Active Antfins

Curtis Abe, Jiawen Bao, Ethan Chen, Lawrence Lu
Advisor: Moatasem Fouda

UCI Samueli School of Engineering

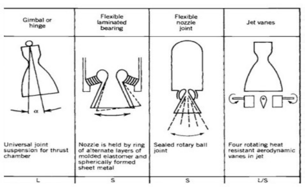
Executive Summary:

The UCI Active AntFin team is designing an active fin control module for the UCI Rocket Project Solids Team. As the team builds larger rockets reaching higher altitudes, the flight time will increase. Longer flight times increase the risk of the rocket becoming unstable.

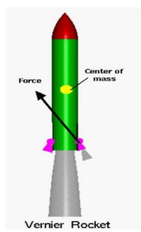
Objectives:

- Design an active fin control unit to keep the rocket vertical and reach a higher apogee
- Develop control algorithms for pitch, row, and yaw
- Design alignment jigs and mounting solutions for the actuation system

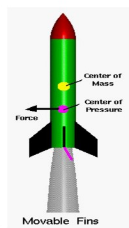
Existing Solutions:



Thrust Vectoring



Vernier Thrusters

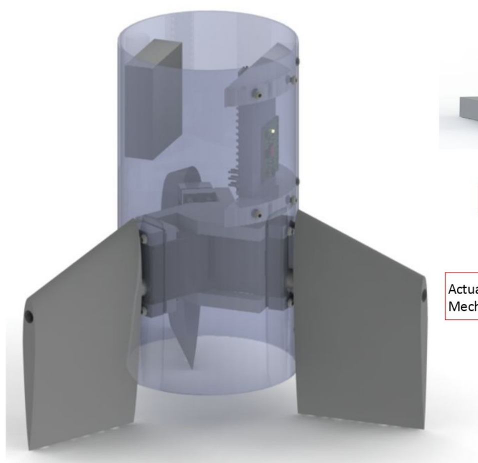


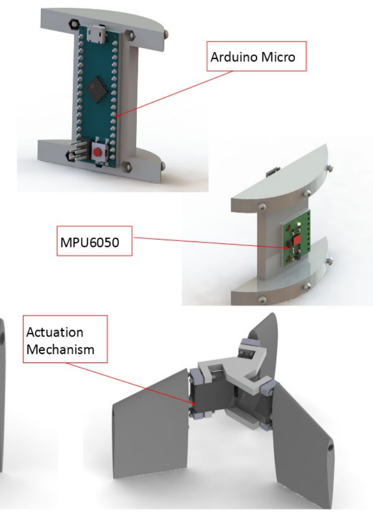
Active Fins

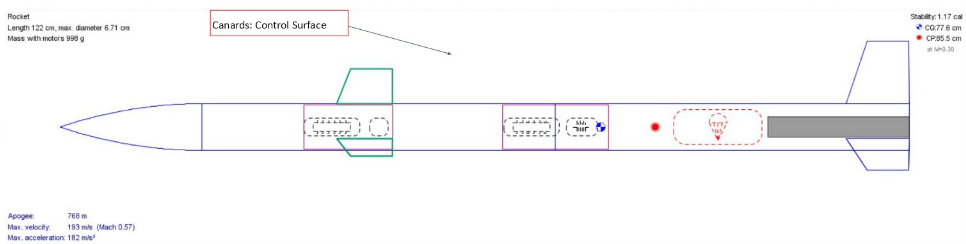
Requirements:

Lightweight	System less than 761g
Portable	Fits in 5.5 inch body tube
Easy to Manufacture	UCI Manufacturing methods: 3D-print, Laser-Cut, Hand Drill, Bandsaw, Screwdriver etc.
Easy to install	No special tools needed
Cost	Under $350
Stable	Controls all 3 rotational axes at 5°/s, stable factor greater than 1
Safety	Strong enough to withstand 300m/s airspeed and 5m/s ground hit velocity

Final Design







Future Recommendations:

- Filter IMU readings: the servos reacted to very small IMU changes, making them twitch sometimes.
- PID Testing: Our control constants are theoretical only, experimental testing could further optimize the system

Reference

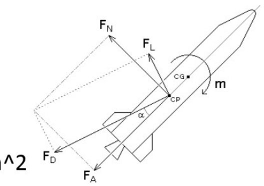
"Rocket Control." *Www.grc.nasa.gov*.

Acknowledgement

We would like to express our sincere gratitude to our supervisor Dr. Fouda for providing invaluable suggestions and guidance throughout the quarter.

Analysis:

$$L = \frac{1}{2} c_l \rho V^2 A$$



- Stable factor: 1.17
- Required canard size: 34.2 cm^2

Actuation Mechanism:

- Direct Drive: the servos are mounted directly to the servos to ensure a fast response time. Extra care had to be taken to ensure servos were strong enough to support the fins and aerodynamic forces
- Drag force: 7 N
- Fin Moment of Inertia: 0.0307kg.cm

Control Matrix:

$$\begin{bmatrix}\theta_{S1}\\ \theta_{S1}\\ \theta_{S1}\end{bmatrix} = \begin{bmatrix} 0 & -\frac{\sqrt{3}}{2I_\theta} & \frac{\sqrt{3}}{2I_\theta} \\ \frac{1}{I_\psi} & -\frac{1}{2I_\psi} & -\frac{1}{1I_\psi} \\ \frac{r_f}{I_\phi D} & \frac{r_f}{I_\phi D} & \frac{r_f}{I_\phi D}\end{bmatrix}^{-1} \left[\frac{2}{At^2}\begin{bmatrix}\Delta\theta\\ \Delta\psi\\ \Delta\phi\end{bmatrix} - t\begin{bmatrix}\omega_\theta\\ \omega_\psi\\ \omega_\phi\end{bmatrix} + \frac{Bt^2}{2}\begin{bmatrix}\frac{\sqrt{3}}{I_\theta}\Delta\theta\\ \frac{2}{I_\phi}\Delta\psi\\ 0\end{bmatrix}\right]$$

Our control matrix decouples our fins to control all 3 axes of rotation, taking into account:

- angle from vertical
- angular rotation
- angular acceleration

PID Control Simulation/Tuning: