



SolarSAT

Colorado State University

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Matt Lyon

Justin Nelson

Kenny Vogel

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April 17, 2010



Mission Statement & Goals



Mission Objectives

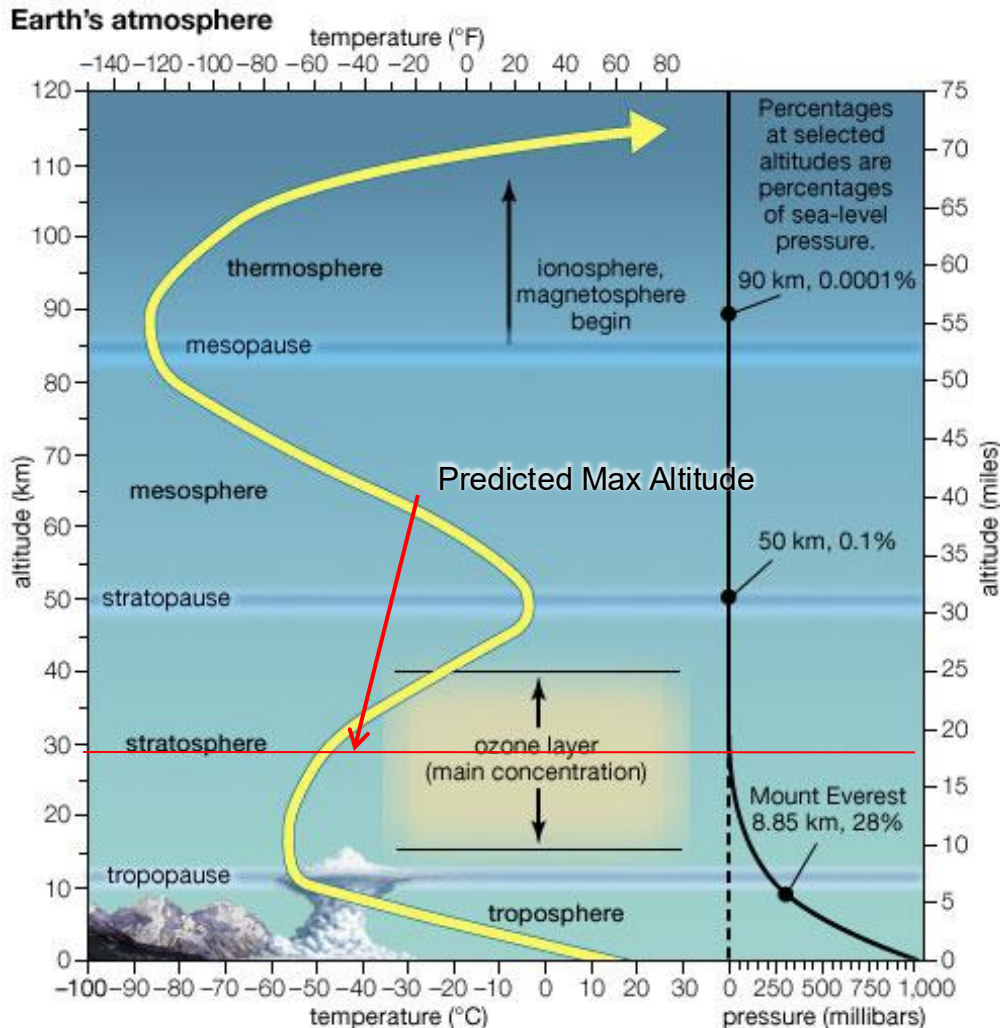
- *Primary:*
 - Determine the effects of change in altitude on solar cell efficiency
- *Secondary:*
 - Post-flight, roll into a specific orientation, and deploy solar panels for increased solar panel exposure to the sun

Level of Success

- *Minimum:*
 - Measure T, P, V output from solar cells
 - All onboard sensors and circuits operational during entire flight
- *Maximum:*
 - Have solar panel deploy upon reaching the surface, and for all sensors to continue recording data
 - All minimum goals



Mission Overview



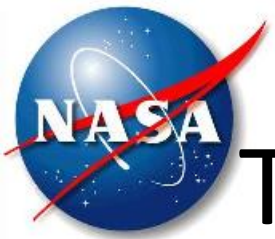
Expectations:

- Lower temperatures should improve solar cell efficiency.
- Pressure should have minimal effects on solar cell performance.
- Solar cell efficiency should increase at higher altitudes due to less light being scattered by the atmosphere



Possible Benefits

- Determine an ideal altitude at which solar cells have high efficiency.
- Could be self sustained and used take data from hostile environments.
- Can be used as a remote charging station for rovers on other planets.
- Has ample open space inside for additional/future experiments.



Team Member Responsibilities

Group – Design, Analysis, Testing.

Khongor Jamiyanaa – Pro/E, Manufacturing, Carbon
Fiber.

Justin Nelson – Pro/E, Manufacturing, Solar Panel
Deployment.

Matt Lyon – Electronics, Programming.

Kenny Vogel – Electronics, Programming.



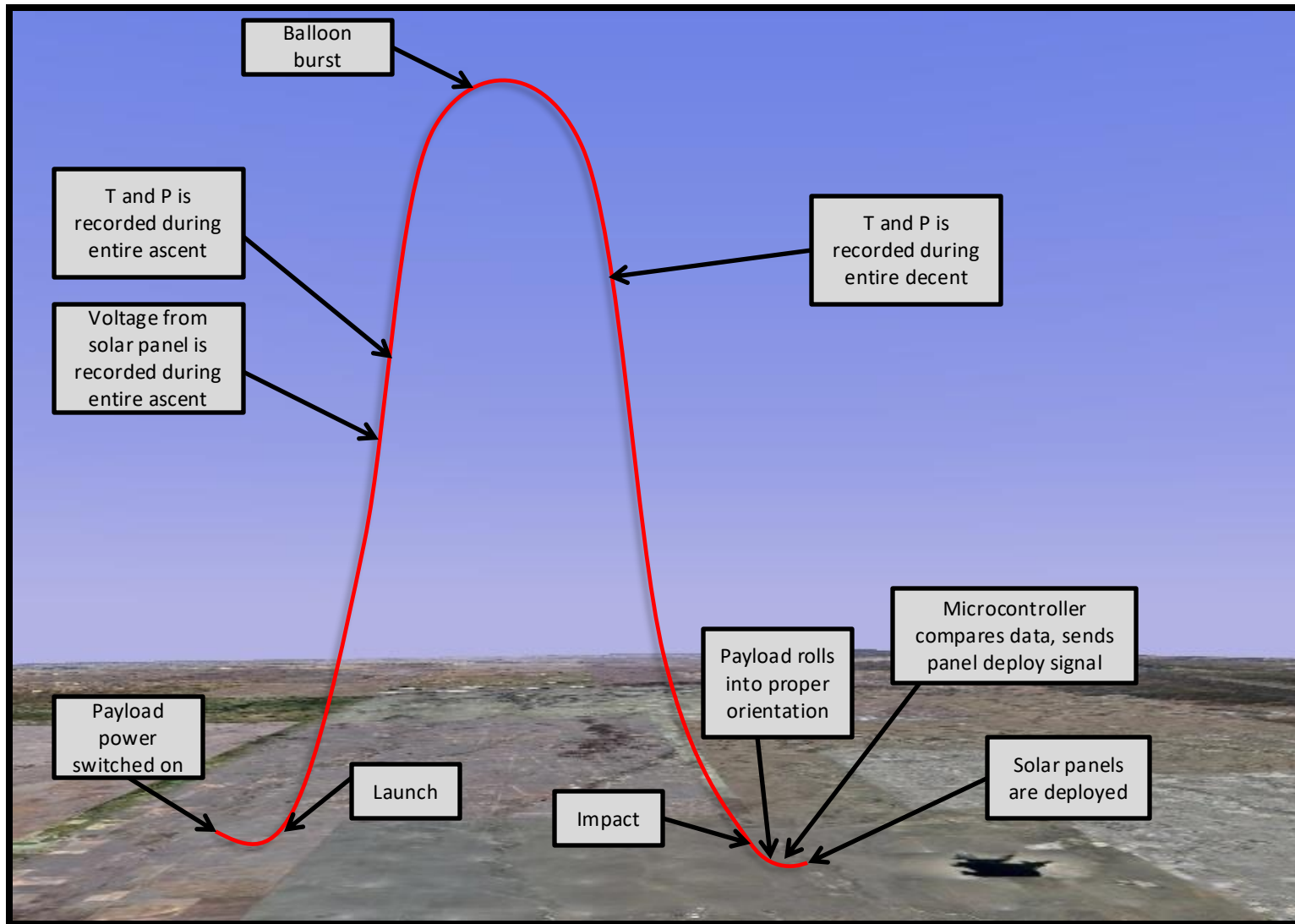
Mission Requirements



Requirement :	Method:	Status:
Payload must not exceed weight of 1.5 kg	Design	Not Compliant
Payload must survive the environment at 100,000ft in elevation.	Design, Test, Analysis	Compliant
Payload must be able endure up to 15 G's	Design, Test, Analysis	Compliant
The center of gravity for the payload must be within one inch of flight string.	Design	Compliant
Payload must not interfere with communication frequencies of the balloon.	Design	Compliant
Shall not exceed budget of \$1000	Design	Not Compliant
The SolarSat must meet all mission objectives.	Design, Test	Partially Compliant

