MIT ROCKET TEAM

NASA ULSI 2012-2013 FRR

Overview

- Mission Updates
- Payload and Subsystem Updates
- Rocket and Subsystem Updates
- Testing Updates
- Management Updates

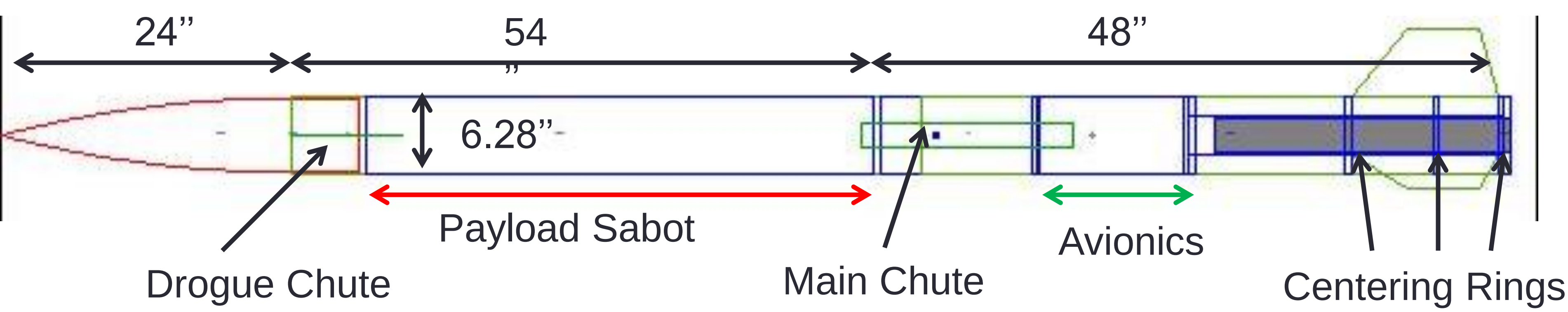
Mission Requirements

- VORTEX Rocket:
  - Safely house quadrotor payload during launch and ascent
  - Safely deliver the quadrotor payload to an altitude of 2500ft during decent
- SPRITE Payload:
  - Exhibit a controlled deployment from a descending rocket
  - Safely house all hardware and electronics during all phases of the mission: launch, normal operations, and recovery
  - Relay telemetry and video to the ground station
  - Relay telemetry to the nose cone via optical communication
  - Track the nose cone and ground station
- HALO Payload:
  - Ability to detect high altitude “lightning” events
  - Gather atmospheric measurements of: the local magnetic field, EMF radiation, ULF/VLF waves, and the local electric field.
  - Gather atmospheric measurements of pressure and temperature at a frequency no less than once every 5 seconds upon decent, and no less than once every minute after landing.
  - Take at least two still photographs during decent, and at least 3 after landing.
  - All data must be transmitted to ground station after completion of surface operations.

Rocket Overview/ Updates

- Requirements:
  - Launch rocket to 5280 ft
  - Deploy Quadrotor Sabot at 800 ft
- Concept
  - Solid Rocket Motor
  - Carbon Fiber Airframe
  - Redundant Flight Computers
  - Sabot Deployment
  - Dual Deployment Recovery

- Launch Vehicle Dimensions
  - 10.54 feet Tall
  - 6.28 inch diameter
  - 46.27 Pound liftoff weight



Rocket Propulsion Design

- Rocket Motor – Cesaroni L1115
  - 4996N-s impulse - more than enough to reach target altitude given mass estimates
  - Proven track record and simple assembly
  - Cheaper and more reliable than Aerotech alternative
- Full-scale Test Motor – Cesaroni K1085
  - Will provide nearly identical flight profile to verify launch vehicle design

