Final Report
New Mexico Space Grant Consortium

San Juan College

Team Members:

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Mission Overview

Objectives

The objectives of this mission are to capture and interpret data for:

- Local atmospheric conditions as a function of flight time (approximately 15 minutes total) and altitude from ground level (1-2 km) up to approximately 120 km in the lower thermosphere. This includes:
    - Temperature
    - Pressure
    - Radiation levels

- Rocket vehicle acceleration as a function of time along three perpendicular axes, which may be analyzed to estimate its velocity, altitude, and rotational speed as functions of time.

Mission Overview

Expected Results

- Measured atmospheric conditions are expected to reflect the general trends predicted by atmospheric models such as the US Standard Atmosphere or COSPAR International Reference Atmosphere models. However, regional and/or seasonal deviations are also expected and of interest.
- Rocket performance data are expected to be similar to flight conditions specified for the Up Aerospace SpaceLoft-XL vehicle. vertical acceleration should approach 16 g's during the early ascent phase. Radial accelerations are expected to reach 18-20 g's primarily due to the vehicle design spin rate of around 6 cycles per second spin rate on ascent, and should be detectable with x and y axes accelerometers.
- Measured radiation intensity should show an increase with increasing altitude due to decreased atmospheric shielding from solar and cosmic sources. The Geiger counter is expected to primarily detect gamma rays since beta and alpha particles will not be able to penetrate the metallic skin of the vehicle body. Again, any deviations from expected trends are of interest.

Mission Overview

Background

- As a general trend, atmospheric pressure decreases exponentially with altitude (according to the US Standard Atmosphere for 0-85 km).
- With increasing altitude, ambient atmospheric temperature goes through several regions of differing temperature dependencies characterized by "lapse rate." The temperature first decreases through the troposphere, increases through the stratosphere, again decreases through the mesosphere, and finally increases in the thermosphere. It is expected that significant surface heating at the vehicle surface due to air friction may affect the temperature measurements such that the measured temperature will likely reflect that of the rocket and payload can, more than that from the surrounding external atmosphere.
- In principle, the z-axis accelerometer data in combination with 1-dimensional kinematic equations should be useful for calculating estimates of the altitude of the vehicle as a function of time. Moreover, the x-axis accelerometer data should be useful for determining the rotational rate of the vehicle based upon rotational kinematics.

Mission Overview

Requirement	Method	Status
The useable payload must not exceed weight of 2.5 Lb.	Design, Test	
The payload must operate on 1W or less.	Design, Test	
The spacecraft's center of gravity (CG) shall be within 0.25" of the geometric central axis of the ICU.	Design, Analysis	
The payload must be capable of meeting all mission objectives.	Design	

Mission Overview

Mission Requirements

The equipment must be able to withstand accelerations of up to 20 g’s on ascent and 60 g’s upon touchdown, and temperatures ranging from -18°C to 49°C typical (66°C max).

The equipment must also be able to withstand the acoustic pressure exposure during maximum dynamic pressure. Internal sound pressures should not exceed 110 dB.

All customers sharing a single payload canister must fit the size and mass requirements specified for the Up Aerospace SpaceLoft-XL PTS-10 payload container:

- Maximum inside height: 9.25 inches
- Maximum inside diameter: 9.75 inches
- Maximum functional payload weight: 10.0 Lb

System Requirements

- Data acquisition is controlled by the 8-bit AVR Atmega 32 Microcontroller
- 4 MHz speed is sufficient for reasonable data/time resolution
- C programming language used
- All of the Atmega's 8- channel ADC inputs are required for the sensors:
  - 1 Temperature sensor (2 bytes)
  - 1 Pressure sensor (2 bytes)
  - 6 accelerometers (9 bytes)
  - 1 Geiger counter (1 byte) using the USART Receive Data/counter
  - Total of 14 bytes per sample cycle
- Data collected at 20 samples/s rate or 280 bytes/s for the above data
- At this sampling rate the 2 Mb Flash memory has capacity for 7142 seconds of data or about 119 minutes.

System Requirements

- Bench testing revealed a total system (AVR and Geiger counter) current of 61 mA at 9 V, implying approximately 550 mW continuous power demand for the complete system.
- A power consumption of 550 mW for a short time period permits use of a small 9V battery power supply. System power needs for both the AVR (5V) and Geiger counter (9V) can be provided with two standard 9 V commercial lithium batteries ("UltraLife") configured in parallel.
- Assuming use of two 9V lithium batteries rated for 1200 mA-h and a supply voltage cutoff of 8 V (with a 100 Ω load) the useful battery life is about 1000 mA-hr. That will provide a safe 16 hours of reliable power.

Subsystem Exposures (source: UP Aerospace)

- Acoustic Exposure

  Internal sound pressures will typically not exceed 110 dB.

- Thermal Exposure

  Aerodynamic heating of the vehicle's airframe during flight is the dominant source of thermal energy. The airframe greatly disperses the thermal energy; maximum internal temperature is thus unlikely to exceed 66°C with 26 – 49°C the typical temperature range. Higher temperatures are possible depending on the size of the access panel openings and location of payload components.

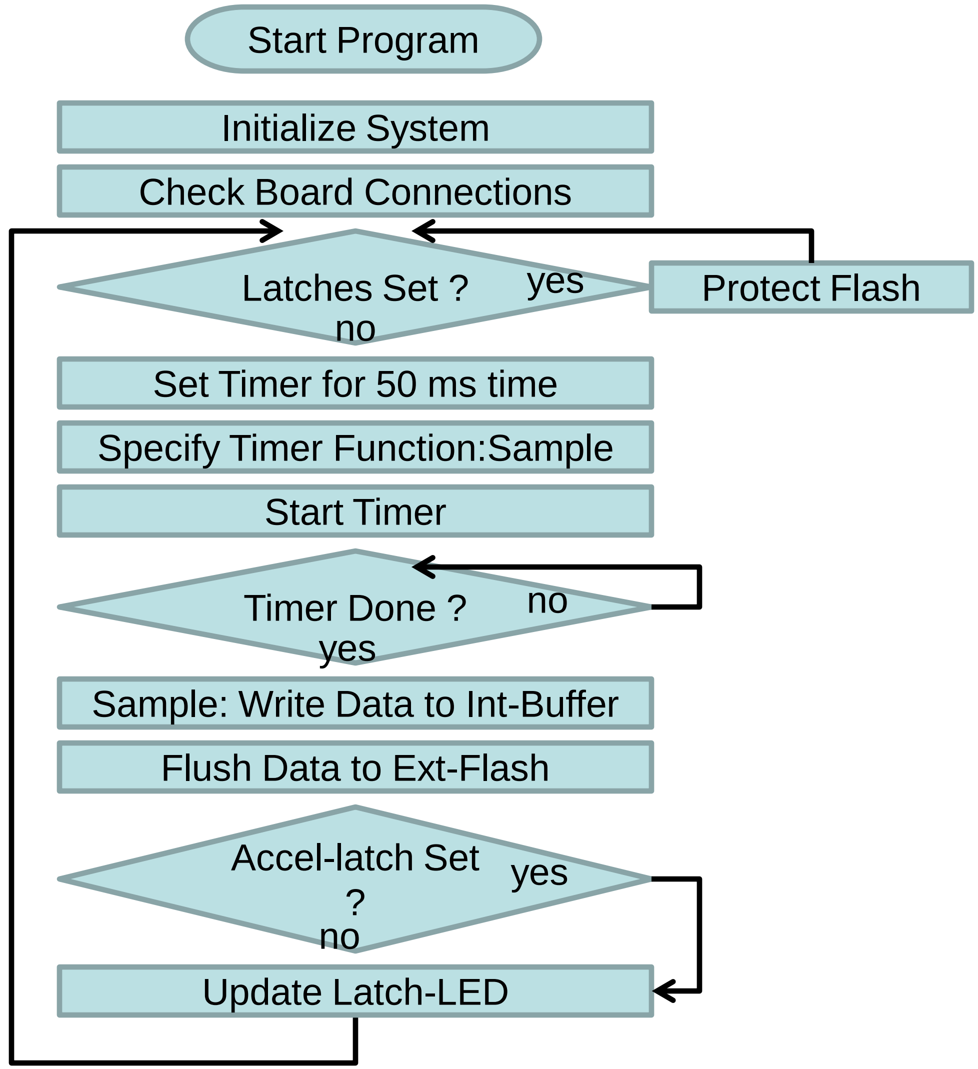
- Atmospheric Pressure Change

  Pressure within the SpaceLoft® XL spacecraft diminishes as the vehicle ascends through the atmosphere. Vent holes within the vehicle generally maintain equilibrium with the ambient pressure throughout the entire vehicle flight.

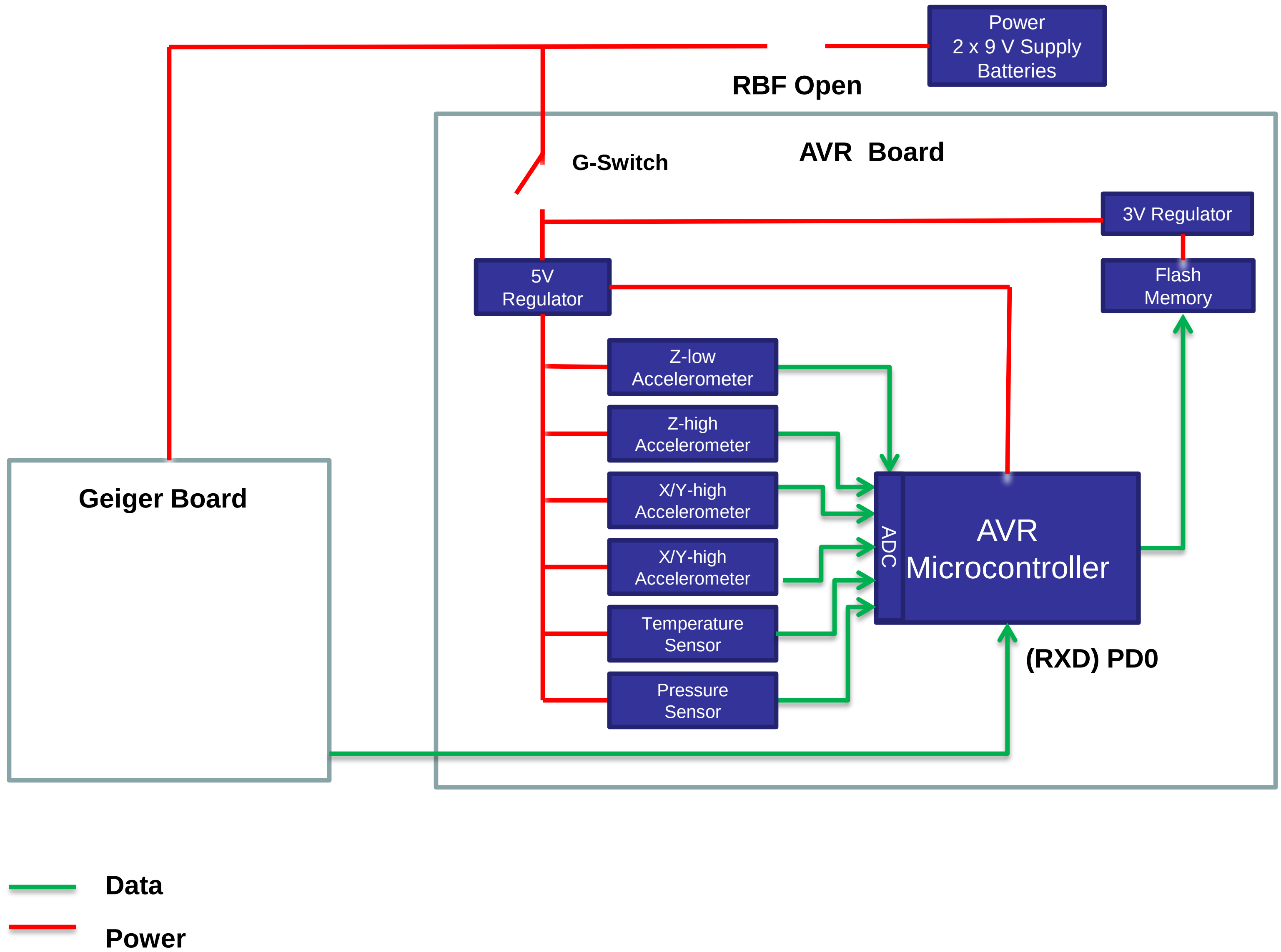
Subsystem Requirements

- The following subsystems are included in the payload:
  - AVR PCB
    - Pressure sensor (0 – 15 psi, 30 psi max. burst pressure)
    - Temperature sensor
    - Accelerometers
  - Geiger counter PCB
- Each of these must be able to with stand :
  - Temperatures ranging from 26°C – 66°C
  - Pressures ranging from 0 – 15 psi.
  - Axial loads range from 16 g's at peak acceleration, up to 60 g's at touchdown
  - Radial loads are primarily due to a 6 cycles per second spin rate of the vehicle on ascent and range up to 18.5 g's.

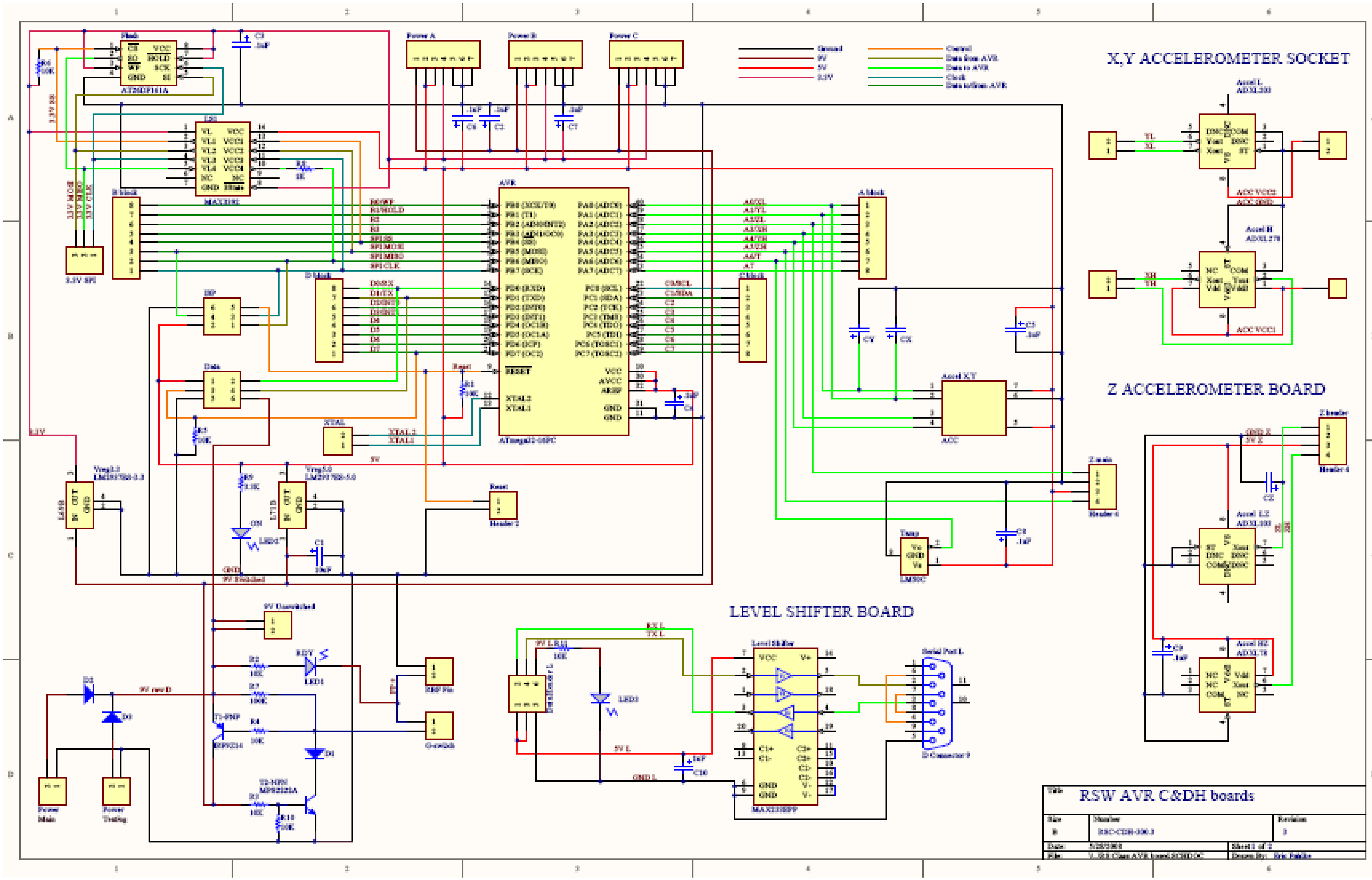
Concept of Operations (Program Flow)