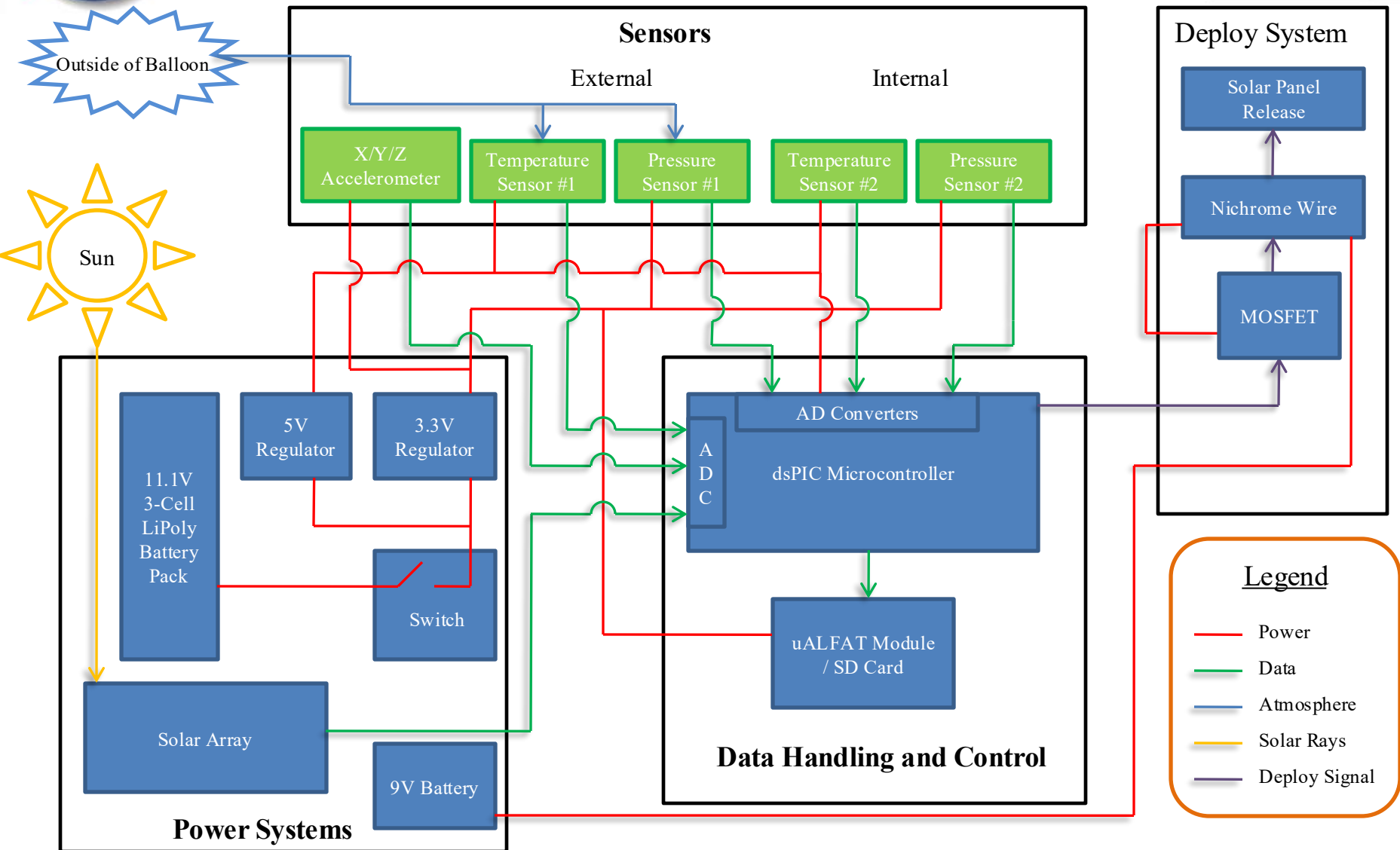


Concept of Operations



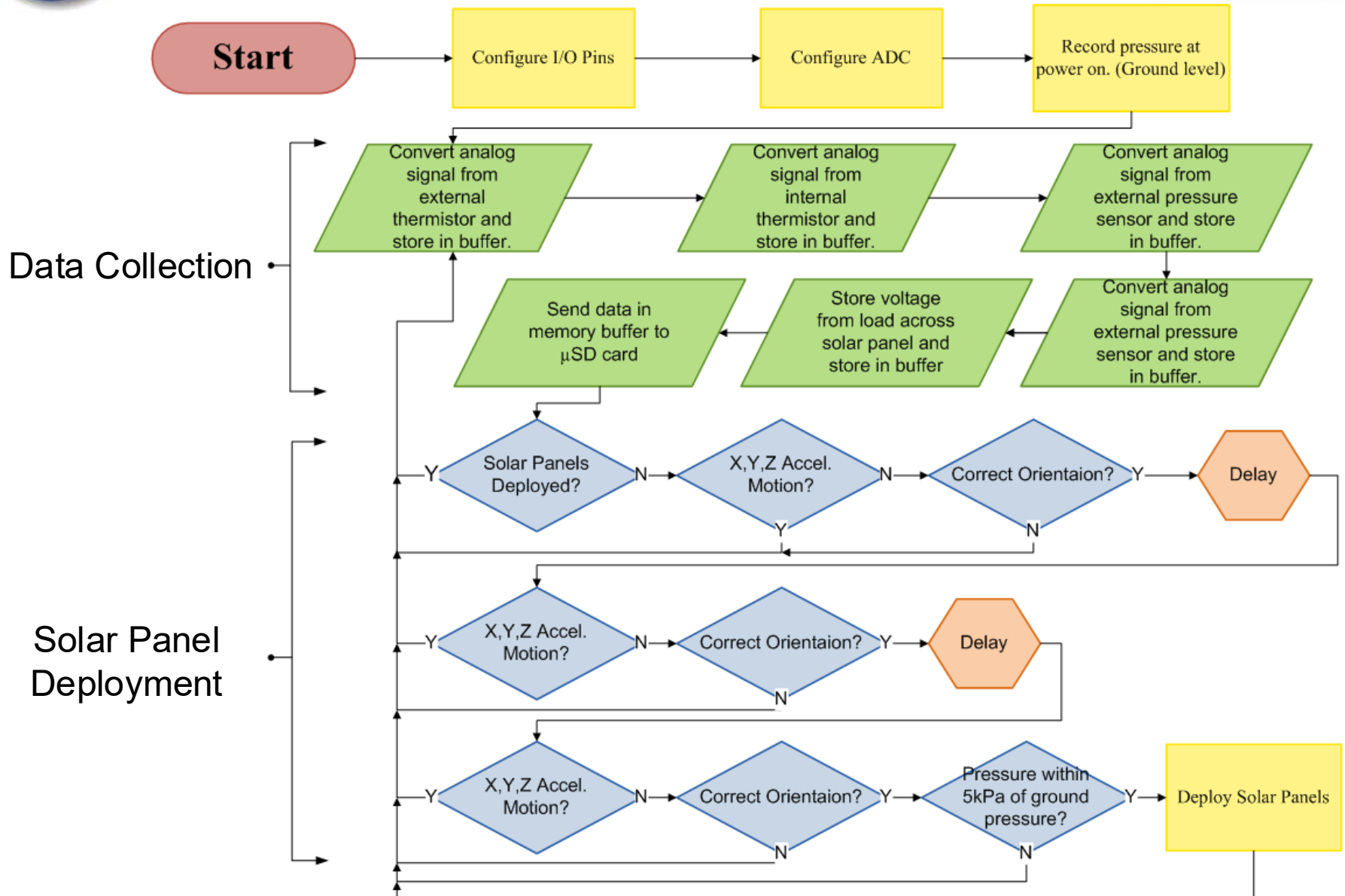


Subsystems and Specifications



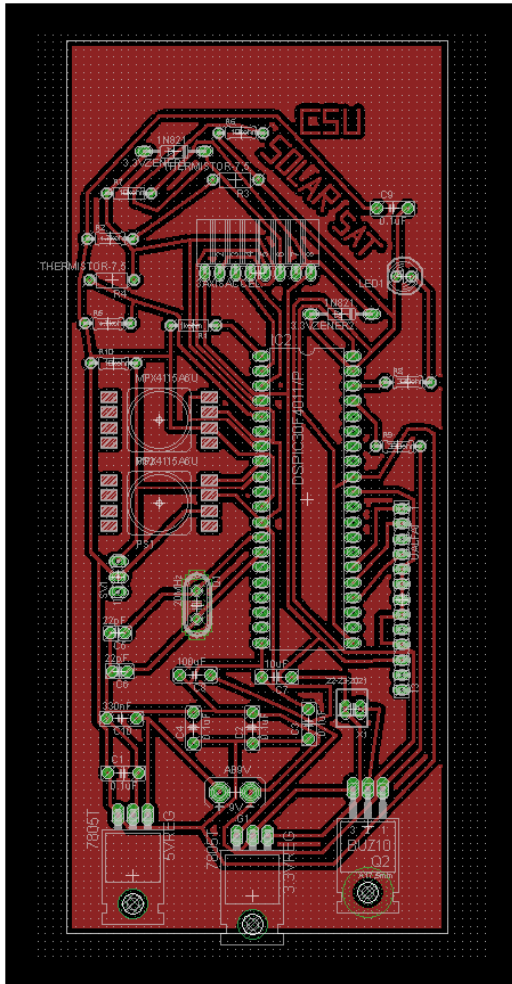


Software Flow Chart

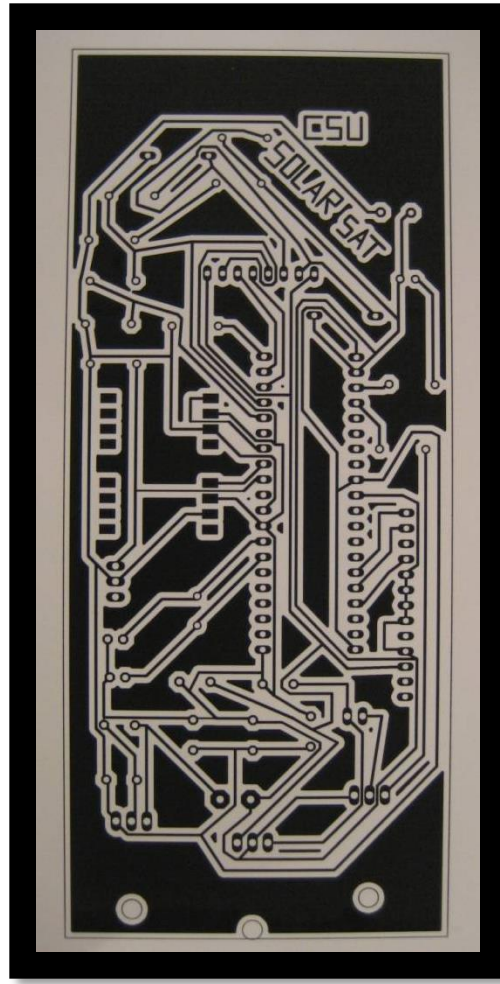




PCB Design



Software Image



Printed on Photo paper

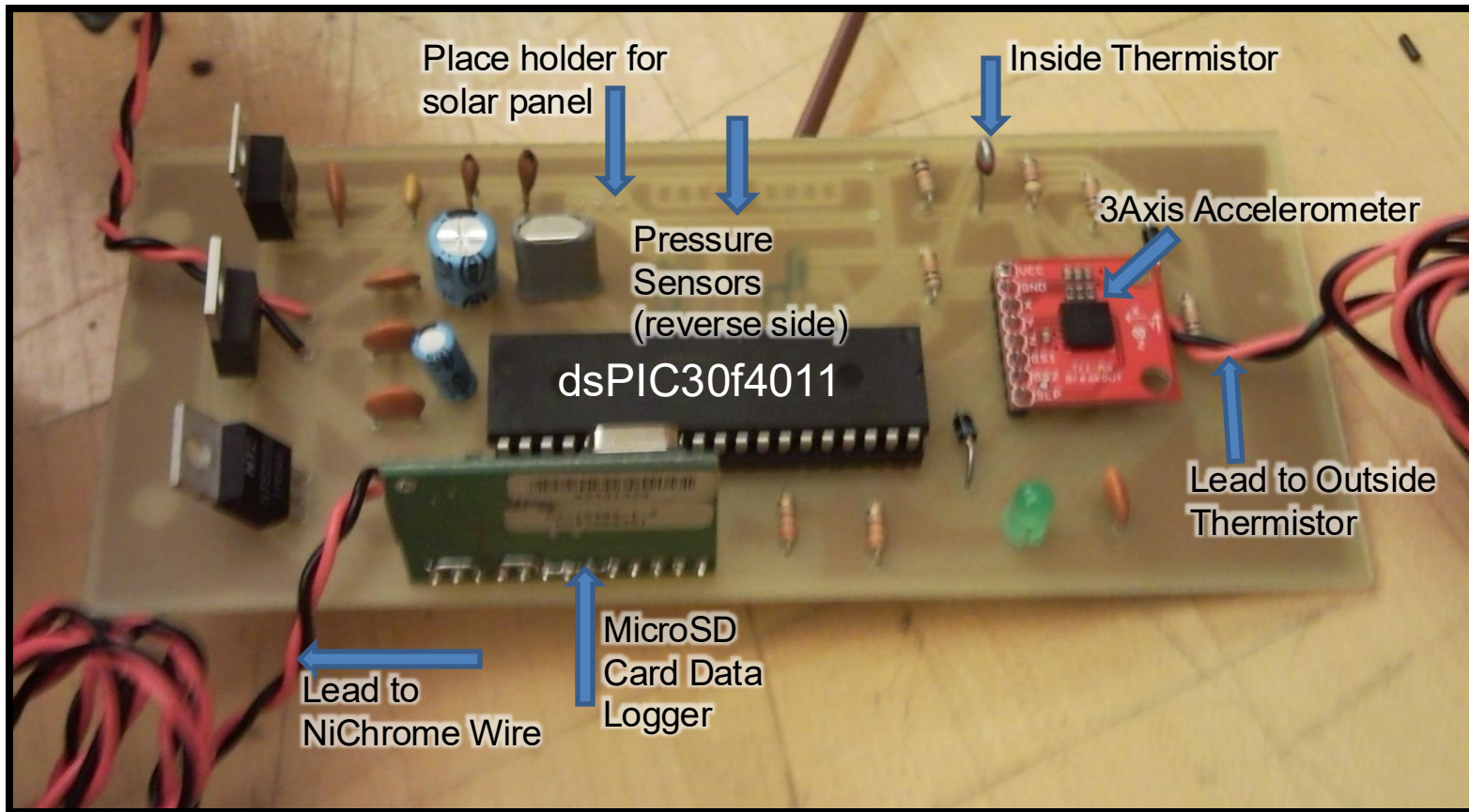


Manufactured



