Project A.P.E.S.
Flight Readiness Review

Presented by:

Georgia Institute of Technology
Mile High Yellow Jackets

Agenda

1. Mission Overview (3 Min)
2. Project Budget (1 Min)
3. Project Schedule (2 Min)
4. Educational Outreach Update (2 Min)
5. Launch Vehicle (7 min)
6. Flight Systems (3 Min)
7. Flight Avionics (7 min)
8. Questions (15 Min)

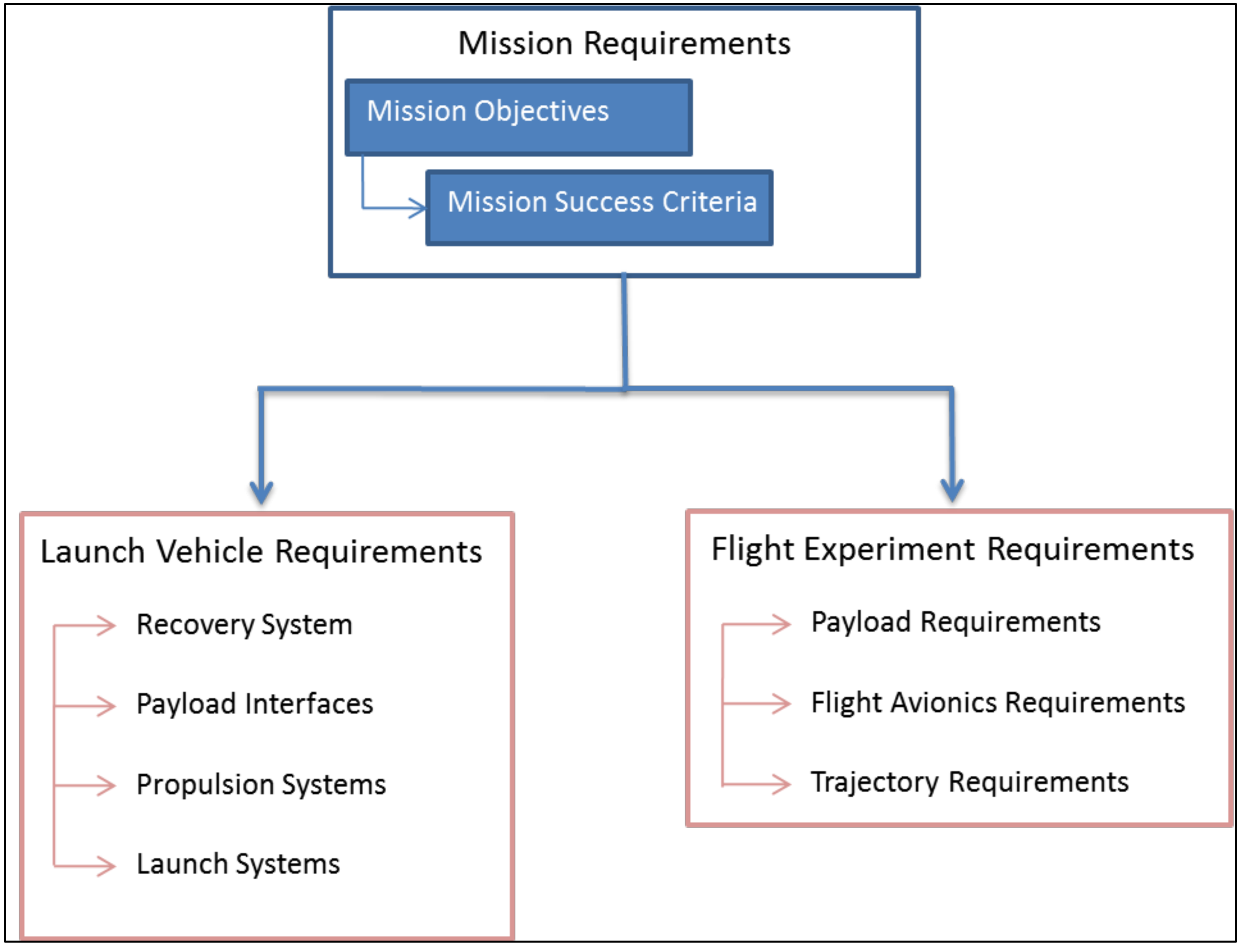
Project A.P.E.S. FRR

MISSION OVERVIEW

Mission Overview

To maintain a sustainable team dedicated to the gaining of knowledge through the designing, building, and launching of reusable launch vehicles with innovative payloads in accordance with the NASA University Student Launch Initiative Guidelines.

Requirements Flow Down

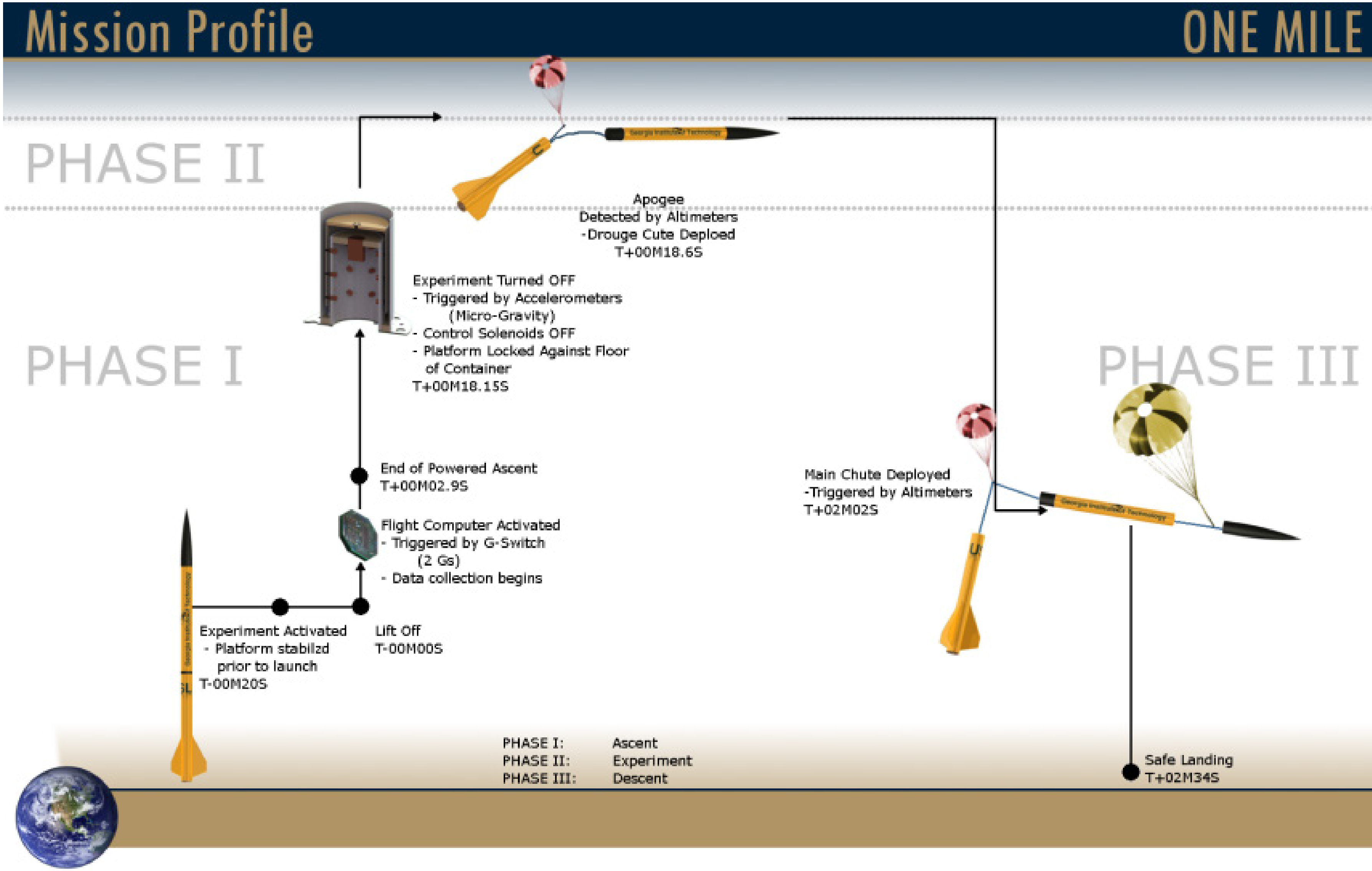


Mission Objectives& Success Criteria

MO	Mission Objectives
MO-1	An altitude of 5,280 ft. above the ground is achieved.
MO-2	Stabilize and isolate the A.P.E.S. platform from the induced vibrations of the Launch Vehicle.
MO-3	Closed-loop control of the platform via real-time image processing.
MO-4	Successful recovery of the launch vehicle resulting in no damage to the launch vehicle.

MSC	Mission Success Criteria	Source	Verification Method	Status
MSC-1	Achieve an altitude of 5,280 ft., with a tolerance of +320 ft./-640 ft.	MO-1	Testing, Analysis	Completed
MSC-2	The Flight Experiment is successfully activated and data is collected.	MO-2, MO-3	Inspection, Analysis	Completed
MSC-2.1	*Minimum Mission Success*: Platform is stabilized and isolated during the coast phase of flight	MO-2	Testing	In Progress
MSC-2.2	*Minimum Mission Success*: Relative position and rotation data of the platform to the camera is collected during all phases of the experiment.	MO-2, MSC-2	Testing	In Progress
MSC-2.3	*Minimum Mission Success*: The flight experiment terminates at apogee.	MO-4, MSC-2	Inspection	In Progress
MSC-2.4	*Full Mission Success*: Platform is stabilized and isolated from environmental vibrations during the powered and un-powered portions of the flight.	MO-2, MSC-2	Testing	In Progress
MSC-2.5	*Full Mission Success*: Platform does not come into contact with any other components of the A.P.E.S. System.	MO-3, MSC-2.4	Testing	In Progress
MSC-3	The launch vehicle experiences no in-flight anomalies.	MO-4	Testing	In Progress
MSC-3.1	*Minimum Mission Success*: The launch vehicle is recovered with no damage.	MO-4, MSC-3	Testing	In Progress
MSC-4	*Minimum Mission Success:* The cost of the all the components, including the Launch Vehicle, Flight Experiment, Flight Avionics, and Motor, shall cost no more than $5,000.	USLI Handbook	Inspection, Analysis	Completed

Mission Timeline

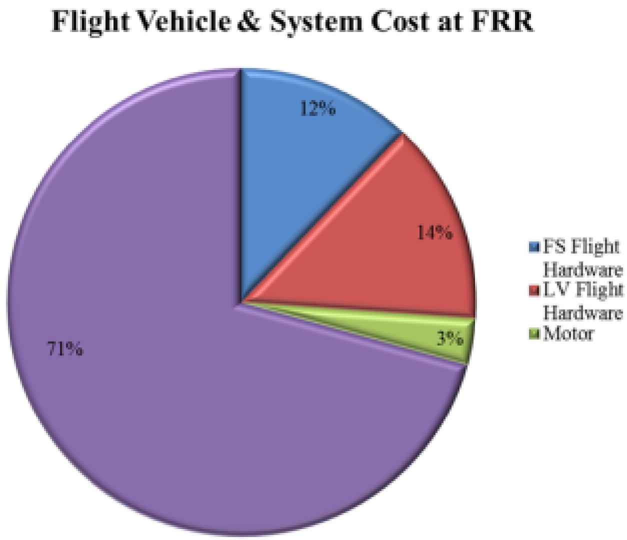


Project A.P.E.S. FRR

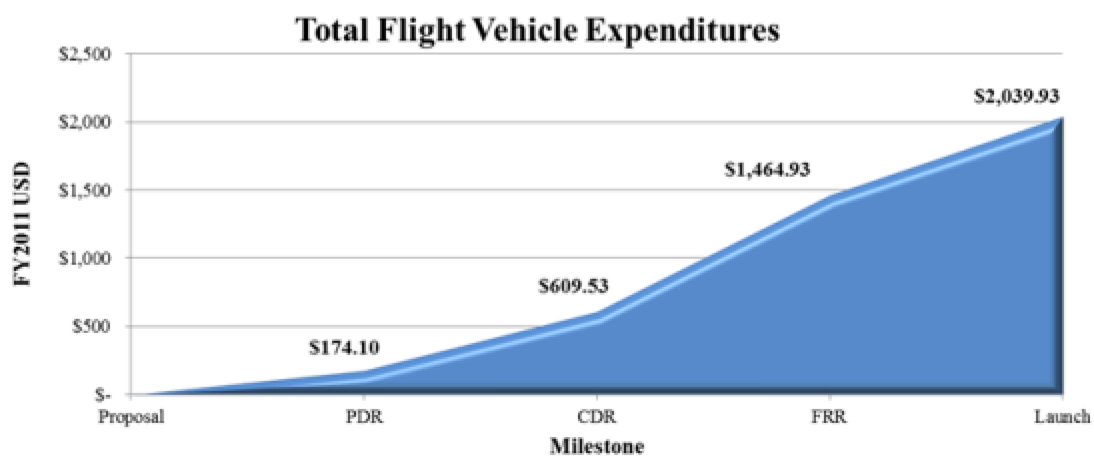
PROJECT BUDGET

Flight Vehicle Expenditure Summary

2011-2012 Overall Flight Vehicle Costs ($5,000 Limit)	
FS Flight Hardware	$ 438.20
LV Flight Hardware	$ 458.90
Motor	$ 300.00
Remaining	$ 3,802.90
Total	$ 5,000.00



	Cumulative Costs	*% Remaining*
PDR	$ 174.10	96.5 %
CDR	$ 609.53	87.8 %
FRR	$ 1,464.93	70.7 %
Launch	$ 2,039.93	59.2 %

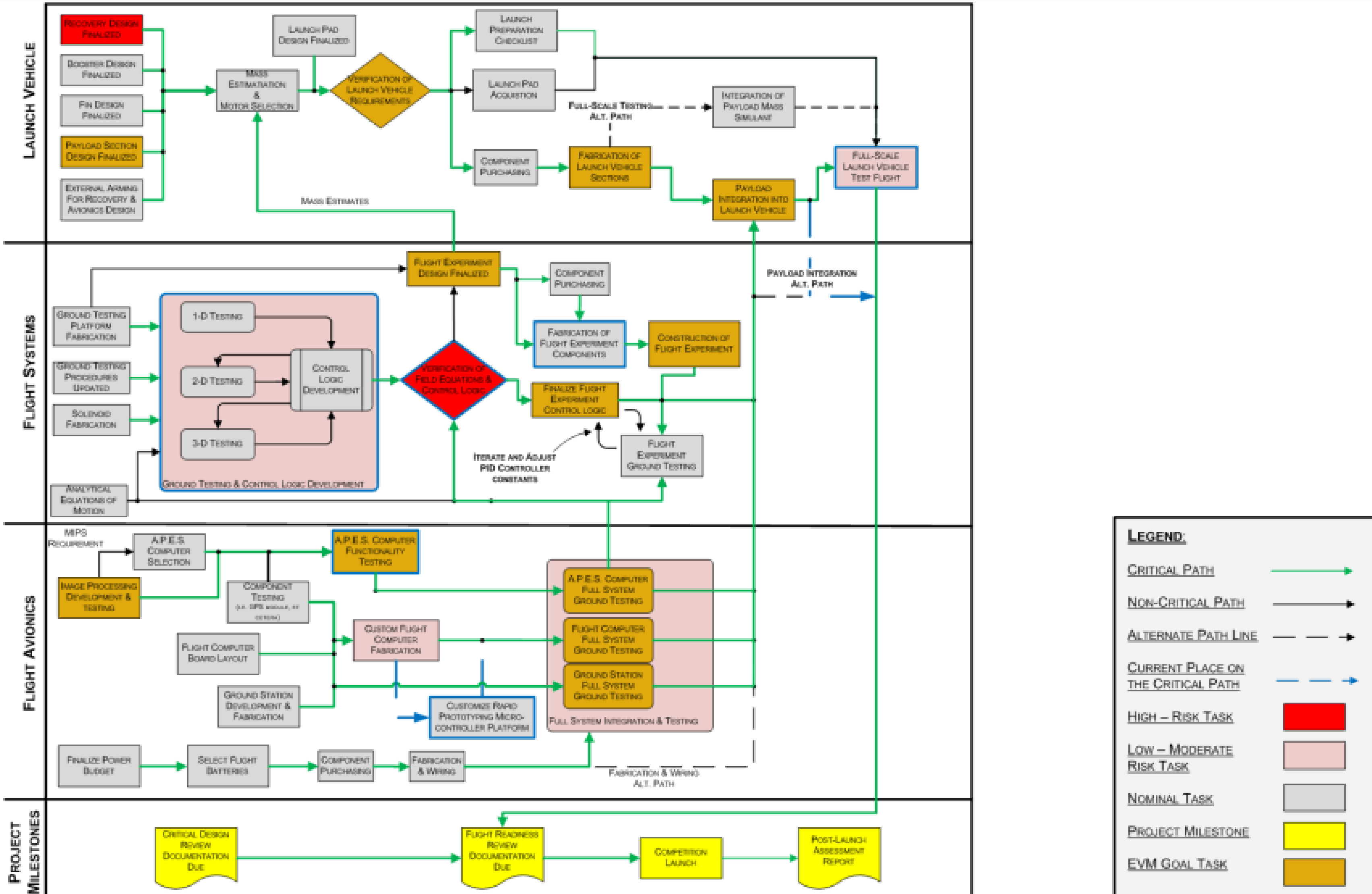


Georgia Tech USLI UNIVERSITY STUDENT LAUNCH INITIATIVE

Project A.P.E.S. FRR

PROJECT SCHEDULE

Critical Path Chart



Georgia Tech USLI University Student Launch Initiative

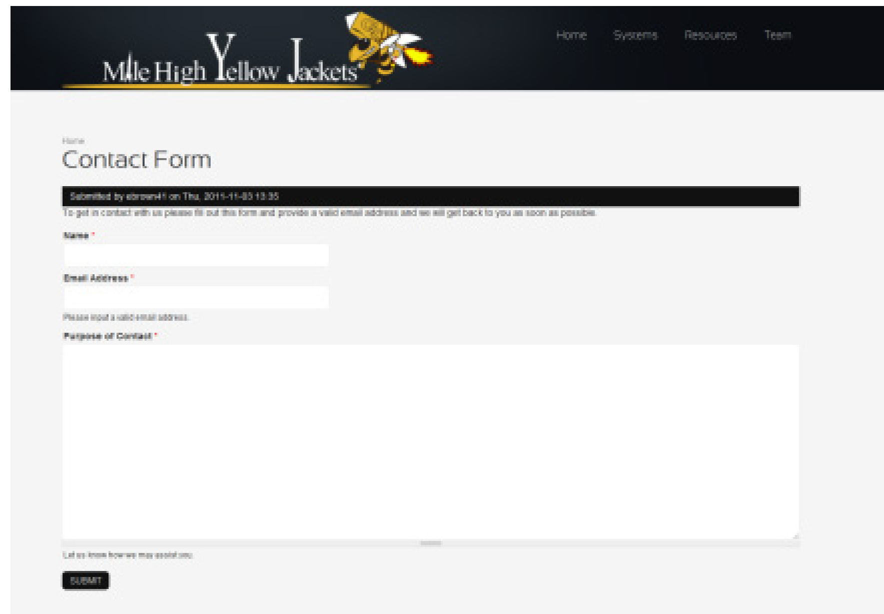
Project A.P.E.S. FRR

EDUCATIONAL OUTREACH

Educational Outreach

- Goal: Promote interest in STEM fields

- Educators can request presentations or hands-on activities for their classroom



Education Outreach Activities

First LEGO League EO Event

National Air & Space Museum Discovery Station

Activity	Date	No. of Students & Educators Reached
FIRST LEGO League	Jan. 28th	700+
Civil Air Patrol Model Rocketry Program	April 5th, April 20th	20-30
National Air & Space Museum Discovery Station	March 24th	~137 (in 2 hrs.)

