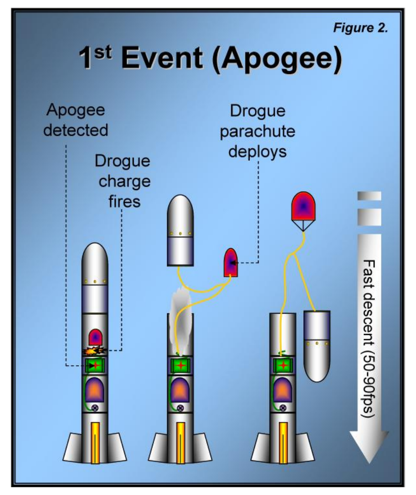
CO2 Ejection System

UCI Samueli School of Engineering

Overview

- A rocket enters it's recovery phase when it reaches apogee, the highest altitude it will achieve on it's flight path.
- During the recovery state it's imperative the ejection system is able to pop the nosecone and deploy the chutes for a successful recovery of the rocket.
- Traditional ejection systems use black powder charges which have two issues:
  - Potential damage to chutes.
  - Black powder experiences combustion issues at elevations exceeding 20,000 ft.
- We designed an ejection system for UCI's liquid rocket project that uses compressed CO2 as the pressurizing agent.



Existing Solutions

The RAPTOR is another CO2 ejection system designed and manufactured by Tinder Rocketry for parachute deployment in high powered rockets at any altitude. The newest CO2 ejection system, The RAPTOR, is lightweight, compact and versatile! It is designed to be easy to use and works with many CO2 cartridges ranging in size from 20 to 85 grams. Comes with:

- Precision Machined Aluminum Mounting Cap (With mounting hardware)
- Precision Machined Aluminum Pyro Housing
- Single and Dual Charge Cups (With red dot seals)
- E-match Potting Putty& O-ring seals
- Puncture Piston Assembly & Return Spring
- Assembly Lube
- Extra O-rings, Disassembly Punch, Cotton Swabs
- Powder Measure Vials
- Two 23gm & Two 35gm CO2 ctgs

Design Decisions

Requirements

1. Will fall within the $800 budget
2. Will weigh less than 3 lbs
3. Will require 3 people or less to assemble
4. Will puncture one 25g CO2 cartridge
5. Will fit within a 11.41" diameter and 18" height cylinder
6. Will create a ~33000 Pa pressure spike in a ~0.06 m3 volume

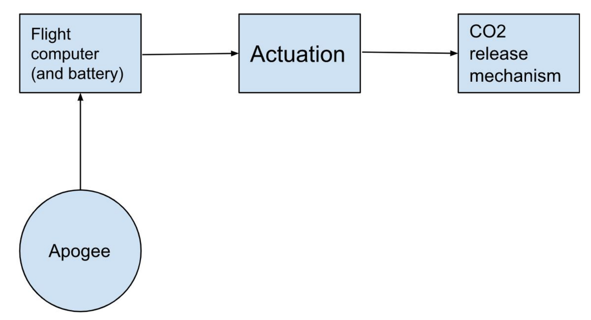
Attribute	O	C	F	M
Should be compatible with current preliminary test rocket	x			
Should not use black powder as pressurizing agent	x			
Components should be commercially available or easily manufactured	x			
Should be inexpensive	x			
Should be lightweight	x			
Should be easy to assemble	x			
Should 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 a combination of metal and plastic				x
Should be reliable	x			
Should be simple	x			
Should be durable	x			

Decision Matrix

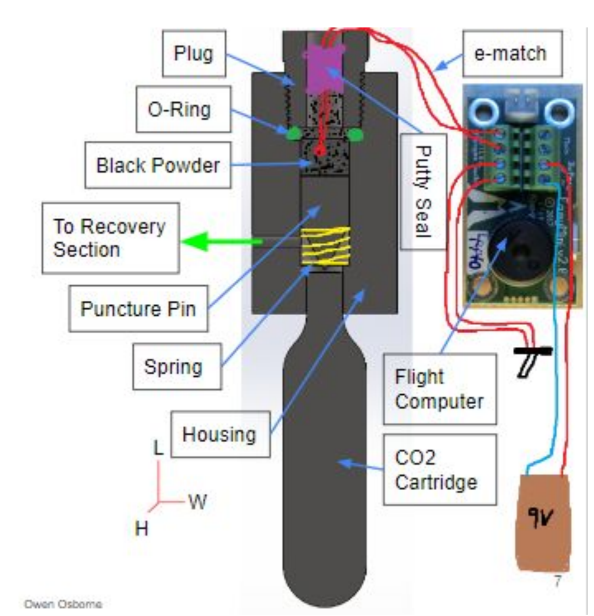
Design	Scaling	1 (BP Charge+Pin)	2 (BP Charge+Valve)	3 (Solenoid+Pin)	4 (Solenoid+Valve)	5 (Servomotor+Pin)	6 (Servomotor+Valve)
Cost	0.1	4	3	1	2	6	5
Weight	0.25	6	5	1	4	3	2
Integrability	0.15	6	4	5	2	3	1
Simplicity	0.1	6	2	5	3	4	1
Manufacturability	0.05	4	1	6	2	5	3
Durability	0.05	2	1	6	5	4	3
Reliability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

