A Compressed Air Reaction Control System for Model Rocketry

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Background - Stability and Controls

Orbital rockets have guidance requirements beyond aerodynamic stability

Control surfaces can't do this, they only work in the atmosphere

Guidance solutions for orbital rockets include thrust vectoring, reaction wheels, reaction control thrusters

The Project

My objective was to design an rocket reaction control thruster system for use in a model rocket

I chose to use compressed air as a propellant because it is extremely safe and allows for unlimited testing, although it provides the least thrust

I divided the project into the following areas

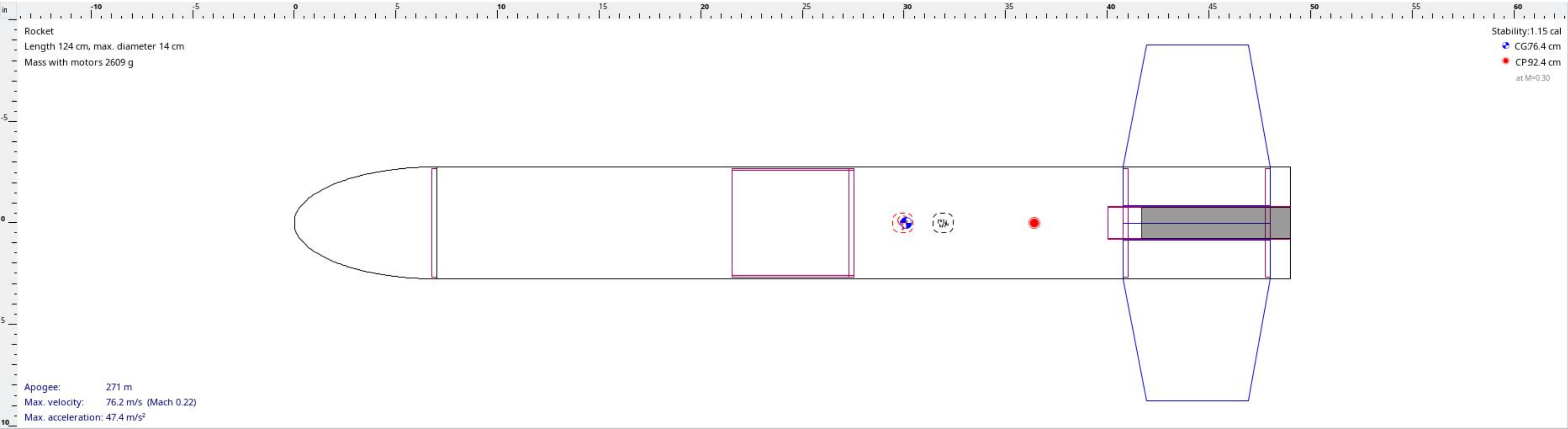
- The rocket
- The electronics
- The control system hardware
- The control system code

The Rocket Design

I used OpenRocket to design my rocket and simulate flights

Stability: 1.15 caliber

Wet Mass: 5.75 lbs

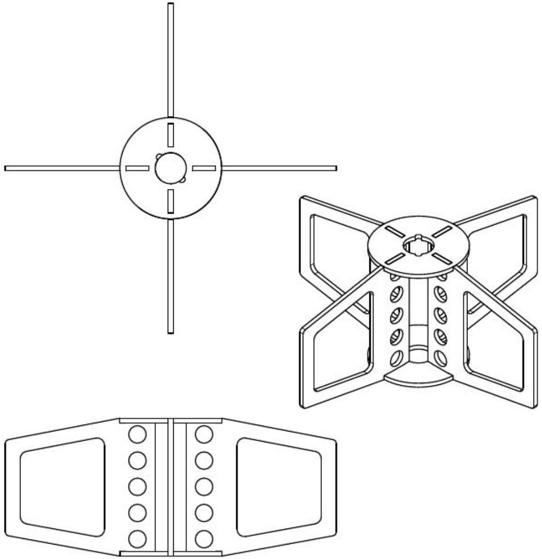


The Rocket

Laser-cut plywood centering rings and fins, hollowed out and shrink-wrapped

3D printed elliptical nose cone and motor cap

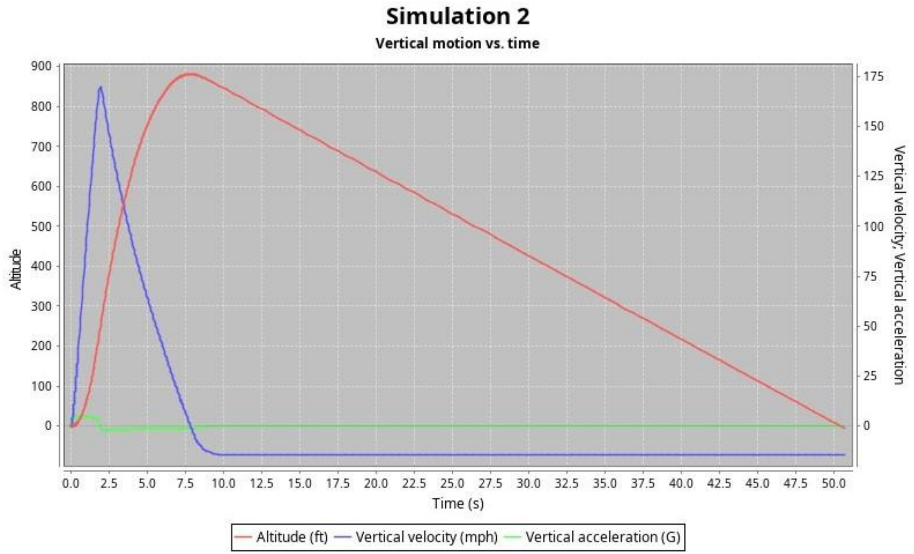
Uses standard 38 millimeter solid fuel composite motors



Test Flight

Look for

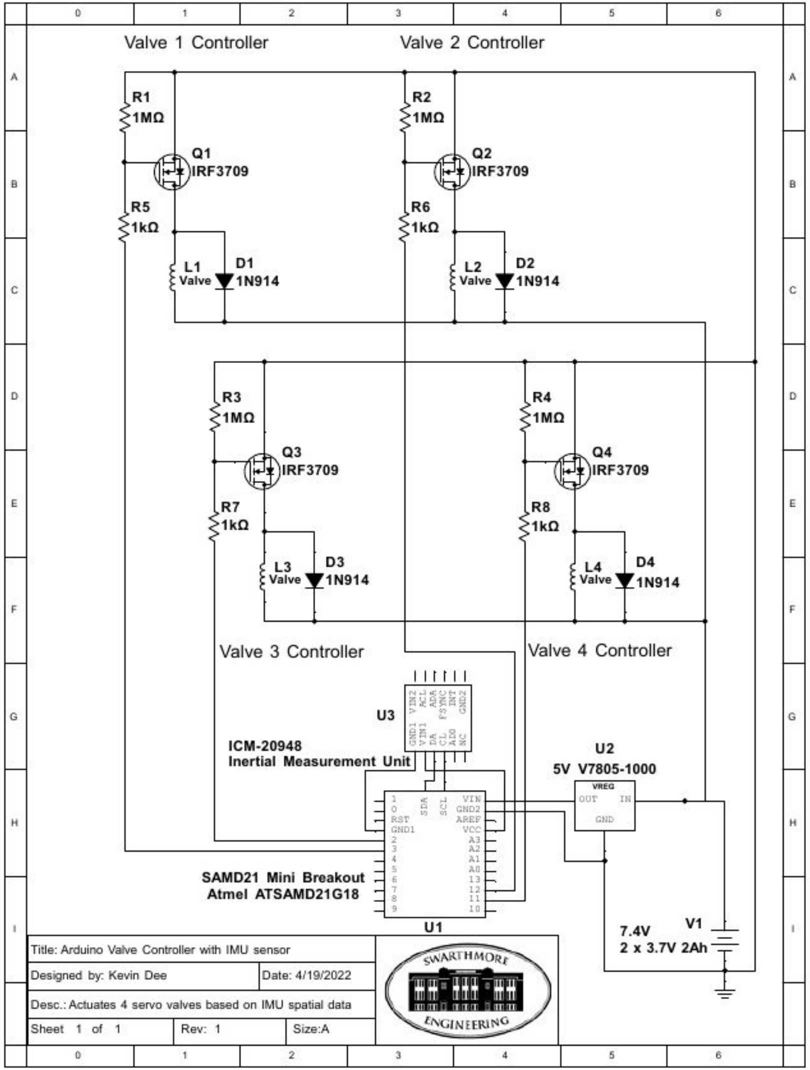
- Roll rate (spinning)
- Stability (how straight it flies)



The Electronics Design

Criteria:

- Arduino microcontroller for programming simplicity and hardware compatibility
- Inertial measurement unit (IMU) for orientation sensing
- Capable of actuating four valves, controlling the flow of compressed air out of each nozzle
- Powered from a single battery, but meets all operating voltage requirements



Power Supply

One of the greatest challenges I faced was distributing power to all components at the correct DC voltages from a single power supply. I addressed this problem by using a 5V DC-DC converter.

Component	V_{min} (V)	V_{max} (V)	Power Supply Solution
Solenoid Valves	6	12	Directly from 7.4V battery
Arduino	3.6	6	7.4V battery through 5V buck converter
IMU	1.8	3.6	Through Arduino 3.3V pin

I was also concerned about effective distribution of power under peak loads, so I tested simple Arduino functions while all four valves were powered, and observed no effect

The Control System Hardware Design

This hardware is responsible for promptly delivering compressed gas through open valves and out of the rocket via a nozzle

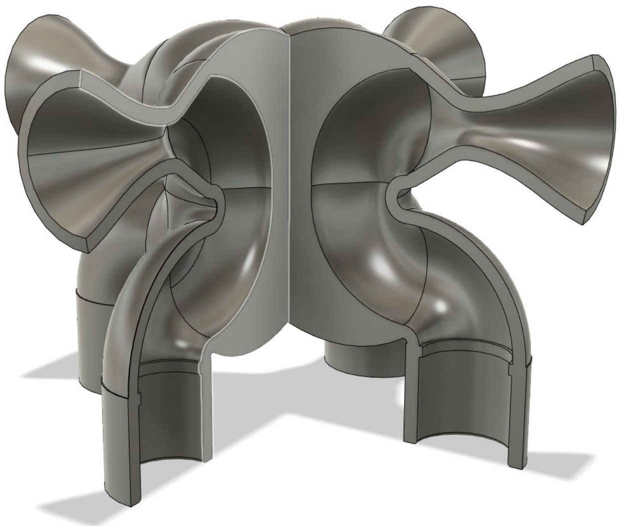
There are four main parts:

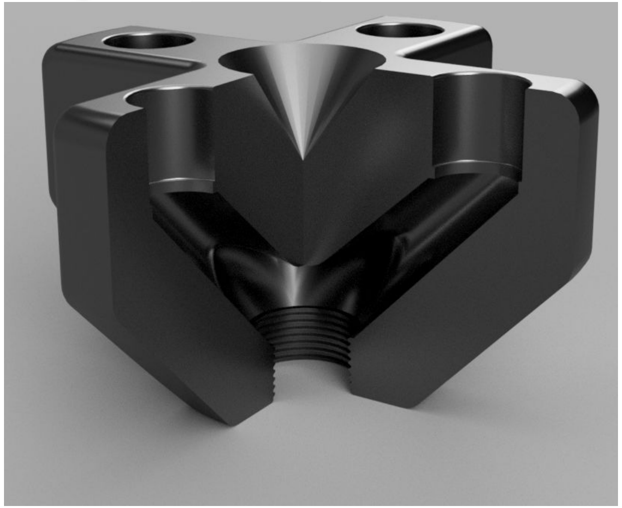
- Compressed air storage
- Gas manifold
- Valves
- Nozzles

