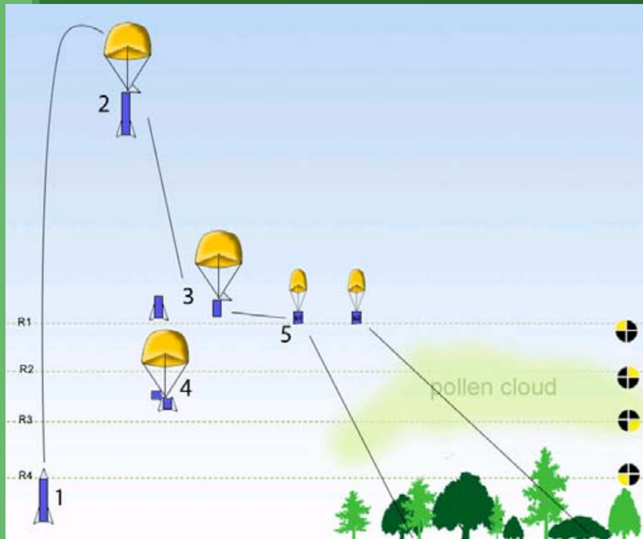
MADISON WEST

SLI 2008

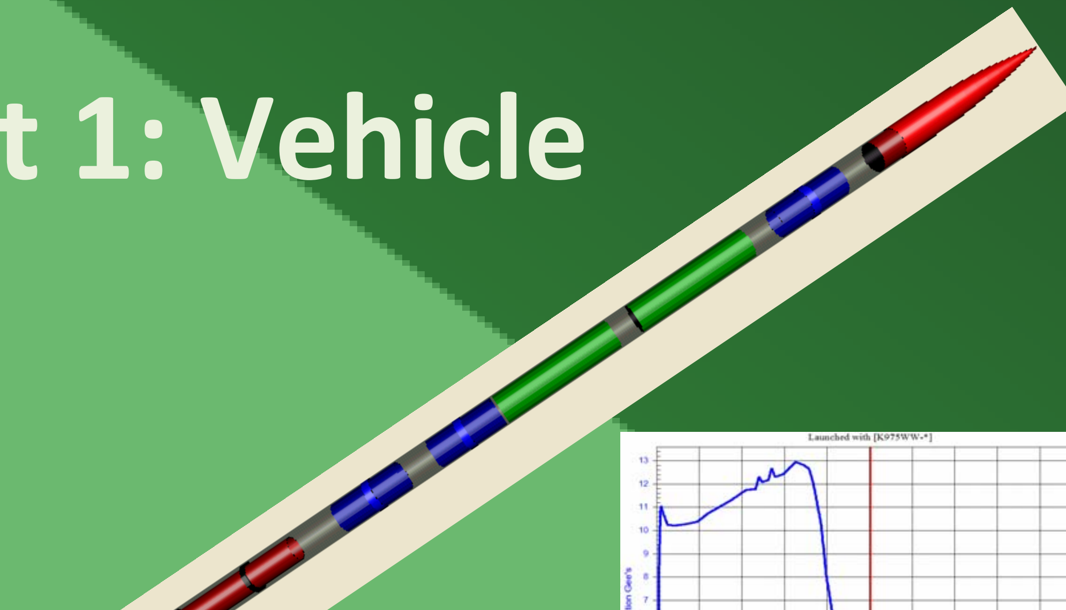
PROJECT STINGER

Analysis of Pollen Distribution
at Various Altitudes



Component	Weight	Parachute Diameter	Descent Rate
Booster	196 oz	24" (drogue)	47 fps
Booster	196 oz	62" (main)	18 fps
Payload section	133 oz	24"	39 fps
Empty payload section	37 oz	24"	20 fps
Payload Collector (Bee)	48 oz	34"	16 fps

Part 1: Vehicle



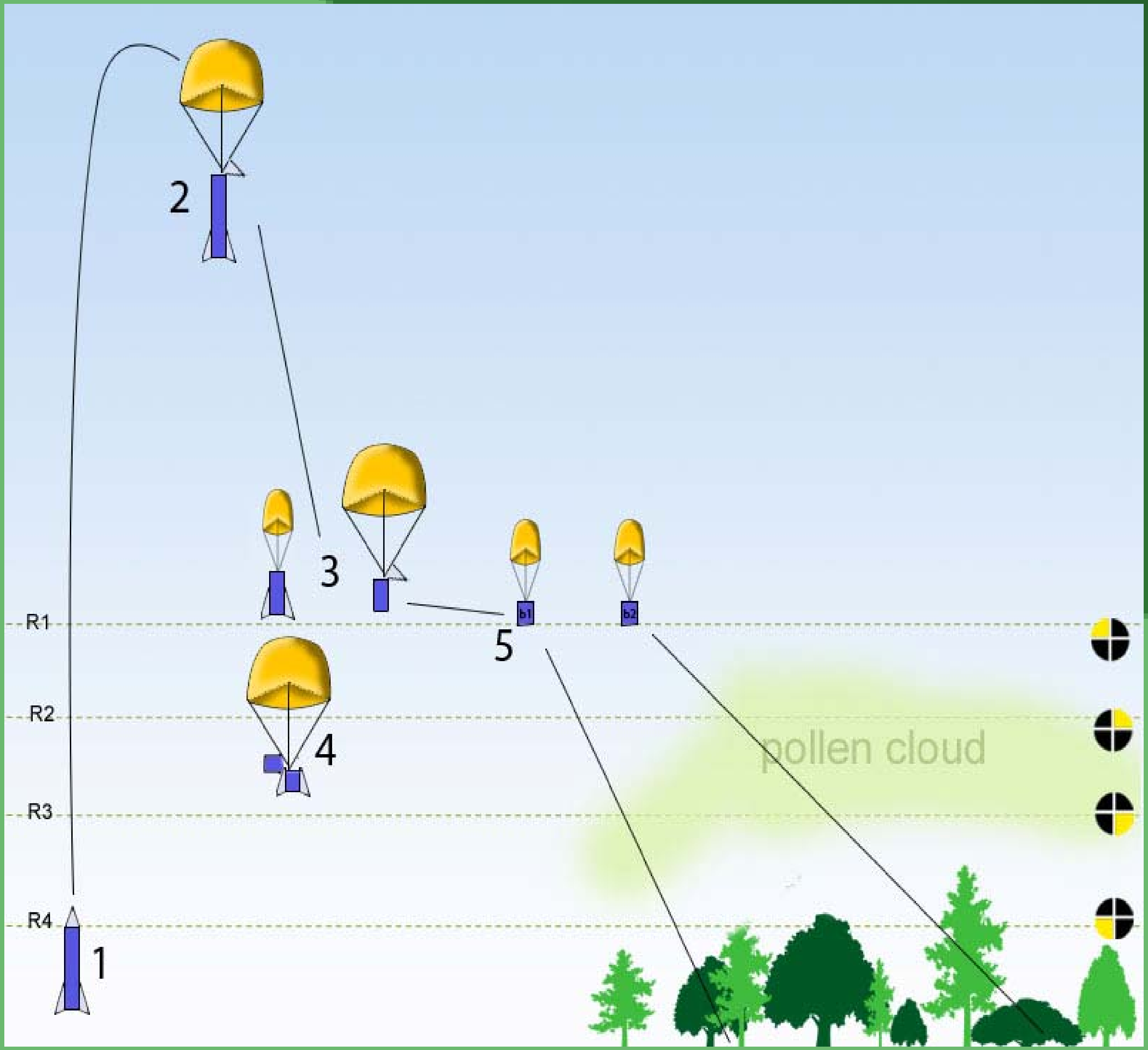
Terminology

- **Hive:** Payload Section Housing Two Bee Modules
  - B1 – pronounce Bee One
  - B2 – pronounce Bee Two
- **Bee:** Electro-Mechanical Pollen Collecting Module
- **Bee Brain:** electronic board for collector control and data acquisition/recording
- **Stinger:** Project Code Name
- **Beekeeper:** Full Scale Vehicle Preliminary Name
- **Wobbling Bee:** Scale Model Name

Major Milestone Schedule

- **April 6** Final flight test
- **April 20** Rocket ready for final launch
- **April 26** Launch rocket with all components
- **May 23** PLAR due

Flight Sequence

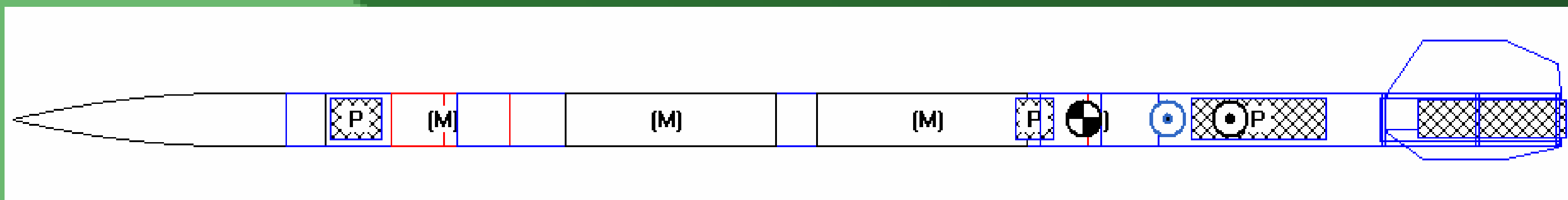


1. *Rocket is launched and coasts to an apogee of 1 mile*
2. *The common drogue parachute deploys at apogee*
3. *Payload separates from booster at 4,200ft*
4. *After drogue controlled descent, booster deploys main parachute at 700ft*
5. *Pollen collectors are deployed and activated at 4,200ft, eventually passing through 4 different altitude ranges, taking samples of pollen in each range*

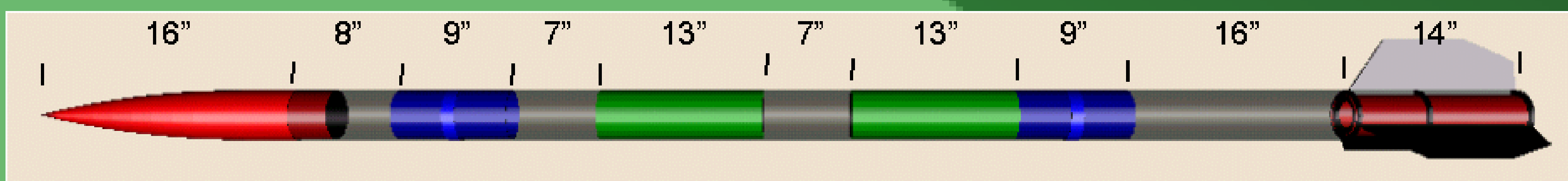
Success Criteria

- A stable launch of the vehicle
- Target altitude of 1 mile reached
- Separation of the payload compartment from the booster at 4,200ft
- Deployment of the pollen collection modules from the payload bay at 4,200 feet
- Proper deployment of all parachutes
- Safe recovery of the booster, payload compartment and the two pollen collectors without damage.

Full Scale Rocket

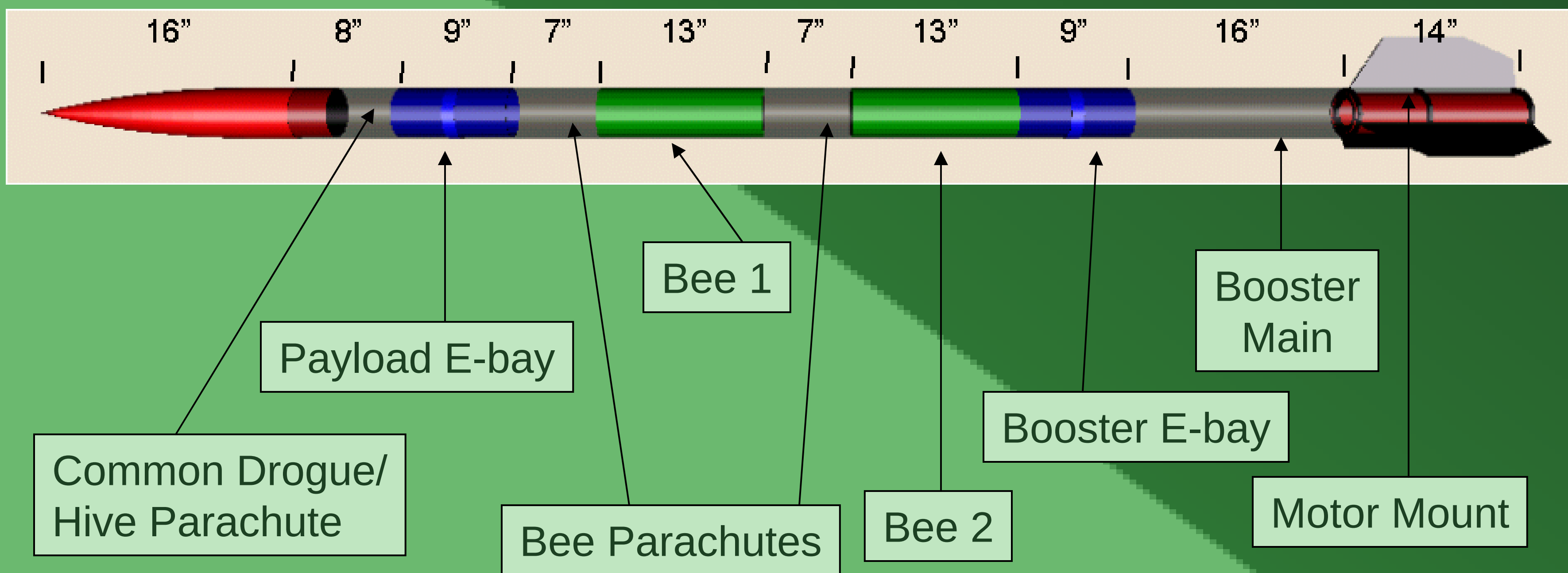


C_p	92.6”
C_g	81.4”
Static Margin	2.79 calibers



Length	118”
Diameter	4”
Liftoff weight	26.6 lbs
Motor	K780 Redline 75mm

Rocket Schematics

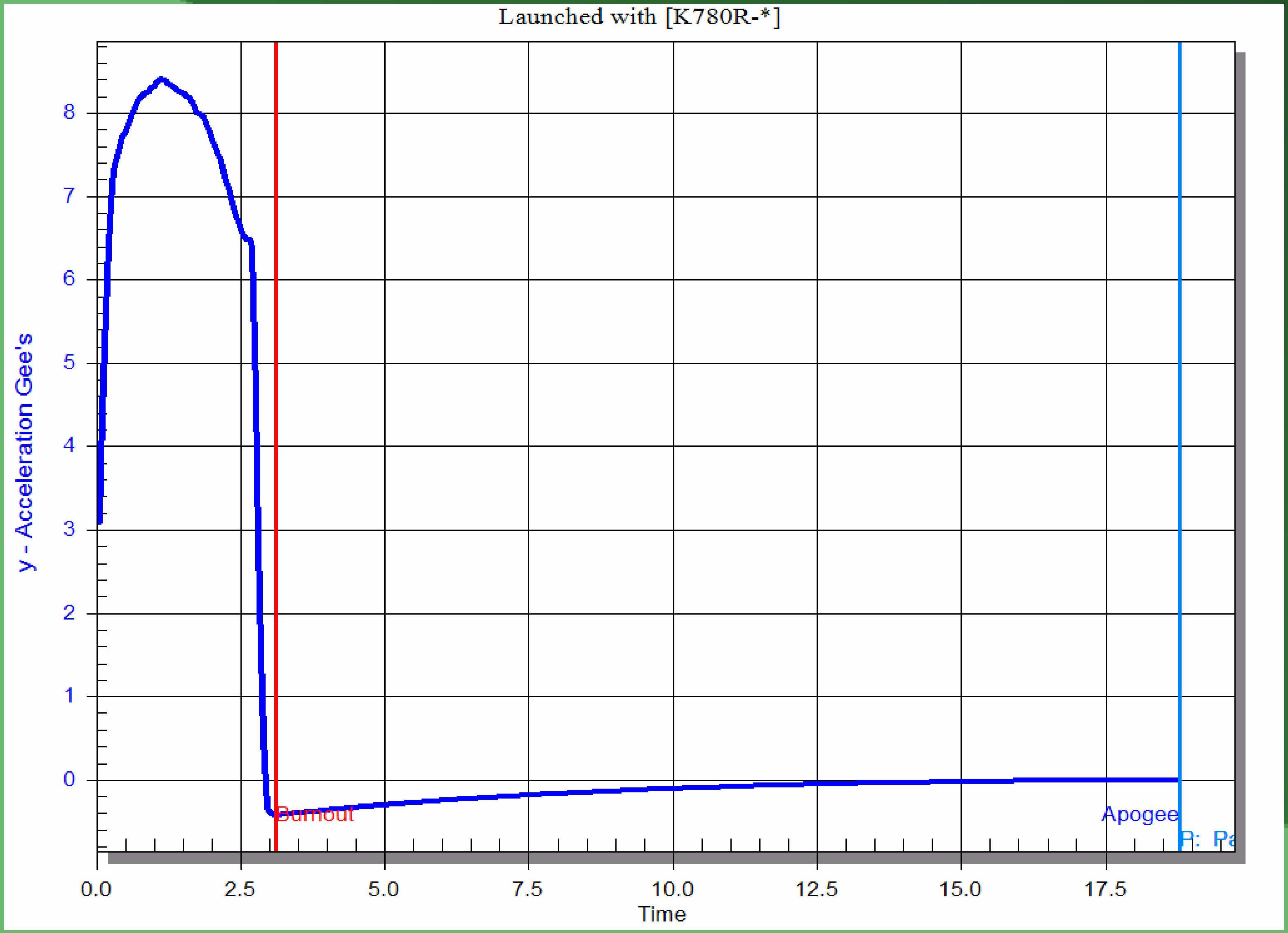


Construction Materials

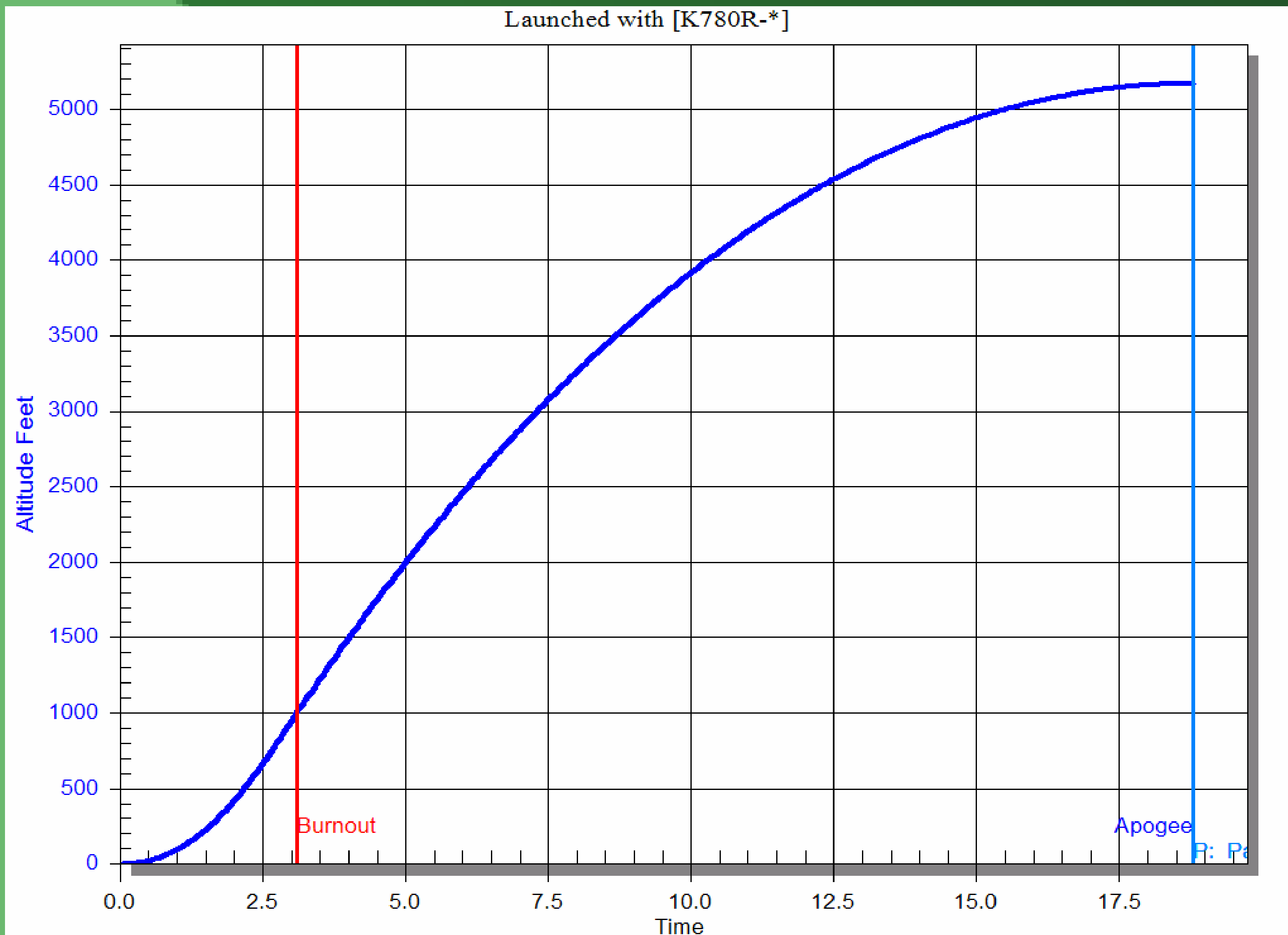
- **Fins:** 1/32” G10 fiberglass (outer layers) + 1/16” balsa sandwich (inner layer), 1/8” total thickness
- **Body:** fiberglass tubing, fiberglass couplers
- **Bulkheads:** 1/4” plywood
- **Motor Mount:** 75mm phenolic, three 1/4 ” plywood centering rings

Thrust Profile for K780R

Acceleration Profile for K780R



Altitude Profile for K780R



Flight Safety Parameters

- **Flight Stability Static Margin:** **2.79**
  (with Aerotech K780R motor)

- **Thrust to Weight Ratio:** **6.47**

- **Velocity at Launch Guide Departure:** **37 mph**
  (launch rail length 96”)

Ejection Charge Calculations

$$Wp = dP * V / R * T$$

- ***dP*** - ejection charge pressure, 15psi
- ***R -*** combustion gas constant, 22.16 ft-lbf/lbm R for FFFF black powder.
- ***T*** - combustion gas temperature, 3307 degrees R
- ***V*** - free volume in cubic inches.
- ***Wp*** - ejection charge weight in pounds.

Parachutes and Ejection Charges

Component	Weight	Parachute Diameter	Descent Rate	Ejection charge
Booster (Main)	4476g	60"	23 ft/sec	1.9g (FFFF)
Common Drogue	10241g	40"	38 ft/sec	2.0g (FFFF)
Payload Bay (Empty)	2809g	40"	20 ft/sec	N/A
Pollen Collector	1412g	30"	19 ft/sec	3.0g (FFFF)

Verification Matrix: Tests

- ***V1 Integrity Test:*** *applying force to verify durability.*
- ***V2 Parachute Drop Test:*** *testing parachute functionality.*
- ***V3 Tension Test:*** *applying force to the parachute shock cords to test durability*
- ***V4 Prototype Flight:*** *testing the feasibility of the vehicle with a scale model.*
- ***V5 Functionality Test:*** *test of basic functionality of a device on the ground*
- ***V6 Altimeter Ground Test:*** *place the altimeter in a closed container and decrease air pressure to simulate altitude changes. Verify that both the apogee and preset altitude events fire (Estes igniters or low resistance bulbs can be used for verification).*
- ***V7 Electronic Deployment Test:*** *test to determine if the electronics can ignite the deployment charges.*
- ***V8 Ejection Test:*** *test that the deployment charges have the right amount of force to cause parachute deployment and/or planned component separation.*
- ***V9 Computer Simulation:*** *use RockSim to predict the behavior of the launch vehicle.*
- ***V10 Integration Test:*** *ensure that the payload fits smoothly and snuggly into the vehicle, and is robust enough to withstand flight stresses.*

Verification Matrix: Components

- ***C1:*** *Body (including construction techniques)*
- ***C2:*** *Altimeter*
- ***C3:*** *Data Acquisition System (custom computer board and sensors)*
- ***C4:*** *Parachutes*
- ***C5:*** *Fins*
- ***C6:*** *Payload*
- ***C7:*** *Ejection charges*
- ***C8:*** *Launch system*
- ***C9:*** *Motor mount*
- ***C10:*** *Screamers, beacons*
- ***C11:*** *Shock cords and anchors*
- ***C12:*** *Rocket stability*

Verification Matrix

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
C_1	F			F						P
C_2	F			F	F	F	F			
C_3				P	P		P			
C_4	F	F		F	F			F		
C_5	F			F						
C_6	P				P			F		P
C_7				F	F		F	F		
C_8	F			F	F					
C_9	F			F	F					
C_{10}	F			F	F					
C_{11}	F		F	F						
C_{12}				F					F	

Test Flight Parameters

- **Liftoff Weight:** **15,400g**
- **Motor:** K1100T
- **Length:** 149 inches
- **Diameter:** 4 inches
- **Stability Margin:** 7 calibers

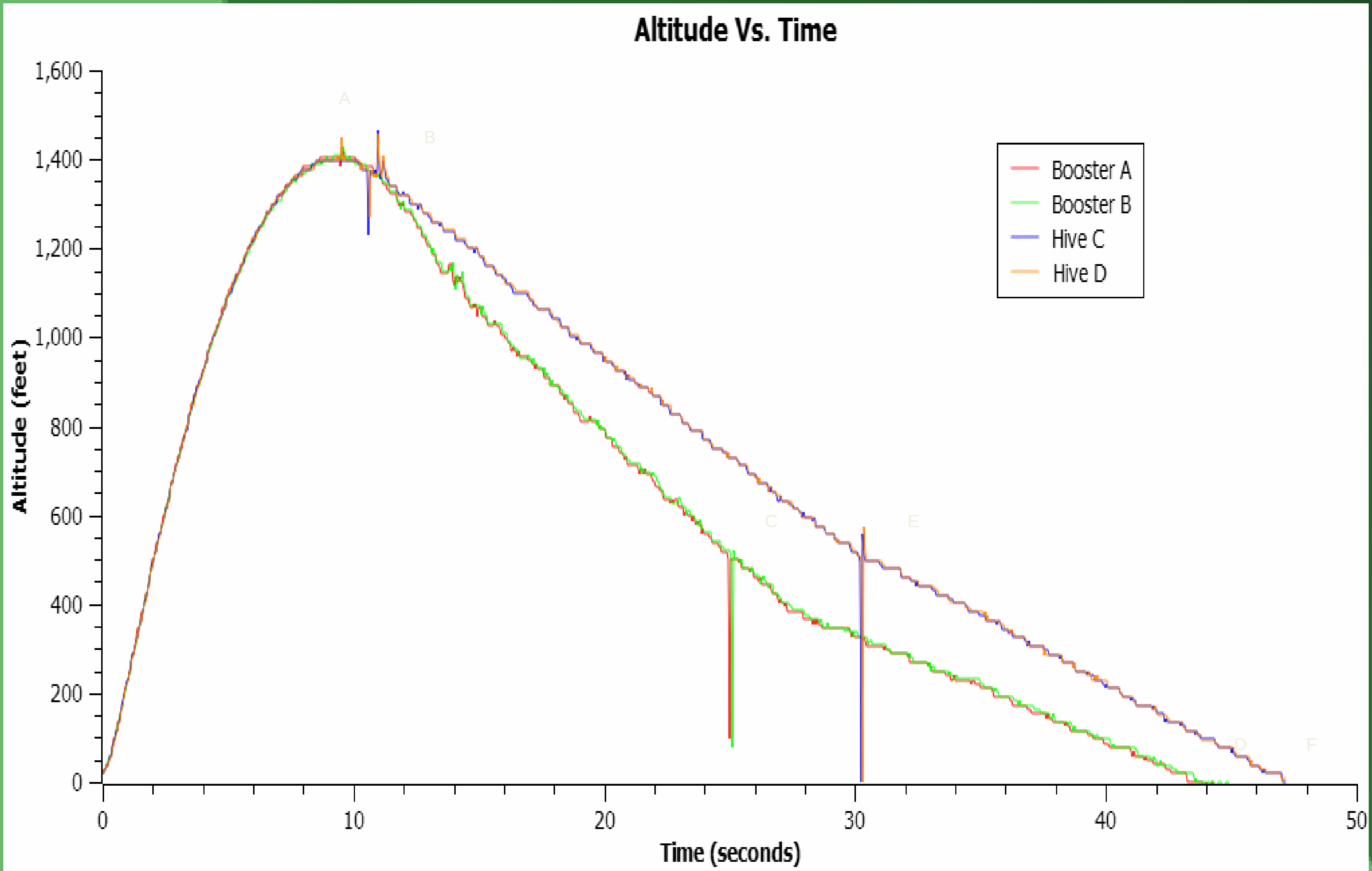
Test Flight Objectives

- Test dual deployment avionics
- Test full deployment scheme
- Test ejection charge calculations
- Test payload integration
- Test validity of simulation results
- Test rocket stability

