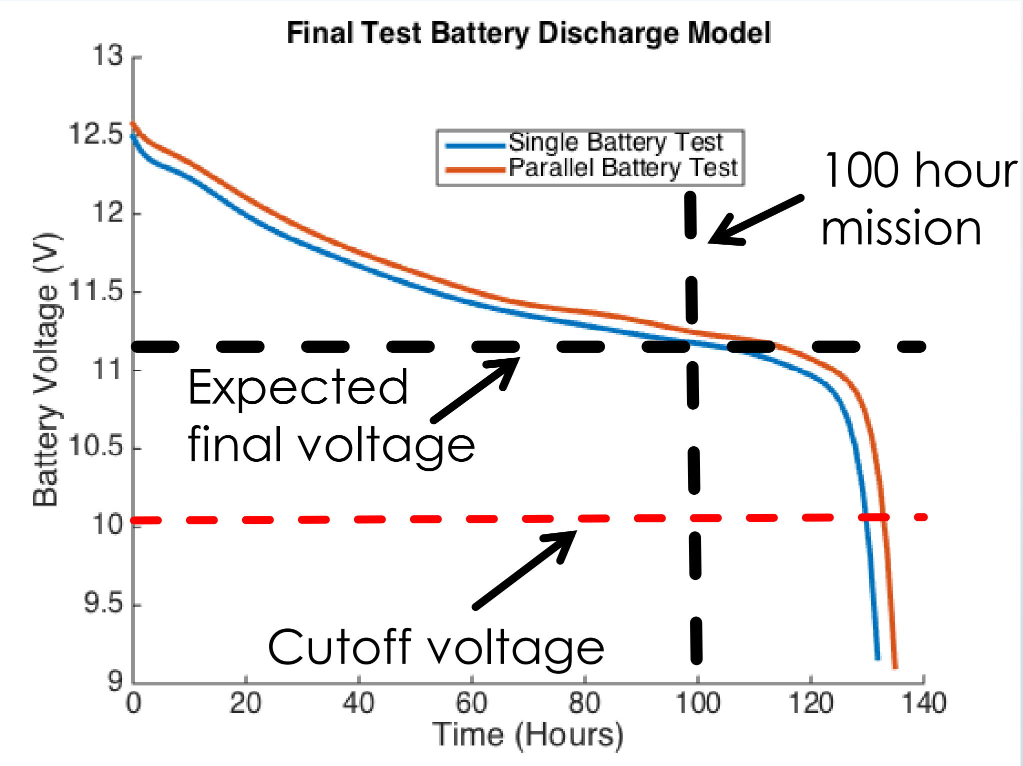
Parallel
Connectors

Battery Testing

- Two batteries were connected in parallel and discharged
- Data from the tests compared below.
- As expected, the capacity of two batteries is approximately twice that of a single battery.

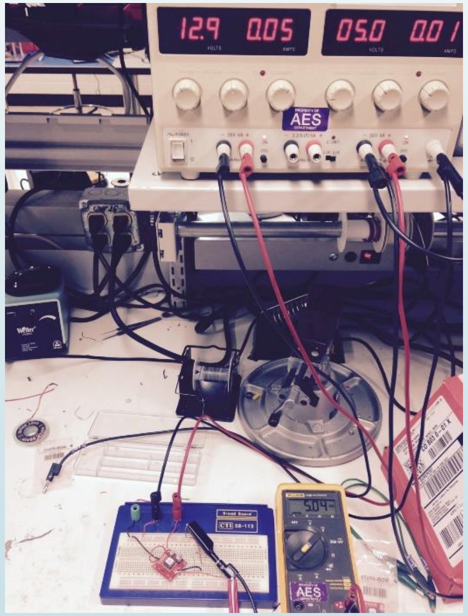


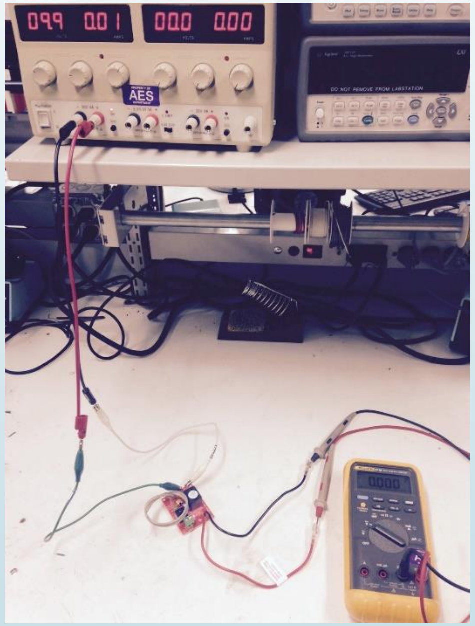
- Both tests were extrapolated to form a model for a 100 hour test.
- As expected, there was a slight increase in capacity

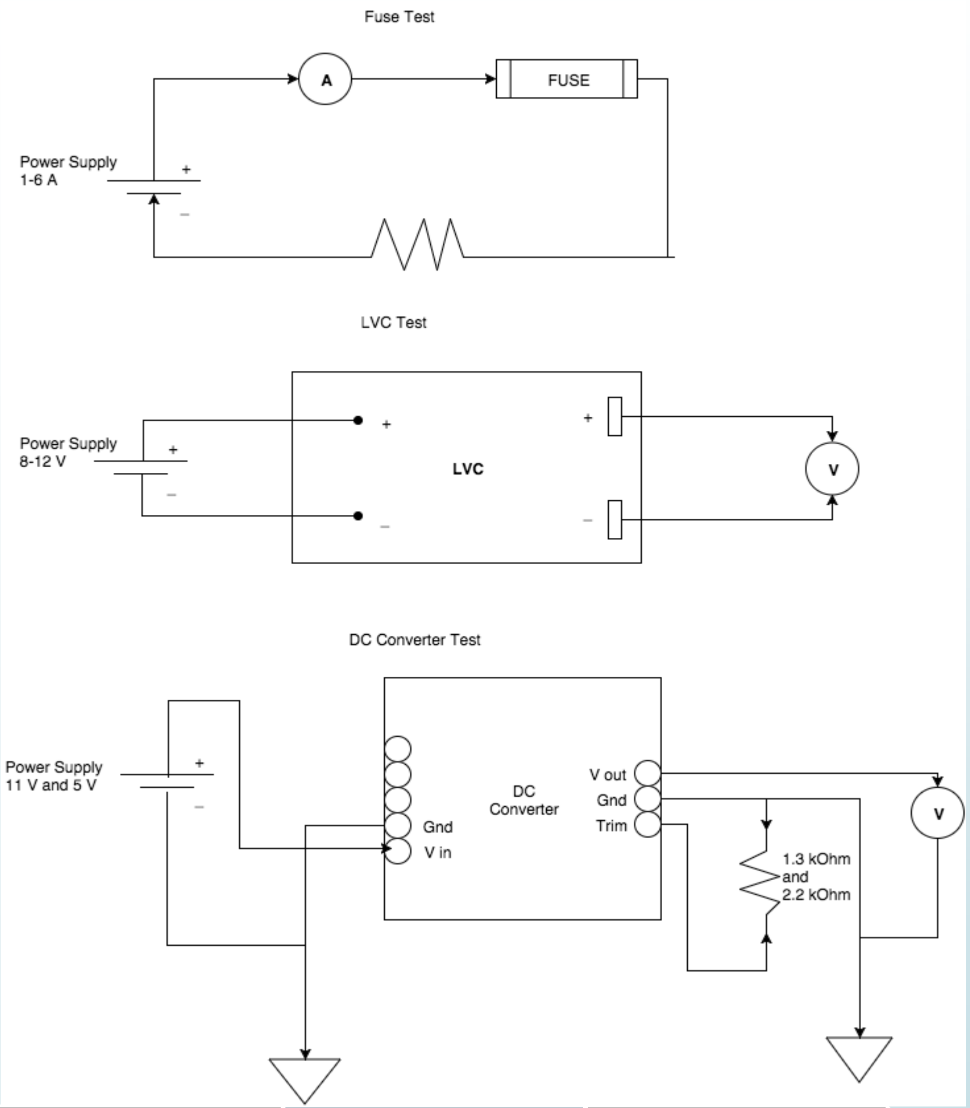


Board Component Testing

- Low voltage cutoff device, fuse, and DC converter have been tested to verify functionality.





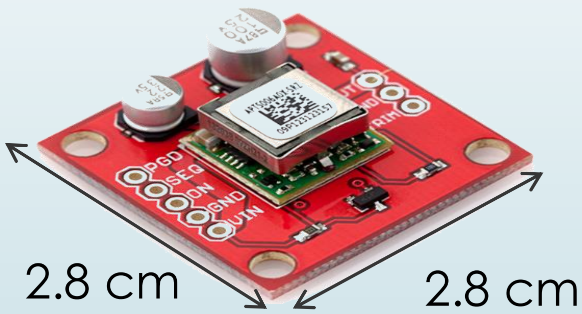


Circuit Diagrams for component tests

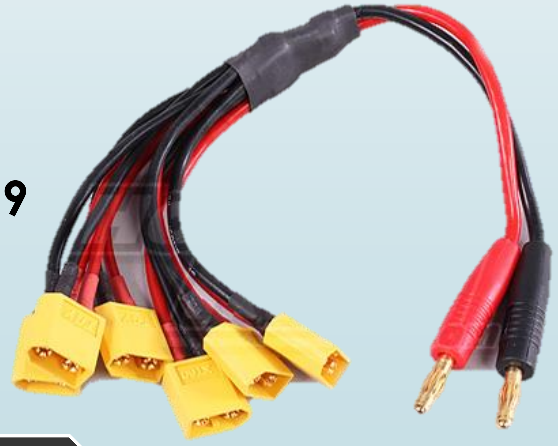
Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

Power Summary

- **Work Completed:**
  - Initial procurement
  - Initial power board design
  - Individual component testing



- **Future Work:**
  - Resistor and connector procurement: **2/5 (4-5 days)**
  - Battery integration: **2/5 (4 hrs)**
  - Power board construction: **2/5 (4 hrs)**
  - Power board testing with power supply**: 2/10 (4 hrs)**
  - PCB redesign: **2/12 (2 hrs)**
  - Full system integration and testing with battery pack: **2/19 (6 hrs)**



Conclusions

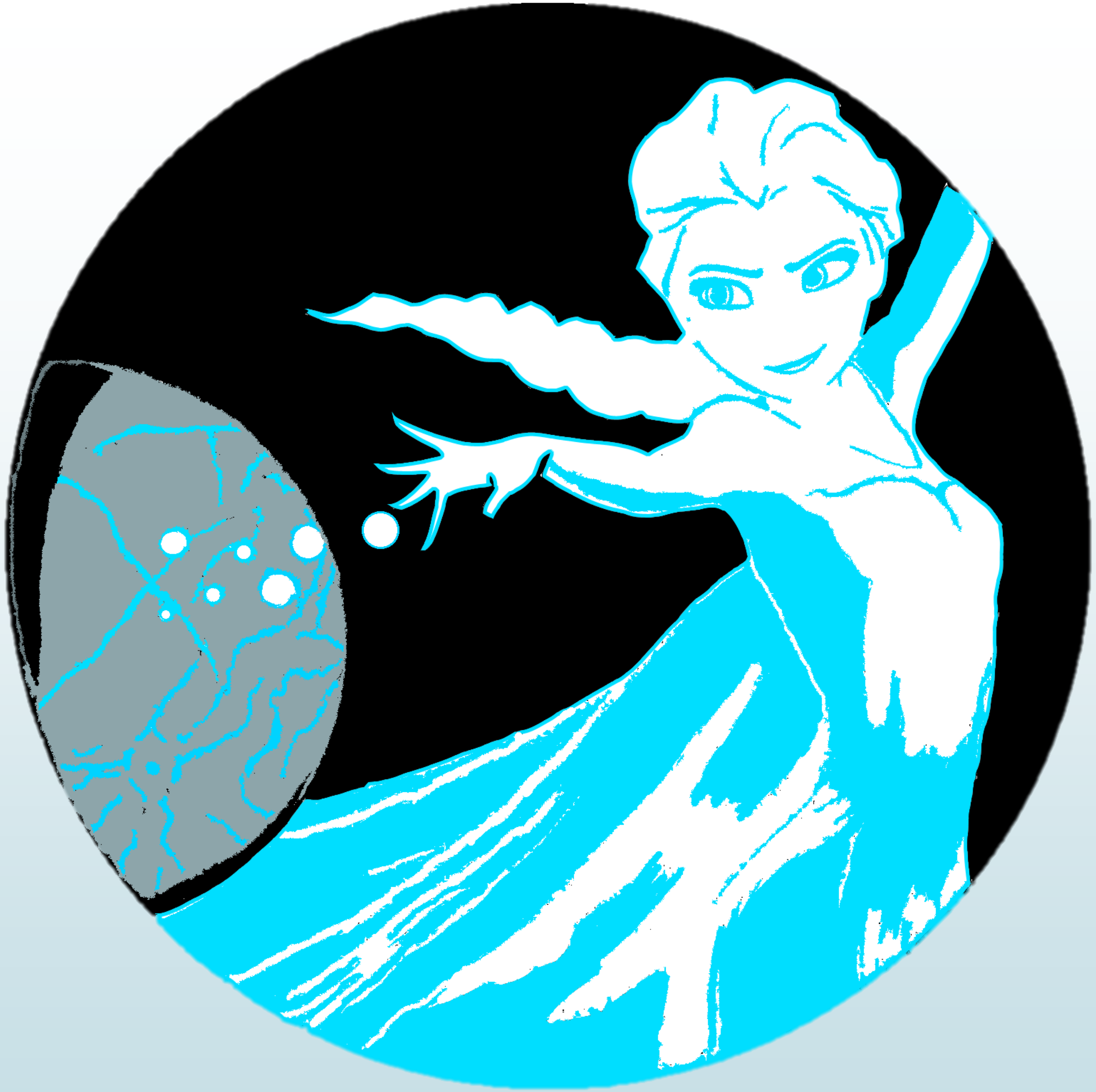
Thank you for your time

Acknowledgements:

- PAB Faculty and Staff
- Faculty Advisor
  - Dr. Robert Marshall
- Our Customer
  - Ball Aerospace
  - Joe Hackel

Ball Aerospace & Technologies Corp.

Questions?



