Preliminary Design Review Presentation

Alabama Rocket Engineering Systems (ARES) Team
The University of Alabama

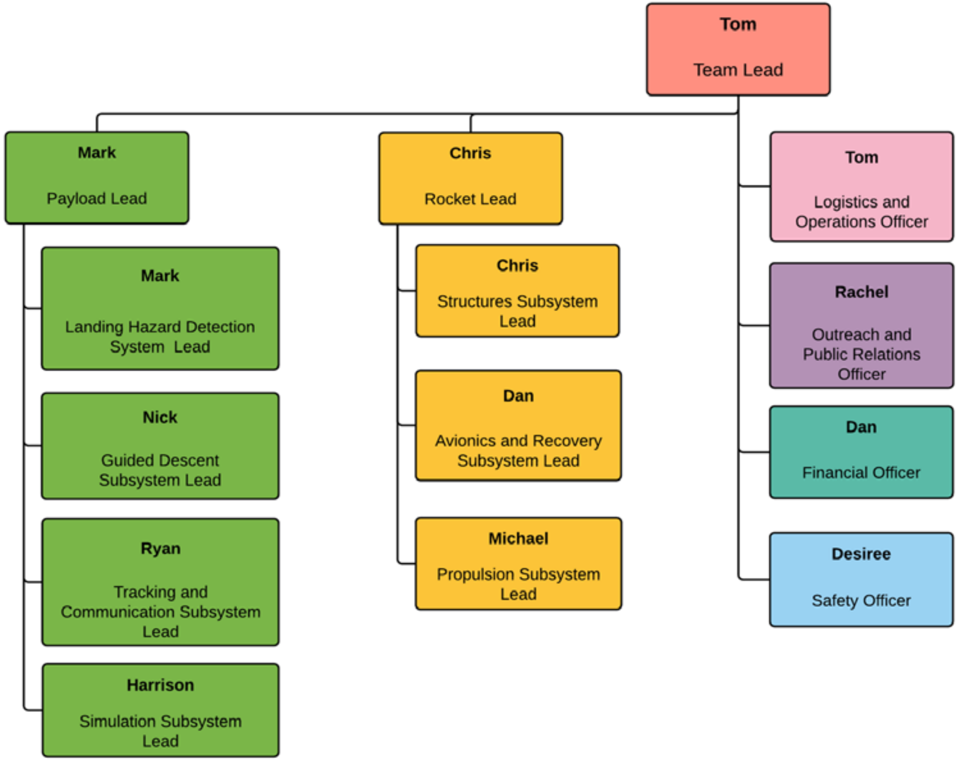
Overview

- Mission Overview
- Team Introduction
- Launch Vehicle Design
- Payload Design
- Safety
- Project Plan
- Q & A

Mission Overview

- Launch vehicle must carry payload to 5,280 ft AGL
- Payload must eject from launch vehicle
- Payload must analyze images of the ground to detect potential landing hazards
- Payload must steer away from detected landing hazards
- All components of the rocket must be safely recovered.

Team Introduction



Vehicle Design

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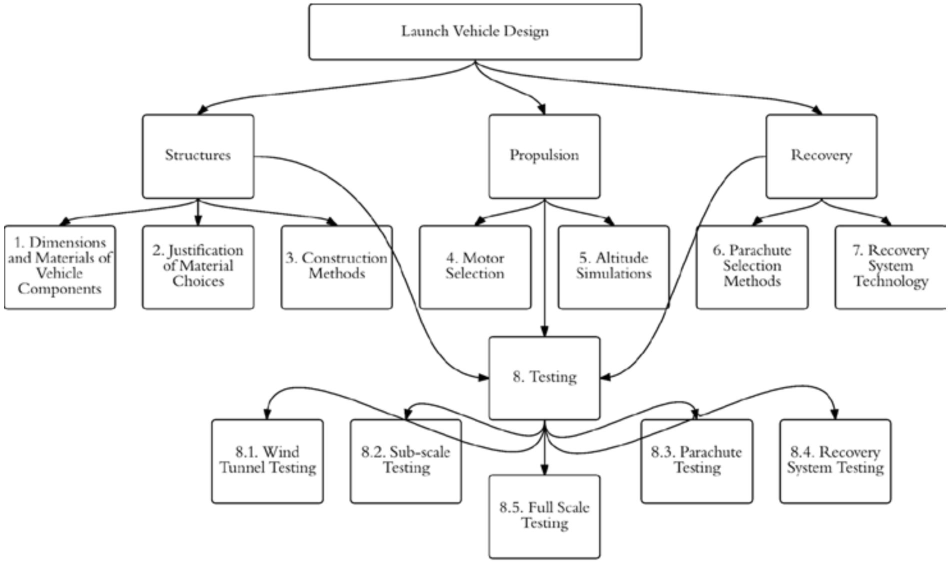
Launch Vehicle Design

Three Tasks

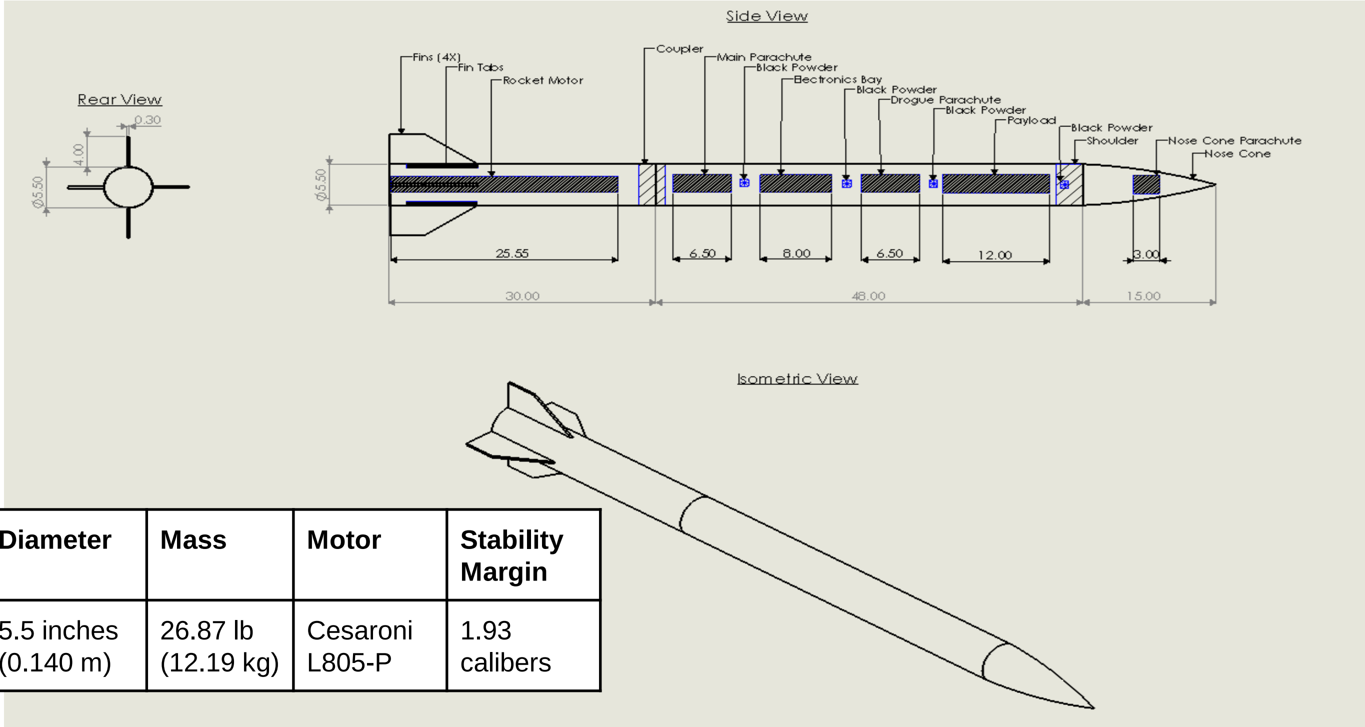
- Eject payload safely at apogee
- Achieve a max altitude of no higher than 5,280 ft AGL
- All sections land undamaged

Three Sub-Systems

- Structures
- Propulsion
- Recovery

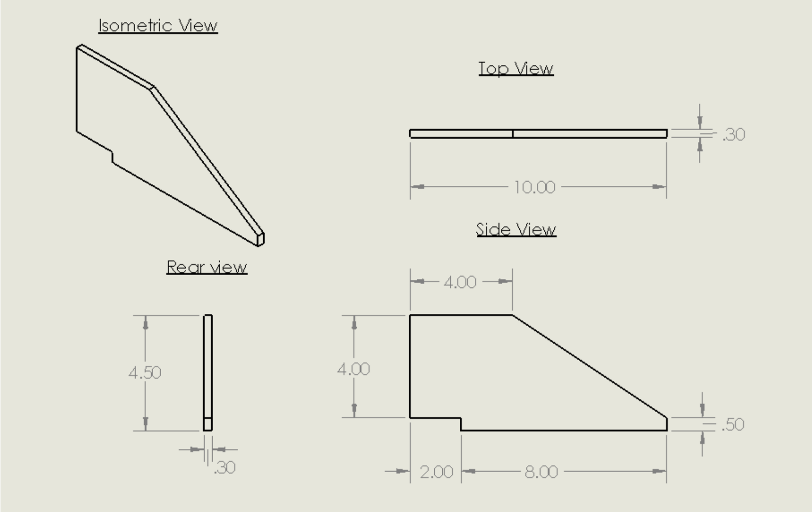


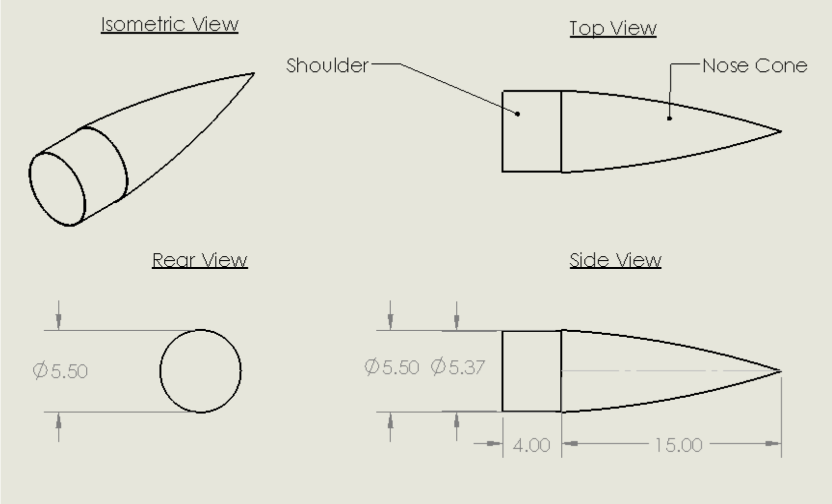
Vehicle Dimensions



Length	Diameter	Mass	Motor	Stability Margin
93 inches (2.36 m)	5.5 inches (0.140 m)	26.87 lb (12.19 kg)	Cesaroni L805-P	1.93 calibers

Component Dimensions





Component Dimensions and Materials

Component	Mass (lb)	Length (in)	Width or Diameter (in)	Supporting Structure Material
Nose Cone	0.965	15	5.5	Plastic
Forward Body Tube	3.45	48	5.5	Wound Fiberglass Tube
Aft Body Tube	0.855	30	5.5	Wound Fiberglass Tube
Payload	6.77	12	5.43	Wound Fiberglass Tube
Electronics Bay	0.575	8	5.43	Wound Fiberglass Tube
Main Parachute (Packed)	1.2	6.5	4.5	Ripstop Nylon
Drogue Parachute (Packed)	0.948	3	3	Ripstop Nylon
Nose Cone Parachute (Packed)	0.18	0.985	0.985	Ripstop Nylon
Fins	1.57	10	4.5	Vacuumed Fiberglass Plate

Materials Justification

Fiberglass will be used for the majority of the components

- inexpensive
- strong
- easy to replace

The choice of fiberglass avoids any of the problems of carbon fiber with electronic components

Carbon fiber limits transmission of electronic components by trapping signals

Weighted Rating of Carbon Fiber and Fiberglass

		Carbon Fiber		Fiberglass	
Criteria	*Importance Weight (%)*	*Rating*	*Weighted Rating*	*Rating*	*Weighted Rating*
Low Weight	35	4	1.4	3	1.05
Low Cost	20	1	0.2	5	1
Easy Production	10	1	0.1	4	0.4
High Strength	35	5	1.75	4	1.4
Total	100	NA	3.45	NA	3.85

Rating	*Value*
Unsatisfactory	*1*
Just tolerable	*2*
Adequate	*3*
Good	*4*
Very good	*5*

Construction Methods

The body tubes will be wound fiberglass tubes manufactured by an independent company

- If a tube breaks or shows defects: a tube furnace is available to the ARES team to construct replacement fiberglass tubes

The payload container, electronics container, and the motor mount tube will also be wound fiberglass tubes, but built by ARES by repurposing old tubes

The fins will be constructed out of vacuumed fiberglass plates

- High pressure vacuum pulls epoxy through fiberglass sheets to create the plates
- Plates will be cut and sanded into the desired shape

Motor Selection

Manufacturer	Cesaroni Technology	**Brandname**	Pro54 2833L805-P
Motor Dim. (mm), (in)	54.00 x 649.00, 2.13 x 25.55	**Total Impulse (N*s), (lb*s)**	2833.0, 636.9
Avg. Motor Efficiency	95.9%	**Maximum Thrust (N), (lb)**	1634.0, 367.3
Specific Impulse (s)	176.1	**Avg. Thrust (N), (lb)**	804.5, 180.8
Burntime (s)	3.52	**Altitude Projection, Bragg Farms - No Wind (ft)**	5290
Thrust-to-Weight Ratio	6.78	**Impulse-to-Weight Ratio**	23.9

Motor Selection

The original motor selection was a Cesaroni Technology Pro54 2645L265

Updated to the current selection of the Pro 54 2833L805-P as the payload weight increased

OpenRocket's library of motors allowed the ARES team to experiment with different motors to find the best motor choice for the launch vehicle

The Cesaroni Pro54 2833L805-P is available through Apogee Components

Lee Brock, the NAR mentor, will handle the rocket motor once ordered

Altitude Simulations

All altitude projections were taken from the open source software, OpenRocket

OpenRocket uses the Runge-Kutta 4 integration method to calculate altitude and Barrowman's Method is used to calculate the center of pressure location

OpenRocket provides a hobbyist stability margin not a true static stability margin

OpenRocket has limitations that will affect the altitude calculations

Simulation	**Apogee (ft)**
Bragg Farms (0 mph)	5290
Bragg Farms (5-10 mph)	5256
Manchester (0 mph)	5304
Manchester (5-10 mph)	5280

Parachute Selection Methods

Maximum ground hit velocity calculated with

$$v = \sqrt{\frac{2 \cdot KE}{m}}$$

Descent Rate Calculator (fruitychutes.com)

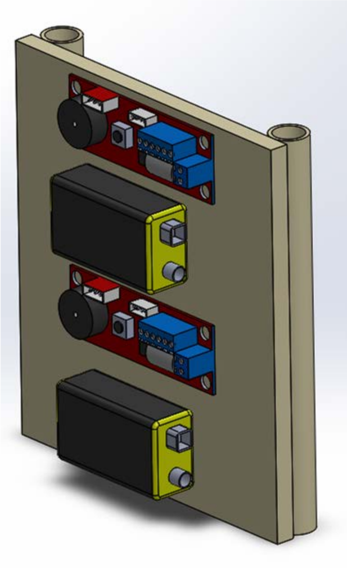
- Helped determine appropriate parachute size

