Active Stabilization and Precision Altitude Targeting
2019 - 2020 Senior Project

California State Polytechnic University, Pomona

Active Stab

Project Goal

To develop an active stabilization and precision altitude targeting drop-in module for amateur high-powered rockets. As well as compete in the FAR 1030 Competition.

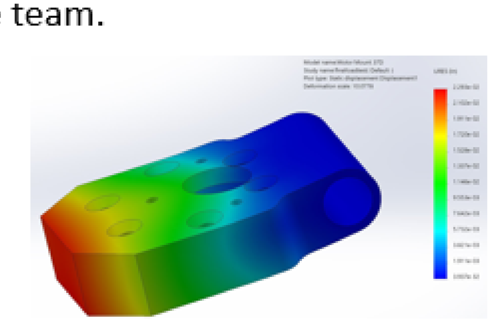
Team Overview

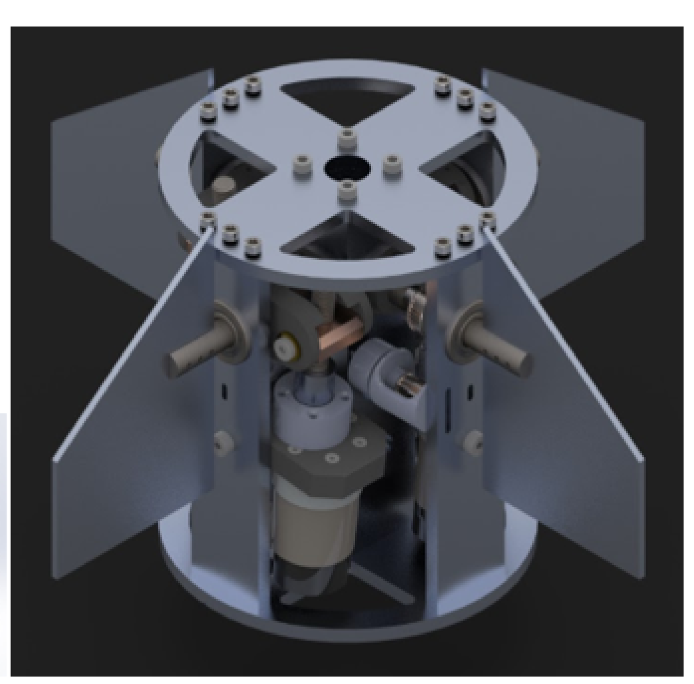
The Active Stab team consist of approximately 30 undergraduate students from Cal Poly Pomona, Arizona State University, and Cal State Fullerton and majors ranging from Aerospace Engineering to Computer Science.

Fin Control Mechanism

The Fin Control Mechanism (FCM) is made up of 4 independently actuated fins which allow the rocket to move in pitch, roll, and yaw. The ability of each fin to move +- 20 degrees gives the user the flexibility to control in all phases of flight. Each part was designed for manufacturability; everything from conventional machining to 3D printing was used to keep the FCM as strong and light as possible. Using HP Multi Jet Fusion we were able to print strong, reliable, and repeatable parts for rapid prototyping and final flight hardware.

To ensure the success of the system each part was simulated in SOLIDWORKS. Everything from maximum stress, deflection, and factor of safety was checked. Shown below is a test of the motor mount deflection in PA12 Nylon from the MJF machine which aided in the material selection and solidified 3D printing as a viable option for the team.

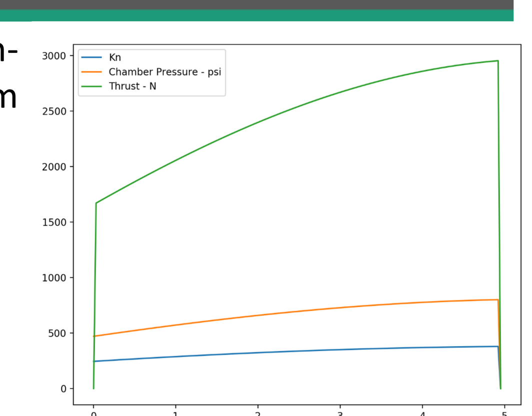


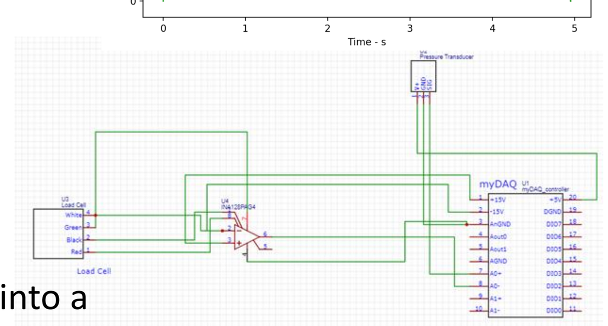


Propulsion

Propulsion focused on development of a high-efficiency, high-density solid fuel and development of a data acquisition system for characterizing the performance of solid rocket motors.