The Control System Hardware

I sourced the valves from Adafruit very cheaply, but they limit the system to 100 PSI (~7 atm)

The manifold and nozzle assembly are 3D printed





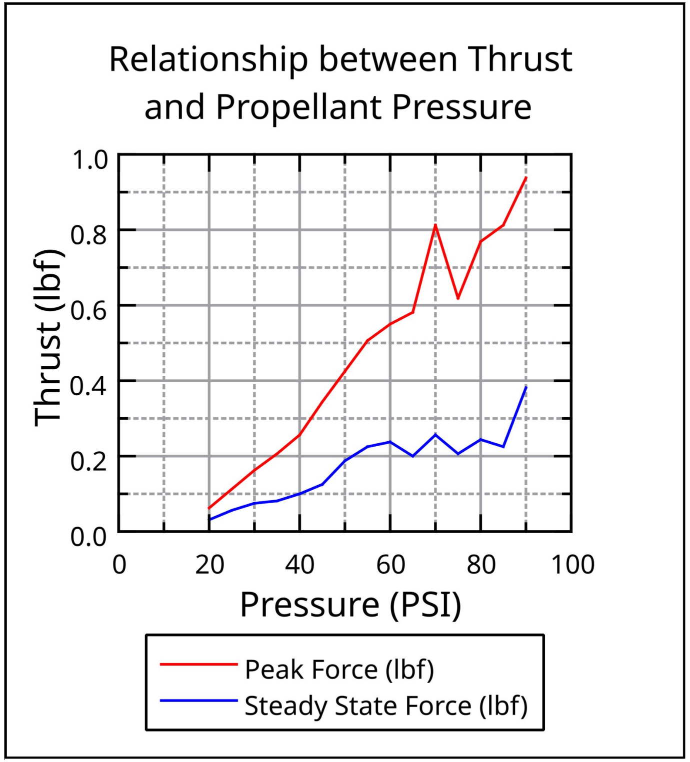
Integration

I sealed the system, attached the electronics, and sleeved it into the rocket's airframe

The system can be put in upside-down to allow for testing directly from the machine shop air compressor instead of a tank in the rocket airframe

Results - Thrust

I measured the thrust a single nozzle could produce at various propellant pressures to determine how powerful of a rocket engine I had created