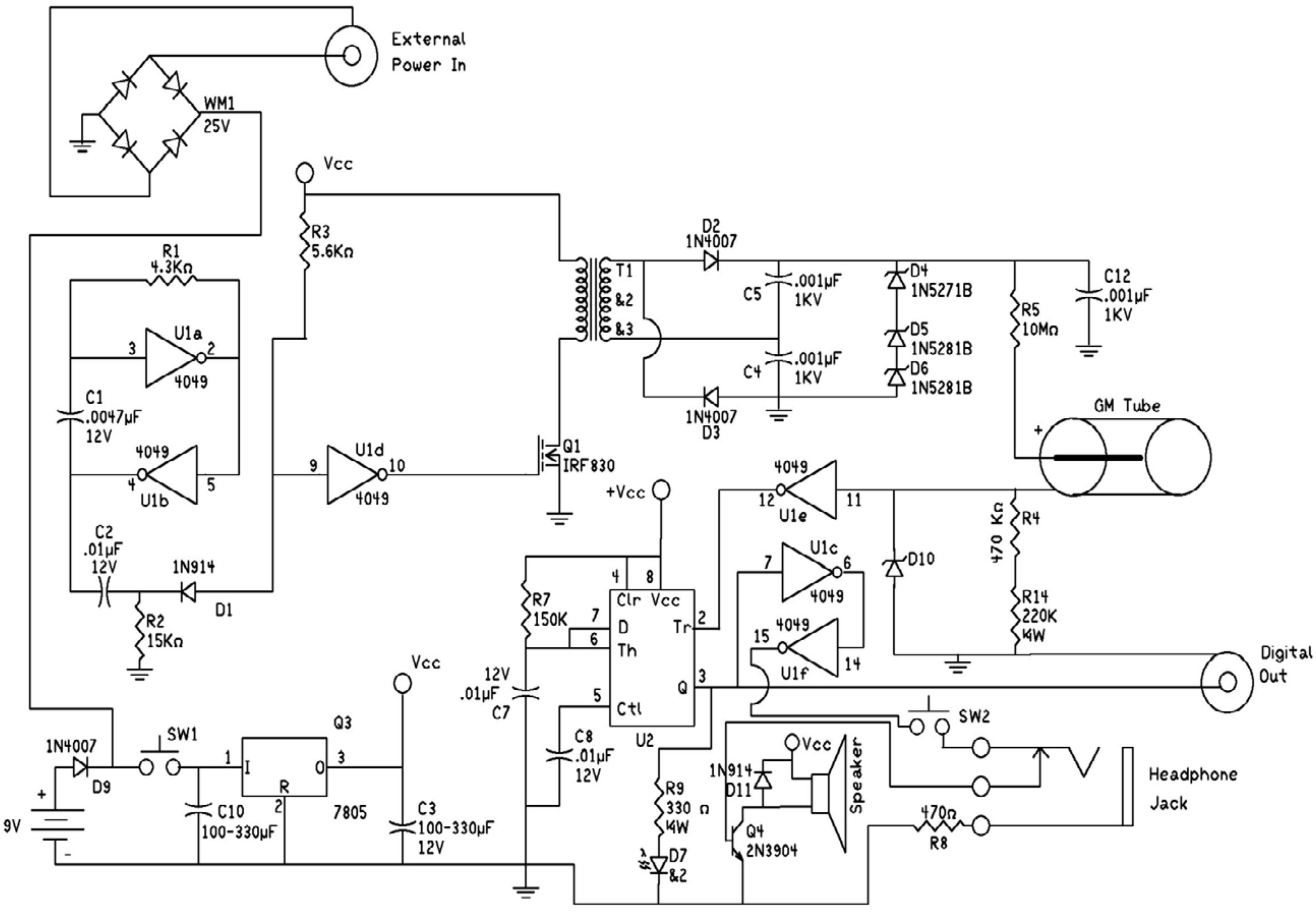
Payload System Block Diagram



Main AVR Microprocessor Schematic with Sensors



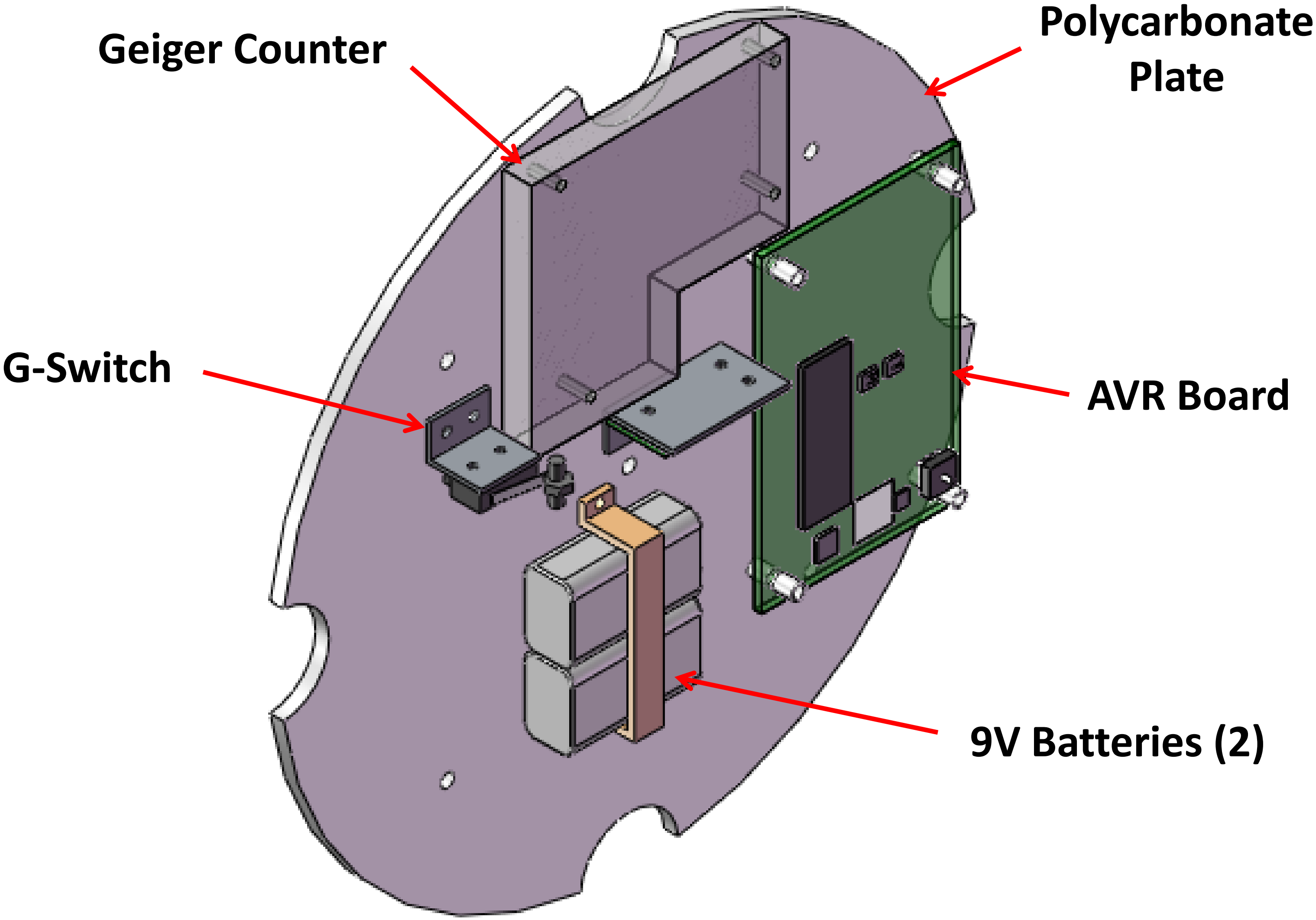
Geiger Counter Schematic



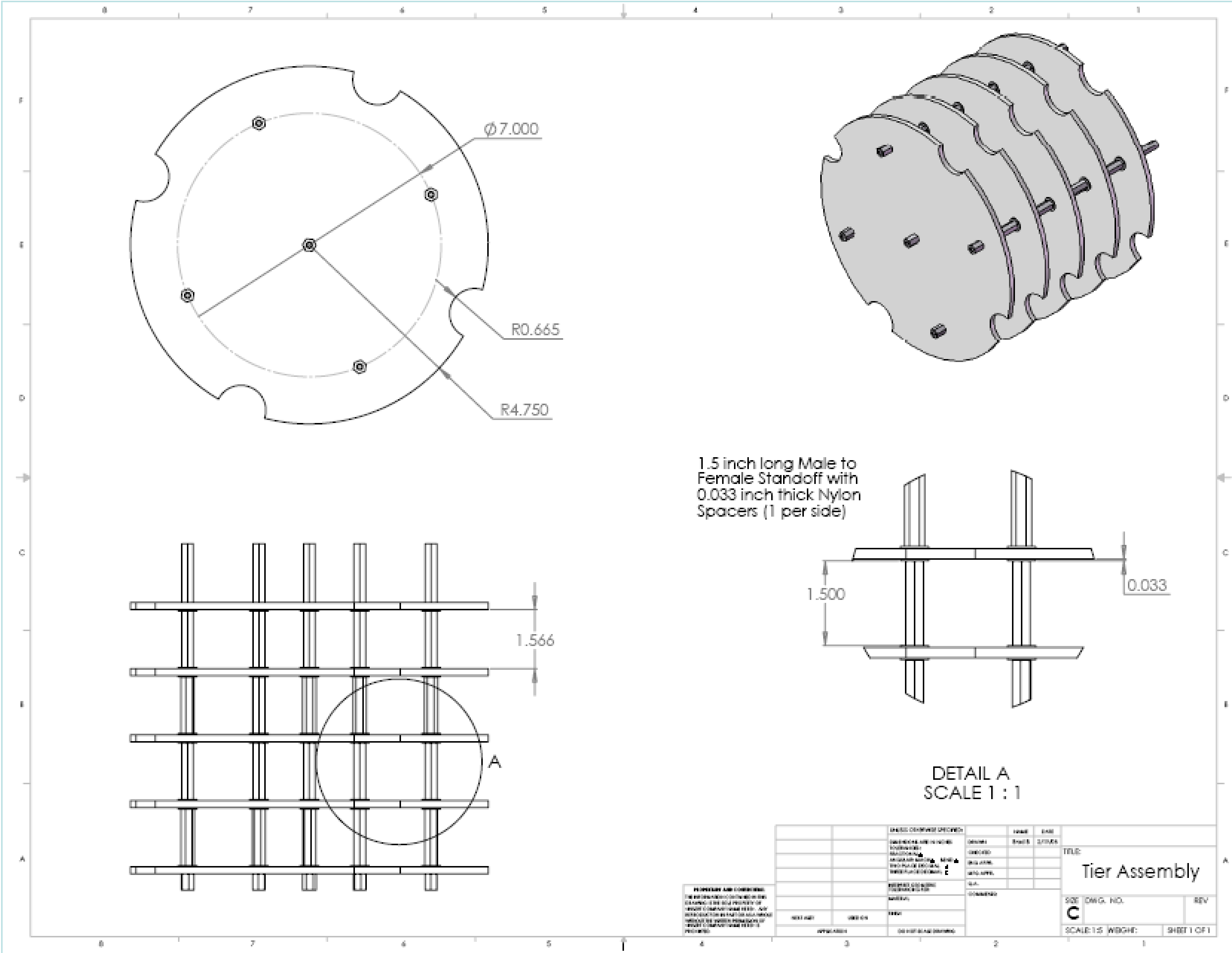
Major Parts List

Parts	Company	Model
Low range accelerometers		
x and y-axis	Analog Devices	ADXL 203CE
z-axis		ADXL 103CE
High range accelerometers		
x and y-axis	Analog Devices	AD22284-A-R2
z-axis		AD22279-A-R2
Microcontroller	Atmel	ATmega32-16PU
Pressure Sensor	Sensym ICT	ASDX015A24R
Temperature sensor	National Semiconductor	LM50CIM3CT-ND
3.3V Voltage Regulator	Texas Instruments	M2937IMP-3.3CT-ND
5V Voltage Regulator	Texas Instruments	M2937IMP-5.0CT-ND
Flash memory	Atmel	AT26DF161A-SU
PNP Power Transistor	International Rectifier	IRF9Z14PBF
NPN Transistor	ON Semiconductor	MPS2222ARLRAG
SPI Level Shifter	Maxim Integrated Products	MAX3392EEUD

Mounting Plate Assembly



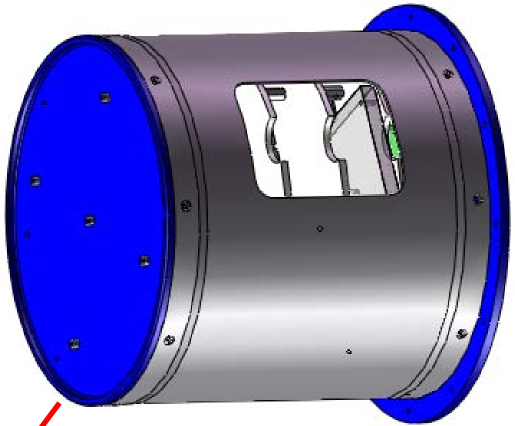
Tier Assembly



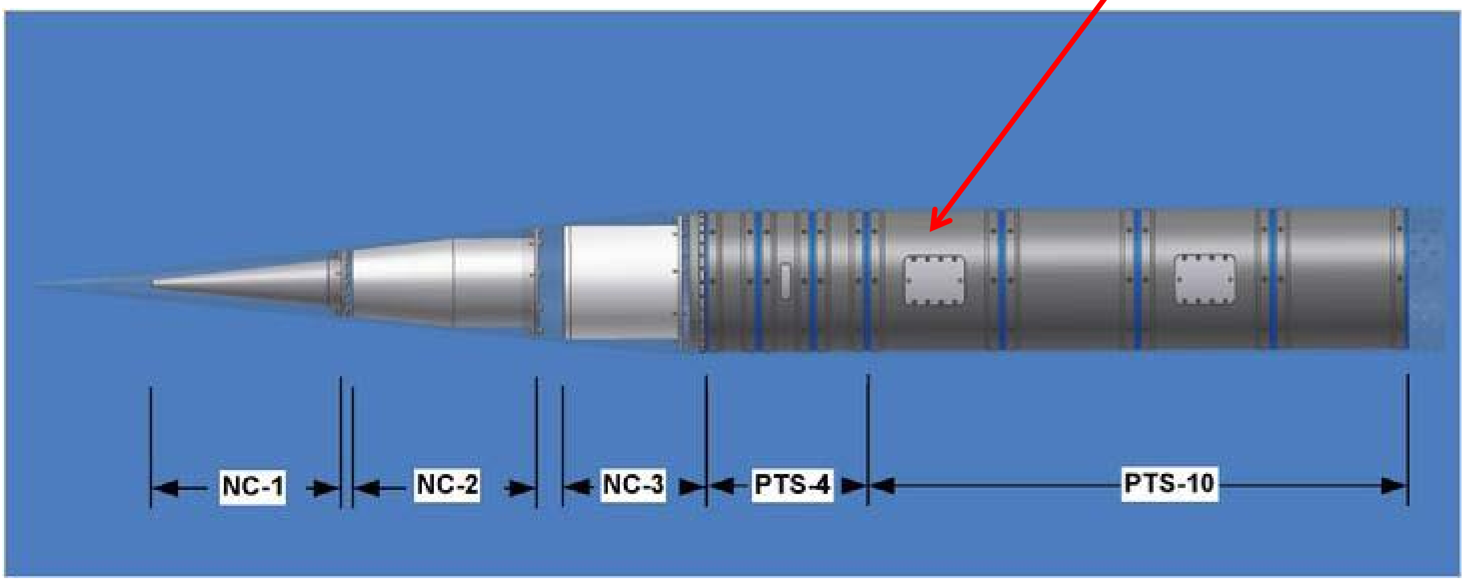
Tier Assembly inside PTS-10 Payload Canister

PTS-10 Shared Can Logistics Plan

- Fourth (Top): SJCC
- Third: SIPI
- Second: CNM
- First: T or C

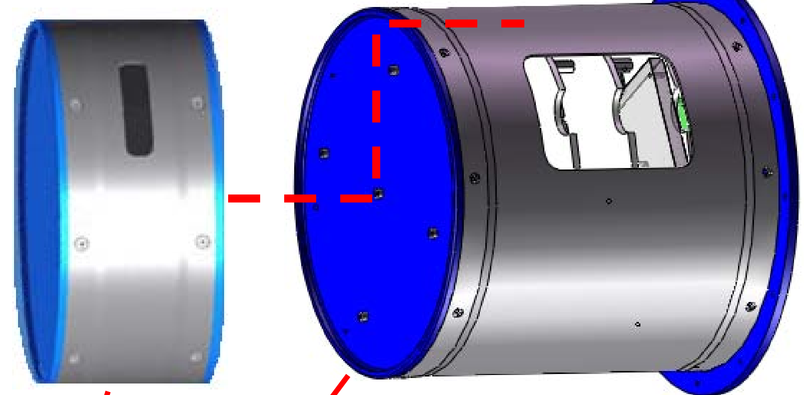


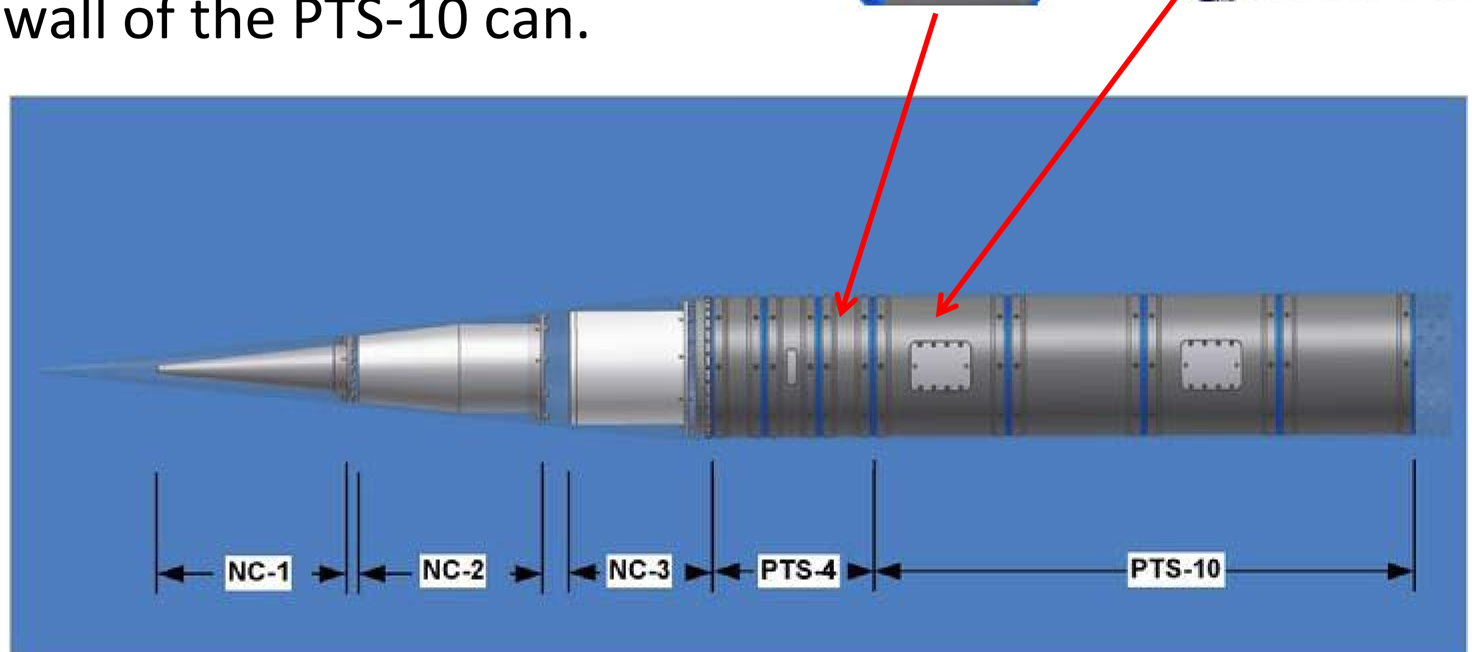
*SIPI payload will house the master switch



PTS-4 and PTS-10 Adjacent Can Logistics Plan

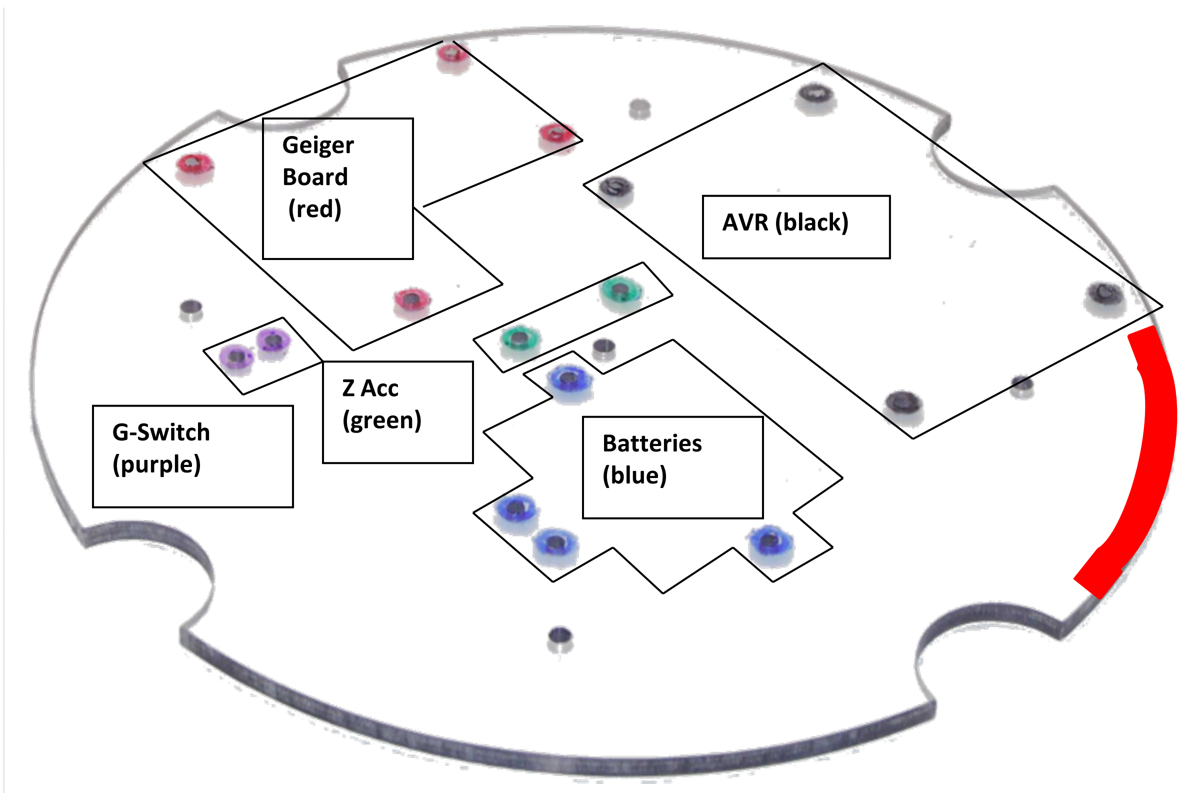
- An RG-400 (0.20 in. diam.) shielded cable will be run from the adjacent PTS-4 can into the PTS-10 can
- The cable will pass through the center of the end plates of each can and then pass to the inside wall of the PTS-10 can.





PTS-4 and PTS-10 Adjacent Can Logistics Plan

- In order to accommodate and constrain the RG-400 cable running from PTS-4 into PTS-10, the SJC mounting plate (position-4) in PTS-10 was modified by cutting a slot (2-inch long x 0.25 inch deep) in the location shown below in red:



PTS-10 Payload Canister User Guide Compliance

Type of Restriction	Restriction	Status
Mass allotment: (measured = 1.24 Lb)	<= 2.50 Lb	
Volume allotment: (calculated = 55.6 in^3)	<= 112 in^3	
Possible Restriction: The payload's center of gravity (CG):	Within 0.1 in. of payload cylindrical axis. GC of entire PTS-10 can must be determined after all four payloads and PTS-4 thru-cable are installed in can.	
No-Volt Requirement Compliance:	Yes (RBF link)	
Structure mounts:	Top and bottom bulkheads. No mounts to sides of cans.	

PTS-10 Payload Canister User Guide Compliance

The experimental equipment must fit the size and mass requirements specified for the Up Aerospace Spaceloft-XL PTS-10 payload compartment:

- Maximum inside height: 9.25 inches (1.50 inches/customer plate)

  Actual: 0.78 in.

- Maximum inside diam: 9.75 inches

  Actual: 9.53 in.

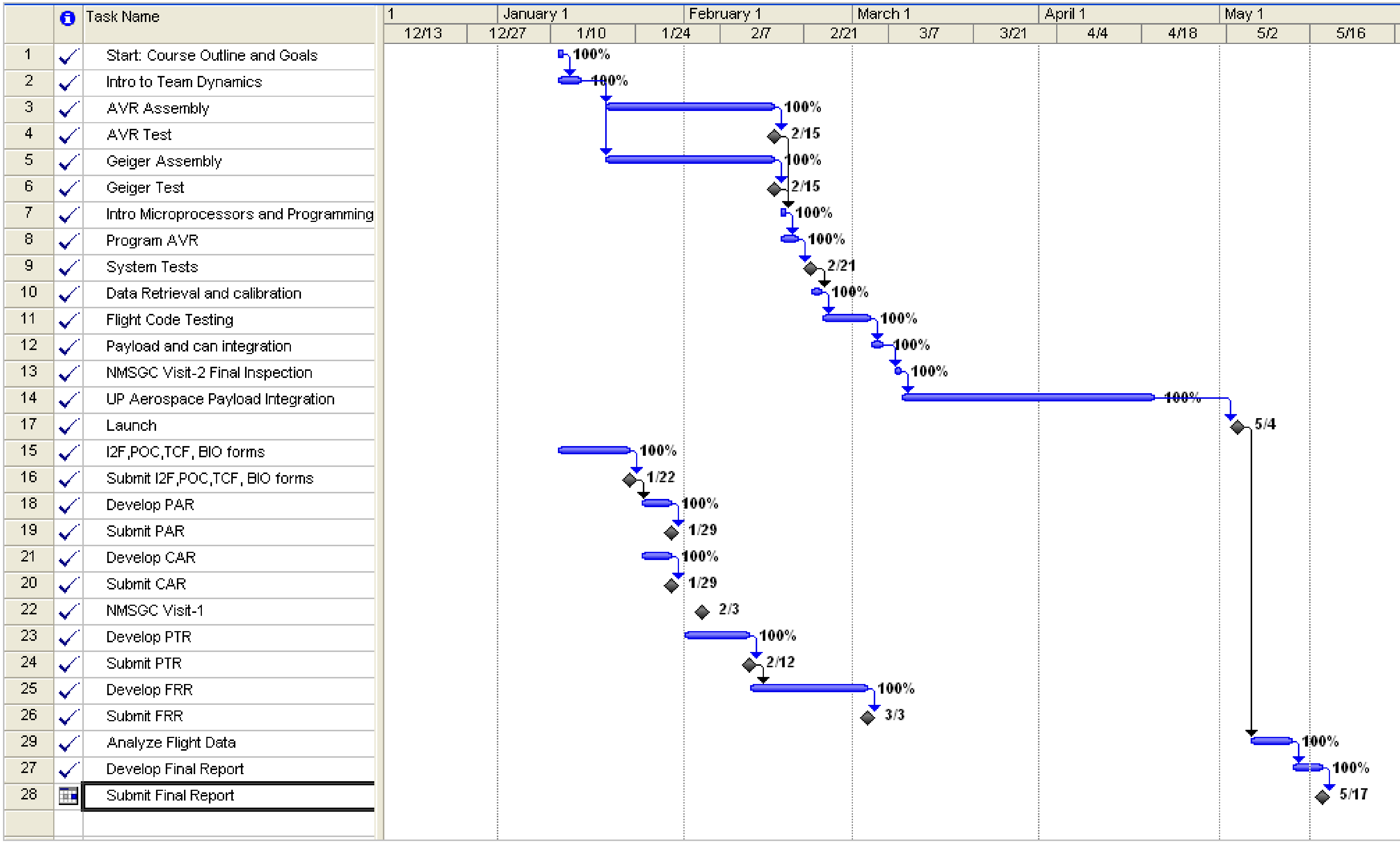
- Maximum inside volume: 691 inches^3 (112 inches^3/customer plate)

  Actual: 55.6 in^3

- Max. useable payload weight: 10.0 Lbm (2.50 Lbm/customer)

  Actual: 1.24 Lb

Schedule



Task Name
1
January 1
February 1
March 1
April 1
May 1
12/13
12/27
1/10
1/24
2/7
2/21
3/7
3/21
4/4
4/18
5/2
5/16
1 Start: Course Outline and Goals 100%
2 Intro to Team Dynamics 100%
3 AVR Assembly 100%
4 AVR Test 2/15
5 Geiger Assembly 100%
6 Geiger Test 2/15
7 Intro Microprocessors and Programming 100%
8 Program AVR 100%
9 System Tests 2/21
10 Data Retrieval and calibration 100%
11 Flight Code Testing 100%
12 Payload and can integration 100%
13 NMSGC Visit-2 Final Inspection 100%
14 UP Aerospace Payload Integration 100%
17 Launch 5/4
15 I2F,POC,TCF, BIO forms 100%
16 Submit I2F,POC,TCF, BIO forms 1/22
18 Develop PAR 100%
19 Submit PAR 1/29
21 Develop CAR 100%
20 Submit CAR 1/29
22 NMSGC Visit-1 2/3
23 Develop PTR 100%
24 Submit PTR 2/12
25 Develop FRR 100%
26 Submit FRR 3/3
29 Analyze Flight Data 100%
27 Develop Final Report 100%
28 Submit Final Report 5/17

SJC Payload Team Management

Faculty Advisor:
Dr. J. W. Wood

AVR Team Leader:
Valerie Goodtooth

- Kedrick Davis
- Michael Schmitt
- Joshua Smith
- Destiny Smouse

Geiger Team Leader:
Matthew Vigil

- Bryan Kinsel
- Jody Moore
- Rebekah Palmer
- Juan Robles
- Florence Storey

Integration Team Leader:
Robert Branam

- Jonathan Backe
- Kenneth Jung
- David Liebel
- Jonathan Tsosie

Test Plan

Pre-flight Testing

- The full functionality of the payload and data transfer capabilities were bench-tested prior to launch
- The test plan consists of multiple hardware verification milestones that occur during the construction of the equipment as well as multiple software verification milestones following construction. These are listed below:
  - Power system-1
  - Power system-2
  - Temperature sensor
  - Accelerometers
  - Power On System Test (POST)
  - LED Status light testing

Test Plan

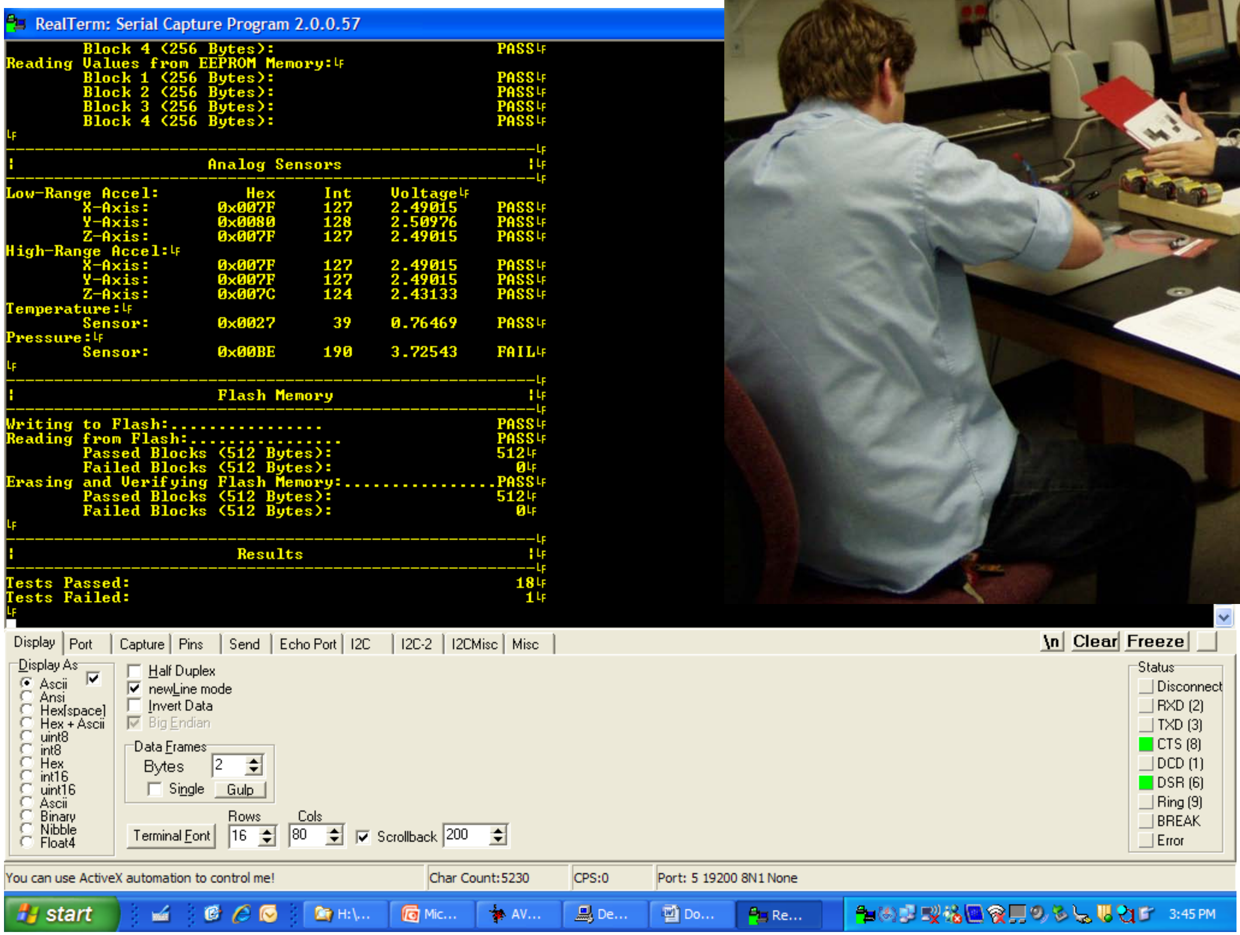
Pre-flight Testing (continued)

- Geiger counter functionality
- Final Flight Code Testing
    - Flash memory read-write functionality
    - Data retrieval
    - Raw data conversion
    - Geiger Counter data conversion
    - Temperature Sensor calibration/verification
    - Pressure Sensor calibration
    - X, Y, and Z Accelerometer high and low range calibrations

Test Plan

Pre-flight Testing Results

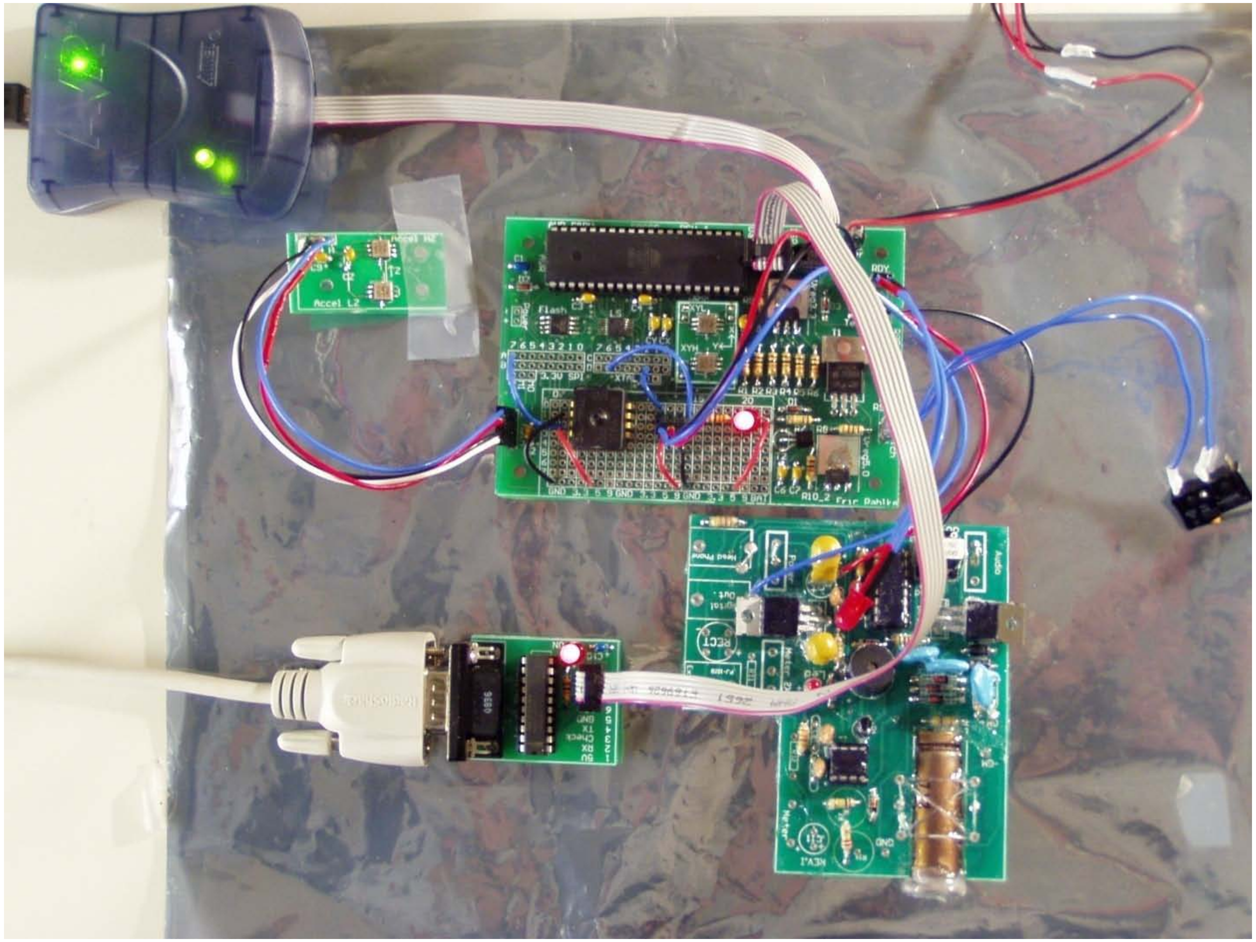
- Power On System Test



Test Plan

Pre-flight Testing Results

- Complete System undergoing Power On System Test (POST)



Test Plan

Pre-flight Testing Results

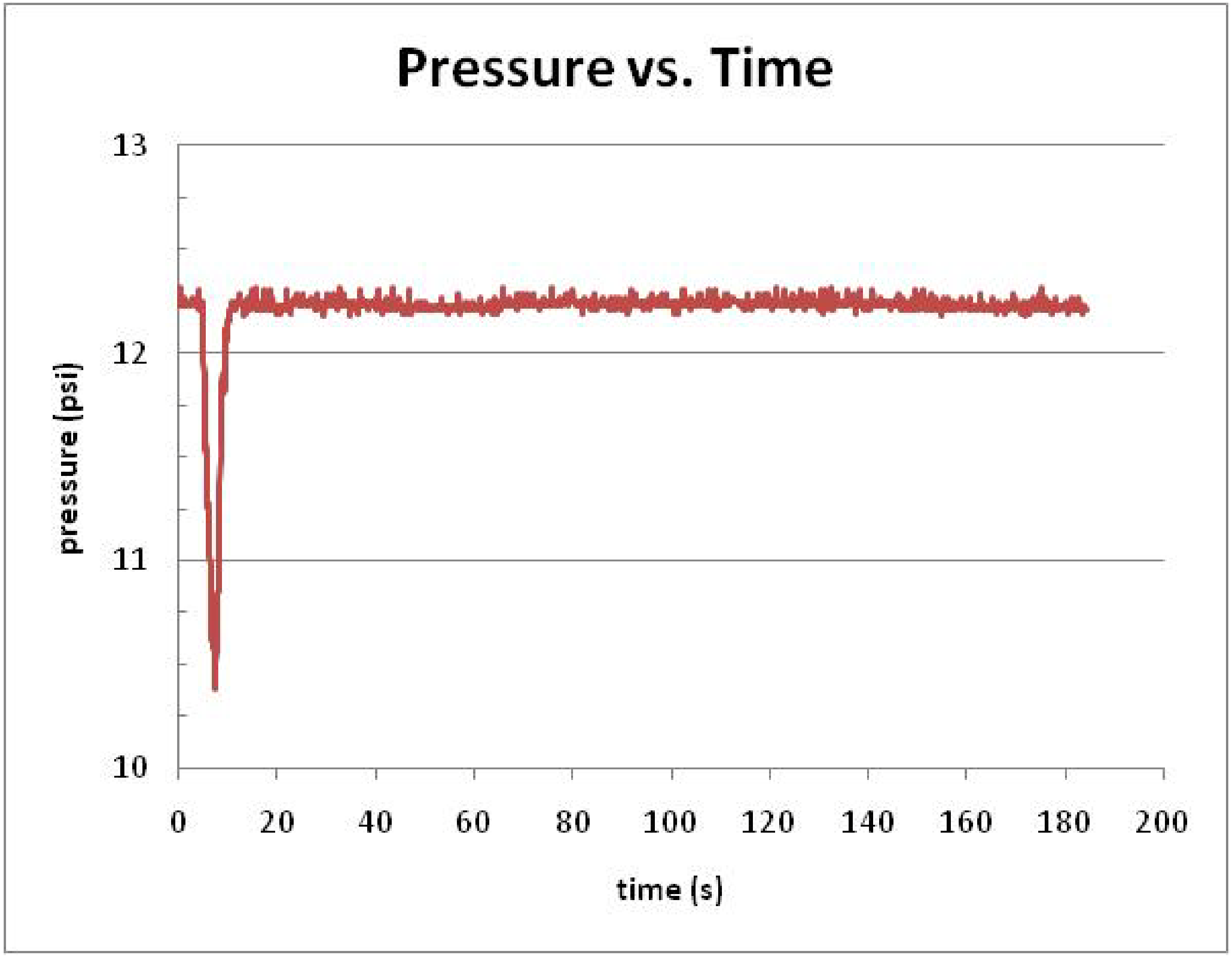
- **Power On System Test (POST)**
  - System passed all tests with the exception of the pressure sensor
  - Pressure sensor was determined to be operating correctly (after converted values matched ambient atm pressure measured with a commercial barometer).
  - The observed pressure "fail" was found to be due to an improper assignment of the full value of 255 (8-bit = 2^8) to the variable "sensor_vals[7]" in the "post.c" program. The appropriate value for this variable needs to reflect local altitude for a valid test to occur. For Farmington, NM the value is 192 for 12.2 psi.

```
-----------------------------------------------------
|                Internal EEPROM                    |
-----------------------------------------------------
Writing to EEPROM Memory:
      Block 1 (256 Bytes):                 PASS
      Block 2 (256 Bytes):                 PASS
      Block 3 (256 Bytes):                 PASS
      Block 4 (256 Bytes):                 PASS

Reading Values from EEPROM Memory:
      Block 1 (256 Bytes):                 PASS
      Block 2 (256 Bytes):                 PASS
      Block 3 (256 Bytes):                 PASS
      Block 4 (256 Bytes):                 PASS

-----------------------------------------------------
|                 Analog Sensors                    |
-----------------------------------------------------
Low-Range Accel:   Hex     Int   Voltage
      X-Axis:     0x0080   128   2.50976   PASS
      Y-Axis:     0x007F   127   2.49015   PASS
      Z-Axis:     0x007C   124   2.43133   PASS
High-Range Accel:
      X-Axis:     0x007F   127   2.49015   PASS
      Y-Axis:     0x007F   127   2.49015   PASS
      Z-Axis:     0x007C   124   2.43133   PASS
Temperature:
      Sensor:     0x0026    38   0.74508   PASS
Pressure:
      Sensor:     0x00BF   191   3.74504   FAIL

-----------------------------------------------------
|                  Flash Memory                     |
-----------------------------------------------------
Writing to Flash:................          PASS
Reading from Flash:................        PASS
      Passed Blocks (512 Bytes):           512
      Failed Blocks (512 Bytes):           0
Erasing and Verifying Flash Memory:.....   PASS
      Passed Blocks (512 Bytes):           512
      Failed Blocks (512 Bytes):           0

-----------------------------------------------------
|                    Results                        |
-----------------------------------------------------
Tests Passed:                              18
Tests Failed:                               1
```

Test Plan

Pre-flight Testing Results

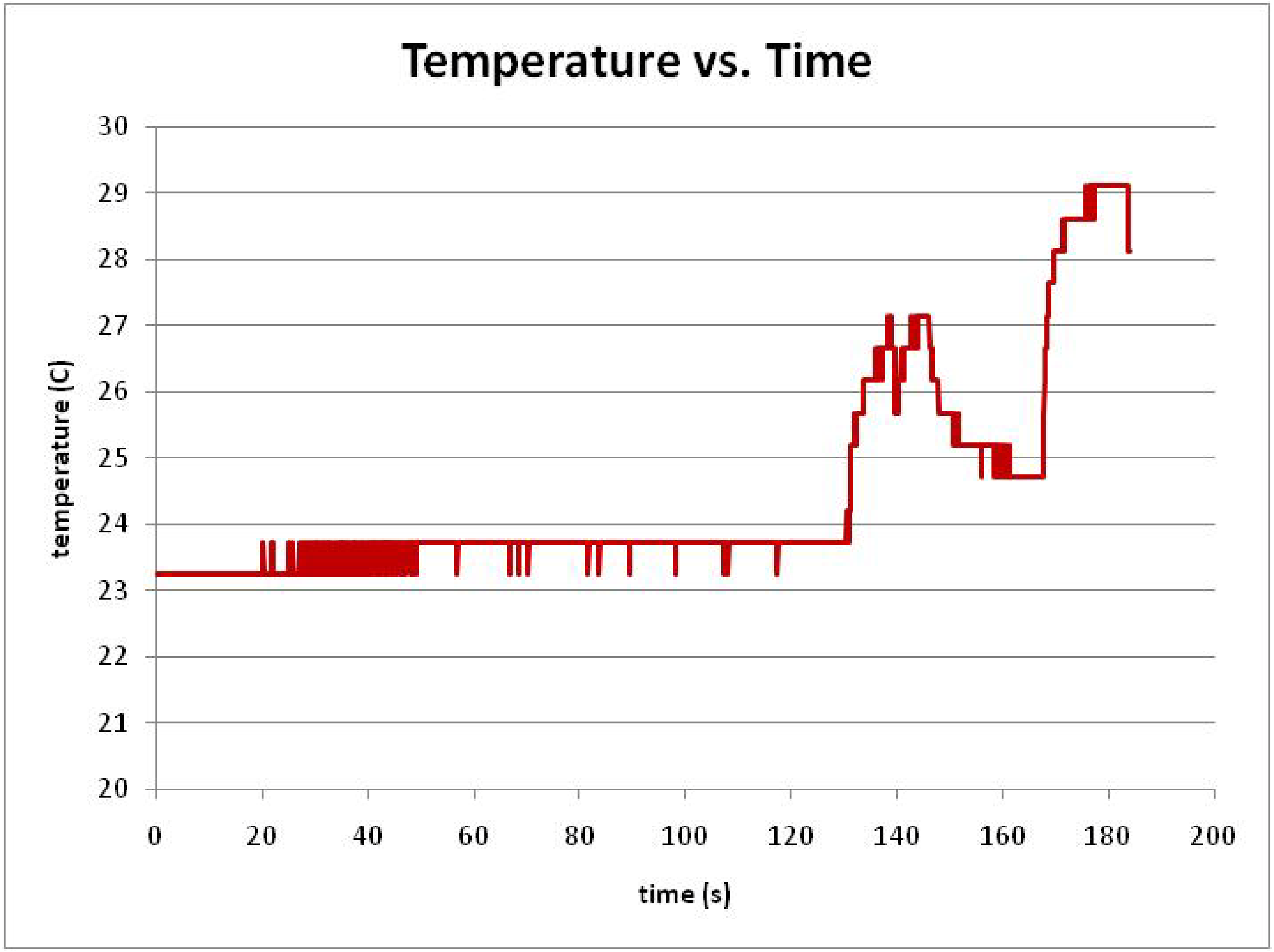
- Pressure Sensor function tested with partial-vacuum at 5 s



Test Plan

Pre-flight Testing Results

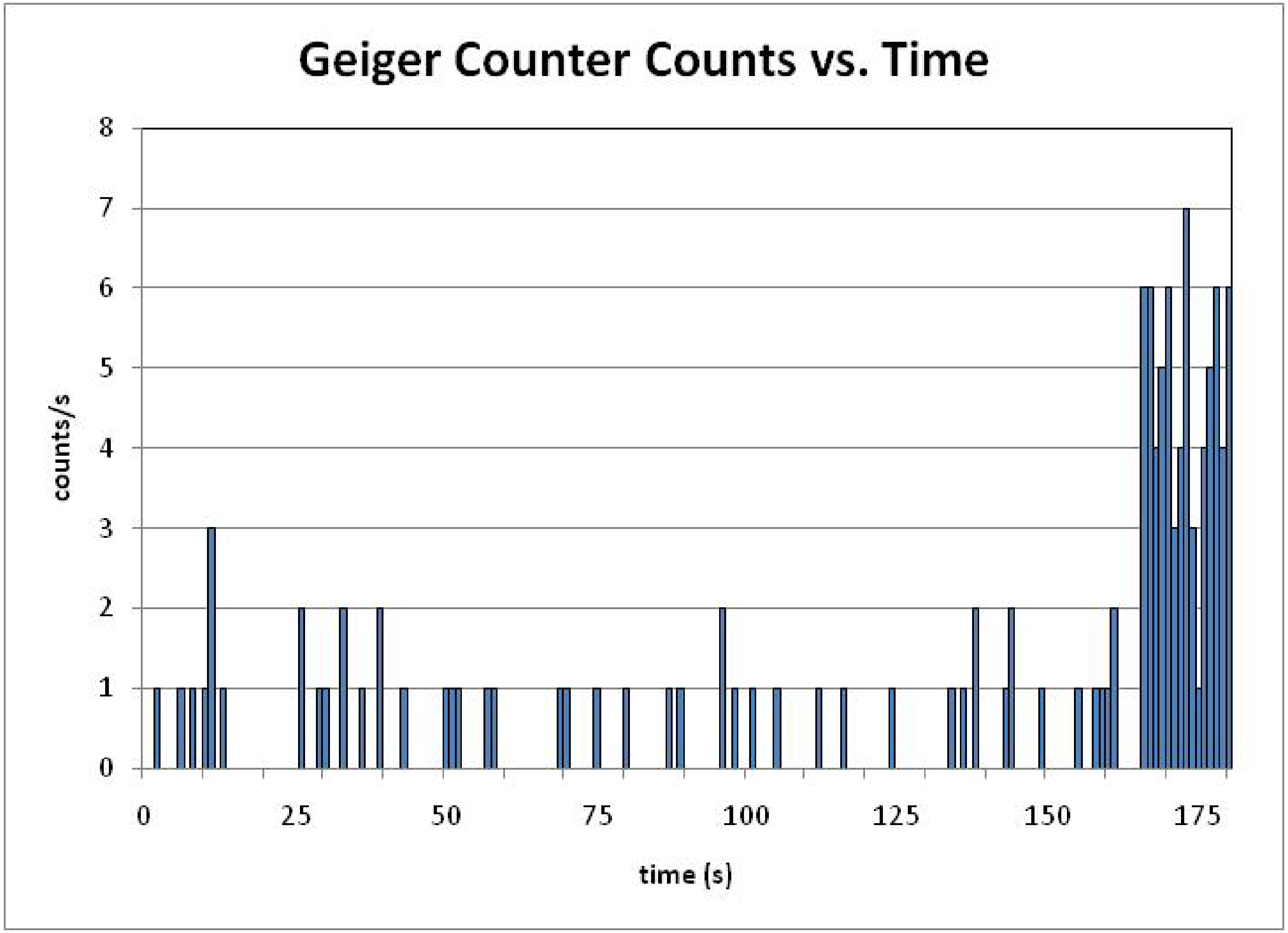
- Temperature Sensor function tested with finger contact at 128 and 164 s



Test Plan

Pre-flight Testing Results

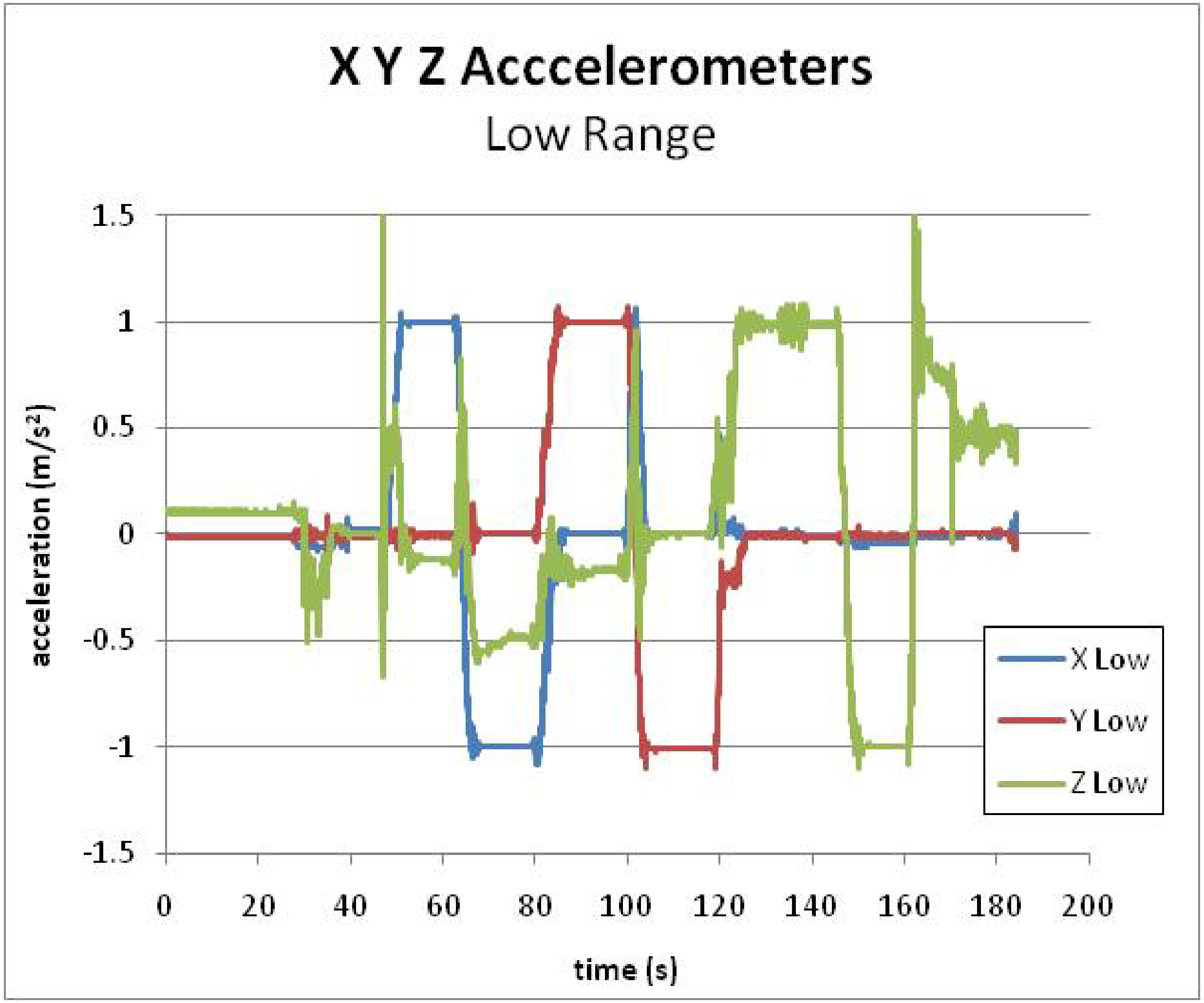
- Geiger counter function tested with Am-241 gamma source at 165 s



Test Plan

Pre-flight Testing Results

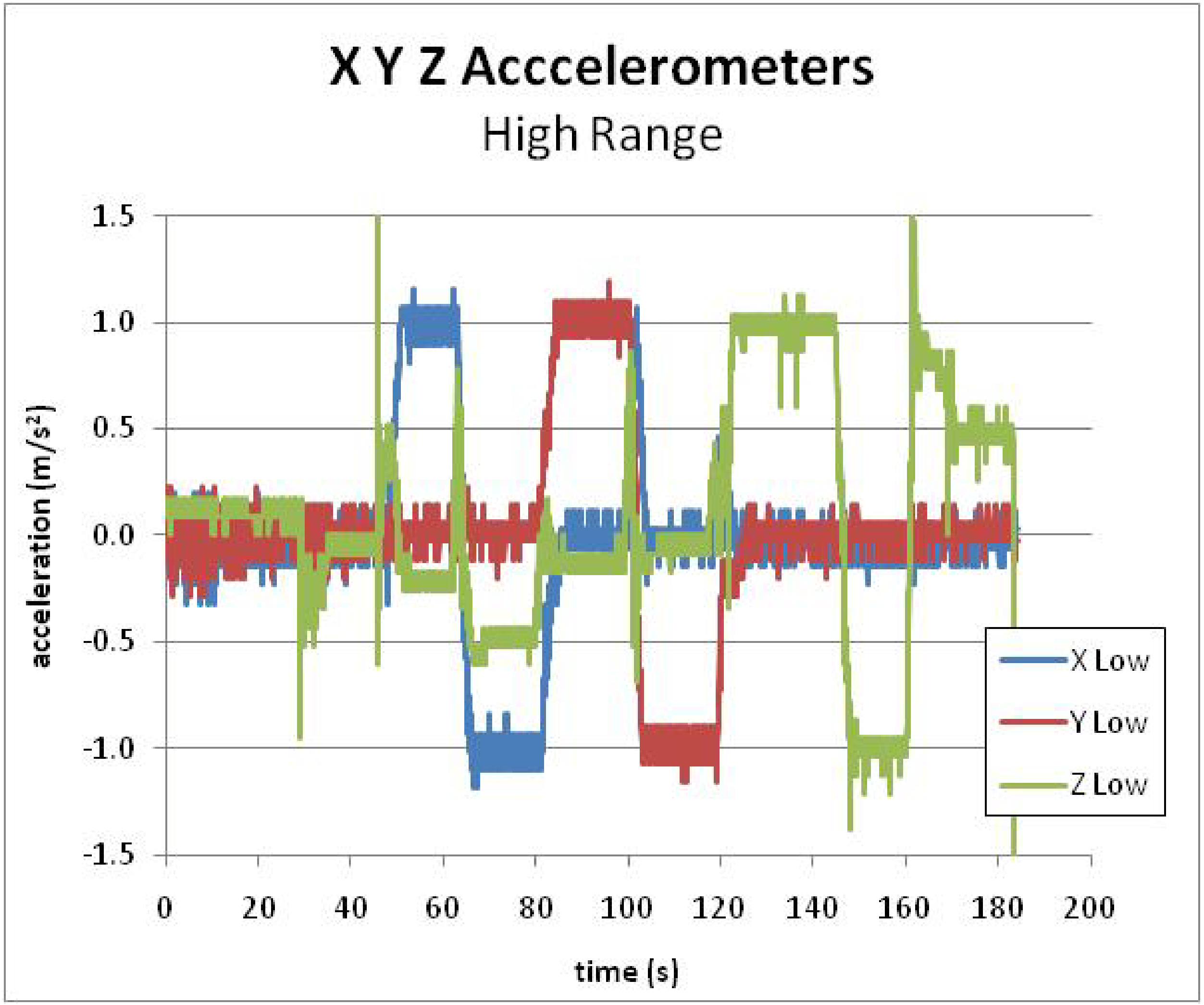
- X, Y, and Z Accelerometer low range calibrations for -1, 0, +1 g



Test Plan

Pre-flight Testing Results

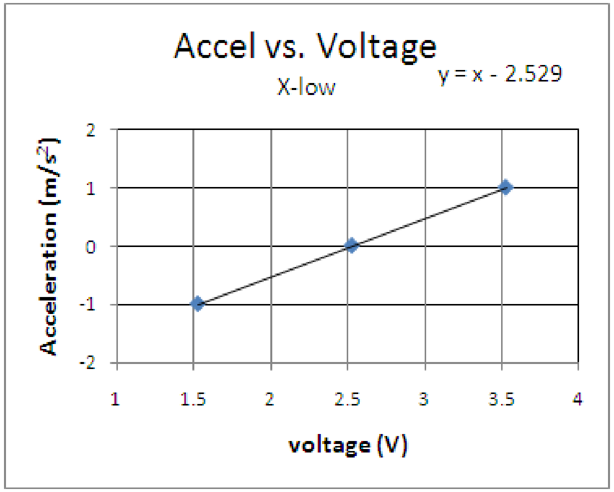
- X, Y, and Z Accelerometer high range calibrations for -1, 0, +1 g

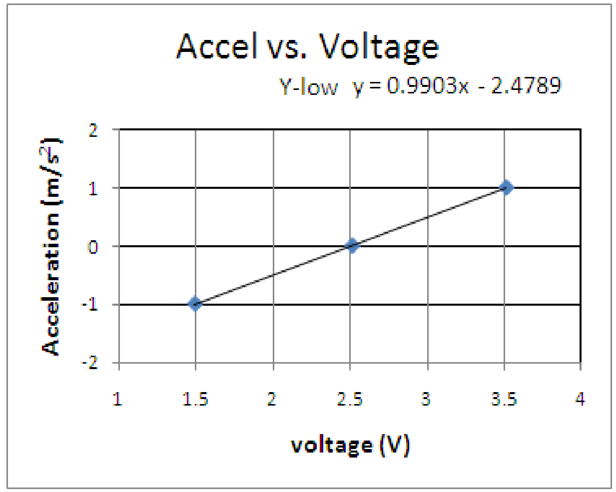


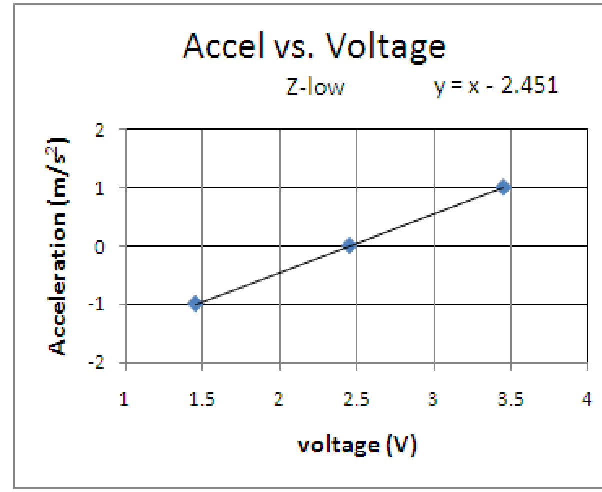
Test Plan

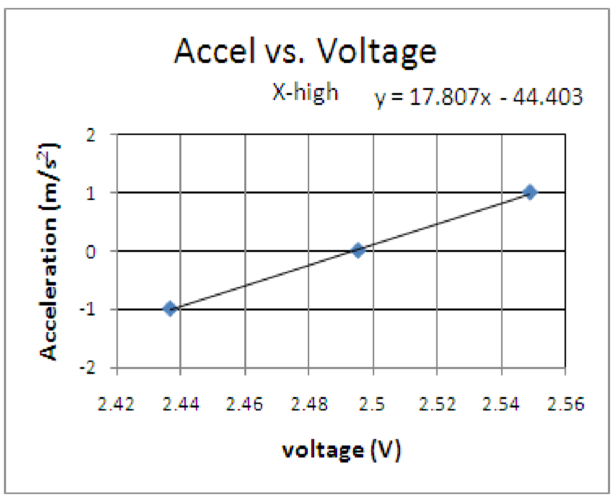
Pre-flight Testing Results

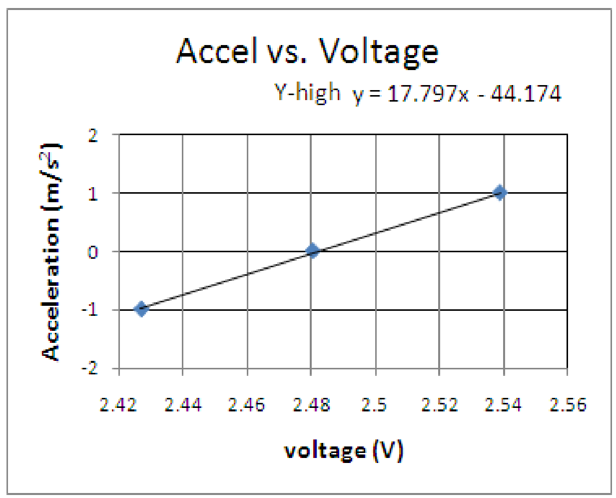
- X, Y, and Z Accelerometer calibration equations for -1, 0, +1 g

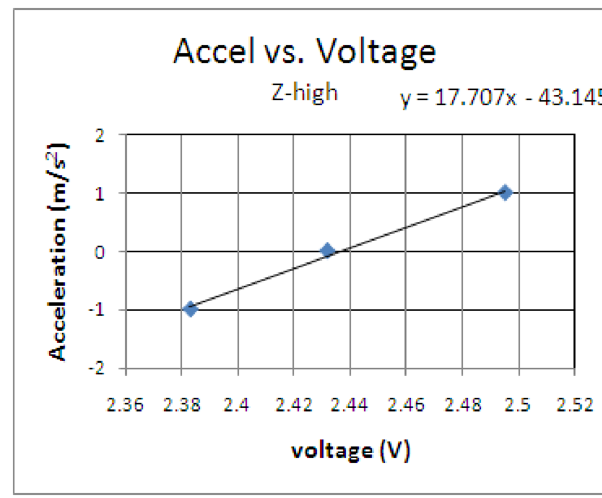






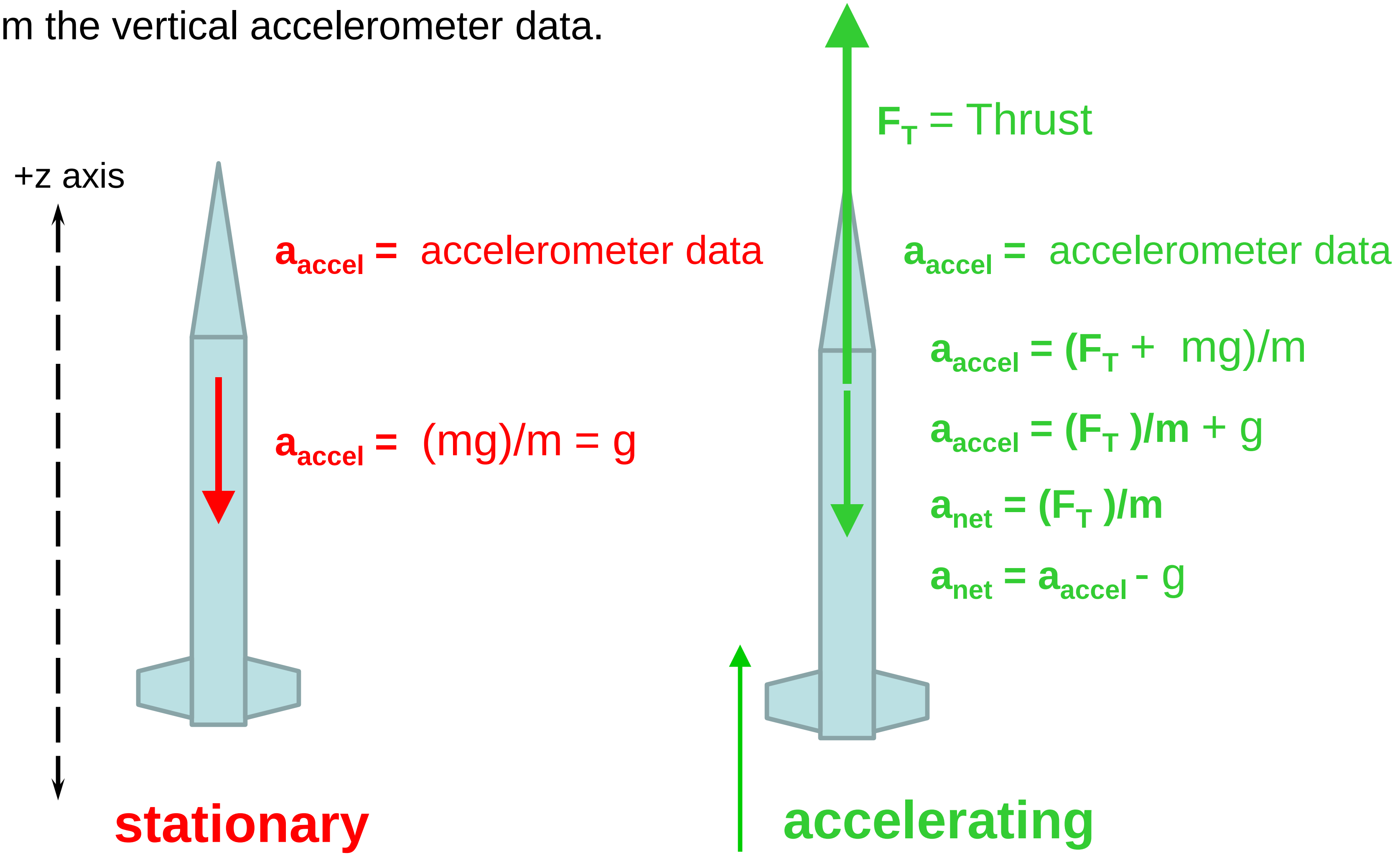






Accelerometer Physics Analysis

Diagram showing accelerometer measurements for a **stationary** or **accelerating** object. Net acceleration calculations for the rocket require the subtraction of 1.00 g from the vertical accelerometer data.



Typical Mission Sequence of Events

(SpaceLoft® XL Vehicle data from UP Aerospace, Inc.)

Event	Time (s)	Alt (m)	Relative Velocity (m/s)	Range (mi)
Booster Ignition	0	1404	0	0
Launch Rail Clear	0.6	1417	61.8	0
Booster Burnout	12.1	11093	1553	0.9
Apogee	158	112654	190	18.3
Payload Separation	240	80874	800	27.8
Recovery Deploy	402.6	6096	78.2	35.2
Touchdown	906.9	1220	7.69	35.2

Event	Axial Load, (g's)	Radial Load (g's)
Launch	15	0
Ascent Maximum Acceleration	16	18.5
Atm Re-entry Decel.	5.0 – 7.0	5.0 – 7.0
Vehicle Touchdown	60	0

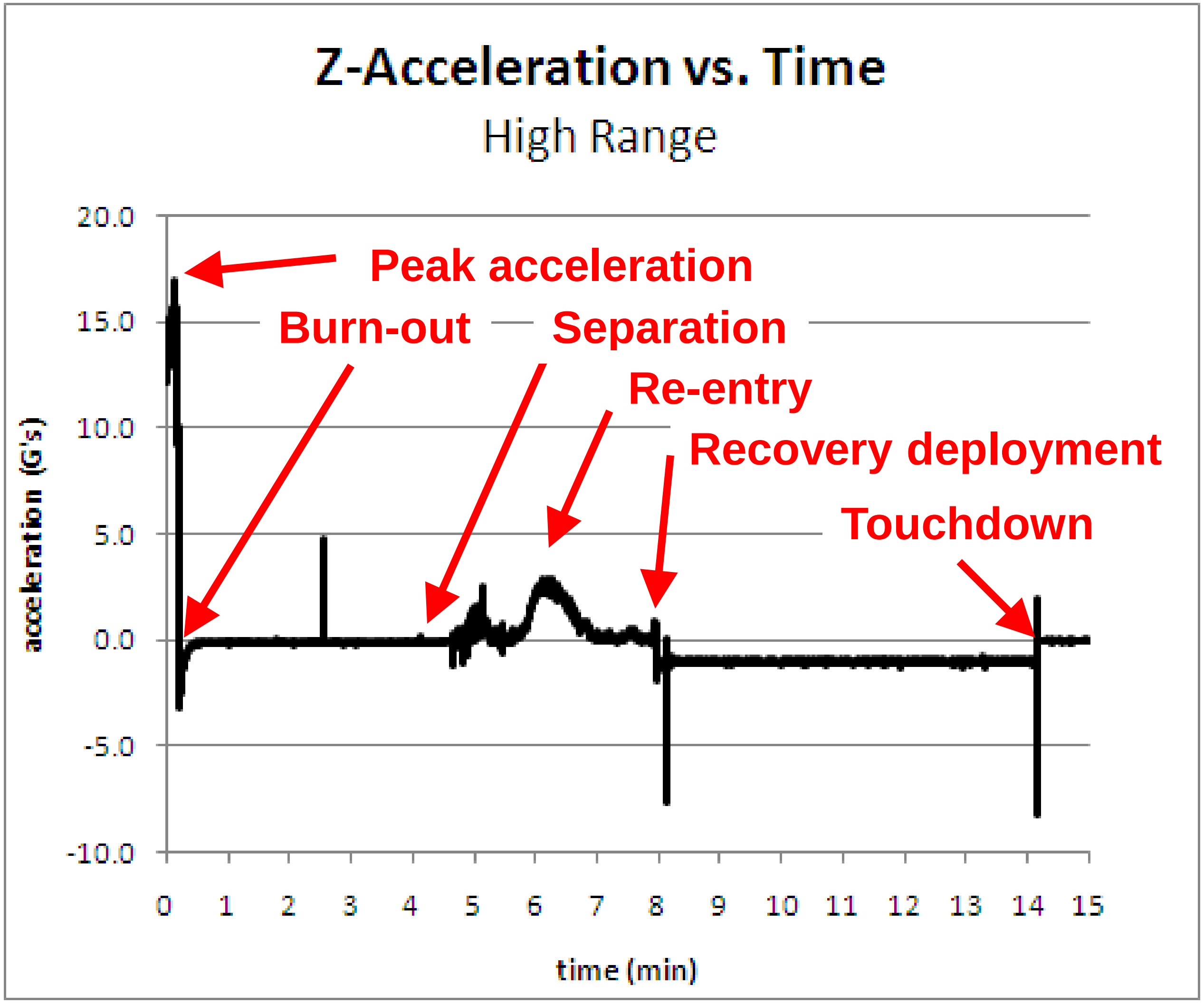
Flight Data

- Mission Sequence of Events
- Vertical Acceleration
- Velocity and Altitude
- Atmospheric Pressure
- Temperature
- X-Acceleration
- Y-Acceleration
- Radiation
- Re-entry
- Recovery Deployment
- Touchdown

Flight Data

Mission Sequence of Events

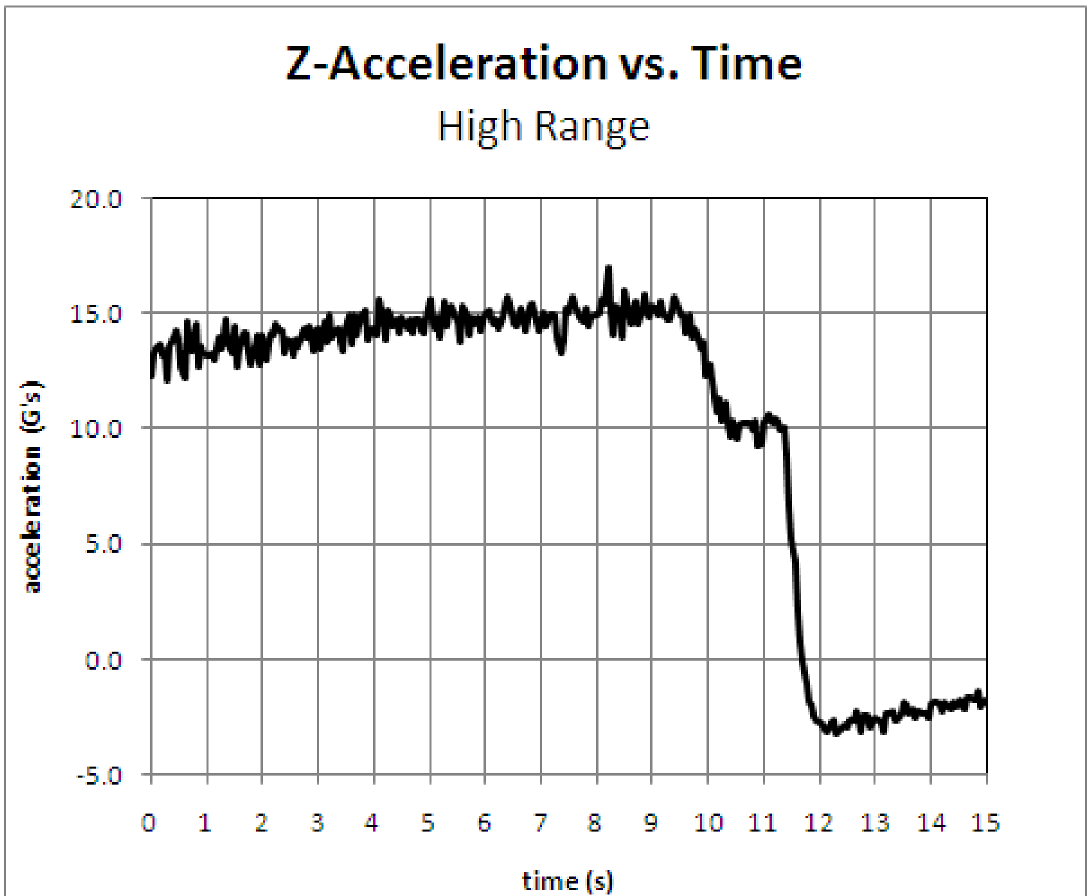
- Flight events can be readily identified from the Z-Accelerometer data.



Flight Data

Vertical Acceleration (Z-axis)

- The earliest stages of acceleration data were not captured due to the use of g-switching activation. It is estimated that the first 0.1 s of is missing.
- Acceleration achieved an average maximum value around 15 g's.
- The burnout process began around 9.5 seconds and ended near 12 seconds.



Flight Data

Velocity and Altitude calculated from Z-Accelerometer Data

- Vertical acceleration data may be used with Newton's laws to estimate altitude.
- To simplify calculations, it was assumed that the flight was purely vertical (z-axis) with no x or y components of translational acceleration. The equations used for velocity and altitude are below where each time interval has a length Δt that is equal to the sample period:

$$V_{n+1} = V_n + a_n \Delta t$$

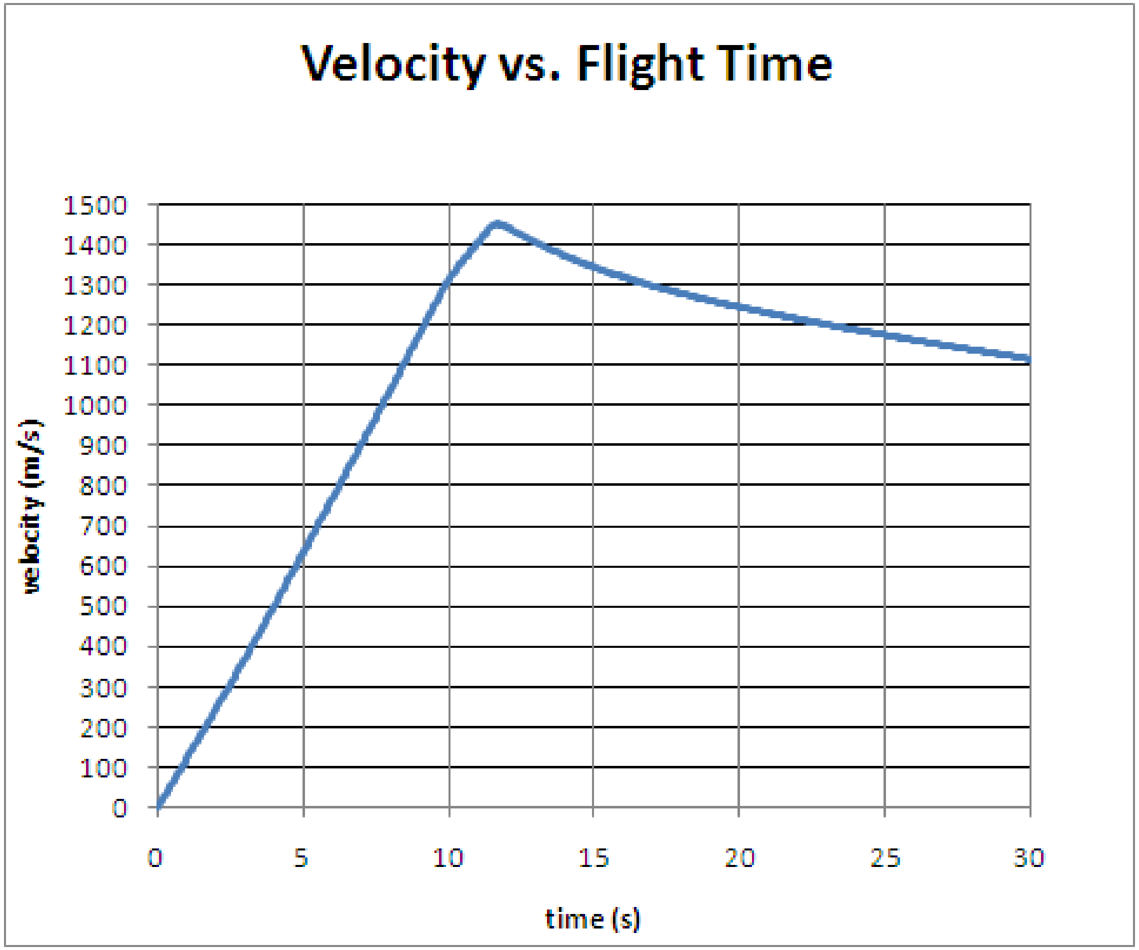
$$Z_{n+1} = Z_n + V_n t + \frac{1}{2} a_n \Delta t^2$$

- The z-acceleration data cannot be readily used following apogee because the vehicle (payload) orientation is not known (vehicle may be tumbling without sufficient atmosphere to provide aerodynamic stabilization).

Flight Data

Velocity

- Velocity calculated from acceleration data can be seen to reach its maximum value near burnout as expected. Its maximum value is 1450 m/s.
- Aerodynamic drag and gravity are seen to decrease velocity after burnout.



Altitude from Pressure Data

It is also possible to estimate altitude by using atmospheric pressure data which decreases exponentially with altitude (for 0-85 km) approximately as:

$$P = P_0 \cdot exp\left(\frac{-g \cdot M \cdot (h - h_0)}{R \cdot T_0}\right)$$

Where:

P_0 = base pressure (Pa)

$g = 9.80665\ m/s^2$

M = molar mass of air (0.0289644 kg/mol)

h = altitude above sea level (m)

h_0 = base altitude (1404 m at Spaceport America)

R = gas constant [8.314472 J/(K·mol)]

T_0 = base temperature (K)

- The pressure sensor used (ASDX015) is based upon piezoelectric technology which does not have the sensitivity to measure pressures below about 10 mbar (equivalent to 35 km altitude).

Altitude from Pressure Data

- **The sensor voltage output equation can be solved for pressure in terms of voltage.**

  Pressure (mbar)= (258.4 mbar/V) * V_{OUT} - 128.9 mbar

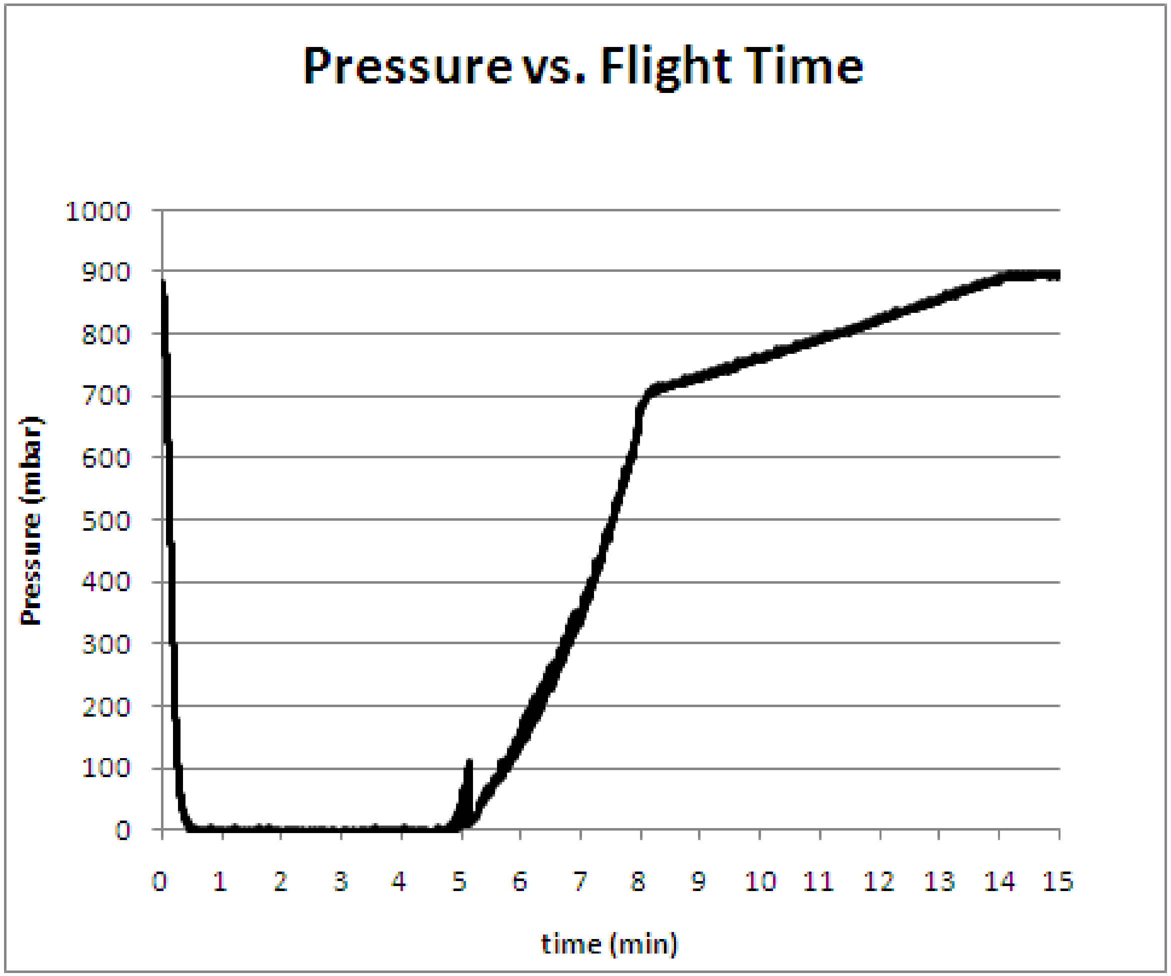
- **The pressure equation can then be solved for altitude in terms of pressure (mbar).**

  Altitude (km) = -8.1*[Ln(Pressure/1013)]

Altitude from Pressure Data

Measurement Limitations of pressure sensor

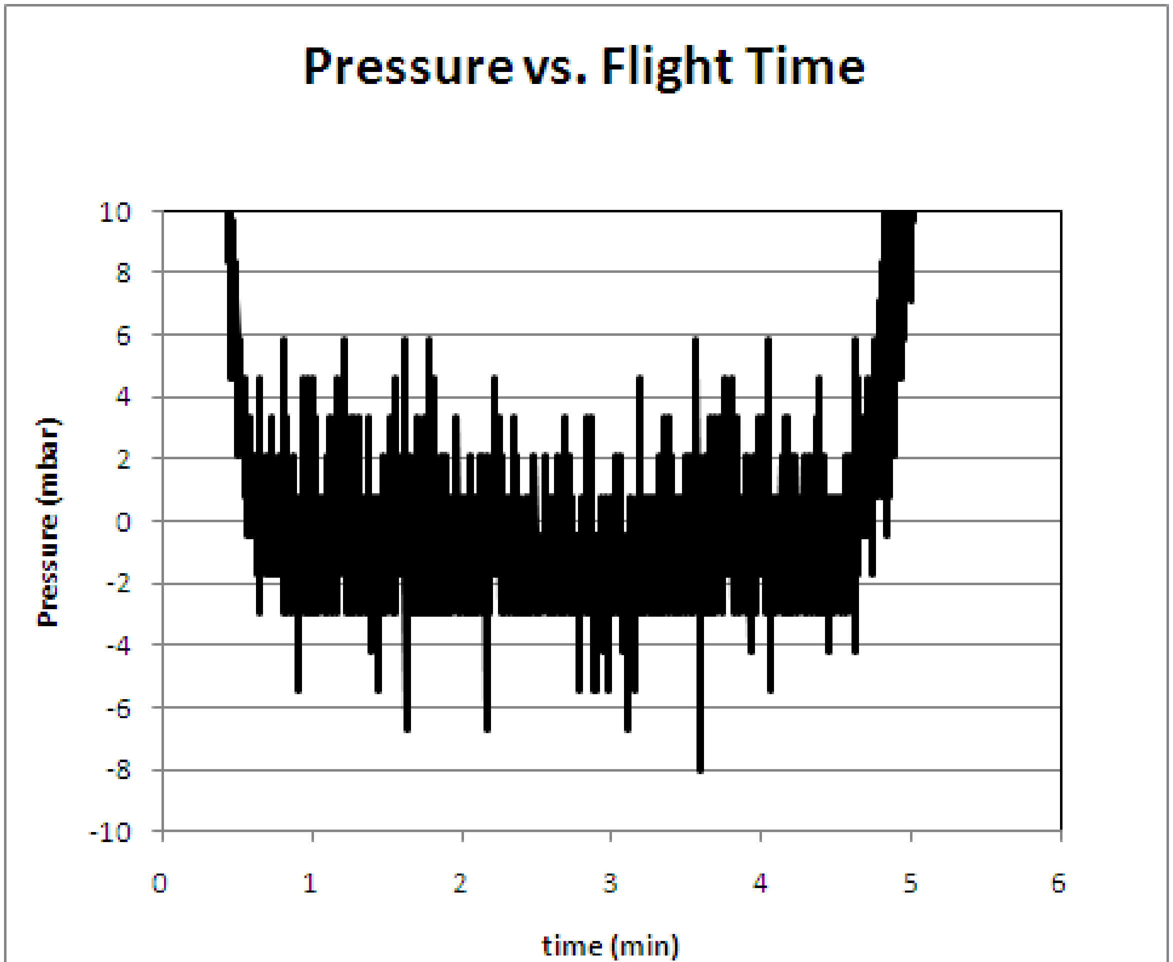
- The graph below shows pressure sensor data as a function of time. It is important to note how pressure appears to zero out around 0.5 second.