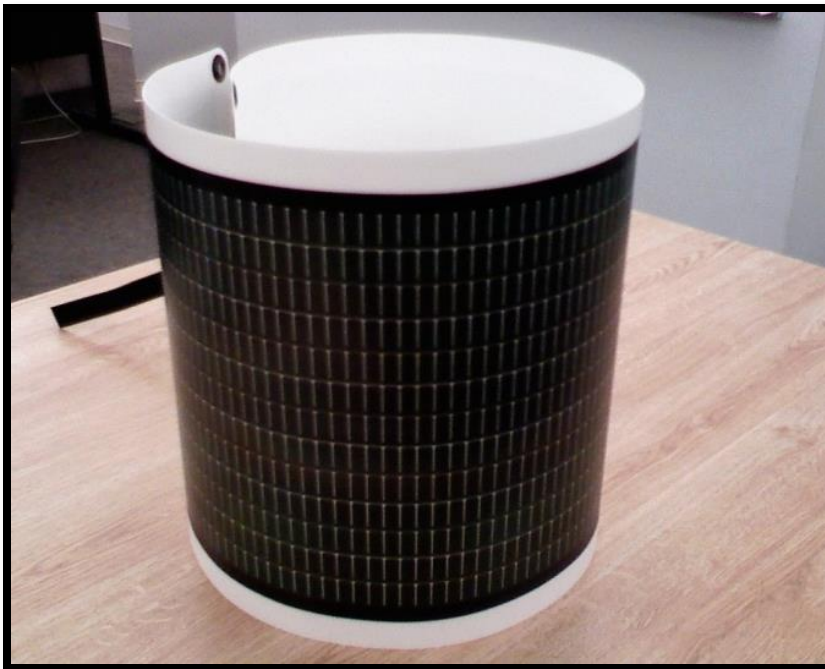
Design Features

Circuit Board





Solar Panel



PowerFilm R-14

Dimensions: 42.0 x 14.5 inches



Design Features

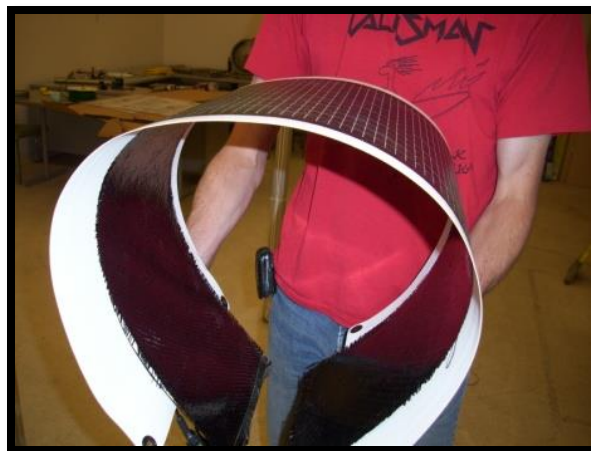
Cylindrical Body





Design Features

Carbon Fiber Springs

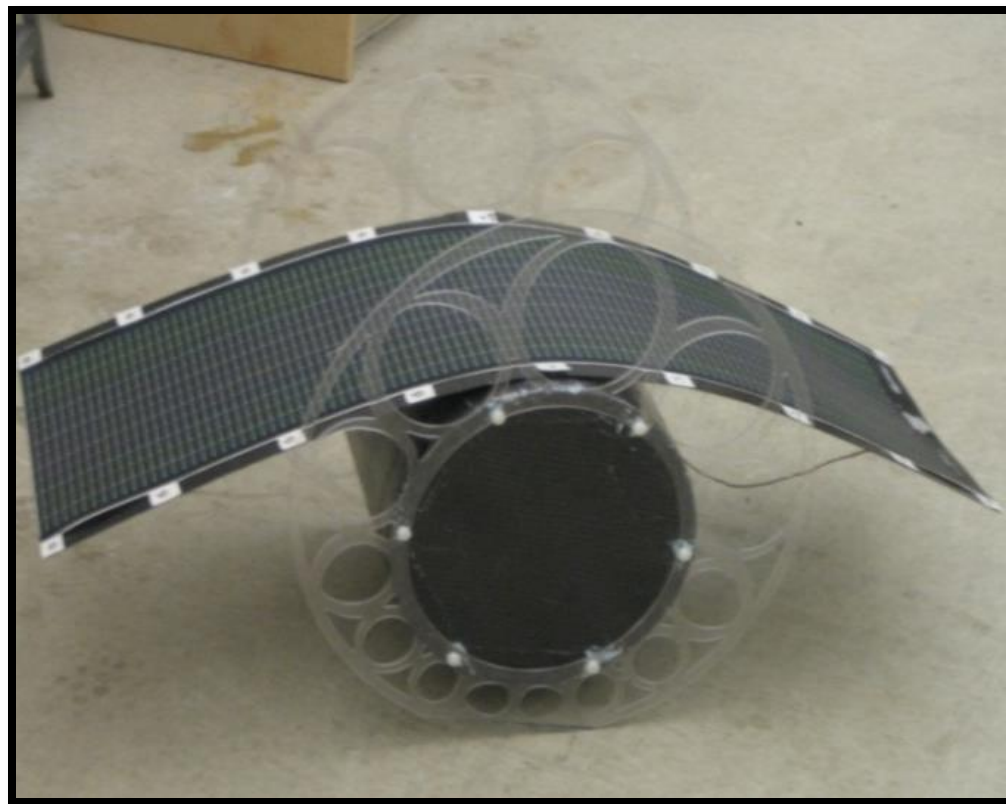
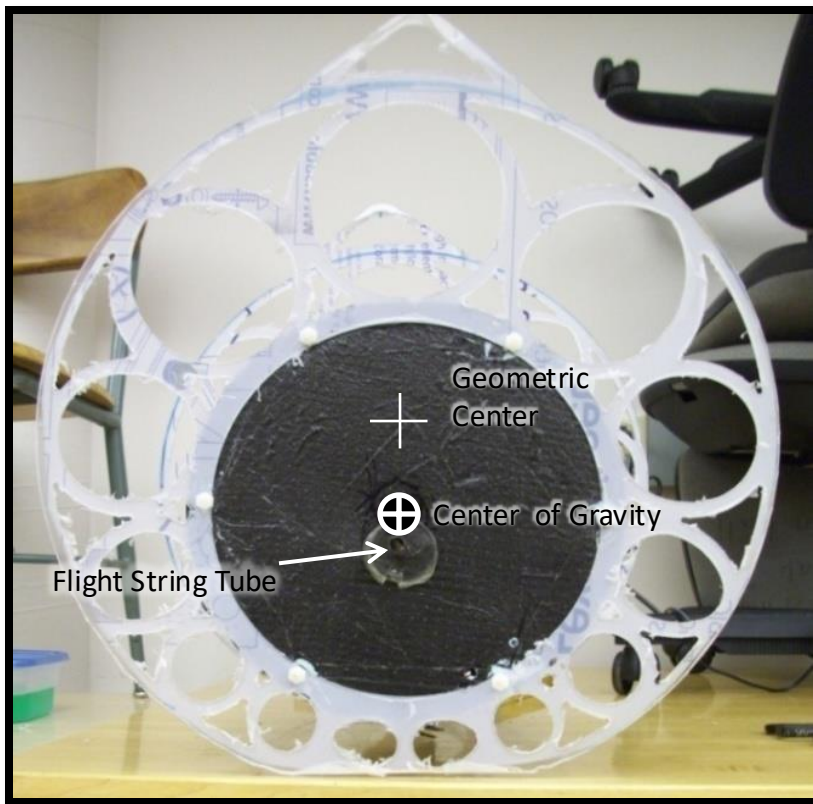


Allows for solar panel deployment.



