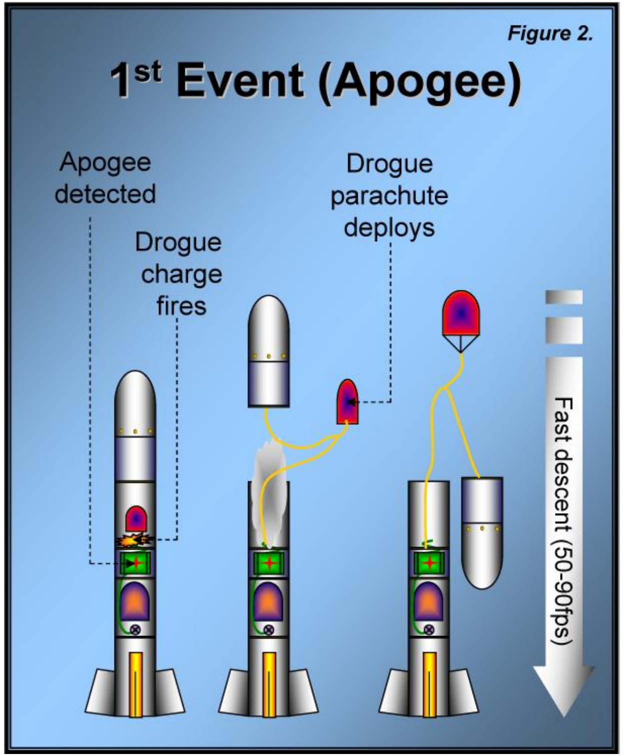
CO2 Ejection System

Owen Osborne, Stella Van Note, Michael Pace, Michael Kwan, Darin Sie, Chester Amkhamavong

Sponsor: Professor Shi

Problem Definition: Ejection System

- Recovery phase
  - During apogee (highest altitude reached by rocket), an ejection system is needed to eject the parachute out of the nose cone for safe recovery
- Traditional method: Black powder
  - black powder is ignited at apogee to create the pressure force needed to eject the nose cone
    - Issues
      - potential damage to parachute
      - ignition/pressurization trouble at high altitudes >20,000ft
- Solution/Objective: CO_2 system
  - Instead of black powder, use CO_2 cartridges as the pressurizing agent



Michael Pace

Design attributes table

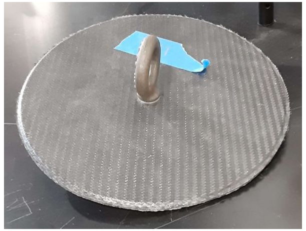
Attribute	O	C	F	M
Should be compatible with current preliminary test rocket	x			
Should not use black powder as pressurizing agent	x			
Components should be commercially available or easily manufactured	x			
Should be inexpensive	x			
Should be lightweight	x			
Should be easy to assemble	x			
Should create enough pressure to eject the nose cone and parachute			x	
Will use current flight computer available in rocket lab		x		
Will mount to existing rocket hardware/bulkheads		x		
Can be made out of some type of metal like aluminum				x

O: objectives
C: constraints
F: functions
M: means

Constraint details

- Flight computer applies 5 volts to apogee terminal at apogee
- 11.41” diameter bulkhead