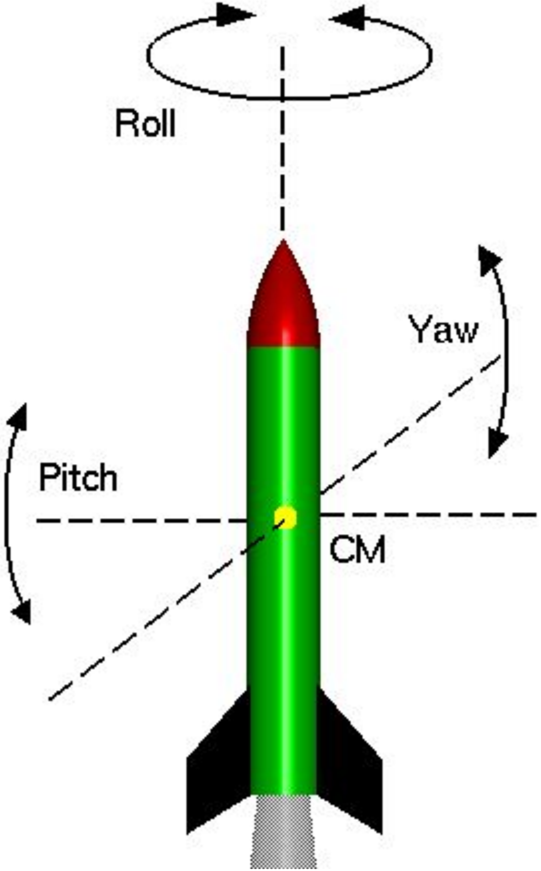


The Control System Code

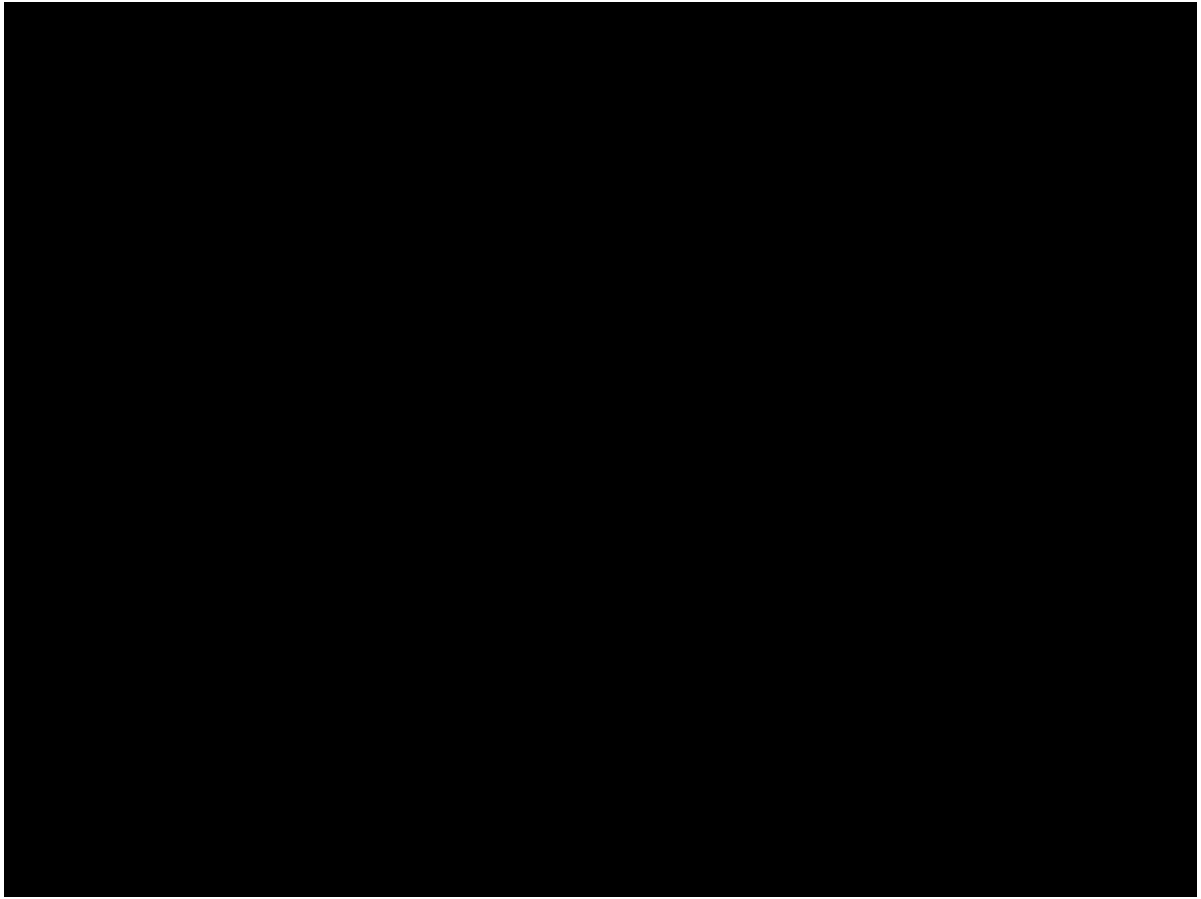
The project was coded in Arduino, and I had a lot of help from example code packaged with the IMU's Arduino library

Currently, the code simply reads the yaw and pitch from the IMU and sends a signal to open the valve necessary to correct course

In testing, I found that the DMP ran slowly while valves were powered open, meaning the single power supply could not handle the load