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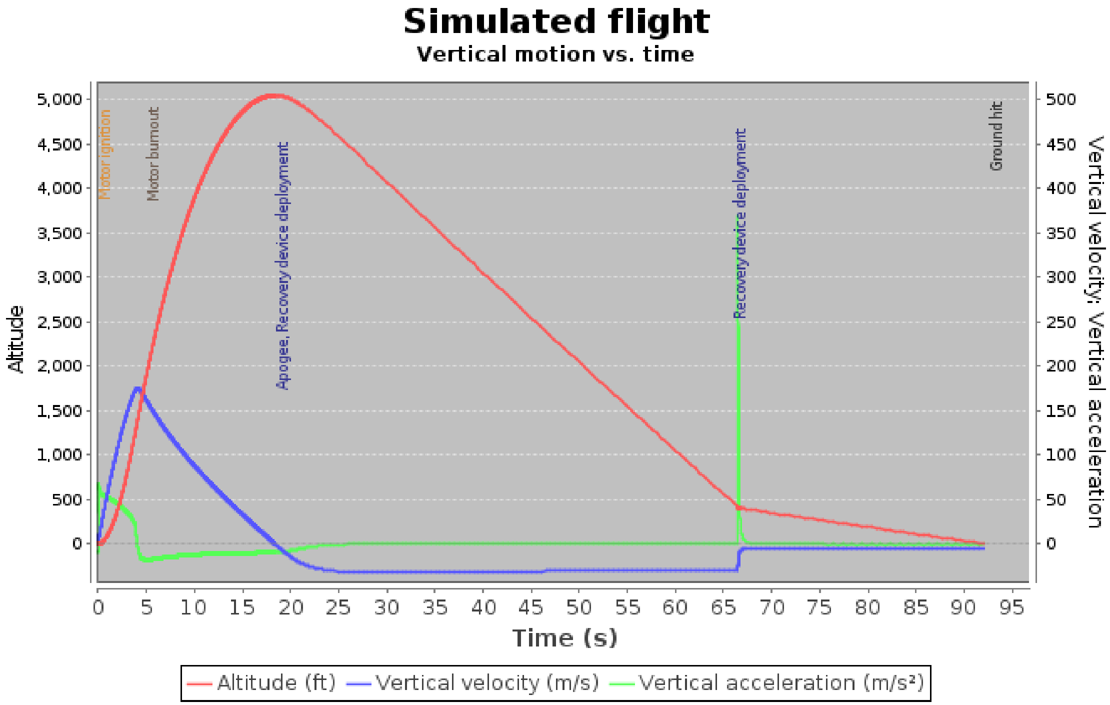
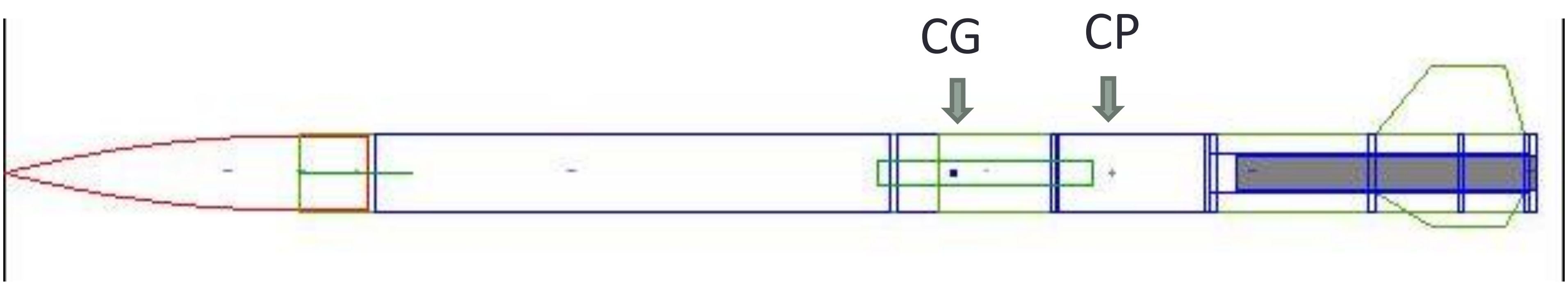
Static stability margin

- Center of Pressure
  - 90" from nose tip
- Center of Gravity
  - 77" from nose tip at launch
- Stability Margin
  - ~2.11 Calibers





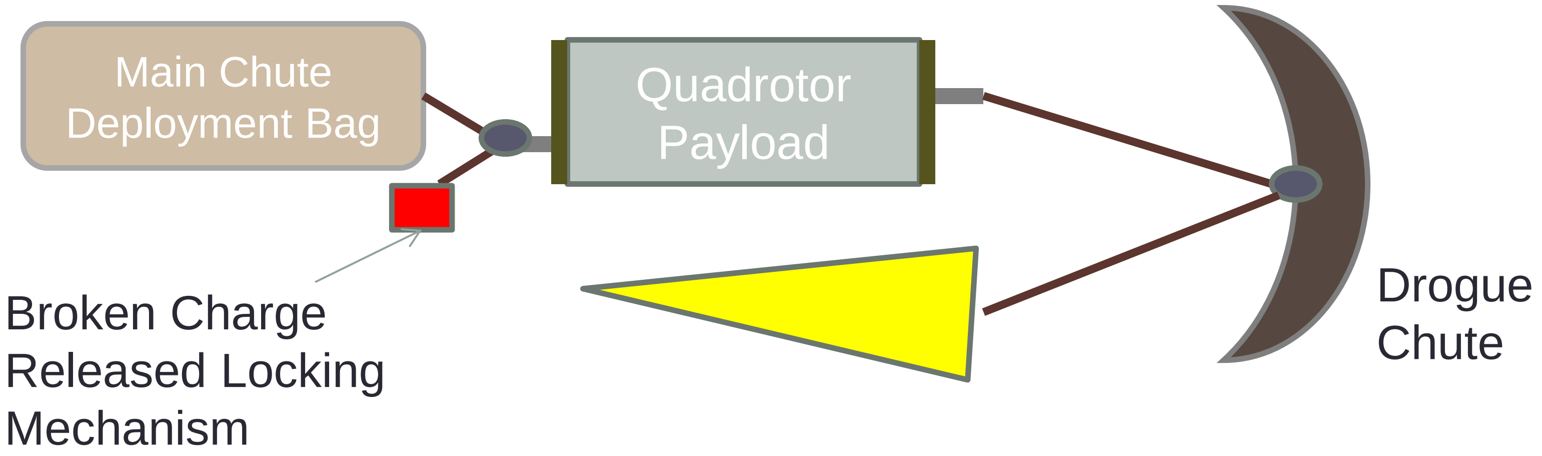
Rocket Recovery System

- 5 ft drogue parachute
  - Deployment at apogee
  - Shear 2x 2-56 screws
  - 3.5 g black power charge
  - 16’ x 1” tubular nylon webbing harness
- 16 ft main parachute
  - Deployment at 2500 feet
  - Pulled out by Quadrotor and sabot
  - Sabot released by Tender Descender
  - Deployment Bag used
  - 3.25’ x 1” tubular nylon webbing harness
- Calculated Energy and descent rates within USLI parameters. Calculated drift in 15 mph wind is within ½ mile.