Flight computer



Bulkhead

Darin Sie

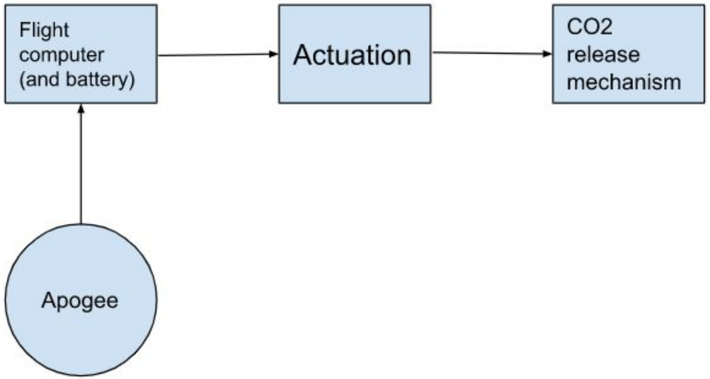
Requirements

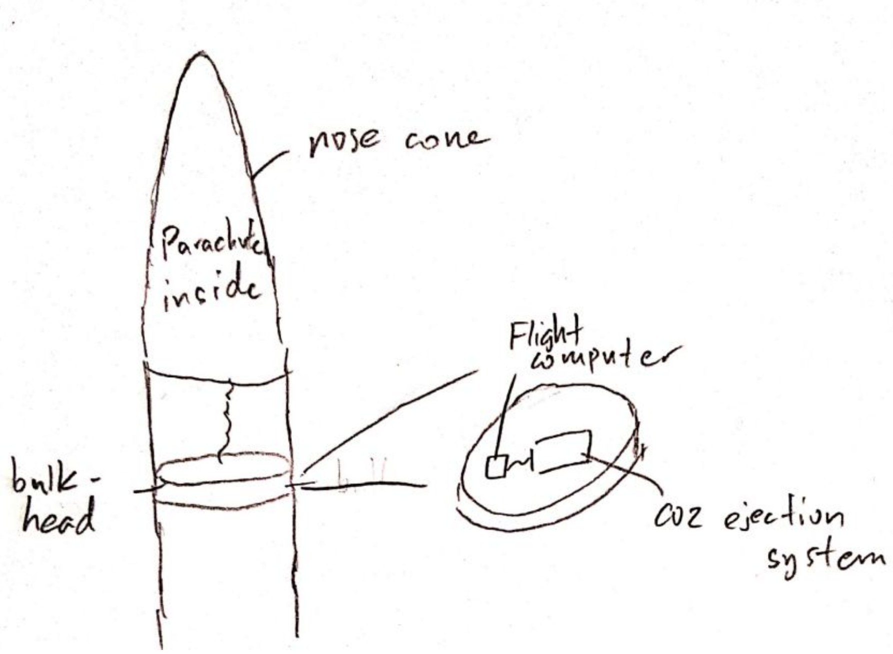
- Will fall within the $800 budget
- Will weigh less than 3 lbs
- Will require 3 people or less to assemble
- Will pressurize cabin to a gage pressure of 30000 Pa using 1-2 25g CO2 cartridges (largest we could find on Amazon)
- Will fit within a 11.41” diameter and 18” height cylinder

Darin Sie

System breakdown and mount location

- Flight computer detects apogee
- Flight computer sends current to actuation method
- Actuation method triggers CO_2 release mechanism





Flight computer and entire CO_2 ejection system would be mounted directly onto bulkhead using brackets and screws

Darin Sie

Component considerations

Actuation

- Black powder (BP) charges with e-match
- Solenoid
- Servomotor

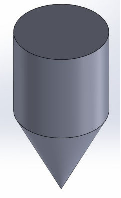
CO2 release mechanism

- Puncture (pin)
- Pre-puncture (valve-release)

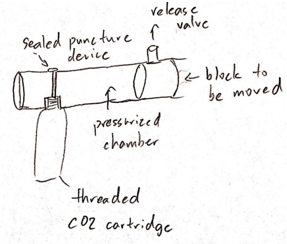
BP Charge

Solenoid

Servomotor



Pin



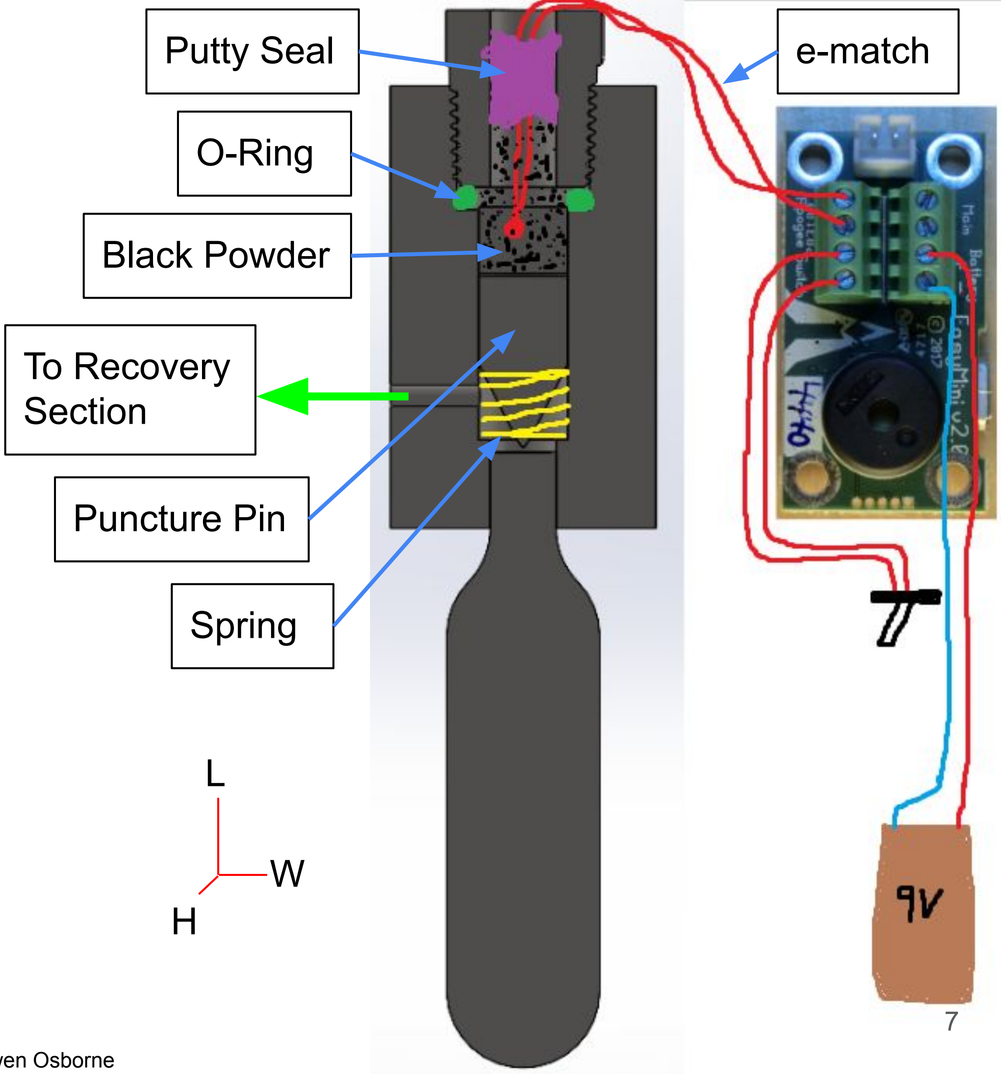
Valve-release

*6 total system design combinations are evaluated as a whole rather than on a component basis to ensure system cohesiveness and functionality

Darin Sie

Design 1: Owen Osborne

- Pin puncture system (BP Charge+Pin)
  - Putty (clay) keeps black powder and ematch in place, acts as a cap
  - Flight computer ignites ematch at apogee
  - e-match ignites black powder
  - Black powder applies sufficient pressure to the puncture pin and punctures CO2 cartridge
  - CO2 cartridge pressure presses puncture pin into o-ring seal, and the gas escapes through the vent to the recovery section
  - 5.54” L x 1.5” W x 1.5” D
    - V = 12.47in^3
  - W ~ 0.7 lbs (Solidworks est.)
  - Cost ~ body = $17.62, pin = $15.20, plug = $12.10, o-ring = $3.26/100, spring = $7.26/6
    - Total = $55.44 (doesn’t include co2 or parts we already have)

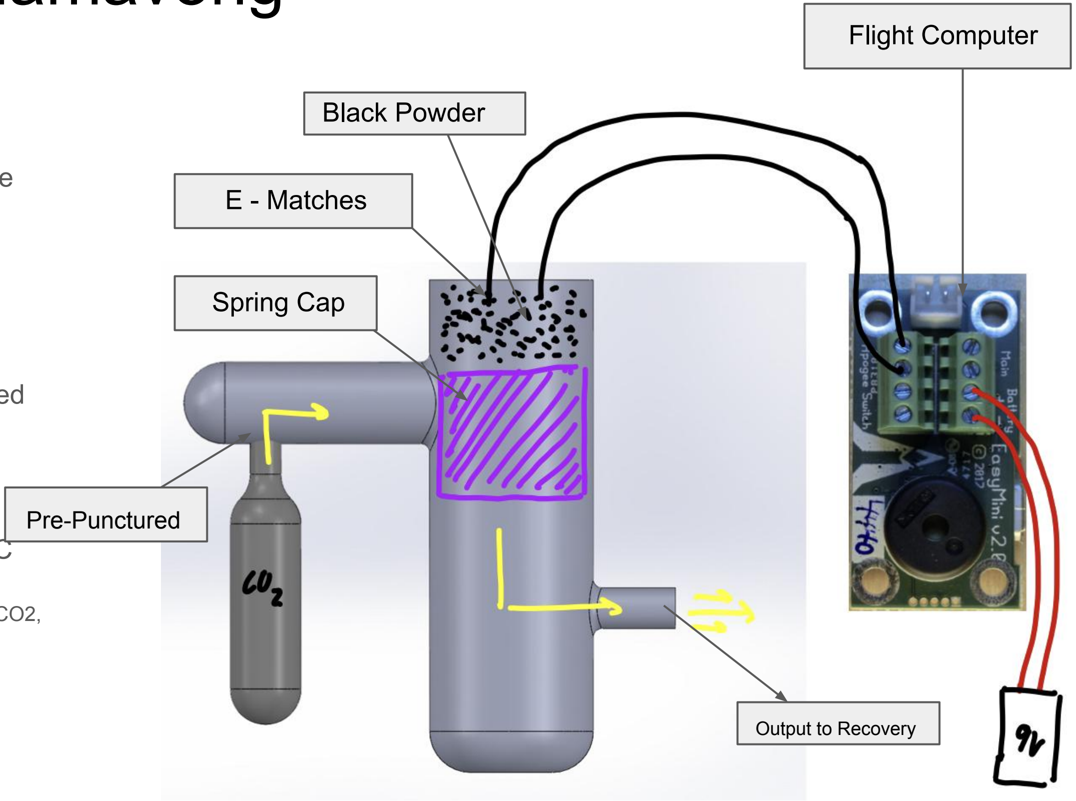


Owen Osborne

Design 2: Chester Amkhamavong

Pyro-Valve (BP Charge+Valve)