Altitude from Pressure Data

Measurement Limitations of pressure sensor

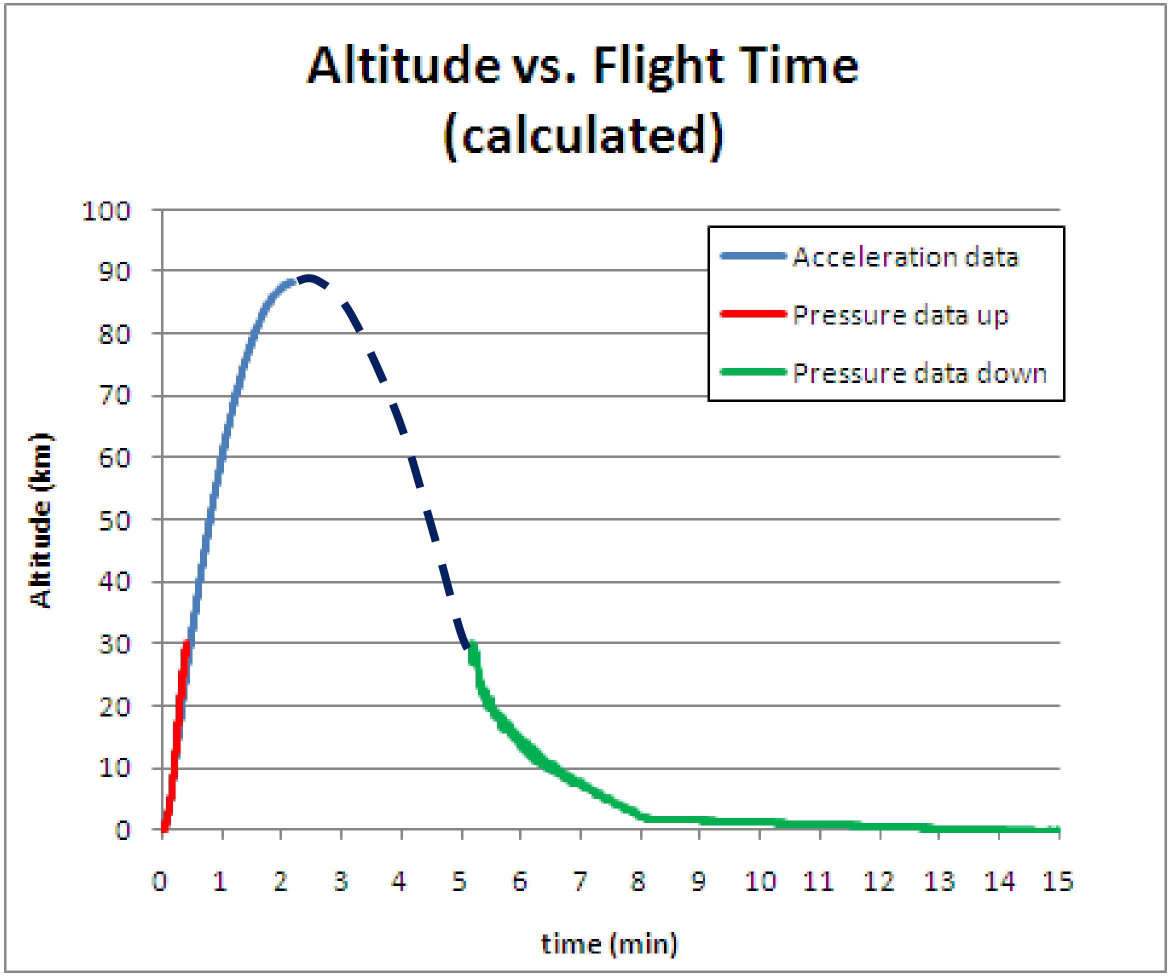
- The graph below shows the fluctuations in calculated pressure inherent in the sensor data values. These fluctuations limit minimum pressure sensitivity, and thus maximum altitude calculations to about 35 km.



Flight Data

Altitude and Velocity from Z-Accelerometer Data

The graph below displays combined altitude calculations from both acceleration and pressure data. The dashed line is an interpolation between the two.



Flight Data

Temperature Data

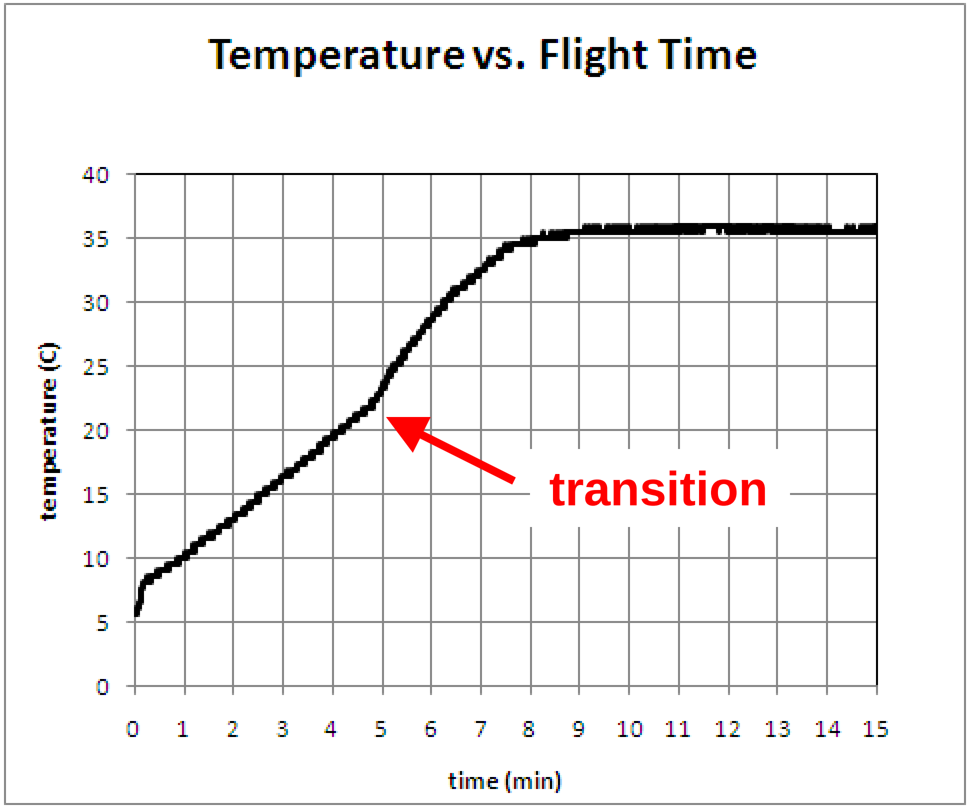
- **The sensor voltage output equation can be solved for temperature in terms of voltage.**

$$\text{Temp } (°C) = (100°C/V) * V_{OUT} - 50\ °C$$

Flight Data

Temperature Data

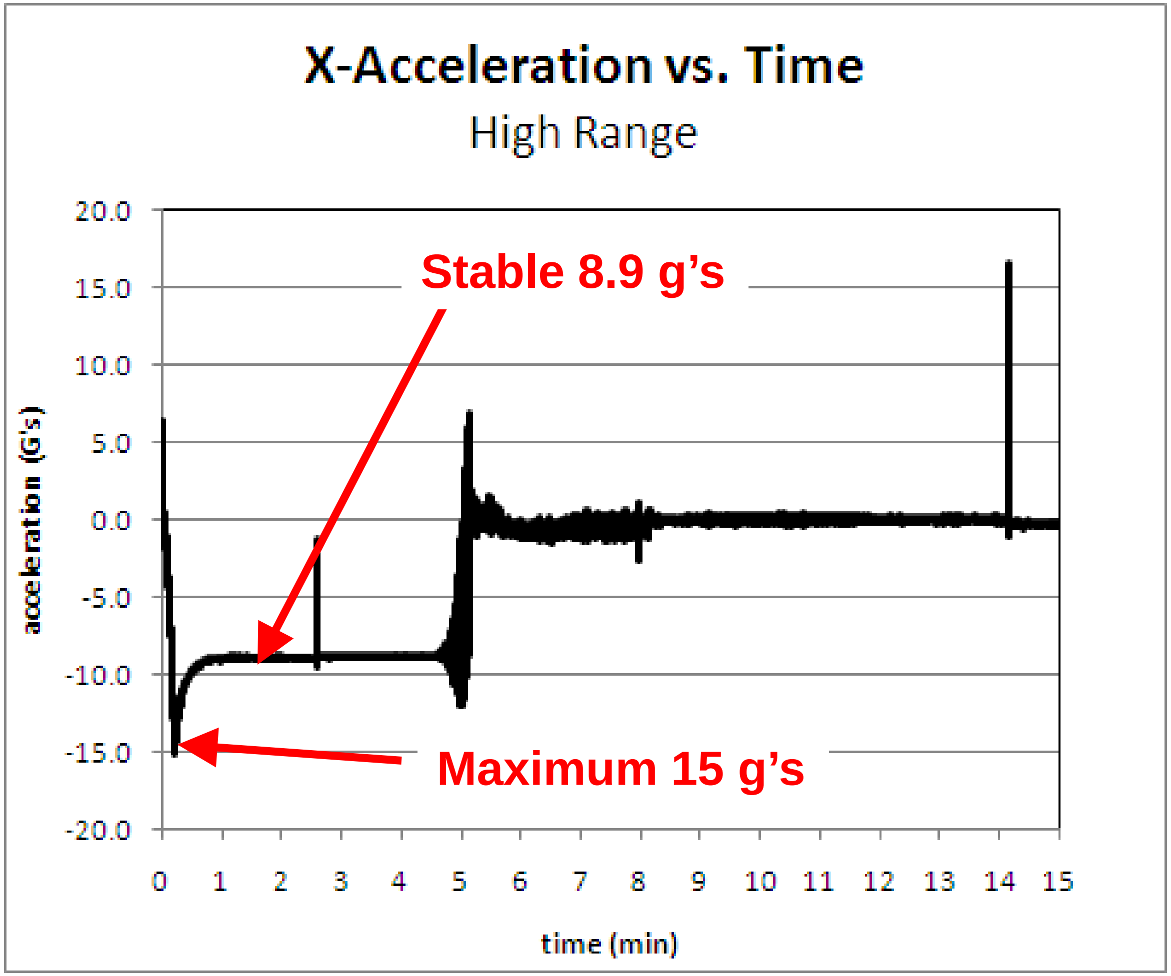
- Temperature increases with time as expected most likely due to aerodynamic heating of the airframe.
- There is an interesting transition from linear to non-linear heating that appears to occur around 5 minutes.



Flight Data

X-Accelerometer Data

- Acceleration achieves an average maximum value of around 15 g's and then stabilizes to 8.9 g's prior to separation at 4.15 minutes.



Flight Data

X-Accelerometer Data

- The stable x-acceleration of 8.9 g's is a result of rotation of the vehicle about its cylindrical axis (of symmetry).
- This is a centripetal acceleration which may be used to calculate the rate of rotation, or angular speed ω.

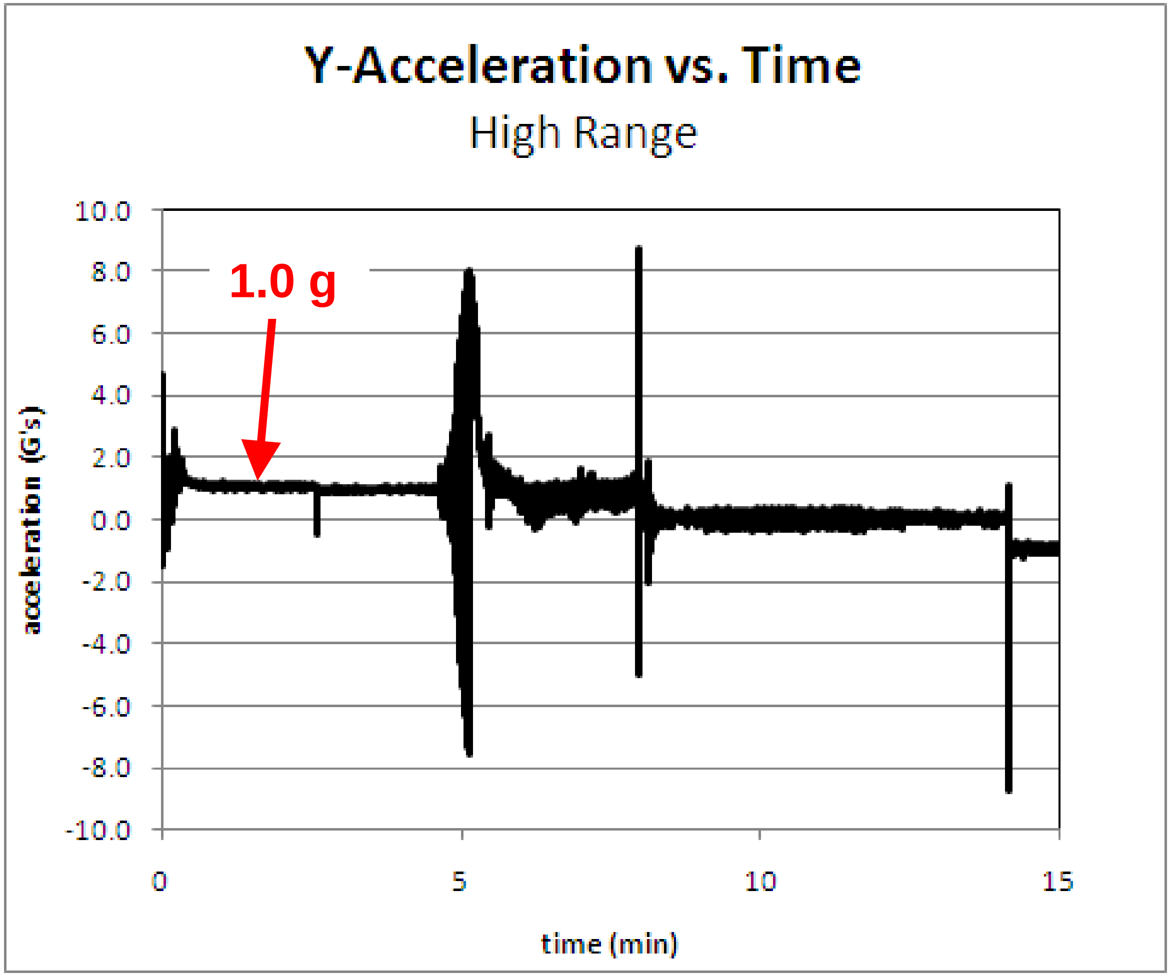
$$a = r \cdot \omega^2 \text{ so that } \omega = \sqrt{a/r}$$

- r = 7.0 cm to the center of the X-High Accelerometer.
- Rate of rotation is calculated to be 35 radians/sec or 5.6 rev/s.

Flight Data

Y-Accelerometer Data

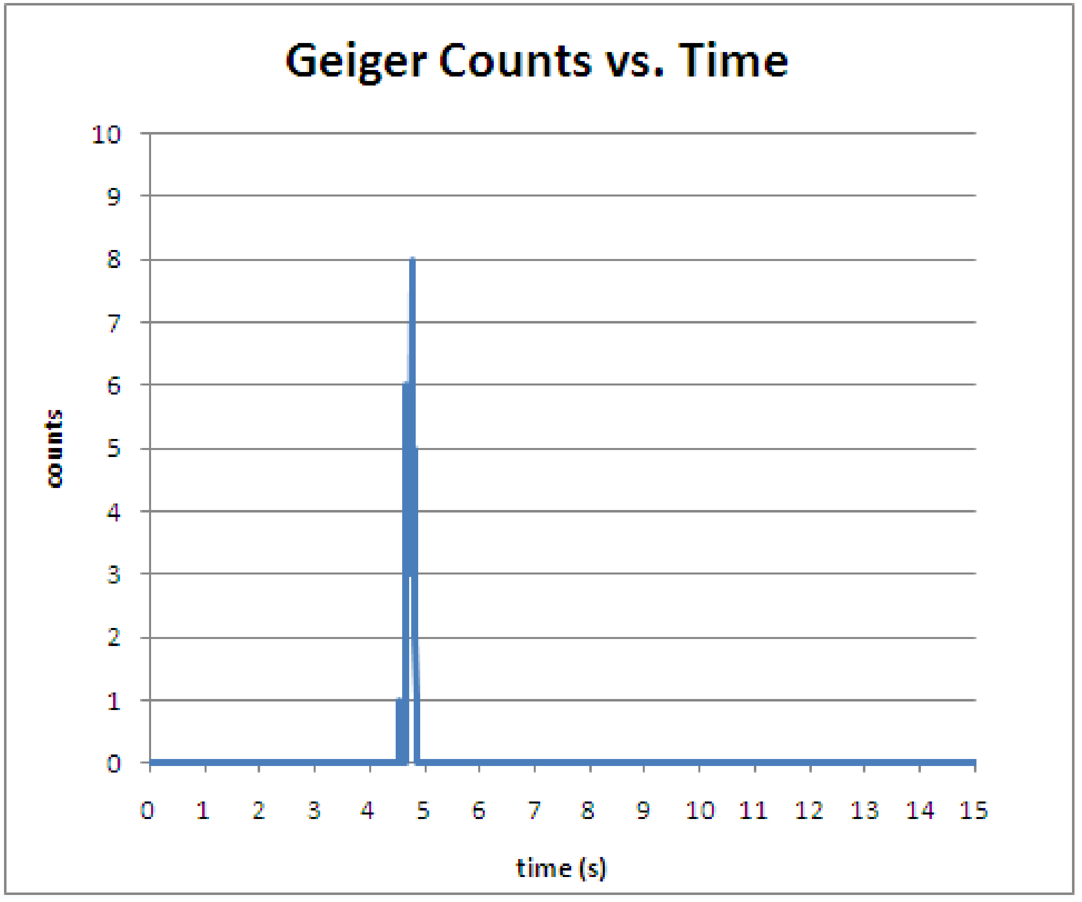
- The stable y-acceleration of 1.0 g is a result of rotation of the vehicle about its cylindrical axis.



