UVU MECHANICAL ENGINEERING
UTAH VALLEY UNIVERSITY

Rocket Altitude

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Scope of Work

- Design an aerodynamic drag system, which acts as an air brake during rocket flight.
- Aerodynamic drag system must provide sufficient drag to correct predicted flight altitudes within a 10% error margin.
- Include sensors to measure real-time data and enable changes in-flight.
- Final system design must be easily implemented into standard rocket body sizes and geometries commonly flown in IREC competitions.
- Individual components within system must be able to withstand maximum anticipated forces and loads present through the course of a launch.

The goal of this project was to design an aerodynamic braking system for an IREC competition rocket to help it reach a target apogee of about 10,000 ft AGL. The system needed to be lightweight, compact, reliable, and compatible with the rocket's other subsystems. The design process included concept generation, CAD modeling, FEA, prototyping, and aerodynamic testing.

Objectives

- Many drag system requirements were defined by IREC guidelines and regulations
- The design is intended for student and hobbyist use
- User input was gathered from students involved in launches and local launch board members
- Feedback helped guide the design toward practical user needs

Specific Needs Gathered:	Source:	Classification of Needs:
The rocket reliably reaches an apogee of 10,000 feet above ground level.	IREC Rules & Reg.	Primary & *Explicit*
The vehicle shall be inherently stable in flight using only fixed aerodynamic surfaces.	IREC Rules & Reg.	
The altitude control system is designed to trim altitude without providing active path guidance.	IREC Rules & Reg.	
The system operates safely, defaulting to a neutral (retracted) state in the event of abort, power loss, or excessive attitude deviation.	IREC Rules & Reg.	
The system remains dormant during boost phase and only activate at safe flight conditions.	IREC Rules & Reg.	
The design ensures safe recovery and reusability of the launch vehicle.	IREC Rules & Reg.	
All components must comply with IREC rules and safety standards, including electronics, wiring, and structural integrity.	IREC Rules & Reg.	
The system will utilize an on-board power source when power is required.	L1 & L2 Cert. Flyers	Secondary
The altitude control system can withstand any heat generated from motor during powered ascent.	L1 & L2 Cert. Flyers	
The system utilizes rigorous construction and design to withstand ejection charges/residue.	L1 & L2 Cert. Flyers	
All components and supporting pieces are accurately dimensioned regarding size and mass, to facilitate accurate simulations.	L1 & L2 Cert. Flyers	
The altitude control system is designed to minimize potential damage to the system during operation.	UROC/Tripoli Board	Latent
The design minimizes any unneeded complexity.	UROC/Tripoli Board	
The system features an easy set-up, allowing for pre-flight programming.	UROC/Tripoli Board	

The primary and explicit needs were deemed to be essential in the proper function of the design and were used in conjunction with the IREC guidelines to form a basic set of design requirements. These design requirements were used to guide the concept generation and design selection process later on.

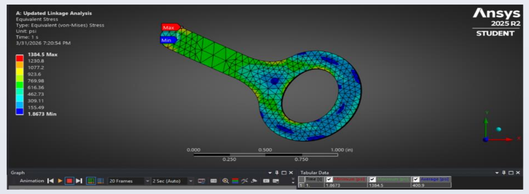
Design Requirements Table

Customer Need	Metric	Units	Ideal Value
Hit Target Altitude	Apogee altitude	ft AGL	10,000 ± 5% (9,500–10,500)
Inherent Stability	Static stability margin (no ACS)	calibers	≥ 1.5
Fail-safe Operation	ABS fail-safe response time	sec	≤ 1
Dormant until Safe Altitude	ABS dormancy activation altitude (10k class)	ft AGL	≥ 6,500
Symmetric Braking	Symmetry of flap deployment	mm	≤ 0.5 difference
Effective Altitude Control	Change in drag coefficient (ΔCd)	–	≥ 0.2
Size/Weight Limits	ABS system mass fraction	% of liftoff mass	≤ 10%
Power Budget	ABS operational endurance	minutes	≥ 20

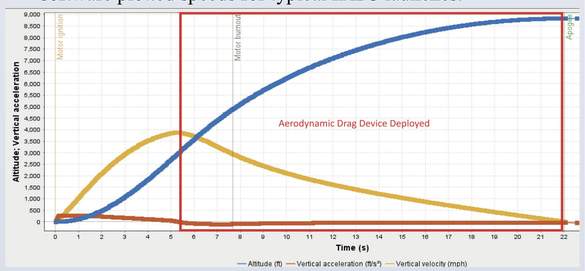
Materials and Methods

CAD models were created, FEA (Finite Element Analysis) was performed to evaluate structural performance, PLA prototypes were built for mechanism testing, and scaled wind tunnel models were used to study aerodynamic behavior.

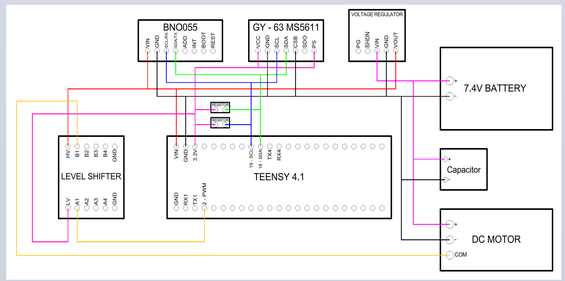
- Initial prototyping and designing was planned around a two-layer linkage system.
- Through further prototyping and FEA simulations, the team found that a single-layer linkage system would provide adequate strength.
- Loads utilized during FEA were derived from hand-calcs and MATLAB script in which maximum loads were determined.



To assist in determining load forces for design validation through the use of FEA, the team utilized OpenRocket. This software plotted speeds for typical IREC launches.