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Back up Slides

Project Overview → Schedule → Budget → Manufacturing & Status → Conclusion

Systems Backup Slides

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Structures Status

Hardware Component	Acquisition Method	Status
Raw Materials	Purchase	• Received
2 Shelves	Manufacture	• Both machined from plates • Need threading
8 Clips	Manufacture	• Designed • Manufacture:(Week of 02/08)
Spherical Shell	Provided by Customer	• Received from Customer
Standoffs	Purchase	• Chosen Standoffs and Screws • Need to be purchased

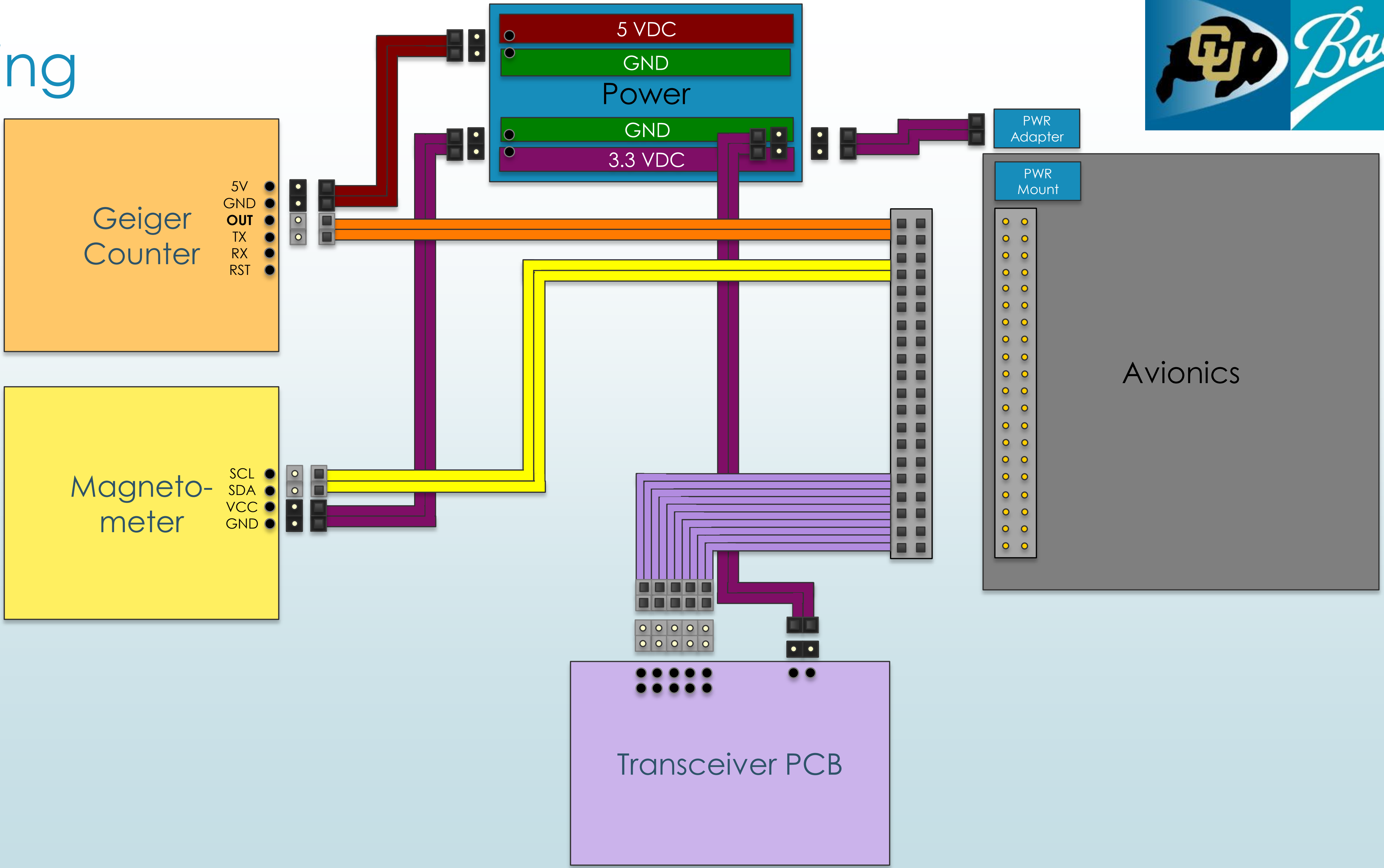
Power System Status

Hardware Component	Acquisition Method	Status
Batteries	Purchased	Received
Power Distribution Board	Ordered/Manufactured	Received, Rev 0
Power Board Components	Purchased	Waiting on Select Parts
Battery Test Equipment	Purchased	Received
Wiring	Purchased	Received

Communications Acquisition and Status

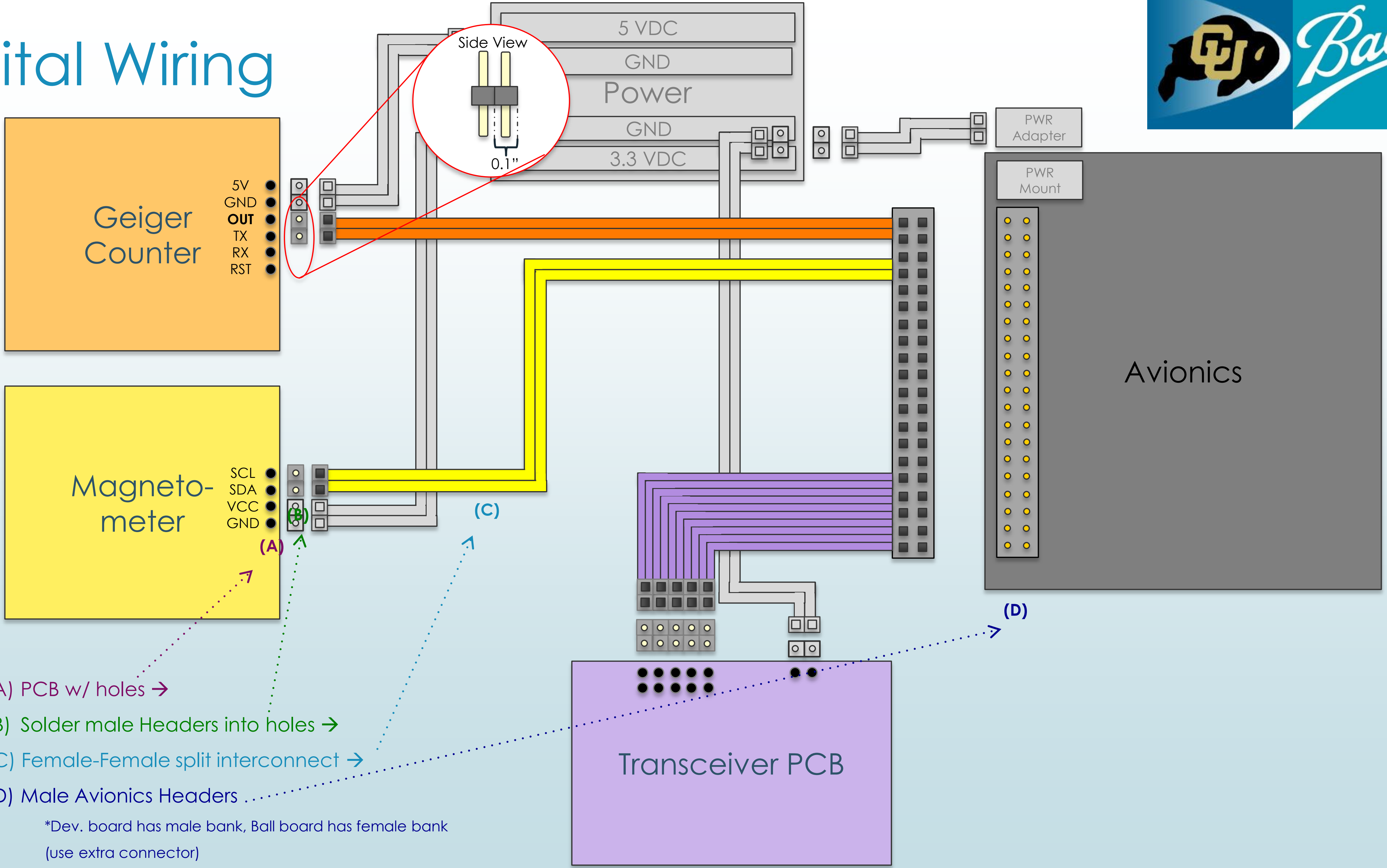
Hardware Component	Acquisition Method	Status
Transceiver Chips (2)	Purchased	Received
Printed Circuit Board(1)	Ordered/Manufactured	Received, Rev 0, electrical testing required
Development Kits for Testing/Ground Station (2)	Purchased	Received
NeoPod Patch Antenna (1)	Provided	Received from Customer
Shielded SMA Cabling(1)	Purchased	Received

Wiring



5 VDC
GND
Power
GND
3.3 VDC
PWR Adapter
PWR Mount
Geiger Counter
5V
GND
OUT
TX
RX
RST
Magneto-meter
SCL
SDA
VCC
GND
Avionics
Transceiver PCB

Digital Wiring



(A) PCB w/ holes →

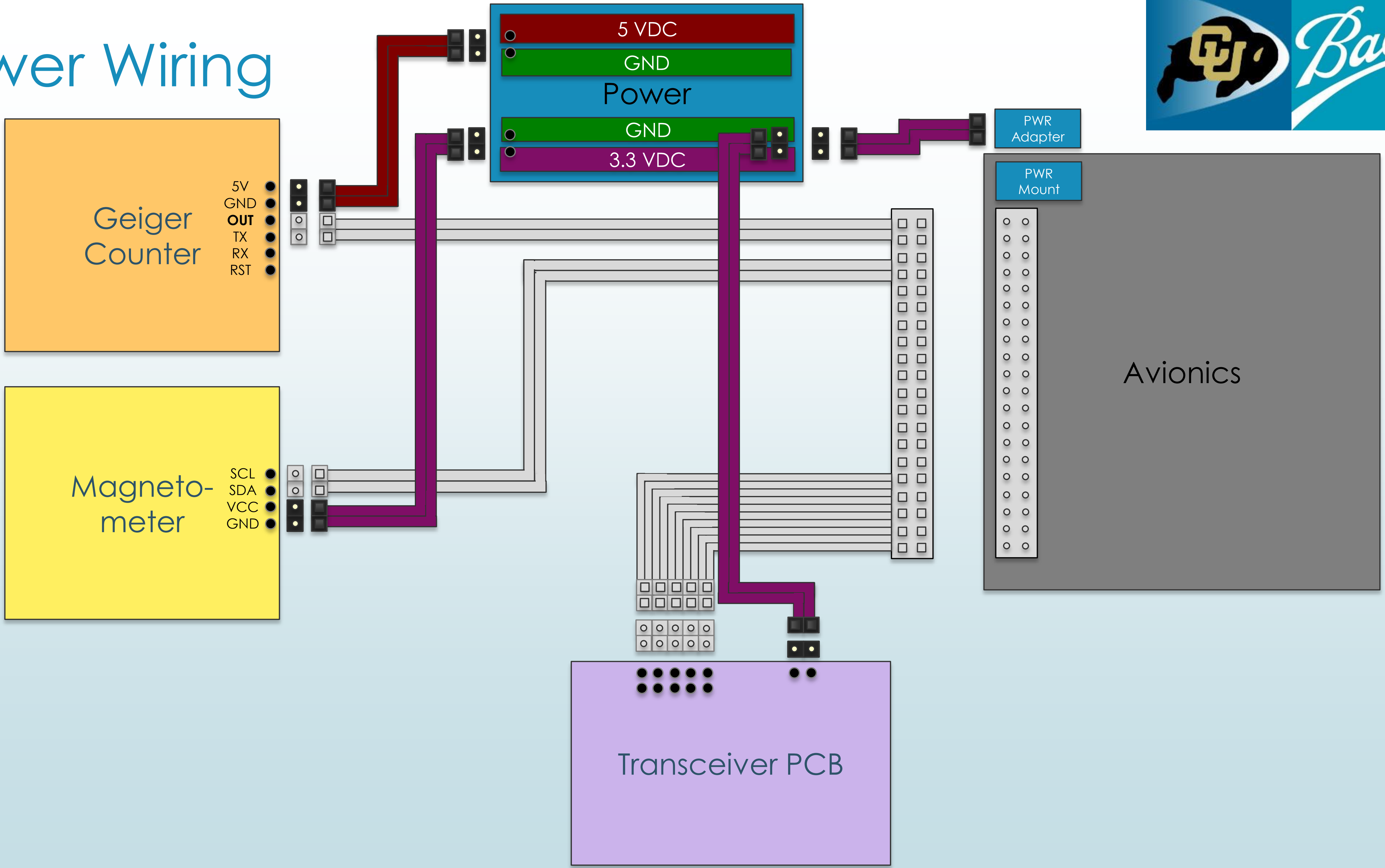
(B) Solder male Headers into holes →

(C) Female-Female split interconnect →

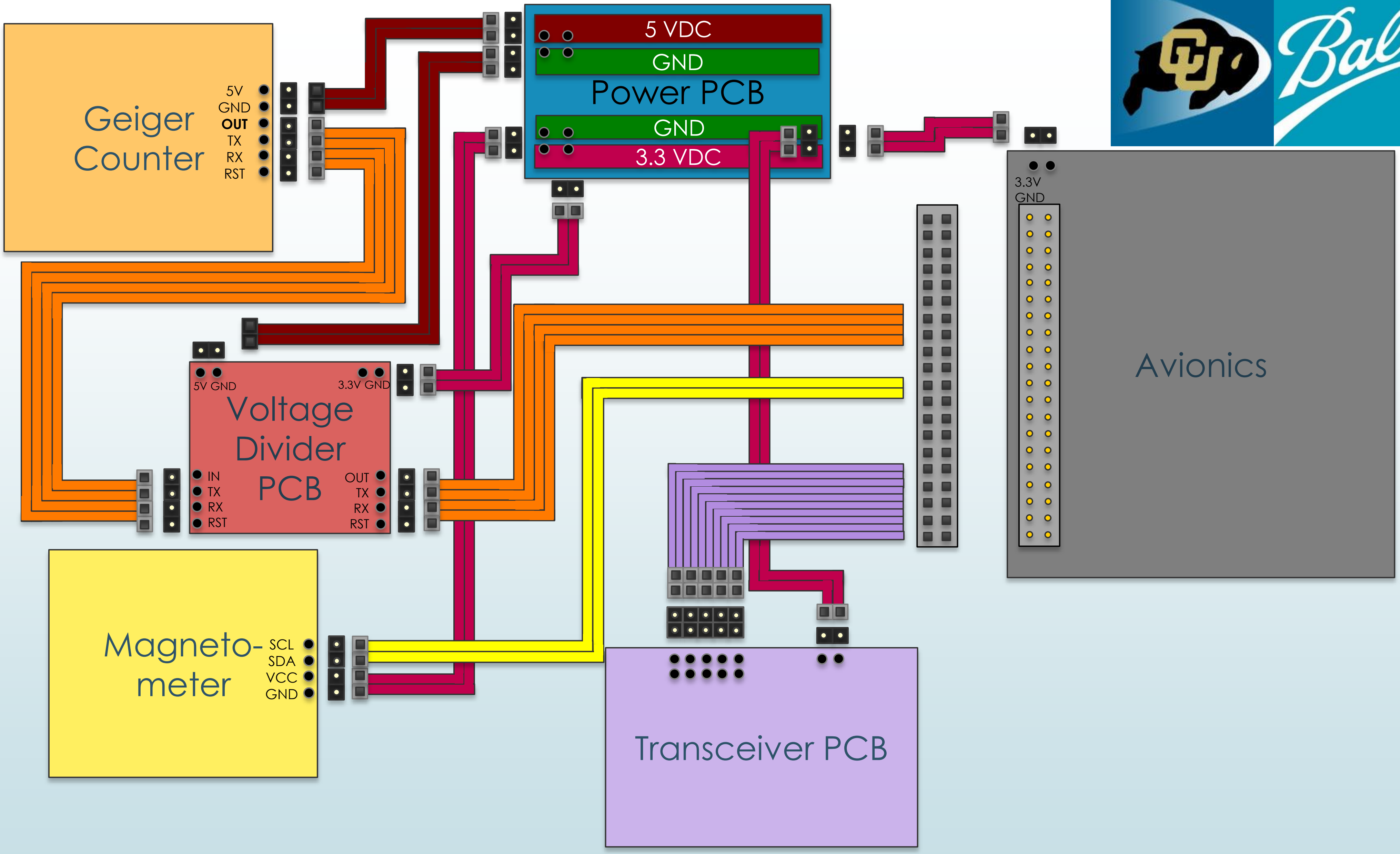
(D) Male Avionics Headers

*Dev. board has male bank, Ball board has female bank (use extra connector)

Power Wiring

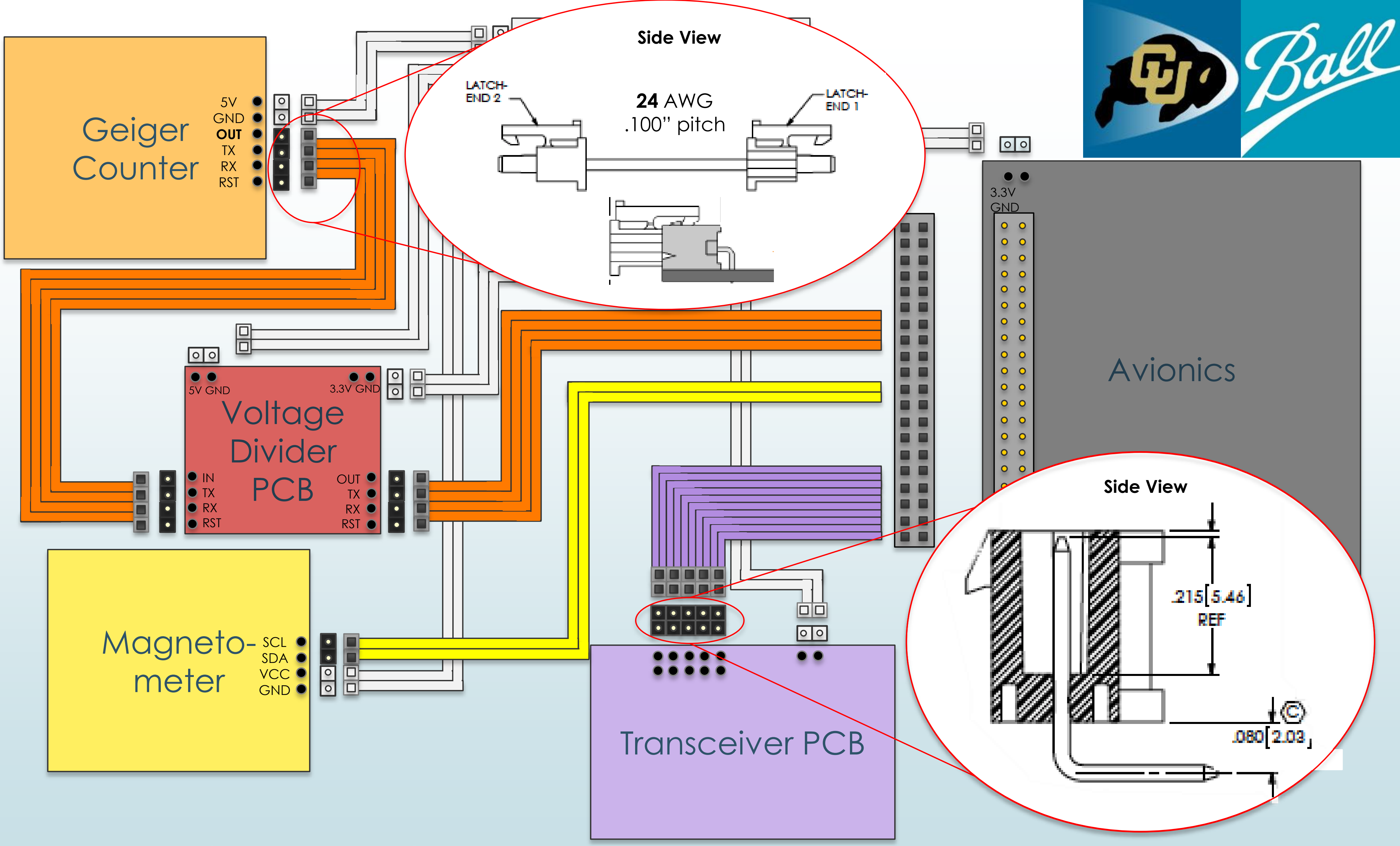


Wiring



5 VDC
GND
Power PCB
GND
3.3 VDC
Geiger Counter
5V
GND
OUT
TX
RX
RST
5V GND
3.3V GND
Voltage Divider PCB
IN
TX
RX
RST
OUT
TX
RX
RST
Magneto-meter
SCL
SDA
VCC
GND
3.3V
GND
Avionics
Transceiver PCB

Digital Wiring



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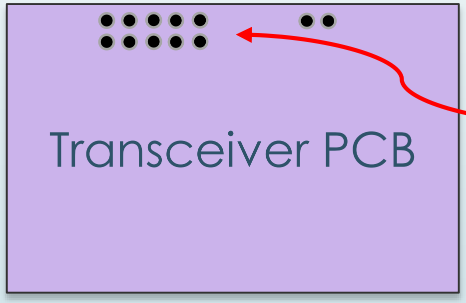
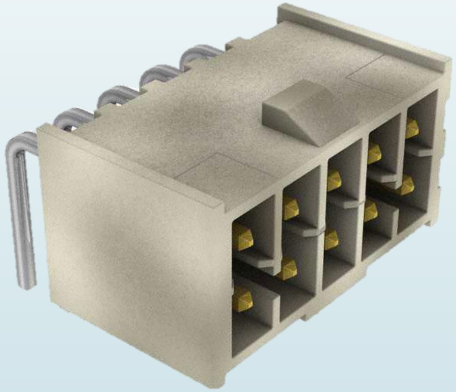
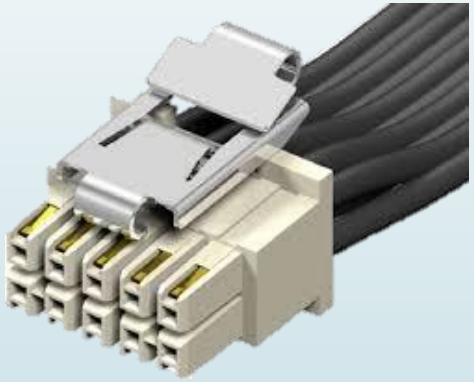
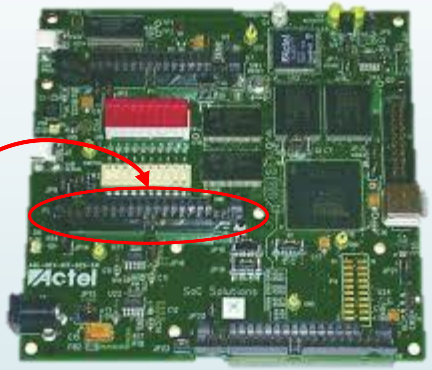
Digital Connectors

PCB Through Holes ⟷ IPL1 Connector ⟷ 24 AWG MMSS Wire Assembly ⟷ CHG Wire Housing ⟷ Dev. Board/ Ball Board



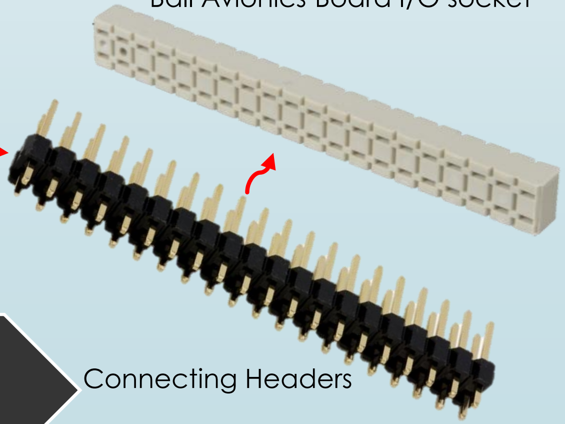






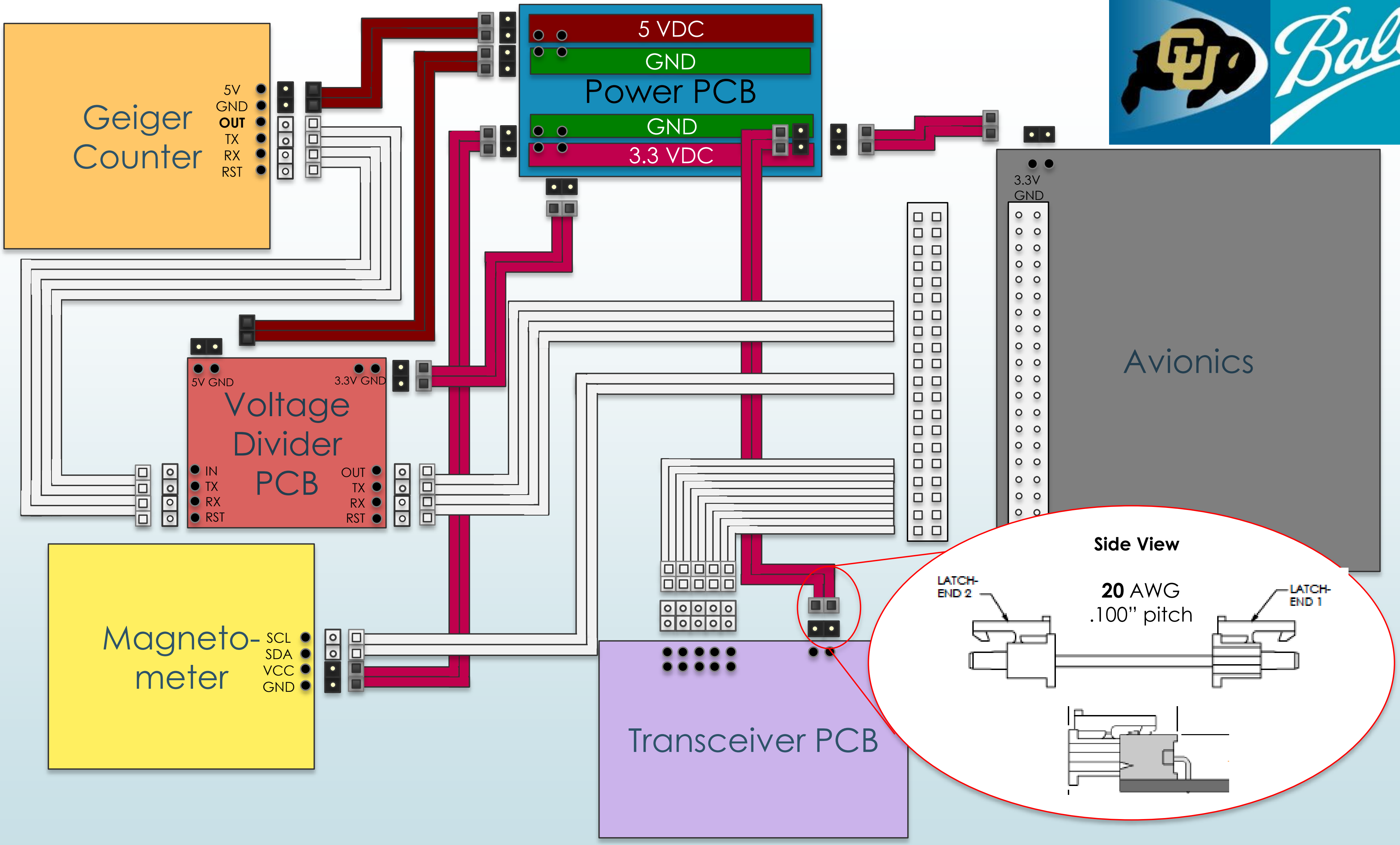
Microsemi Development Kit

Ball Avionics Board I/O socket

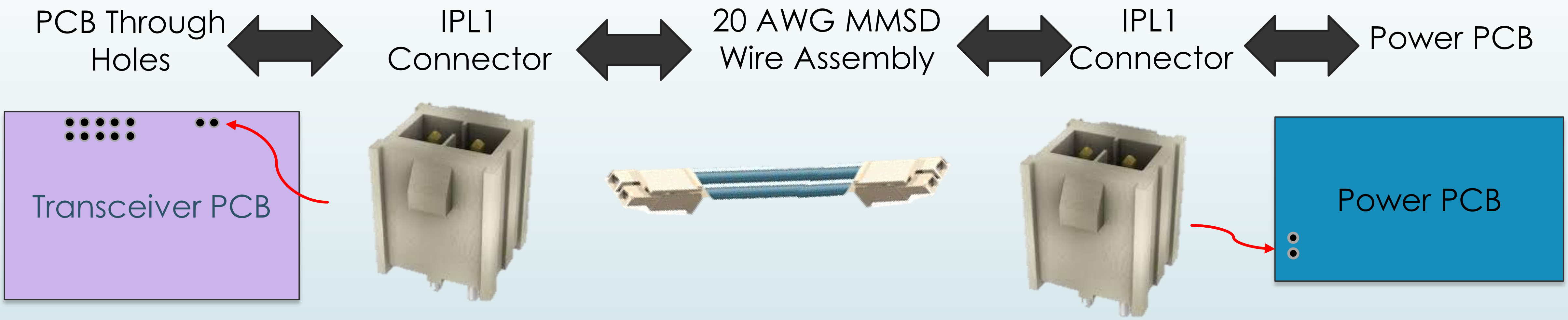


Connecting Headers

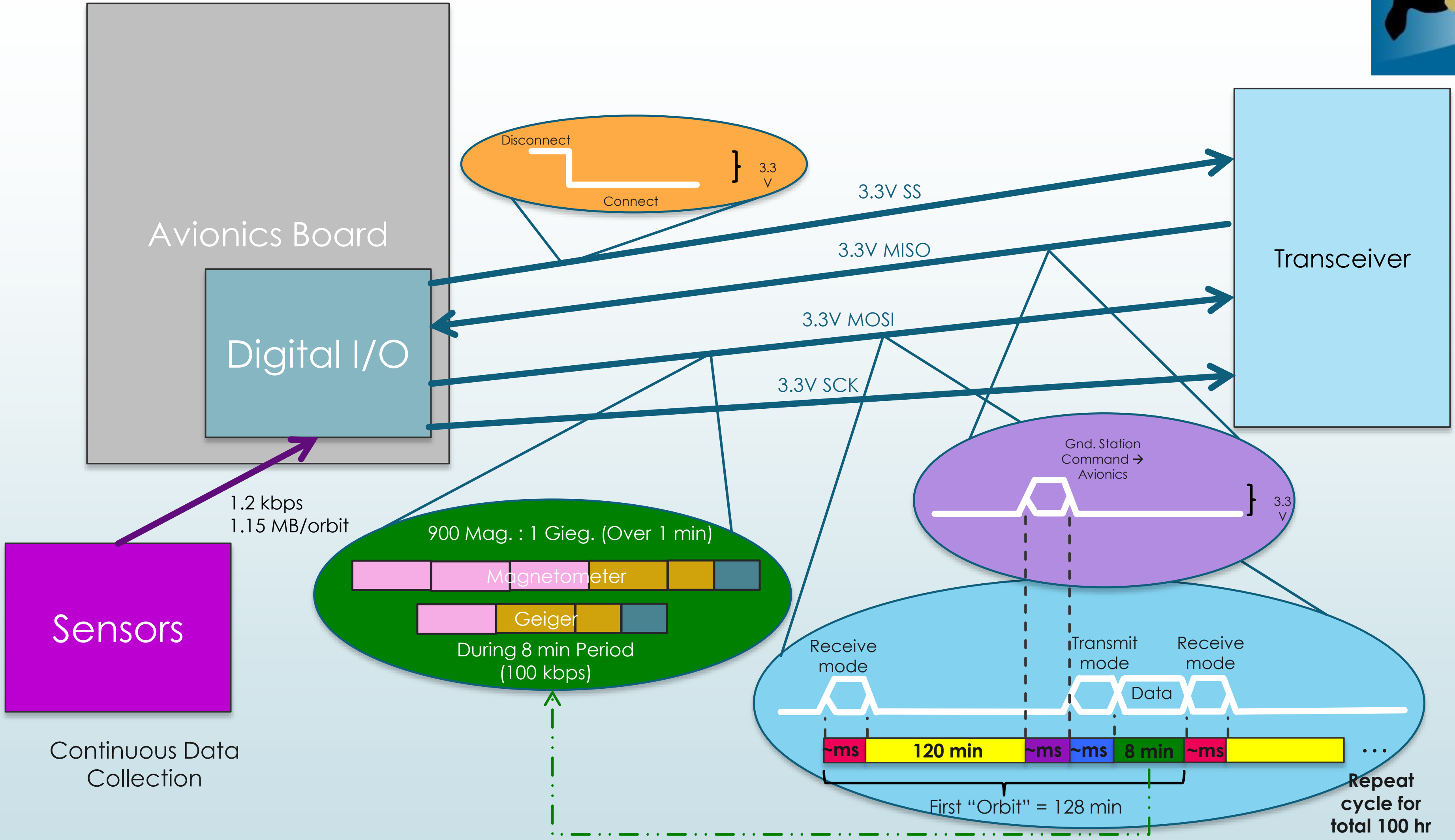
Power Wiring



Power Connectors



Timing



Avionics Board
Digital I/O
Disconnect
Connect
3.3 V
3.3V SS
3.3V MISO
3.3V MOSI
3.3V SCK
Transceiver
1.2 kbps
1.15 MB/orbit
Sensors
Continuous Data Collection
900 Mag. : 1 Gieg. (Over 1 min)
Magnetometer
Geiger
During 8 min Period
(100 kbps)
Gnd. Station Command → Avionics
3.3 V
Receive mode
Transmit mode
Receive mode
Data
~ms
120 min
~ms
~ms
8 min
~ms
…
First "Orbit" = 128 min
Repeat cycle for total 100 hr

Risk Introduction

Likelihood	Rating
1	Very Low: 0-20%
2	Low: 21%-40%
3	Medium: 41%-60%
4	High: 61%-80%
5	Very High: 81-100%

Severity	Rating
1	No Effect on Cost/Schedule
2	Schedule Slip < 1 week
3	Moderate Schedule Slip (~2 weeks) , Not All Requirements Met
4	Major Schedule Slip (1 month), Majority of Reqs. Not Met
5	Project Failure, Damage to Components

Risk Assessment

Risk	Description	Mitigation
RP1: FPGA Software	FPGA Software Development learning curve. Related to CPE-1	**Learning curriculum** completion. Practice on **development FPGA**. Attend **Microsemi trainings** and seminars
RP2: ESD Component Safety	Possible component damage or failure if handled in non-ESD environment	**ESD environment** required for all avionics development and testing, this is provided through **Bobby and Trudy's lab.** Internal **ESD certification and training** for team members handling sensitive hardware.
RP3: Schedule Slip	Critical path on schedule (FPGA software development and procurement) falls behind schedule affecting final testing schedule	**Schedule margin** built in. Development of code begun before winter break. **1/3 of team devoted to FPGA development**. If Ball FPGA board is not delivered on time, **COTS development FPGA** has been acquired. **Developed software applies to both design solution.**
RP4: Unable to Dissipate Heat	Structure unable to dissipate the heat in an earth environment, components are damaged or inoperable	**Extensive thermal model** concludes that there will be **low chance of overheat**. Worst case, **ball will be opened** and placed under an **external desktop fan to remove heat.**
RP5: Power Failure	Power system unable to power system for full 100 hour test. Battery failure or damage. Over-current to system causing damage to components.	Safety systems include **fuse to prevent overcurrent** to system, as well as **voltage cutoff circuit** to stop power at minimum voltage limit. **Battery characterization test** provided evidence that power model is correct.

Severity

Likelihood

	1	2	3	4	5
5 (Very High)					
4 (High)					
3 (Moderate)				RP3	
2 (Low)					RP2
1 (Very Low)		RP4 RP1	RP5		

(red)	Unacceptable
(yellow)	Acceptable with Mitigation
(green)	Acceptable

Test Plan Overview

Subsystem Tests

- Power – 6 Tests
- Comms – 7 Tests
- Payload – 2 Tests

Avionics Peripheral Tests

- Avionics/Power
- Avionics/Comms
- Avionics/Payload – 2 Tests

Flat-Sat without Batteries Test

- Avionics, Comms, Payload

Flat-Sat with Batteries Test

- Power, Avionics, Comms, Payload

Final System Test

- All Subsystems

Testing Design Requirements, Levels of Success, and Models

Subsystem Tests	Avionics Peripherals Tests	Flat-Sat without Batteries Test	Flat-Sat with Batteries Test	Final System Test
Payload L1 – L2, L4	Payload L3	–	–	Power L3
Power L1 – L2	Communication L1 – L4	–	–	Structure L1 – L4
Ground Station L1 – L3	Avionics L1 – L4	Ground Station L4	–	–
SCI 1	SCI 3	–	–	SCI 2
COM 1 – 4	COM 5	–	–	COM 6
INT 3	–	INT 6, 9	INT 5 – 6, 9	INT 1 – 2, 4 – 9
RF Link	–	*RF Link	*RF Link	*RF Link
–	–	–	Battery Discharge	*Battery Discharge
–	–	–	–	Thermal Model

Key
Levels of Success
Functional Requirements
Models

* Redundant test for statistics

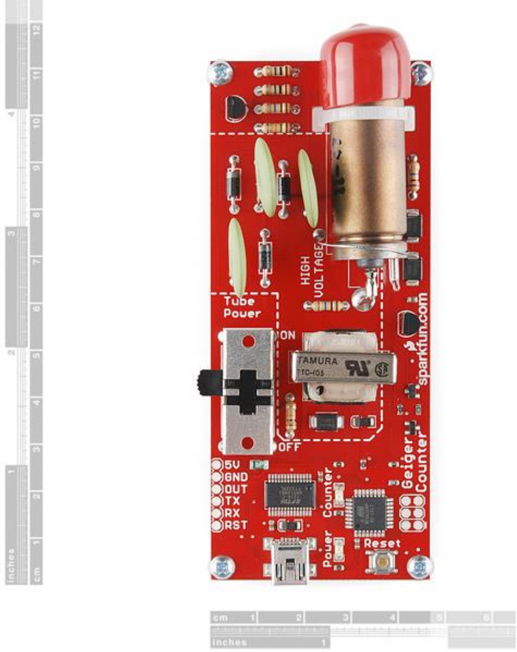
Payload

Sensor Payload

Magnetometer:

Key Specifications
Model: SparkFun Triple Axis Magnetometer HMC5883L
Interface: I2C
Sampling Rate: 0.75 – 75 Hz
Power and Logic: 3.3VDC and 3.3V Logic
Range: ± 8e5 nT
Resolution: 500 nT

Geiger Counter:



Key Specifications
Model: SparkFun Geiger Counter
Interface: Serial
Sampling Rate: Maximum of 100 Hz
Power and Logic: 5VDC and 5V Logic

Highest Payload Level of Success: Samples data and relays it to Avionics Board for onboard storage

Payload Acquisition and Status

Hardware Component	Acquisition Method	Status
Magnetometer	Purchased	Received/ Successfully tested
Geiger Counter	Purchased	Received/ Successfully tested
Geiger Counter Logic Converter	Purchased	Received/ Unsuccessful testing → New revision
Geiger Counter Voltage Divider	Purchased	Design In Progress

Progress and Path Forward

COMPLETED:

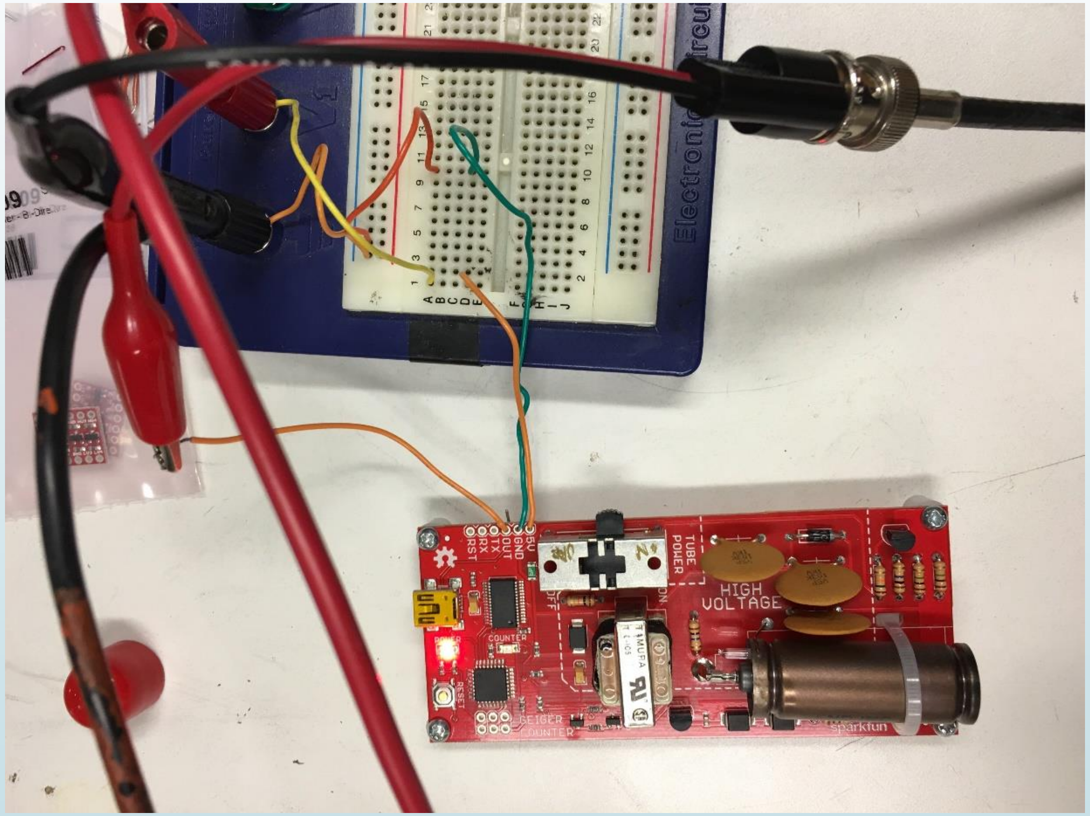
1) Sensor Procurement (2 hr)
2) Magnetometer Testing (3 hr)
3) Geiger Counter Testing (3 hr)
4) First Geiger Counter PCB design (10 hr)

Future Work:

1) Second Revision of Geiger Counter PCB design (5 hr): 2/5
2) Second Revision PCB Testing (3 hr): 2/12

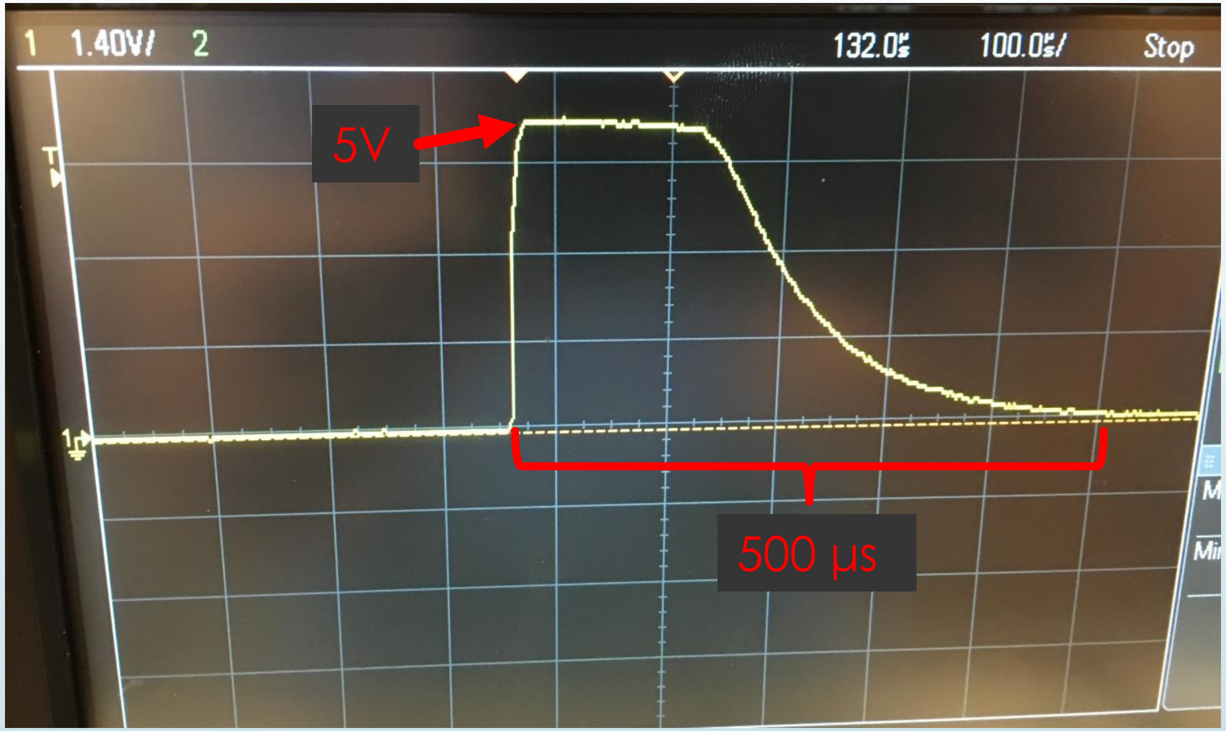
Geiger Counter Testing

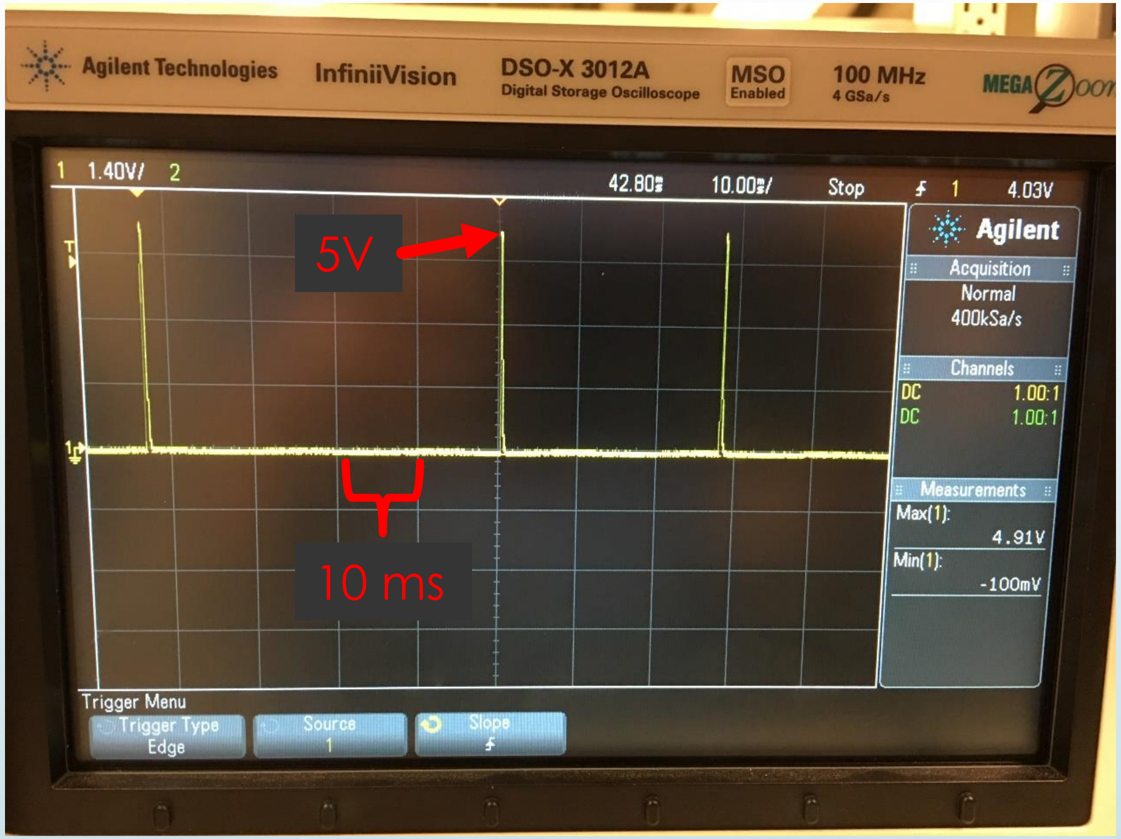
- Connected to Power Supply and Oscilloscope to confirm output
- Plan to test with Americium (from smoke detector) to induce higher count rates this week (Feb 4)



Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

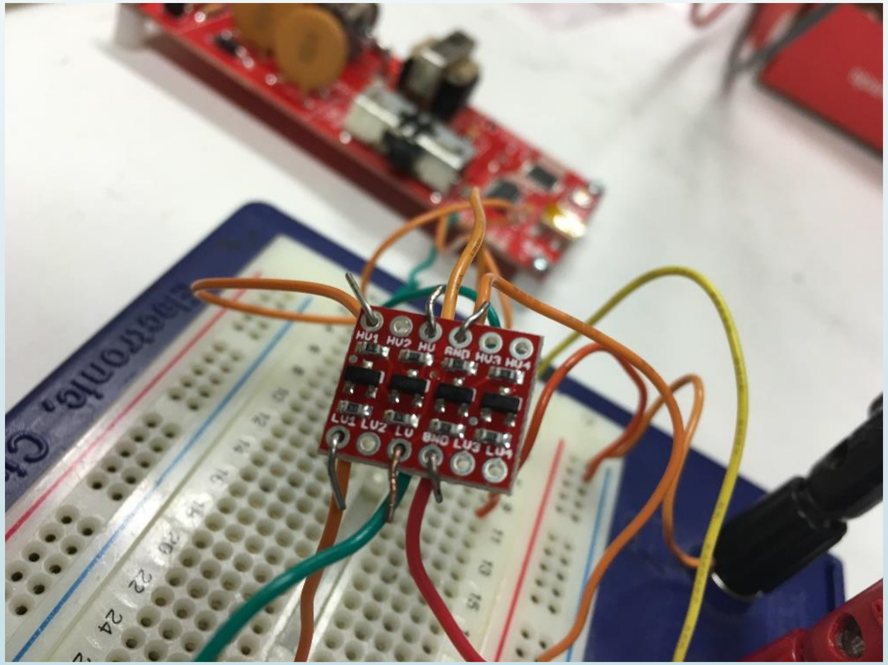
Results:


1 1.40V/ 2
132.0$
100.0$/
Stop
5V
500 µs


Agilent Technologies
InfiniiVision
DSO-X 3012A
Digital Storage Oscilloscope
MSO
Enabled
100 MHz
4 GSa/s
1 1.40V/ 2
42.80$
10.00$/
Stop
1 4.03V
Agilent
Acquisition
Normal
400kSa/s
Channels
DC 1.00:1
DC 1.00:1
Measurements
Max(1):
4.91V
Min(1):
-100mV
5V
10 ms
Trigger Menu
Trigger Type
Edge
Source
1
Slope

Change to Design:

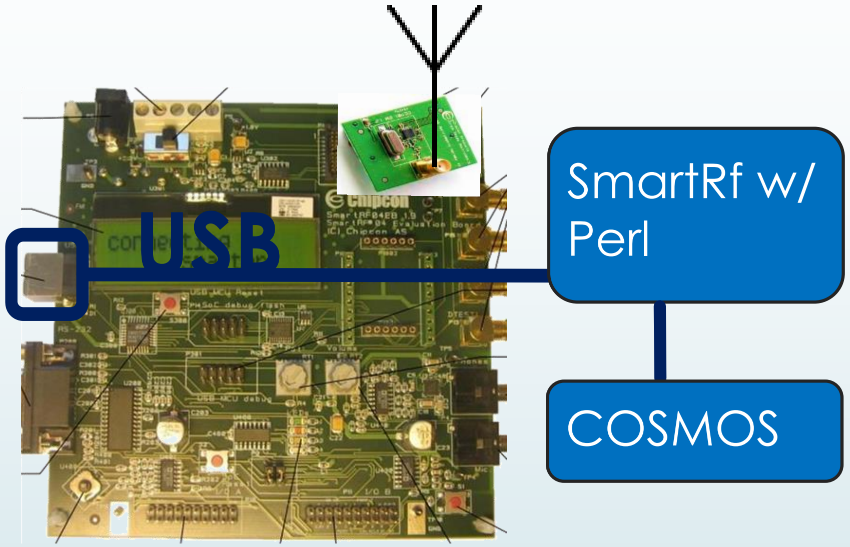
- Bi-Directional Level Shifter does not work as anticipated due to signal from Geiger Counter not behaving like a digital signal.
- Pull up resistors on the Shifter mean that the signal always reads a high 5V and 3.3V
- Designing a Voltage Divider Circuit PCB to get same effect
  - Still need to test with Resistors from Trudy's Lab



Communications System Backup

Ground Station Software (COSMOS Integration)

- The only program capable of interfacing with the dev. Kit via USB is SmartRF (without re-writing driver software)
- A SmartRF friendly **Perl** script will automatically send commands as well as direct telemetry to **COSMOS** for parsing
- Data will be displayed **real-time** and commands will be sent **automatically**
- **Future Work:**
  - Mission-specific automation and parsing software development is **yet to be completed**



Ground Station

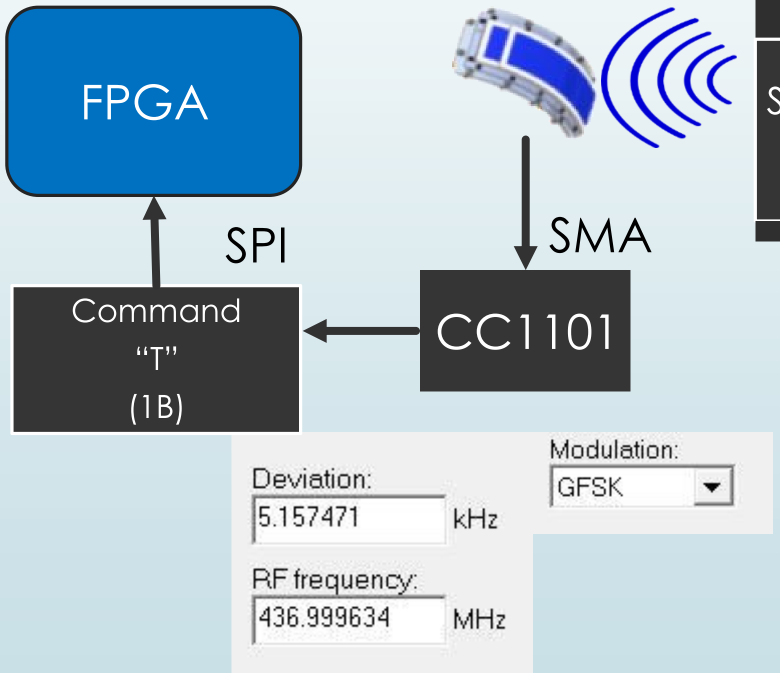
Expected Completion Date: 02/05/16

Communication Timeline

- 1. *Avionics* configure *transceiver* mode to RECEIVE .... **< 1 ms**
- 2. Wait for *ground station* to send TX command .... **120 min**
  - *Ground Station* sends TX command.
  - *Ground Station* transitions to receive mode.
- 3. *Avionics* process command, configure *transceiver* mode to TRANSMIT.......... **< 1 ms**
- 4. *Avionics* sends data to *transceiver*.. **8 min**
  - Simultaneous write/read. Max read/write time allowable: 833 μs
    - Read Time ~ 300 ns
    - Write Time ~ 200 ns
- 5. **Return** to step 1.

Comm: NeoPod Command Reception

Driver: COM 1.1: NeoPod shall use provided patch antennas from Ball Aerospace
COM 1.2: NeoPod shall use same modulation scheme as ground station
COM 1.3: NeoPod shall receive commands within 1 MHz of 437 MHz



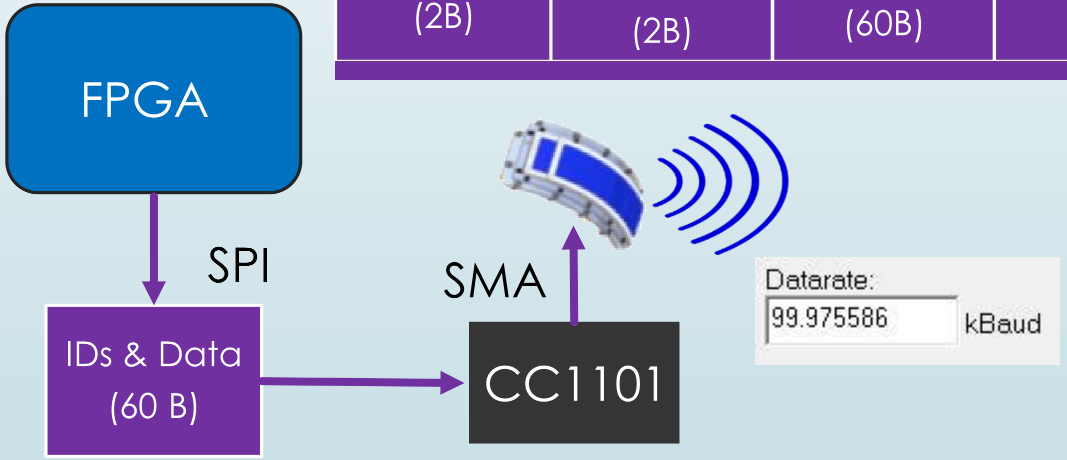
"Begin Telemetry Transmission" Command		
Sync Word "SA" (2B)	Command "T" (1B)	CRC Checksum (2B)

- FPGA will receive command and reconfigure CC1101 into transmit mode and begin transmitting data
- Data and configuration both done via SPI

Comm: NeoPod Data Transmission

Driver: COM 2.1: NeoPod shall use provided patch antennas from Ball Aerospace
COM 2.3: NeoPod data transmission shall not exceed 128 kbps
COM 2.5: NeoPod shall packetize data with appropriate overhead for RF transmission

Outgoing Telemetry Packet			
Preamble “10101010” (2B)	Sync Word “EL” (2B)	IDs & Sensor Data (60B)	CRC Checksum (2B)



- SPI will be connected via PCB and ribbon cables
- CC1101 will packetize data and transmit at 437.5 MHz & +10 dBM
- CC1101 will be powered via on board power at 3.3 V & 30 mA
- Data rate programmable in steps of 0.2 kBaud

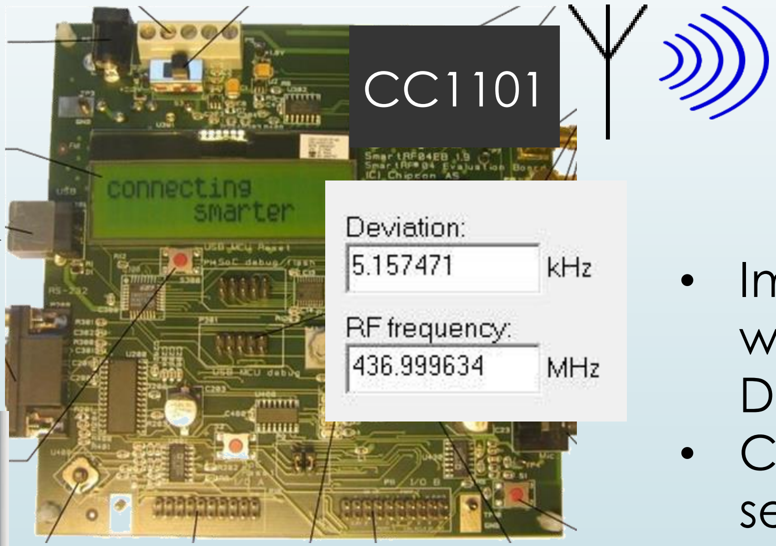
Comm: Ground Station Command Transmission

Driver: COM 3.1: Ground Station shall be compatible with 437 MHz frequency
COM 3.2: Ground Station shall send command every 120 minutes
COM 3.3: Ground Station shall packetize commands with appropriate overhead for RF transmission

“Begin Telemetry Transmission” Command		
Sync Word “SA” (2B)	Command “T” (1B)	CRC Checksum (2B)

Command
“T”
(1B)

USB



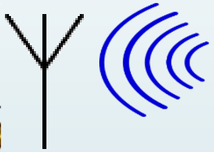
Cosmos

- Immediately after command CC1101 will be go into receive mode (Half Duplex)
- Commands will be automated and sent using Cosmos

Comm: Ground Station shall receive data over RF

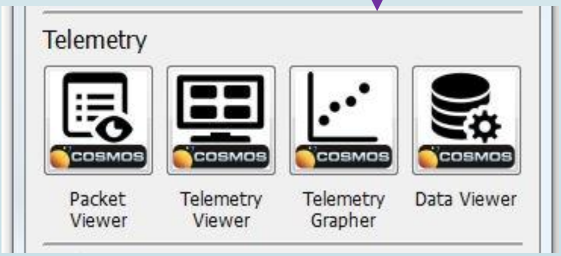
Driver: COM 4.1: Ground Station shall store received data from NeoPod
COM 4.2: Ground Station shall separate data into appropriate file location and format
COM 4.3: Ground Station shall display metrics on performance of communications system

Incoming Telemetry			
Preamble “10101010” (16)	Sync Word “10101010” (32)	IDs & Data (60 B)	CRC Checksum (16)



IDs & Data (60 B)

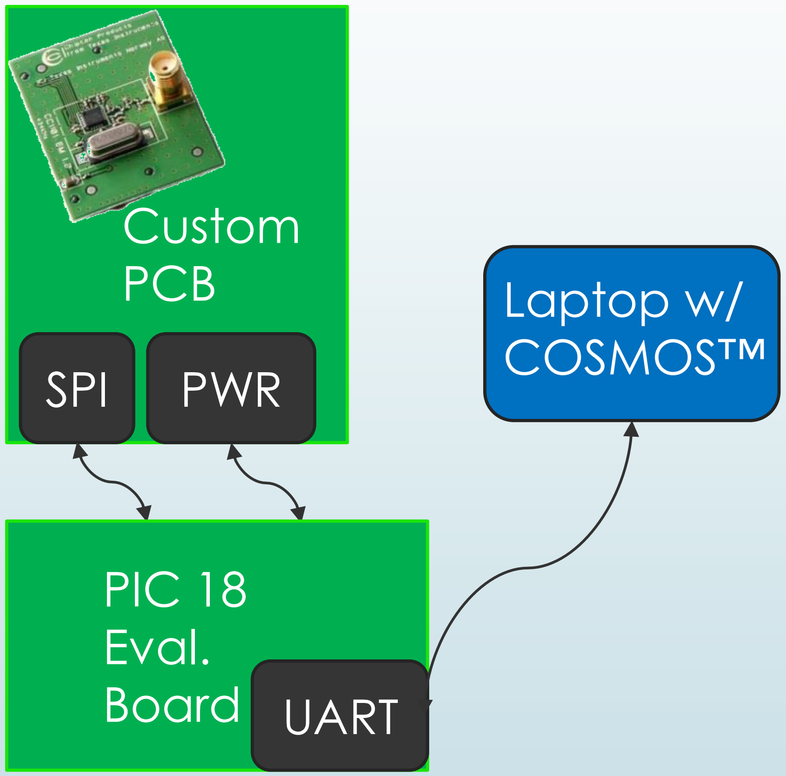
Cosmos



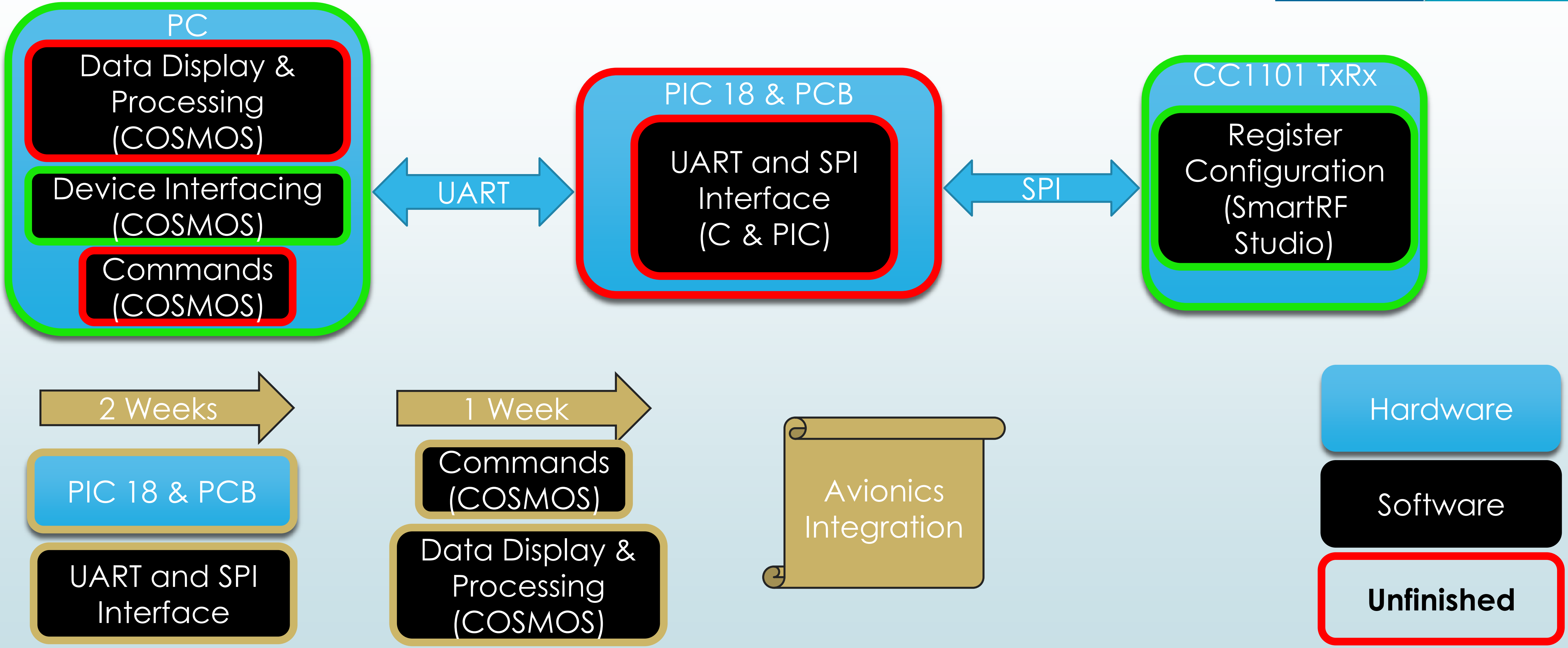
- CC1101 will de-packetize data
- Cosmos will identify separate data files using the 1 Byte ID attached to each data point
- Smart RF will be used to Debug CC1101 and display RSSI and LQI

Alternative Ground Station

- Successfully mechanically mated with CC1101 Transceiver headers
- Continuity has been proved
- Standoffs and avionics/power headers still need to be added on
- Functionality will be tested by attaching PCB and CC1101 to PIC18 dev. Kit provided by CU for rent



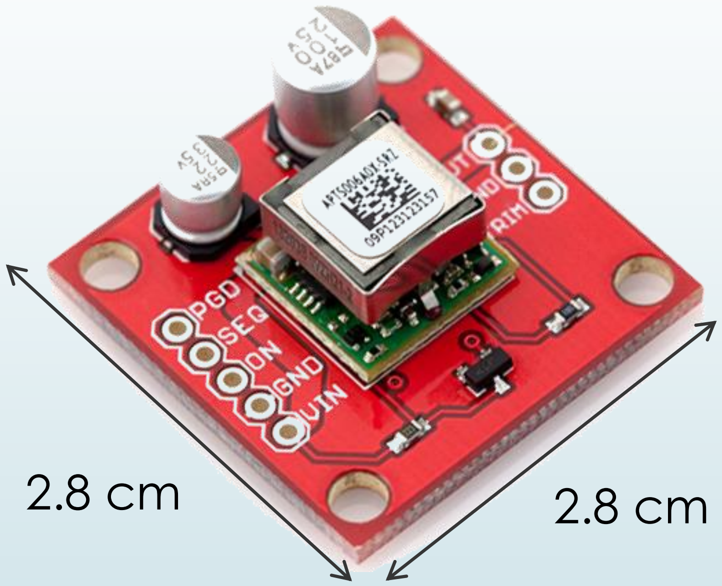
Alternative Ground Station Development Plan