Project A.P.E.S. FRR

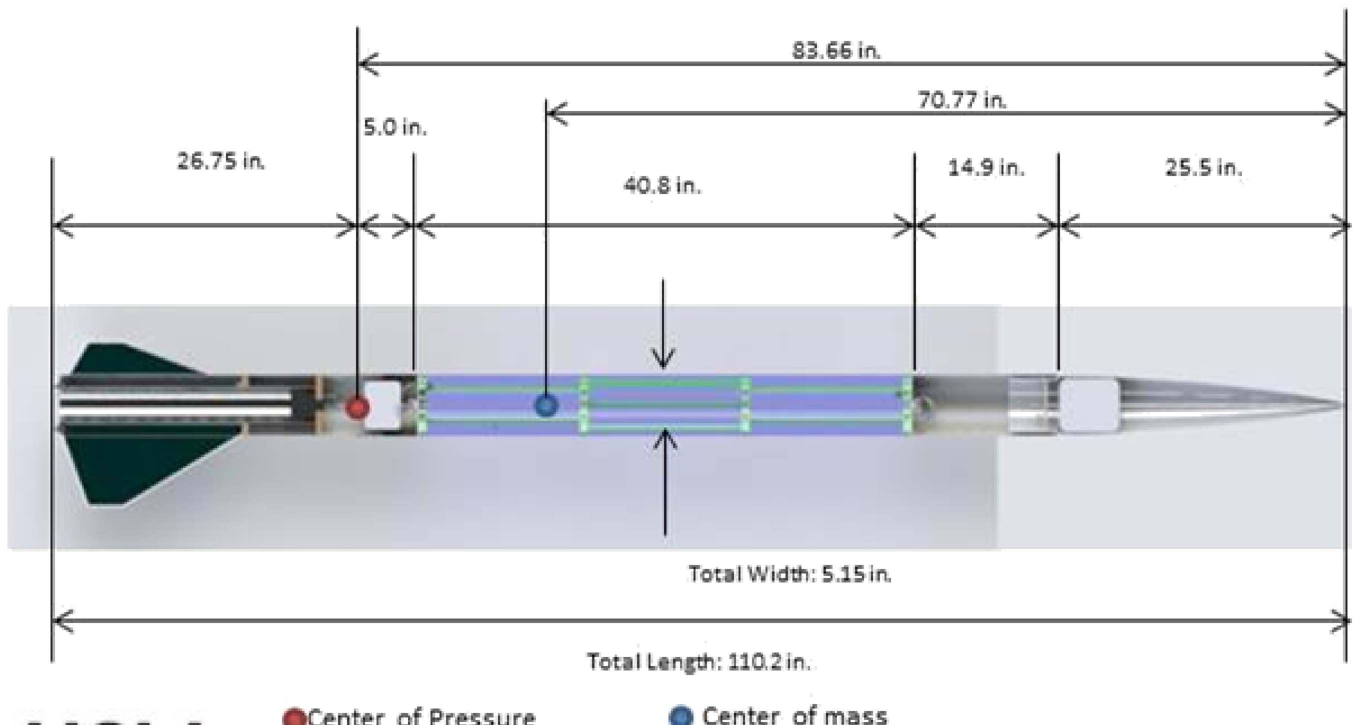
LAUNCH VEHICLE

Changes Since CDR

- The main parachute diameter was reduced from 12 ft. to 10 ft.
- The new landing velocity under the 10 ft. diameter main parachute is 17 ft./s with a corresponding maximum landing kinetic energy of 62.2 ft.- lb_f .
- The ejection charge masses have been reduced from 3.6g and 4.5g to 3.0g and 4.0g respectively.
- L-brackets have been added to the recovery system bulkheads at epoxy joints for added strength.

Launch Vehicle: Summary

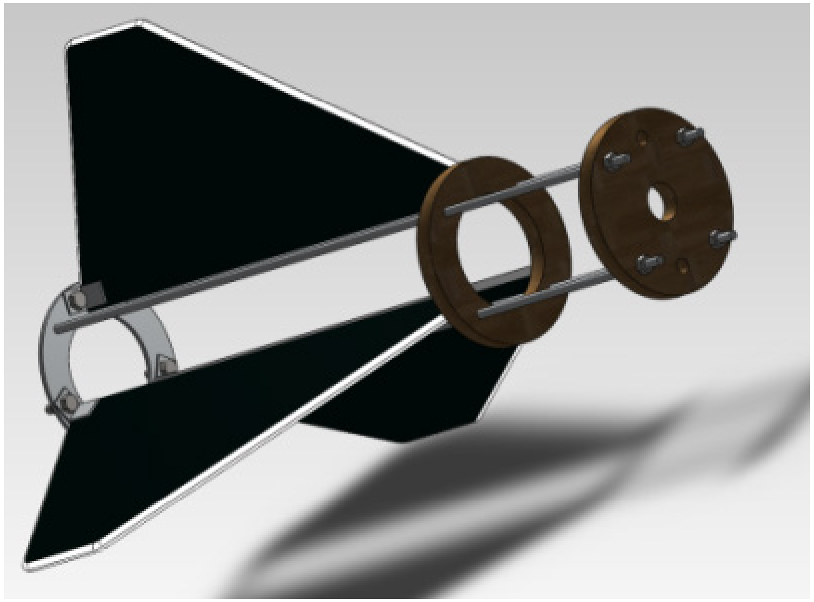
- Predicted apogee: 5312 ft
- Stability margin: 2.5 calibers
- Motor: AeroTech L850
- 47 ft/s at 60 inches up the rail
- Max Mach 0.57
- Total weight: ~31 lbs
- Dual deployment

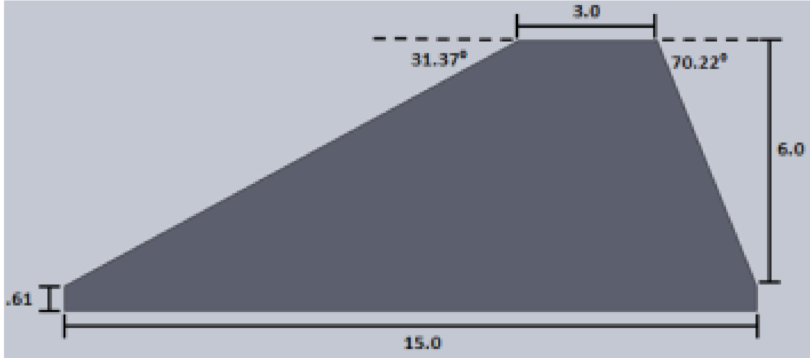


Launch Vehicle: Fins

- Material: Carbon fiber honeycomb
- Attachment: Epoxy

Variable	Value
Number of fins	3
Root chord	15 in
Tip chord	3 in
Height	6 in
Sweep Angle	59.6°
Sweep Length	9.8 in



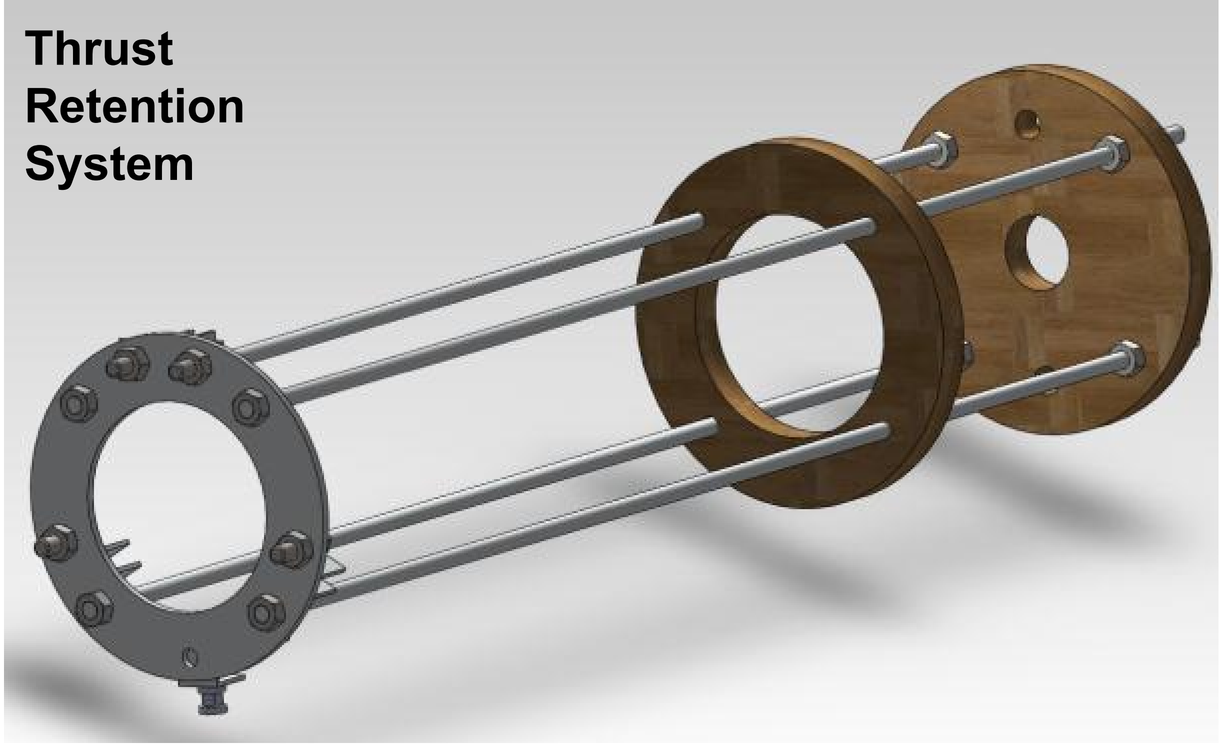


Launch Vehicle: Fin Testing

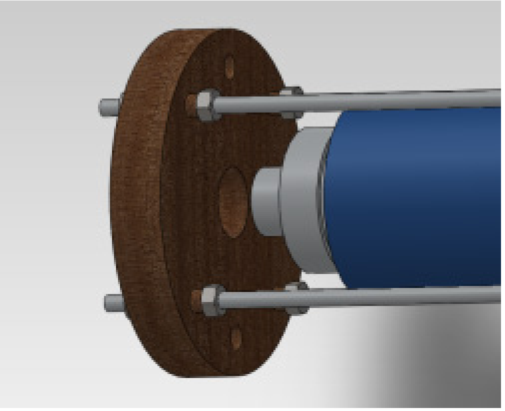
- 28 lbf applied at aerodynamic center of fin
- Corresponds to 3x greater than expected drag force

Launch Vehicle: Booster Section

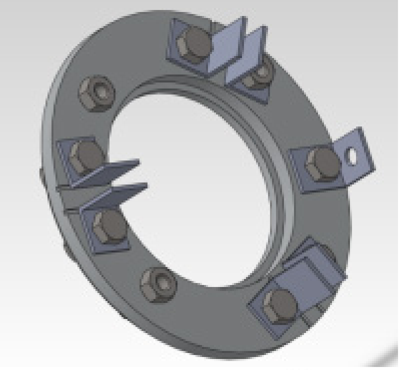
- Material: Aluminum and wood
- Attachment: Nuts, bolts, and epoxy



Thrust Plate

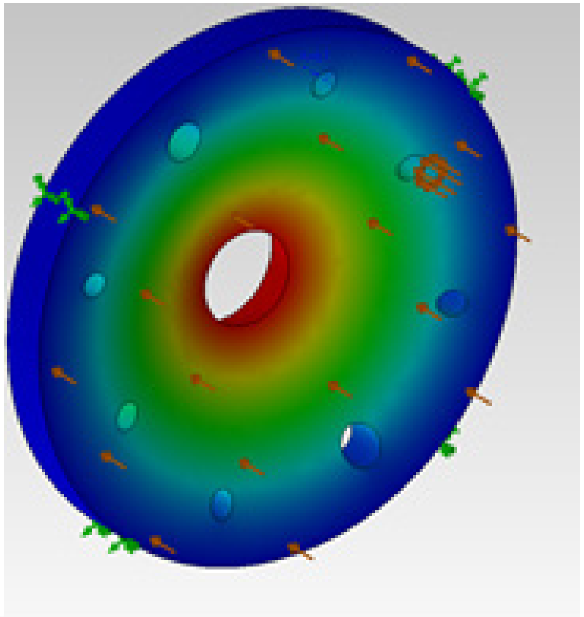


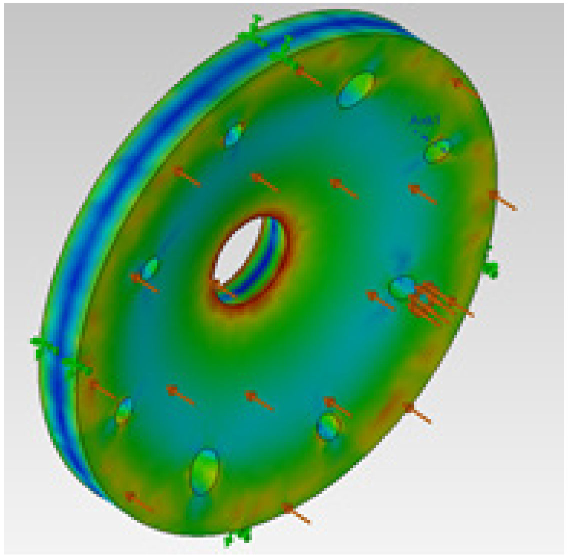
Retention Plate



FEA Analysis & Results

Part	Material	Force applied (lb_f)	Max displacement (inches)	Max stress (psi)	Safety factor
Thrust Plate	BS1088 Plywood	408	.00838	404.6	3.3
Stringers	AL 6061	408	.00526	483.3	2.9