The fuel utilizes a novel ingredient to drastically increase density specific impulse. This allows the motor to have a gentler thrust profile. This fuel is pourable, a desired characteristic that allows for greater processability and increased density.

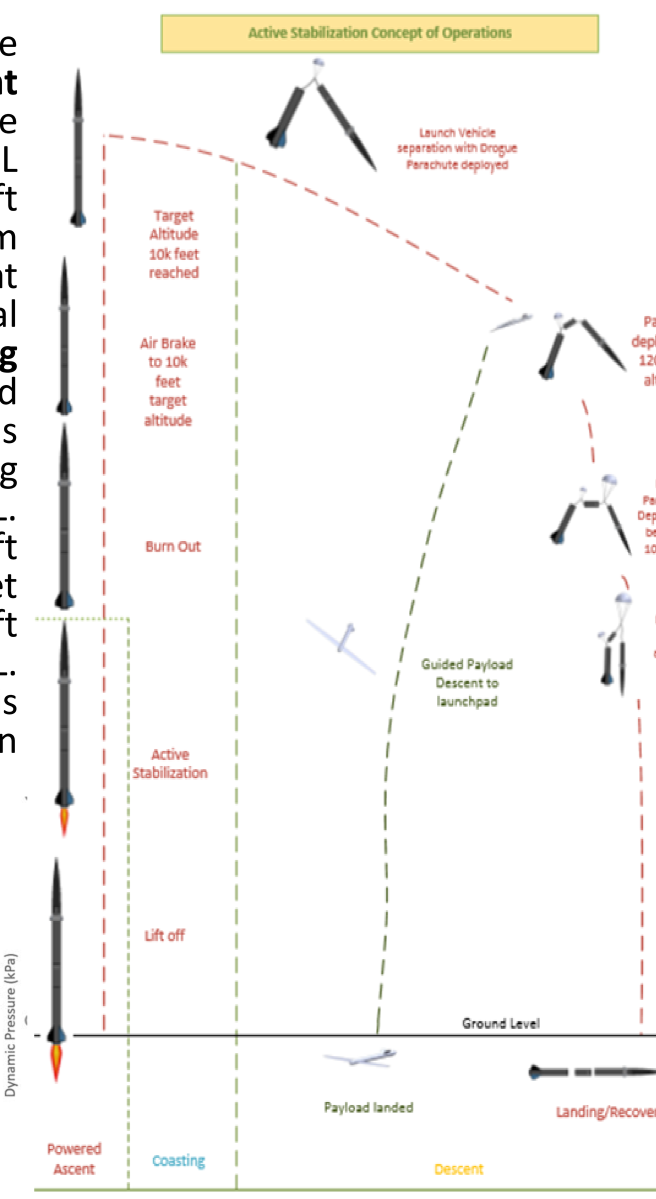


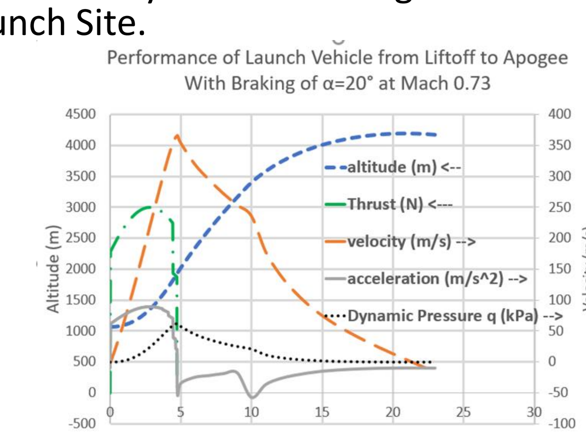


The data acquisition module allows for chamber pressure reading, load cell input to measure thrust, and room for expansion via additional instruments. These sensors feed into a NI MyDAQ, which interfaces with LabView to record data.

