Rocket Stability Capstone

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Sponsor: College of Engineering and Technology

Introduction

Problem: High-powered rockets often turn into the wind, resulting in excess spin, reduced altitude, and increased downrange drift, which negatively impacts performance, recovery, and safety.

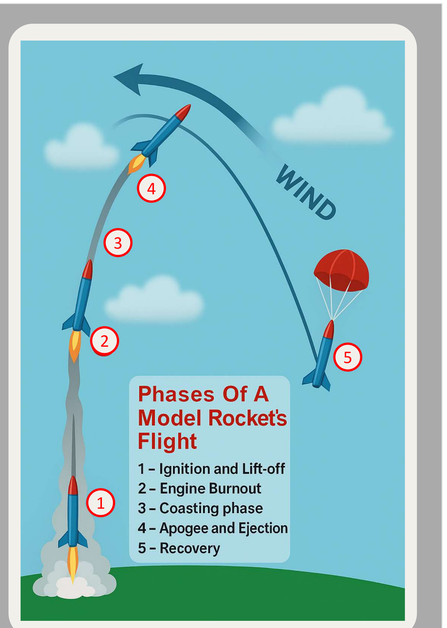
Scope: Design, build and test an active control system to maintain near-vertical ascent, minimize roll, and ensure safe recovery.

Project:

The project was divided into two parts

1. Designed a physical rocket system to control stability during ascent.

2. Developed a controller to guide the rocket through a stable and controlled ascent.



Design Requirements

Metric #	Need #'s	Metric	Units	Ideal Value	Allowable Value
1	1	Total Degrees of Pitch	deg	5	30
2	1	Total Degrees of Yaw	deg	5	30
3	4, 6, 7	Final decent speed	ft/sec	15	30
4	2	Amount of roll	deg	30	900
5	2	Max roll rate at any time	deg/s	3	90
6	3	Static Stability at end of burn	cal	2	5
7	3	Static Stability at lift-off	cal	1.5	2
8	4, 5, 11	Electronics able to withstand g	g	30	10
9	5, 6	Max Operational Humidity Max	RH	65	45
10	5, 6	Max tempature operation	C	100	85
11	8	Total BOM Cost	$	<2500	2500
12	11, 15	Data storage size	GB	32	1
13	4	Max lateral velocity during boost	m/s	0	5
14	4, 6	Recovery deployment altitude error	%	5	30
15	4	GPS continuity	% of flight	95	90
16	7	telemetry range	km	5	2
17	15	Frame rate	fps	60	30
18	15	Recording duration	min	5	2
19	4	Horizontal velocity during parachute deployment	meters/sec	0	10
20	4	Vertical velocity during parachute deployment	meters/sec	0	10
21	10	Smooth attachment points	in	1/16/	1/8/

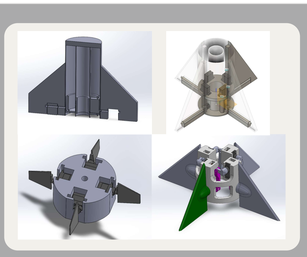
Metrics Used to Evaluate Project Success

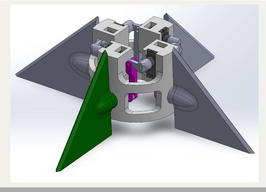
- *"Needs #'s" represent categories under which metrics were defined, including safety, accuracy, and codes & standards.*
- *Requirements were compared to government regulations and industry standards to ensure compliance with safety and code requirements.*
- *These constraints guided the mechanical geometry specifications, electrical component selection, and airframe development.*
- *These requirements dictate a successful controller design and enable reuse of the rocket for further testing.*

Design Process

Idea Generation

- Identified and evaluated potential methods to control the rocket during ascent.
- Ideas were evaluated using a scoring matrix based on design requirements and control effectiveness.
- Top concepts from chart were 3D modeled and further developed for evaluation as a group.