Design Features

Offset End Rings



Allows for proper orientation.



Design Features

Carbon Fiber Tube



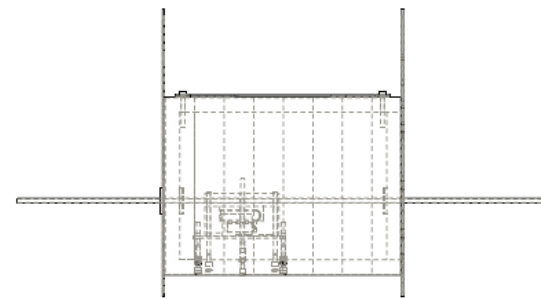
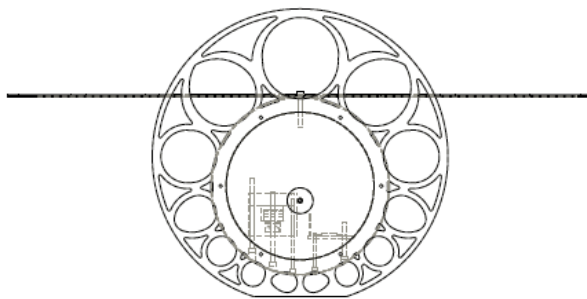
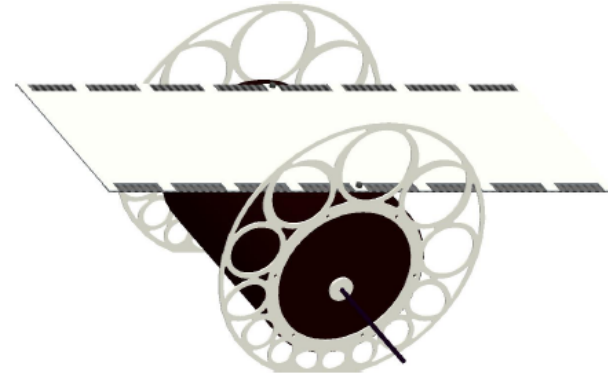
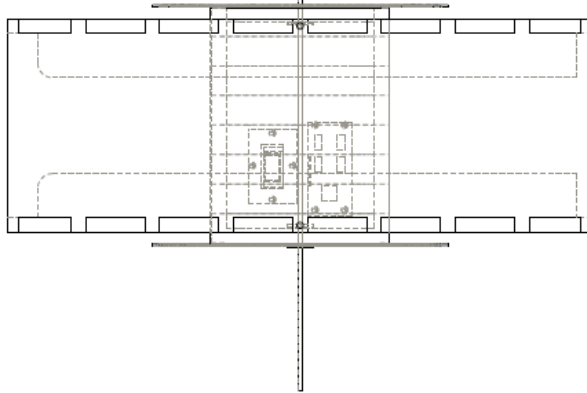
Assists with proper landing



Model (deployed position)



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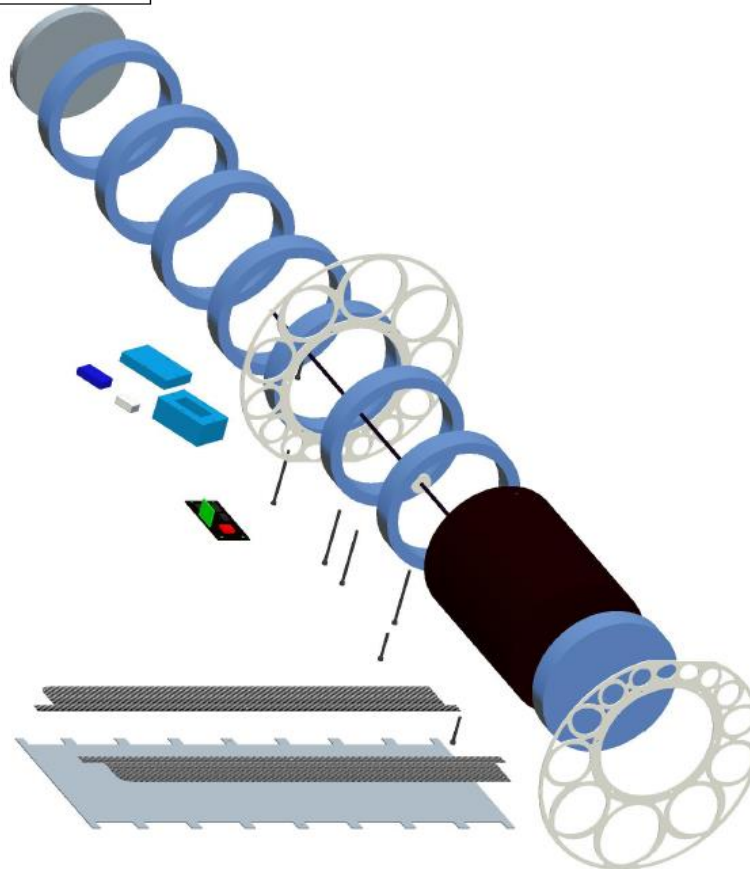
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SCALE:	.1	DRAWN BY:		MATERIAL:	Hardwork
SHEET:		FINISH:			



Exploded View



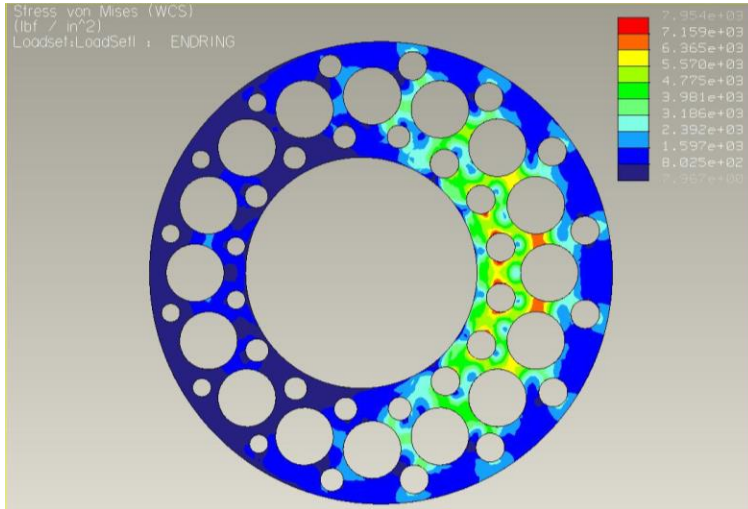
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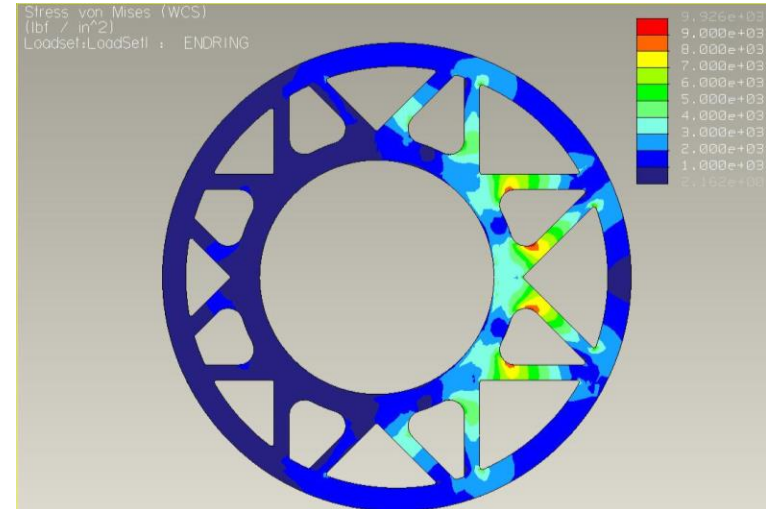
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Colorado State University			UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:		
Mechanical Engr. Dept. Fort Collins, Co 80521 (970) 491-6558			FRACTIONS: 1/32 DECIMALS: ±.002 ANGLES: ±.5		
SCALE:	.085	DRAWN BY:		MATERIAL:	
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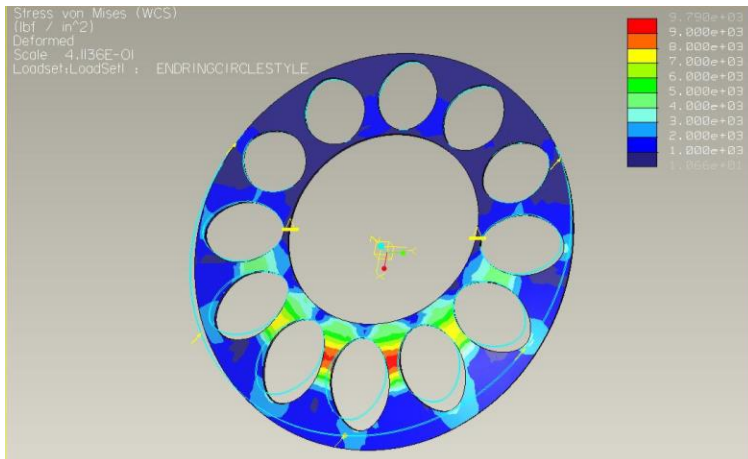
Clear Polycarbonate End Ring Design Analysis