Power System Backup

Voltage Supply Lines

- **We will use 2 SparkFun DC/DC Converter Breakouts**
- **Will step 11.1 V down to 5 V, then down to 3.3 V**
- **Switching regulators**
- **High efficiency (~95%)**
- **Maximum ±0.1V ripple voltage**



Battery Parallel Connectors (Hobbyking.com Website)

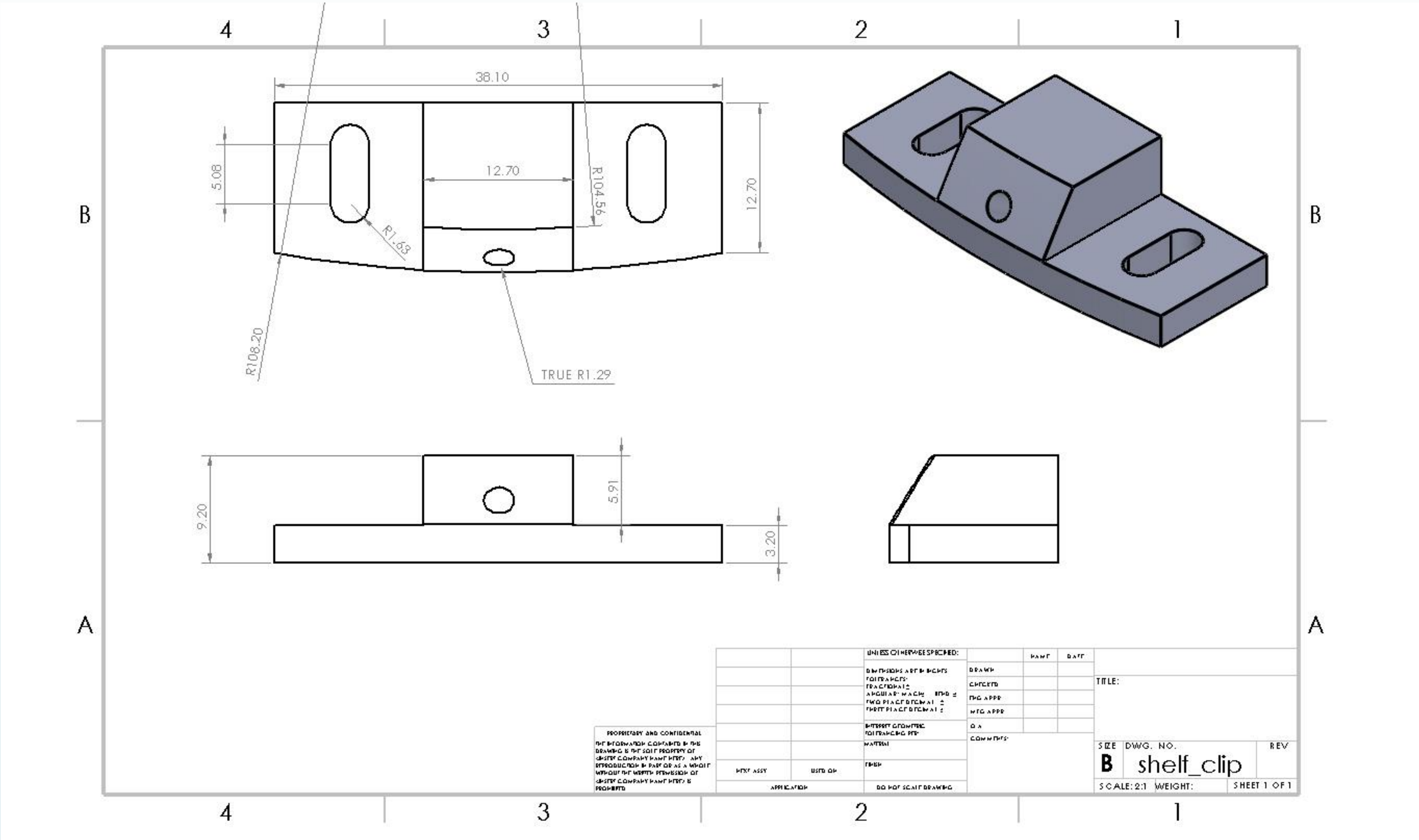
- XT-60 Parallel Connector
- Will cut off banana cable end and solder on female connector

Updated Mass Budget

		Raw Mass	Uncertainty Category	Margin Percent	Mass With Margin
Total mass	Requirement	10000	N/A	N/A	N/A
Avioinics	Avionics Board	67	Measured	1	67
Structures	Top Shelf	272	Measured	1	275
	Bottom Shelf	281	Measured	1	284
	Shells w/Antenna	883	Measured	1	892
	Battery Box	122	Modeled	15	140
	Clips	56	Modeled	15	64
Connectors	3 Power Cable Conn.	292	Measured	1	295
	52 Screws	46	Modeled	15	52
	SMA Cable	11	Measured	1	11
	28 standoffs	26	Measured	1	27
	Misc Wires	500	WAG	20	600
Power	15 Batteries	4965	Measured	1	5015
	LVC	44	Measured	1	44
	Power Board w/comps and geiger converter Board w/ level shifter	34	Measured	1	35
Comms	Tranceiver	18	Measured	1	18
Payload	Geiger Counter	55	Measured	1	56
	Magnetometer	2	Measured	1	2
Total		7673			7876
Remaining					2124

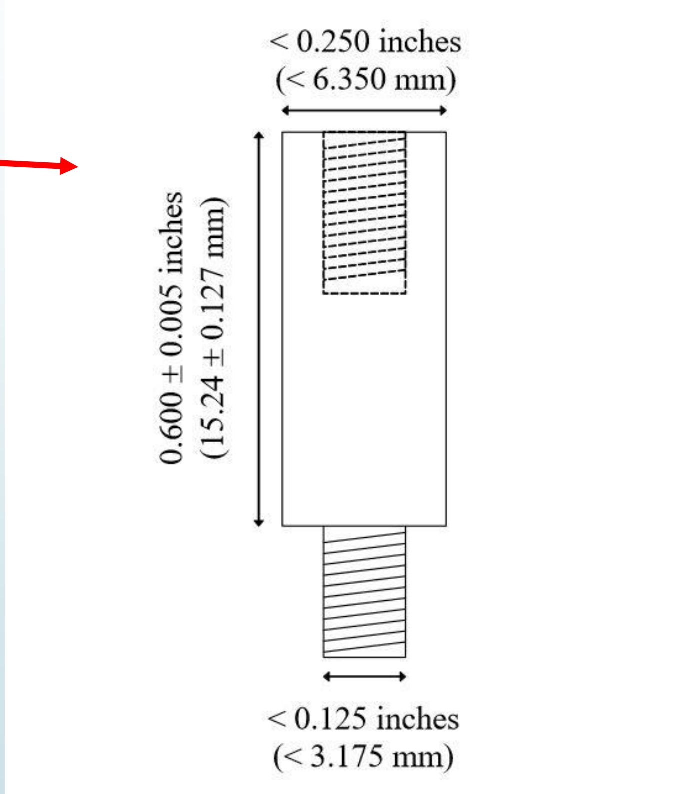
Meets mass requirement

Backup Clip Drawing (dimensions in mm)

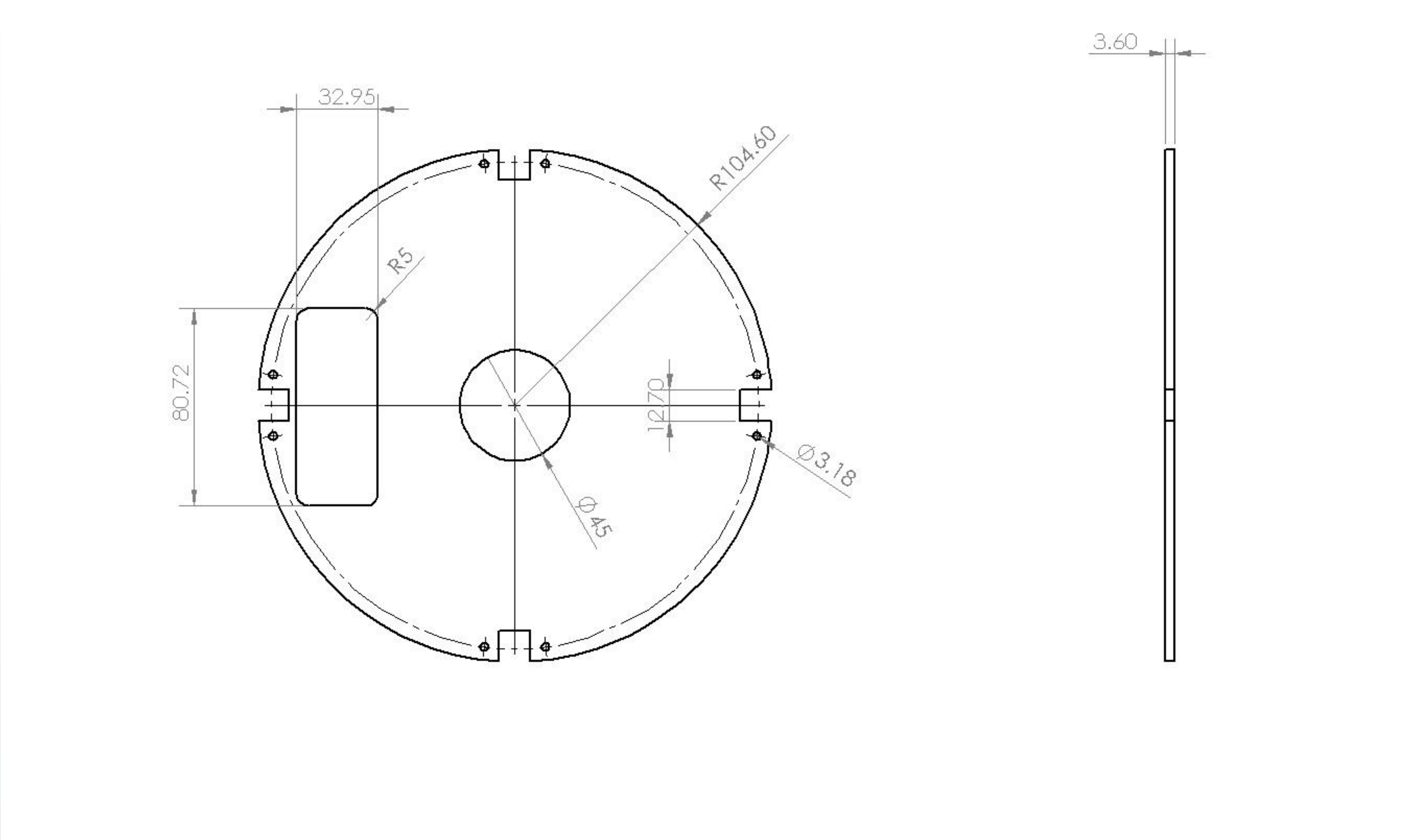


Standoffs and Battery Connectors

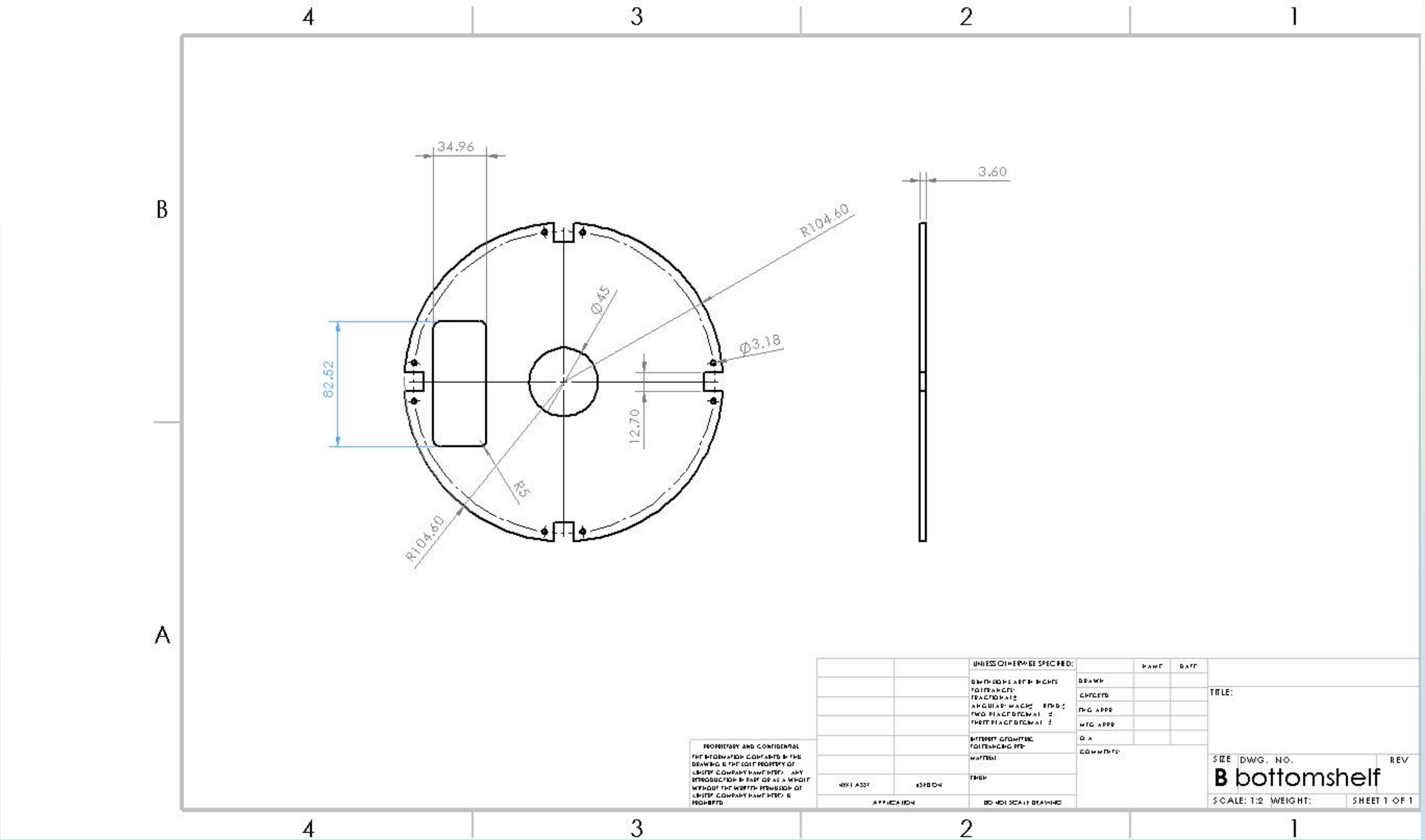
- Avionics/Power/Comms Board Standoff
- Sparkfun science instruments come with Standoffs



