BYU Propulsion Development

Experimental LOX/Paraffin Hybrid Rocket

Overview

The "Blue Jay" is a 12 ft., LOX and paraffin hybrid rocket with a designed total impulse of 20,330 Ns. The rocket will have its maiden flight summer 2022 at the Friends of Amateur Rocketry with a target altitude of 10,000 ft. above ground level. The rocket is expected to weigh around 100 lbs. dry. This is BYU's first hybrid rocket, and one of the first LOX paraffin hybrids to be flown. The rocket is divided into four subsystems: structures and recovery, electronics and controls, plumbing, and propulsion.

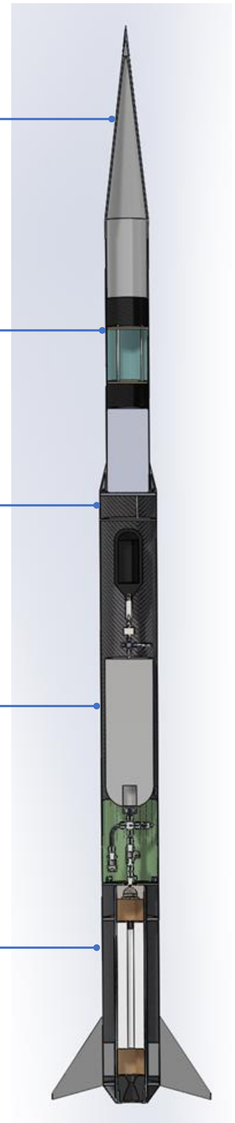
Airframe
Fiberglass conical nose cone with GPS unit. A 6 in. carbon fiber body tube section transitions to an 8 in. section with four fiberglass fins.

Recovery Bay
A 6 ft. drogue chute deploys at apogee to control the decent. Then a 16 ft. main chute deploys at 1200 ft. and slows the rocket down to 20 ft/s.

Electronics and Controls Bay
The flight computer is located just above the plumbing system.

Plumbing System
A 4500-psi nitrogen tank pressurizes the LOX tank to 1266 psi during the burn. LOX is fed through a ball valve to the injector at 0.88 kg/s.

Propulsion System
The 4 in. OD combustion chamber burns a 1.5 ft. paraffin fuel grain with a single 1 in. port at 1000 psi. The nozzle is made from graphite with an exit Mach number of 3.1.



Subsystem Designs

Electronics and Controls
The electronics are composed of two redundant systems, a Teensy 4.1 and an Arduino Due, that control the launch sequence and valves as well as logging and transmitting flight performance data. Additional pressure data from the plumbing system is also recorded and monitored.

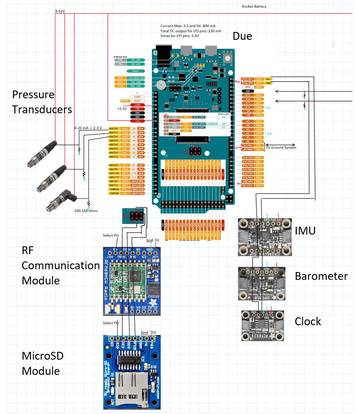


Figure 1. Schematic of the Arduino Due and sensors.

Propulsion System
NASA CEA was used to predict the thermochemistry of liquid oxygen combusting with paraffin wax. The team also decided to keep the total empty weight of the rocket to around 100 lbs., and the thrust to weight ratio was chosen to be 6.5. The burn time was also not to exceed 6 seconds. These requirements, in addition to the objective altitude of 10,000 ft., enabled Python code developed in house to iteratively solve the equations of motion for this rocket and determine the thrust required to reach to target altitude. Code was also developed to employ the method of characteristics in designing the contour for the nozzle.

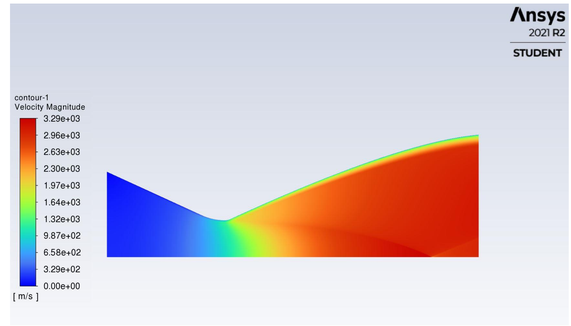


Figure 2. ANSYS simulation showing the flow velocity through the nozzle.

Plumbing System
The plumbing system provides the combustion chamber a pressure difference of 250 psi across the injector to achieve a mass flow rate of LOX of 0.88 kg/s while accounting for losses. The flight computer controls the solenoid valves that open the nitrogen line and vent the system. A manual ball valve acts as the fill and drain valve. A pneumatic actuator opens the run valve to release the LOX to the injector.

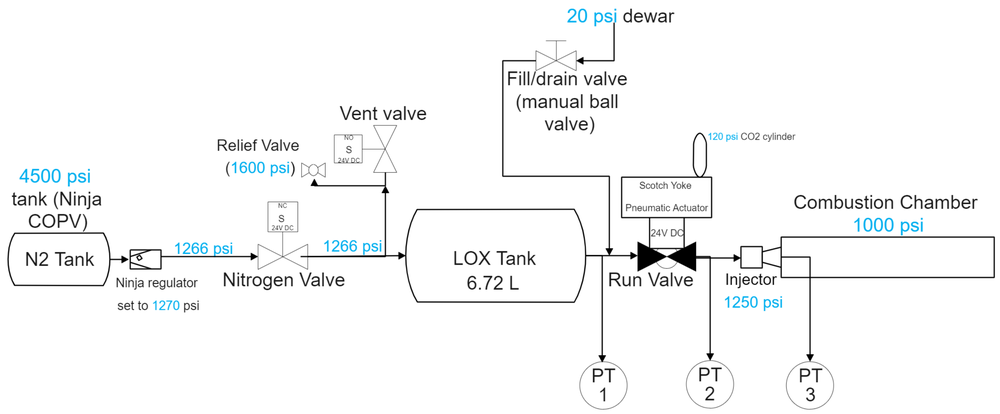


Figure 3. Piping and instrumentation diagram of the plumbing system.

Next Steps
As parts are coming in, the rocket is nearing its completion. A series of tests are planned to check the integrity of the rocket, the impulse of the motor, and the control of the valves. "Blue Jay" is only the beginning for hybrid and eventually liquid rocket engine development at BYU.

Acknowledgments:
Dr. Steve Gorrell, Bryant Brown, Kevin Cole, Brett Coles
Weidman Center, Utah NASA Space Grant Consortium

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Jayson Davis, Lincoln Stewart, Logan Morse, David Andelin, Joshua Cook, Brennen Dover, Cameron Van Dyke, Cole Halverson, Elizabeth Barnett, Eric Christie, Gerritt Graham, Jacob Hansen, Jason Metten, Kendall Green, Matt Bozer, Oscar Escobar, Samuel Craven, Zachary Lyman, Courtney Payne, Ben Larson, Tyson Butterfield