Final Design

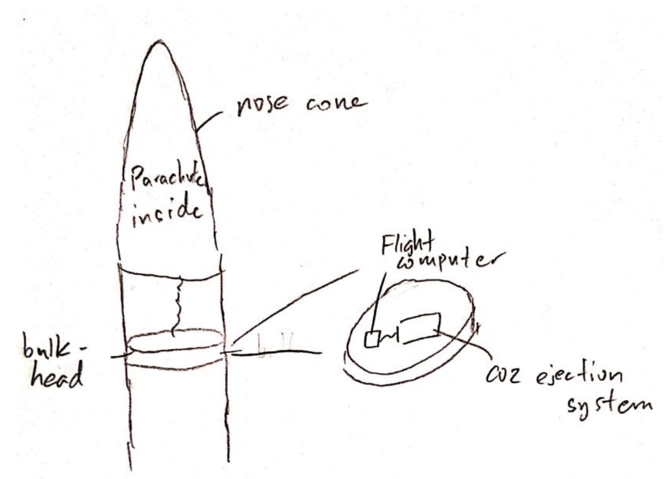
Functional Breakdown



Final Design



System Overview



Component Details

Components:

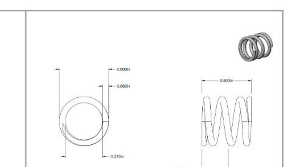
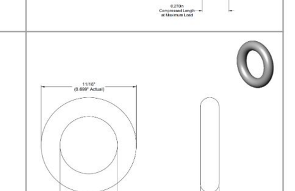
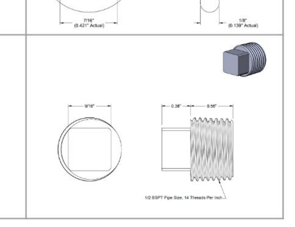
Housing - Main body of ejection system. Encases the pin puncture system, has a female threaded port for CO2 cartridge, and vent holes. Mounts onto bulkhead.
Puncture Pin - Rod sharpened to a point on one end. Rod is actuated by black powder detonation to puncture the CO2 cartridge.
O-ring - Seats pin and creates airtight seal.
Plug - Threads into housing via a machined NPT female port on the housing. The ematch is wired externally from the flight computer to the black powder via a small hole in the plug, which is sealed with putty.
Spring - Placed between pin and CO2 cartridge seal to prevent contact and accidental puncturing of the co2 cartridge.
Ematch - Ignites black powder to trigger actuation of CO2 cartridge puncture.
Flight Computer - Detects apogee and sends ignition signal to ematch.

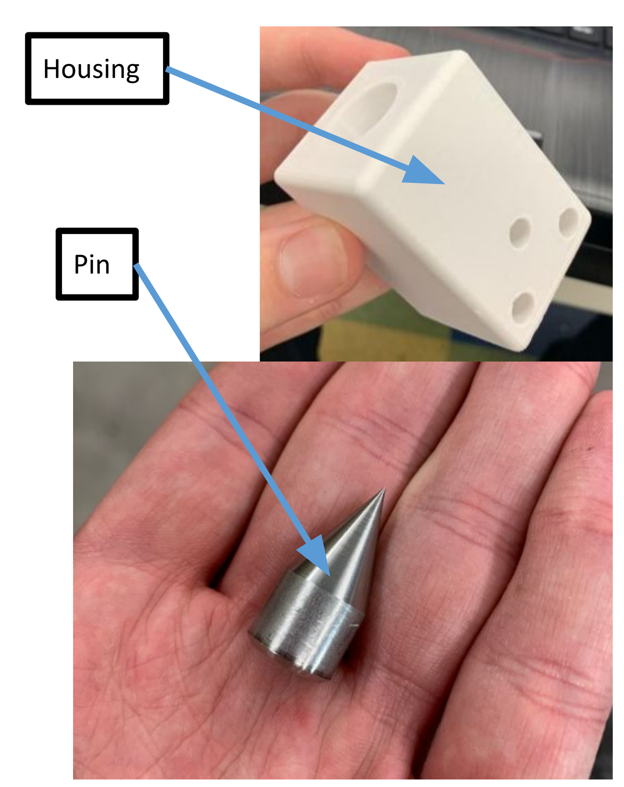
Analysis: Mass of Black Powder Required to Actuate System

Combustion chamber diameter: d=.4 in
Area of pin exposed to bp: Apin=*d2/4=*(.4 in)2/4=0.126 in2
Spring force at max compression: Fspring=23.72 lbf
Pressure required for pin to overcome spring force: Prequired
Prequired=Fspring/Apin=23.72 lbf/0.126 in2=188.76 psi
Black powder mass: m
Black powder volume: V=m/
Density of black powder: =1.76 gcm31 lbm453.6 g16.37 cm31 in3=0.0635 lbmin3

Online calculator:
m=.01 g
V=m/=.01 g/1.76gcm3=.057 cm3

Flight computer	
E-match	

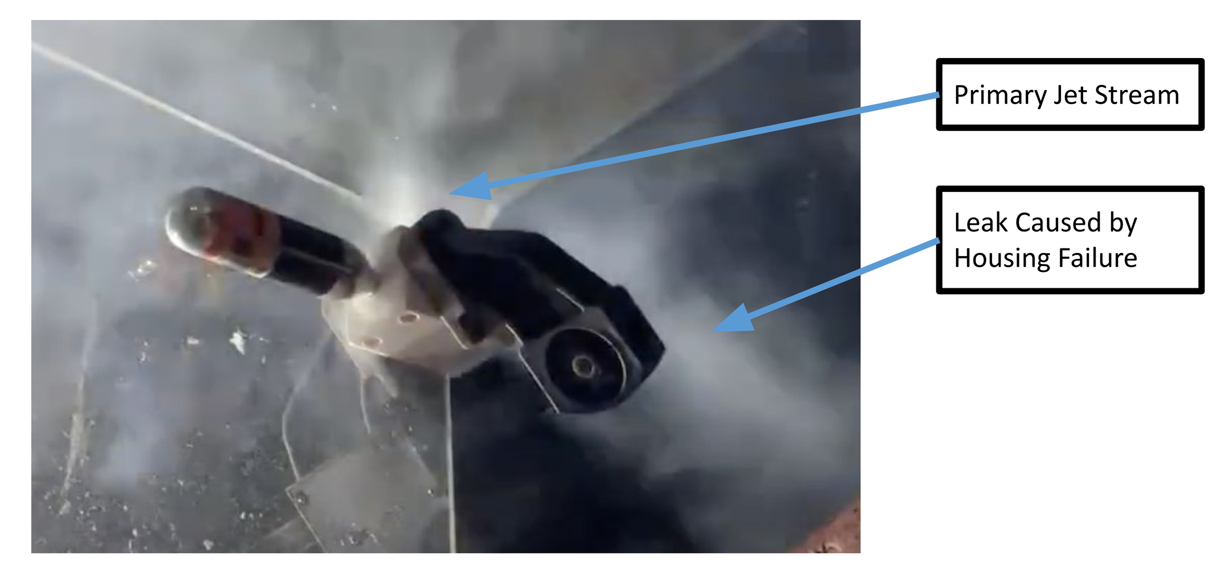
Spring	
O-ring	
Aluminum NPT Threaded Plug	



Prototype

Analysis & Performance

- Performed actuation test with 10x BP calculated
  - Purpose: Test actuation system, which is the primary co2 release mechanism
- Actuation test was a success
  - Function of system verified
- Failures: Housing
  - Test proved that housing must be made of a stronger material
    - We will be using Al 6061T6
      - Maintains structural integrity while being as lightweight as possible



Future Recommendations

- Current System
  - Create housing with a denser infill (50%?) vs current prototype of 20% infill
  - Create housing out of metal, Al 6061 T6 is a great option
  - Explore different pin tip geometries for a larger puncture area which will increase mass flow of CO2
  - Explore different housing geometry to reduce material and weight while maintaining structural integrity
  - Fine tune tolerances so that alignment is better and pin puncture happens more concentrically
- Future System(s)
  - Versatility: create a system that can be used in many rockets
  - Zero black powder: Move towards a fully independent recovery system that does not use black powder

References & Acknowledgements

- UCI Rocket Project: Pressure Calculations