Concept of Operations

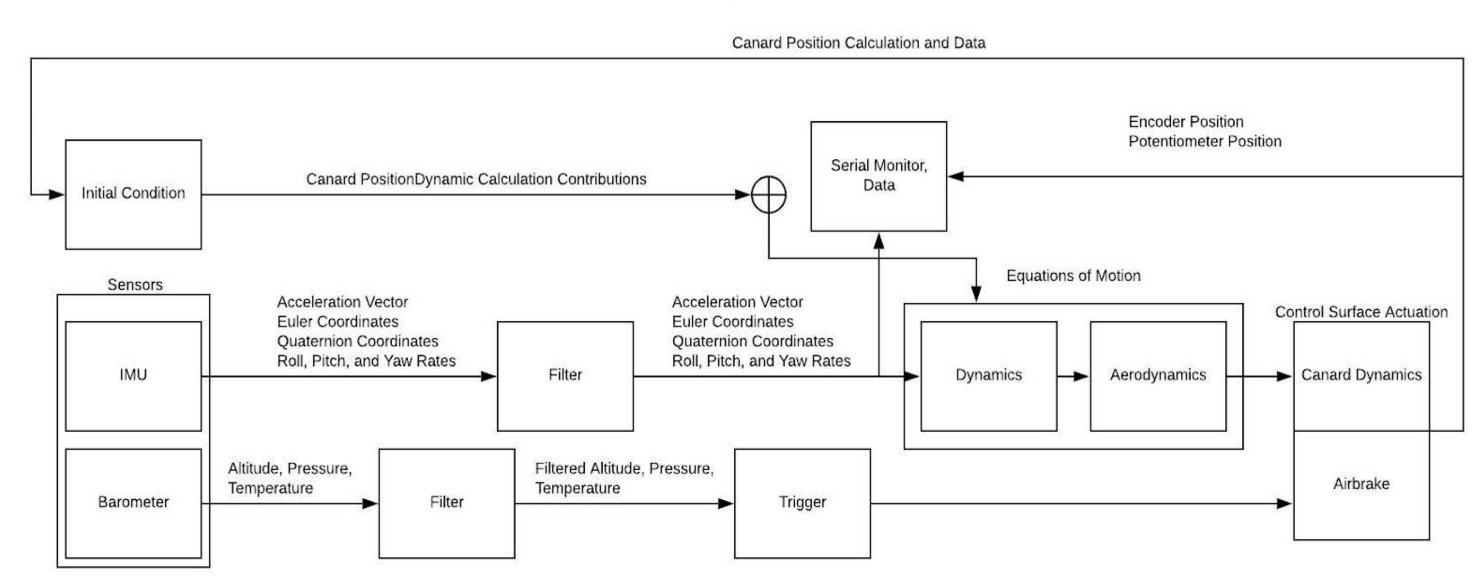
The rocket's mission is divided into three phases: **Power Ascent**, **Coasting**, and **Descent Phase.** During the **Power Ascent Phase**, the rocket lifts off from an elevation of 3,504 ft ASL until it reaches a burnout altitude of 6,389 ft AGL. During this phase, the canard mechanism is actively stabilizing the rocket to ensure that the rocket does not deviate from its vertical trajectory. Then the rocket enters the **Coasting Phase**, where the rocket coasts until the canard mechanism brakes by deflecting all four canards to 20 degrees opposite of one another, allowing the rocket to reach an altitude of 11,186 ft AGL. The original altitude without braking is 14,758 ft AGL. During the **Descent Phase**, the rocket deploys its drogue, then its payload at 1,200 ft AGL, and its main parachute at 1,000 ft AGL. The payload is a homing glider that is programmed to fly back to a targeted location at the Launch Site.





Guidance, Navigation, and Controls

The stabilization system is centered around recognizing the accelerations recognized by the IMU. Based upon a filtered IMU signal, the system utilizes coded dynamics based upon lookup tables dependent upon DATCOM to properly calculate the lift, drag, and side forces due to the body and the control surfaces. After recognizing the correct deflection, the system utilizes DC Motor Position Control to actuate to a calculated deflection angle relative to free stream velocity to negate the non-axial forces and prevent the launch vehicle from tipping over. The air braking system is based upon DC Motor Position Control but is dependent on filtered barometer inputs. After a user-defined relative height is reached the canards all actuate to a full 20 degrees opposite to one another to brake without introducing external forces.

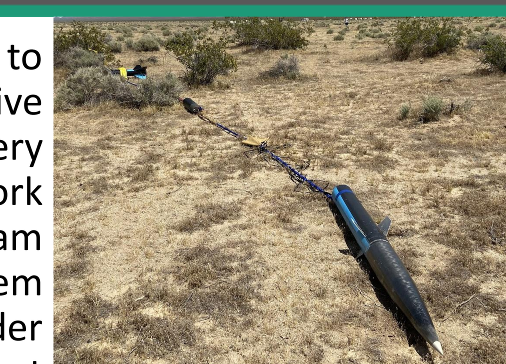


Avionics

The rocket used 3 avionics systems. Two of them were commercial systems, which were the Missile Works Corporation RRC3 and an Eggtimer Quantum. The third system was custom made. This custom system consisted of a BNO055 IMU, MS5611 Barometer, XBee transceiver, Adafruit Ultimate GPS v3 and a Teensy 3.5 on a custom PCB. These systems were placed into the avionics bay right below the fin mechanism.