Full Vehicle Rocket Test Flight Results

- **Apogee:** 1420ft
  - RocSim Prediction: 1285ft
- **Time to apogee:** 9s
- **Apogee events:** 3s after apogee
- **Payload deployment:** 500ft at 30s
- **Booster main parachute:** 500ft at 25s

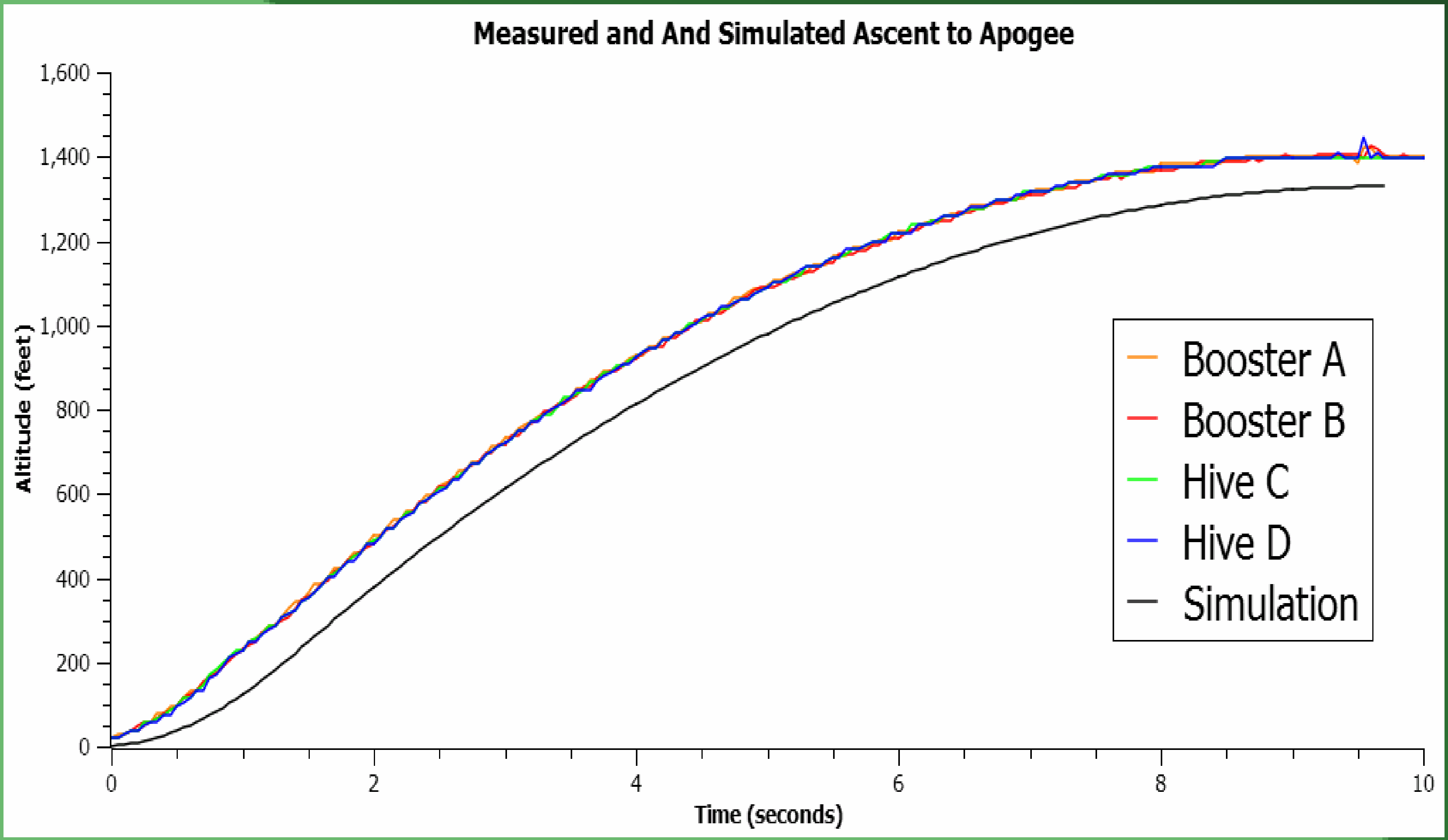
Full Scale Test Flight Data



Measured Descent Rates

Parachute	Start time/ End time	Start Altitude/ End Altitude	Descent Rate
Booster Drogue	14s	1200ft	***57fps***
	28s	400ft	
Booster Main	32s	500ft	***33fps***
	47s	0ft	
Hive with Bees	12s	1500ft	***69fps***
	28s	400ft	
Hive without bees	28s	400ft	***25fps***
	44s	0ft	

Measurements and Simulation



Excess Weight

Rocket is 10lbs overweight!

Reasons:

- Hawk-Mountain fiberglass 33% heavier than “RockSim” fiberglass
- Overkill E-bay caps and U-Bolts
- Length creep
- Dual diameter motor mount
- Heavy booster main parachute
- Incorrect weight of the dummy payload modules
- Overgenerous use of epoxy
- Overkill tie-rods
- Heavy 1/8” G10 fins

Proposed Remedy

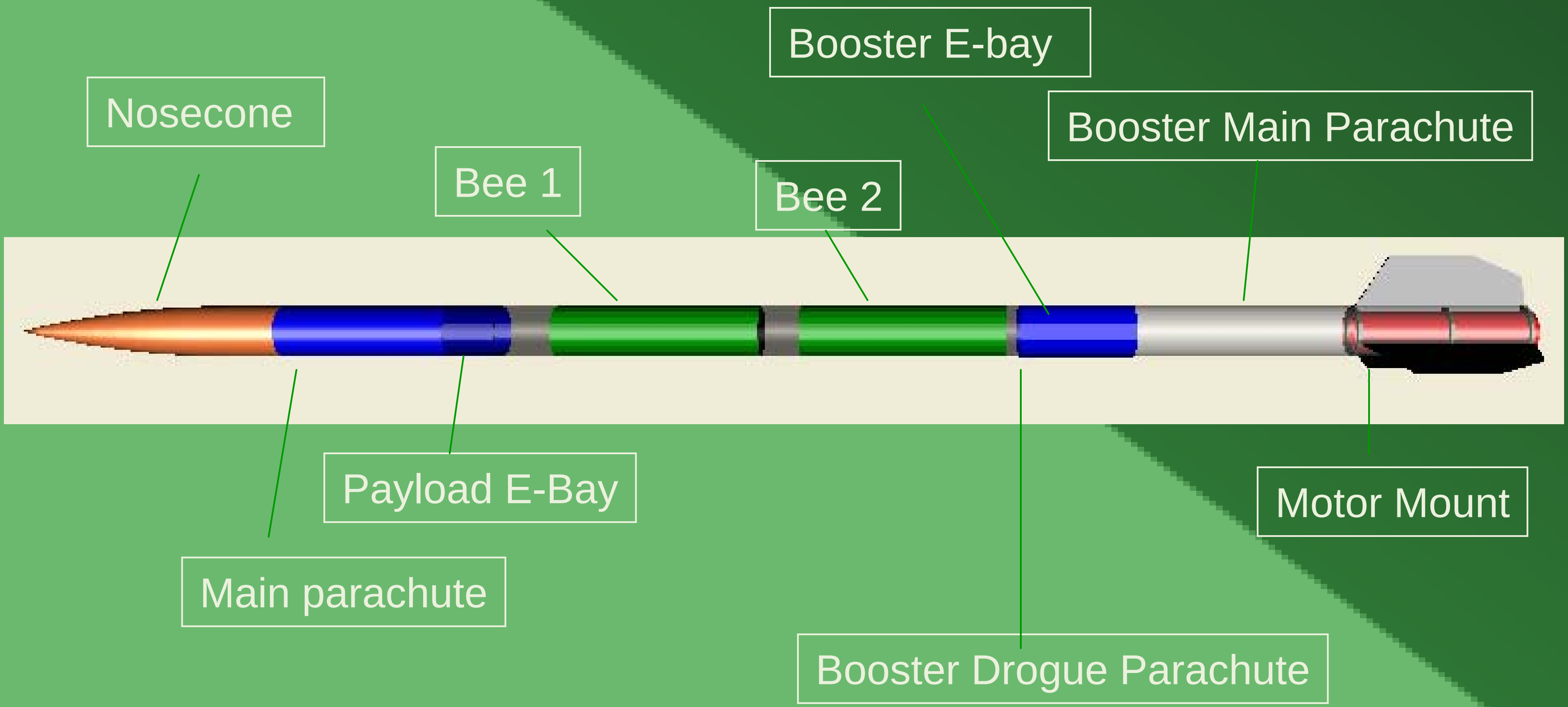
Bigger motor is not an option

Weight reduction opportunities:

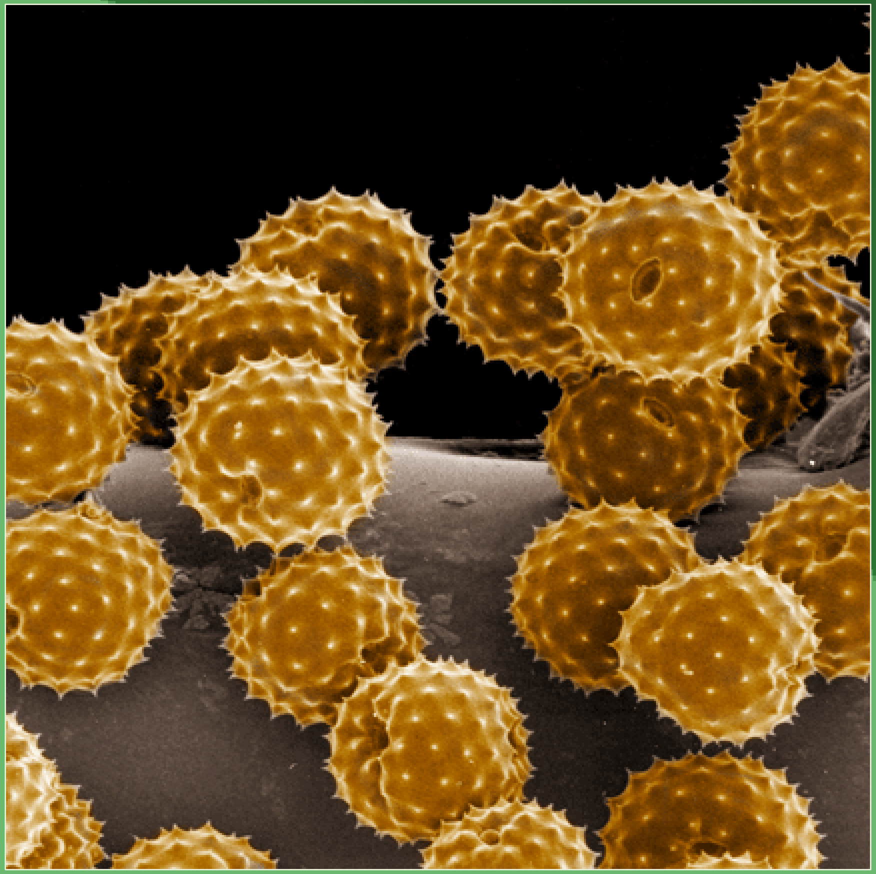
- Balsa/fiberglass sandwich for fins
- Shorter/lighter booster
- No dual diameter motor mound
- Sufficient but not overkill bulkheads, caps, U-Bolts, tie-rods
- Lighter parachutes and shockcords
- Loc precision fiberglass tubing for new booster
- Better recovery packing to remove extra length

Care must taken not to compromise the rocket robustness

Payload Integration



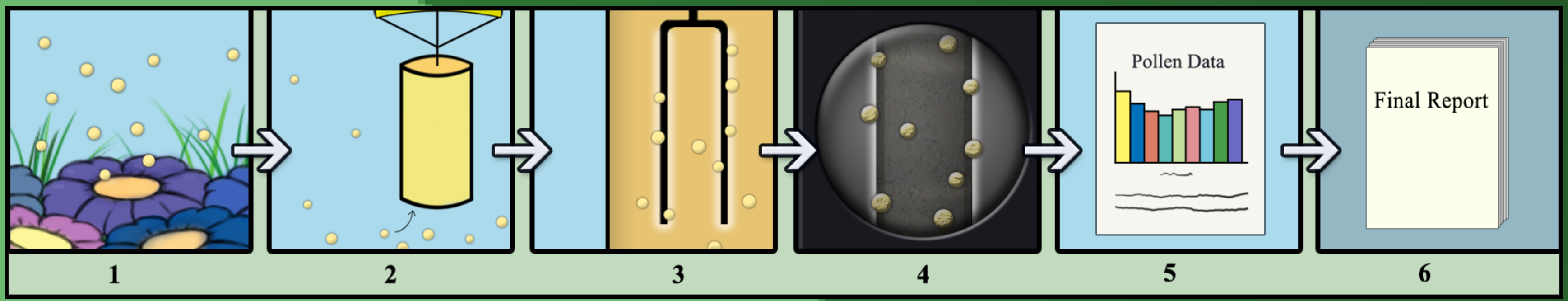
Payload Presentation



Experiment Concept

- Pollen is distributed unevenly even in a sub-mile atmosphere layer.
- Pollen sampling will provide information on pollen distribution patterns which affect cross-pollination and the spread of invasive plant species.
- Pollen particles are very small and thus difficult to trap. With a conventional small-particle trapping device, we would not be able to capture pollen. This necessitates a unique and creative design.

Experimental Approach



Primary correlation

$Y_x = f(A)$ or $Y = f(A)$ ……….pollen distribution vs. altitude range

Other correlations

$Y_x = f(T)$ ………………….. pollen type X amount vs. temperature
$Y_x = f(H)$ ………………….. pollen type X amount vs. humidity
$Y_x = f(P)$ ………………….. pollen type X amount vs. pressure
$Y_x = f(Z)$ ………………….. pollen type X amount vs. location/wind speed

Variables and Controls

Variables

Independent

- *T*…..air temperature
- *H*…..humidity
- *P*…..atmospheric pressure
- *A*…..altitude range
- *Z*…..GPS position
- *X*…..pollen type

Dependent

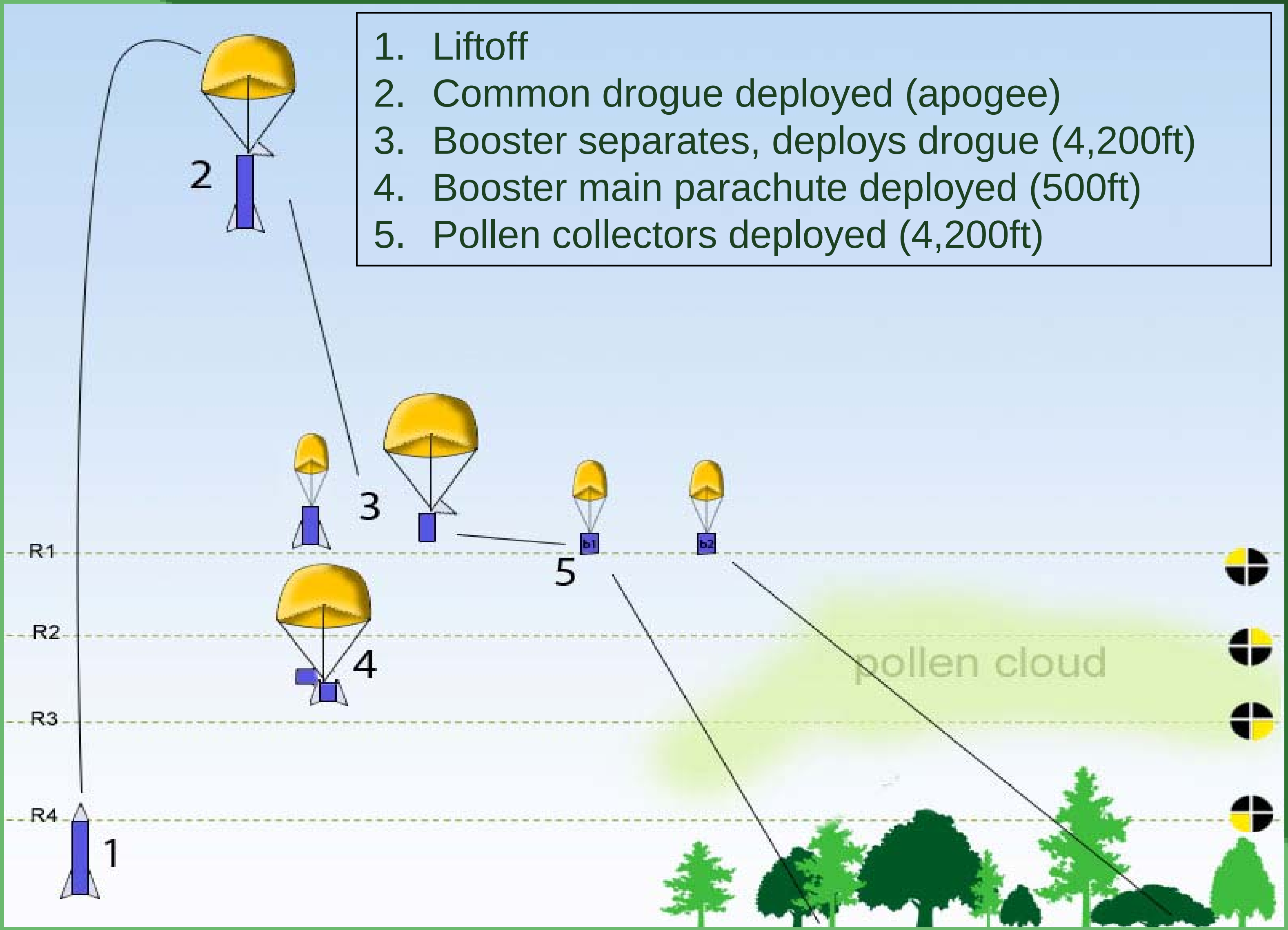
- Y_x …..amount of pollen of a specific type
- *Y* ….. total amount of pollen