System		Mass (lb)	Allowable Velocity (ft/s)
Nose Cone		1.15	64.88
Forward & Aft Body Sections (Main Parachute)		17.17	16.77
System	**Minimum Parachute Diameter (in)**	**Drag Reduction Velocity from Minimum Parachute (ft/s)**	**Chosen Parachute Diameter (in)**
Nose Cone	12	29.25	12
Forward & Aft Body Sections (Main Parachute)	83	16.17	110

Recovery System Technology

The Recovery System is governed by 2 Stratologger SL100 altimeters

- Powered by 2, 9.1V D batteries
- Primary altimeter sends a charge to each black powder squib
- Secondary altimeter sends a back-up charge at a later altitude



Testing

Testing is critical to determining any inconsistencies between the ARES design and reality

Testing can be broken down into three areas:

- Sub-Scale Testing
- Recovery System Testing
- Full Scale Testing

Sub-Scale Testing

Sub-scale has a 0.8 scale factor

- Determined by matching Reynolds number
- Scale factor ensures aerodynamic similarity
- Planned sub-scale launch on November 21-22

Subscale Diameter (in)	Scaling Factor	Velocity to match FS Reynolds number (ft/s)	Mach Number
5.5	1	650	0.572
4.95	.9	722.2	0.636
4.4	.8	812.5	0.716
3.85	.7	928.5	0.818
3.3	.6	1083.3	0.954
2.75	.5	1300	1.145

Recovery System Testing

Drop Tests

- Drop test main and drogue parachute from a significant height
- This will ensure packing method is correct

Ground Tests

- Charge tests will ensure clearance from the launch vehicle
- Altimeters will be tested in vacuum container to verify altitude readings

Sub-Scale Tests

- The sub-scale will prove that sizing selections are correct

Full Scale Testing

Two full scale launches are currently planned

- February 13 and 14

Observe and verify that 5,280 foot apogee is achieved within 1%

Verify that recovery is completed successfully

Payload Design

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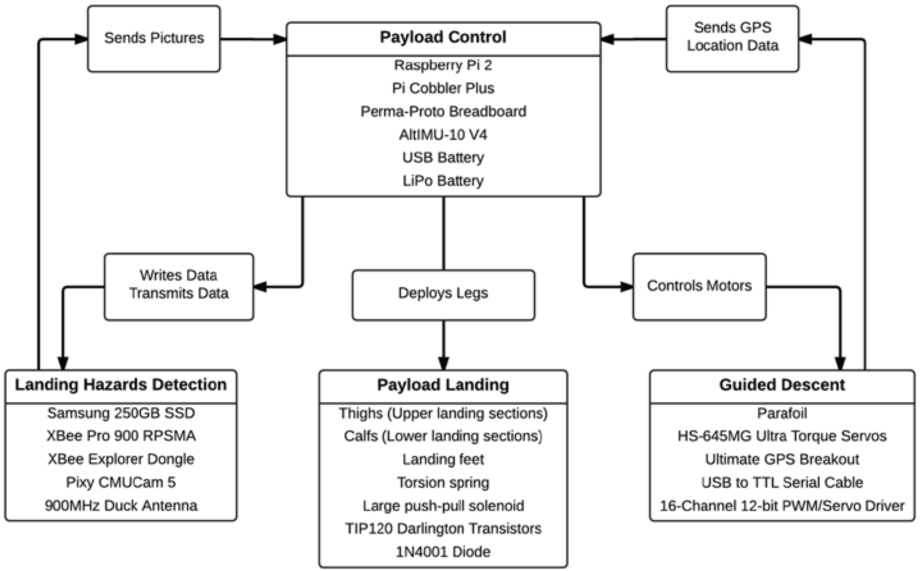
Baseline Payload Design

Two Tasks:
- Landing Hazards Detection
- Guided Descent

Four sub-systems:
- Payload Control
- Landing Hazard Detection
- Guided Descent
- Payload Landing



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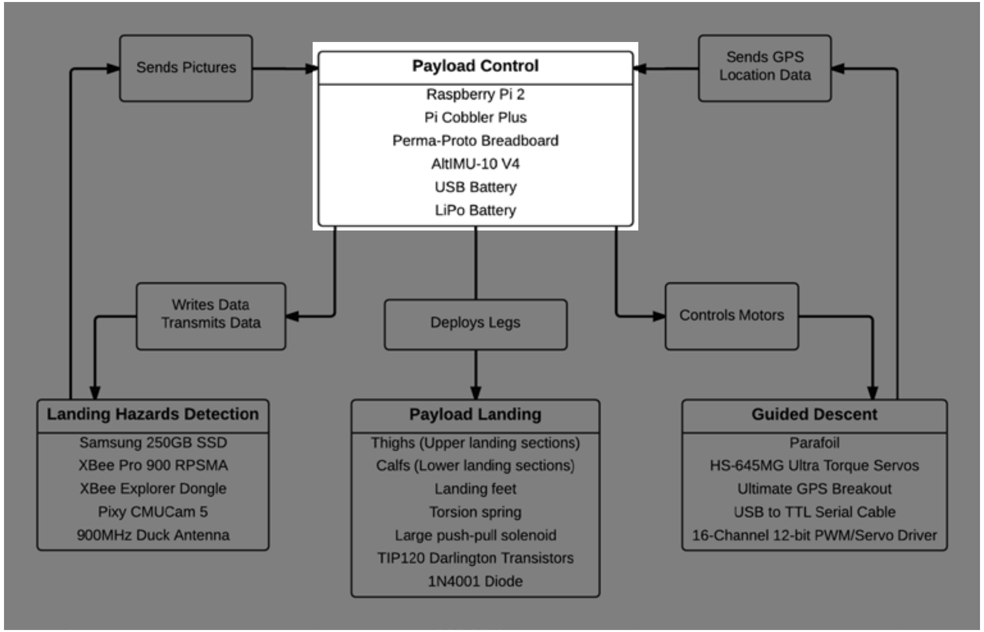

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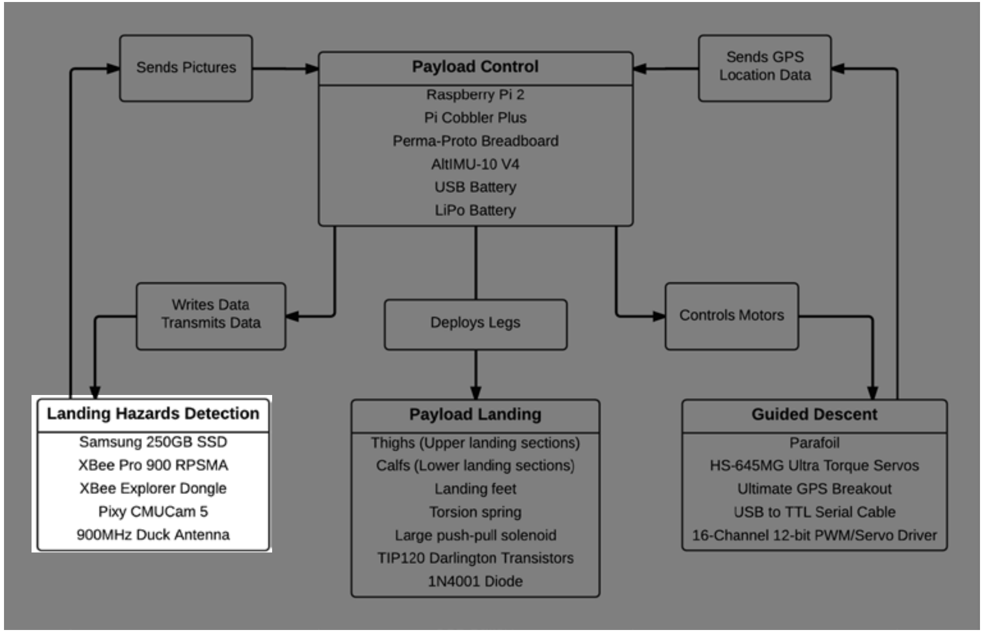

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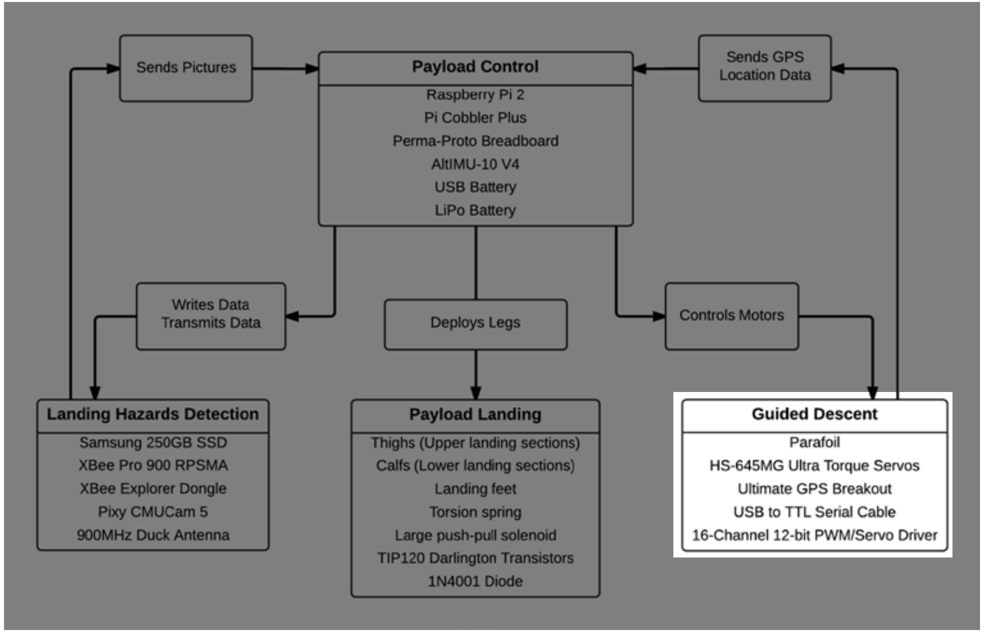

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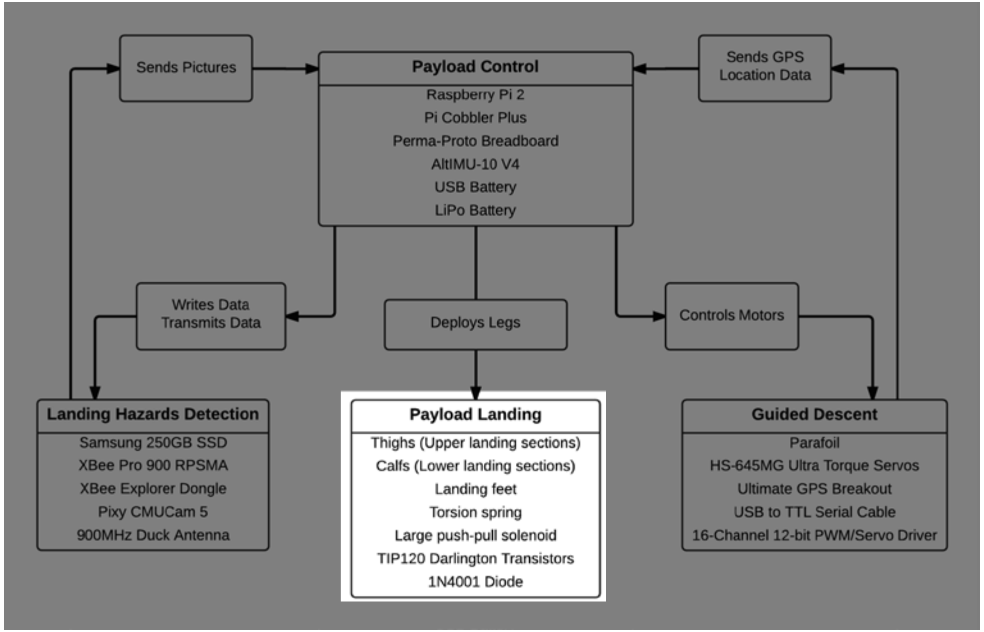
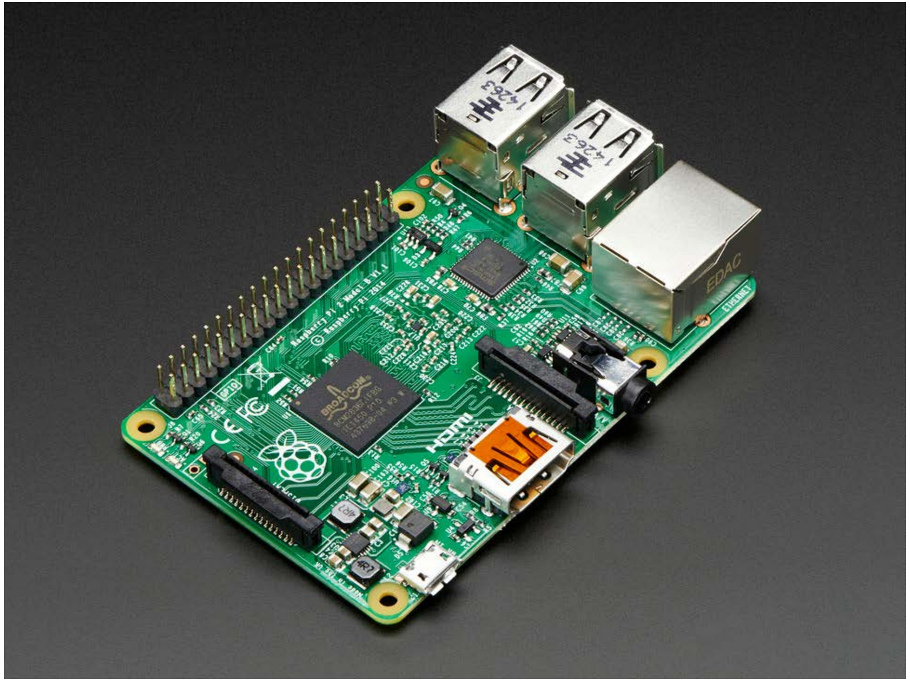


Payload Control

Raspberry Pi 2
- Dedicated GPU
- GPIO Control
- USB Interfaces

Pi Cobbler Plus

Perma-Proto Breadboard
- Easy Manufacturing



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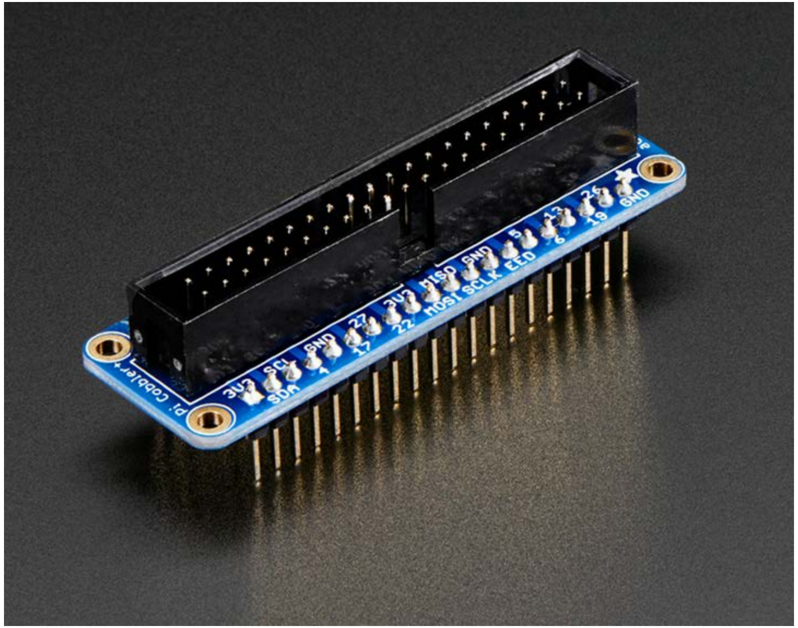