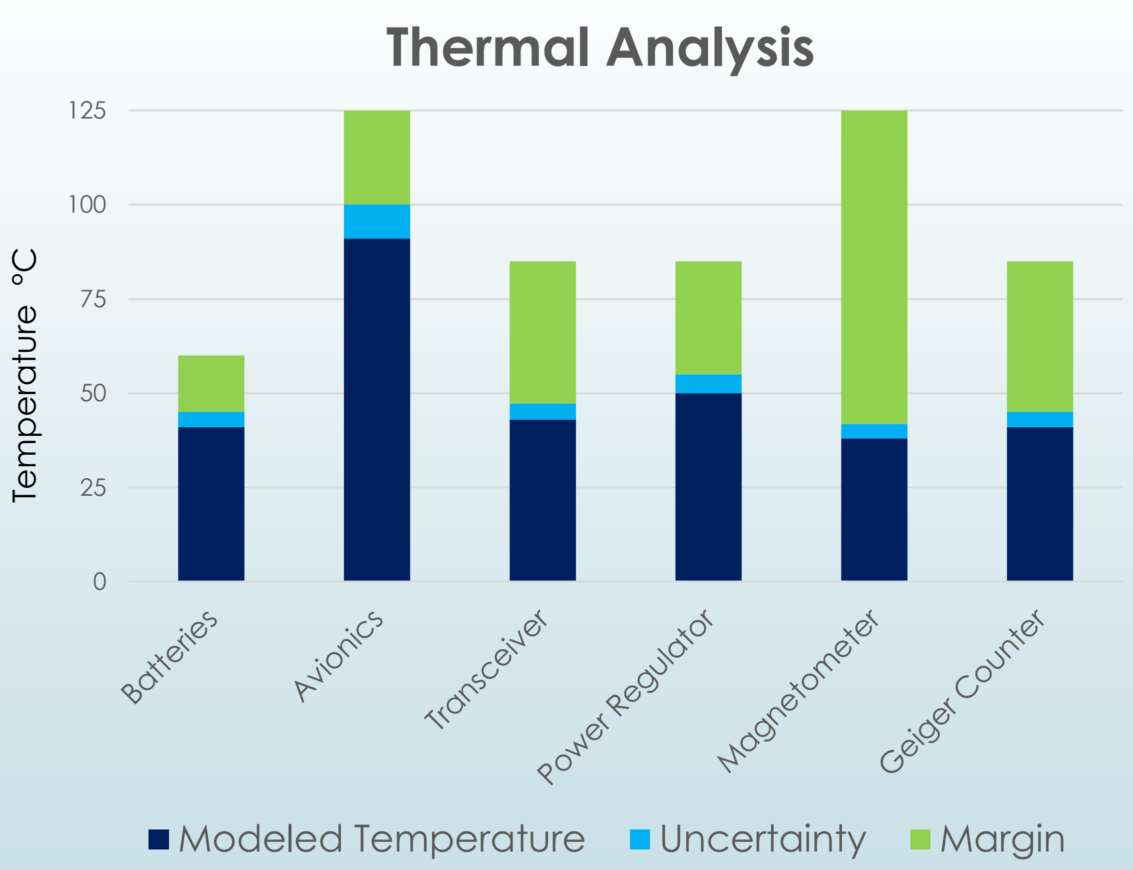
Top Shelf Drawing (dimensions in mm)

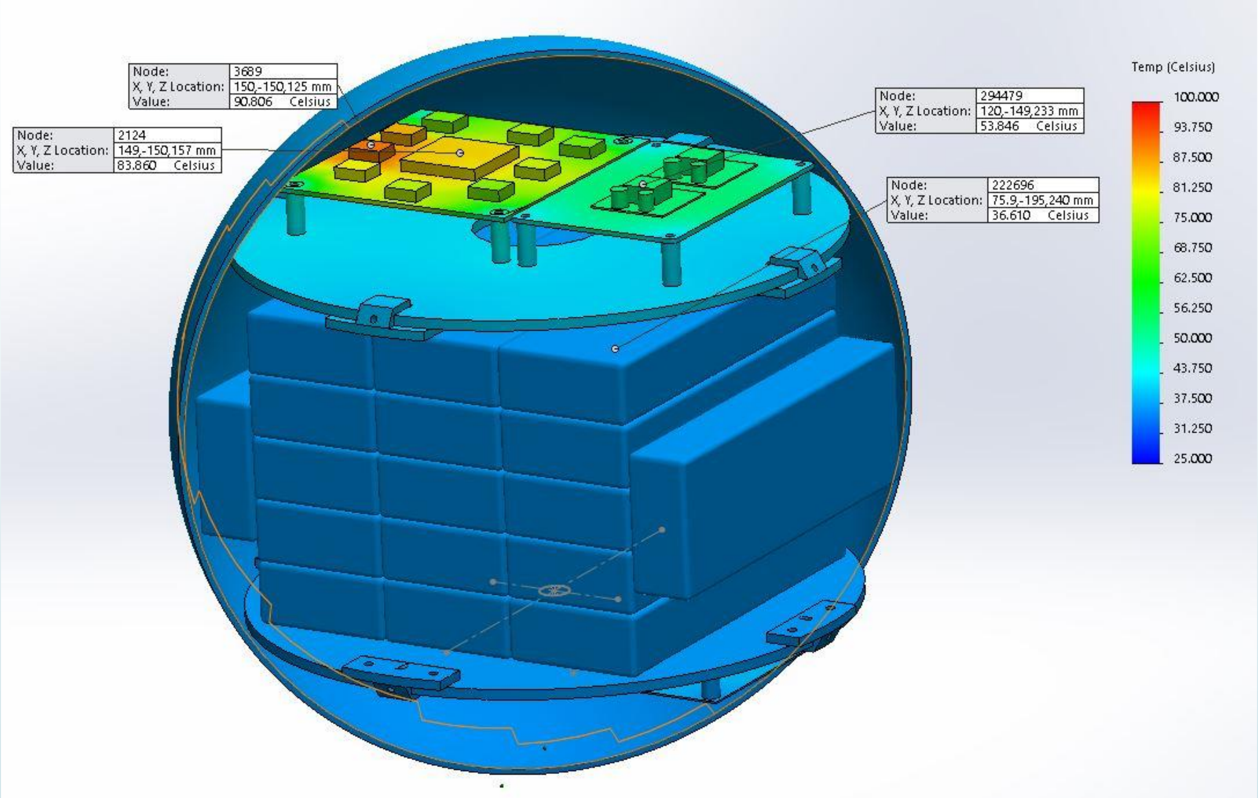


Top Shelf Drawing (dimensions in mm)



Temperatures within Operating Conditions





INT 6: All temperatures are within acceptable range of onboard components

Will be refining models through component testing

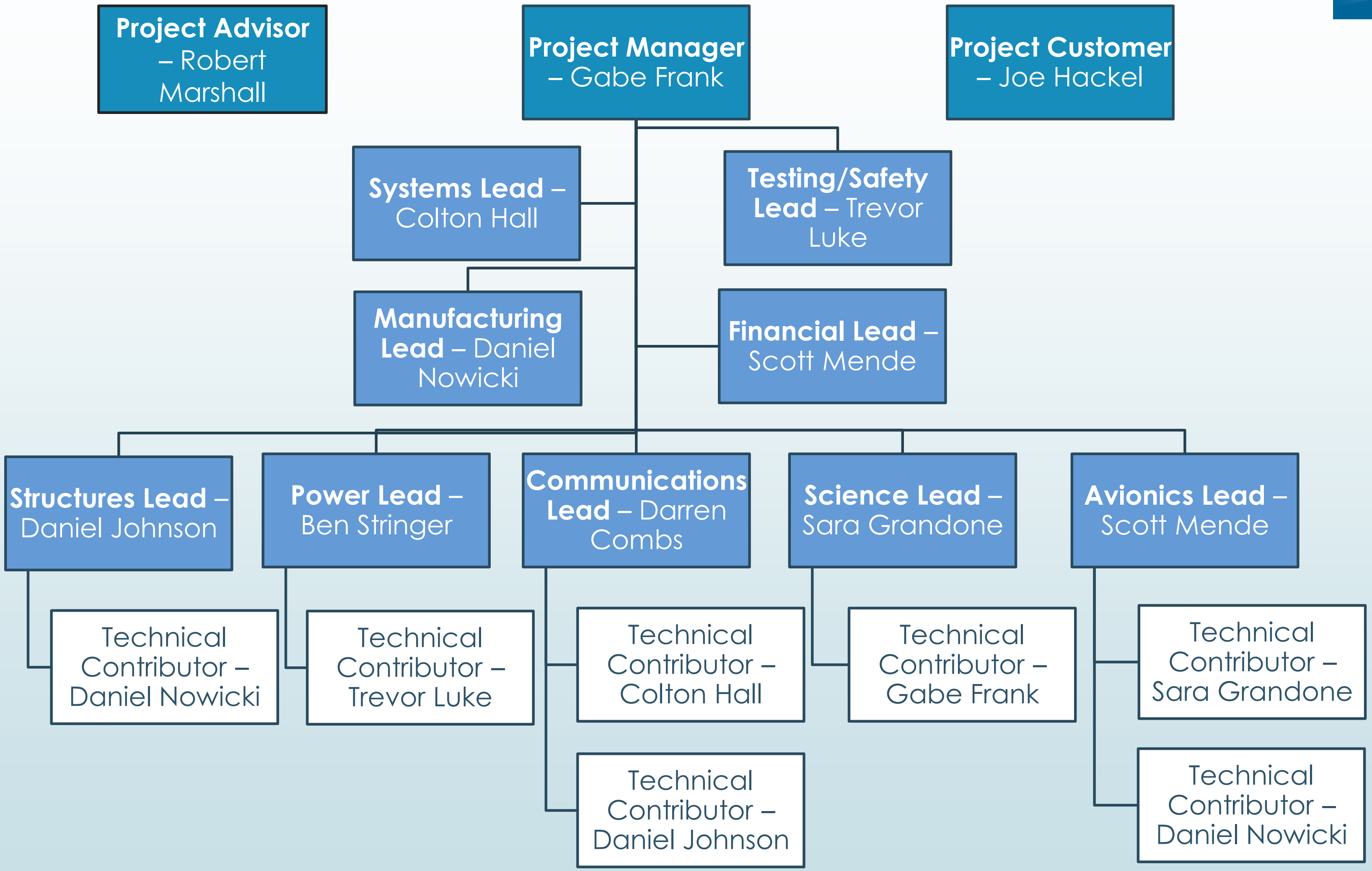
Project Management Backup

Budget Status

Part	Projected Cost	Projected + Margin	Actual Cost	Difference
Batteries (x20)	$640.00	$768.00 (4 Batt.)	$404.88	$235.12
CC1101 Transceiver Kit	$500.00	$1000.00 (100%)	$471.42	$28.58
Metals and Fasteners	$177.00	$531.00 (200%)	$135.56	$41.44
DC/DC and Logic Converters	$35.00	$70.00 (100%)	$65.8	$30.8
Wires, Connectors, Cables	$400.00	$1200.00 (200%)	$206.6	$193.4
Printed Circuit Boards	$100.00	$400.00 (300%)	$102.38	$2.38
Power Safety Devices	$20.00	$80.00 (300%)	$40.45	$20.45
Sensors	$165.00	$330.00 (100%)	$179.85	$14.85
Avionics Programmer	$50.00	$100.00 (100%)	$51.25	$1.25
Testing Equipment	$240.00	$265.00 (10%)	$236.35	$3.65
Miscellaneous	-	-	$21.83	$21.83
Total:	**$2327**	**$4744**	**$1916.37**	**$410.63 under budget**

$410 dollars under expected budget

Organizational Chart



Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

Work Breakdown Structure

Communications System
- STK Pass-time Model
- Short Range Link Budget
- Communications Protocol
- Detailed Data Flow FBD
- Ground Station Software
- Transceiver Chip
- Antennas

Avionics System
- FPGA Software Module Design
- Timing Diagrams
- Testing Suite Plan
- Avionics Board Hardware
- Testing Suite Software
- Avionics Board Software

Structure
- Component Mounting Plan
- Thermal Model
- CAD Model
- Radiation
  - 1-D Radiation Model
  - CAD Radiation Shielded Model
- External Sphere Shell
- Manufactured Mounting Brackets and Internal Shelving
- Integrated NeoPod

Science Payload
- Trade Study and Traceability Matrix
- Functioning Geiger Counter
- Functioning Magnetometer

Power System
- Battery Characterization
  - Single Battery Curve
  - Parallel Battery Curve
- System Circuitry
  - Battery Layout
- Procured Batteries
- Power Board

Integration and Testing Plan
- Semester Test Plan
- System Interface Plan
- Interface Control Documents
- Subsystem Tests
- Integrated Subsystems Tests
- Full System Test

Class Deliverables (Fall)
- Project Defininition Document
- Conceptual Design Document
- Preliminary Design Review
- Critical Design Review
- Fall Final Report

Class Deliverables (Spring)
- Manufacturing Status Review
- Test Readiness Review
- AIAA Report
- Spring Final Review
- Spring Design Symposium
- Spring Final Report

Program Management
- WBS
- Gantt Chart
- Budget
- Risk Analysis Matrix

Key
Completed
Future Work

Manufacturing Work Breakdown Structure

- **Models**
  - STK Pass-time Model
  - Short Range Link Budget
  - Power Characterization
  - Thermal Model
  - SolidWorks CAD Model
- **Hardware**
  - Ball Aerospace Provided FPGA & Avionics Board
  - Transceiver Chip
  - External Sphere Shell with Mounted Antenna
  - Functioning Magnetometer
  - Functioning Geiger Counter
  - Batteries and Wiring Acquired
  - Manufactured Mounting Brackets and Internal Shelving
  - Fully Integrated NeoPod
- **Electrical**
  - System Circuitry
    - Power board Design
    - Battery Layout
  - Communications Printed Circuit Board Design
  - Sensor Printed Circuit Board Design
- **Software**
  - FPGA Software Module Design
  - Timing Diagrams
  - Testing Suite Software
  - Avionics Board Software
  - Ground Station Software
- **Integration and Testing**
  - Semester Test and Integration Plan
  - Subsystem Tests
  - Integrated Subsystem Tests
  - Full System Tests
- **Class Deliverables**
  - Preliminary Design Review
  - Critical Design Review
  - Fall Final Report
  - Manufacturing Status Review
  - Test Readiness Review
  - Spring Final Review and Report
- **Program Management**
  - Work Breakdown Structure
  - Gantt Chart
  - Budget
  - Risk Analysis Matrix

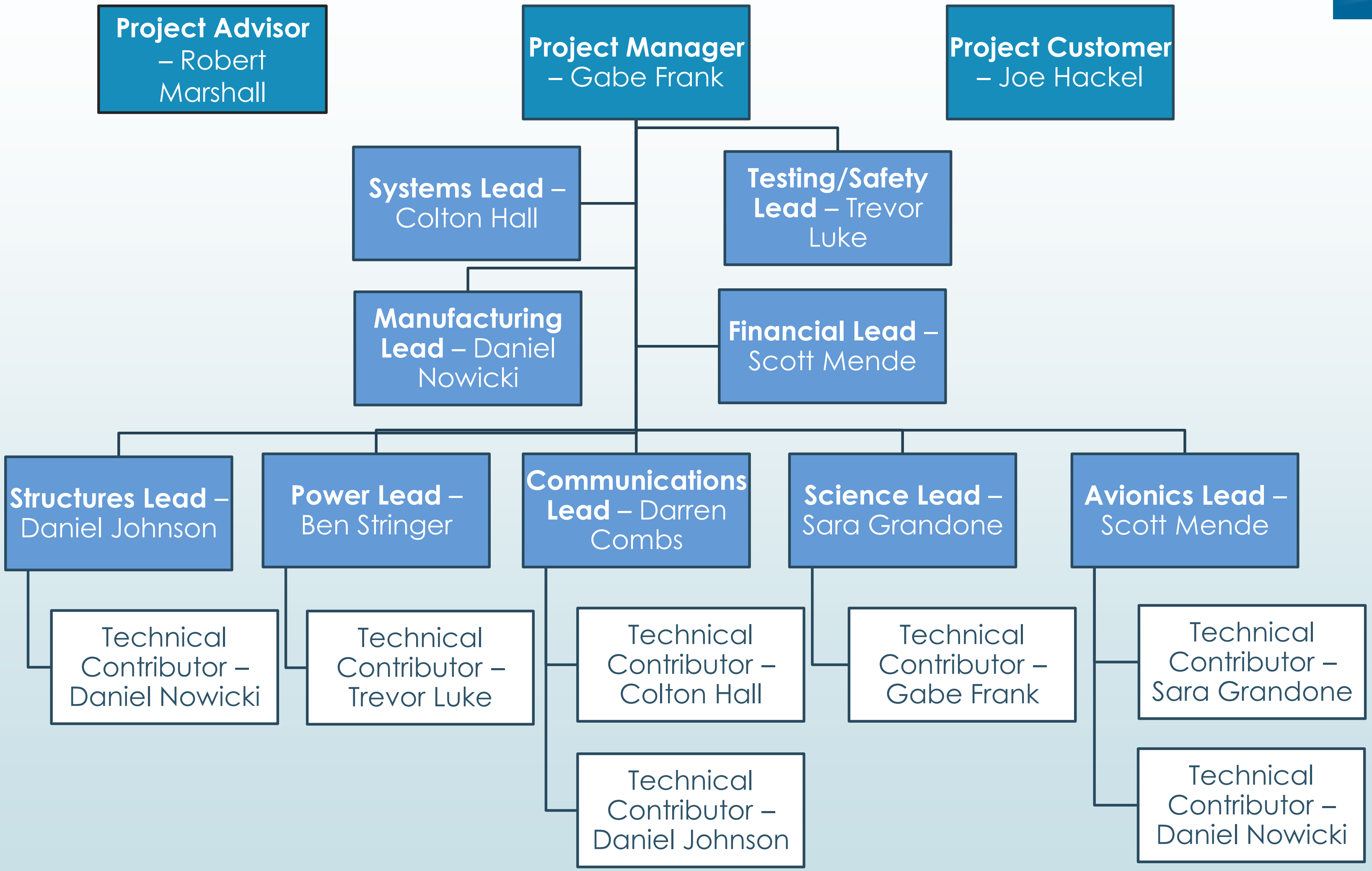
Key
Completed
In Work
Future Work

Item	Vendor	#	Total Cost (w/ shipping)	Shipping Cost	Ordered	Received	Concur Logged		Budget Limit	$5,000
TOTALS			**1916.37**	**82.1**						
M1A3PL1000 Dev Kit	Microsemi	1	0	0	NA	10/9/2015			Budget Used	1916.37
Thunder Power RC TP1430C	Amazon	1	214.65	0	11/6/2015	11/12/2015			Budget Remaining	$3,084
Multi Star High Capacity Lipo	Amazon	3	107.69	0	11/6/2015	11/13/2015				
FFR Printing	FedExOffice	1	21.83	0	12/14/2015	NA	X			
CC1101DK433	ARROW	1	471.42	4.05	12/15/2015	Y	X		Purchased	
40A ParaBoard	BUDDYRC	1	21.7	3.75	12/15/2015	Y	X		Recieved	
DC/DC Converter Breakout	SparkFun	2	59.9	0	12/18/2015	Y	X			
Fuse 5mm 125VAC 5A	SparkFun	5	2.5	0	12/18/2015	Y	X			
Fuse Clip 5mm	SparkFun	4	1	0	12/18/2015	Y	X			
Triple Axis Magnetometer HMC5883L	SparkFun	2	29.9	0	12/18/2015	Y	X			
Logic Level Converter	SparkFun	2	5.9	0	12/18/2015	Y	X			
Geiger Counter	SparkFun	1	149.95	0	12/18/2015	Y	X			
Micro Dean 2R Plug	NewEgg	2	10.6	0	12/18/2015	Y	X			
Parallel Charge Cable	NewEgg	4	51.96	0	12/18/2015	Y	X			
Seco-Larm Low-Voltage Cutoff	Amazon	1	24.95	0	12/18/2015	Y	X			
RC Lipo Safety Bag	Amazon	1	12	0	12/18/2015	Y	X			
Multistar High Capacity 3S 5200mAh	HobbyKing	17	297.19	0	12/20/2015	Y	X			
FlashPro5	Digikey	1	51.25	4.54	12/20/2015	Y	X			
SMA Cable	Digikey	1	43.21	0	12/20/2015	Y	X			
Shelf Metal	Online Metal Store	2	76.93	15.17	12/31/2015	Y				
Clip Metal	Online Metal Store	1	15.26	0	12/31/2015	Y				
Shelf Metal .125 thick	Online Metal Store	2	43.37	18.21	1/15/2016	Y				
Connectors and Cabling #1	SAMTEC	na	93.22	0	1/21/2016			See requests for itemized		
Connectors and Cabling #2	SAMTEC	na	7.61	0	1/19/2016			See requests for itemized		
Darren PCB	Advanced Circuits	1	51.19	18.19	1/19/2016					
Gabe PCB	Advanced Circuits	1	51.19	18.19	1/19/2016					

Connectors Order

IPL1-105-01-L-D-RA-K	4	$2.49 each
IPL1-102-01-L-S-RA-K	4	$1.59 each
IPL1-104-01-L-S-RA-K	6	$1.76 each
IPL1-102-01-L-S-K	16	$1.29 each
MMSS-05-24C-L-18.00-S-K	3	$1.51 each
MMSS-05-24C-L-24.00-S-K	1	$1.55 each
MMSS-05-24C-L-12.00-S-K	1	$1.47 each
MMSS-02-24C-L-08.00-S-K	3	$0.776 each
MMSS-02-24C-L-18.00-S-K	1	$.804 each
MMSS-02-24C-L-06.00-S-K	1	$.77 each
MMSS-04-24C-L-08.00-D-K-LUS	3	$2.15 each
MMSS-04-24C-L-12.00-D-K-LUS	1	$2.17 each
MMSS-04-24C-L-18.00-D-K-LUS	1	$2.20 each
MMSS-04-24C-L-18.00-S-K	3	$1.28 each
MMSS-04-24C-L-14.00-S-K	1	$1.26 each
MMSS-04-24C-L-20.00-S-K	1	$1.29 each
MMSS-02-20C-L-18.00-D-K-LUS	6	$1.43 each
MMSS-02-20C-L-12.00-D-K-LUS	1	$1.41 each
MMSS-02-20C-L-24.00-D-K-LUS	1	$1.45 each
MMSS-02-20C-L-08.00-D-K-LUS	4	$1.40 each
MTSW-120-10-G-D-480	1	$3.36 each
SSW-106-03-T-S	4	$0.41 each
SSW-103-03-T-S	5	$0.307 each
SSW-105-03-T-S	5	$0.393 each
TSW-103-09-T-S	5	$0.116 each
TSW-105-09-T-S	5	$0.193 each
TSW-106-09-T-S	4	$0.231 each
CHG-2040-J01010-KEP	2	$9.36 each
TFM-110-02-L-D-A-K-TR	4	5.85 each

Organizational Chart



Project Overview | Schedule | Budget | Manufacturing & Status | Conclusion

Work Breakdown Structure

- **Communications System**
  - STK Pass-time Model
  - Short Range Link Budget
  - Communications Protocol
  - Detailed Data Flow FBD
  - Ground Station Software
  - Transceiver Chip
  - Antennas
- **Avionics System**
  - FPGA Software Module Design
  - Timing Diagrams
  - Testing Suite Plan
  - Avionics Board Hardware
  - Testing Suite Software
  - Avionics Board Software
- **Structure**
  - Component Mounting Plan
  - Thermal Model
  - CAD Model
  - Radiation
    - 1-D Radiation Model
    - CAD Radiation Shielded Model
  - External Sphere Shell
  - Manufactured Mounting Brackets and Internal Shelving
  - Integrated NeoPod
- **Science Payload**
  - Trade Study and Traceability Matrix
  - Functioning Geiger Counter
  - Functioning Magnetometer
- **Power System**
  - Battery Characterization
    - Single Battery Curve
    - Parallel Battery Curve
  - System Circuitry
    - Battery Layout
  - Procured Batteries
  - Power Board
- **Integration and Testing Plan**
  - Semester Test Plan
  - System Interface Plan
  - Interface Control Documents
  - Subsystem Tests
  - Integrated Subsystems Tests
  - Full System Test
- **Class Deliverables (Fall)**
  - Project Defininition Document
  - Conceptual Design Document
  - Preliminary Design Review
  - Critical Design Review
  - Fall Final Report
- **Class Deliverables (Spring)**
  - Manufacturing Status Review
  - Test Readiness Review
  - AIAA Report
  - Spring Final Review
  - Spring Design Symposium
  - Spring Final Report
- **Program Management**
  - WBS
  - Gantt Chart
  - Budget
  - Risk Analysis Matrix

Key
Completed
Future Work

Manufacturing Work Breakdown Structure

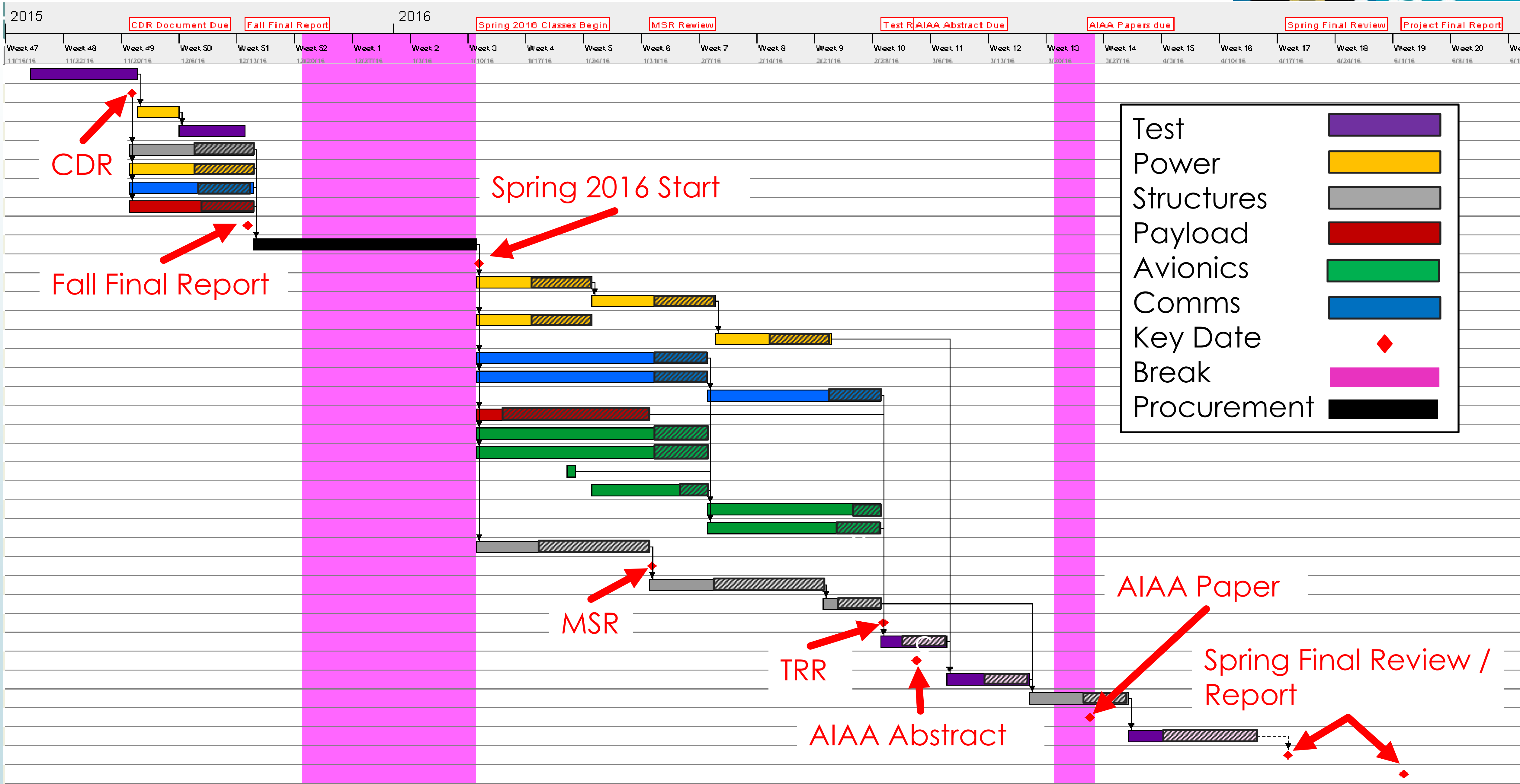
- **Models**
  - STK Pass-time Model
  - Short Range Link Budget
  - Power Characterization
  - Thermal Model
  - SolidWorks CAD Model
- **Hardware**
  - Ball Aerospace Provided FPGA & Avionics Board
  - Transceiver Chip
  - External Sphere Shell with Mounted Antenna
  - Functioning Magnetometer
  - Functioning Geiger Counter
  - Batteries and Wiring Acquired
  - Manufactured Mounting Brackets and Internal Shelving
  - Fully Integrated NeoPod
- **Electrical**
  - System Circuitry
    - Power board Design
    - Battery Layout
  - Communications Printed Circuit Board Design
  - Sensor Printed Circuit Board Design
- **Software**
  - FPGA Software Module Design
  - Timing Diagrams
  - Testing Suite Software
  - Avionics Board Software
  - Ground Station Software
- **Integration and Testing**
  - Semester Test and Integration Plan
  - Subsystem Tests
  - Integrated Subsystem Tests
  - Full System Tests
- **Class Deliverables**
  - Preliminary Design Review
  - Critical Design Review
  - Fall Final Report
  - Manufacturing Status Review
  - Test Readiness Review
  - Spring Final Review and Report
- **Program Management**
  - Work Breakdown Structure
  - Gantt Chart
  - Budget
  - Risk Analysis Matrix

Key
Completed
In Work
Future Work

Project Statement

The ELSA team will **design and build a probe (the NeoPod) to collect, store, and transmit data** to a Ground Station. The system will operate for a 100 hour mission lifetime, on Earth, with a short distance between the NeoPod and the Ground Station. The ELSA team is **responsible for designing and integrating the payload, communications, Ground Station, power system, and internal structure** with the customer supplied avionics board, spherical shell, and patch antennas.

Last Semester's Schedule



Backup: Schedule Table with Values

Task	Hours Complete	Total Hours Required	Percent Complete	Hours Remaining
Test Individual Power Components	10	10	100.00%	0
Power Board Assembly	2	6	33.33%	4
Battery Integration	2	6	33.33%	4
Initial Comms Component Testing	20	25	80.00%	5
Ground Station Development Testing	30	35	85.71%	5
Payload Component Testing	12	15	80.00%	3
Avionics Module Development	89	134	66.42%	45
Avionics Testbench Development	5	35	14.29%	30
Manufacturing / Integration Plan	25	25	100.00%	0
Machine Shelves and Clips	10	40	25.00%	30

Science Traceability Backup

Science Trade

Metric	Weight	Magnetometer	Seismometer	Imager Visual	Imager IR	Imager Micro
Science Value	15%	5	5	3	1	5
Cost	15%	4	3	3	3	1
Availability	16%	5	3	4	3	1
Complexity	20%	4	3	3	1	1
Size	22%	4	2	3	4	1
Mass	12%	4	2	4	4	1
Total	100%	4.31	2.96	3.28	2.64	1.44

Science Trade Cont.

Metric	Weight	Imager Zoom	Spectrometer	Radiation	Temperature	Pressure
Science Value	15%	3	5	5	1	1
Cost	15%	3	1	4	5	5
Availability	16%	4	1	4	5	5
Complexity	20%	2	1	4	3	3
Size	22%	3	2	2	5	5
Mass	12%	3	2	4	5	5
Total	100%	2.96	1.94	3.71	4.00	4.00

Science Traceability

Requirement ID	Magnetometer	Seismometer	Imager Visual	Imager IR	Imager Micro
SCI 0: Neopod shall collect scientific data relevant to Europa	✓ Ice shell characterization	✓ Surface geology characterization	✓ Surface geology characterization	✗ Stationary probe leads to static and not unique results	✓ Surface geology characterization
SCI 2.1: Neopod Power Subsystem shall sustain the scientific instruments for a 96 hour period.	✓ Low Power	✓ Low Power	✓ Low Power	✓ Low Power	✓ Low Power
SCI 2.2: Neopod sensors shall mechanically and electrically	✓ Only internal interface	✓ Only internal interface	✗ Must interface with external structure	✗ Must interface with external structure	✗ Must interface with external structure
INT 1: Neopod shall have a mass less than 10 kg.	✓ m_{mag} << .5 kg	✗ m_{mag} >.5 kg	✓ m_{mag} < .5 kg	✓ m_{mag} < .5 kg	✗ m_{mag} >.5 kg
INT 2: Neopod shall have a maximum diameter of 30cm	✓ Largest Dimension << 5 in	✗ Largest Dimension >> 5 in	✓ Largest Dimension << 5 in	✗ Largest Dimension >> 5 in	✗ Largest Dimension >> 5 in
Requirements Met	5	3	4	2	2
Trade Score	4.31	2.96	3.28	2.64	1.44

Science Traceability Cont.

Requirement ID	Imager Zoom	Spectrometer	Radiation	Temperature	Pressure
SCI 0: Neopod shall collect scientific data relevant to Europa	✓ Surface geology characterization	✓ Surface composition characterization	✓ Surface composition characterization	✗ Little desired scientific value	✗ Little desired scientific value
SCI 2.1: Neopod Power Subsystem shall sustain the scientific instruments for a 96 hour period.	✓ Low Power	✓ Low Power	✓ Low Power	✓ Low Power	✓ Low Power
SCI 2.2: Neopod sensors shall mechanically and electrically	✗ Must interface with external structure	✗ Must interface with external structure	✓ Only interfaces internally	✗ Must be isolated from electronics and interface externally	✗ Must interface with external structure
INT 1: Neopod shall have a mass less than 10 kg.	✓ m_{mag} < .5 kg	✗ m_{mag} >.5 kg	✓ m_{mag} << .5 kg	✓ m_{mag} << .5 kg	✓ m_{mag} << .5 kg
INT 2: Neopod shall have a maximum diameter of 30cm	✓ Largest Dimension < 5 in	✗ Largest Dimension >> 5 in	✓ Largest Dimension < 5 in	✓ Largest Dimension << 5 in	✓ Largest Dimension << 5 in
Requirements Met	4	2	5	3	3
Trade Score	2.96	1.94	3.71	4.00	4.00