Final Descent Rates and Energy		
Nose/Sabot Final Descent Rate	21.48 ft/s	60.95 ft-lbf
Rocket Body Under Main	10.98 ft/s	42.58 ft-lbf
Quadrotor Under Chute	23.84 ft/s	33.29 ft-lbf

Payload Deployment

- Tube-stores payload during flight
- Charge released locking mechanism - releases sabot at 500 ft
- Chute Bag – ensures clean main parachute opening
- Separation of rocket and nose cone prevents parachute entanglement



Staged Recovery System

- Proven Recovery Method
- 8 Successful Flights

Full Scale Flight

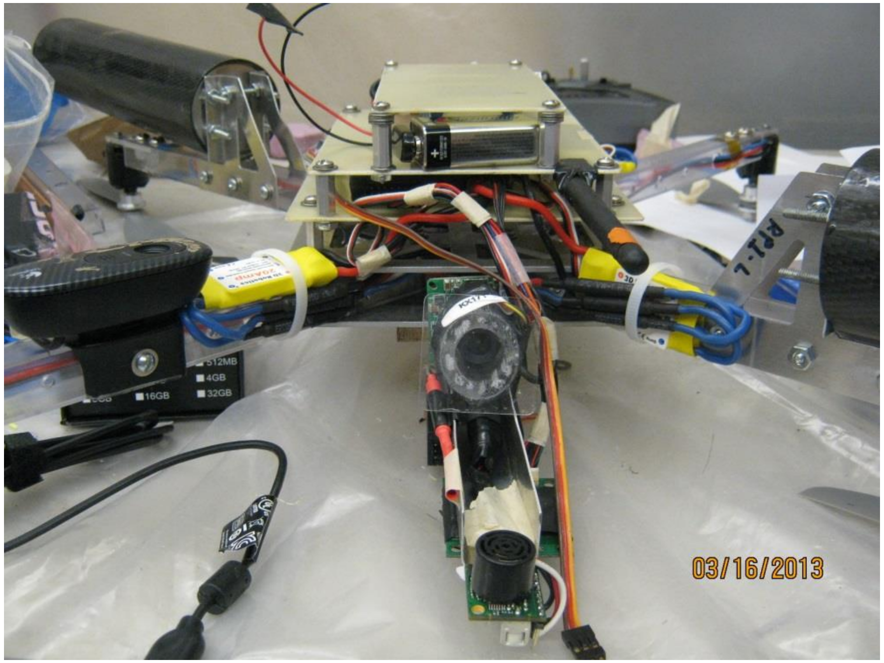
- 3/17/2013 MDRA, Maryland
- Weighed 40.2 lb with K1085
- Sabot failed to deploy
  - Cocked within airframe
  - Backup black powder charge to be implemented
  - Follow up flight 4/6/2013

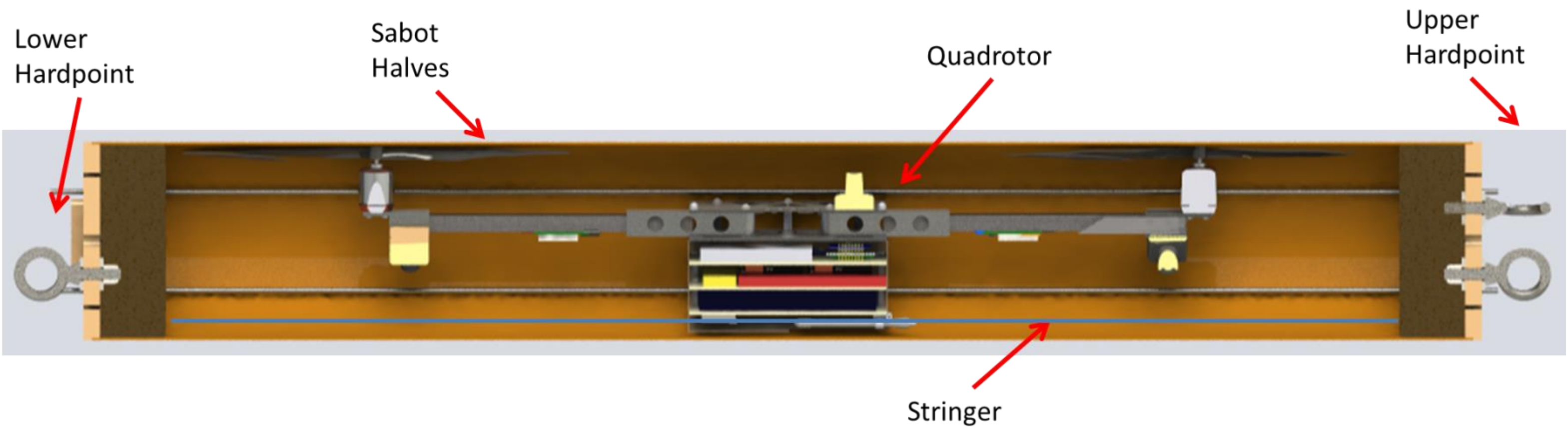
Payload Design

- Sprite
  - **Specialized Rotorcraft for IR Communications, Object Tracking and On-board Experiments**
- Halo
  - **High Altitude Lightning Observatory**