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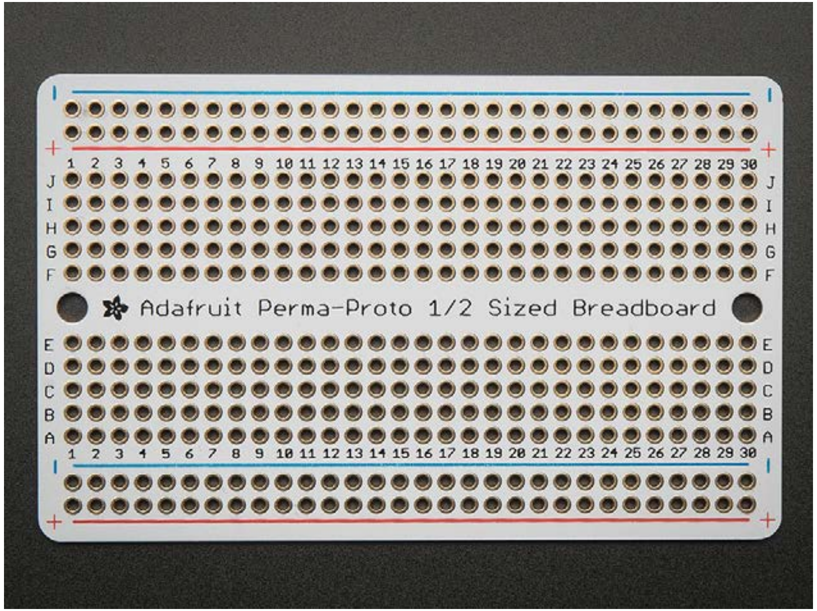
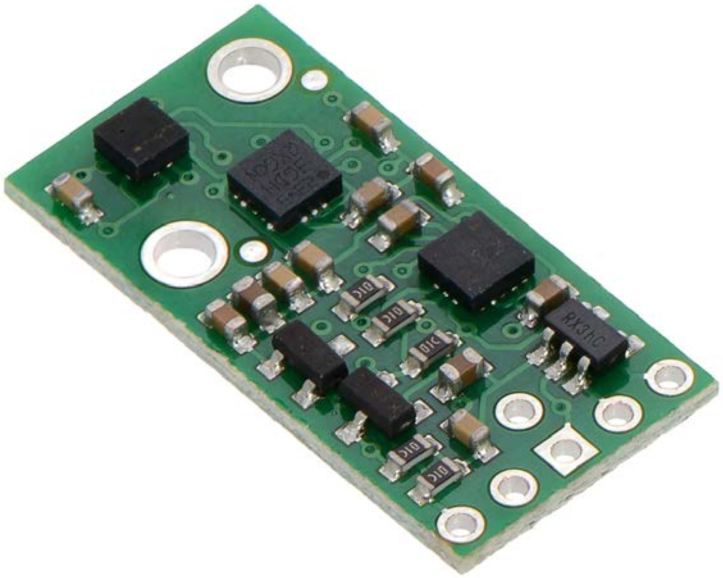


Payload Control

AltIMU-10 v4
- Altimeter
- Gyroscope
- Accelerometer
- Magnetometer

Two Battery System
- 4400 mAh / 5V
- 5000 mAh / 14.8V



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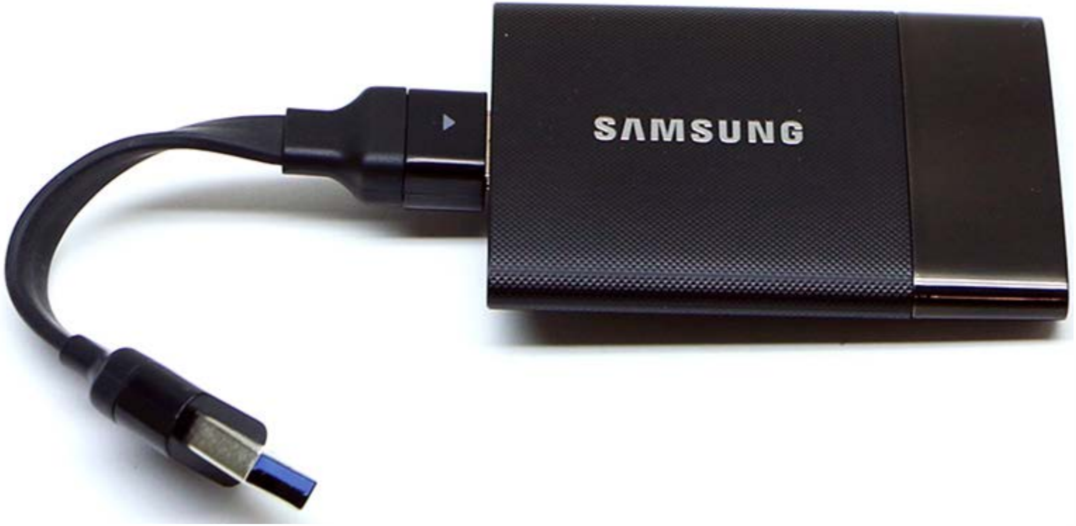
Landing Hazards Detection

Samsung 250 GB SSD
- Low profile, weight
- Vibration resistant

Pixy CMUCam5
- Pi compatible
- USB/I2C Compatible
- Open-source software



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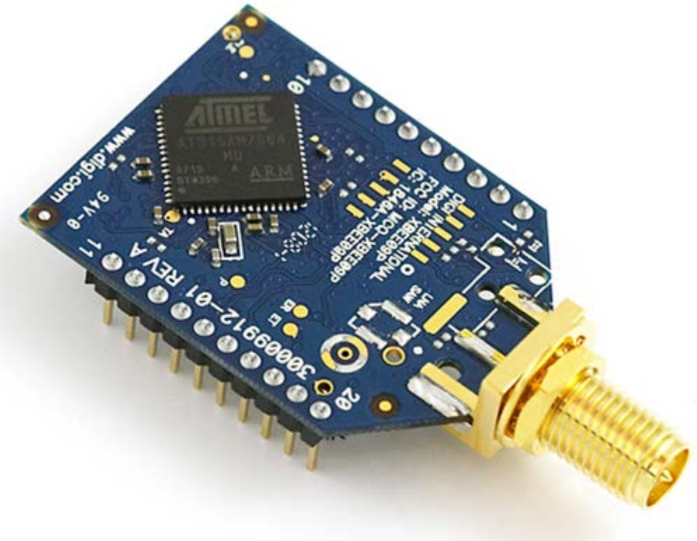
- 156 Kbps transfer rate
- Up to 6 miles of range

XBee Explorer Dongle

- USB Connection

900 MHz Duck Antenna



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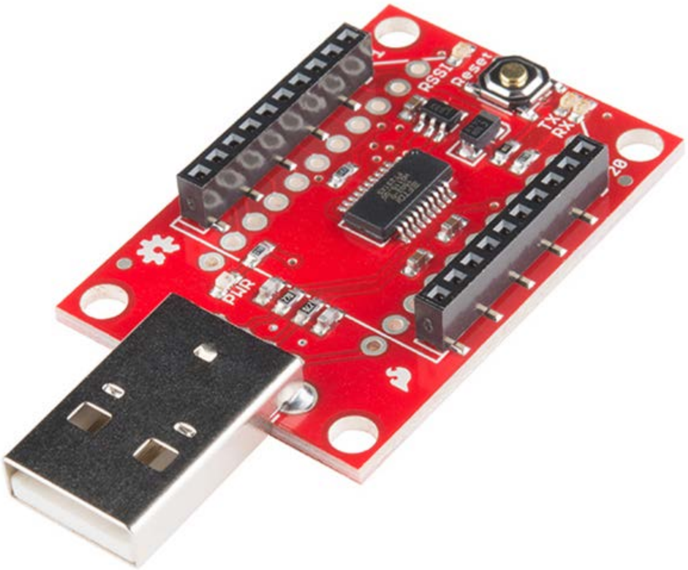

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Guided Descent

Parafoil
- Allows steering
- Stiffer internal ribs for low speed flight

Ultimate GPS Breakout
- Low power draw (20 mA)

USB to TTL Cable

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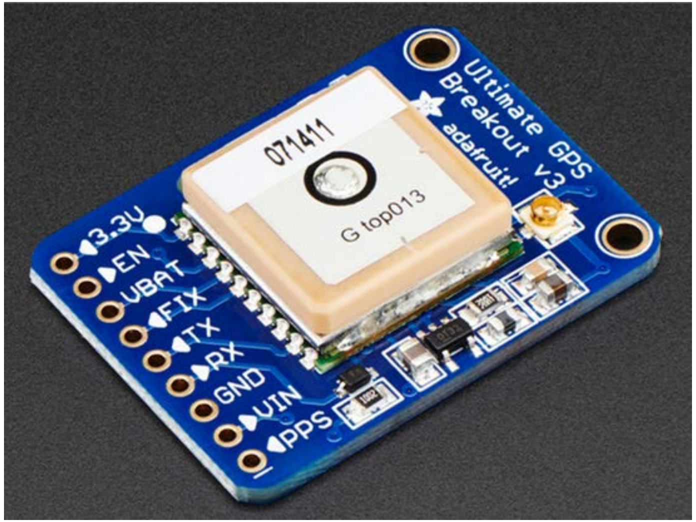

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- Continuous rotation

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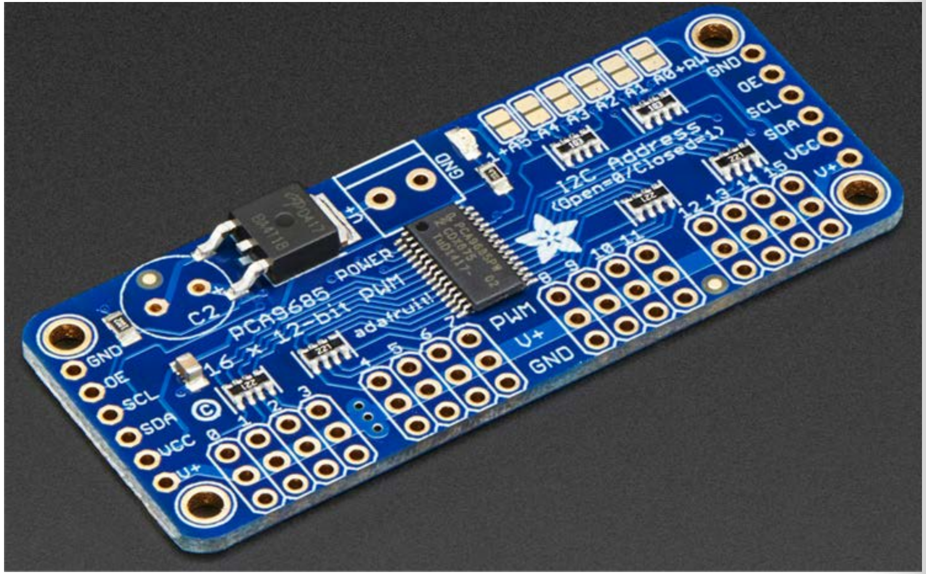
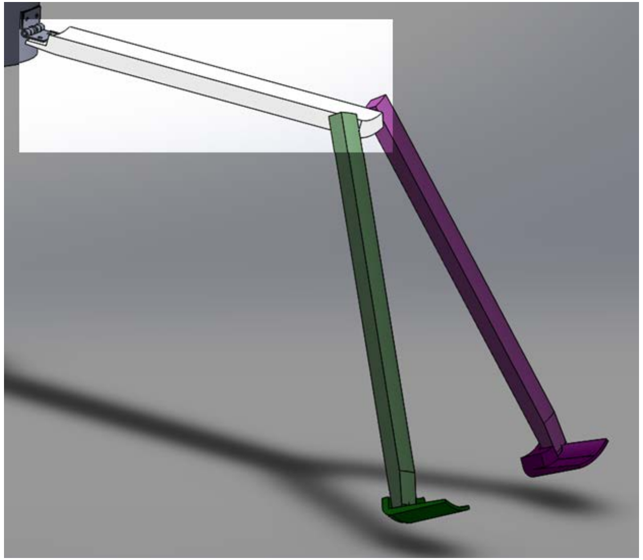


Payload Landing

Thigh (Upper landing section)
Calf (Lower landing section)
Landing Feet
Torsion Springs
Hinge



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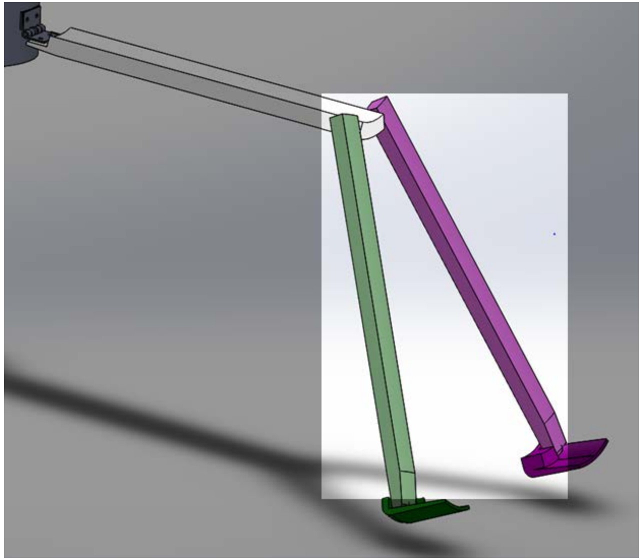

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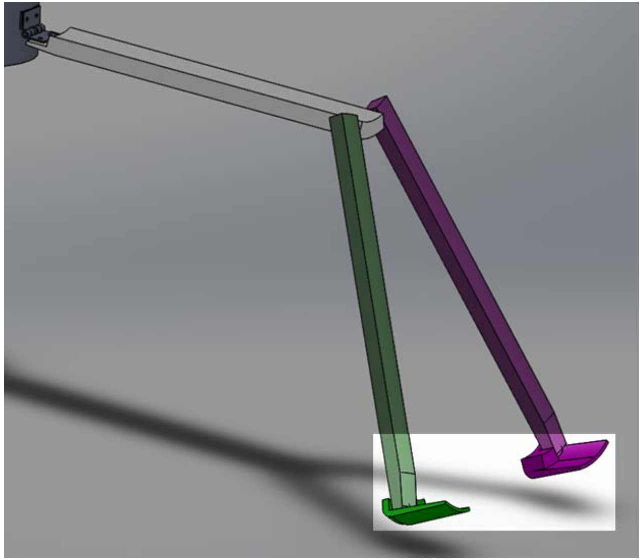