Flight Data

Radiation Data

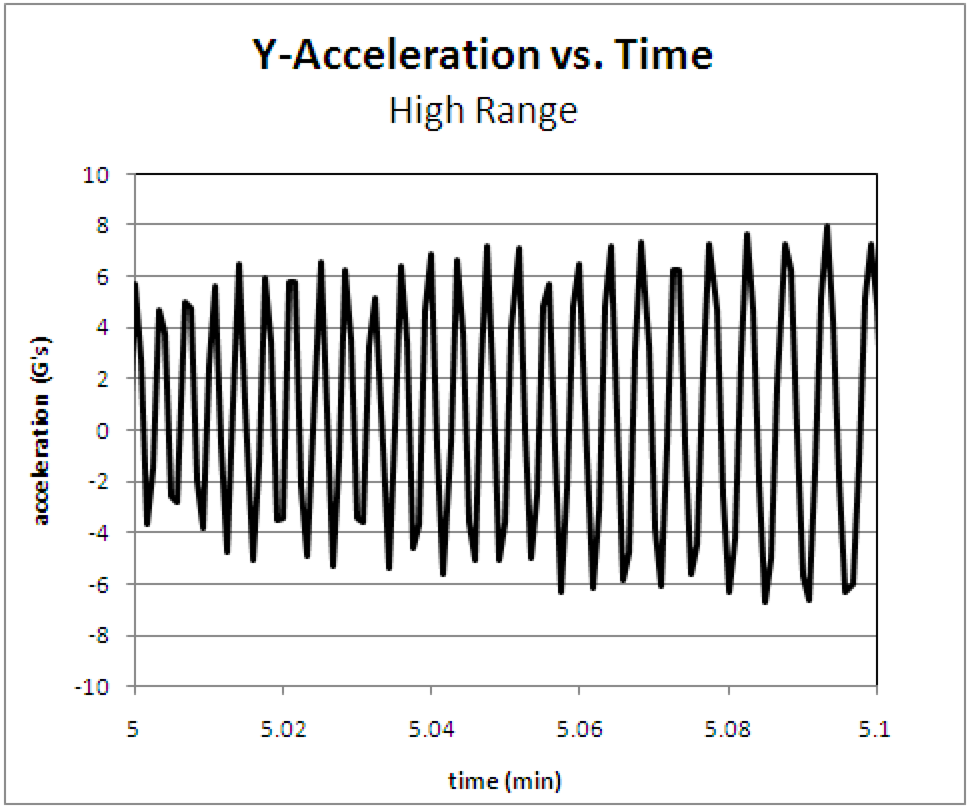
- Geiger data did not behave as expected with a continuous increase in counts with increasing altitude. There only appeared to be a short burst of radiation around the time of separation.



Flight Data

Re-entry Data

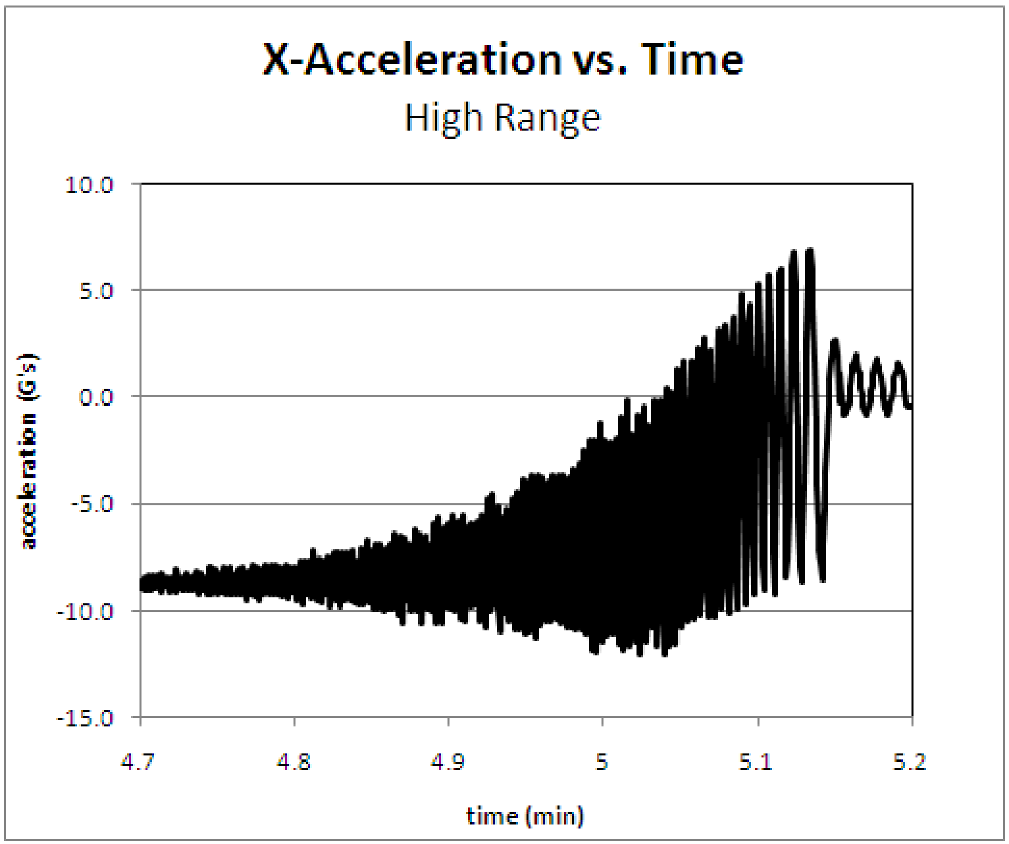
- It is assumed that the large oscillating values of acceleration observed in the Y-accelerometer data is due to re-entry induced spinning of the free payload (post separation).
- The graph below shows Y-axis oscillations (240 Hz) shortly after separation leading up to maximum re-entry acceleration values (~8 g's).



Flight Data

General Acceleration Data

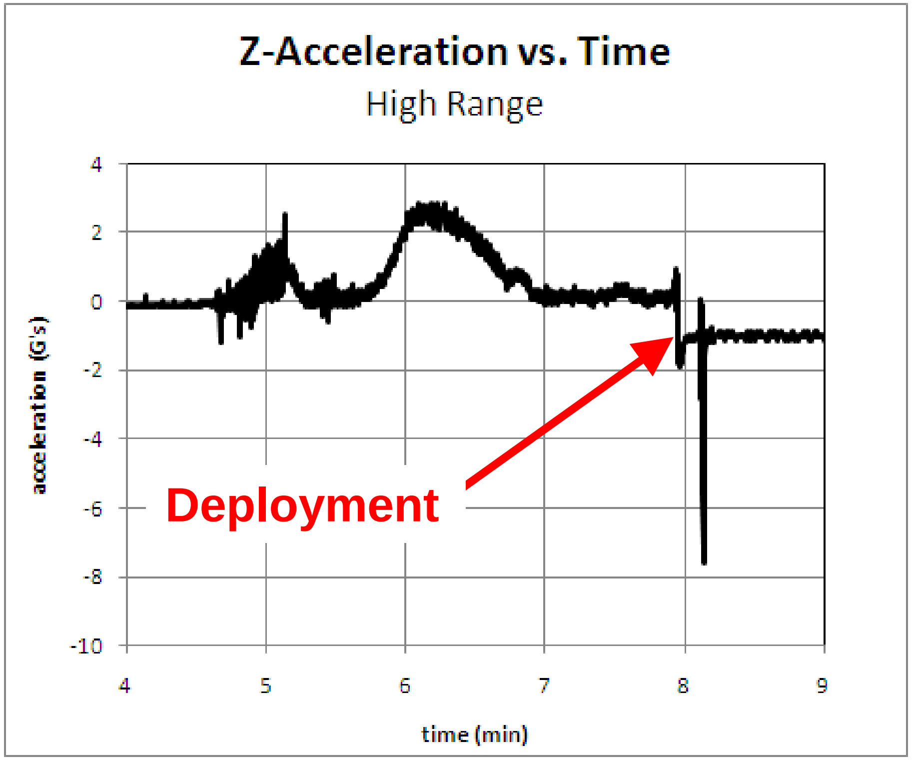
- Assorted oscillatory behavior may be seen at various points in the flight after separation, in all three accelerometer axes. This indicates multi-axis rotational dynamics of varying amplitude and complexity.
- The graph below shows X-axis oscillations of increasing amplitude shortly after payload separation.



Flight Data

Recovery Deployment

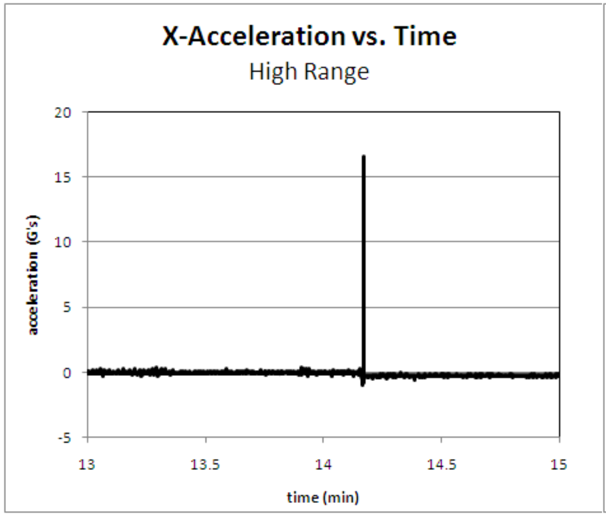
- The drogue chute can be seen to deploy around 7.9 min resulting in a brief acceleration of about 2 g's on the Z-axis.
- The main parachute deployment resulted in a maximum acceleration of around 7.6 g's on the Z-axis.
- The -1.0 g acceleration indicates an inverted orientation of the payload.

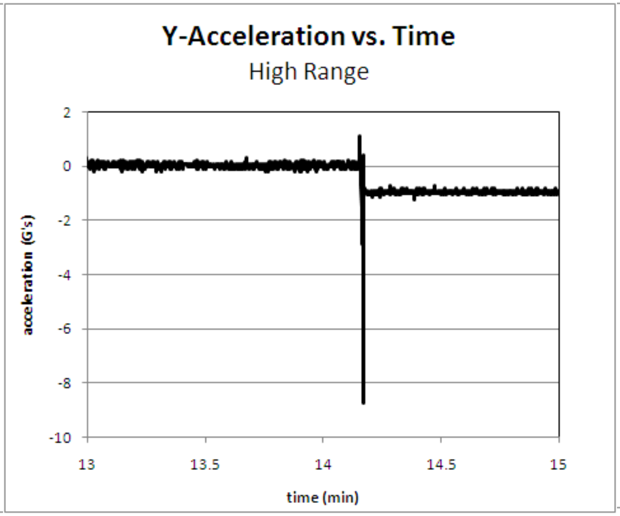


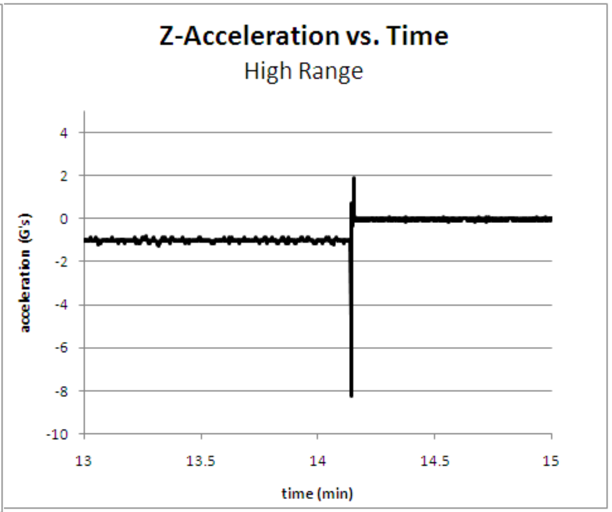
Flight Data

Touchdown

- Touchdown resulted in a maximum acceleration of around 16.5 g's on the x-axis, and 8 – 9 g's on the other axes.
- Based upon resting accelerometer data, the payload then rested on its side with the Geiger counter board rotated toward the top of the can, away from the ground.







Hypothesis-1

- Rocket performance data were expected to be similar to flight conditions specified by UP Aerospace for the SpaceLoft-XL vehicle.
- The sequence of most mission events could be identified from the Z-Accelerometer data and corroborated the expected UP Aerospace schedule and values within 25% difference in most cases.

Event	Expected Time (s)	Measured Time (s)	Expected Altitude (m)	Calculated Altitude (m)
Launch Rail Clear	0.6	0.5	14	14
Booster Burnout	12.1	11.65	11093	9226
Apogee	158	132.1	112654	88287
Payload Separation	240	249	80880	N/A
Recovery Deploy	402.6	460	6096	3826
Touchdown	906.9	848.5	-184	-138

Hypothesis-1 (continued)

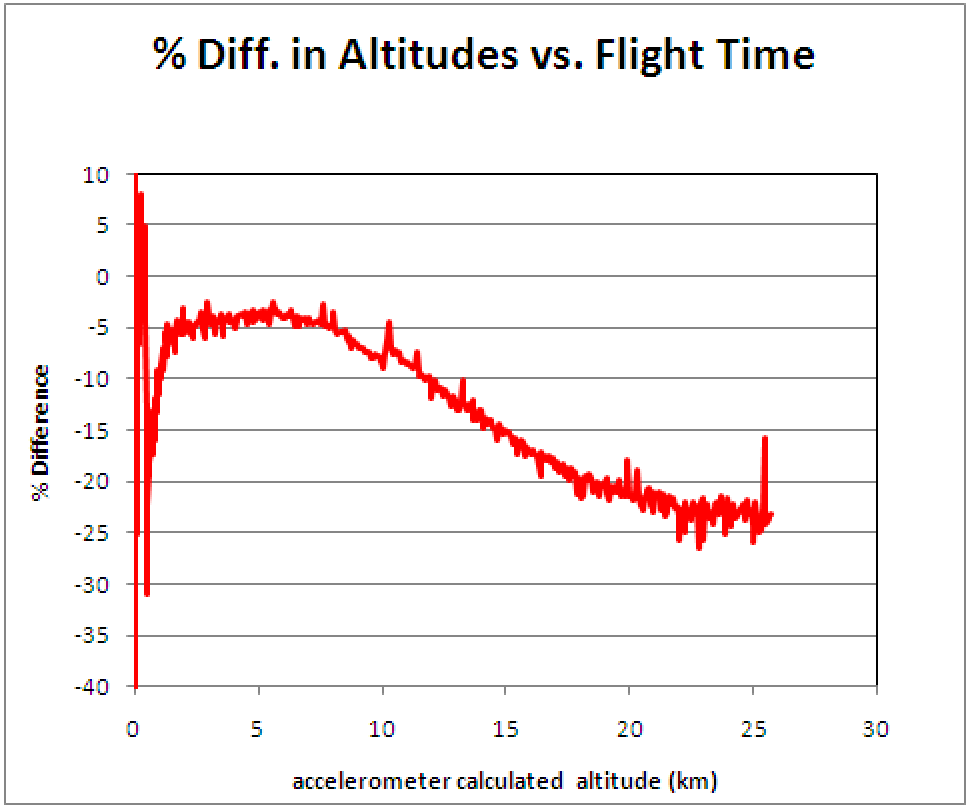
- The measured accelerations and rate of rotation about the vehicle axis corroborated the expected UP Aerospace values within 25% difference in most cases.

Event	Expected Load (g's)	Measured Load (g's)
Ascent Max Axial Accel.	16	15.8
Ascent Max Radial Accel.	18.5	14.5 @ 13s
Atm Re-entry Decel.	7.0	7.6
Vehicle Touchdown	60	16.5

- The calculated rate of rotation was 5.6 rev/s vs. the expected 6 rev/s.

Hypothesis-2

- Measured atmospheric pressure data were assumed to reflect the general trends predicted by the US Standard Atmosphere model where the atmospheric pressure decreases exponentially with altitude. The altitude values calculated from the pressure model were hypothesized to agree with altitude data calculated from acceleration data. Most data agreed within a 25% difference, up to a 25 km altitude.



Hypothesis-3

- It was expected that significant surface heating at the vehicle surface due to air friction would strongly affect measured temperature inside of the can such that the temperature would likely reflect that of the rocket and payload can, more than that from the surrounding external atmosphere.
- In conditions of vacuum at the highest altitudes, the dominant heat transfer mechanism would be conduction through solid parts in physical contact. This is observed as an equilibration trend as the energy acquired from aerodynamic heating distributes itself throughout the vehicle.
- This is what was observed in the form of a temperature increasing linearly from 5 to 22°C in the first 5 minutes of flight and then continuing to increase up to 35°C in the next 3 minutes.

Hypothesis-4

- Measured radiation intensity data were expected to show an increase with increasing altitude due to decreased atmospheric shielding from solar and cosmic sources.
- Geiger data did not behave as expected with a continuous increase in counts with increasing altitude. There only appeared to be a short burst of radiation around the time of payload separation.
- The Geiger counter was checked following the flight and found to be working properly so the observed behavior is not yet understood, but may be due to shielding by the aluminum payload canister wall.

Conclusions

- The first hypothesis that vehicle performance data would be similar to flight conditions specified for the UP Aerospace SpaceLoft-XL vehicle, was supported within a 25% difference for most values.
- The second hypothesis that altitude values calculated from the pressure model would agree with that from acceleration data was also supported within a 25% difference (for the range of validity for the sensor sensitivity).
- The third hypothesis predicting that significant surface heating at the vehicle surface due to air friction would dominate temperature measurements inside of the can more than that from the surrounding external atmosphere, was supported.
- The forth hypothesis relating Geiger counts to altitude were not directly supported. Additional information about the mounting of the payload board within the canister and more bench testing with the Geiger counter is needed to better understand the flight data.

Conclusions

- Additional analysis needs to be performed to determine the cause of the systematic underestimation of altitudes calculated via acceleration kinematics vs. that from atmospheric pressure data.
- For future pressure investigations, a low-pressure gauge such as an ionization gauge is needed in combination with the piezoelectric sensor in order to cover the entire pressure range from surface to apogee.
- Payload separation appears to be a subtle event based upon the expected time and corresponding accelerometer data, and its time is uncertain.
- Use of the NMSGC provided data retrieval utility and data parser utility caused data corruption when the entire memory was read and/or parsed at once. Consequently, only memory from addresses of 0 to 500,000 bytes were read and parsed to provide reliable data.

Conclusions

- SJC began the Student Launch payload construction course on January 11th 2010 with 16 undergraduate students. The students were exclusively freshmen and sophomores, and most did not have prior experience in soldering, electronics, or programming.
- The students were enthusiastic about the work, developed proficiency in soldering, solving various problems, and learned to work effectively together in teams. They were successful in achieving the overall payload and course learning objectives.
- All of the students greatly appreciated this opportunity and recognize the generous support provided by NASA and all of the various sponsors, but they are especially grateful to Aaron Perez and the helpful staff of the NMSGC.

Conclusions

“Thank you!”

from the students and faculty advisor at San Juan College.