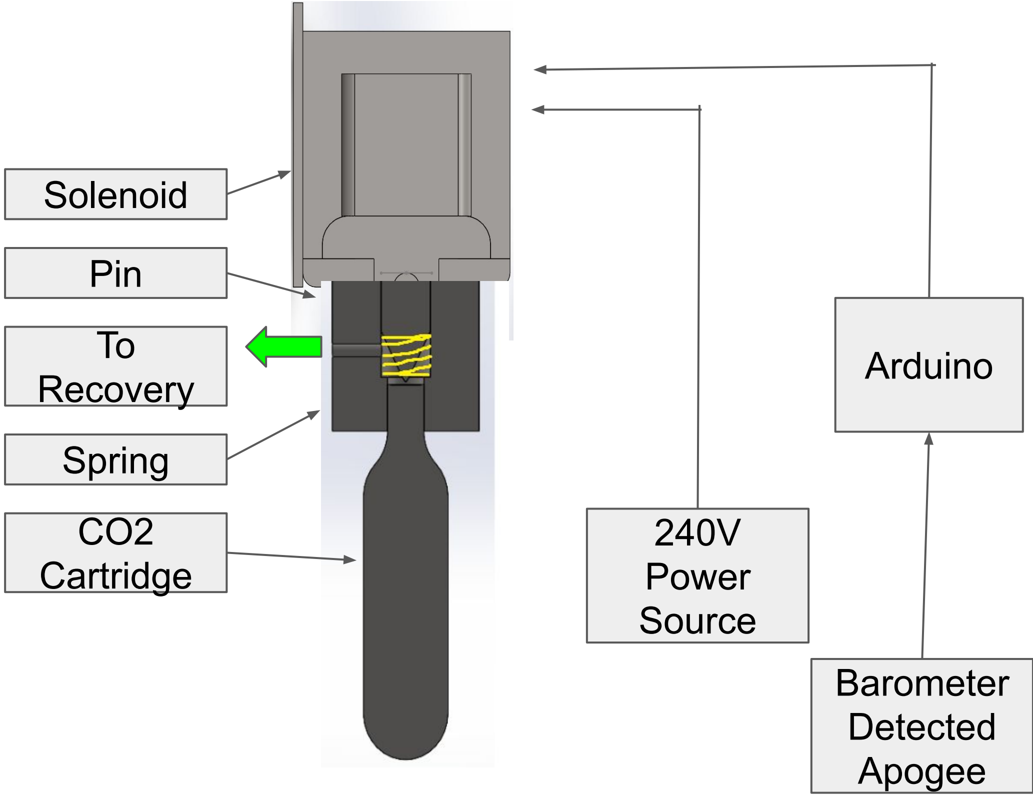
- Use a sealant that contains CO_2 until E-matches are ignited
  - Sealant could possibly be alter the BP for thicker consistency (coarse vs fine)
  - A spring cap would shoot down when BP ignited which releases CO_2
- CO_2 will be pre-punctured
  - No necessary tools or equipment to be added to release CO_2
- Potential Leaks are high due to pre-puncture
- Using FC to read altitude from Pressure
- Weight: ~0.97 lbs (via Solidworks)
- Cost: Spring ($12.32), Body (~$25), Cap ($5.25), FC ($80), Battery ($2.50)
  - Total: ~ $125.07 (not accounted for testing with BP, CO2, and E-matches)
- Size: 6” L x 6” W x 2” D



Design 3: Stella Van Note

Pin Puncture System (Solenoid+Pin)

- Spring prevents vibrations from puncturing the CO2 canister prematurely
- Barometer detects Apogee, arduino actuates solenoid at apogee
- Solenoid pushes pin to puncture CO2 cartridge
- CO2 Cartridge punctures and the release goes to recovery for ejection
- Force output
  - 195 ozf or 54.21 N
- 7.0” L x 1.5” W x 1.5” D
  - V = 15.75 in^3
- Weight
  - ~2.5 pounds + 24 pound battery
- Cost
  - Solenoid = $84.80; Body = $17.62; Pin = $15.20; Battery = 188.99
  - Total = $306.61 (doesn’t include co2 or parts we already have)