Controls

- Identical collection process
- Identical methods of pollen particles counting and identification
- Selected altitude ranges

Flight Sequence

1. Liftoff
2. Common drogue deployed (apogee)
3. Booster separates, deploys drogue (4,200ft)
4. Booster main parachute deployed (500ft)
5. Pollen collectors deployed (4,200ft)



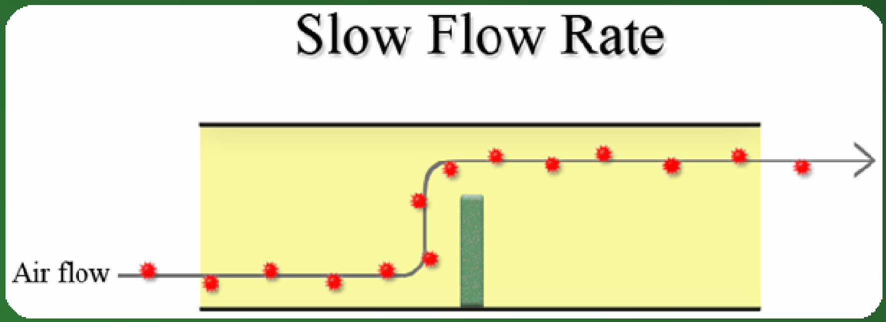
Payload Subsystems

1. **Pollen Samplers:** each pollen collector carries four pollen samplers, each sampler is activated in a different altitude range. Pollen samplers collect pollen grains.

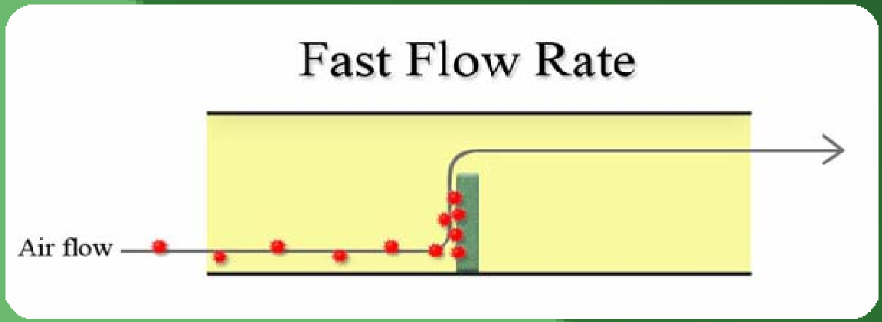
2. **Control/Data Acquisition Electronics:** in addition to pollen samplers, each collector is equipped by an electronic board (“Bee Brain”) for recording atmospheric and GPS data.

Pollen Sampling

Pollen is not captured by traditional particle collecting methods that work with larger particles. Instead of being trapped against the wall, like the large particles, pollen stays in the airflow.

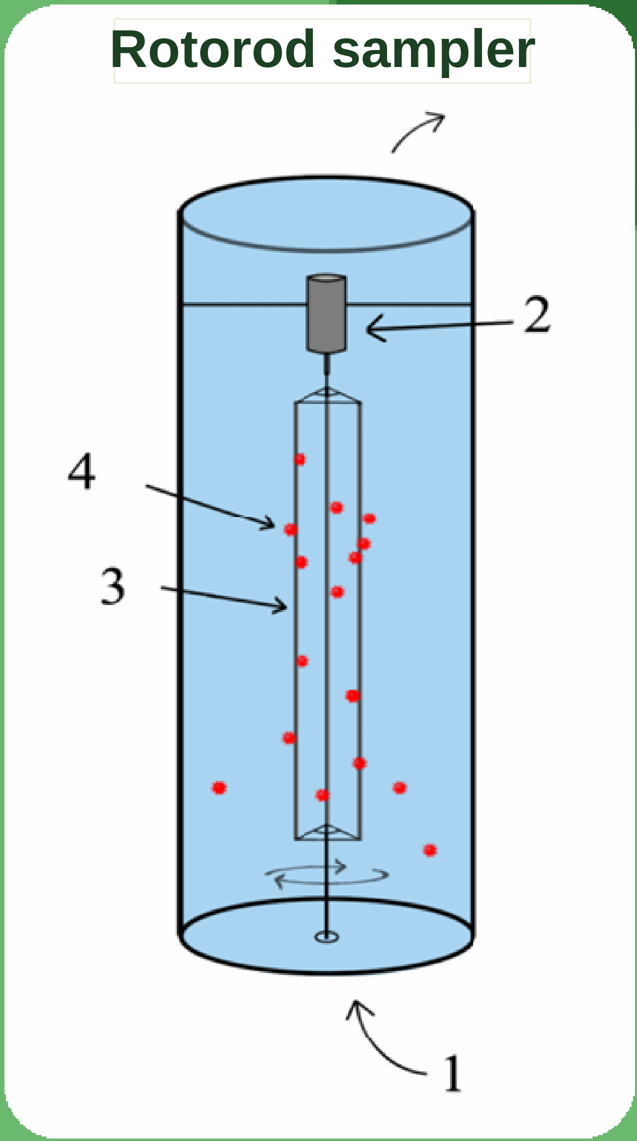


Increasing the flowrate through a labyrinth system requires expensive pumps to process sufficient volume and to overcome the pressure difference caused by the labyrinth (cost ineffective).



• = Pollen

Pollen Sampler

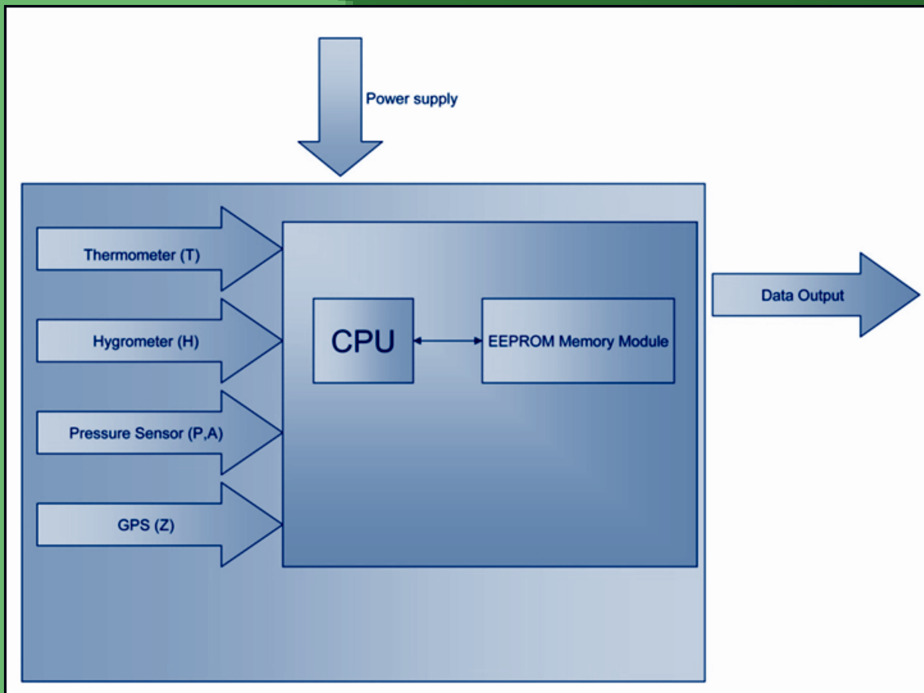


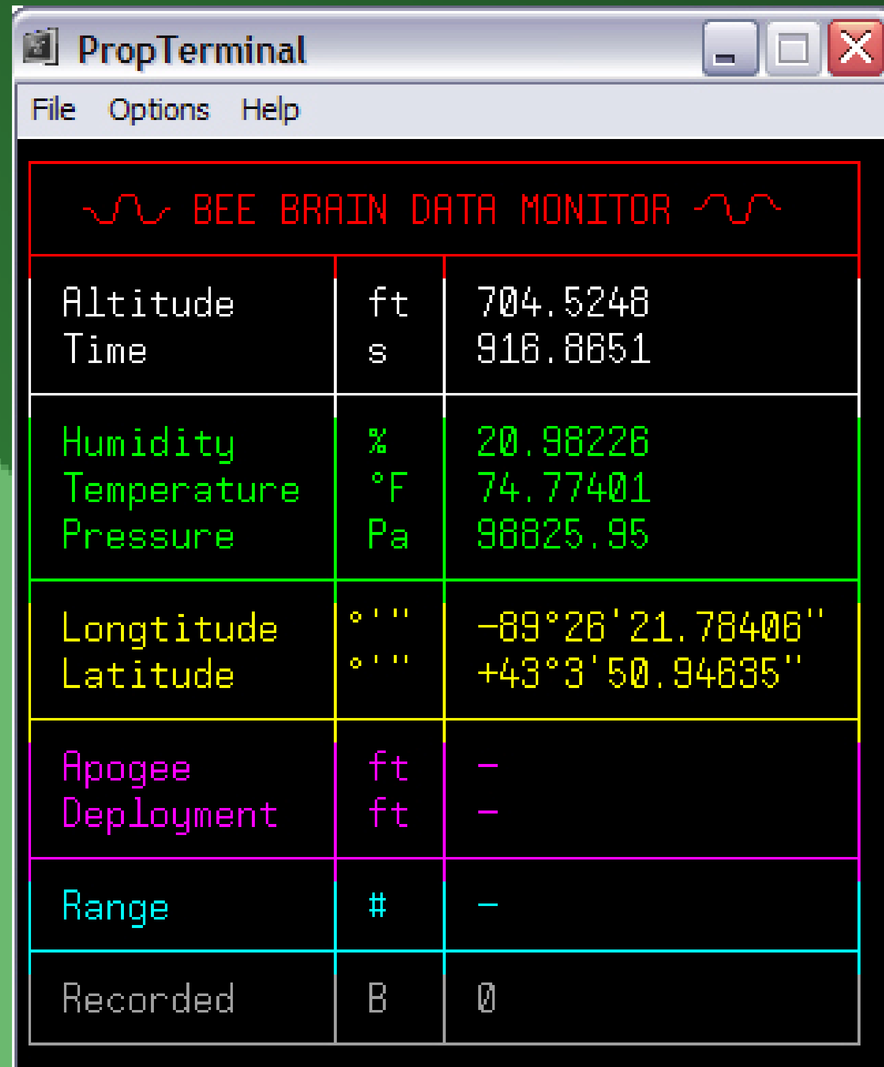
Rotorod Collection Method: airborne pollen particles passing through the collector tube collide with rapidly spinning sampling rods coated with adhesive gel.