- Final design was prototyped over several months
- The linkages and fins were strong enough for expected loads
- Electronic fin actuation system was still being developed
- AutoCAD was used to create a circuit layout for component integration
- Sensors were included to support real-time drag adjustment
- The system design was nearly complete, with feedback-loop coding still needed



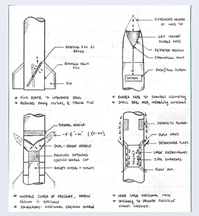
Design Process

The project began with a review of IREC rules, customer needs, and design requirements. Brainstorming methods, including mind mapping and reverse brainstorming were used to generate concepts. A weighted decision matrix was then used to compare designs and select the deployable fins concept for further development. The brainstorming map and design matrix are shown below

Design Scoring Matrix

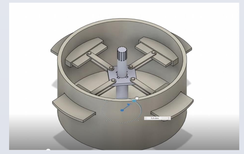
Design Criteria Below:	Notes	Wgt.	Control Surfaces Sketch	Deployable Fins	Rear End Brake Sys. Variable Diam.	Telescopic Nose	Vented Body	Adaptable Fairing Cone	Inverted Iris Door
Ease of manufacturing		0.05	2	4	2	1	2	2	1
Cost		0.05	3	2	2	1	4	3	2
Weight		0.05	4	3	2	3	4	4	4
Ease of Replacement	can individual components be replac	0.05	3	4	4	1	3	2	1
Scalability	can it be resized to fit a different size	0.05	1	1	5	2	1	4	2
Schedule Risk	estimated design-to-flight readiness t	0.1	2	4	1	2	4	3	2
System Complexity	does it have a lot of moving parts, wi	0.1	5	4	3	3	3	2	2
Testing Feasibility		0.1	4	4	2	4	3	3	4
Altitude Control Accuracy		0.1	5	3	2	2	2	2	4
Stability		0.1	5	4	3	2	4	3	4
Final Weighted Avg. Score		1	3.94	3.99	2.54	2.03	2.91	2.78	2.84





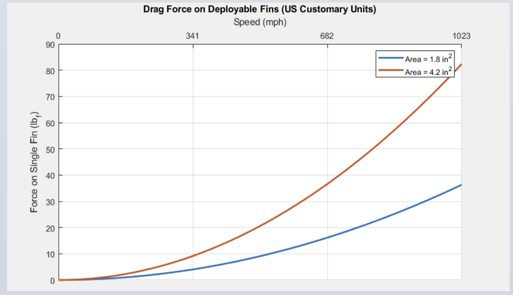
Design Sketches

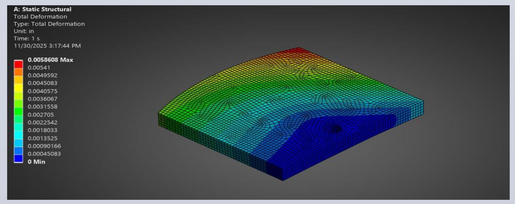




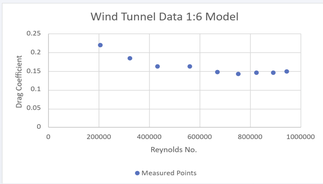
Results

The deployable fins concept was chosen for its simpler design and lower failure risk. FEA supported Aluminum 6061 as a practical material choice/ Prototyping improved symmetry, simplified the linkage system and reduced part count. Wind tunnel testing showed increased drag with minimal transverse forces, indicating the system could reduce altitude without major stability issues.

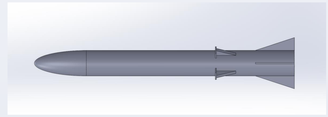


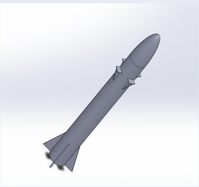


Results Cont.



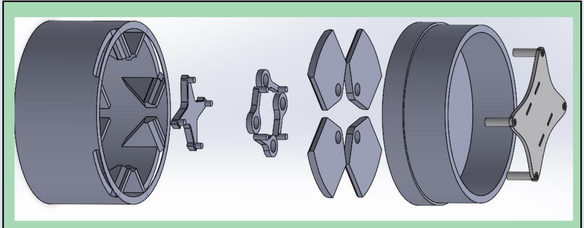
In order to gain a further understanding about the aerodynamics of a typical rocket during powered ascent, the team conducted several tests in the UVU Smith College of Engineering Wind Tunnel. The team tested 1:6 and 1:4 scale models, and the 1:6 scale model provided valuable insight towards rocket aerodynamics during late laminar and transitional flow regimes.





- 3D-printed scale models produced results differing from expected fluid behavior
- Flow separation likely occurred in the late laminar regime
- Moving deployable fins forward could reduce separation – at the cost of stability.
- Wind tunnel tests did not use the exact aerodynamic drag design
- Design was modified to prevent potential wind tunnel damage

Final Design



This project demonstrates that deployable fins are a promising solution for altitude control in an IREC rocket; capable of meeting user and technical standards while providing suitable performance when correctly optimized with a planned rocket design.

- The system was developed over the course of two semesters in which the team applied engineering principles.
- The design process narrowed multiple concepts into one practical design that met key customer needs and engineering requirements.
- FEA, prototyping, and wind tunnel testing supported the feasibility of the system.

References & Acknowledgements

- A special thanks to Matthew Burns, for guidance and instruction during wind tunnel testing.
- Curtis Burgess, for his flexibility and guidance in achieving well machined components for the final design.
- Dr. Masood Amin for academic support and advising during the two- semester course of design and implementation.
- Reference: IREC Regulations Rulebook
- Fundamentals of Fluid Mechanics, 8th edition by Munson, Young, & Okiishi

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