Launch Vehicle: Thrust plate Testing

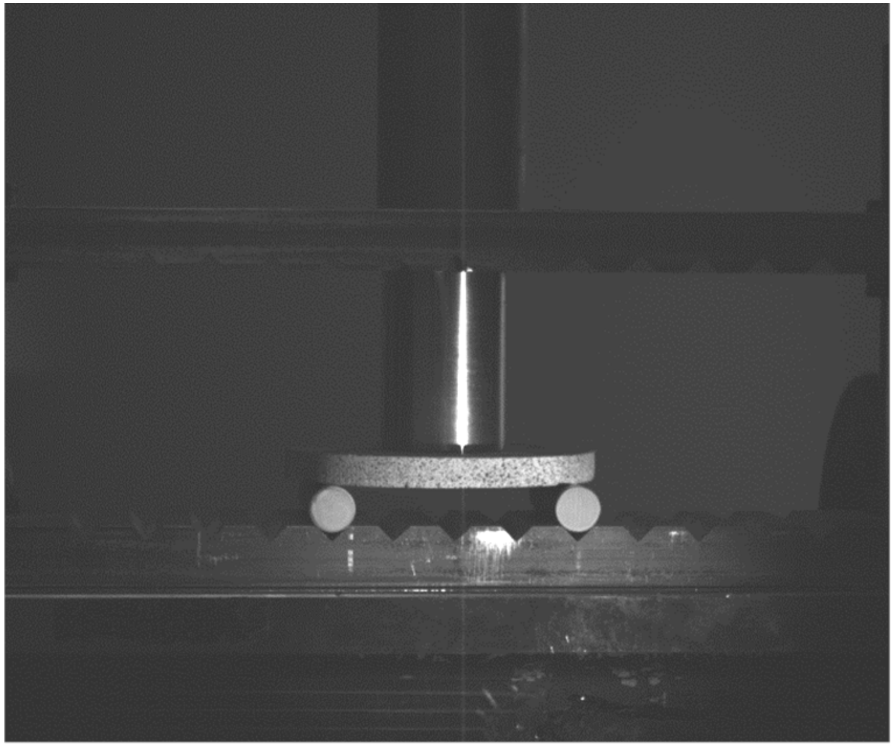


Figure 1: Test article at 400 lbs

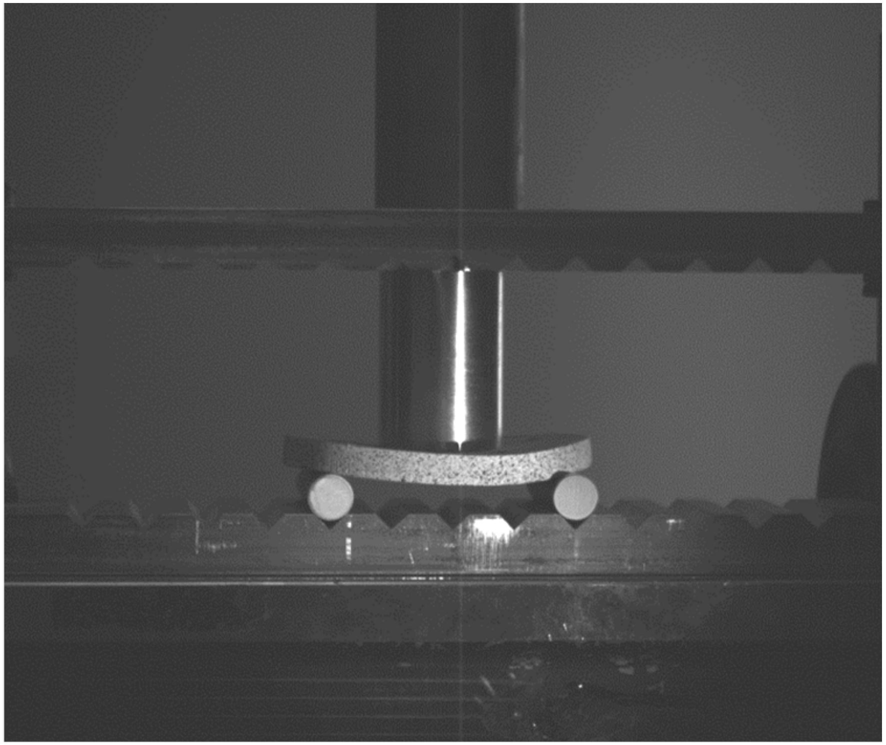
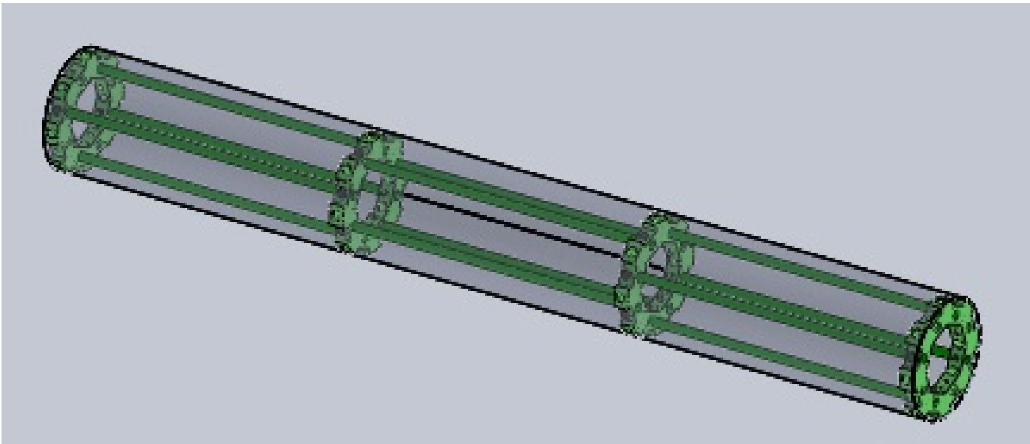
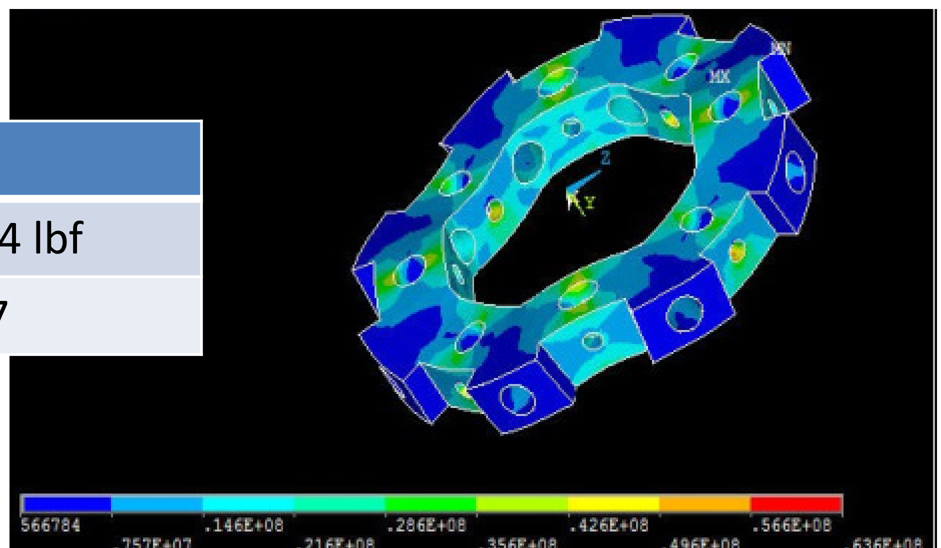


Figure 2: Test Article at critical failure (947 lbs)

Integrated Modular Payload System (iMPS)

- Material: G10 Fiberglass, bolts

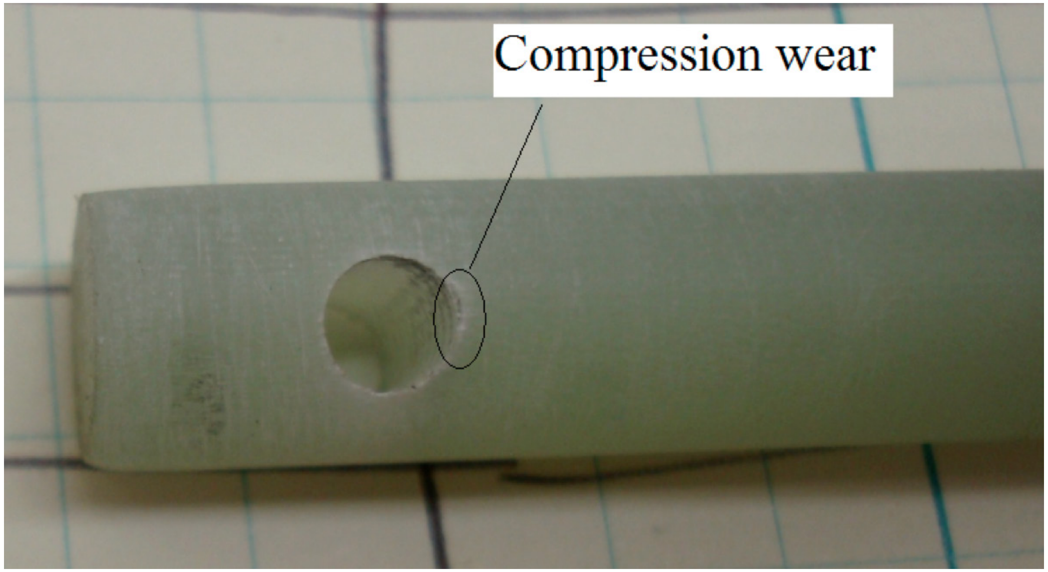




Rib FEA	
Load	684 lbf
FS	4.7

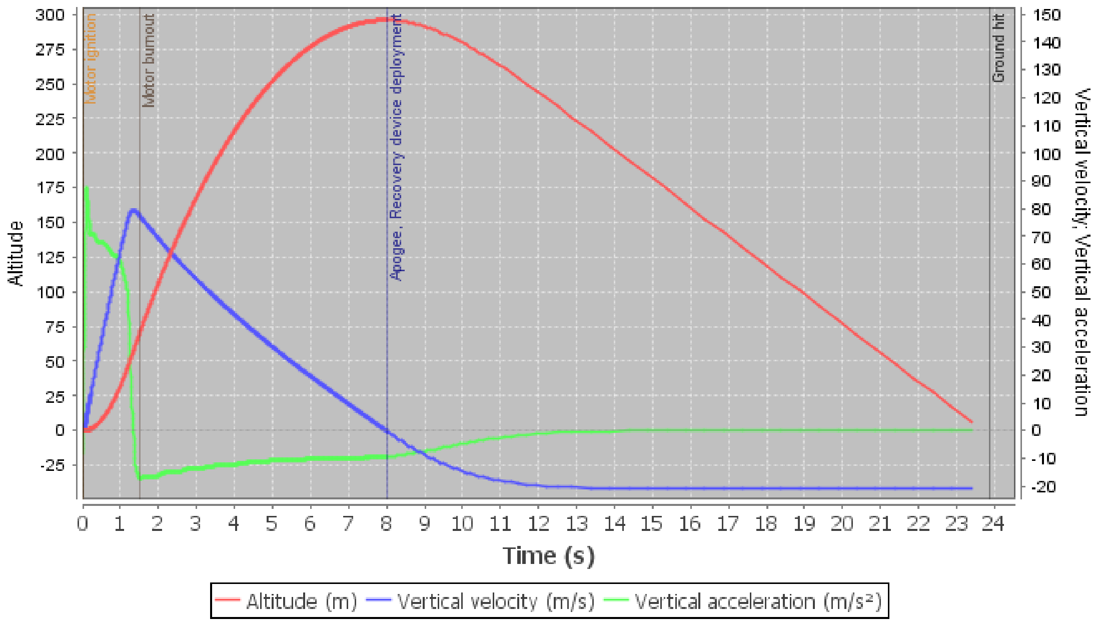
Payload Structure Impact Test

Impactor mass (kg)	Factor of Safety	Impact Energy (J)	Impactor Height (in)	Stringer length (in)	Notes
3.98	1	5.23	11.08	14	Pass
3.98	2	10.47	22.16	14	Pass
3.98	3	15.70	33.24	14	Pass



Skin – Test Vehicle, Korsakov

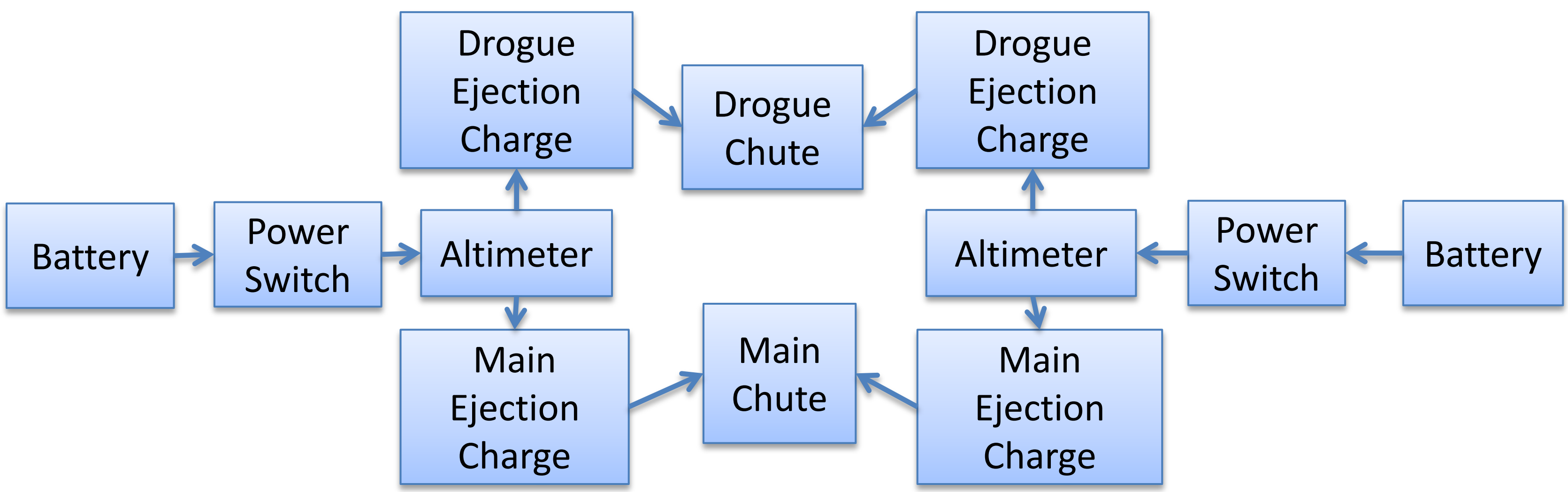
Korsakov Estimated Flight Profile



Launch Vehicle: Recovery

- Dual deployment system
- Altimeter: 2 StratoLoggers for redundancy

	Mass (lbs)	Velocity (ft/sec)	KE (ft-lb)	KE Margin (ft-lb)
Nose Cone	1.59	17	7.2	90.5%
Booster Section	7.59	17	34.2	54.5%
Payload Section	13.82	17	62.2	17.1%



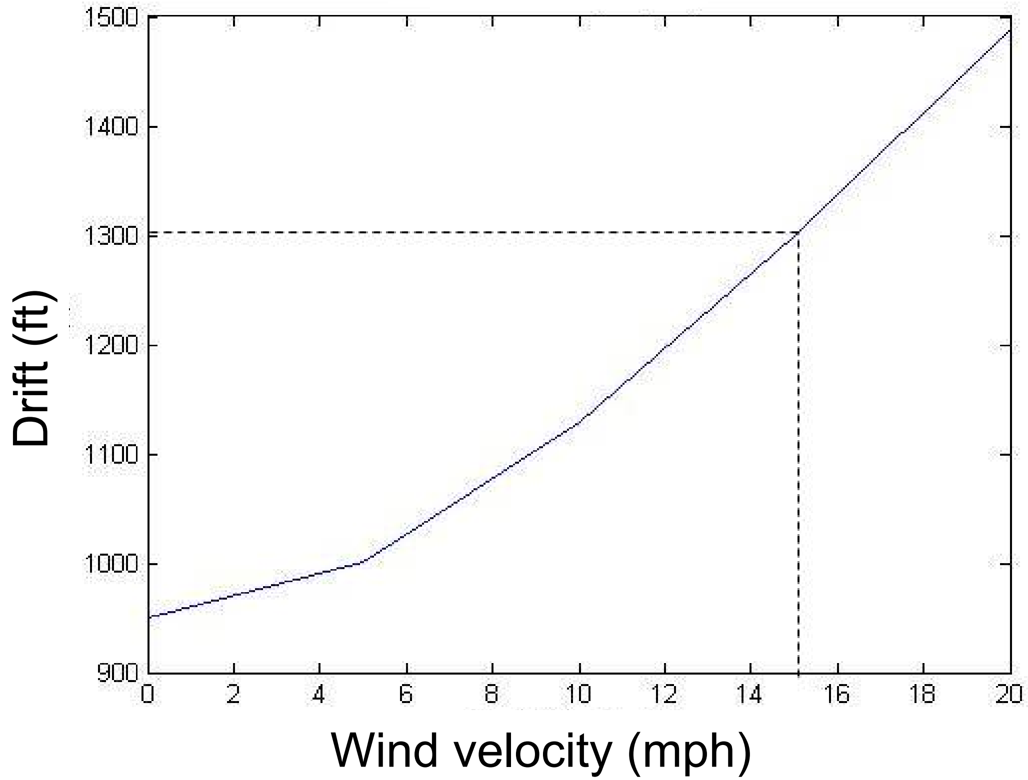
Launch Vehicle: Recovery Testing

Black powder ejection charges:

Drogue: 3 grams   Main: 4 grams

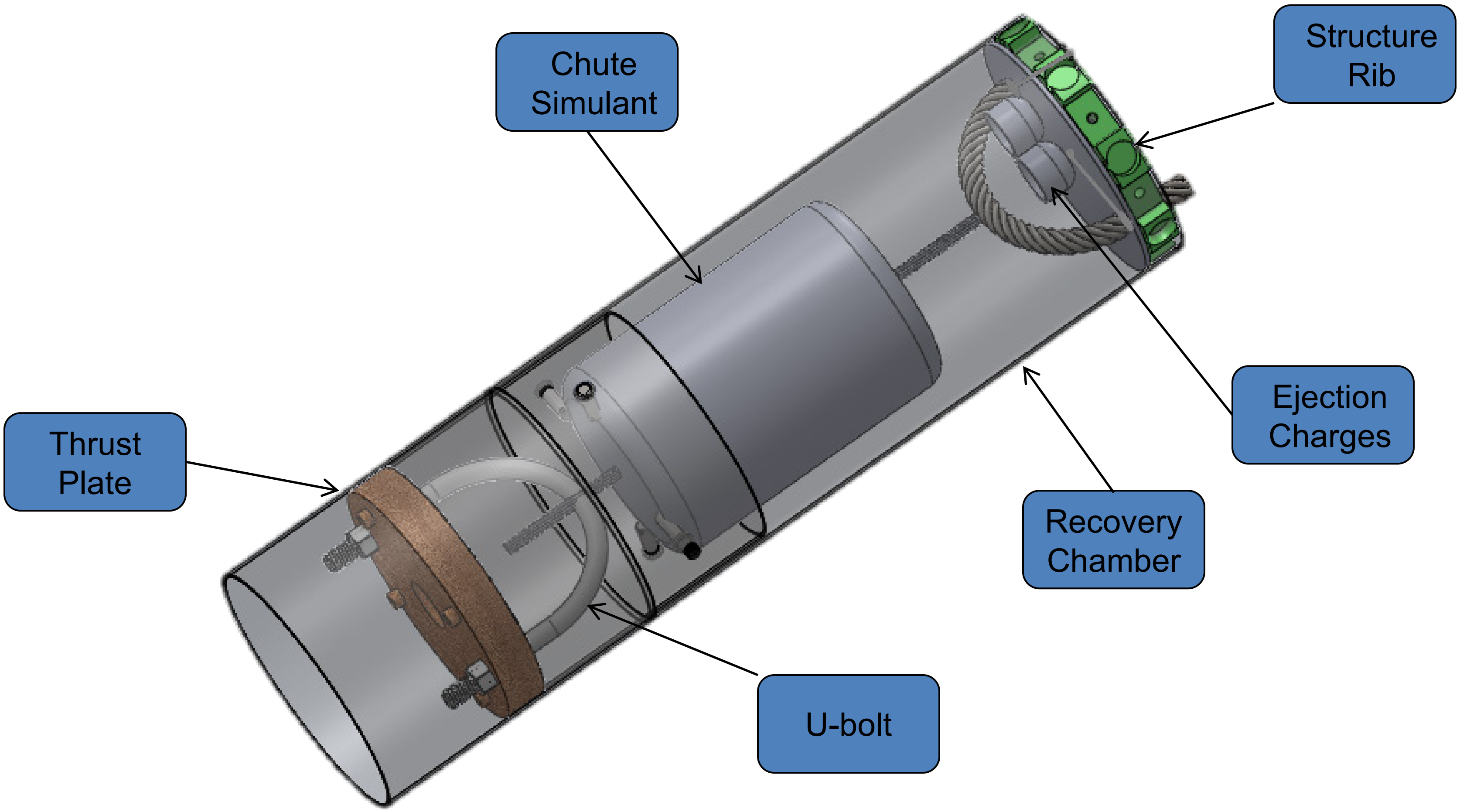
Launch Vehicle: Drift Profile

Drift From Launch Pad at Various Wind Speeds

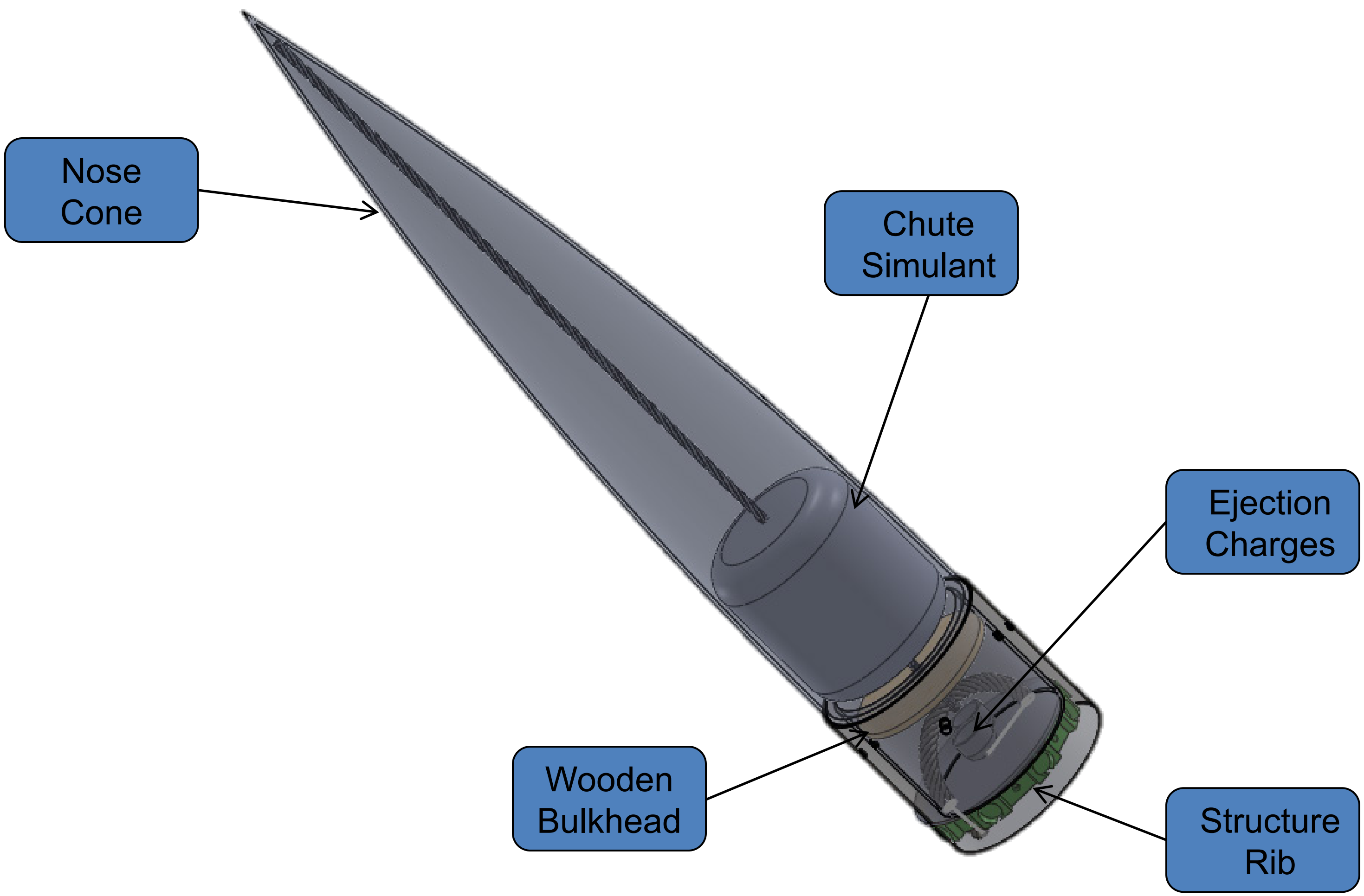


Test data point supporting accuracy of Recovery Calculations located in the back-up slides

Launch Vehicle: Recovery – Drogue



Launch Vehicle: Recovery – Main



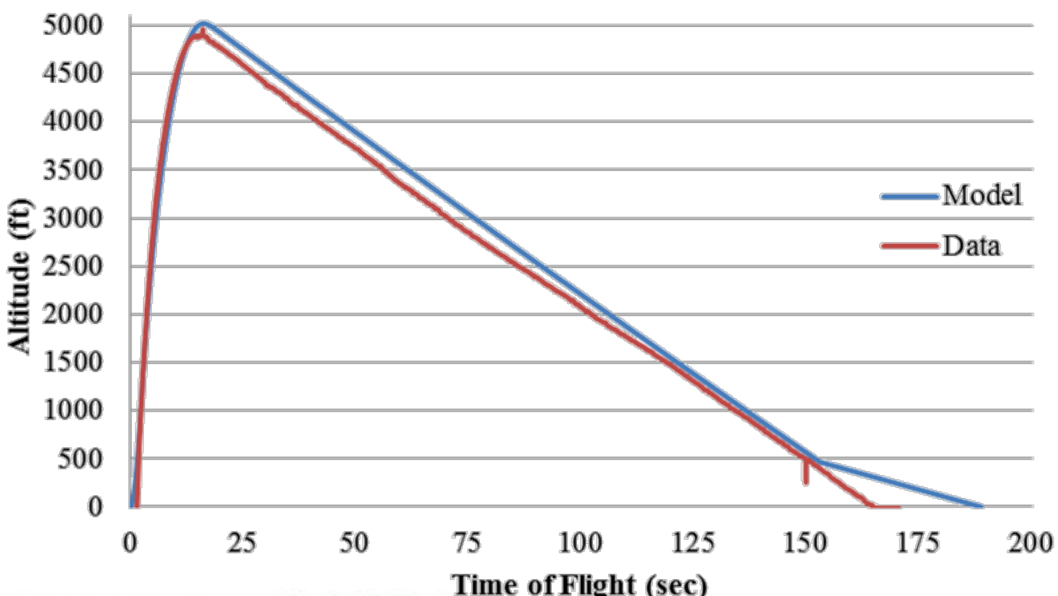
Launch Vehicle: Full Scale Flight Test

Location: Manchester, TN

Motor: L990 motor

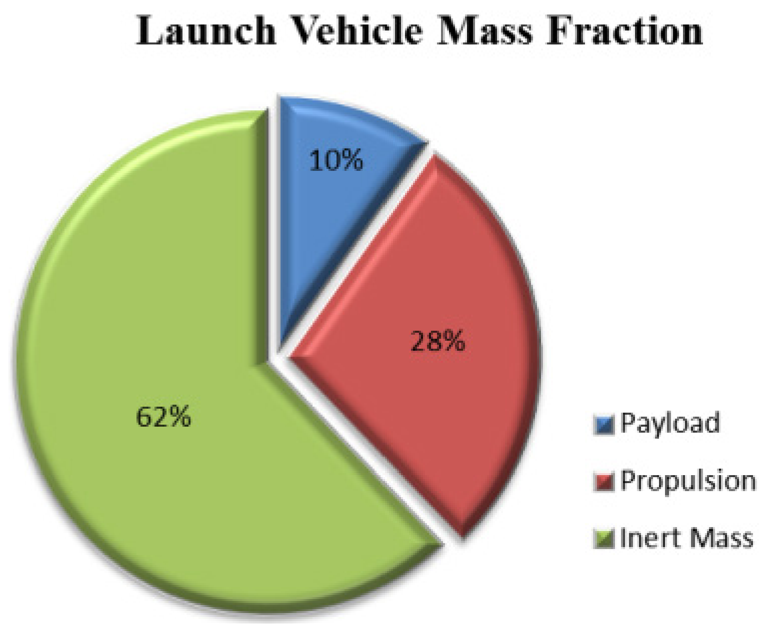
Altitude: 4,910 ft.

Failures: Main Parachute Deployment Failure



Launch Vehicle: Mass Breakdown

Component	Weight (lbs)
Nose Cone	1.6
Avionics System/Payload	2.9
Ballast	5.0
Payload & Recovery Structure	5.9
Parachutes and Shock Cords	4.2
Booster Structure	3.9
AeroTech L850 Motor	8.3
Total	**31.8**



Launch Vehicle: Finished Product

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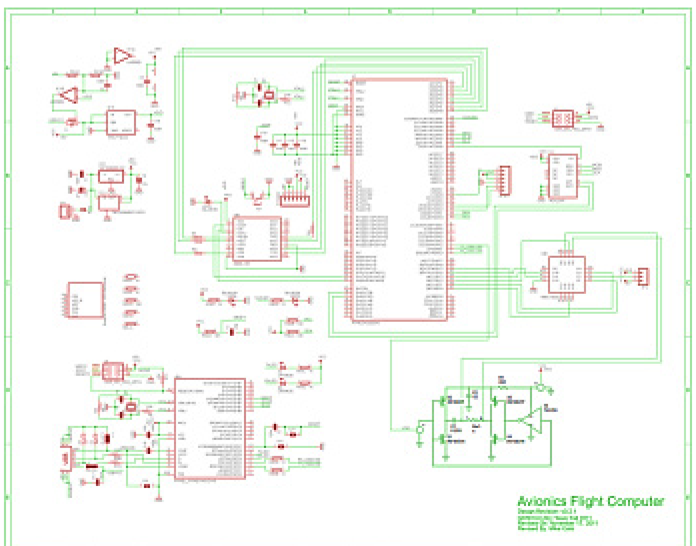
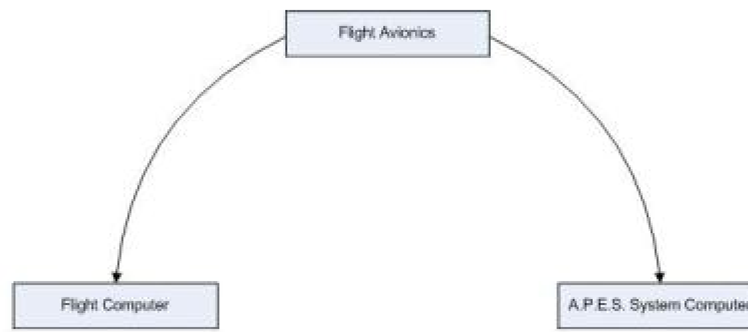
FLIGHT SYSTEMS

Flight Systems Responsibilities

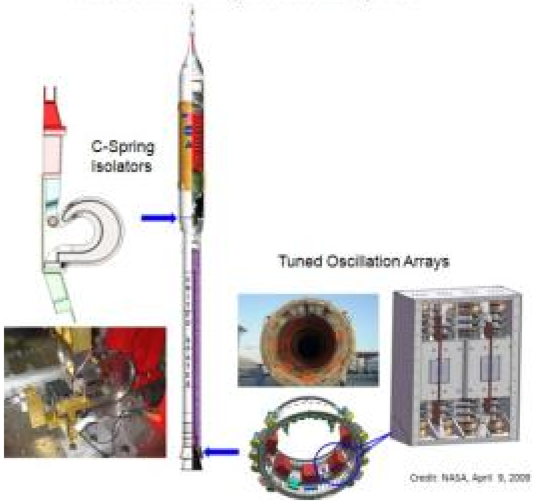
- Payload
- Avionics
- Communications
- A.P.E.S. Ground Testing





Flight Systems: Payload

- Current solutions to the problem of eliminating natural frequency oscillations
  - Mechanical C-Spring Isolators
  - Tuned Oscillation Arrays
  - Long duration exposure without blurring
- Use of advanced isolation components adds mass and design constraints



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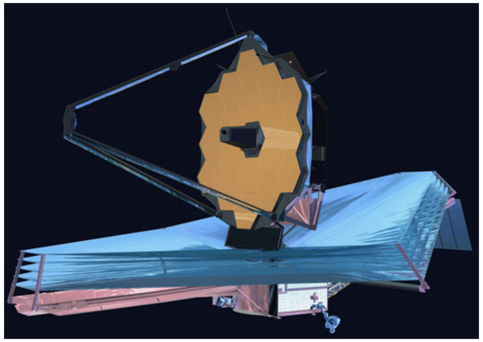

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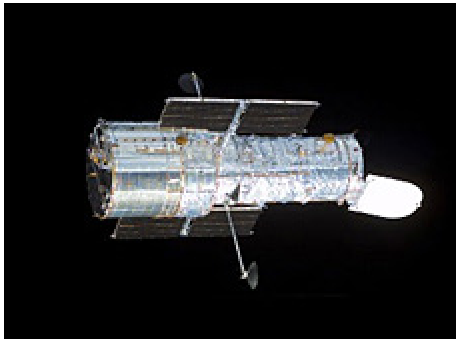

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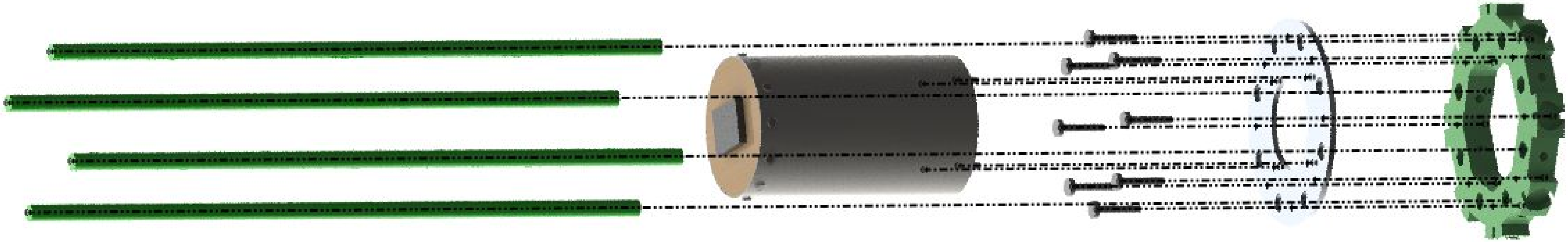
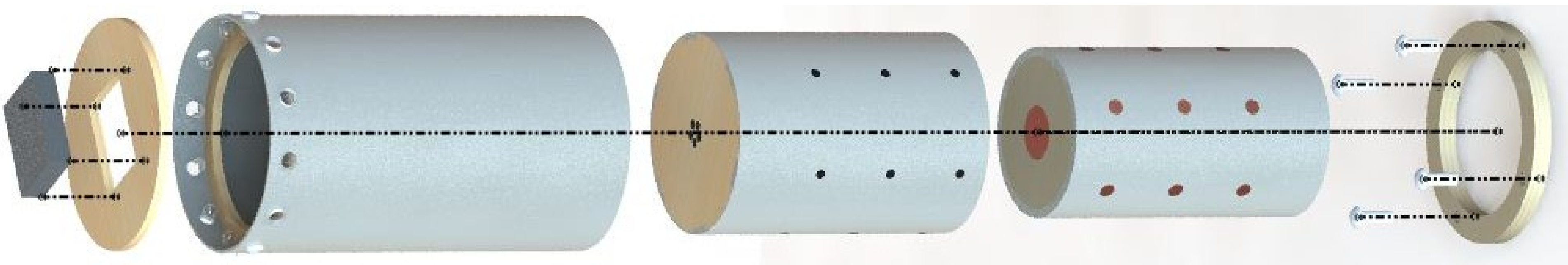
Flight Systems: Expanded Views