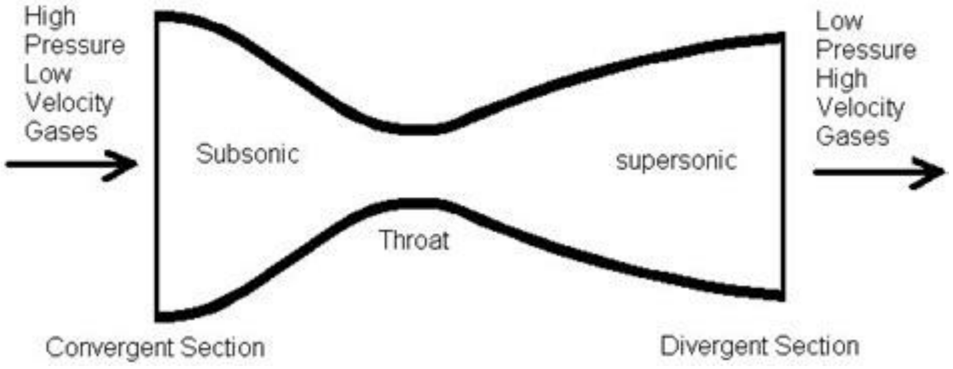


Results



Future work

- On-board compressed air tank
- Separate power supplies for each part
- Second flight test with system installed
- Improve nozzle design