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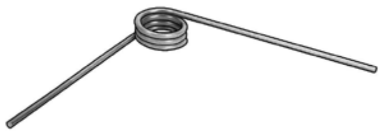

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Payload Landing

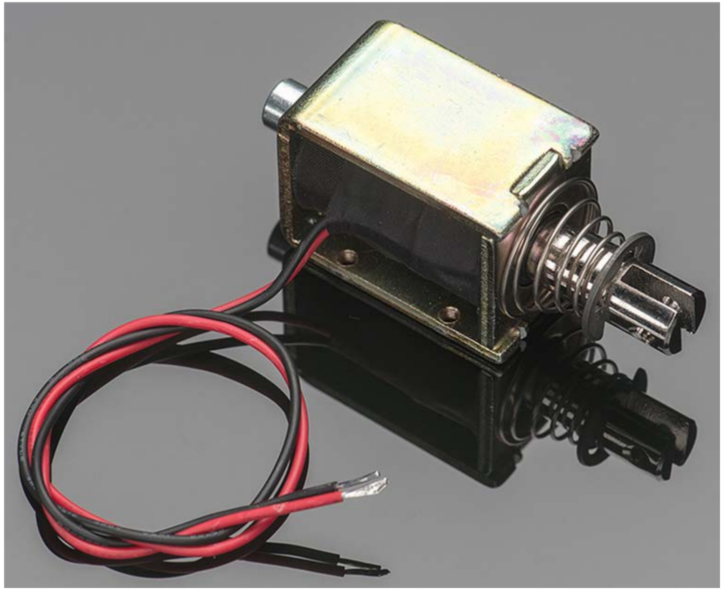
Large push-pull solenoid

- 0.317 lbs of force
- No power draw when off

TIP120 Darlington Transistor

- 60V/5A continuous max

1N4001 Diode



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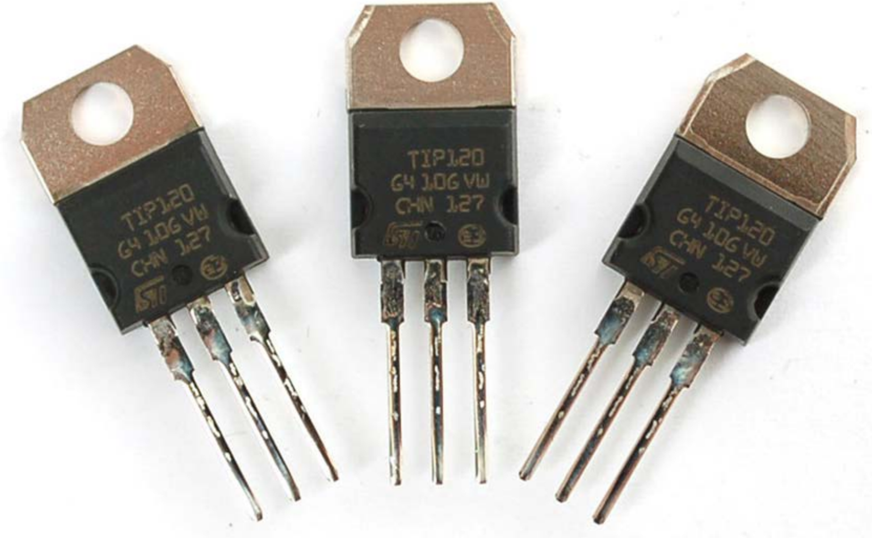

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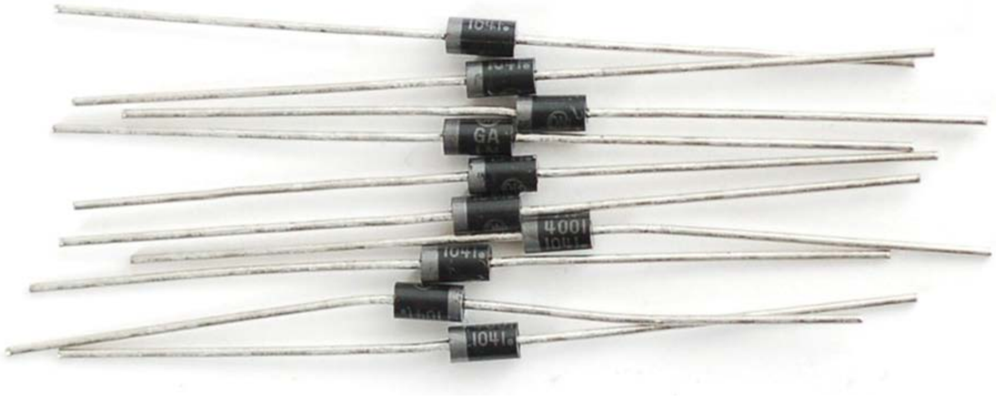

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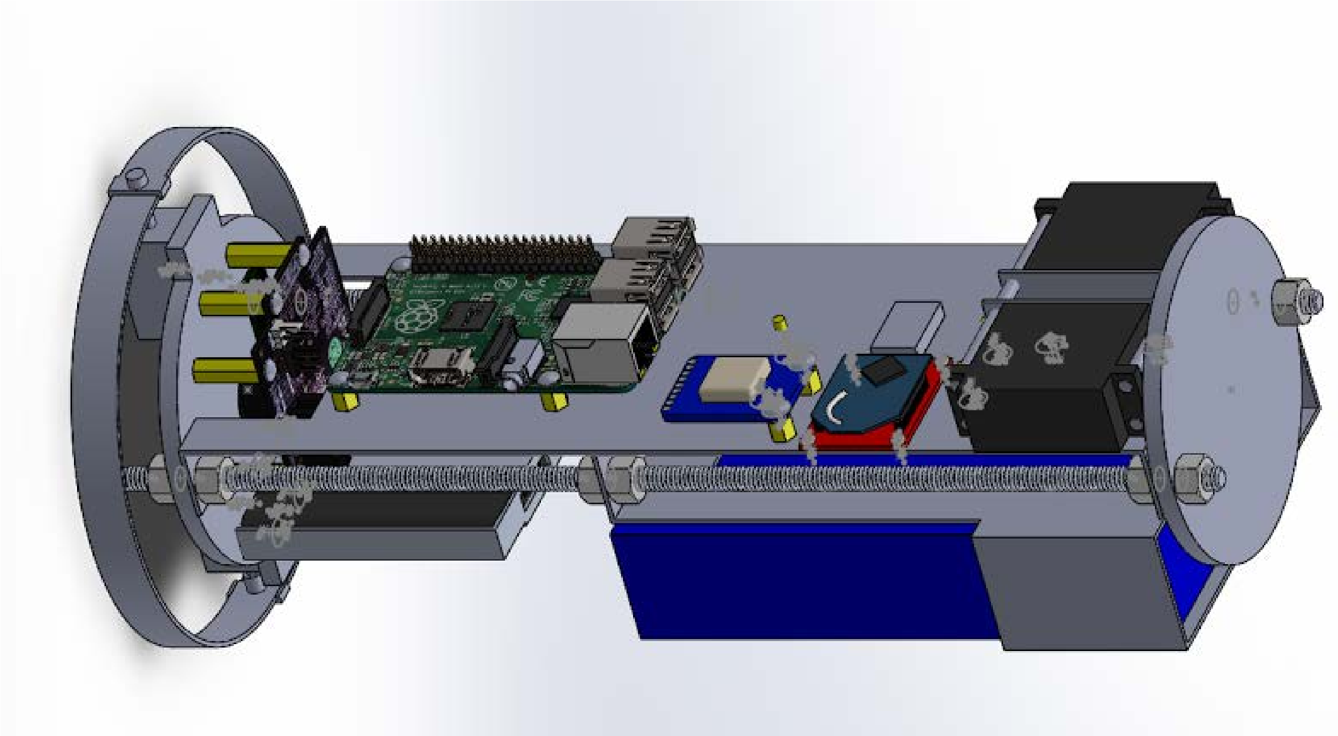

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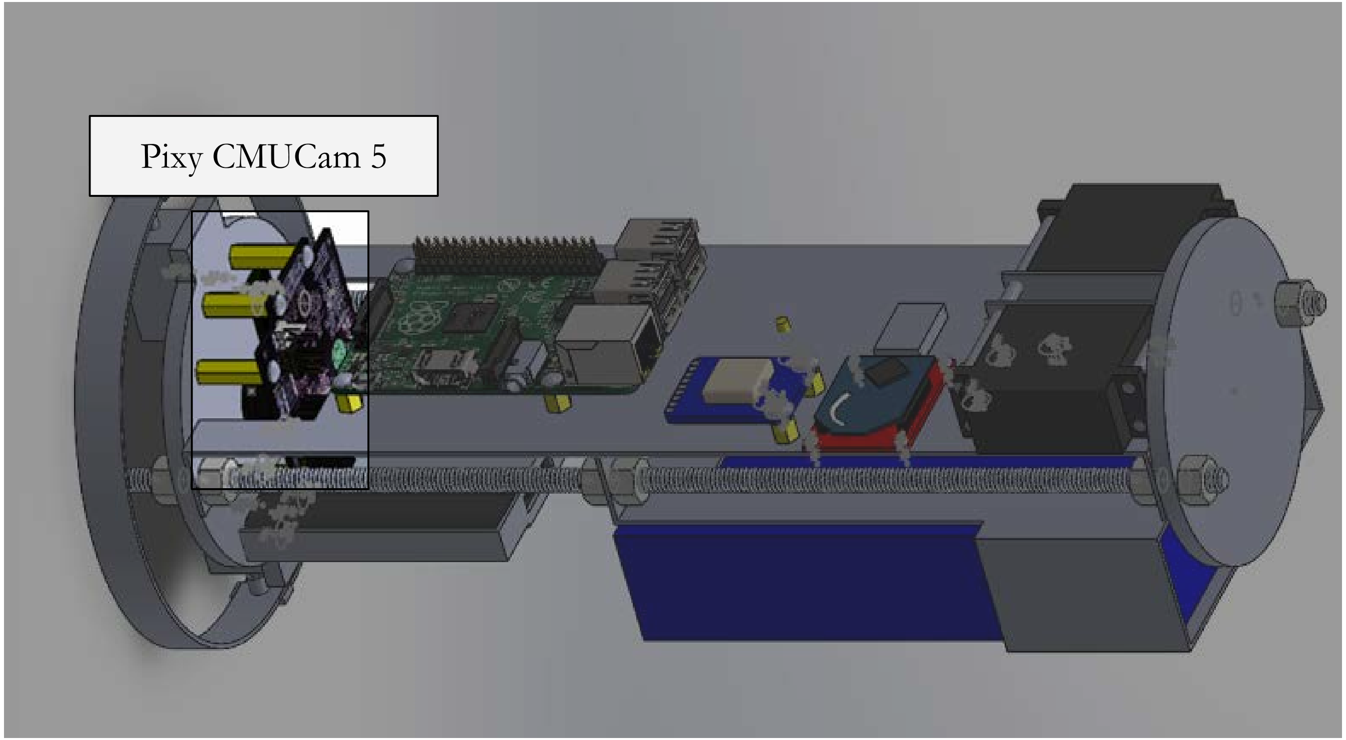

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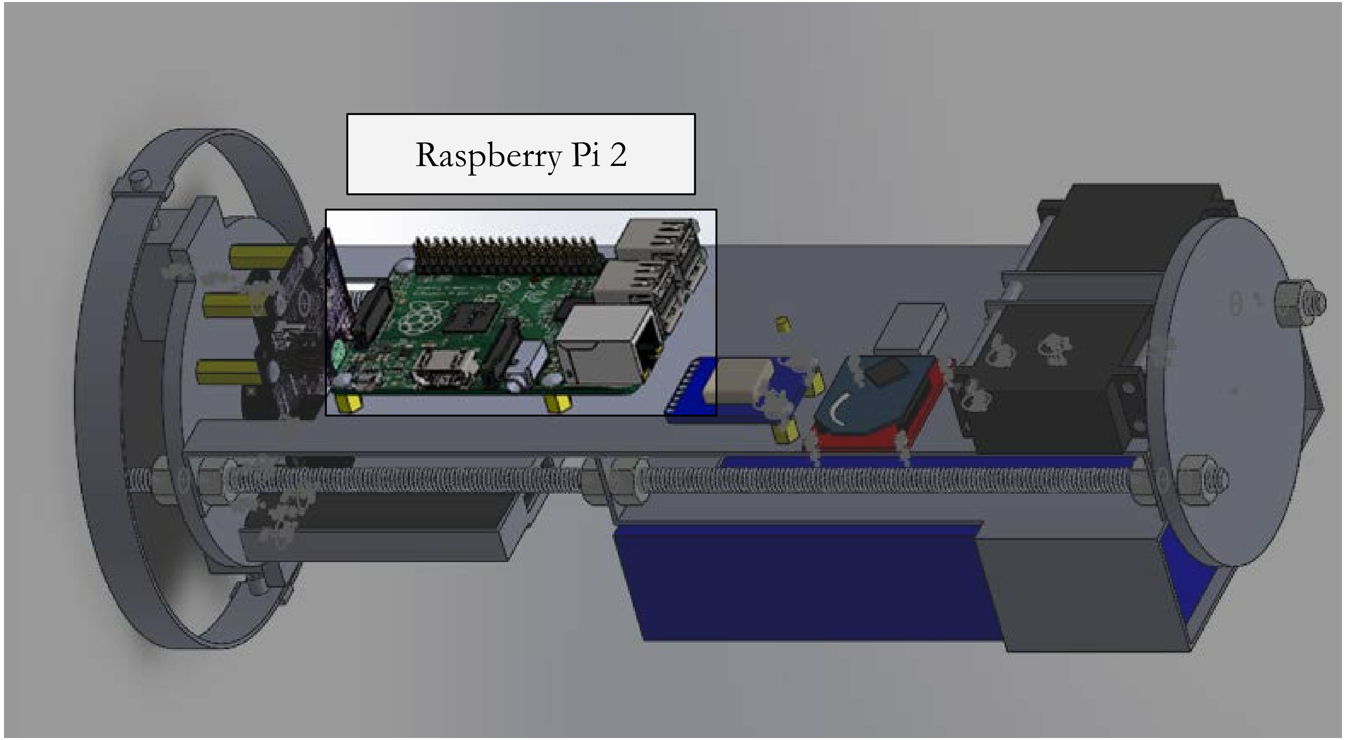