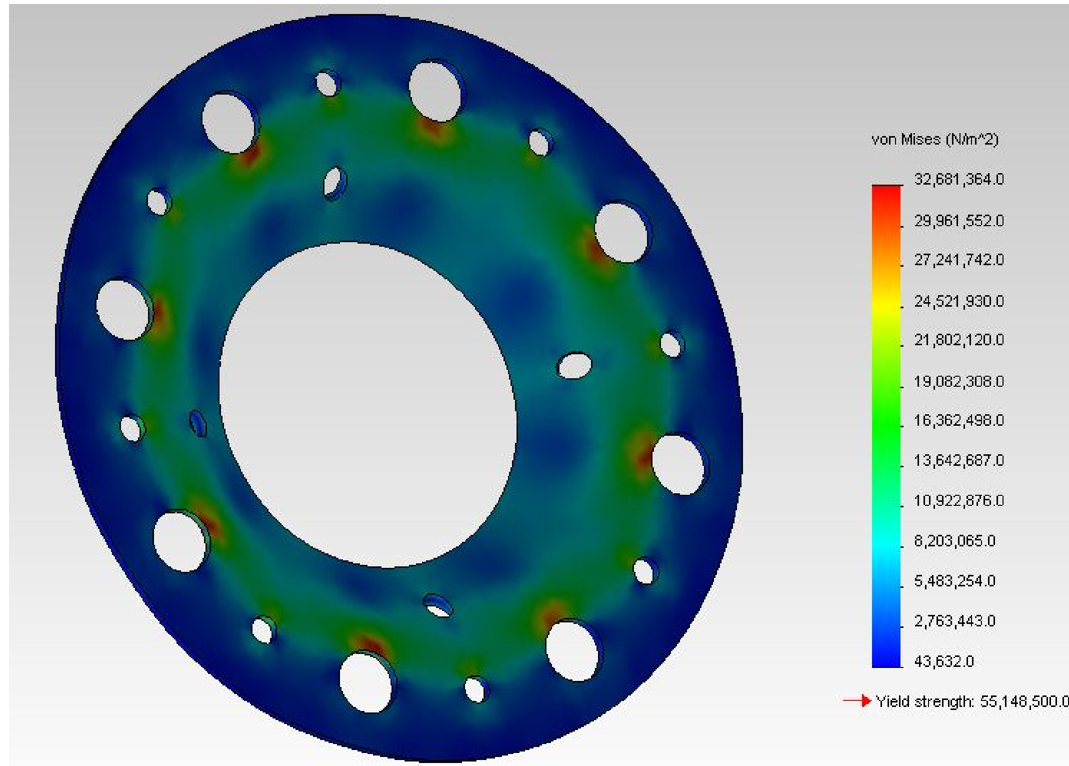
Payload Integration Expanded View



A.P.E.S. Expanded View

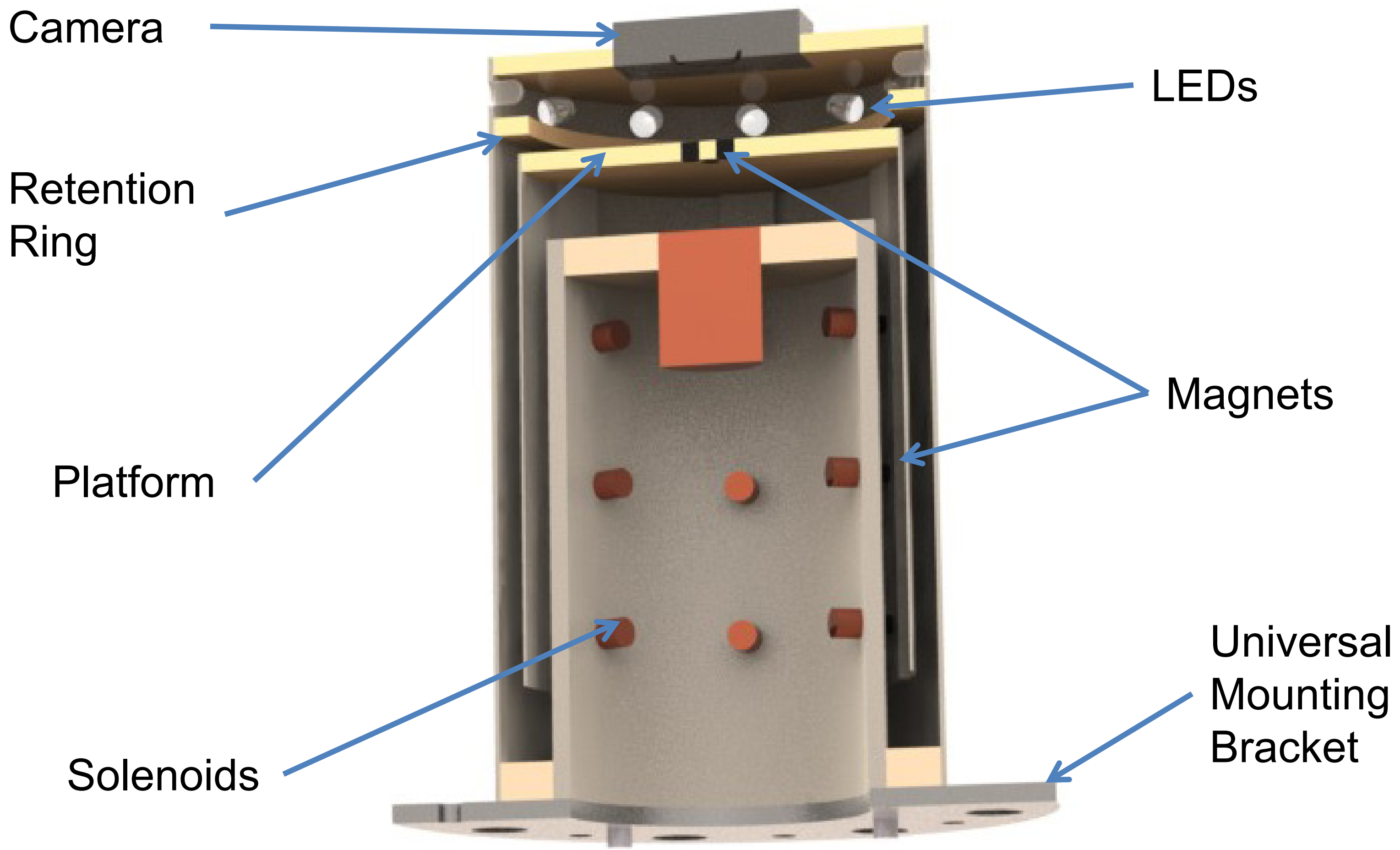
Flight Systems: Universal Mounting Bracket

- Repeatable manufacturing
- Few constraints on Payloads
- Ease of mounting hardware
- High durability



**Deformation Exaggerated

Flight Systems: A.P.E.S.

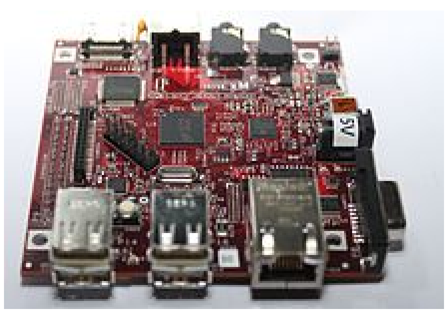


Project A.P.E.S. FRR

FLIGHT AVIONICS

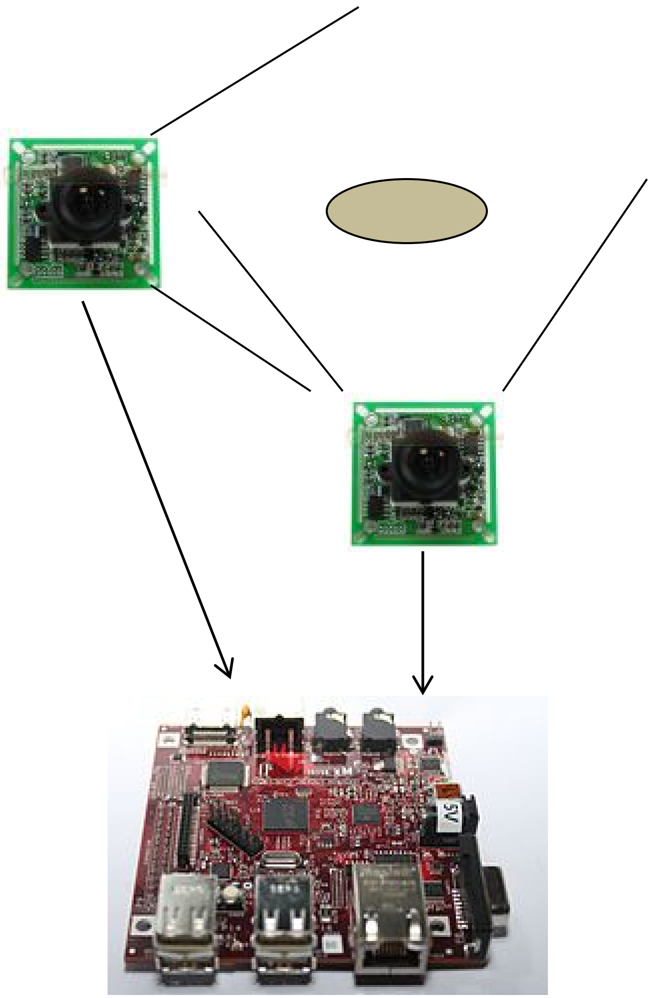
A.P.E.S. Computer

- BeagleBoard xM
  - ARM TI DM3730
  - ~850 BogoMIPS
  - Hardware DSP
  - 512MB DDR RAM
  - NEON CoProcessor
  - 3x i2c Bus
  - 2x webcams

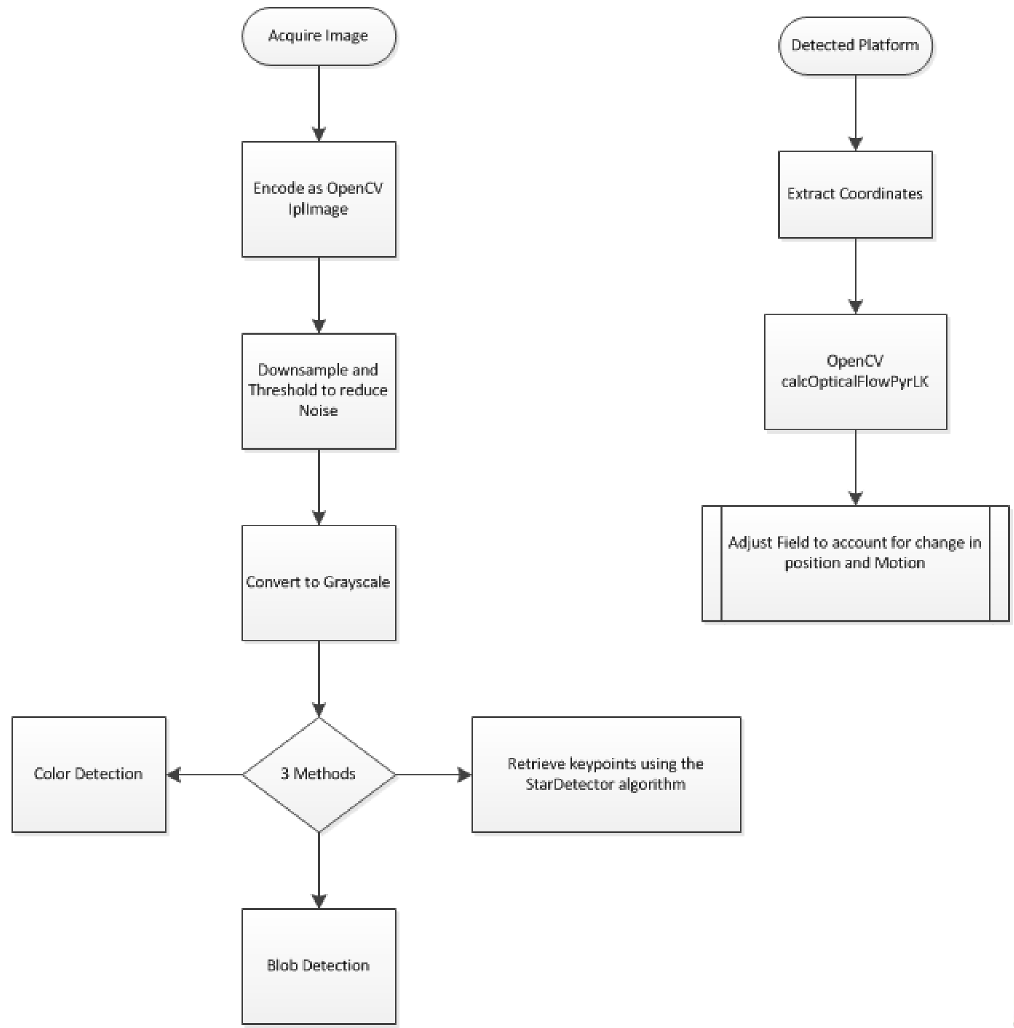


- Linux
  - Kernel 3.2
  - Angstrom (flight)
  - Xubuntu (development)
  - OpenCV
  - DSP optimized GStreamer

Platform Localization

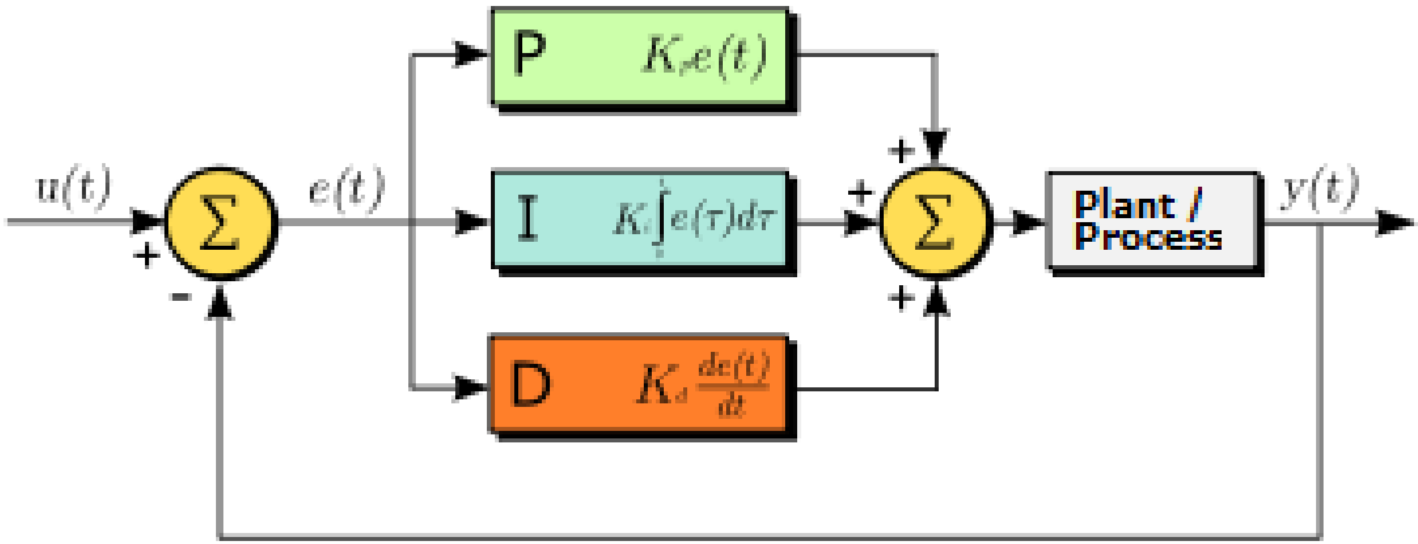


Object Detection, Motion Characterization, and Compensation Process



A.P.E.S. Controller

PID Control System to be Implemented



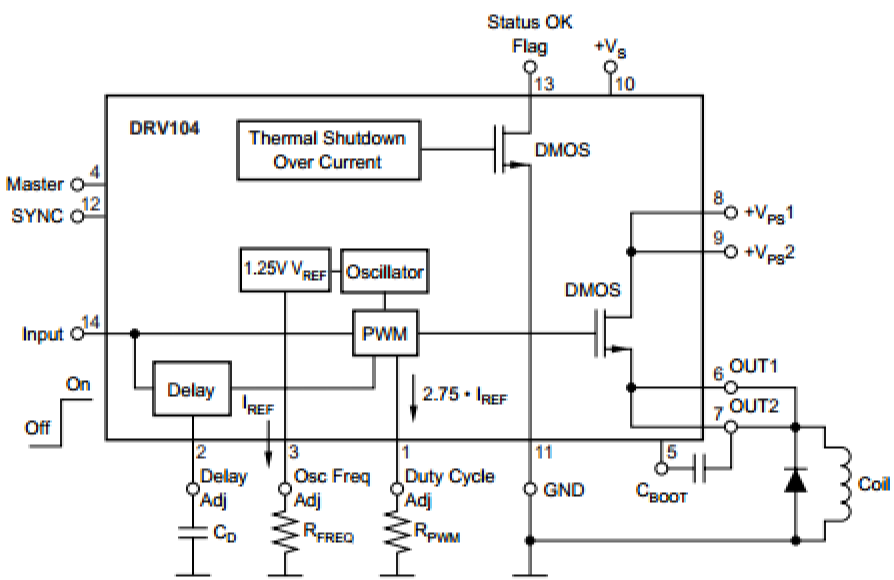
proportional-integral-derivative feedback loop