Rotorod Pollen Sampler:

1. Incoming air and pollen particles.
2. Motor spinning fork.
3. Rotating fork, each arm is equipped by an adhesive strip for trapping the pollen particles.
4. Pollen particle.

Atmospheric/Location Data

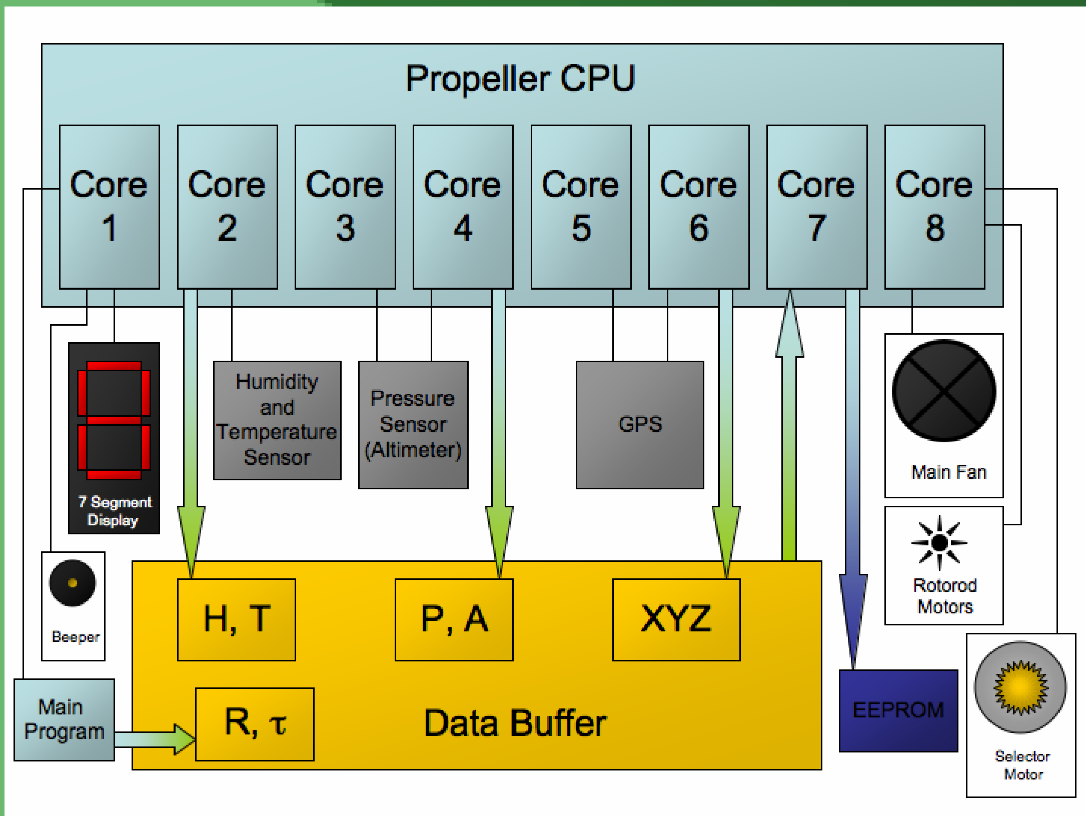


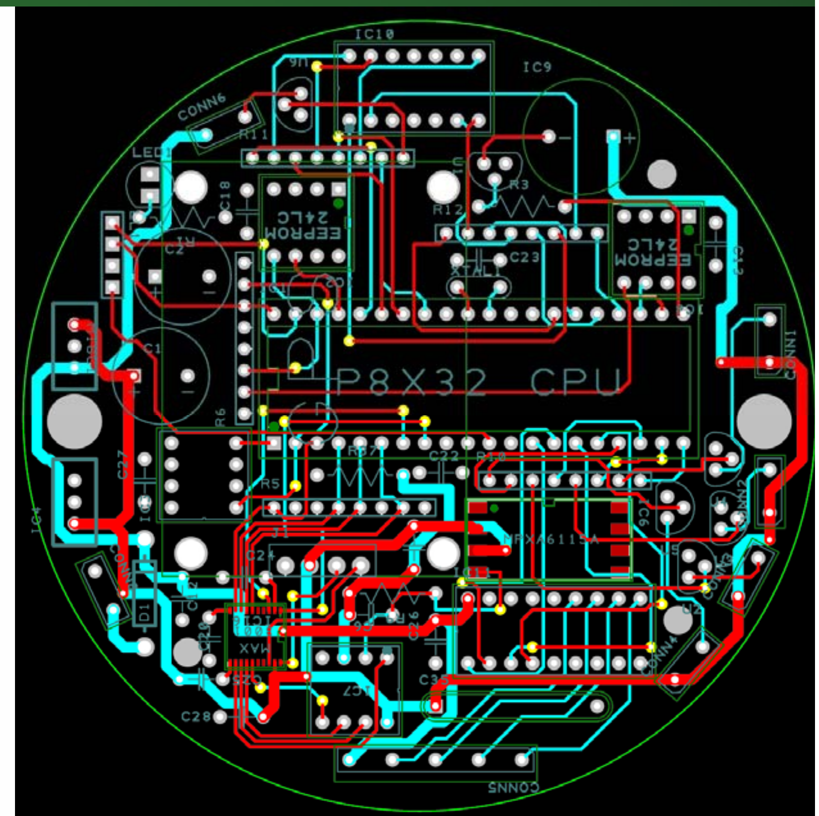


An electronic board ("Bee Brain") measures and records atmospheric/GPS data during payload descent.

The board also controls the operation of the mechanical pollen collector.

Bee Brain





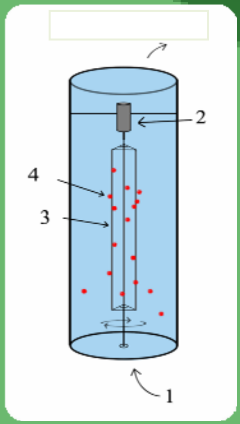
Bee Brain is an electronic board that measures and records atmospheric/location data and also controls the operation of the mechanical pollen samplers.

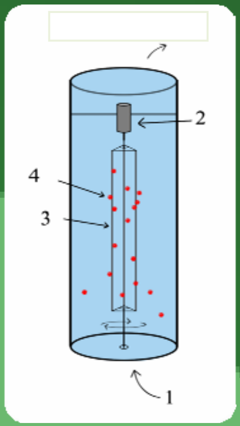
Bee Brain is built around a multi-core microcontroller (Parallax Propeller).

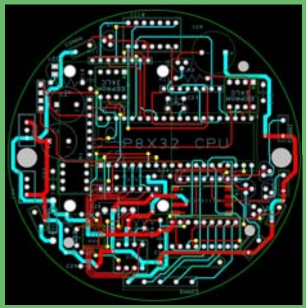
Sensors and Components

ATMOSPHERIC DATA AND LOCATION ELECTRONIC COMPONENTS		
Sensor/Chip Type	**Model**	**Accuracy**
GPS	Parallax GPS Receiver Module	**±5 meter position, ±0.1 meter per second velocity**
Pressure	Freescale Semiconductor MPXA6115A6U	**±1.5% over 0° to 85°C**
Temperature/Humidity	Sensirion SHT11 Humidity & Temperature Sensor	**±0.5°C @ 25°C, ±3.5%RH**
Microcontroller/CPU	Parallax Propeller I P8X32	**N/A**
32KB Serial EEPROM Memory	24LC256	**N/A**