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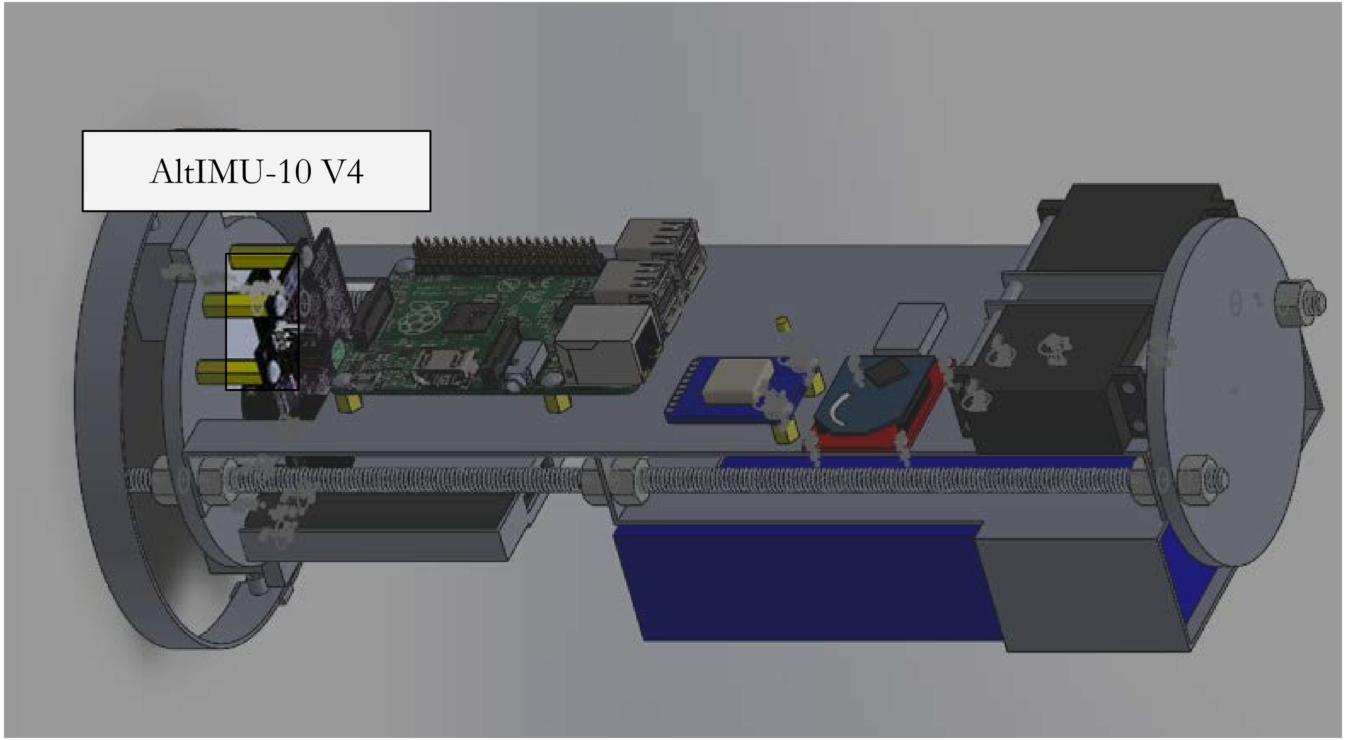

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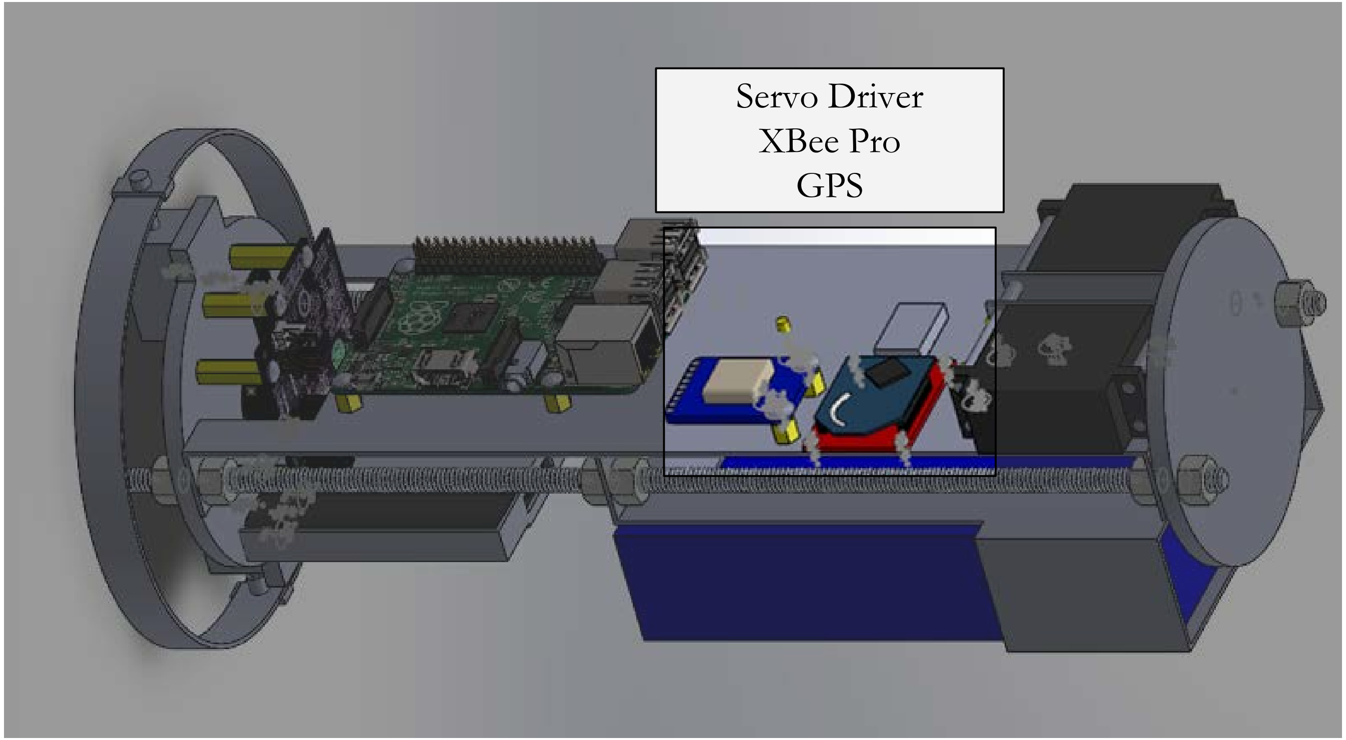

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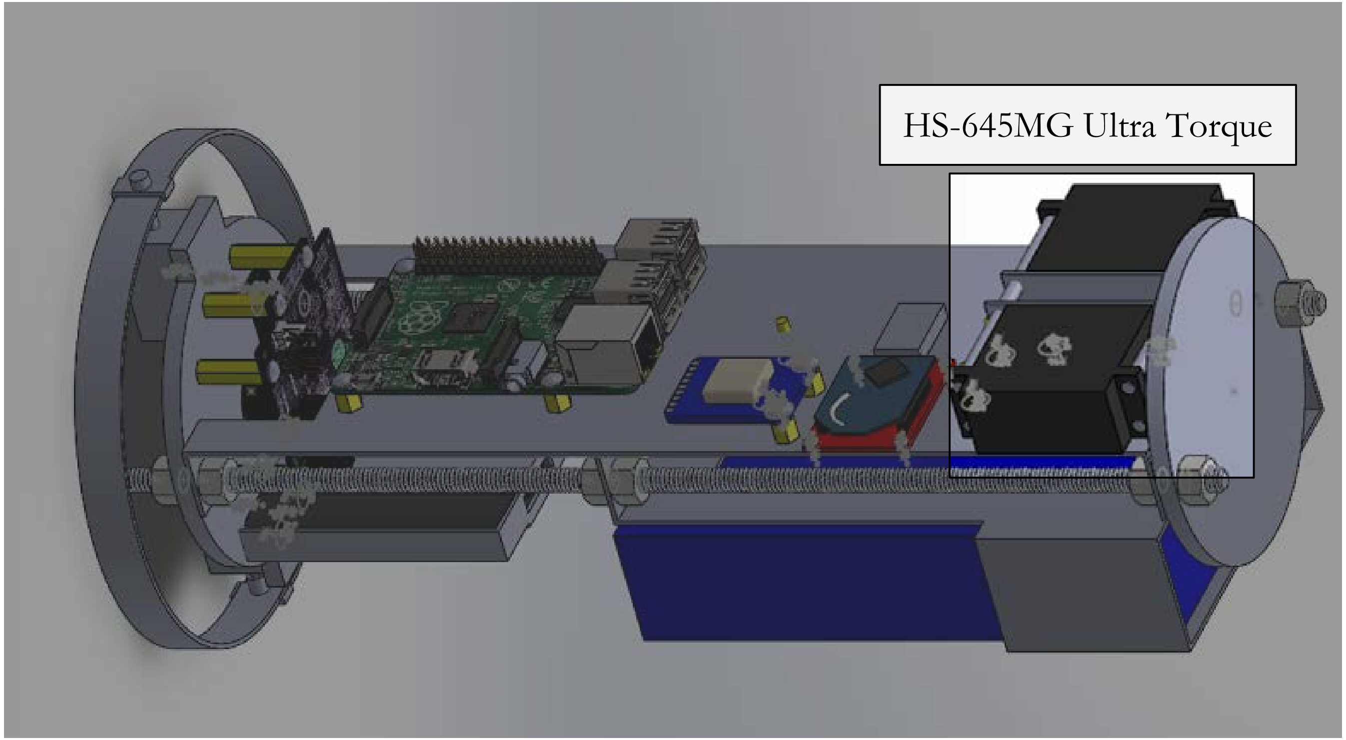

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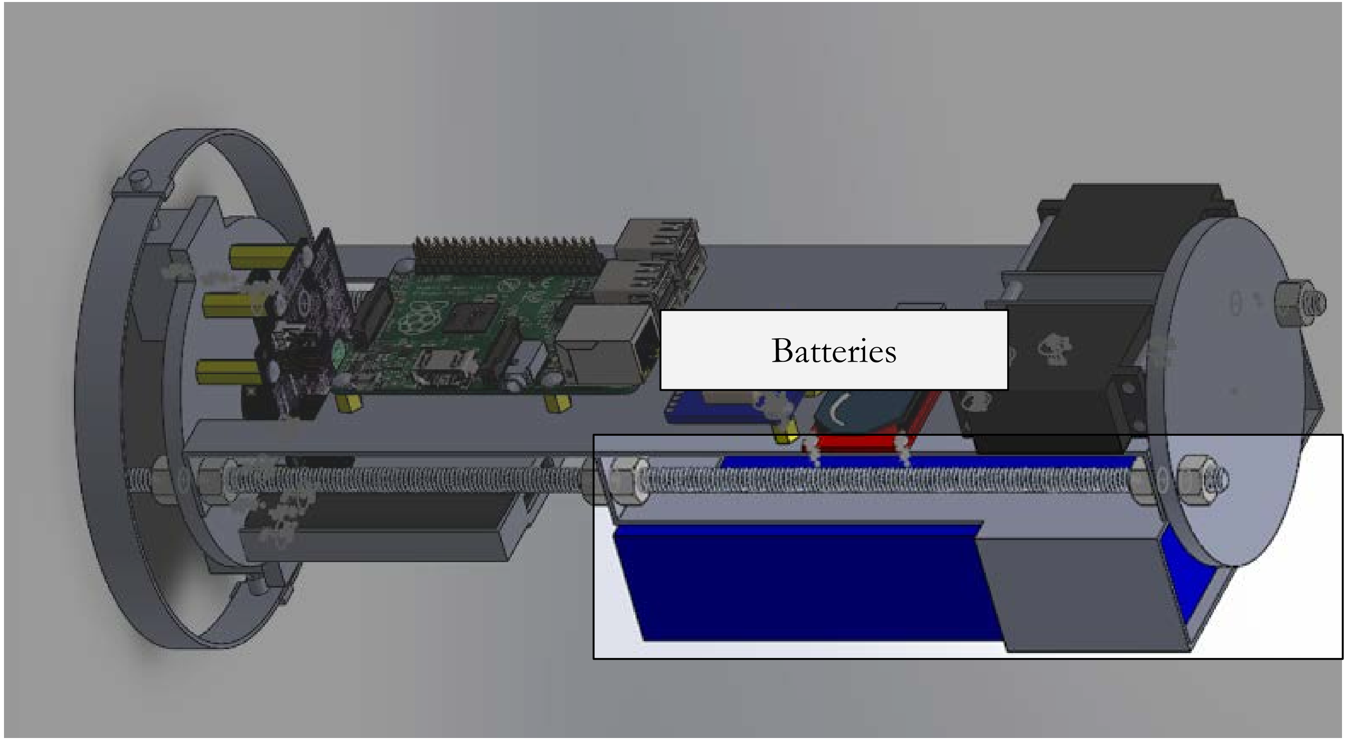

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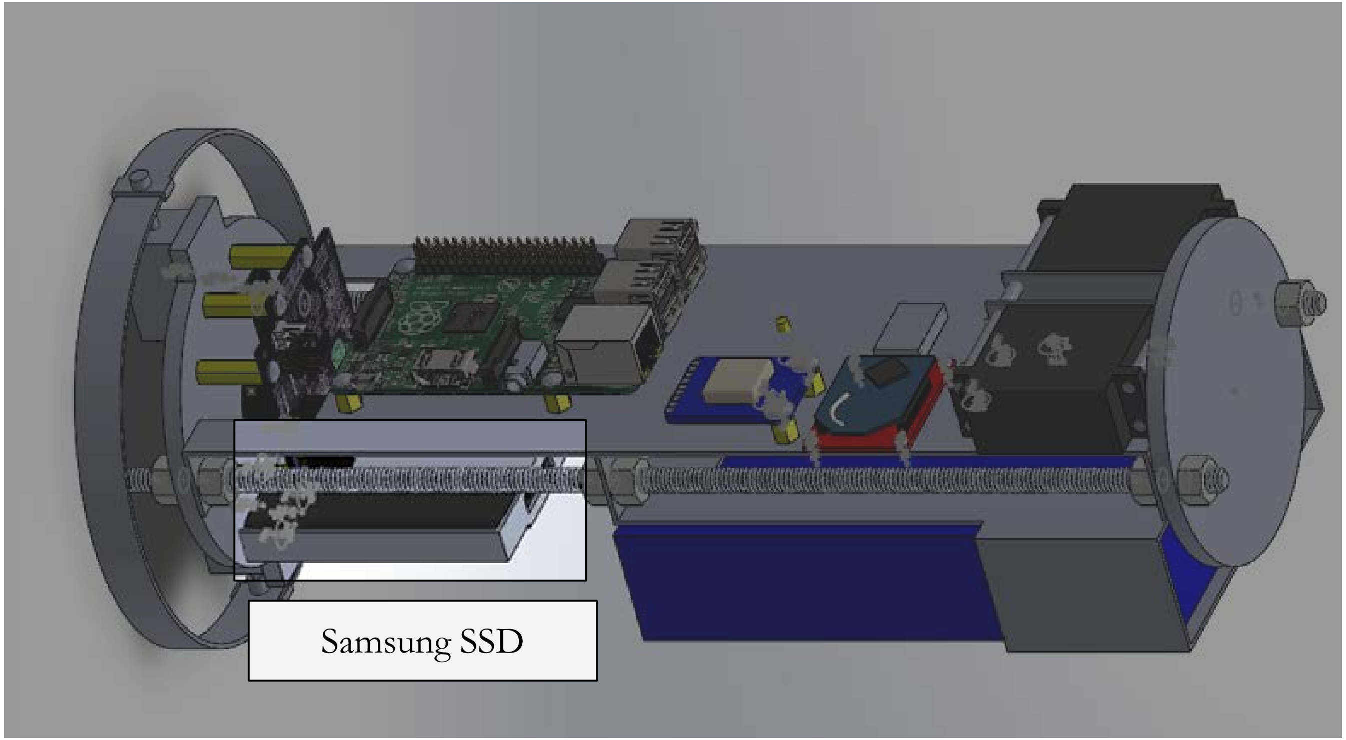

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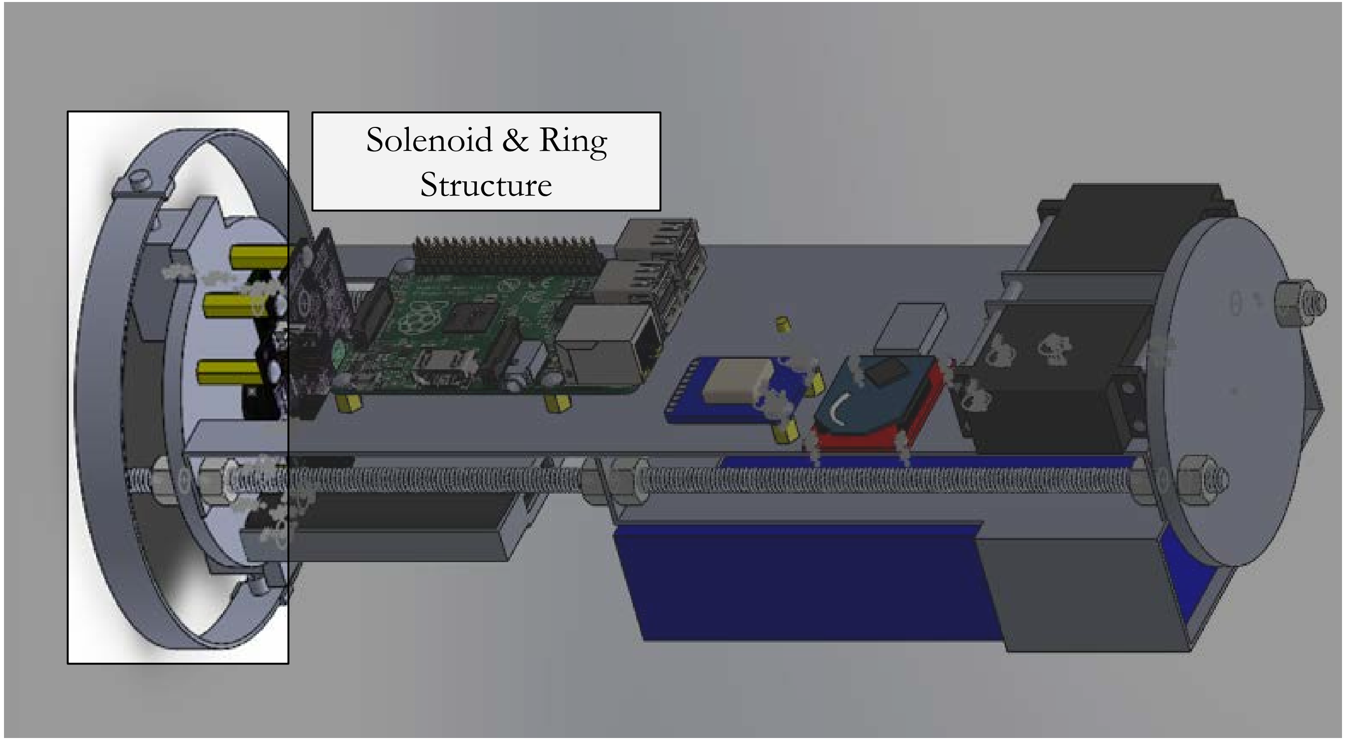

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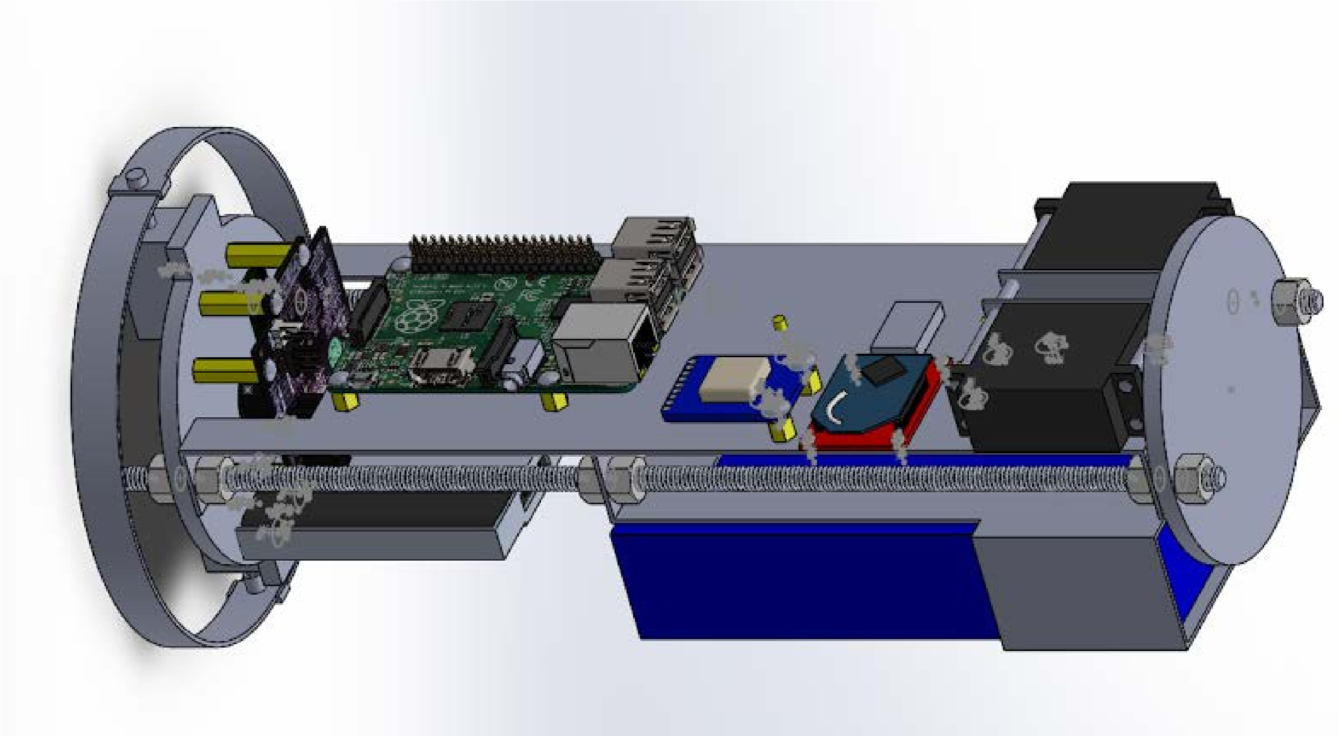

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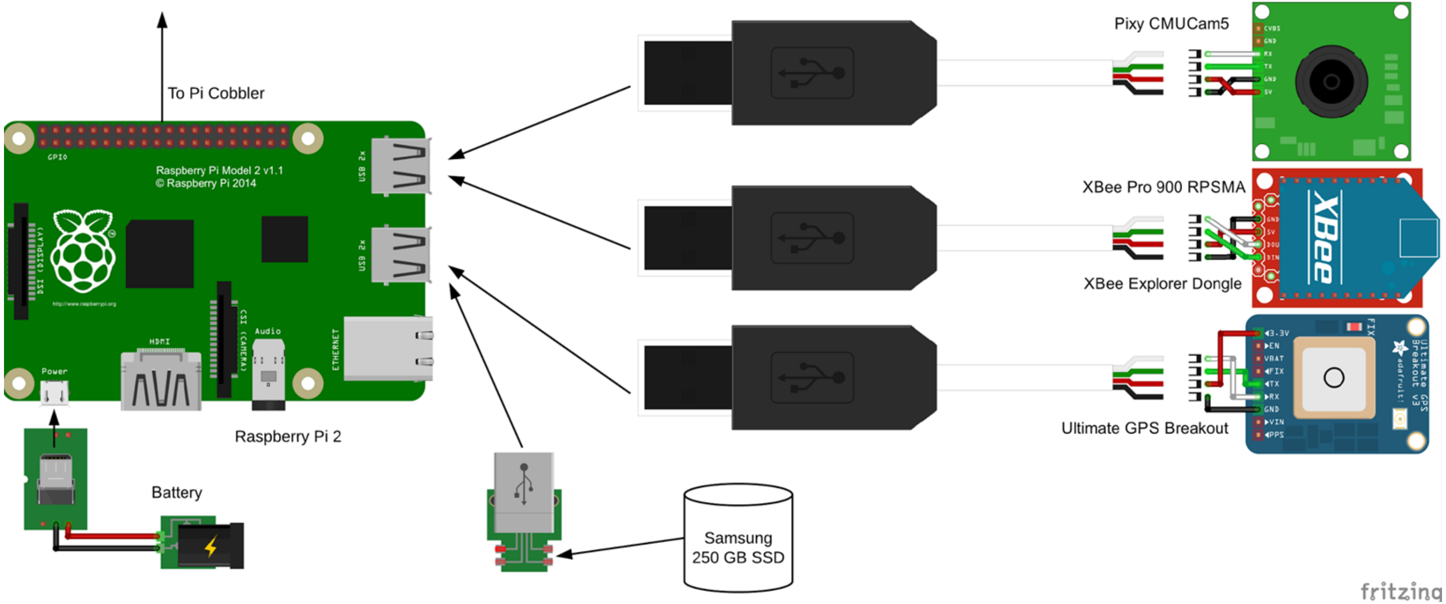

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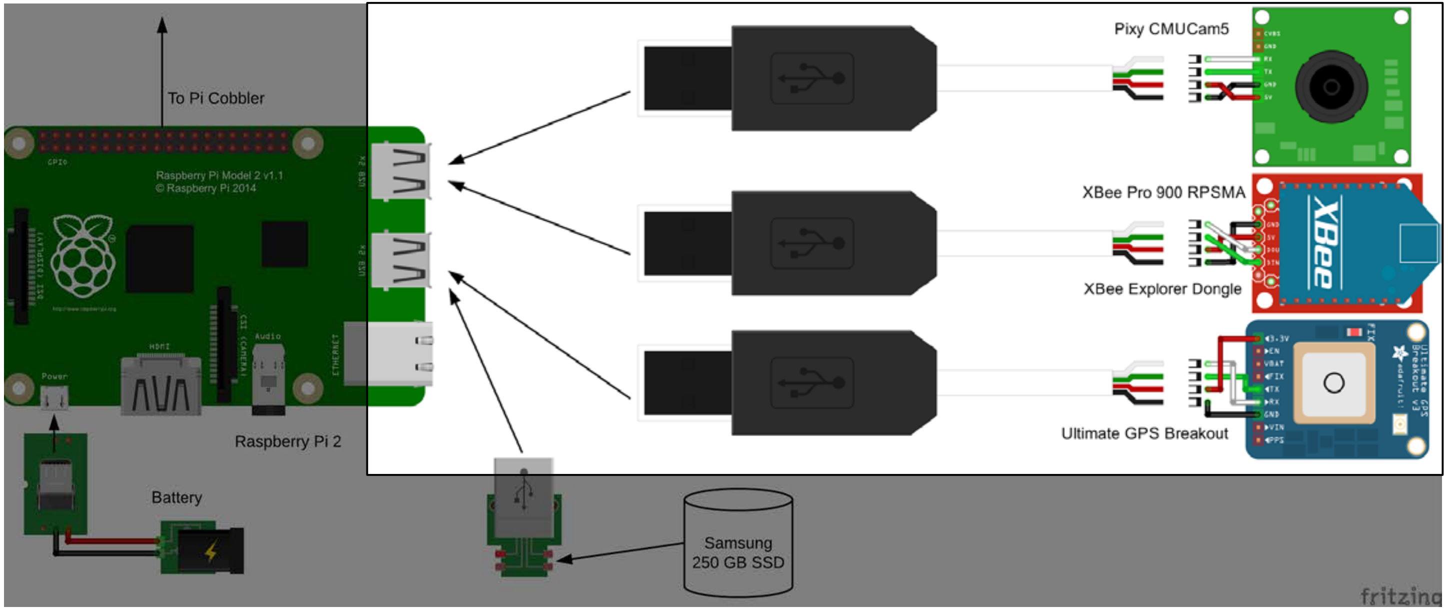

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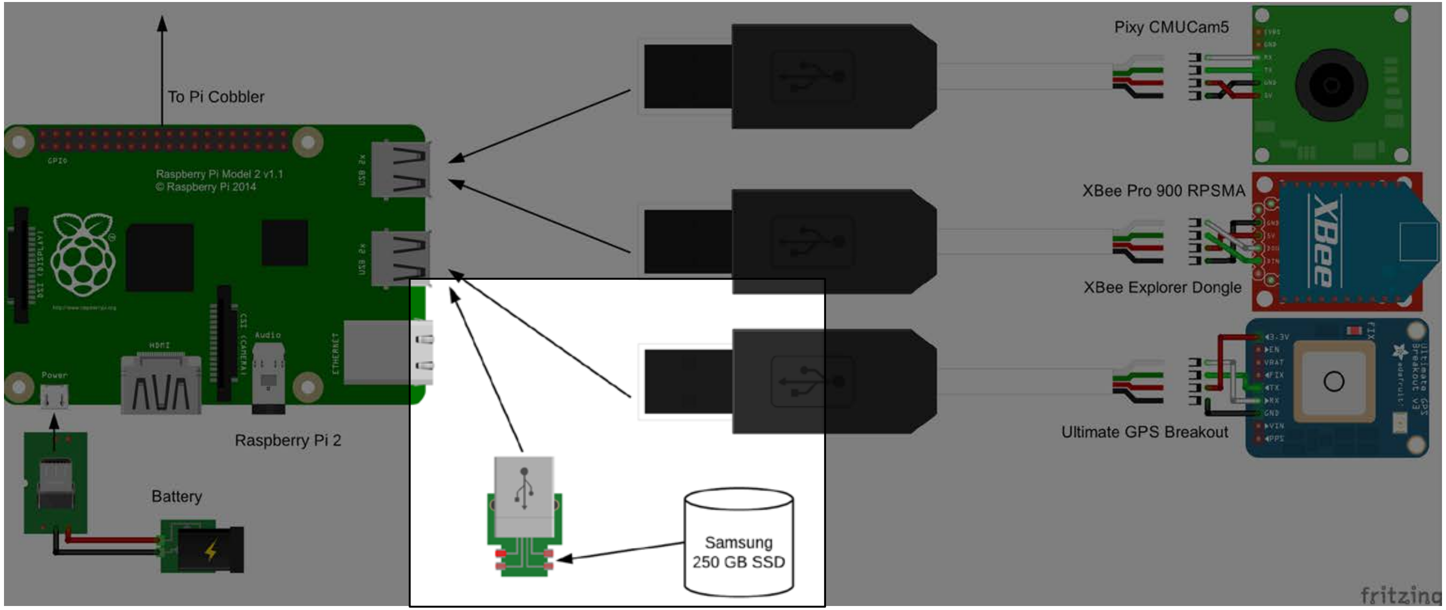

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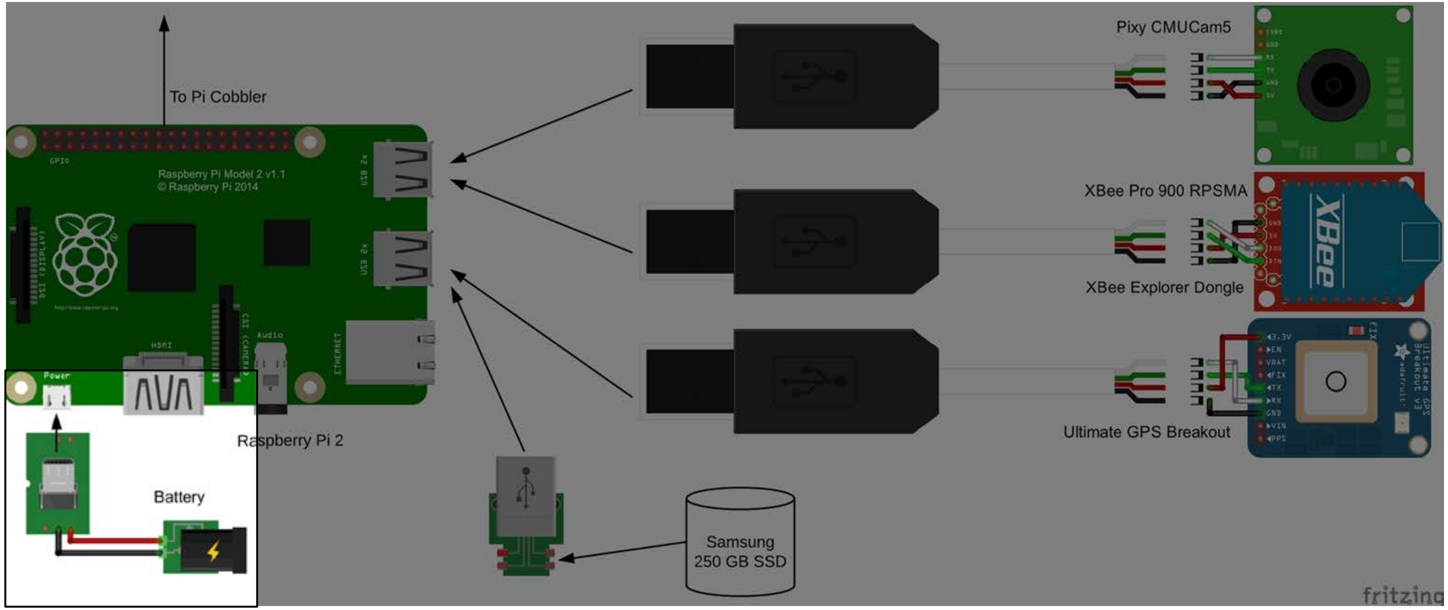

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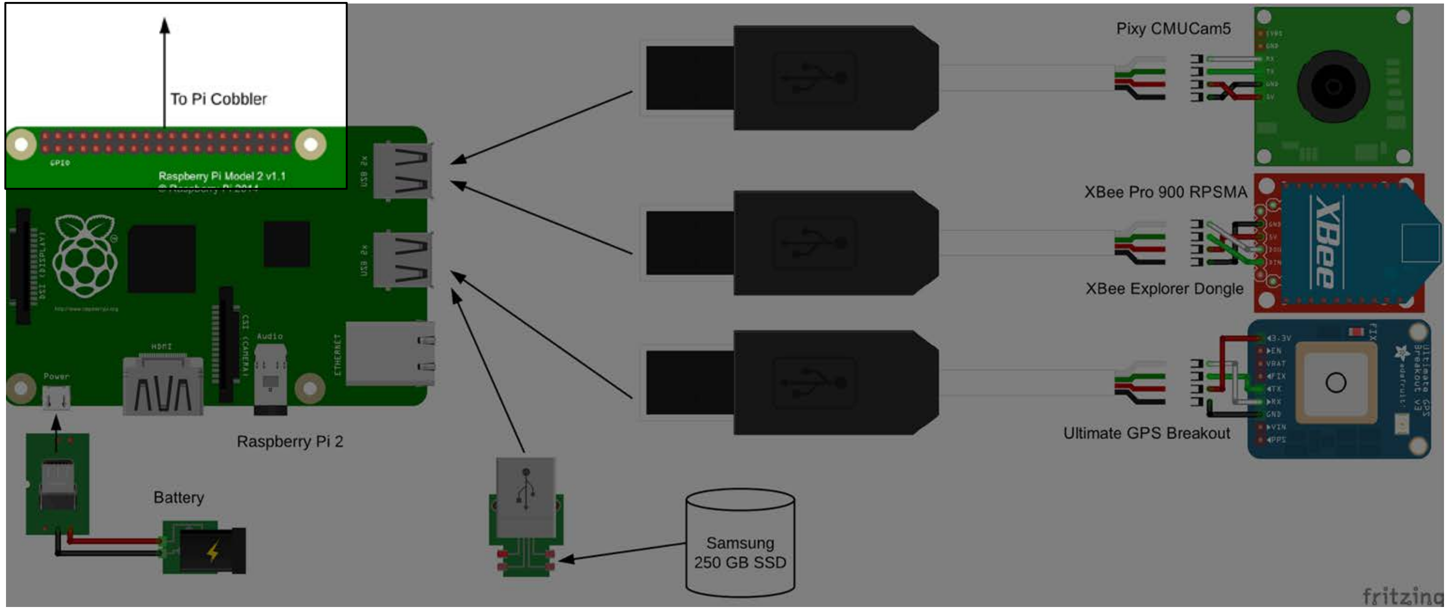

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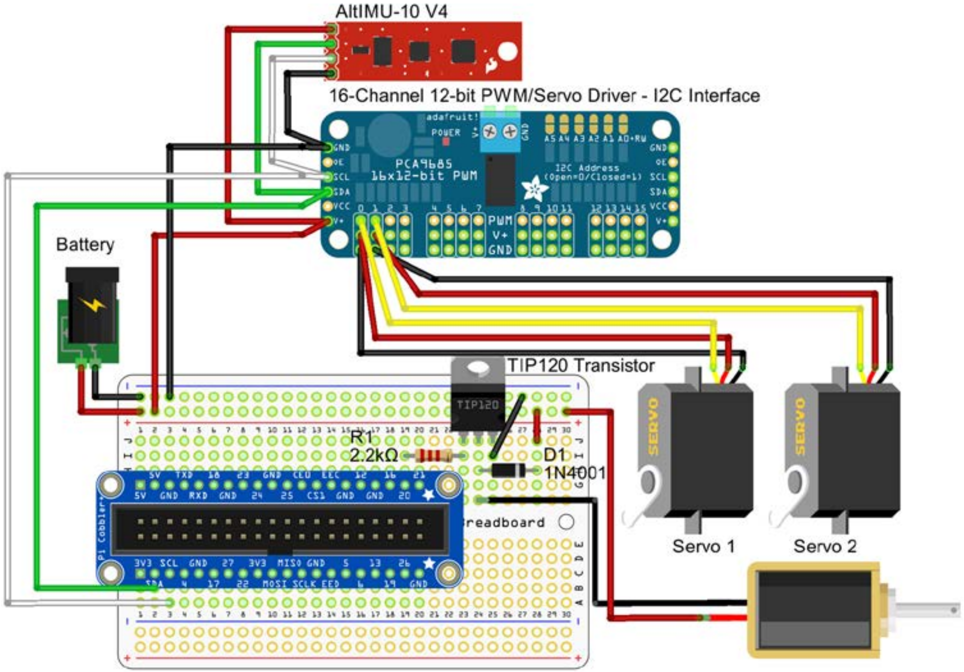
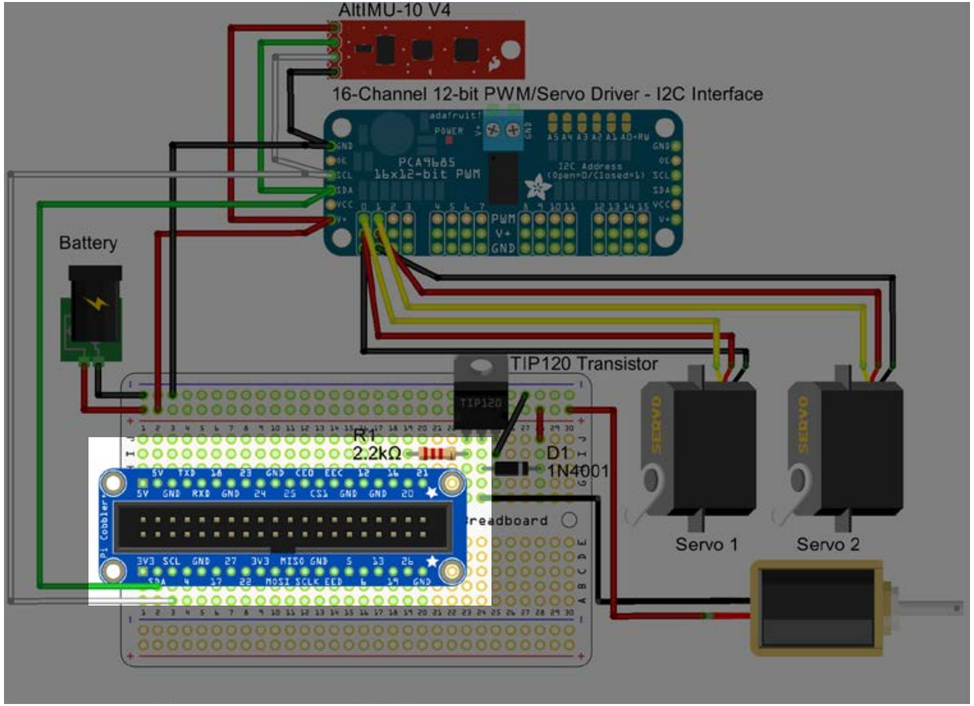
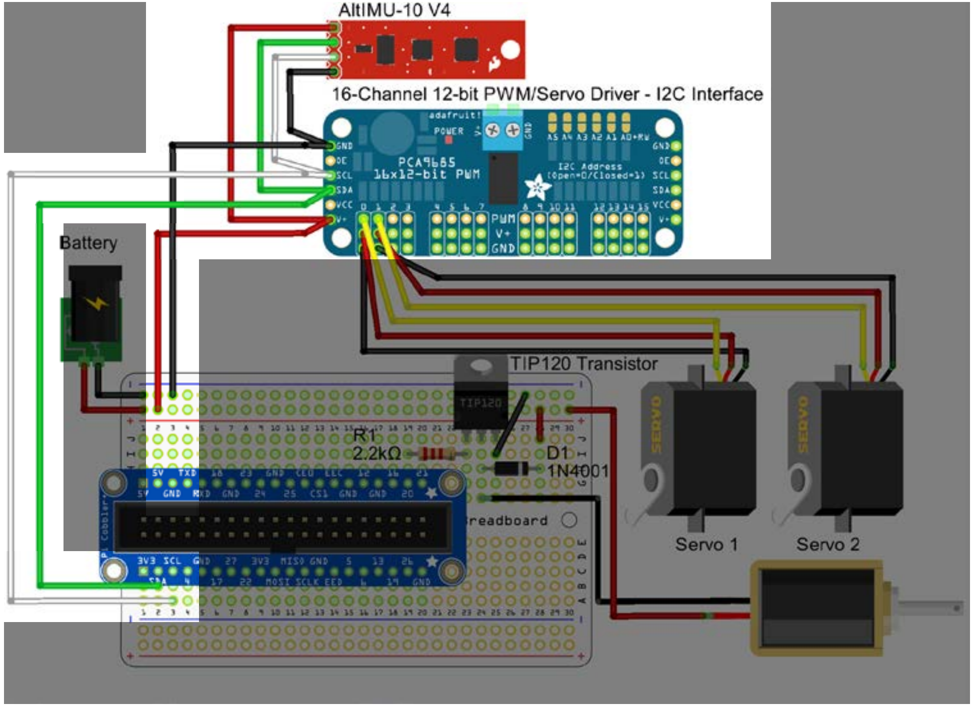


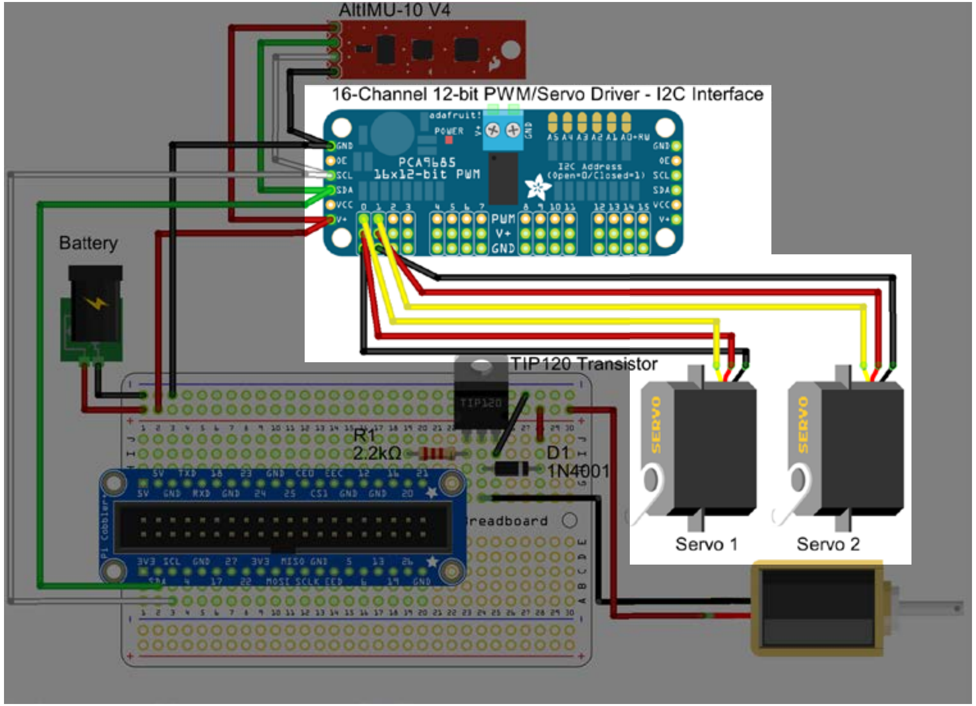
Payload Electrical Configuration



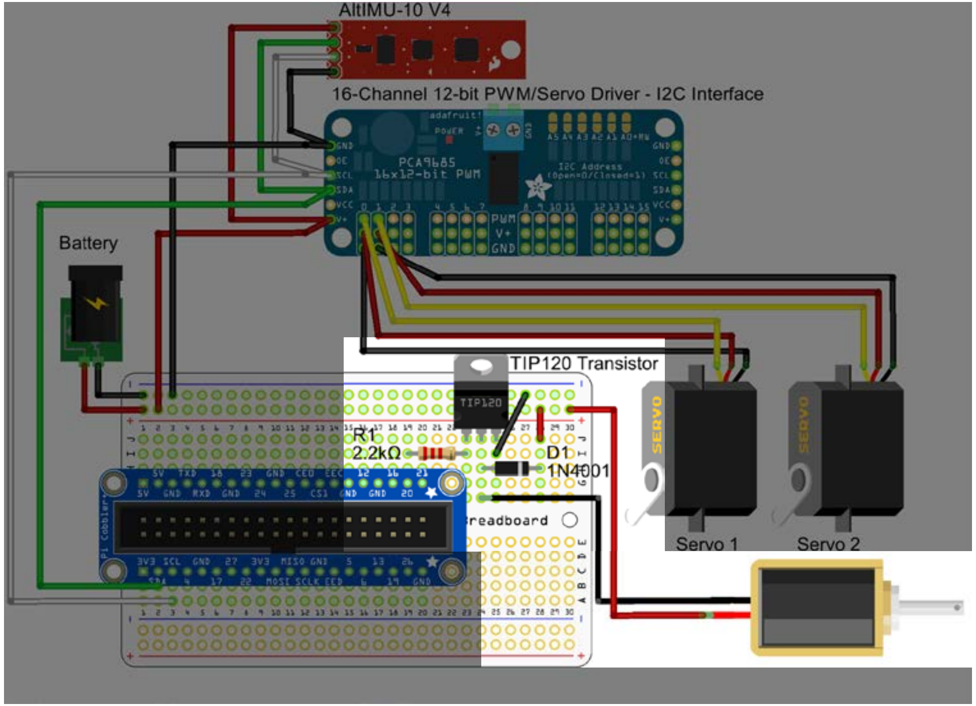
Payload Electrical Configuration



Payload Electrical Configuration



Payload Electrical Configuration



Component Testing

Payload Control

- Raspberry Pi SSD boot test
- Configure AltIMU-10 V4

Landing Hazards Detection System

- Image acquisition test
- Dummy data transmission test
- Dummy data software test

Component Testing

Guided Descent

- GPS Data transmission test
- Dummy payload parafoil test
- Servo test runs

Payload Landing

- 3-D printed part inspection

Ground/Subsystem Testing

Breadboard test

- Test components on a subsystem level
- Check battery drain times

Landing Subsystem test

- Leg release mechanism will be repeatedly tested
- Weighted drop tests
- These will ensure integrity and functionality

Parafoil investigation

- Drop test with similar mass profile
- find approximate lift-to-drag ratio, lift coefficient, and drag coefficient.