Setpoint: platform in center of module

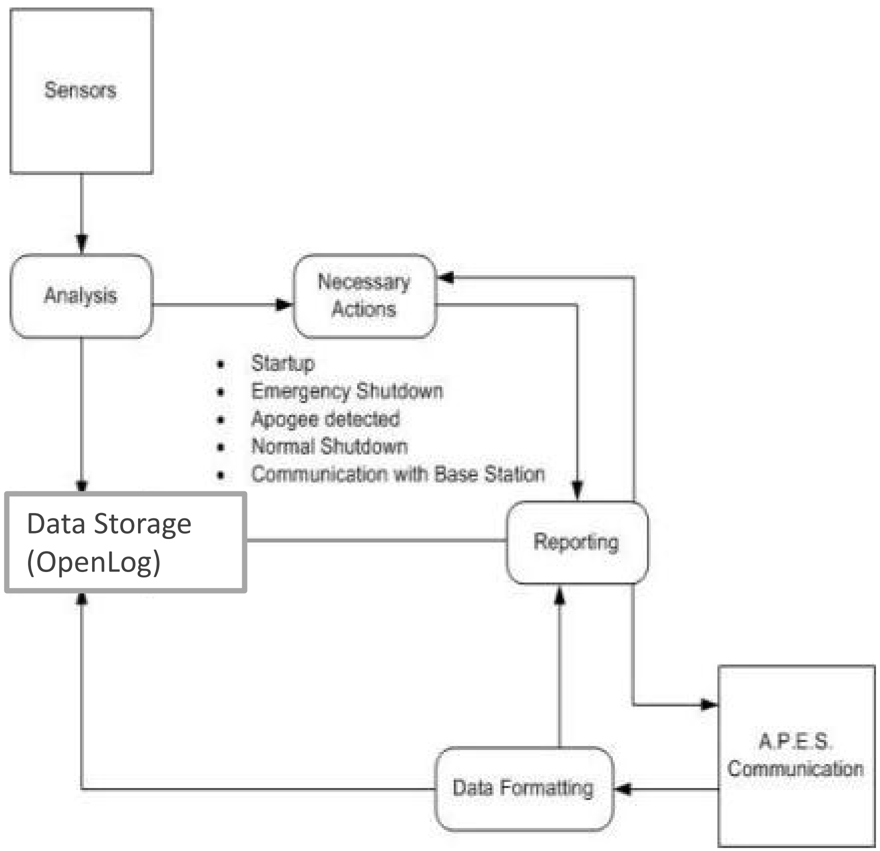
Error: distance from setpoint

Field Generation and Control

- 5x TI DRV103 Solenoid driver ICs
- 12x solenoids with ~300 turns of 30 gauge magnet wire
- 1x Large Z axis Solenoid

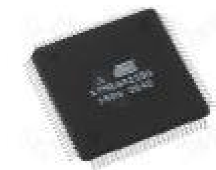


Flight Systems: Avionics

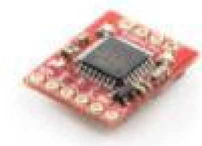


Flight computer board

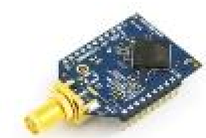
- ATmega 2560



- OpenLog

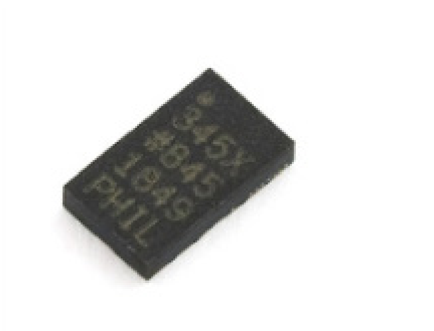


- Xbee Pro

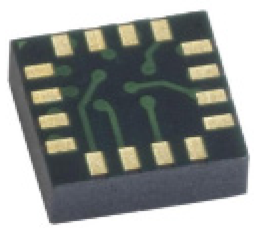


- Sensors

Sensors Used



- ADXL345 Triple Axis Accelerometer
  - Logs orientation and acceleration
  - Data sent to A.P.E.S. controller and logged



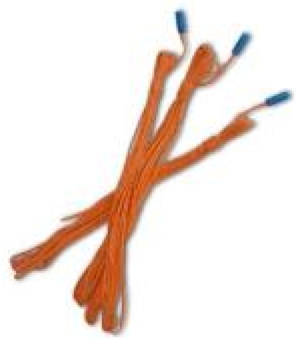
- HMC1043 3-Axis Magnetic Sensor
  - Magnetic field strength logging

- Fastrax UP501 GPS Module
  - Tracking data for logging and recovery

Telemetry and Communication

- 100mW Transceiver
- 902-928MHz FHSS
- Reliable Delivery
- 10kbps RF Data Rate
- Up to 6 mile Line of Sight Outdoor Range

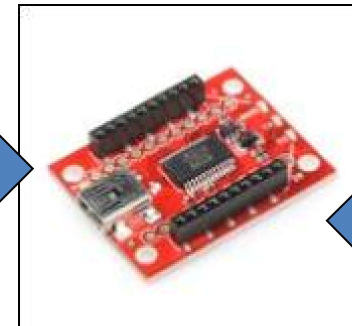
Safety Considerations



Transmitter verified to *not* ignite e-matches at maximum power

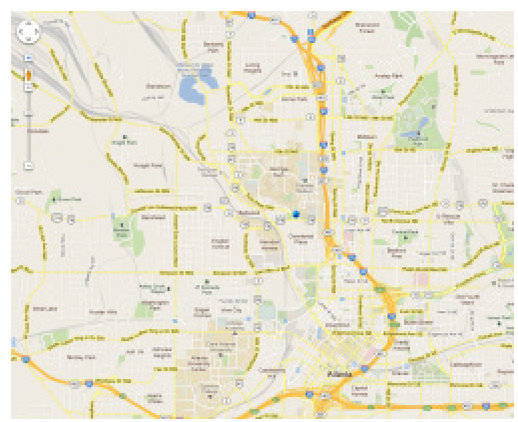
Flight Systems: Ground Station Comm

GPS Data



Xbee Explorer

- GPS Data will be received via Xbee pro
- Xbee Explorer will convert data packets
- Data sent to computer and displayed on map



Questions?

Project A.P.E.S. FRR

BACK-UP SLIDES

Project A.P.E.S. FRR Back-up Slides

TEAM OVERVIEW

Team Summary

Team Summary	
School Name	Georgia Institute of Technology
Team Name	Mile High Yellow Jackets
Project Title	Active Platform Electromagnetic Stabilization (A.P.E.S.)
Launch vehicle Name	Vespula
Project Lead	Richard Z.
Safety Officer	Matt S.
Team Advisors	Dr. Eric Feron, Dr. Marilyn Wolf
NAR Section	Primary: Southern Area Launch vehicle (SoAR) #571 Secondary: GA Tech Ramblin' Launch vehicle Club #701
NAR Contact	Primary: Matthew Vildzius Secondary: Jorge Blanco

Georgia Tech Team Overview

- 7 person team composed of both undergraduate and graduate students
  - Grad Students: 2
  - Undergraduates: 15

- Highly Integrated team across several disciplines

Field	No. of Students
Aerospace Engineering	9
Electrical Engineering	6
Computer Science/ Computer Engineering	3
Mechanical Engineering	2
Mathematics	1

Project A.P.E.S. FRR Back-up Slides

SYSTEM REQUIREMENTS VERIFICATION MATRIX

Launch Vehicle RVM

LV	*Launch Vehicle*	*Source*	*Verification Method*	*Status*	*Verification Source*
`LV-1	The Launch Vehicle shall carry a scientific or engineering payload.	USLI Handbook	Inspection	Completed	Section 4.4
LV-1.1	The maximum payload weight including any supporting avionics shall not exceed 15 lbs.	LV-1	Inspection	Completed	Table 21,
LV-1.2	The Launch Vehicle shall have a maximum of four (4) independent or tethered sections	LV-1	Inspection	Completed	Figure 4
LV-2	The Launch Vehicle shall carry the payload to an altitude of 5,280 ft. above the ground.	USLI Handbook, MSC-1, MO-1	Inspection, Testing	Completed	Figure 43
LV-2.1	The total impulse provided by the Launch Vehicle shall not exceed 5,120 N-s.	LV-2	Inspection	Completed	Figure 44
LV-2.2	The Launch Vehicle shall use a commercially available solid motor.	LV-2	Inspection	Completed	Figure 13
LV-2.3	The Launch Vehicle shall remain subsonic throughout the entire flight.	LV-2	Analysis	Completed	Figure 43
LV-3	The Launch Vehicle shall be safely recovered and be reusable.	USLI Handbook, MSC-3.1, MO-4	Testing, Inspection	Completed	Section 4.2
LV-3.1	The Launch Vehicle shall contain redundant altimeters.	LV-3, USLI Handbook	Inspection	Completed	Figure 7
LV-3.2	The Launch Vehicle shall carry one altimeter for recording of the official altitude used in the competition scoring.	LV-3, USLI Handbook	Inspection	Completed	Figure 8
LV-3.3	The recovery system shall be designed to be armed on the pad.	LV-3, USLI Handbook	Inspection	Completed	Figure 9
LV-3.4	The recovery system electronics shall be completely independent of the payload electronics.	LV-3, USLI Handbook	Inspection, Testing	Completed	Figure 7

Launch Vehicle RVM

LV	Launch Vehicle	Source	Verification Method	Status	Verification Source
LV-3.5	Each altimeter shall be armed by a dedicated arming switch.	LV-3, USLI Handbook	Inspection	Completed	Figure 9
LV-3.6	Each altimeter shall have a dedicated battery.	LV-3, USLI Handbook	Inspection	Completed	Figure 7
LV-3.7	Each arming switch shall be accessible from the exterior of the airframe.	LV-3, USLI Handbook	Inspection	Completed	Figure 9
LV-3.8	Each arming switch shall be capable of being locked in the "ON" position for launch.	LV-3, USLI Handbook	Testing	Completed	Figure 10
LV-3.9	Each arming switch shall be a maximum of six (6) feet above the base of the Launch Vehicle.	LV-3, USLI Handbook	Inspection	Completed	Figure 41
LV-3.10	The Launch Vehicle shall stage the deployment of its recovery devices	LV-3, USLI Handbook	Testing	Completed	Figure 2
LV-3.11	Removable shear pins shall be used for both the main and drogue parachute compartments	LV-3, USLI Handbook	Inspection	Completed	Section 4.2.3
LV-3.12	All sections shall be designed to recover within 2,500 ft. of the launch pad assuming 15 MPH winds.	LV-3, USLI Handbook	Analysis	Completed	Figure 46
LV-3.13	Each section of the Launch Vehicle shall have a maximum landing kinetic energy of 75 ft-lb_f.	LV-3, USLI Handbook	Analysis	Completed	Table 16
LV-3.14	The recovery system electronics shall be shielded from all onboard transmitting devices.	LV-3, USLI Handbook	Testing, Analysis	Completed	Table 27 , Section 9.3.1
LV-4	The Launch Vehicle shall be launched standardized launch equipment	USLI Handbook	Inspection	Completed	Section 7
LV-4.1	The Launch Vehicle shall not require any external circuitry or special ground support equipment to initiate the launch other than what is provided by the range.	LV-4, USLI Handbook	Inspection	Completed	Appendix II

Launch Vehicle RVM

LV		*Launch Vehicle*	*Source*	*Verification Method*	*Status*	*Verification Source*
	LV-4.2	The Launch Vehicle shall be launched from a standard firing system using a 10 second countdown.	LV-4, USLI Handbook	Inspection	Completed	Appendix II
	LV-4.3	The Launch Vehicle shall have a pad stay time on one (1) hour.	LV-4, USLI Handbook	Testing, Analysis	Completed	Figure 66
	LV-4.4	The Launch Vehicle shall be capable of being prepared for flight at the launch site within 2 hours from the time the waiver opens.	LV-4, USLI Handbook	Testing	Completed	Appendix II

Flight Systems RVM

FS	Flight Systems	Source	Verification Method	Status	Verification Source
FS-1	The platform shall be stabilized and isolated during ascent.	MSC-2.4, MO-2	Testing	In Progress	
FS-1.1	The platform shall not deviate more than 0.1 inches from the center of experiment cylinder.	FS-1	Analysis, Testing	In Progress	
FS-1.2	The platform shall not come into contact with any components of the A.P.E.S. System.	FS-1, MSC-2.5	Testing	Designed	
FS-1.3	The platform shall not rotate more than 1 rad per second for than 1/10 of a second with respect to the camera.	FS-1	Analysis, Testing	In Progress	
FS-2	All elements of the A.P.E.S. Systems shall weigh no more than 15 lbs.	LV-1.1	Inspection	Completed	Table 21
FS-2.1	The A.P.E.S. Flight Experiment shall not weigh more than 10 lbs.	FS-2	Inspection	Completed	Table 21
FS-2.2	The A.P.E.S. supporting electronics shall not weigh more than 5 lbs.	FS-2	Inspection	Designed	
FS-3	The A.P.E.S. experiment shall be terminated at apogee.	MSC-2.3	Testing	In Progress	
FS-3.1	The platform shall be secured during descent and landing.	FS-3	Testing	In Progress	

Flight Avionics RVM

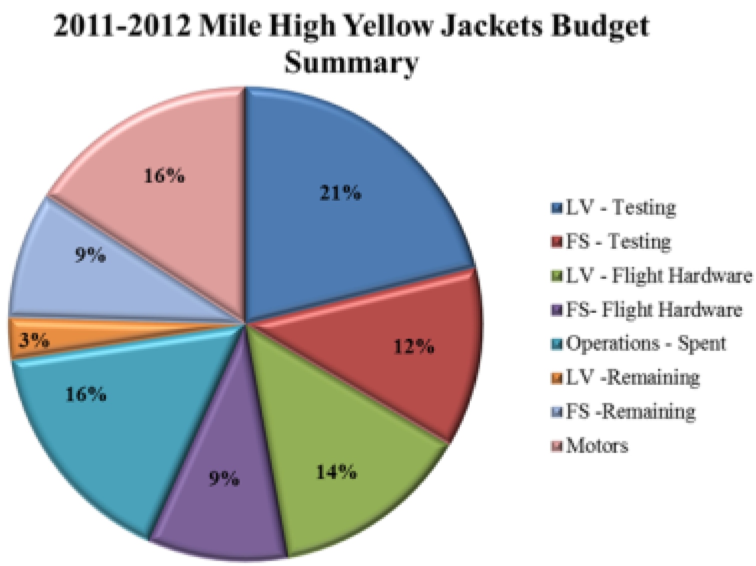
FA	*Flight Avionics*	*Source*	*Verification Method*	*Status*	*Verification Source*
FA-1	All Flight Avionics shall have a burn-in time of no less than 20 hours	MSC-2.2, MO-4	Inspection	In Progress	
FA-2	The Flight Computer shall collect Launch Vehicle position data, environment conditions (e.g. acceleration), and data from the A.P.E.S. experiment.	MSC-2.5, MSC-2.4, MSC-2,MO-2	Testing	Designed	
FA-3	The A.P.E.S. computer shall be able to perform real-time image processing and control the A.P.E.S. experiment.	MO-3	Testing	In Progress	
FA-3.1	The A.P.E.S. computer shall secure the platform at apogee for descent and landing	FS-3.1	Testing	In Progress	
FA-4	The Flight Avionics shall operate on independent power supplies	MSC-2.5, MSC-2.4, MSC-2,MO-2	Inspection	In Progress	
FA-4.1	The power supplies shall allow for successful payload operation during the Launch Vehicle flight with up to 3 hours of wait time.	USLI Handbook	Analysis, Testing	Completed	Figure 66
FA-5	The Flight Avionics shall downlink telemetry necessary to a Ground Station for the recovery of the Launch Vehicle	USLI Handbook	Analysis, Testing	In Progress	
FA-5.1	The GPS coordinates of all independent Launch Vehicle sections shall be transmitted to the Ground Station	MO-4	Inspection	In Progress	
FA-6	The Recovery Avionics and Recovery System shall be separate from the Flight Avionics.	USLI Handbook	Inspection	Completed	Figure 7, Section 9.2

Project A.P.E.S. FRR Back-up Slides

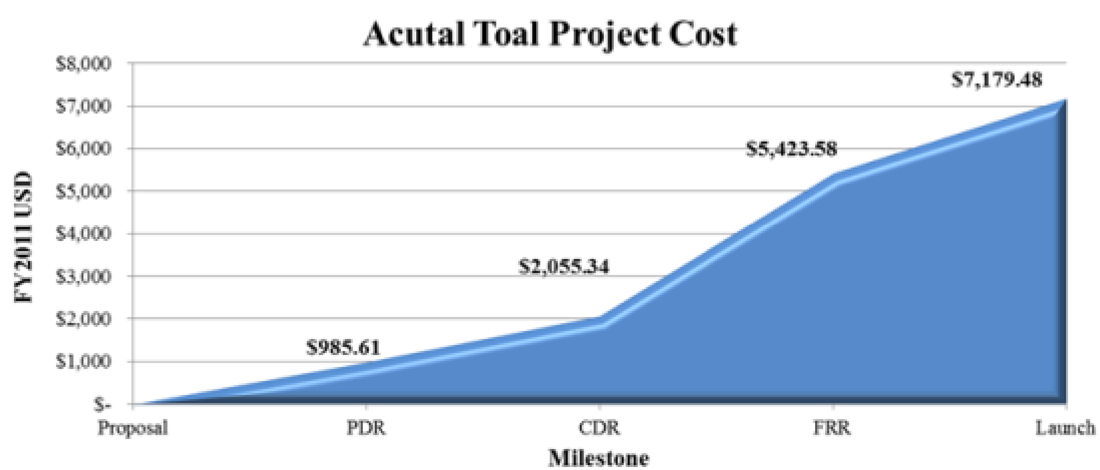
PROJECT BUDGET SUMMARIES

Project Budget: Summary

2011-2012 Budget Breakdown	
LV - Testing	$ 1,333.08
FS - Testing	$ 775.14
LV - Flight Hardware	$ 860.05
FS- Flight Hardware	$ 604.88
Operations - Spent	$ 1,000.00
LV -Remaining	$ 181.87
FS -Remaining	$ 544.98
Motors	$ 1,000.00
Operations - Remaining	$ 700.00
Total	$ 7,000.00



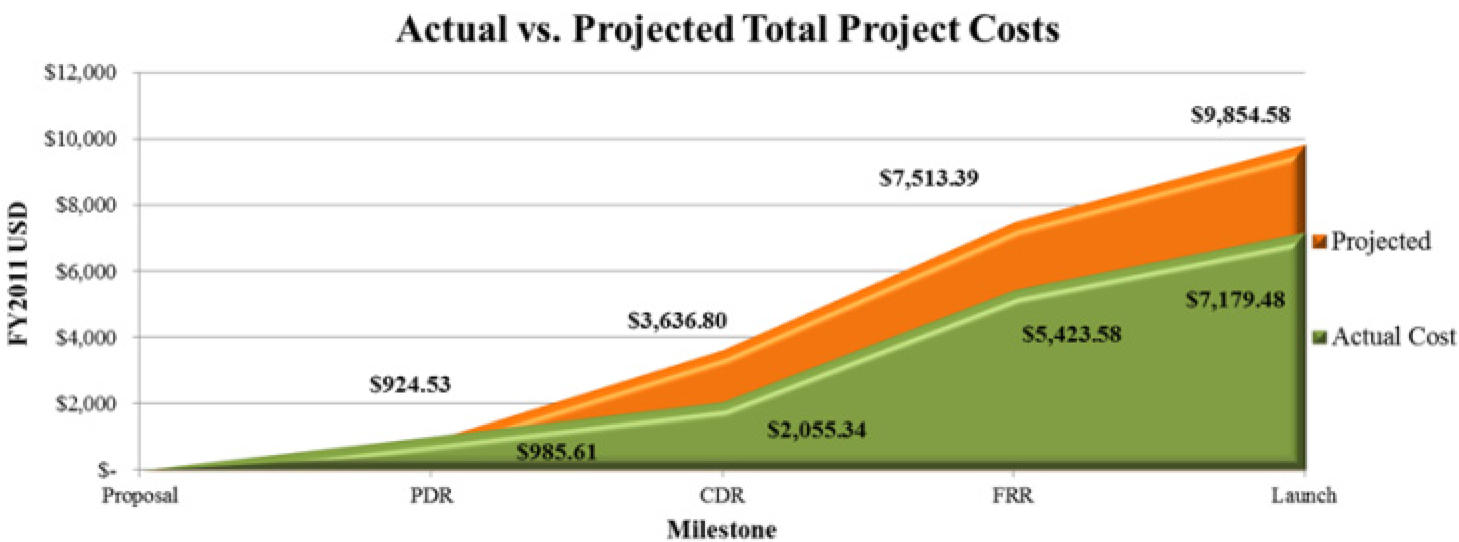
	Actual Cost	*Project Reserves*
PDR	$ 985.61	61.2 %
CDR	$2,055.34	90.0 %
FRR	$5,423.58	28.7 %
Launch	$7,179.48	--



Georgia Tech USLI UNIVERSITY STUDENT LAUNCH INITIATIVE

Actual vs. Predicted Budget

	% Difference
PDR	6.2 %
CDR	-43.5 %
FRR	-27.8 %
Launch	-27.2 %



Project A.P.E.S. FRR Back-up Slides

PROJECT SCHEDULE RISK SUMMARIES

Project Schedule: Low-to-Moderate Risk

High-Risk Task	*Potential Impact on Project A.P.E.S.*	*Mitigation*
Verification of Field Equations & Control Logic	1) Unsuccessful flight experiment demonstration 2) Flight Experiment does not function properly during flight 3) Flight Experiment encounters a flight anomaly that results in excessive draw and damage to the Flight Avionics, Power Supply, and/or Launch Vehicle	1) Develop multiple paths to achieve the end goal of developing thee robust control logic that is required for the successful demonstration of the Flight Experiment. 2) Ensure Flight Systems personnel have direct and free access to experienced personnel on and off of the team. 3) Ensure personnel have direct and free access to the simulation and analysis tools necessary for the development (and subsequent verification) of the control logic. 4) Ensure direct and free access to the proper equipment necessary in developing and implementing the Control Logic for the A.P.E.S. experiment.
Recovery System Design & Fabrication	1) Excessive kinetic energy at landing resulting in dis-qualification from the USLI competition at CDR 2) Excessive kinetic energy during landing resulting in damage to the rocket. 3) Failure to deploy the drogue and/or main parachute resulting in a high energy impact with the ground damaging or destroying the Launch Vehicle.	1) Ensure Recovery System Lead has direct and free access to experienced personnel on and off the team. 2) Provide real-time feedback of the design decisions to ensure all recovery-related requirements are meet with at least a 5% margin wherever possible. 3) Ensure proper manufacturing techniques are utilized during the fabrication of the recovery system.

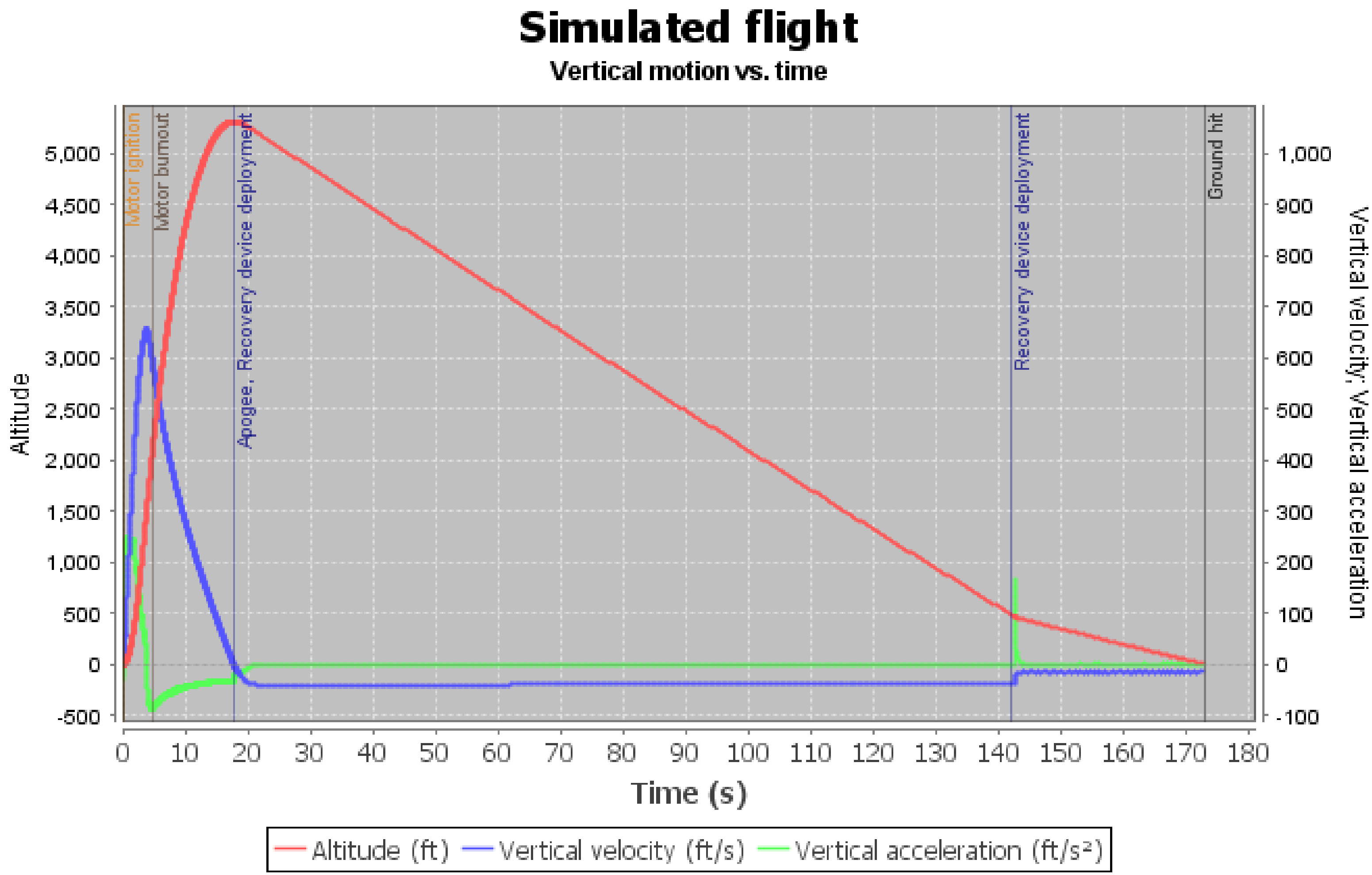
Project Schedule: Low-to-Moderate Risk

Risk	*Risk Level*	*Potential Impact on Project A.P.E.S.*	*Mitigation*
Full-Scale Launch Vehicle Test Flight	Moderate	1) Schedule Impact 2) Budgetary Impact 3) Not qualifying for Competition Launch	1) Ensure Launch Procedures are established practiced prior to any launch opportunity. 2) Ensure proper construction of the Launch Vehicle. 3) Have a sufficient number of launch opportunities that are in different geographical areas as to minimize the effects of weather on the number of launch opportunities.
Ground Testing & Control Logic Development	Moderate	1) Schedule Impact 2) No Experimental Flight Data is recorded prior to the Competition Launch.	1) Ensure personnel have direct and free access to experienced personnel on and off of the team.
Custom Flight Computer Fabrication	Moderate	1) Budgetary Impact 2) Impact to Mission Objectives	1) Ensure proper manufacturing techniques are observed during fabrication. 2) Ensure Manufacturing and Fabrication Orders (MFO's) are sufficiently detailed for the task. 3) Ensure that an alternate path has been identified and implemented in a timely manner that meets the requirements of the Flight Computer and schedule.

Project A.P.E.S. FRR Back-up Slides

LAUNCH VEHICLES

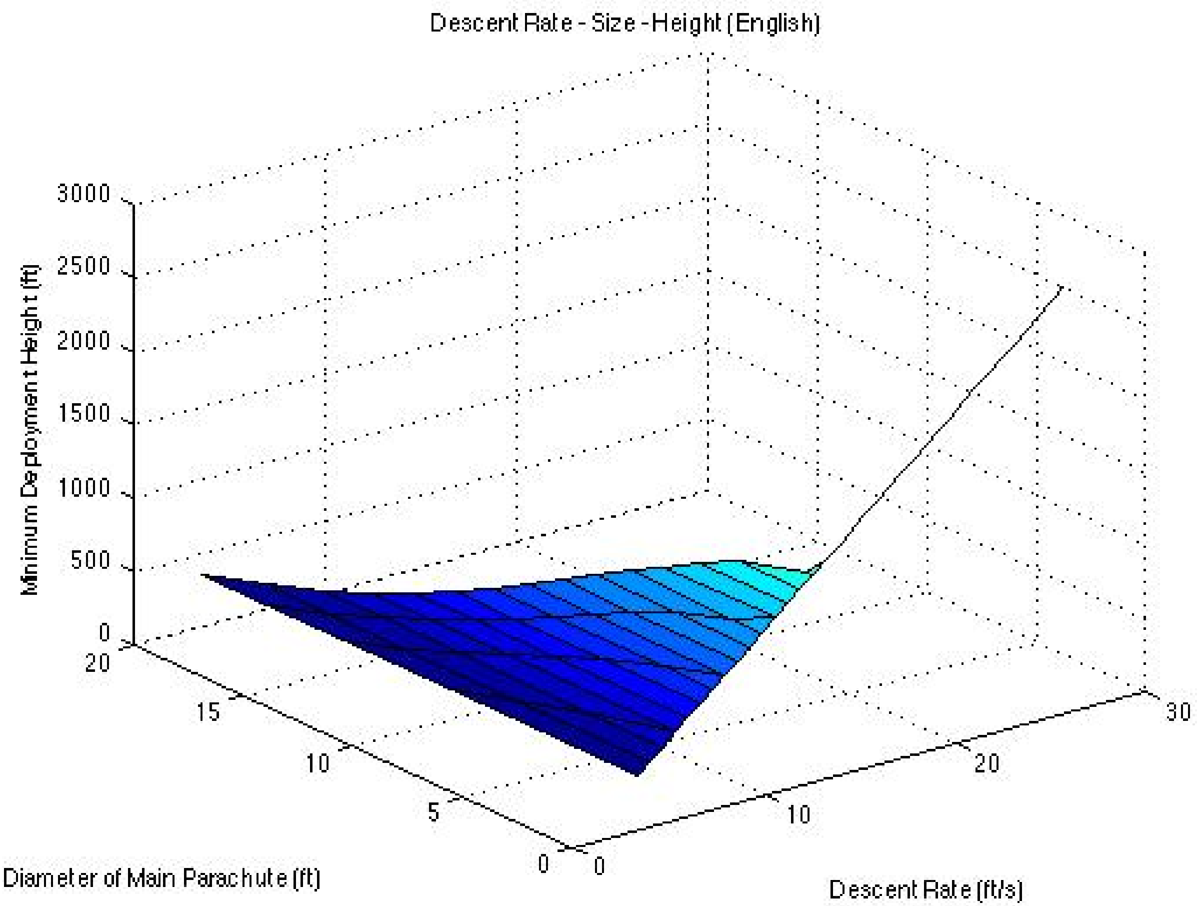
Backup Slide - Flight Profile



Backup - Payload Structure – Test Result

Fastener location	F.S. = 1	F.S. = 1.5	F.S. = 2	F.S. = 2.5	F.S. = 3
1	p	P	p	p	P
2	P	P	P	P	P
3	P	P	P	P	P
4	P	P	P	P	P
1A	P	P	P	P	X
2A	P	P	P	X	X
3A	P	P	P	X	X
4A	P	P	P	P	P
5	P	P	P	P	P
6	P	P	P	P	P
7	P	P	P	P	P
8	P	p	P	P	P

Backup Slide – Recovery Calculations



Backup Slide – Recovery Calculations

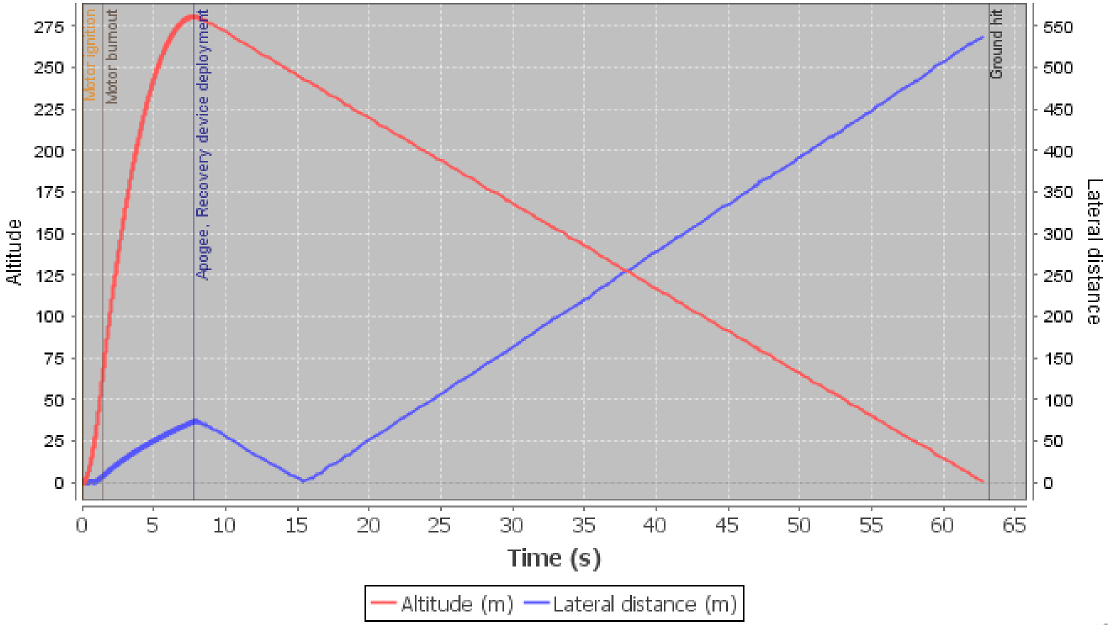
Black Powder Equation: $$W = \frac{V \Delta P}{RT} \qquad (1)$$

Variable	*Description*	*Units*
W	Weight of the black powder in pound mass	$454 \cdot W_{gram}$
V	Volume of the container to be pressurized	in^3
ΔP	Pressure Differential	psia
R	Gas Combustion Constant for black powder	$\frac{22.16 ft\, lb_f}{lb_m \cdot R}$
T	Gas Combustion Temperature	3307 ˚R

$$F_{pin} = \frac{\sigma \pi d^2}{4}$$

- Volume to be pressurized accounts for the parachute packaging
- Pressure calculated at deployment height for each parachute

Backup Slide - Korsakov Drift



Backup Slide - Flight Test Investigation

- Structural Failure at Epoxy seam

- Landing damage on skin

Project A.P.E.S. FRR Back-up Slides

FLIGHT SYSTEMS: PAYLOAD

Backup Slide – Payload Science

- Interaction of magnetics fields and permanently magnetic or ferromagnetic substances
- For ferromagnetic substance:

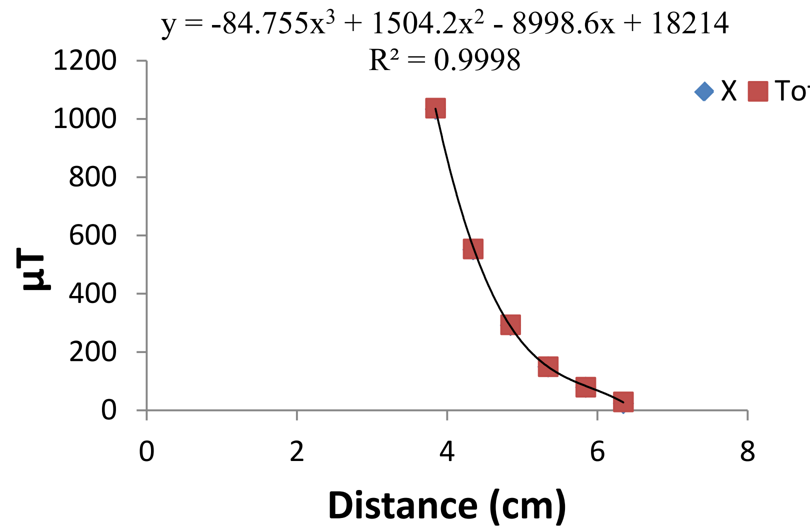
$$\mathbf{F}(\mathbf{r},\mathbf{m}_s,\mathbf{m}) = \frac{3VN^2I^2S^2\mu\chi_m}{16\pi^2r^7}[(\hat{\mathbf{n}}\cdot\hat{\mathbf{r}})\hat{\mathbf{n}} - \hat{\mathbf{r}} - 4(\hat{\mathbf{n}}\cdot\hat{\mathbf{r}})^2\hat{\mathbf{r}}]$$

- For permanently magnetic substance:

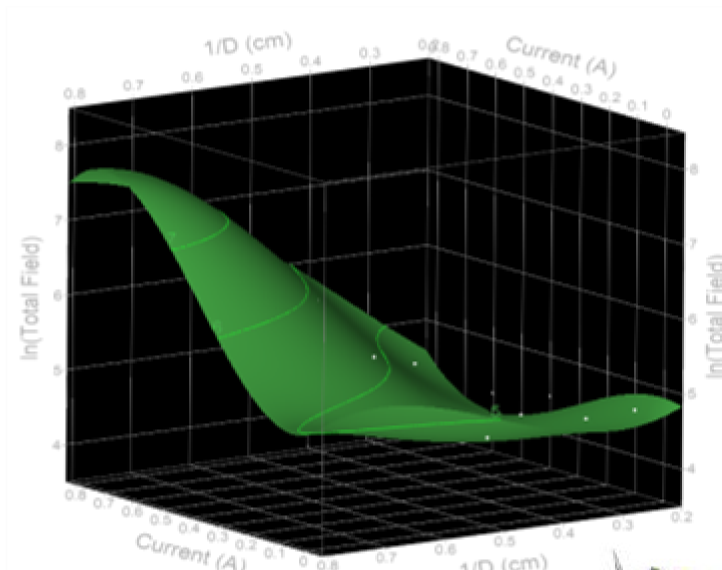
$$\mathbf{F}(\mathbf{r},\mathbf{m}_s,\mathbf{m}) = \frac{3VNIS\mu_0}{4\pi r^4}[(\hat{\mathbf{n}}\cdot\hat{\mathbf{r}})\mathbf{M} + (\mathbf{M}\cdot\hat{\mathbf{r}})\hat{\mathbf{n}} + (\hat{\mathbf{n}}\cdot\mathbf{M})\hat{\mathbf{r}} - 5(\hat{\mathbf{n}}\cdot\hat{\mathbf{r}})(\mathbf{M}\cdot\hat{\mathbf{r}})\hat{\mathbf{r}}]$$

Backup - Detailed Ground Testing Results

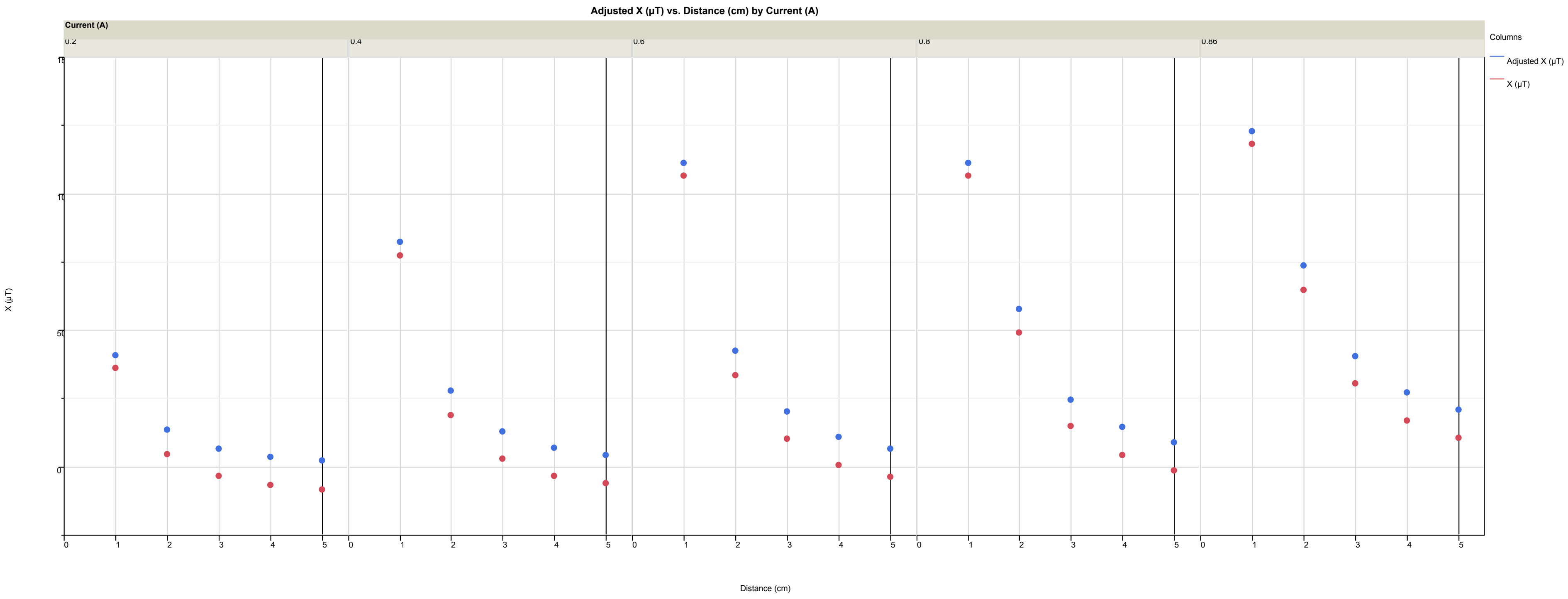
Initial Steady-State DC Ground Testing of Solenoid



Characteristic	Value
Turns	300
Resistance	2.6 Ω
Wire Gauge	30
Field Strength @ 0.86A	1100 µT



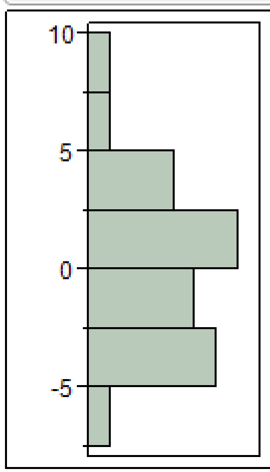
Preliminary Solenoid Ground Testing



Alternative Response Surface Fits

Distributions

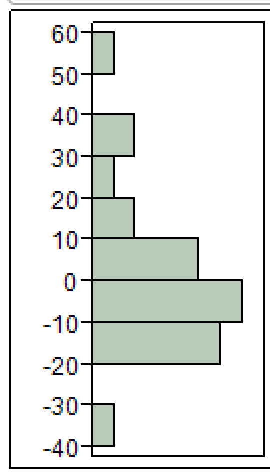
LN Transform Error



Moments

Mean	0.1998487
Std Dev	3.5400164
Std Err Mean	0.7080033
Upper 95% Mean	1.6610957
Lower 95% Mean	-1.261398
N	25

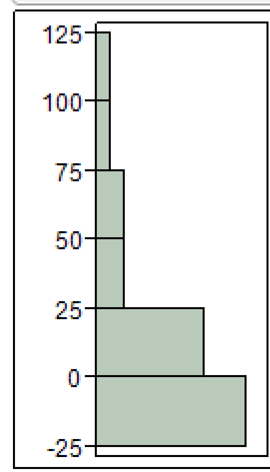
Response Surface Error



Moments

Mean	3.1188285
Std Dev	19.702498
Std Err Mean	3.9404996
Upper 95% Mean	11.25162
Lower 95% Mean	-5.013963
N	25

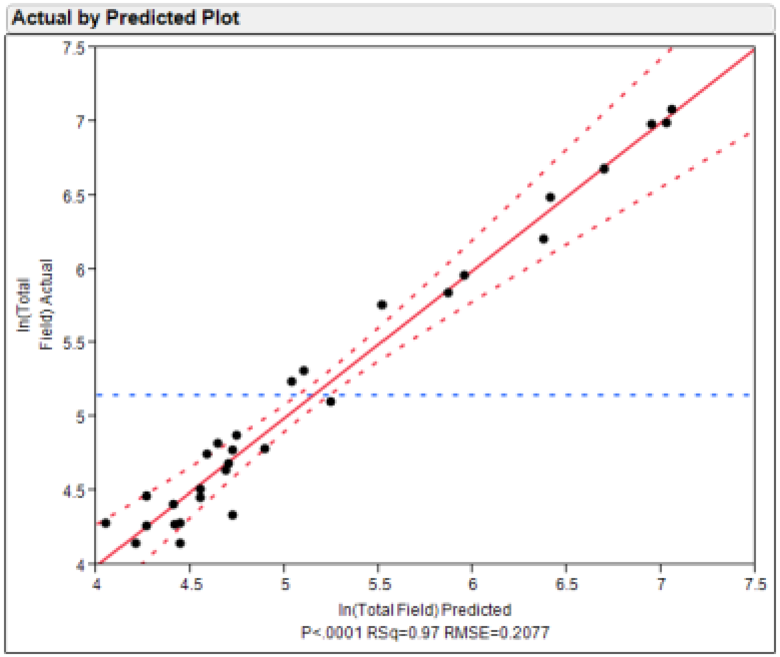
Neural Error

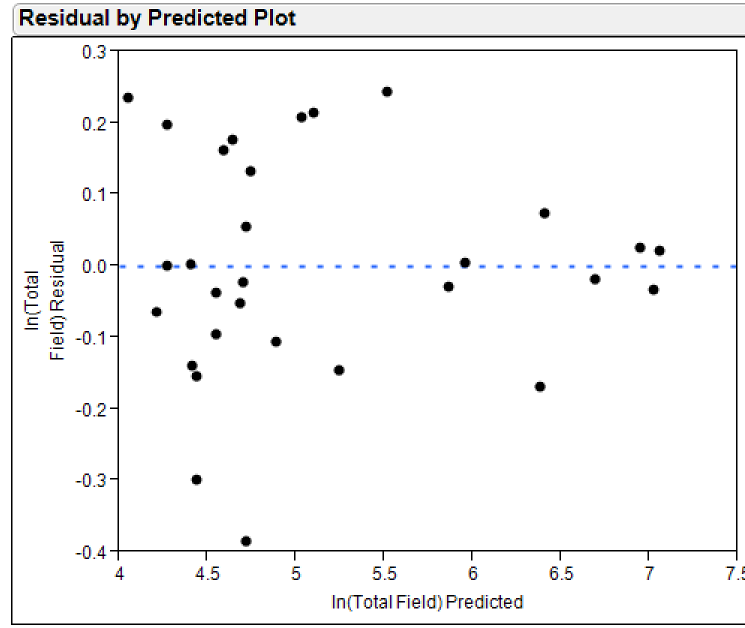


Moments

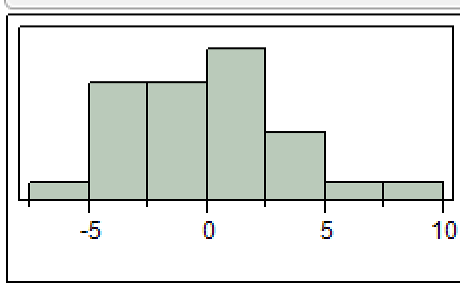
Mean	13.72578
Std Dev	32.454862
Std Err Mean	6.4909725
Upper 95% Mean	27.122489
Lower 95% Mean	0.3290711
N	25

Response Surface: Goodness of Fit





LN Transform Error



Moments

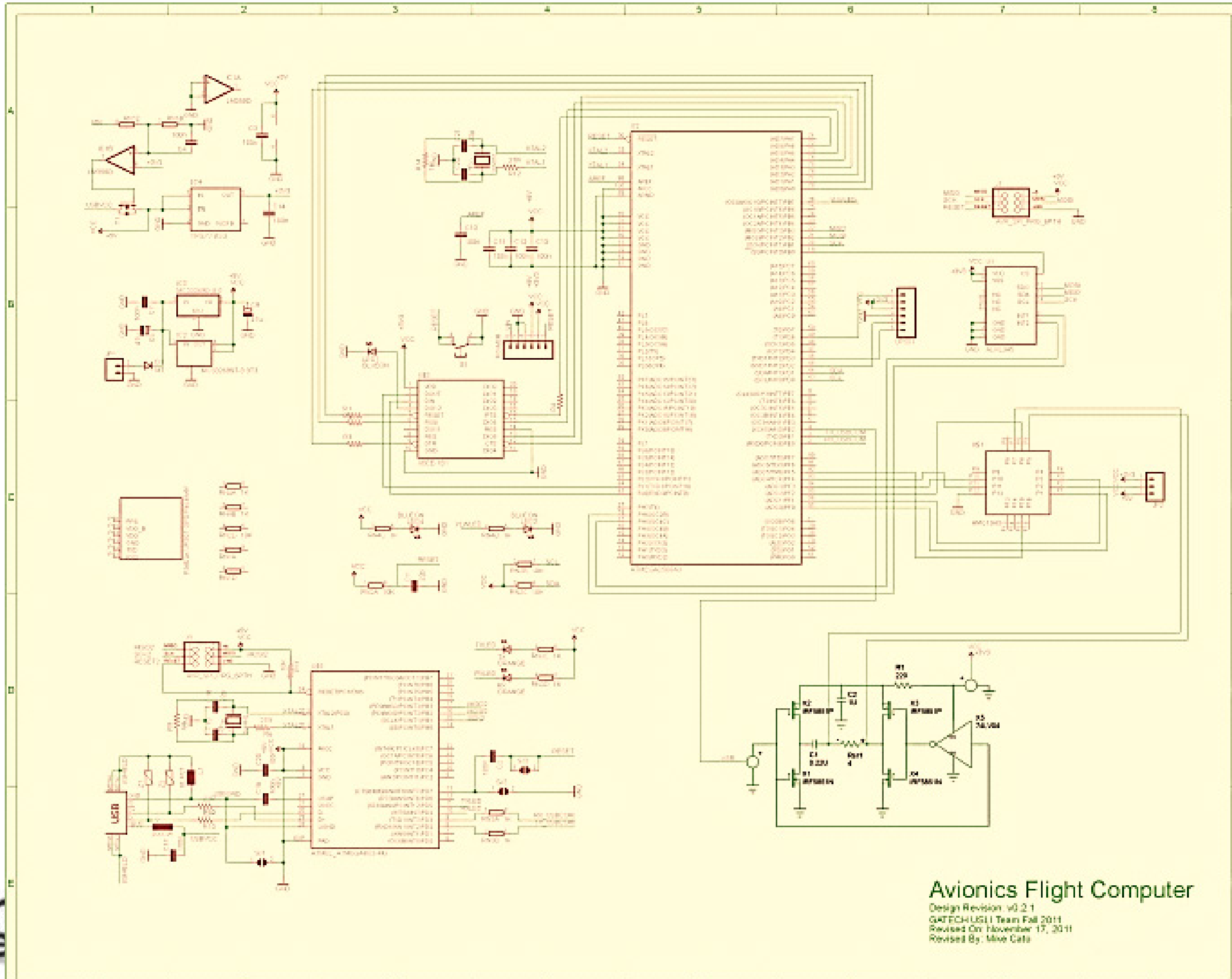
Mean	0.1041408
Std Dev	3.319957
Std Err Mean	0.6061385
Upper 95% Mean	1.3438332
Lower 95% Mean	-1.135551
N	30

Flight Systems: Ground Test Plan

Goals:
1. Develop Control Theories
2. Confirm Force Equations
3. Produce Flight Experiment

Ground Test Sequence
1. Sensor Calibration
2. 1-D Testing
3. 2-D Testing
4. 3-D Testing
5. Flight Model Test

Flight Avionics Schematic



Project A.P.E.S. FRR Back-up Slides

FLIGHT SYSTEMS: FLIGHT AVIONICS

Power Budget: Overview

SubTotals						
Standby		Typical		Maximum		
Amps	Watts	Amps	Watts	Amps	Watts	
0.020	0.070	0.404	1.401	0.434	1.526	**Avionics**
0.300	0.990	0.950	3.646	1.450	5.807	**A.P.E.S.**
0.000	0.000	3.440	41.280	4.300	51.600	**Other**

Power Budget Detailed Summary

Power Consumption			Modes								
			Standby			**Typical**			**Max**		
Subsystem	**Component**	**Voltage**	**Amps**	**Watts**	**Duty Cycle**	**Amps**	**Watts**	**Duty Cycle**	**Amps**	**Watts**	**Duty Cycle**
Avionics	adx1345	3.3	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.001	1.000
	hmc1043	3.3	0.012	0.040	0.000	0.012	0.040	1.000	0.012	0.040	1.000
	atmega8u2	5	0.000	0.002	1.000	0.014	0.070	1.000	0.021	0.105	1.000
	atmega2560	5	0.000	0.002	1.000	0.020	0.100	1.000	0.029	0.145	1.000
	UP501	3.3	0.005	0.017	1.000	0.023	0.077	1.000	0.035	0.117	1.000
	Xbee-XCS	3.3	0.000	0.000	1.000	0.330	1.089	1.000	0.330	1.089	1.000
	OpenLog	5	0.002	0.010	1.000	0.005	0.025	1.000	0.006	0.030	1.000
A.P.E.S.	Beagleboard	3.3	0.300	0.990	1.000	0.650	2.145	1.000	0.850	2.805	1.000
	MCP4275 DAC	5	0.000	0.000	0.000	0.000	0.001	1.000	0.000	0.002	1.000
	2x Webcam	5	0.000	0.000	0.000	0.300	1.500	1.000	0.600	3.000	1.000
Other	DRV103 + Solenoids	12	0.000	0.000	0.000	3.440	41.280	0.182	4.300	51.600	0.800
Max Power Draw (W)			**1.06**			**46.33**			**58.93**		
Duty Cycled Power Consumption (W)			**1.02**			**12.55**			**48.61**		
10% Contingency (W)			**0.10**			**1.26**			**4.86**		
Power Consumption with Contingency (W)			**1.12**			**13.81**			**53.47**		

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