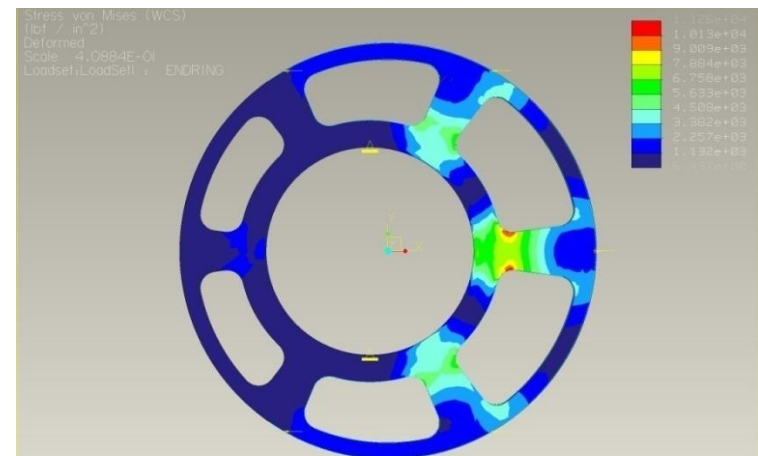
Circular



Triangular



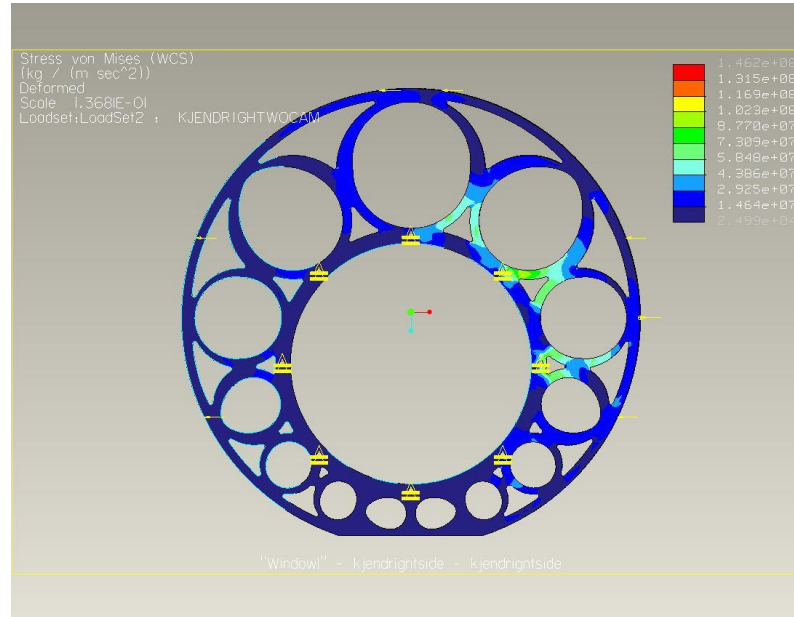
Oval



Rectangular



Clear Polycarbonate End Ring Design Analysis



End Ring Comparison

Style	Max von Mises Stress (kPa)	Weight of two panels (kg)
<i>Rectangular</i>	77634.97	0.65
<i>Oval</i>	67499.67	0.59
<i>Triangular</i>	68258.10	0.66
<i>Circular</i>	54840.90	0.63
Chosen Design	146200	0.48
Ultimate Stress of Polycarbonate (kPa)	86184.47	



Manufacturing Process



Polycarbonate endcap



Ascent position test fit



Deployed position test fit

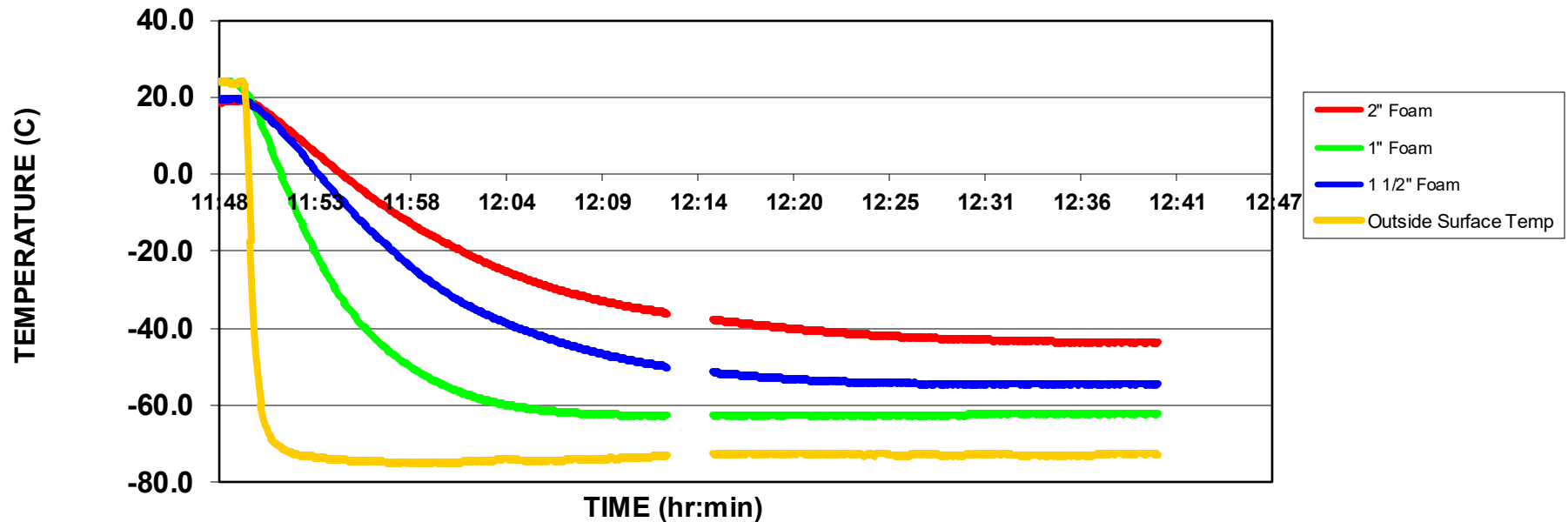


Cutting of polycarbonate



Thermal Testing

TEMPERATURE PROFILE
TRACKING OR REACHING STEADY STATE



- We tested three different foam core thicknesses, each with a thermocouple inside and a slab of dry ice in contact with the outside
- The results show that on average at steady state, every ½ inch thicker the insulation, the inside will be about 10 °C warmer



Manufacturing Process



Template for foam core cut on CNC



Cutting of foam core section with hot wire cutter



Sanding of foam core sections



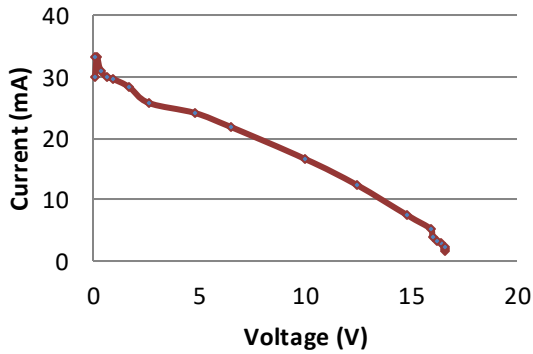
Stack of foam core sections (pre-hollowed)



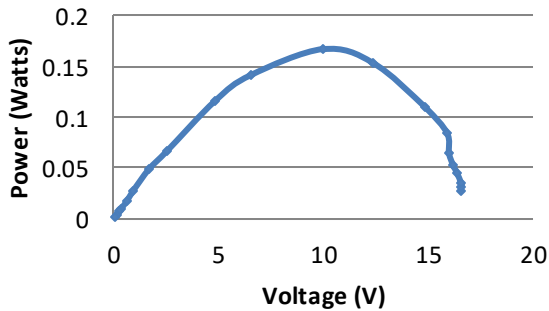
Testing

Solar Cell Testing

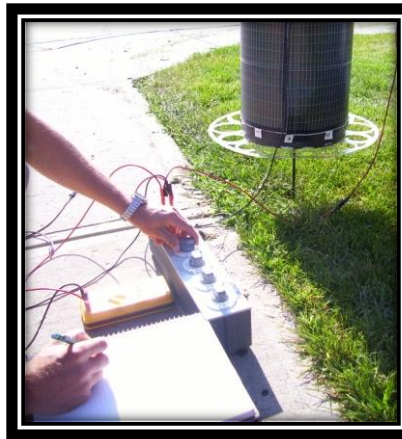
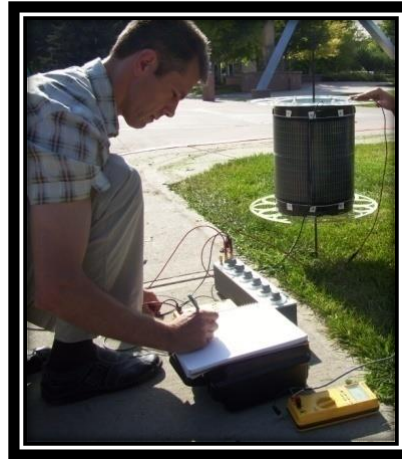
I - V



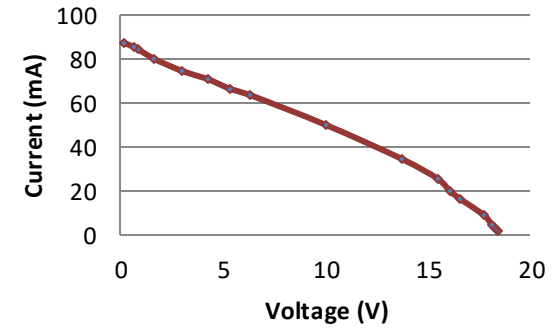
P - V



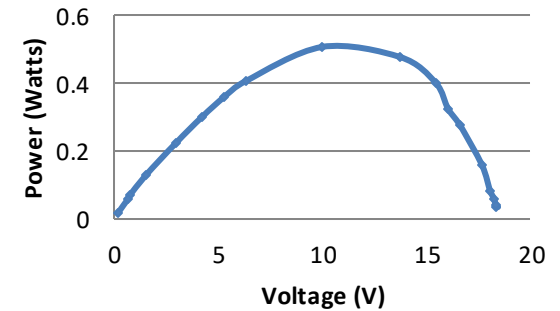
Solar Cell Data from 1/4 Sun



I - V



P - V



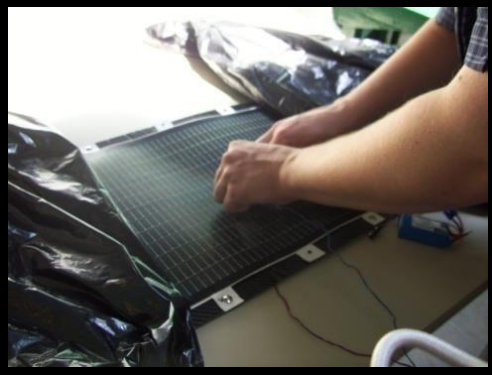
Solar Cell Data from Full Sun

This test was performed to find a load resistor for our solar panel that will allow for maximum power generation. This resistor value is 100 Ω .