Acknowledgements

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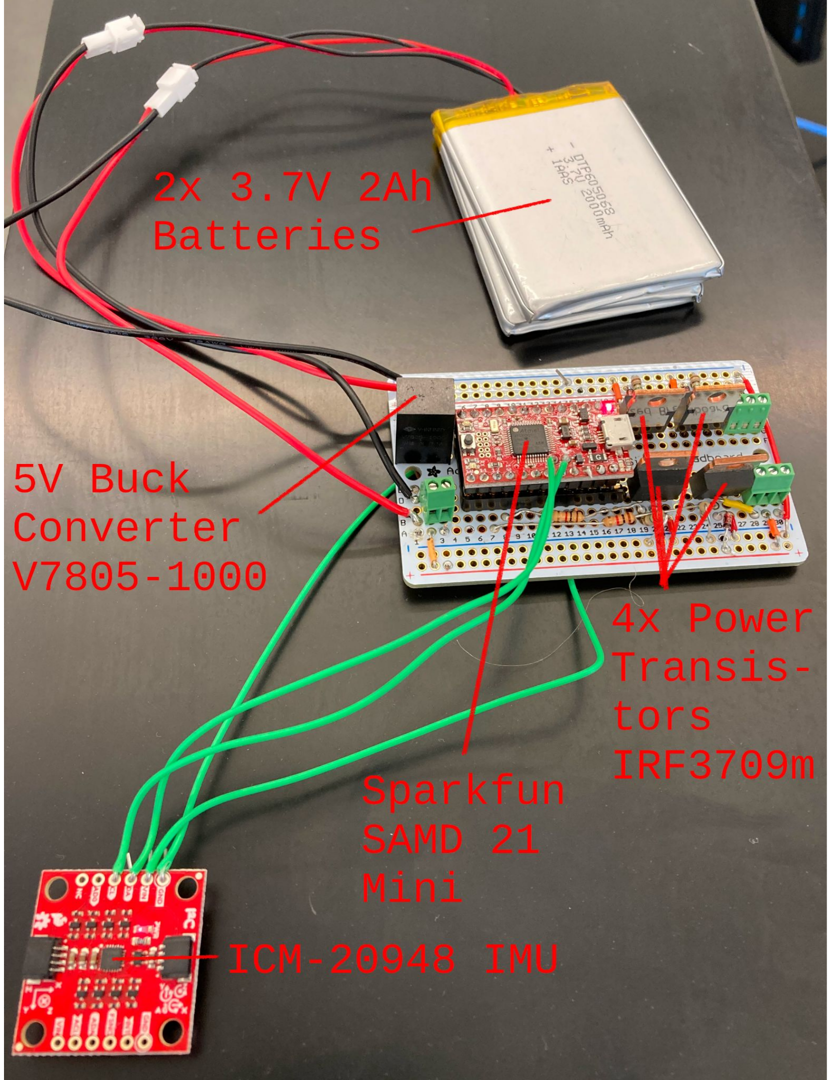
2x 3.7V 2Ah
Batteries
5V Buck
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V7805-1000
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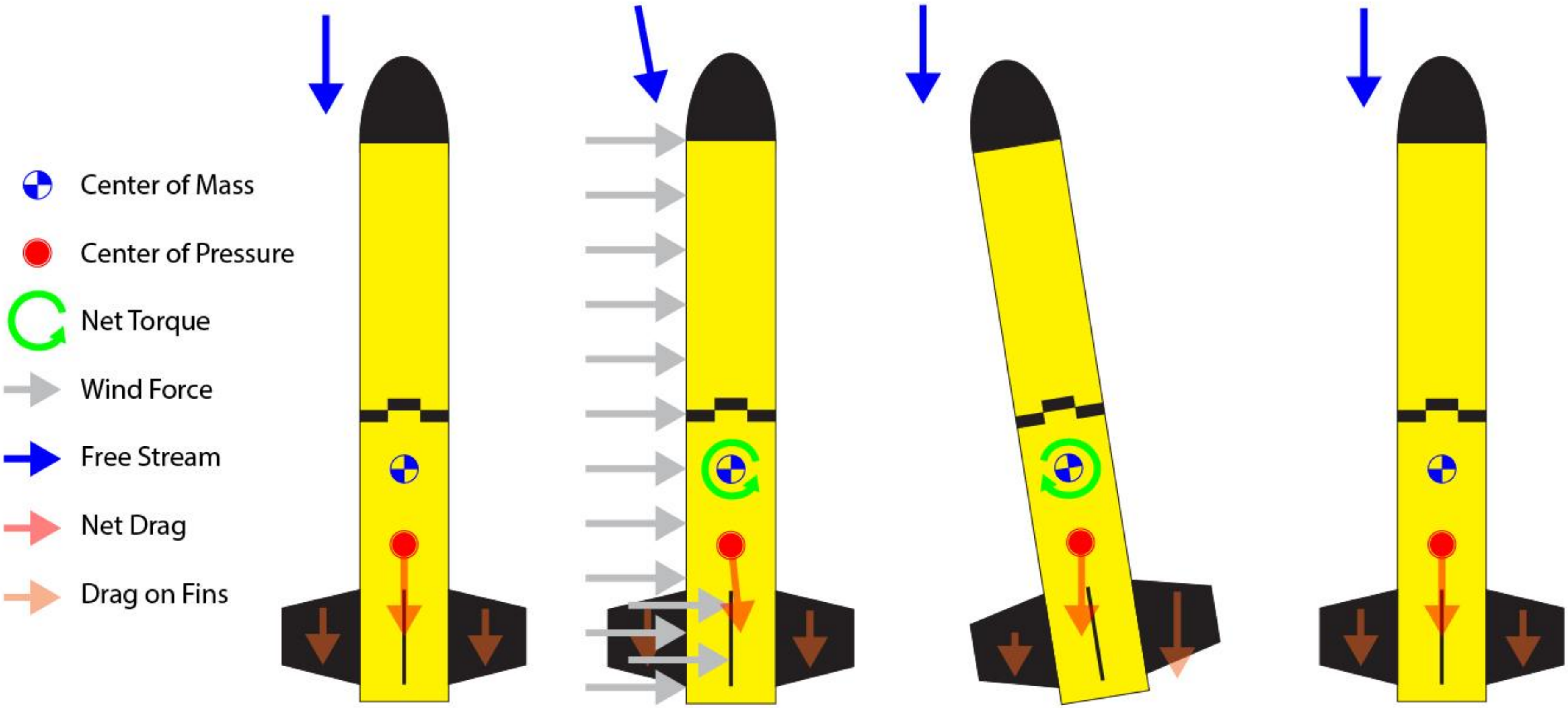
Mini
ICM-20948 IMU



1. The rocket travels upwards in stable flight

2. A gust from the left imparts a torque on the rocket

3. The gust passes and the free stream creates a stabilizing torque

4. The rocket returns to stable flight