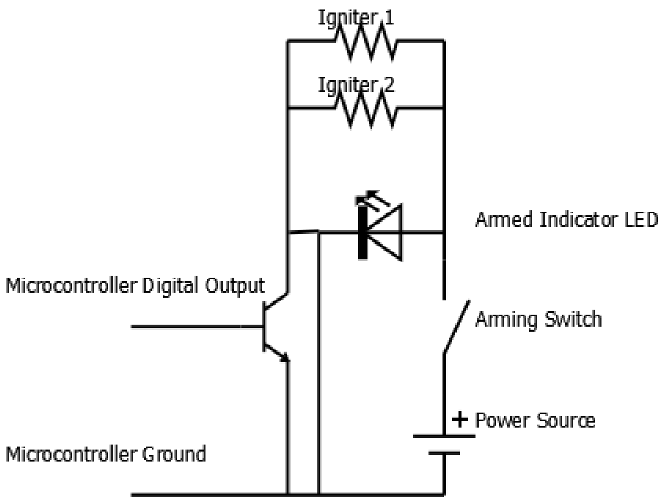
Structures and Propulsion

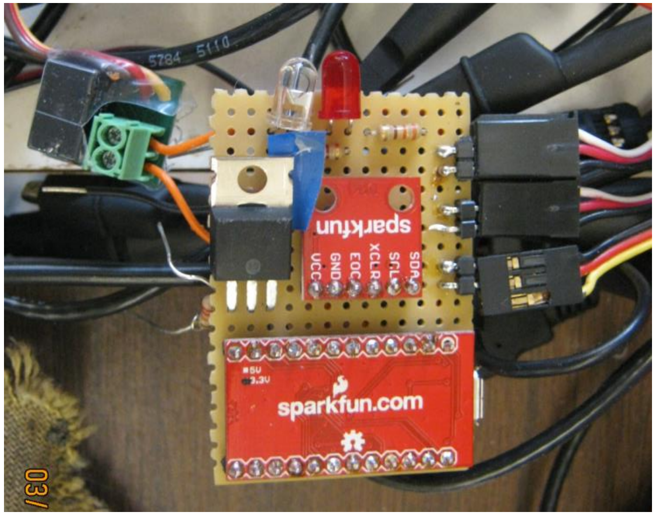
- Composite and aluminum structure
- Avionics housed in covered “trays” below the central platform
- Fits in a 3.5ft sabot
- Mass of ~10lbs with a 24lb thrust
- 13in propeller and 830W motor per arm

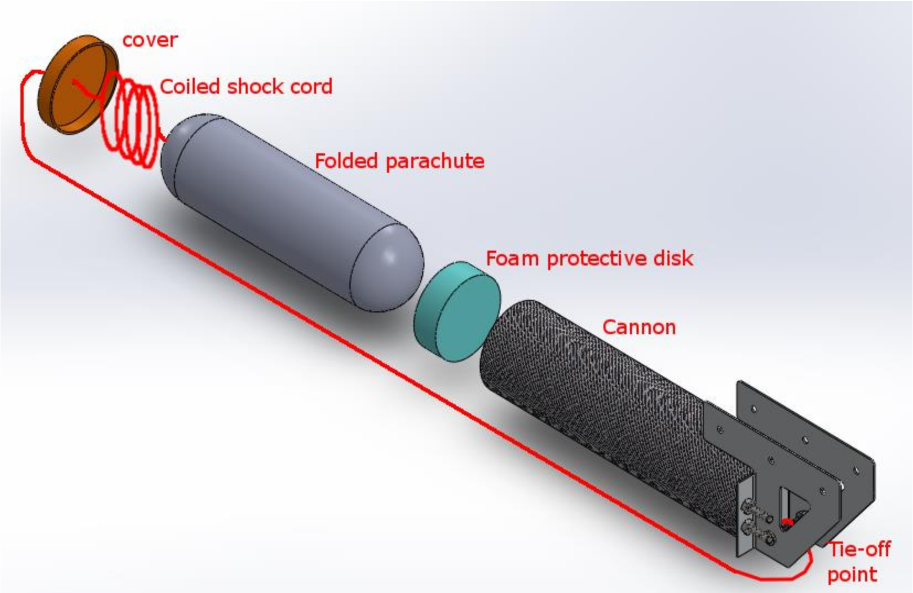




Reserve Parachute







Avionics Hardware and Software

- Ardupilot – Flight computer
  - Controls attitude/position determination and correction
- Cameras – Captures images of rocket and ground
  - Five Logitech HD cameras (USB interface with BeagleBone)
  - One up and four 45 degrees down
- OpenCV – Realtime image processing
  - Runs objections tracking and recognition algorithms
- BeagleBone – Embedded processor running a Linux OS
  - Collects, processes, stores, transmits camera and science data
  - Communicates relative rocket location to Ardupilot
- Test software for each of these systems has been written and tested
  - Final flight software is being finalized