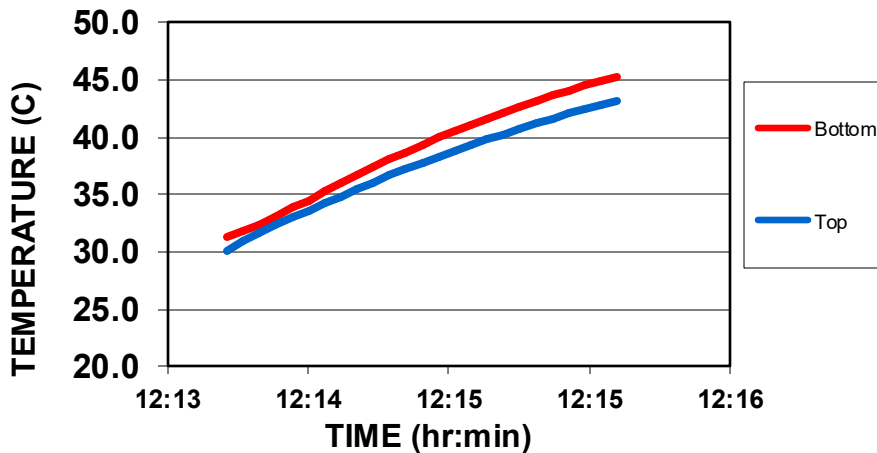


Testing

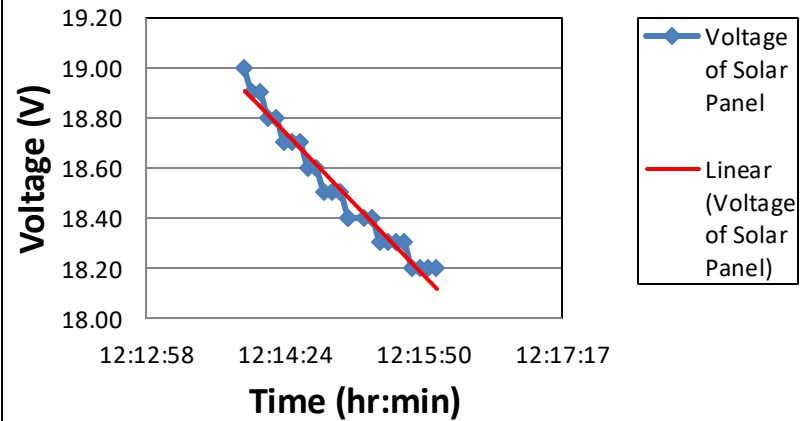
Solar Cell Temperature Test



Thermocouple Temperature Vs. Time



Voltage Vs. Time



During the test, the voltage from the solar panel dropped 0.8V for a temperature increase of 15°C. This corresponds to a drop in efficiency of 4.2% for 15°C, or 0.28% per °C.



Testing

Drop Test



From Horizontal Position



From Vertical Position



Testing

Stair Pitch Test



From Horizontal Position



From Vertical Position



Testing



Whip Test



From Vertical Position



From Horizontal Position



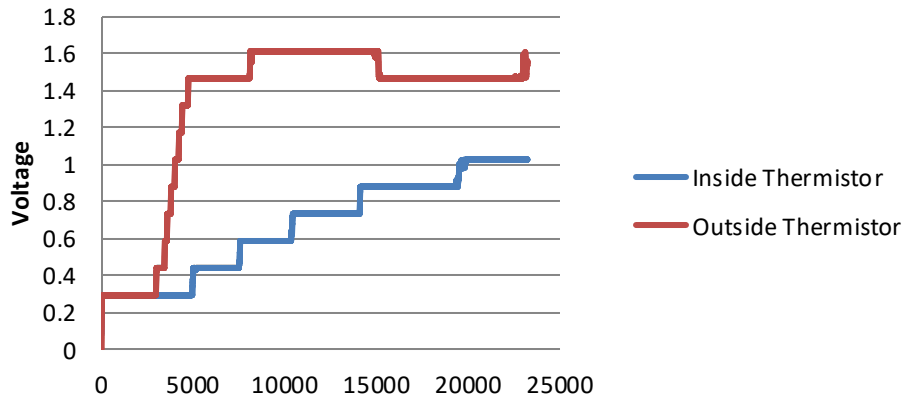
Testing

Cold Test

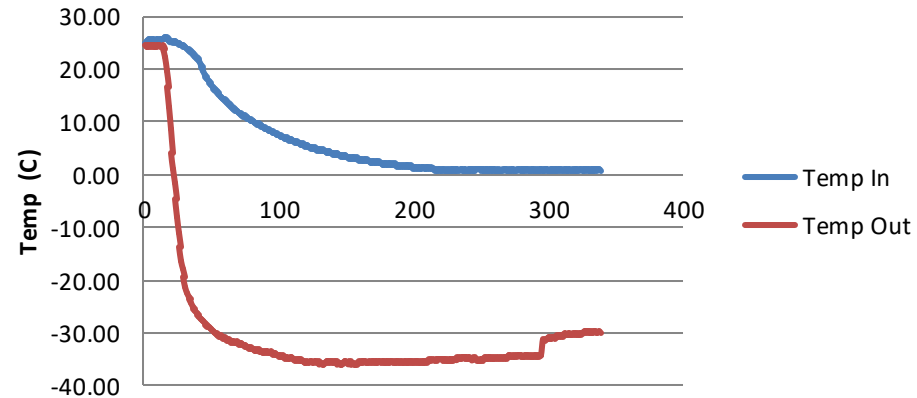
Data collected with our sensors

Data collected from thermocouples in lab

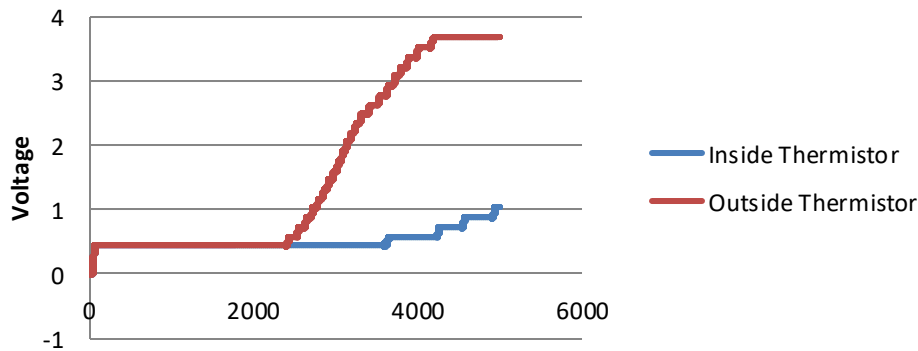
Cold Test 1



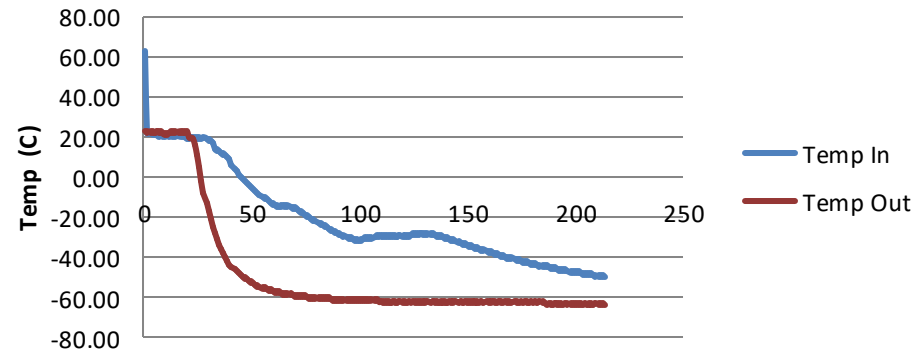
Cold Test 1



Cold Test 2



Cold Test 2



Equation Relating Voltage to Temperature

$$T = -26.304V + 26.305$$



SolarSAT Budget

Component	Mass (g)
Central Foam Tube + Carbon Fiber Shell	587.5
Solar Panel + Carbon Fiber Springs	677.8
Carbon Fiber Tube (for flight string)	58.0
Battery	150.1
Circuit Board + Electronics	74.3
Polycarbonate End Rings	484.6
Nylon Fasteners	39.5
Structural Reinforcement	95.2
TOTAL MASS OF SOLARSAT	2167.0

Initial Mass Budget: 1500.0g

Mass Over Budget: **667.0g**



Parts List



Item	Supplier	Model Number	Cost (\$)
Microcontroller	MicroChip	dsPIC30F4011/4012	7.50
9V Batteries	CSU Bookstore		10.40
Pressure Sensor	FreeScale	MPXV5050GC6U	0.00
11.1V Lipoly Battery (2)	Hobby Town	PKZ1033	76.80
Duct Tape	CSU Bookstore		4.00
DOSonChip μ SD Module	SparkFun	BOB-08215	49.64
Smart Charger	BatterySpace.com	CH-UN1550DC-3	19.95
3 Cell Li-Poly Battery	BatterySpace.com	PL-553562D-3S-WR-10-12C	42.66
50" x 2 yard Carbon Fiber	Composite Envisions	2x2 Twill 50" 3k 5.7oz	73.98
3:1 Epoxy 1.33 Gallons	Composite Envisions	NA / US Composites	84.59
Voltage Regulator	Mouser	LM7805	7.41
uALFAT SD Board	GHI Electronics		46.82
NiChrome Wire	Jacobs Online	NI40030	6.00
Polystyrene Foam	Sutherlands	Dow Styrofoam Scoreboard	31.99
Foam Board Adhesive	Sutherlands	PL300	4.59
Solar Panels	SolarWorld	PowerFilm R-14	244.48
Polycarbonate	Fort Collins Plastic	9034 Lexan	77.70
Microchip	PicKit 2 Programmer	PG164120	34.82
3V Regulator	Texas Instruments	UA78M33	0.00
Carbon Fiber Tube	CarbonFiberTubeShop	SM3236F	47.30
3 axis accelerometer	SparkFun	MMA7260Q	23.92