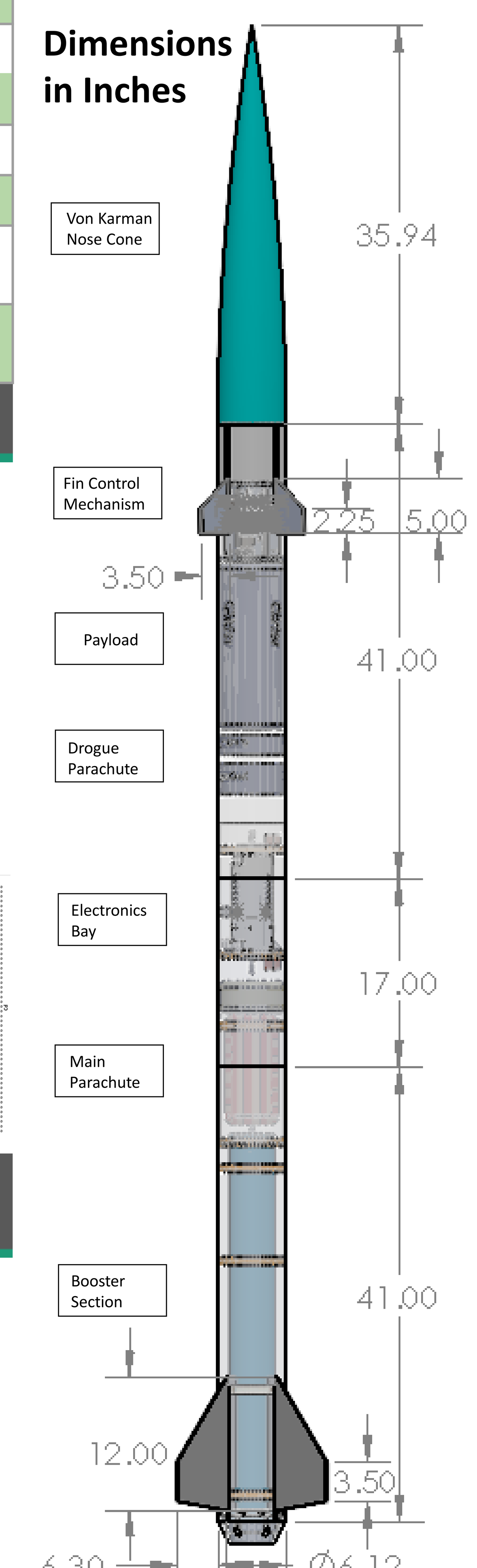
Flight Testing

A flight test was conducted to validate the operation of the active stabilization system and recovery system. It was shown that the work of the GNC and Structures team were sufficient, and the system could withstand operation under real flight conditions. The flight test also served to prove the structural integrity of the rocket through all phases of flight.



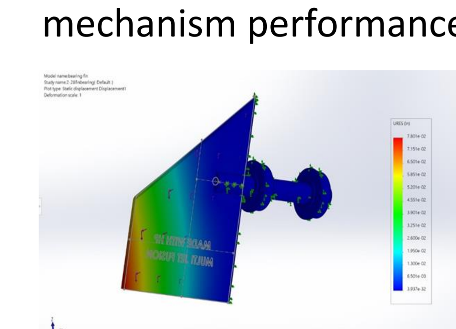
Technical Specification

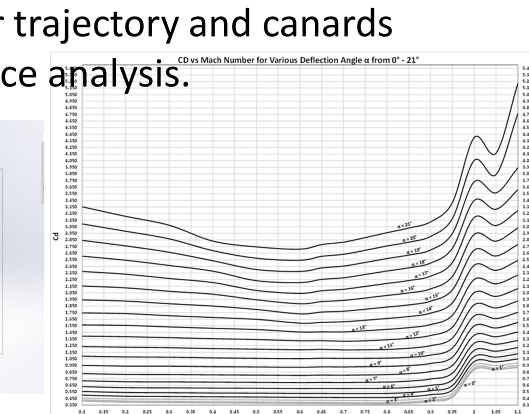
Apogee	11,186 ft with Brakes
Gross Weight	67.8 lb.
Length	137 in
Diameter	6.12 in
Stability Margin	0.616 caliber
Center of Gravity (from top of Nosecone)	81.5 in
Center of Pressure (from top of Nosecone)	85.3 in



Aerodynamics

The canard design is a trapezoidal surface planform that has superior control effect according to the AIAA Education Series' Tactical Missile Design. To make sure this configuration would withstand the flight loads, canard deflection is calculated using lift and drag forces at different Mach number under worst case scenario, which is when the control surface is in breaking configuration at 20° from the vertical axis. The Coefficients of Drag for the entire rocket are also calculated for different Mach numbers and canard's angles of deflection for trajectory and canards mechanism performance analysis.





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