Drop/Prototype Testing

Full prototype implementation

- Battery run times will be tested again
- Components will be rechecked for functionality

Low altitude drop tests

- Check landing leg integrity
- Test flare maneuver

Drop/Prototype Testing

High altitude drop tests

- Drop from weather balloon
- Acquire images & data for software testing
- Realistic test environment

Full Scale test

- Will be launched and verified during Full-scale Flight Readiness tests.

Safety

Alabama Rocket Engineering Systems (ARES) Team
The University of Alabama

Launch Vehicle Safety Verification

Final assembly and launch procedure checklists found in Appendix B of PDR report

- Safety procedures to be followed prior to and during launch
- Distributed to all team members and will be discussed in safety briefings prior to each launch

Launch Vehicle Safety Verification

The launch procedure will verify the vehicle is safe and ready for launch. These procedures are broken down into:

- Ejection Charge Test
- Electronics Bay Preparation Checklist
- Motor Loading Procedures Checklist
- Recovery Preparation Checklist
- Motor Installment Procedure Checklist
- Launch Pad Procedure Checklist

Hazardous Material Operating Procedures

Ares has generated operating procedures for the following:

- Igniter
- Rocket Motor
- Fiberglass
- Epoxy
- Spray Paint
- Black Powder

These operating procedures are based on SDS regulations

Risk Assessment

Black powder (early or unexpected detonation)	Damage to rocket, payload, and equipment; severe injury to team members including burns or death	Improper storage of black powder; exposure of black powder to flame, temperature, or impact prior to expected detonation	1B	Store black powder securely in explosives safe container; keep black powder away from possible sources of heat or impact; ensure black powder charges are properly secured within rocket	2E
Parafoil deployment	Ballistic payload; possible loss of payload due to damage from landing; inability to correctly steer payload	Incorrect parafoil packing; failure of rocket separation	1D	Double check folding and packing of parafoil prior to launch; follow all mitigation steps for failed rocket separation	1E

Risk Assessment

Rocket separation (late or failed)	Kinetic energy of rocket and/or payload may exceed limit; possible damage to rocket or payload upon landing; rocket may cause severe injury or death if a failed separation occurs over a crowded area	Delayed or failed detonation of black powder; failure of shear pins to break as expected	1C	Ensure e-matches will be able to detonate black powder at desired altitude; double-check e-match setup prior to launch; avoid choosing shear pins strong enough to prevent rocket separation	1E
Launch vehicle weathercocks	The vehicle has the potential to enter an improper flight path; would lead to a lower altitude or possible issues with the deployment of the payload with a minor weathercocking	The launch vehicle became unstable	1D	Stability margin will be maintained around 1.5 calibers throughout design iterations in order to avoid any potential weathercocking	3D

Project Plan

Alabama Rocket Engineering Systems (ARES) Team
The University of Alabama

Updated Budget

Additional components have been added to the payload section

Subscale section was itemized, reducing overall costs

Previous Estimation:

- Rocket: $2,933.24
- Total: $7,454.12

Revised total:

- Rocket: $2,933.24
- Total: $7,138.12

Current Expenditures

Purchase	**Actual Cost**	**Budgeted Cost**	**Difference**
Raspberry Pi 2 Kit	$99.95	$57.95	$42.00
Pixy CMUcam5	$74.95	$69.00	$5.95
Parafoil	$20.40	$17.90	$2.50
Total Expenses:	*$195.30*	*Error:*	*$50.45*
Funding Received:	*$8,300.00*		
Balance:	***$8,104.70***		

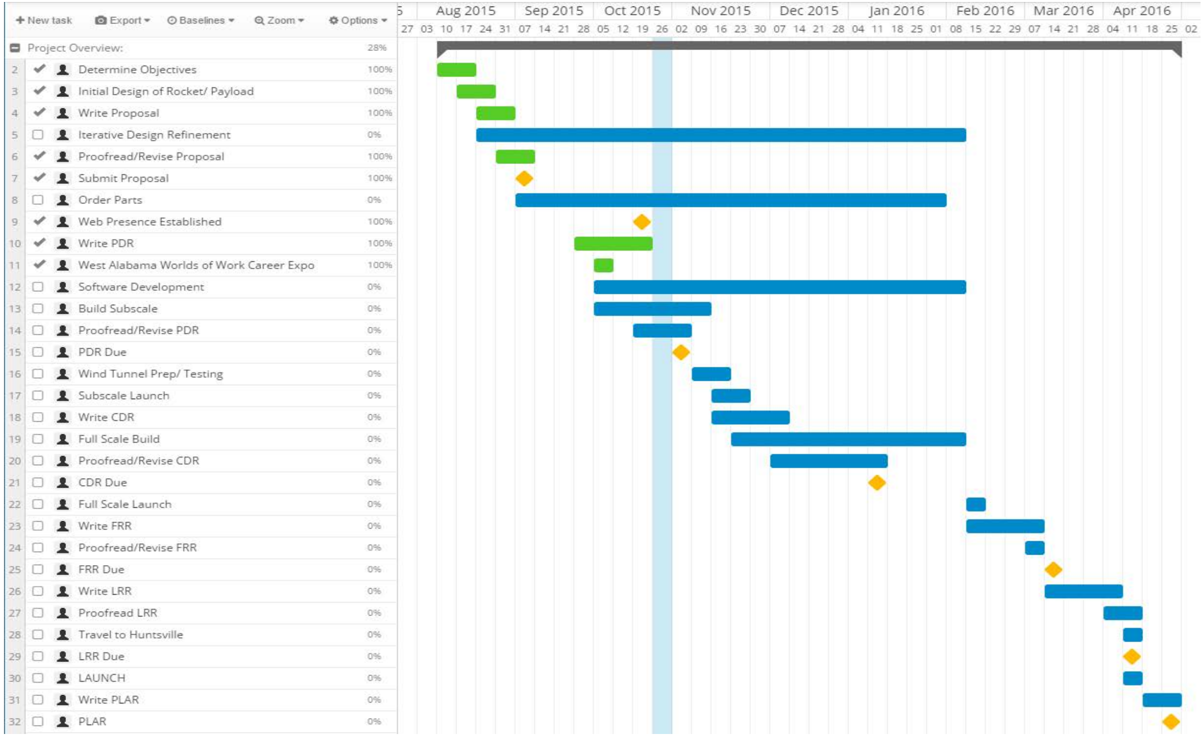
Funding Status

Funding Source	Amount	Status
ASGC	$7,650.00	Confirmed
SGA	$2,400.00	Pending
Department of Aerospace Engineering and Mechanics	$650.00	Confirmed
Fundraising	$500.00	Unconfirmed
Projected Total:	**$11,200.00**	
Confirmed Total:	**$8,300.00**	

ASGC Funding Stipulations

Category	Amount
Materials	$4,500.00
Travel	$2,500.00
Outreach	$650.00
Total	*$7,650.00*

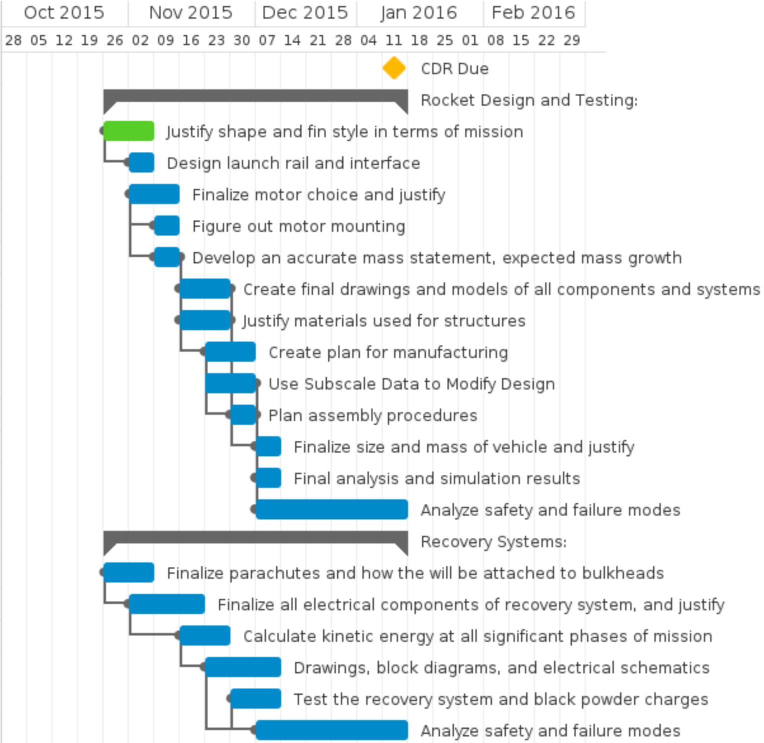
Timeline Overview



Detailed Gantt Chart: PDR to CDR

Gantt Chart: PDR to CDR

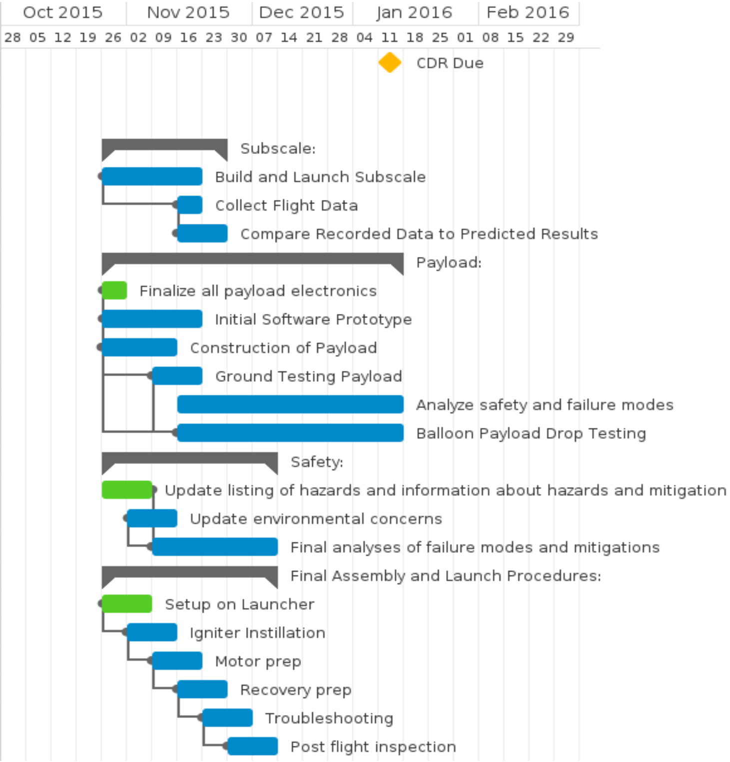
1	CDR Due	0%
	Rocket Design and Testing:	7%
3	Justify shape and fin style in terms of mission	100%
4	Design launch rail and interface	0%
5	Finalize motor choice and justify	0%
6	Figure out motor mounting	0%
7	Develop an accurate mass statement, expected.	0%
8	Create final drawings and models of all compon...	0%
9	Justify materials used for structures	0%
10	Create plan for manufacturing	0%
11	Use Subscale Data to Modify Design	0%
12	Plan assembly procedures	0%
13	Finalize size and mass of vehicle and justify	0%
14	Final analysis and simulation results	0%
15	Analyze safety and failure modes	0%
	Recovery Systems:	0%
17	Finalize parachutes and how the will be attache..	0%
18	Finalize all electrical components of recovery sy...	0%
19	Calculate kinetic energy at all significant phase...	0%
20	Drawings, block diagrams, and electrical schem..	0%
21	Test the recovery system and black powder cha..	0%
22	Analyze safety and failure modes	0%



Detailed Gantt Chart: PDR to CDR

Gantt Chart: PDR to CDR

1	CDR Due	0%
	Rocket Design and Testing:	0%
	Recovery Systems:	0%
	Subscale:	0%
5	Build and Launch Subscale	0%
6	Collect Flight Data	0%
7	Compare Recorded Data to Predicted Results	0%
	Payload:	16%
9	Finalize all payload electronics	100%
10	Initial Software Prototype	0%
11	Construction of Payload	0%
12	Ground Testing Payload	0%
13	Analyze safety and failure modes	0%
14	Balloon Payload Drop Testing	0%
	Safety:	33%
16	Update listing of hazards and information abou...	100%
17	Update environmental concerns	0%
18	Final analyses of failure modes and mitigations	0%
	Final Assembly and Launch Procedures:	16%
20	Setup on Launcher	100%
21	Igniter Instillation	0%
22	Motor prep	0%
23	Recovery prep	0%
24	Troubleshooting	0%
25	Post flight inspection	0%



Educational Outreach

Completed Events

Name of Event	Date	Number of Students Reached	Grades of Students	Direct or Indirect
Get on Board Day	8/27/2015	211	12+	Indirect
Boy Scouts	9/22/2015, 10/6/2015	18	5-9	Direct
E-Day	10/1/2015	186	5-9, 10-12	Indirect
West Alabama Works WOW Expo	10/8/2015, 10/9/2015	573	5-9, 10-12, 12+, educators	Indirect
Northridge High School	10/23/2015	25	10-12	Direct
Hillcrest High School	10/29/2015	50	10-12	Direct

Upcoming Events

Name of Event	Date	Expected Number of Students	Grades of Students	Direct or Indirect
Al's Pals	11/9/2015, 11/10/2015, 11/12/2015	270	1-5	Direct
Girl Scouts "Women in Science" Day	11/14/2015	98	1-5, 5-9	Direct

Questions?