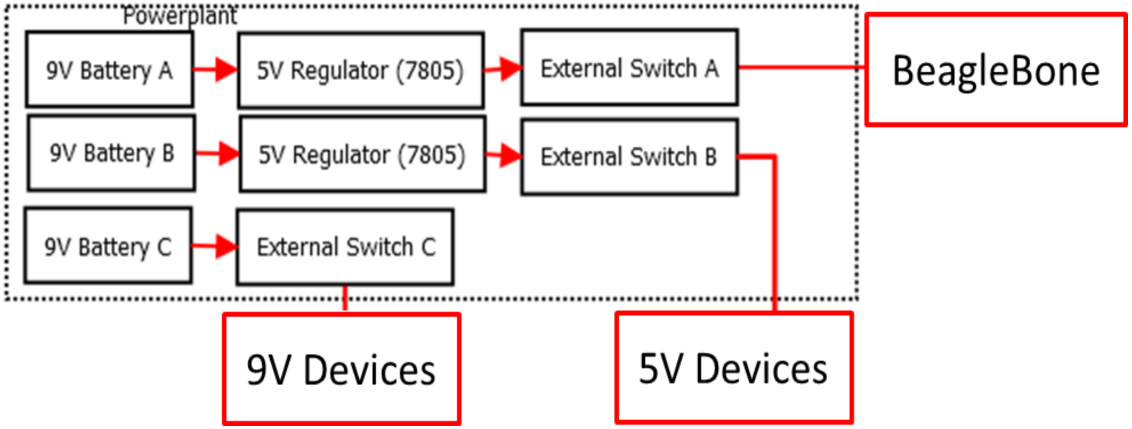
Communications and Power

Redundant TX/RX

- Transceivers
  - Xbee Pro (UART)
    - 933Hz
  - 3DR Radio (SPI)
    - 433Hz
  - Turnigy RC Transmitter (Ground)
    - 9Ch @ 2.4Ghz
  - Turnigy RC Receiver (Airborne)
    - 8Ch @ 2.4Ghz
  - Video Stream
    - 500Hz

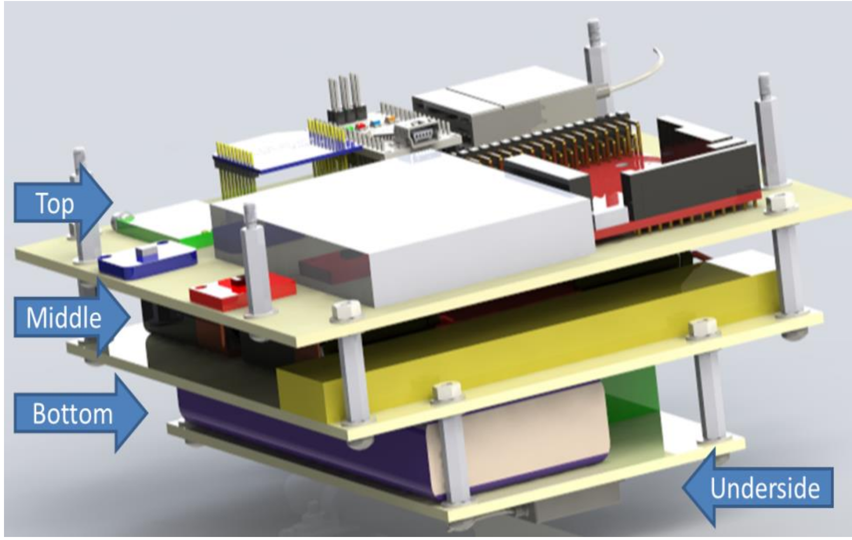
Separate Battery Lines

- Three 9 volt batteries power the science sensors, processor, and secondary chute
- Motors and flight computer are powered by a Turnigy 2650mAh LiPo Battery (with ESC regulators)