Appendices

A. Payload mass budget
B. AVR Component parts list
C. Geiger counter component parts list
D. Miscellaneous parts list
E. CAD drawings of the UP Aerospace payload enclosure.
F. Power Supply Battery Specifications

Appendix-A: Payload Mass Budget

	Mass (lbm)	QTY	Total Mass Alotment
Plate Subassembly (3.10 lbm)			
Spacing Standoff (0.25")	0.00	5	0.02
Female-Female Standoff (1.5"	0.01	5	0.06
Female-Male Standoff (1.5")	0.01	20	0.27
3/16" Polycarbonate Plates	0.55	5	2.74
Kit Assembly (0.82 lbm)			
AVR Board	0.11	1	0.11
9V Battery	0.08	2	0.16
Double 9V Battery Bracket	0.02	1	0.02
G-switch	0.01	1	0.01
G-switch Mounting Bracket	0.00	1	0.00
Z-Axis Accelerometer	0.02	1	0.02
Z-Axis Mounting Bracket	0.02	1	0.02
Geiger Counter	0.13	1	0.13
Camera (optional)	0.35	1	0.35
Canister Subassembly (6.42 lbm)			
Top Lid	1.84	1	1.84
Bottom Lid	2.36	1	2.36
Main Canister	2.17	1	2.17
8-32 Cap-Head Bolts	0.01	10	0.05

Maximum payload + can weight = 15.76 Lbm

Total Mass per Populated Canister:		
Without Camera Plate (lbm):	11.38	lbm
With Camera Plate (lbm):	11.27	lbm

Appendix-B: AVR Parts List

Parts and Vendor List					
Note: *Actual cost may vary due to price breaks and minimum quantities. Shipping not included.			Per Plate	$411.10	
Flight Hardware					
AVR BOARD					
Item	**Part Number**	**Vendor**	**Quantity/Kit**	**Price (Each)**	**Price (Per Kit)**
PCB (3 Parts)	Ask for Details	4PCB.com	1	$11.00	$ 11.00
AVR Microcontroller	ATMega32-16PU	Digikey	1	$8.28	$ 8.28
40-pin DIP Socket for AVR	4840-6000-CP	Digikey	1	$0.42	$ 0.42
Data Flash Memory	AT26DF161A-SU	Arrow	1	$1.99	$ 1.99
SPI Level Shifter	MAX3392EEUD+	Maxim-IC	1	$1.90	$ 1.90
T2 - PNP Power Transistor	IRF9Z14PBF	Digikey	1	$1.52	$ 1.52
T1 - NPN Transistor	MPS2222ARLRAG	Digikey	1	$0.18	$ 0.18
5V Voltage Regulator	LM2937IMP-5.0CT-ND	Digikey	1	$1.83	$ 1.83
3.3V Voltage Regulator	LM2937IMP-3.3CT-ND	Digikey	1	$1.83	$ 1.83
3.3 kOhm 1/4 watt Resistor	3.3KQBK-ND	Digikey	2	$0.05	$ 0.11
R1, R2, R3, R4, R5, R6, R10, R11 - 10 kOhm 1/4 w att Resistor	10KQBK-ND	Digikey	8	$0.05	$ 0.43
R7 - 100 kOhm 1/4 watt Resistor	100KQBK-ND	Digikey	1	$0.05	$ 0.05
R8, R9 - 1kOhm 1/4 watt Resistor	1.0KQBK-ND	Digikey	1	$0.05	$ 0.05
C1 - 10uF Ceramic Capacitor	445-2881-ND	Digikey	1	$0.34	$ 0.34
C2, C3, C4, C5, C6, C7, C8, C9, CX, CY, CZ - .1uF Ceramic Capacitor	BC1101CT-ND	Digikey	11	$0.08	$ 0.88
C10 - 1uF capacitor (16 V) [Data Board]	445-2852-ND	Digikey	1	$0.24	$ 0.24
D1, D2, D3 - Diode (200mA)	1N4454CT-ND	Digikey	3	$0.04	$ 0.13
Red LED	754-1277-ND	Digikey	2	$0.40	$ 0.80
Green LED	HLMP-4740	Digikey	2	$0.51	$ 1.02
1-Axis Low-Range Accelerometer	ADXL103CE	Digikey	1	$16.01	$ 16.01
2-Axis Low-Range Accelerometer	ADXL203CE	Digikey	1	$22.77	$ 22.77
1-Axis High-Range Accelerometer	AD22279-A-R2	Digikey	1	$11.80	$ 11.80
2-Axis High-Range Accelerometer	AD22284-A-R2	Digikey	1	$15.95	$ 15.95
Temperature Sensor	LM50CIM3CT-ND	Digikey	1	$0.96	$ 0.96
Pressure Sensor	ASDX015A24R	Digikey	1	$23.95	$ 23.95
G-Switch	SW156-ND	Digikey	1	$2.11	$ 2.11
6 Pin Header (2x3) (angle or straight)	TSW-103-16-T-D-RA	Samtec	1	$0.45	$ 0.45
RS-232 Level Shifter	MAX233CPP+G36-ND	Digikey	1	$7.45	$ 7.45
20-Pin DIP Socket for Level Shifter [Data Board]	3M5465-ND	Digikey	1	$0.24	$ 0.25
DB9 Connector (Female) [Data Board]	A35109-ND	Digikey	1	$1.09	$ 1.09
6 pin cable [Data Board]	972	pololu.com	1	$2.49	$ 2.49
USB to Serial Adapter	150407	bestlinknetware.com	1	$6.95	$ 6.95
In-System Programmer	ATAVRISP2-ND	Digikey	1	$35.91	$ 35.91
Metallized Anti-Static bags	203920887	buy.com	1	$1.00	$ 1.00
AVR TOTAL					$ 182.14

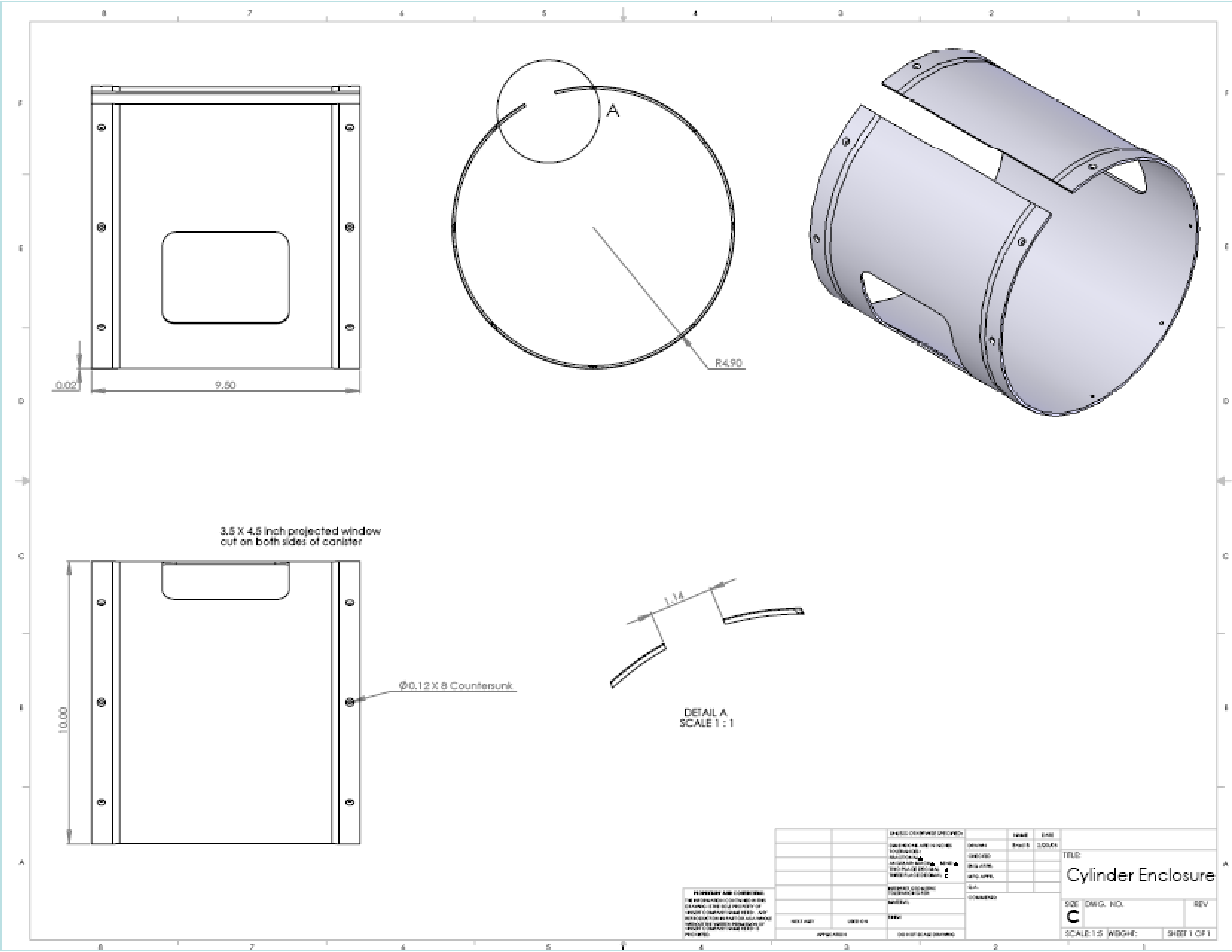
Appendix-C: Geiger Counter Parts List

GEIGER BOARD					
Geiger Board	Ask for Details	4PCB.com	1	$33.00	$ 33.00
Geiger Tube	GMT-01	Imagesco	1	$74.95	$ 74.95
HV Mini Step-up Transformer	TFRM-02	Imagesco	1	$15.00	$ 15.00
Speaker	102-1123-ND	Digikey	1	$2.10	$ 2.10
Conformal Coating	419B-55ml	Allied Electronics	1	$9.57	$ 9.57
Q1 - IRF830 MOSFET Transistor	IRF830IR-ND	Digikey	1	$2.50	$ 2.50
Q3 - GL 7805 Transistor	GL7805	partsexpress.com	1	$0.80	$ 0.80
Q4 - 2N3904 NPN Transistor	2N3904F8-ND	Digikey	1	$0.11	$ 0.11
U1 - 4049 Hex Inverting Buffer	CD4049UBCN-ND	Digikey	1	$0.48	$ 0.48
U2 - 555 Timer	LM555CNFS-ND	Digikey	1	$0.44	$ 0.44
ICS 16 Socket	ICS16	Futurlec.com	1	$0.07	$ 0.07
ICS 8 Socket	ICS8	Futurlec.com	1	$0.04	$ 0.04
R1 - 4.3 Kohm 1/4 watt Resistor	4.3KQBK-ND	Digikey	1	$0.06	$ 0.06
R2 - 15 Kohm 1/4 watt Resistor	15KQBK-ND	Digikey	1	$0.06	$ 0.06
R3 - 5.6 Kohm 1/4 watt Resistor	5.6KQBK-ND	Digikey	1	$0.06	$ 0.06
R4 - 470 Kohm 1/4 watt Resistor	470QBK-ND	Digikey	1	$0.06	$ 0.06
R5 - 10 MegaOhm 1/4 watt Resistor	10MQBK-ND	Digikey	2	$0.06	$ 0.13
R7 - 150 Kohm 1/4 watt Resistor	150KQBK-ND	Digikey	1	$0.06	$ 0.06
R8 - 470 Ohm 1/4 watt Resistor	470QBK-ND	Digikey	1	$0.06	$ 0.06
R9 - 330 Ohm 1/4 watt Resistor	330QBK-ND	Digikey	1	$0.06	$ 0.06
R14 - 220 Kohm 1/4 watt Resistor	220KQBK-ND	Digikey	1	$0.06	$ 0.06
C1 - .0047 uF Ceramic Capacitor	P4559-ND	Digikey	1	$0.05	$ 0.05
C2, C7, C8 - .01 uF Ceramic Capacitor	140-PM2A103K	Mouser	3	$0.13	$ 0.39
C3, C10 - 100 uF Tantalum Capacitor	718-1165-ND	Digikey	2	$4.69	$ 9.38
C4, C5, C12 - .01 uF Ceramic Capacitor (1KV)	P9552-ND	Digikey	3	$0.99	$ 2.97
D1, D11 - 1N914 Silicon Diode	1N914	Futurlec	2	$1.13	$ 2.26
D2, D3, D9 - 1N4007 Diode (1KV)	1N4007	Futurlec	3	$3.70	$ 11.10
D4 - 1N5271 Zener Diode (100V)	IN5271B	Images SI	1	$0.44	$ 0.44
D5, D6 - 1N5281 Zener Diode (200V)	1N5281B	Images SI	2	$1.20	$ 2.40
D7 - Red LED	754-1277-ND	Digikey	1	$0.40	$ 0.40
D10 - 5.1 V Zener Diode	1N5231BDICT-ND	Digikey	1	$0.32	$ 0.32
GEIGER TOTAL					$ 169.41

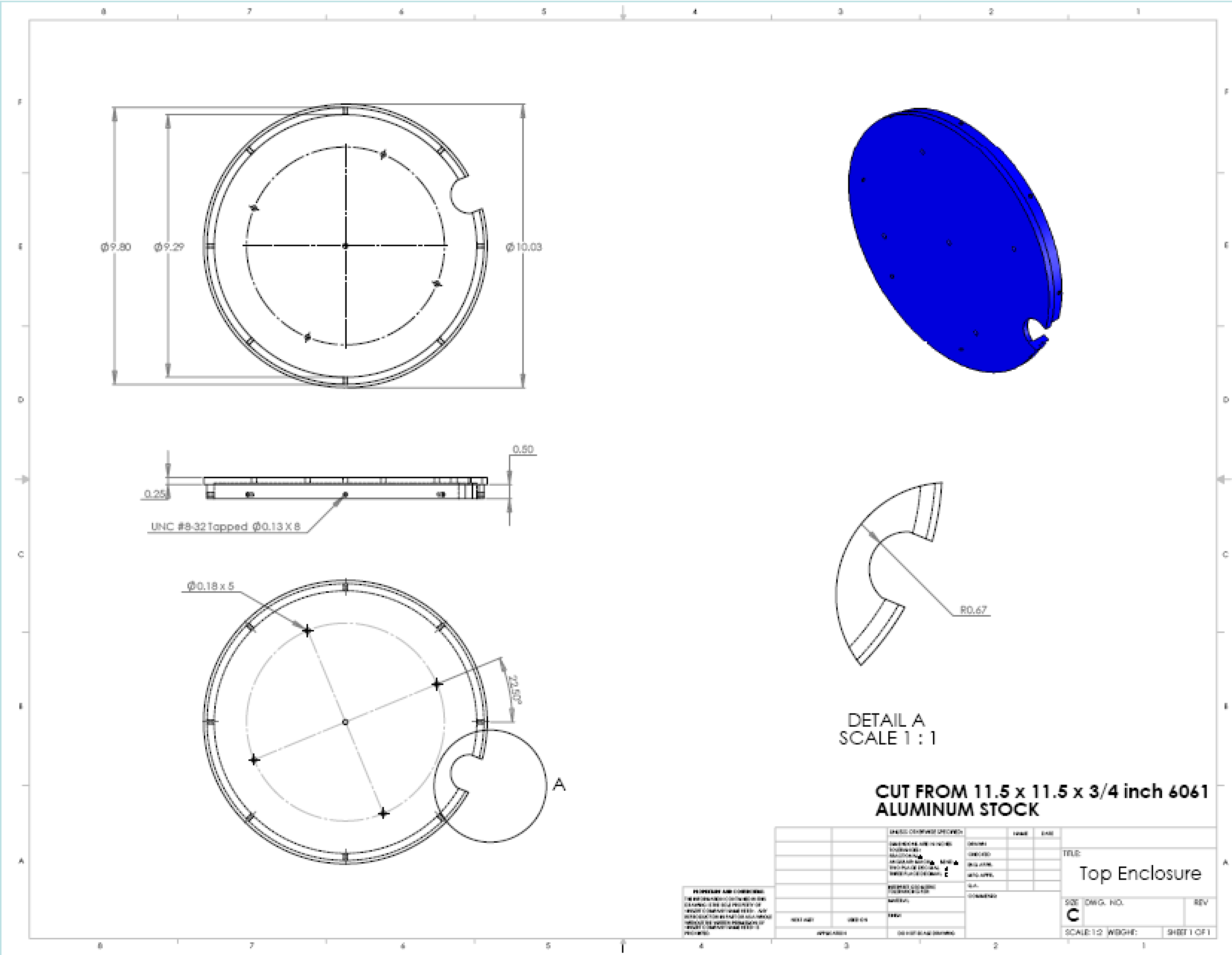
Appendix-D: Miscellaneous Parts List

STRUCTURE					
Poly-Carb plate	51181	Plastic Supply	1	$3.00	**$ 3.00**
Battery Brackets	8859K84	McMaster Carr	1	$1.00	**$ 1.00**
AVR Brackets	Aluminum "L" bar	Home Depot	1	$1.00	**$ 1.00**
Accelerometer Brackets	Aluminum "L" bar	Home Depot	1	$1.00	**$ 1.00**
G-Switch Brackets	Aluminum "L" bar	Home Depot	1	$1.00	**$ 1.00**
Snappable Header	SHS-40	All Electronics	10	$0.35	**$ 3.50**
2 pin Connector	HDCONNS2	Futurlec.com	6	$0.08	**$ 0.48**
3 pin Connector	HDCONNS3	Futurlec.com	1	$0.15	**$ 0.15**
4 pin Connector	HDCONNS4	Futurlec.com	1	$0.15	**$ 0.15**
Battery Connector	BS6I-ND	Radio Shack	2	$0.40	**$ 0.80**
Flight wire, Teflon stranded, 22 gauge, 600 volt	Black, Red, Blue, White	bulkwire.com	10	$0.28	**$ 2.80**
Male-Female Standoffs (Includes Shorts)	93620A138	McMaster Carr	5	$2.50	**$ 12.50**
Female-Female Standoffs	91920A256	McMaster Carr	5	$1.90	**$ 9.50**
Nylon Washers	95610A130	McMaster Carr	9	$0.03	**$ 0.27**
6 mm Nylon Spacers	93657A009	McMaster Carr	20	$0.84	**$ 16.80**
12 mm Nylon Spacers	93657A013	McMaster Carr	4	$1.03	**$ 3.36**
AVR Bolts (M 3.0X25)	92005A130	McMaster Carr	4	$0.03	**$ 0.12**
Geiger Bolts (M 2.0X35)	92005A133	McMaster Carr	4	$0.07	**$ 0.28**
G-Switch Side Bolts (M 2.0X10)	92005A033	McMaster Carr	2	$0.04	**$ 0.08**
G-Switch Side Nuts (#2)	90591A111	McMaster Carr	2	$0.02	**$ 0.04**
G-Switch Plate Bolts (M 3.0X10)	92005A120	McMaster Carr	8	$0.03	**$ 0.24**
Accelerometer Side Bolts (M 2.5X12)	92005A075	McMaster Carr	3	$0.04	**$ 0.12**
Accelerometer Side Nuts (#2.5)	90591A113	McMaster Carr	3	$0.02	**$ 0.06**
Canister Top Bolts (8-32 - 5/8")	91251A196	McMaster Carr	5	$0.13	**$ 0.65**
Canister Bottom Bolts (8-32 - 1/2")	91251A194	McMaster Carr	5	$0.13	**$ 0.65**
STRUCTURES TOTAL					**$ 59.55**

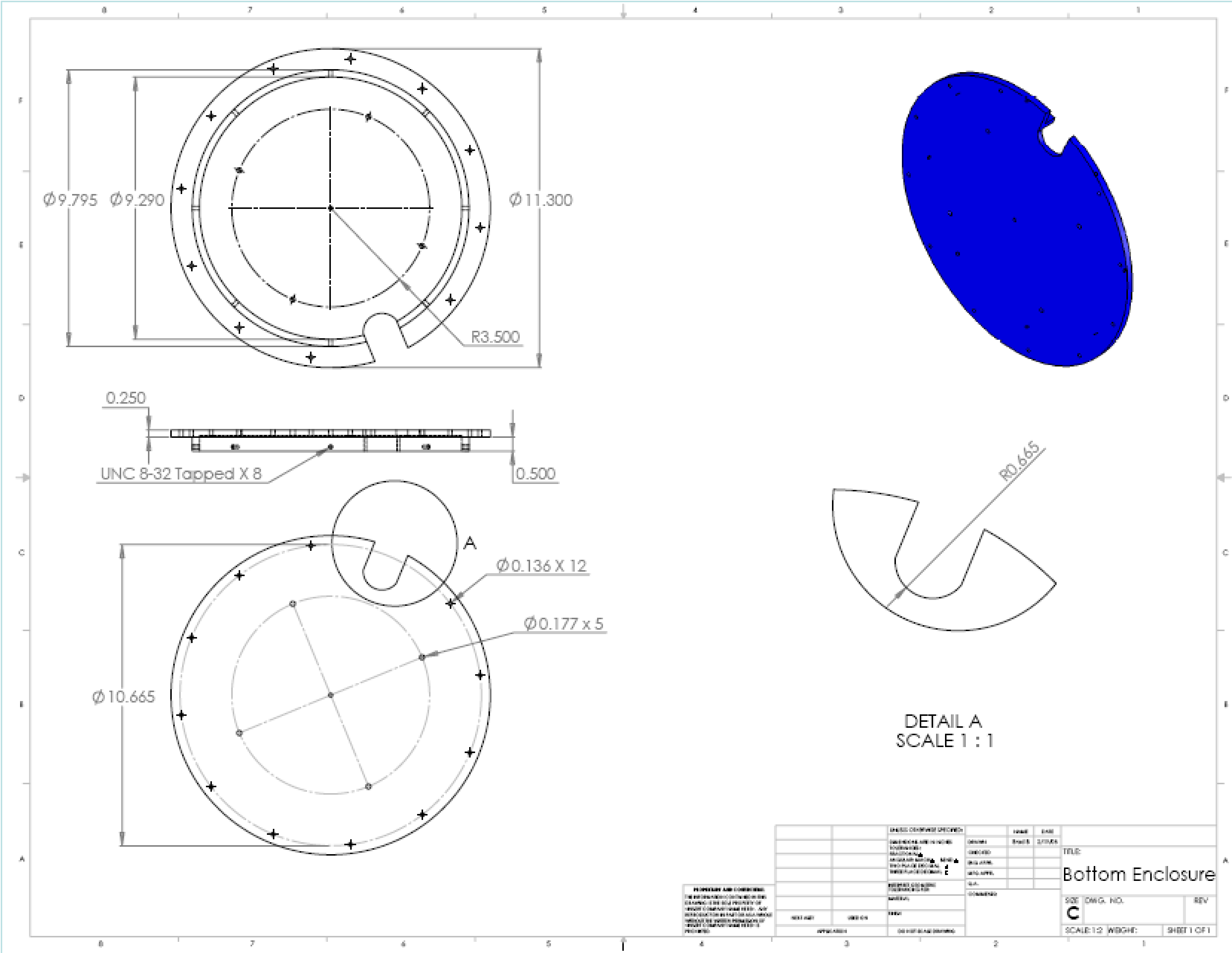
Appendix-E: Payload Enclosure



Appendix-E: Payload Enclosure



Appendix-E: Payload Enclosure



Appendix-F: Power Supply Battery Specs.

TECHNICAL DATA

Li/MnO_2 Primary System

U9VL-J 9V Size Battery

System:	Lithium/Manganese Dioxide
Designation:	NEDA 1604 LC
Nominal Voltage:	9.0 Volts
Capacity (C):	1,200 mAh @ 900 Ω to 5.4V @23°C
Max. Discharge:	120 mA Continuous
Weight:	36.4 grams
Oper. Temp. Range	-20° to 60°C
Storage Temp. Range:	-40° to 60°C
Volume:	22.6 cm^3
Terminals:	Miniature Snap
Housing:	Aluminum/Mylar Label
Safety:	Less than 2 grams of lithium; no restrictions on transport; MSDS available separately