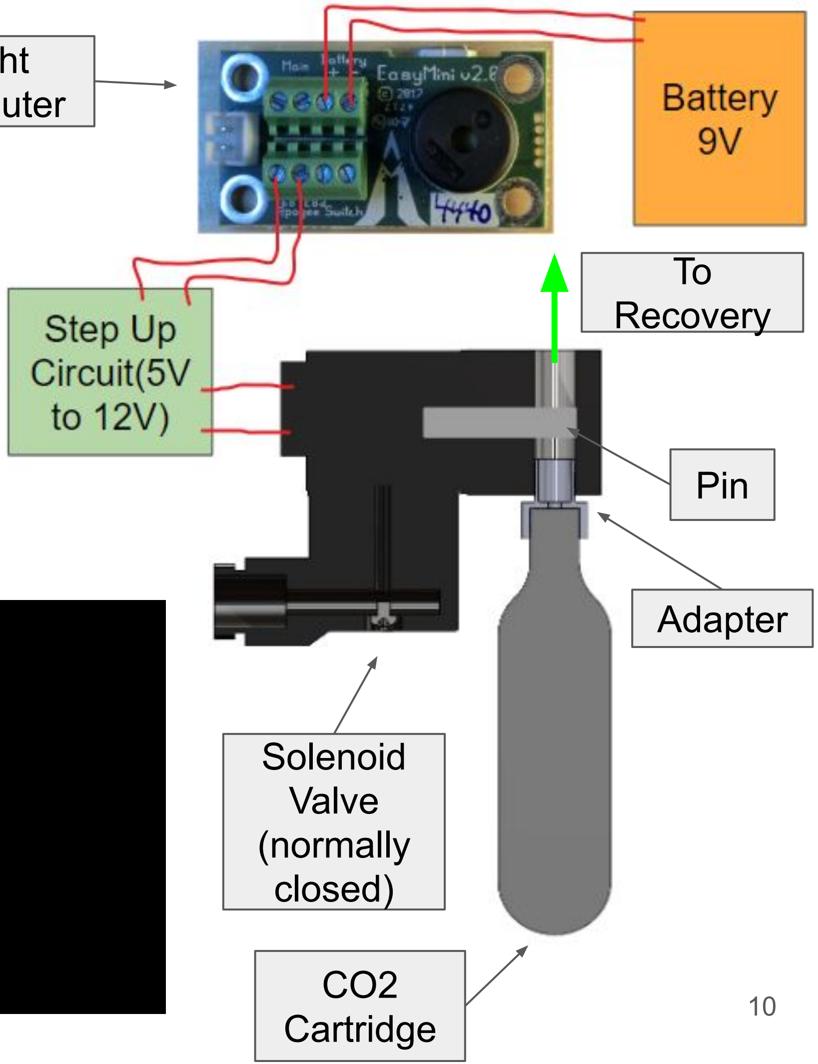


Design 4: Michael Pace

CO2 solenoid+valve release

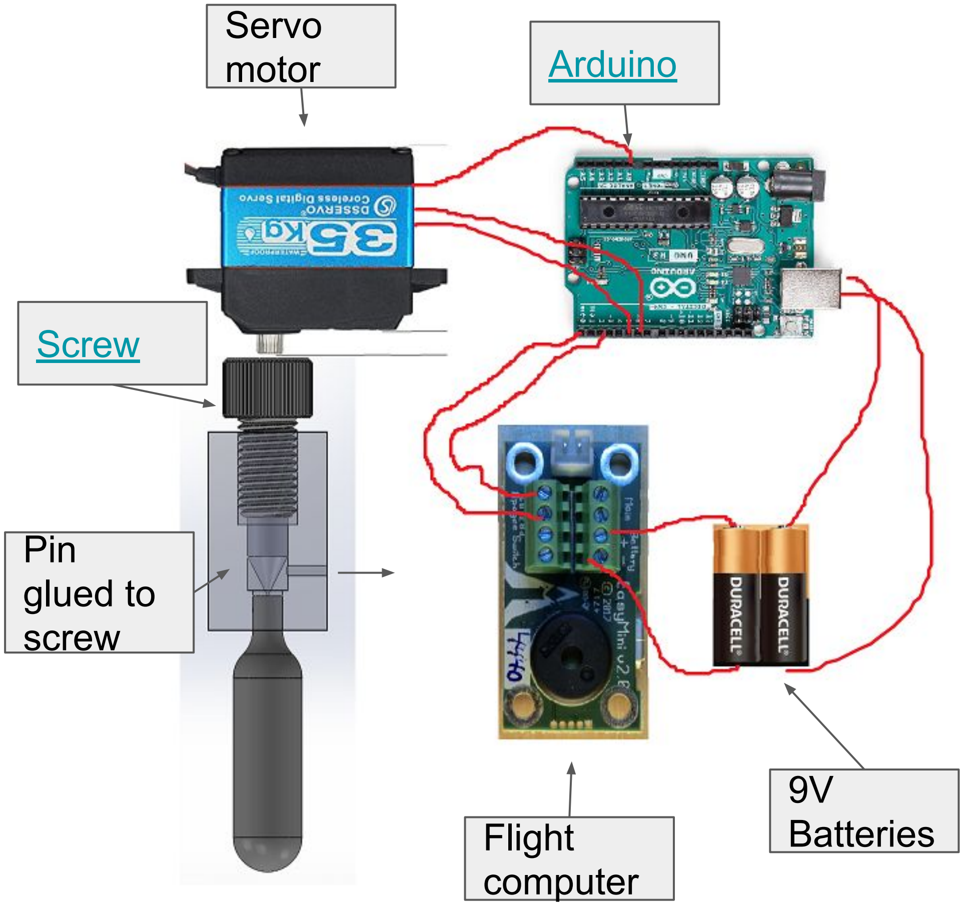
- CO2 is tapped and line is pressurized up until solenoid
- Computer sends open signal at apogee
- Ramp up circuit boosts the 5V signal from the computer to the required voltage
- Solenoid opens and release pressurized co2 into the nosecone
- Flow Rate (Cv) = .04
- Size: 5.5” L x 3.5” H x 1” W
  - Volume: ~19 in^3
- Weight: 1.03 lb
- Cost:
  - Solenoid = $200, adapter = $20
  - Step up circuit (5V to 24V) = $37
  - Total = $254