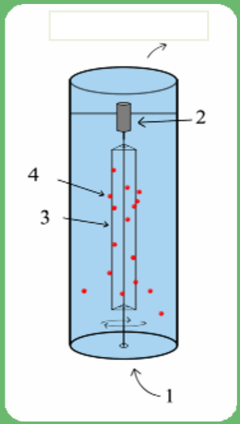
Pollen Collector

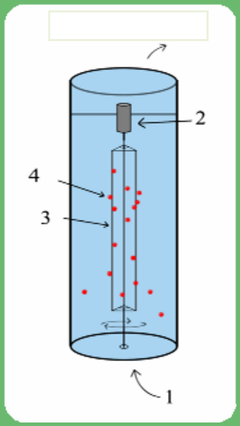


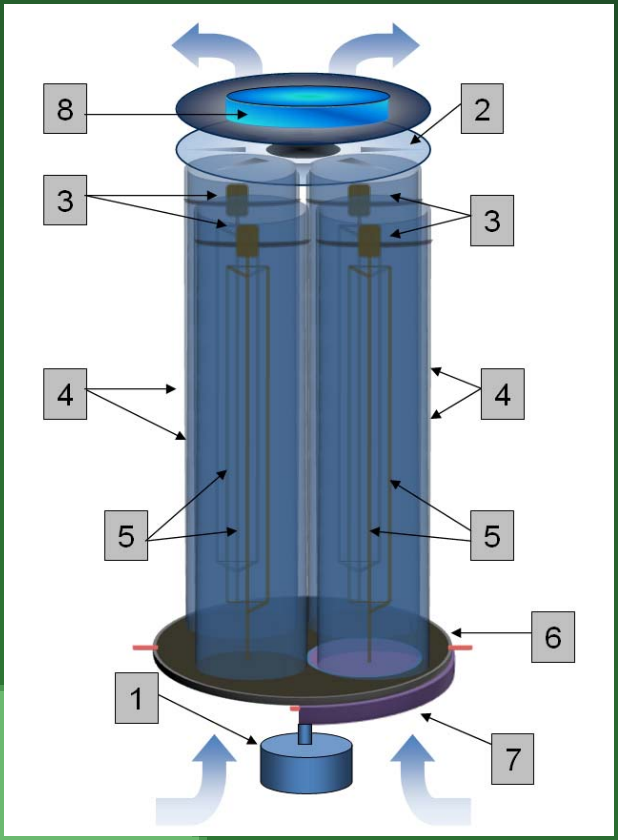




4 samplers + 1 “brain”
in each collector

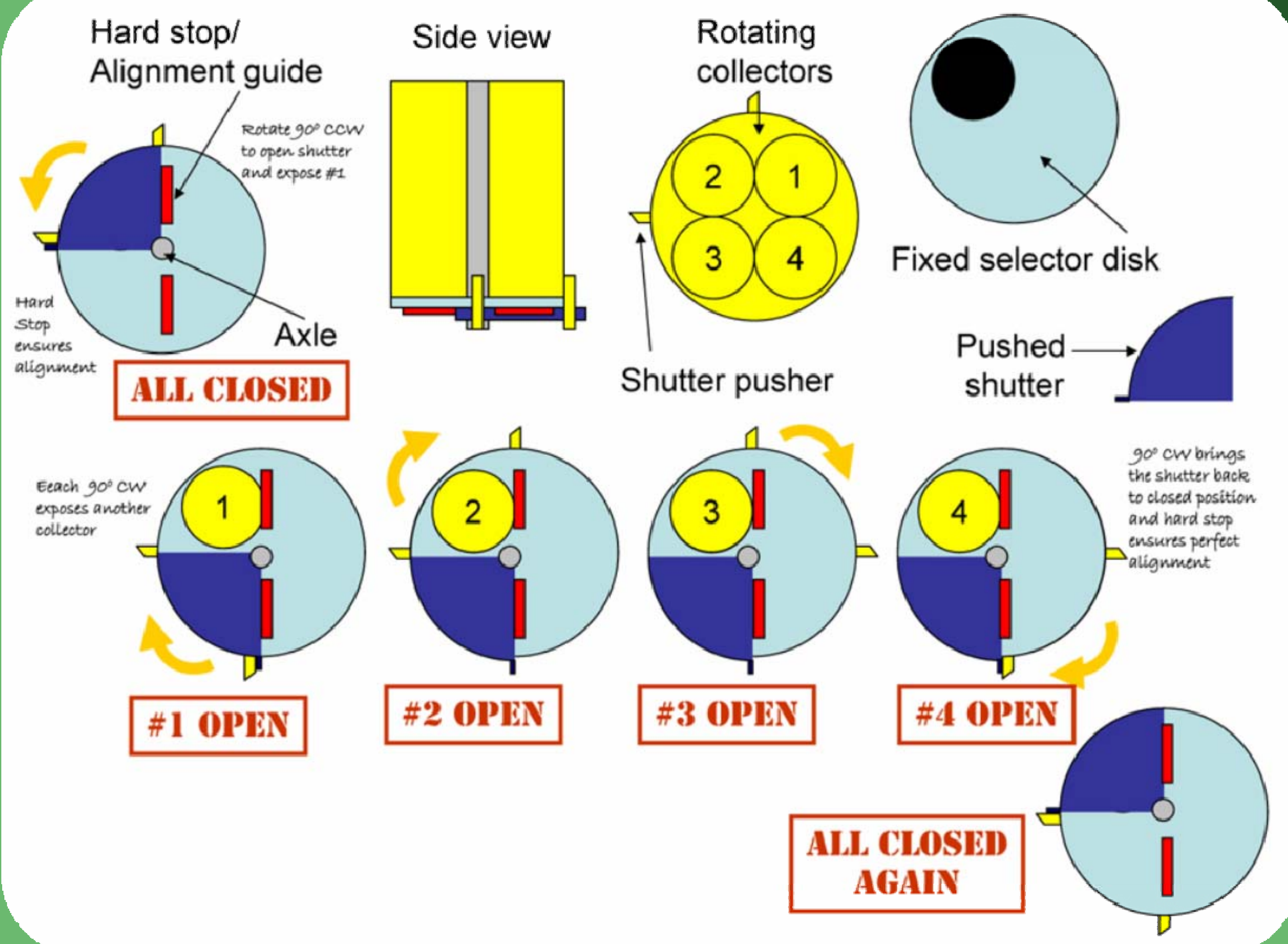






Pollen Collector
1. Stepper motor to change samplers
2. Air intake fan
3. Motors for spinning sampling forks
4. Sampler tubes
5. Sampling forks
6. Selector disk
7. Shutter
8. Control and data acquisition electronics

Tube Selector System



Success Criteria

- Rotorod devices function at the four altitude ranges and are recovered undamaged.
- Pollen particles adhere to the silicone gel.
- Payload collects measurable amounts of pollen.
- Independent variable sensors reliably measure and record atmospheric/location data.

Science Value

Our experiment will explore the correlations between altitude and pollen spread. This will help us learn more about cross-pollination, the spread of invasive species, and the spread of allergies.

Experiment Procedures

1. Test the entire system for functionality without the adhesive on the forks.
2. Prepare the forks with the adhesive.
3. Store in a sealed environment until rocket is ready for flight.
4. After recovery, the data will be downloaded from the “Bee Brain”.
5. Pollen samples will be returned to sealed environment to prevent contamination.
6. Pollen will be stained and examined under the microscope for number and species.

Payload/Vehicle Integration

- The payload parachute is stored behind the nosecone.
- The e-bay compartment is behind the payload parachute
- The 1st collector's parachute is behind the e-bay compartment
- The 2nd collector and its parachute are behind the 1st collector

Preparation Procedure

Flight preparation procedures for pollen samplers

1. Rotate the stepper, checking that nothing is obstructing its path
2. Rotate each of the fans to see that the sampling forks are secure
3. Verify that sensor readings are realistic.
4. Verify that GPS can obtain location fix.
5. Attach parachutes to B1 and B2
6. Properly fold the parachutes and wrap them in Nomex cover
7. Carefully place B1 and parachute into the rocket
8. Carefully place B2 and parachute into the rocket
9. Check that both B1 and B2 are sliding freely inside the hive
10. Cap the hive on the bottom with the tube coupler
11. Connect the hive with the booster section
12. Check that rocket sections will separate properly and smoothly
13. Activate the electronics after the rocket was installed on pad.

Verification Components

1. Fan (to draw the air through pollen samplers)
2. Servomotor (to rotate the selector discs)
3. Selector Disc
4. Rotorod Motor
5. Rotorod Fork
6. Altimeter
7. Thermometer
8. Hygrometer
9. GPS
10. Atmospheric Pressure Sensor
11. Battery Pack

Verification Tests

1. Drop Test
2. Pollen Capture Test
3. Connection Test
4. Battery Capacity Test
5. Pressure Chamber Test (Calibration
6. Scale Model Flight
7. Heating Test (Calibration)
8. Cooling Test (Calibration)
9. Humidity Test (Calibration)
10. GPS Ground Test (Calibration)
11. Acquisition Test
12. Durability Test
13. Air Flow Test

Verification Matrix

Legend
P- Planned
F- Finished

		Test												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Component	1	P		P									P	P
	2	P		P									P	
	3	P											P	
	4	P		F									P	
	5	P	P											
	6	P		F		P	F							
	7	P		F				P	P					
	8	P		F						P				
	9	P		F			F				F	F		
	10	P		F		P								
	11	P			P									

Safety and Environment

PAYLOAD RISKS		
Risk	**Consequence**	**Mitigation**
Fork detaching from fan	Sample(s) lost and possibly injuring people	Fork will be securely attached and extensively tested
Injury from the fork/fan that is spinning at high speeds	Hand/finger injuries	Follow the safety instructions that come with fans and keep fingers away from the immediate vicinity while Rotorod is running
Failure of parachute or shroud lines	Payload falling on people	Recovery systems will be meticulously tested beforehand
Pollen Allergy	Allergic reactions in susceptible individuals	People with pollen allergies will not handle the payload

Approach to Workmanship

- We will construct the payload using precise cutting and measuring instruments.
- We will apply adequate amounts of epoxy.
- We will follow the safety instructions given to use by our mentors.
- We will use high quality materials.

Outreach Plan

- Videos of launches on YouTube
- Sending thank-you notes for raking customers*
- Rocketry presentation to local elementary students

* For each loyal raking customer we wrote a personalized thank you note