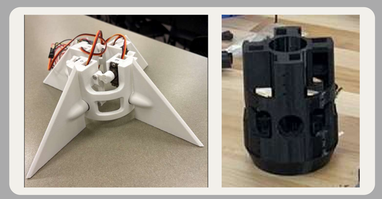


Concept Selection

- The selected design uses fin actuation controlled by a servo at the base of the rocket.
- Design can be 3D printed, allowing for rapid iteration and turnaround.

Prototyping

- Parts were ordered and components were manufactured.
- Servo linkages were tested to evaluate tolerances and clearance.
- Electronics were tested with design and able to execute scripts for fin actuation.





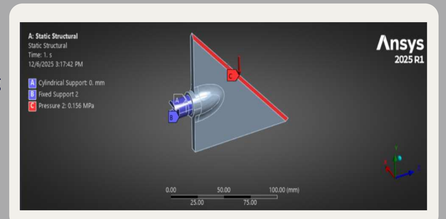
Refinement

- Design was scaled down to a 3'' rocket, restricting lever arm moment and servo placement.
- The rocket is designed to fit within UVU's wind tunnel, with the addition of a test stand allowing all remaining testing to be completed.

Analysis

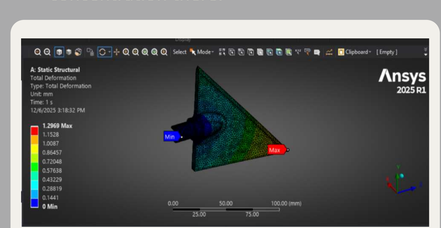
FEA Set Up

- Boundary conditions and loading were defined for fin analysis.
- Load locations were verified using mechanics of materials and fluid dynamics principles.
- Selected material is PLA.
- Mesh was refined near shaft as we know it has higher stress concentration there.



Interpret Results

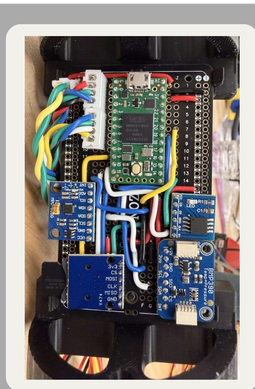
- Figure shows maximum stresses occur at the shaft and tip of fin.
- Results were compared to hand calculations and match forces found in shaft.
- Forces are below the material limits and within the allowable forces for bearing.



Testing

Electronics

- Custom PCB board was created based on initial breadboard design.
- An avionics bay was designed and 3D printed to securely house the PCB during testing and flight.
- Teensy 4.0: Main flight controller enabling high-speed processing.
- NOYITO: Temporary data storage before transfer to microSD.
- BMP 390: Barometric pressure sensor for altitude measurements.
- MPU6050: 3-axis accelerometer and 3-axis gyroscope.



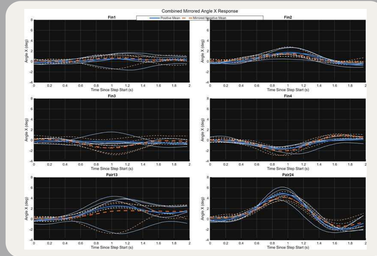


Wind Tunnel Testing

- Test fixture was designed and constructed to be modular and attachable to wind tunnel.
- A pulse test was conducted to actuate fins and measure dynamic response.
- Rocket was able to withstand 100 mph and stay statically stable.
- Using the data collected we were able to calculate our initial gain values for our proportional control.

Data Collection

- A pulse test was conducted to measure rocket acceleration.
- Using system dynamics and equations of motion, a proportional controller was developed.
- Multiple testing iterations were conducted to fine-tune the controller to allow for better results.



Conclusions & Future Work

Conclusions

- Initial testing indicates the controller improves rocket stability.
- Model rocket follows all needed codes and standards for launch.
- Developed control system using embedded electronics.
- Performed FEA to validate structural integrity.
- Designed the rocket based on defined requirements and created a prototype.

Future work

- The rocket assembly will be improved to allow easier internal access.
- The next step is to implement PID or advanced control techniques.
- A higher-class rocket will be tested to evaluate controller performance at higher speeds and accelerations.