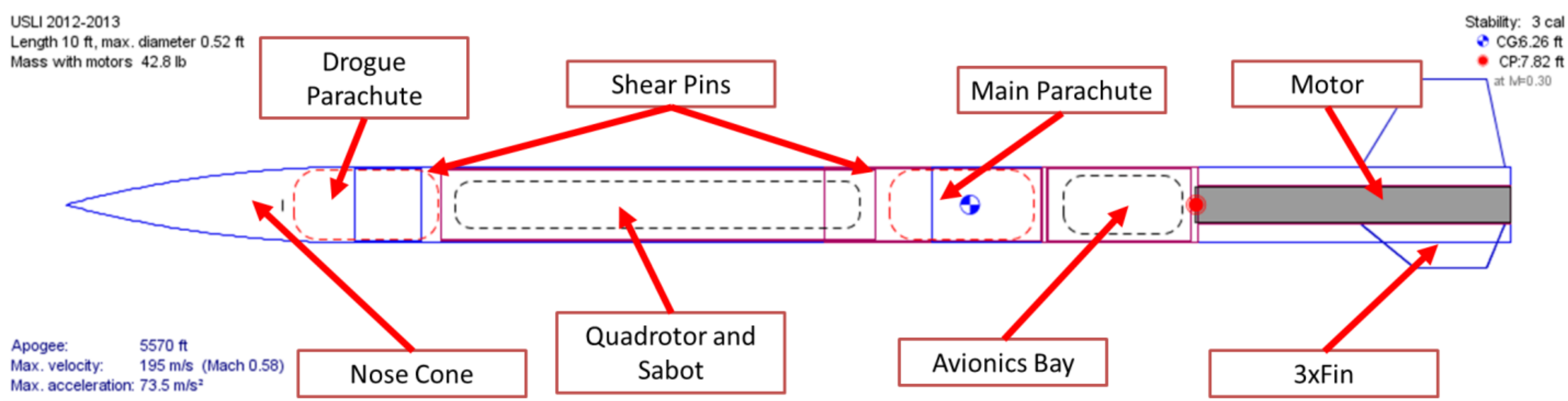


HALO Overview

- Science Computer
  - BeagleBone
- Sensors
  - Pressure and Temperature
  - VLF Receiver
  - Magnetic Field Strength
  - Lightning Detector
- Sensors (Custom)
  - Electric Potential



Payload Integration

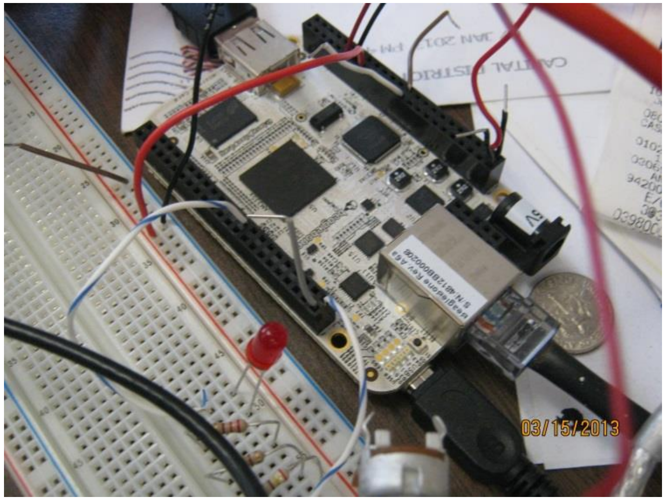


Ground Station

- Battery Charging Station
- RC Transmitter
- ArduPilot GUI
- Beagebone Telemetry Stream
- Video Stream

Payload Safety Verification and Testing Plan

- The rotor and subsystems will be tested in three phases to minimize risk:
  - Phase 1: Ground Testing
  - Phase 2: Test rotorcraft (commercially available RC)
  - Phase 3: Rotorcraft Testing
- Ensures safe and proper function of systems throughout testing.
- Flight testing of craft to analyze and determine margin of error of flight behavior
- Confirm nominal operation of onboard electronics



Test Plan

Rocket and Recovery

- Nose cone release
  - Shear pin failure force
  - Black powder charge
  - Separation distance
  - Barometric testing
- Charge release locking mechanism
  - Black powder charge
  - Operational verification
- Craft deployment testing
- Emergency locator transmitter test

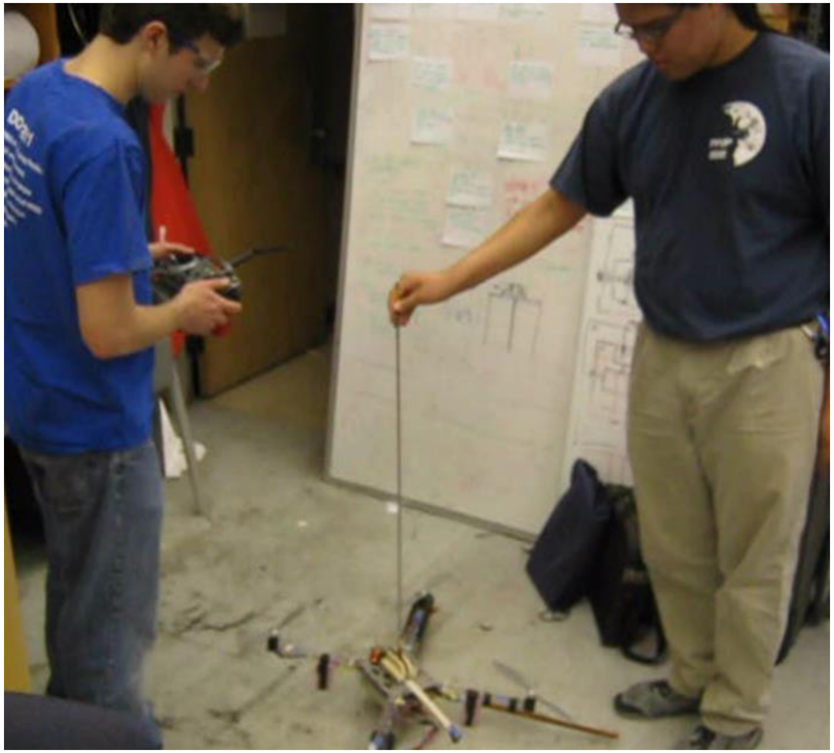
Payload

- Complete avionics system from ‘test craft’ integrated with SPRITE rotorcraft
- Test autonomous flying capabilities
- Drop tests to simulate deployment
- Simulated missions performed
- RC transmit and data telemetry tests