Parts List

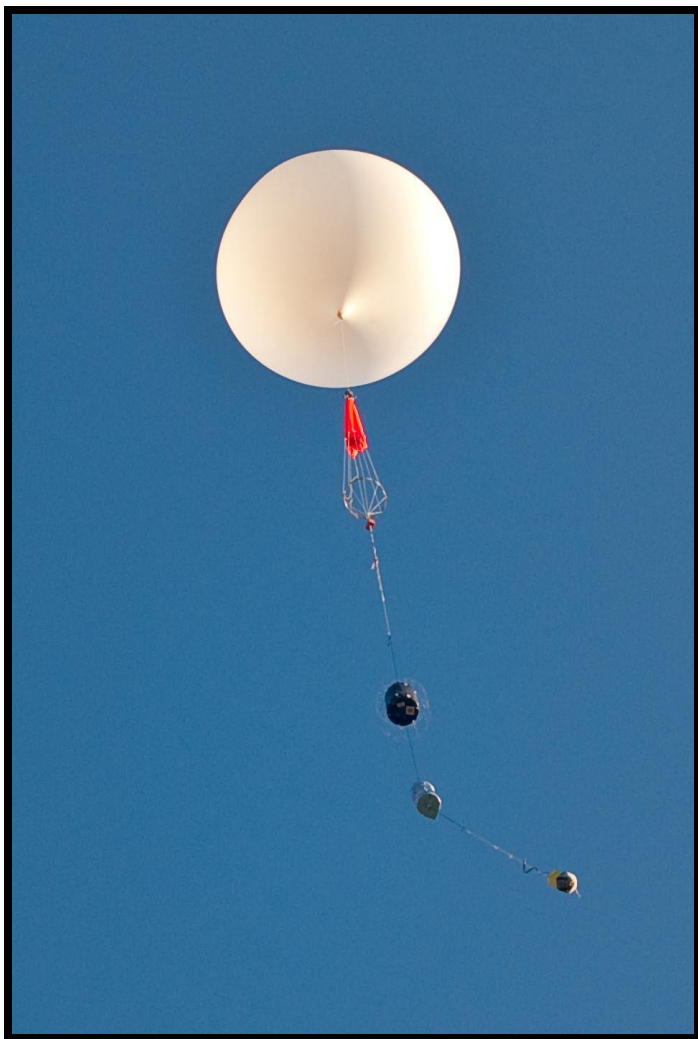


Spray Foam	Great Stuff		5.32
Cooler	Safeway		4.27
Dry Ice	Safeway		109.01
Thermistor	Electronic Goldmine	G2005	2.00
12"x12" Copper Clad	Electronic Goldmine	G17115	5.00
Heavy Duty Switches	Electronic Goldmine	GP64	2.49
10uF Capacitor	Electronic Goldmine	G16635	1.00
Space Heater	Electronic Goldmine	G16346	12.00
LowOhm Thermistor	Electronic Goldmine	G14663	0.99
Paint Brush	Ace		3.19
Vacuum Bag	Ace		14.93
NiChrome Wire	M-Pak Systems Inc		29.32
Epoxy Resin	Fort Collins Plastic		44.68
Hardware and Fasters	Ace		34.38