Michael Pace



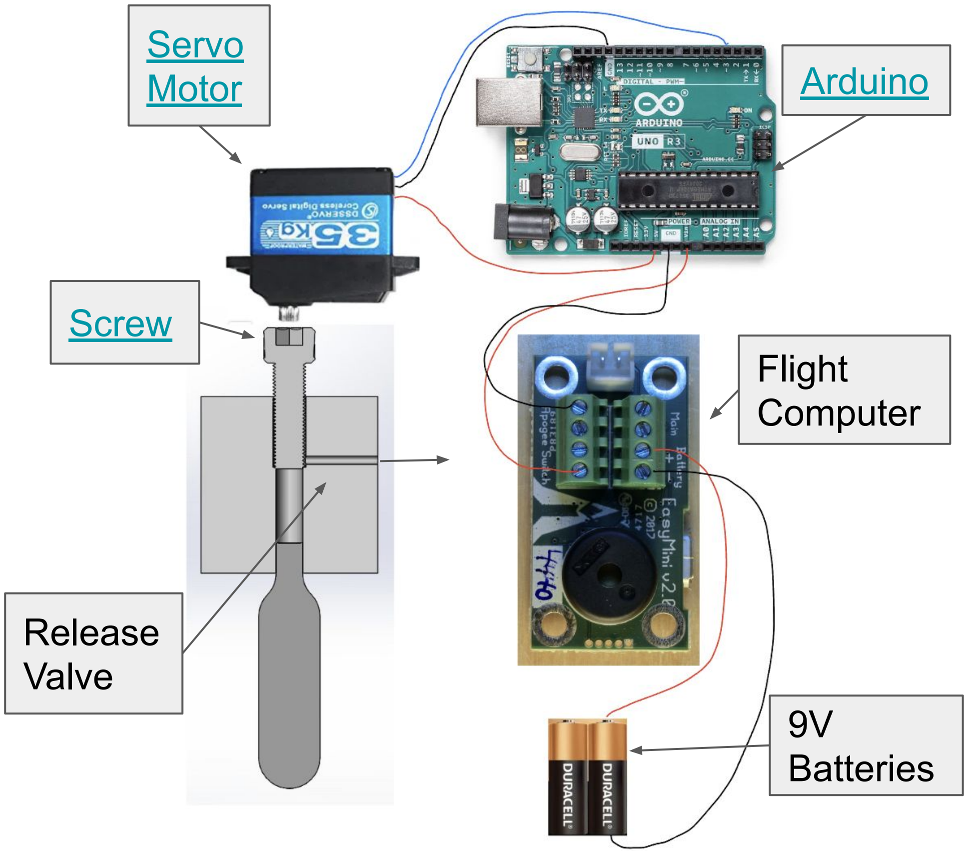
Design 5: Darin Sie

- Screw system (servomotor+pin)
  - Flight computer detects apogee, sends trigger signal to Arduino
  - Arduino provides 5V to run desired program on servomotor (quickly turn to achieve depth of 0.1 inches and then return to original position)
  - At 5V, this particular servomotor has a stall torque of 29 kg*cm
  - Pin glued to screw punctures CO_2 and CO_2 is released through the outlet
  - Cost: ~$101
  - Weight: ~1.166 lb
  - Size: 7.5” L x 4.28” W x 1.5” H
    - ~48.15in^3



Design 6: Michael Kwan

- Screw System (servo motor+valve)
  - CO_2 cartridge is already punctured and is sealed in chamber
  - Chamber is sealed by locked servo holding screw in front of release valve
  - Flight computer detects apogee and sends 5V signal to Arduino
  - Arduino runs program to have servo rotate screw past release valve (0.1in)
  - CO_2 is released out of valve into nose cone
  - Cost: ~$106
  - Weight: ~2.06 lbs
  - Size: 8.49” L x 2.5” W x 2.5” H
    - ~53.0625in^3



Michael Kwan

Design Matrix (weighted rank-order)

Design	Scaling	1 (BP Charge+Pin)	2 (BP Charge+Valve)	3 (Solenoid+Pin)	4 (Solenoid+Valve)	5 (Servomotor+Pin)	6 (Servomotor+Valve)
Cost	0.1	4	3	1	2	6	5
Weight	0.25	6	5	1	4	3	2
Integrability	0.15	6	4	5	2	3	1
Simplicity	0.1	6	2	5	3	4	1
Manufacturability	0.05	4	1	6	2	5	3
Durability	0.05	2	1	6	5	4	3
Reliability	0.3	6	5	3	4	1	2
Total Score	1	5.5	3.95	3.1	3.35	2.95	2.15

- Cost: Estimated cost and difficulty in obtaining (manufacturing and COTS parts)
- Weight: Estimated weight of all parts
- Integrability: Size and orientation on bulkhead
- Simplicity: # of parts and build complexity
- Manufacturability: How easy to manufacture
- Durability: Estimated use repeatability
- Reliability: Consistency

Chester Amkhamavong

SWOT Analysis (Selected design: Design 1)

Strengths	Weaknesses	Opportunities	Threats
● Uses a lot of available/existing parts. Not a lot of things to manufacture or purchase ● Lots of online documentation on similar systems for reference	● Still uses black powder, which is relatively difficult to produce or obtain in California	● With new additive manufacturing technology and few parts, this product, assuming functionality, has the potential to be rapidly iterated and produced for commercial use in hobby rocketry	● Traditional black powder systems are still a high choice for rockets ● Already CO_2 ejection system kits for smaller scale rockets which could affect market competition

Michael Kwan

Plan moving forward

- Week 6: Finalize design, create bill of materials, submit purchase orders
- Week 7: Assemble prototype
- Week 8: Verification and testing (requirements compliance table)
- Week 9: Minor improvements/adjustments to design
- Week 10: Finish final report

Owen Osborne

Questions/Concerns

Key items to be machined: chamber = 6061 Al, pin = 316 SS

- Is it better/easier to machine ourselves or request at UCI's machine shop?
- If at machine shop, need timeline and cost estimate
  - Protolabs?
- Guidance on appropriate tolerances