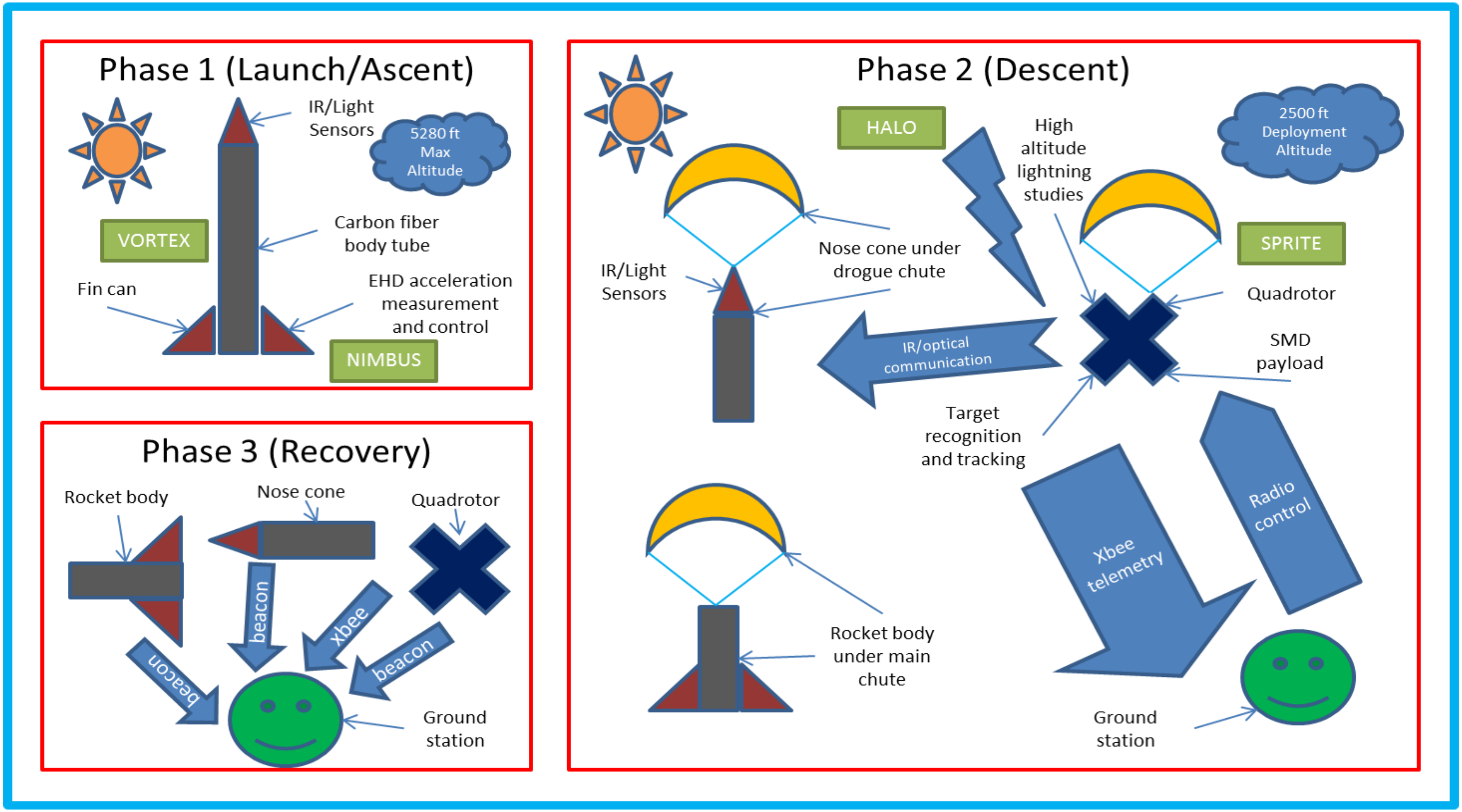
Quadrotor Tests

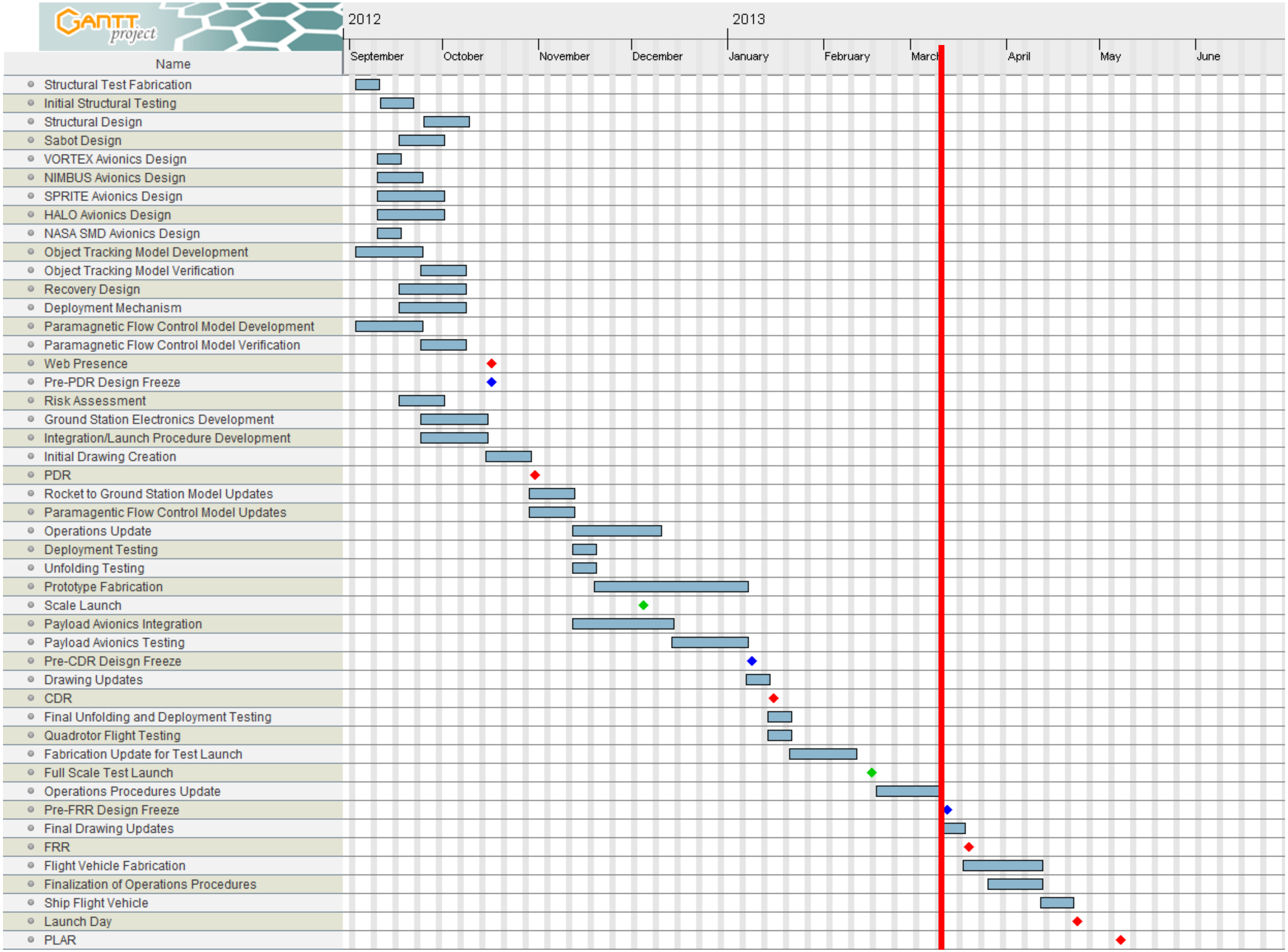
Reserve Parachute

Main Quadrotor Parachute



Flight Operations





GANTT project
2012
2013
Name
September
October
November
December
January
February
March
April
May
June
Structural Test Fabrication
Initial Structural Testing
Structural Design
Sabot Design
VORTEX Avionics Design
NIMBUS Avionics Design
SPRITE Avionics Design
HALO Avionics Design
NASA SMD Avionics Design
Object Tracking Model Development
Object Tracking Model Verification
Recovery Design
Deployment Mechanism
Paramagnetic Flow Control Model Development
Paramagnetic Flow Control Model Verification
Web Presence
Pre-PDR Design Freeze
Risk Assessment
Ground Station Electronics Development
Integration/Launch Procedure Development
Initial Drawing Creation
PDR
Rocket to Ground Station Model Updates
Paramagentic Flow Control Model Updates
Operations Update
Deployment Testing
Unfolding Testing
Prototype Fabrication
Scale Launch
Payload Avionics Integration
Payload Avionics Testing
Pre-CDR Deisgn Freeze
Drawing Updates
CDR
Final Unfolding and Deployment Testing
Quadrotor Flight Testing
Fabrication Update for Test Launch
Full Scale Test Launch
Operations Procedures Update
Pre-FRR Design Freeze
Final Drawing Updates
FRR
Flight Vehicle Fabrication
Finalization of Operations Procedures
Ship Flight Vehicle
Launch Day
PLAR