Total Cost: \$1163.13



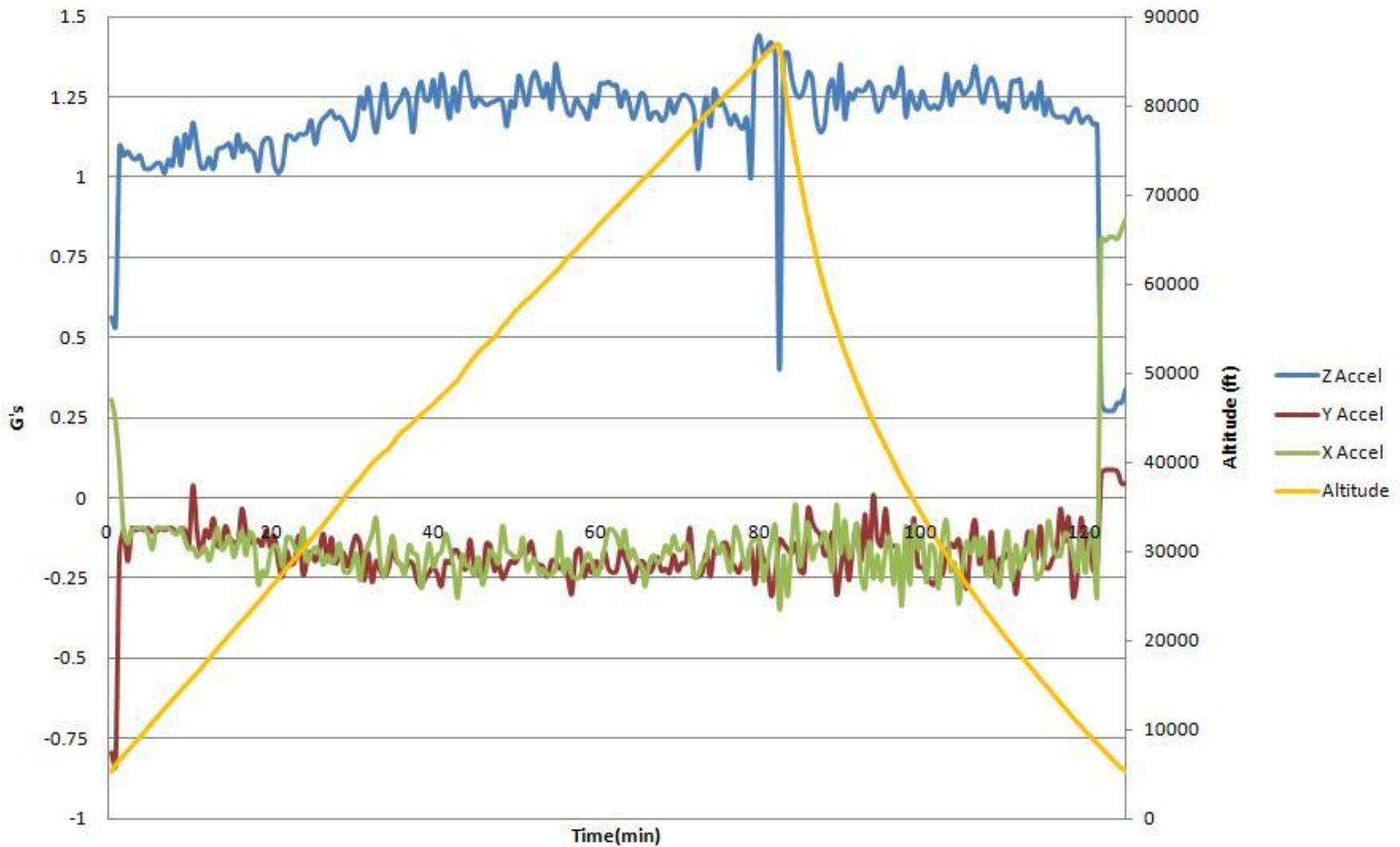
Flight





Mission Results

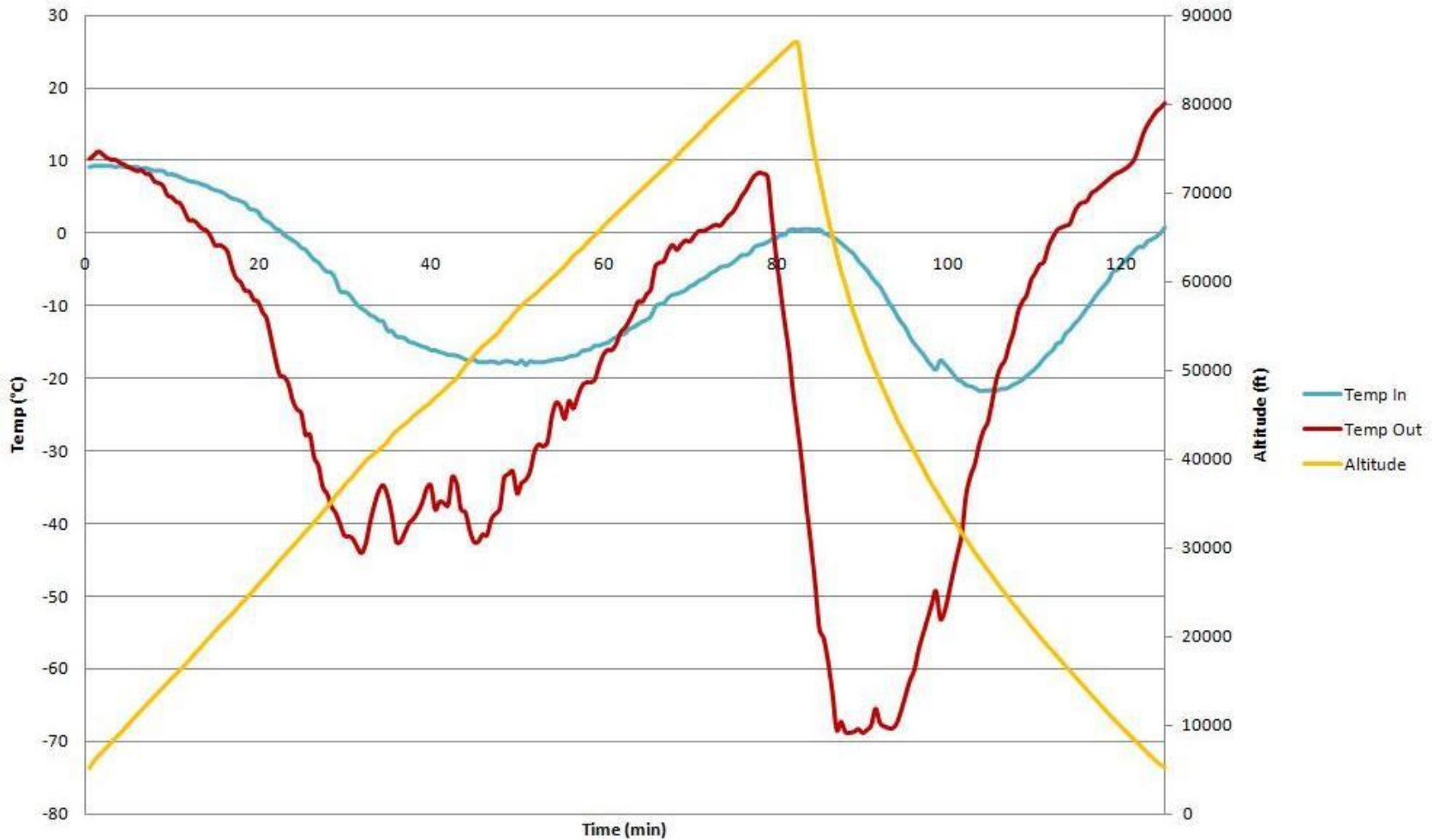
Acceleration vs. Altitude vs. Time





Mission Results

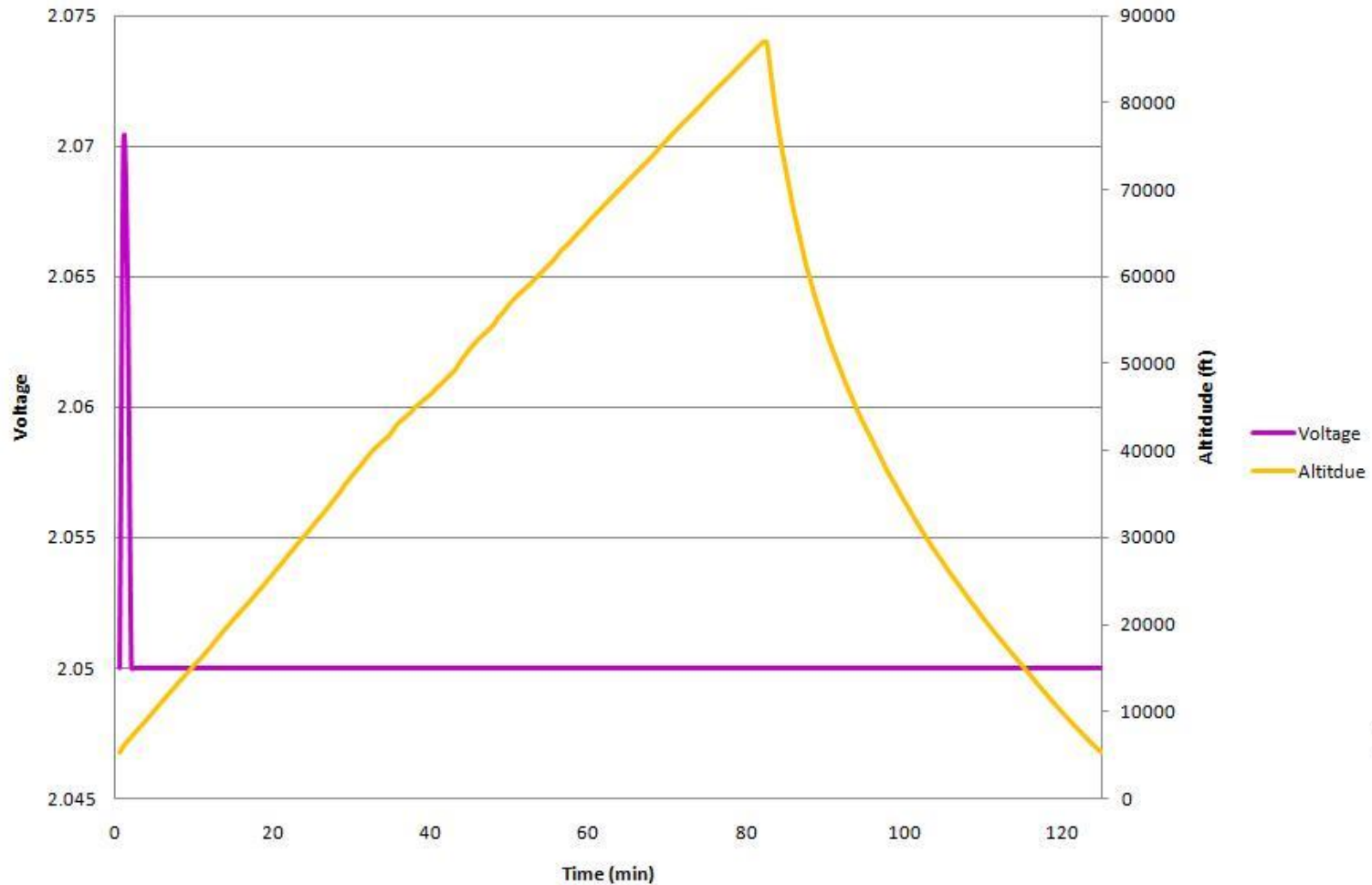
Temperature vs. Altitude vs. Time





Mission Results

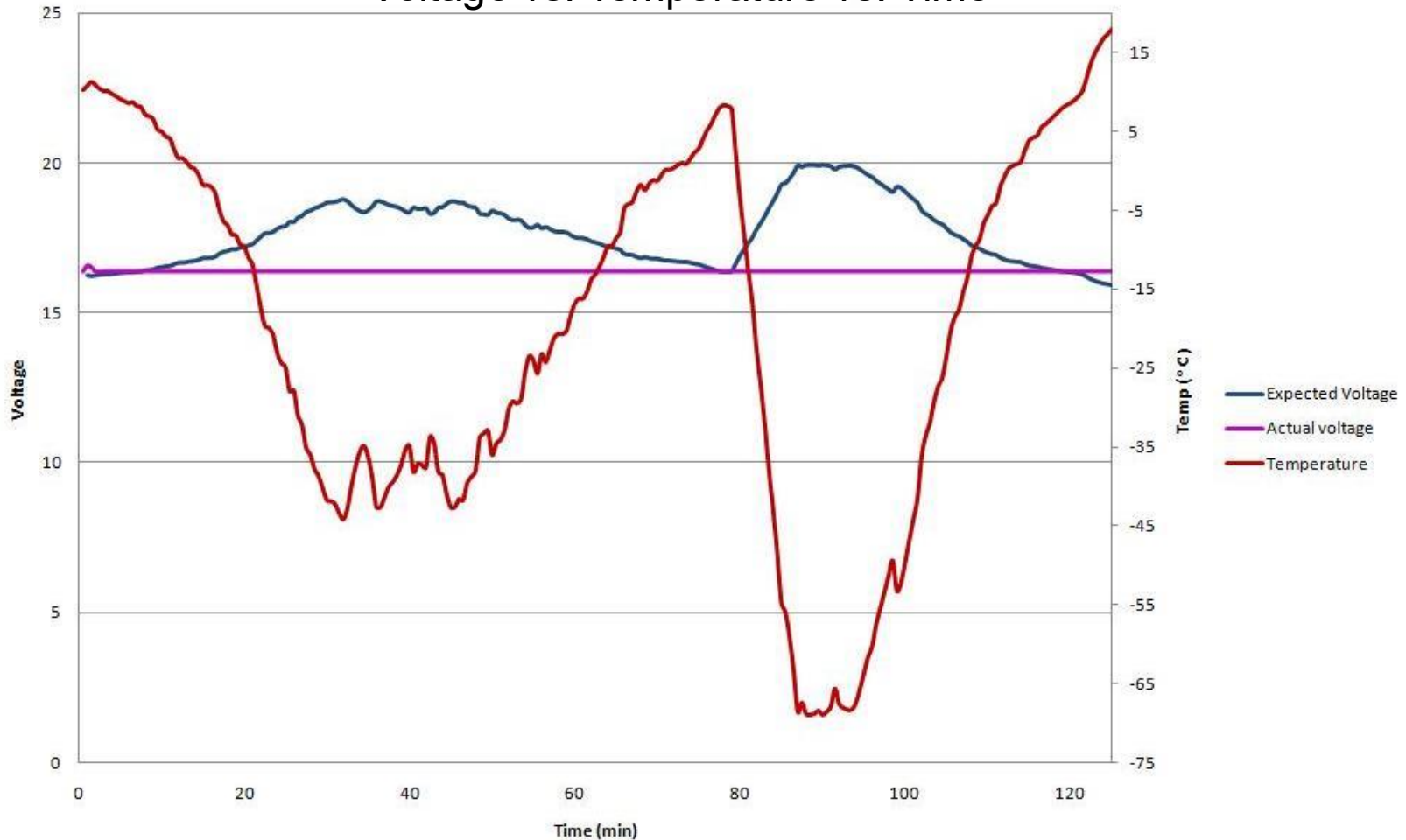
Voltage vs. Altitude vs. Time





Expected Results

Voltage vs. Temperature vs. Time



Expected max voltage at altitude of 40k-50k ft.



Lessons Learned



- Planning and Manufacturing
 - Plan for the unexpected, especially into the mass and cost budget
 - Build redundancy into the system
- Testing
 - Test each component individually before integration
 - Plan for all components breaking during testing into the budget
 - Repeat successful tests to minimize the risk of system anomalies



Questions?



Acknowledgements

- Dr. Azer Yalin, Associate Professor at Colorado State University
- Grant Rhoads, Graduate Student, Mechanical Engineering at Colorado State University
- Dr. Stephen “Doc” Schaeffer, Instructor at Colorado State University
- Jonathan Cox, Undergraduate Student, Electrical and Computer Engineering at Colorado State University
- Dr. Marko Topič, University of Ljubljana, faculty of Electrical Engineering and a guest at Physics Department Photovoltaics Lab , Colorado State University
- Dr. Don Radford, Associate Professor at Colorado State University
- Dr. John Williams, Associate Professor at Colorado State University
- Dr. Binyamin “Binny” Rubin, Post Doctoral Fellow at Colorado State University
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- Kendra Kilbride, Colorado Space Grant Consortium at University of Colorado
- Christopher Koehler, Colorado Space Grant Consortium at University of Colorado
- Shawn Carroll, Colorado Space Grant Consortium at University of Colorado
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- Thomas Aurand, Electronic Engineer at Colorado State University
- Tim Schneider, Undergraduate Student at Colorado State University and
- John Lucas, Undergraduate Student, Mechanical Engineering at Colorado State University

Thank you all for making this project possible