Milestones, Testing, and Outreach

- ~~9/29: Project initiation~~
- ~~10/29: PDR materials due~~
- ~~11/18: Scaled test launch~~
- ~~1/14: CDR materials due~~
- ~~Jan: Scale quadrotor test~~
- ~~Jan: Avionics sensors test~~
- ~~Feb: Deployment test~~
- ~~Feb: Full-scale test launch~~
- ~~3/18: FRR materials due~~
- 4/17: Travel to Huntsville
- 4/20: Competition launch
- 5/6: PLAR due

~~Winter:~~

~~11/17: MIT Splash Weekend~~

Spring:

- ~~MIT Spark Weekend~~
- Rocket Day @ MIT
- MIT Museum

QUESTIONS?

Payload Goals

- Decrease deployment time for quadrotor high altitude missions
- Improve information acquisition, processing, and transmission on and between mobile targets in an dynamic environment
- Validate high altitude lightning models via direct measurements

Payload Requirements (SPRITE)

- Safely house all hardware and electronics during all phases of the mission: launch, normal operations, and recovery
- Relay telemetry and video to the ground station
- Track the nose cone and ground station

Main Payload Requirements (HALO)

- Demonstrate the ability to detect high altitude “lightning” events
- Gather atmospheric measurements of: the magnetic field, EMF radiation, ULF/VLF waves, and the local electric field.
- Gather atmospheric measurements of: pressure and temperature at a frequency no less than once every 5 seconds upon decent, and no less than once every minute after landing.