N-Class Two-Stage Supersonic Sounding Rocket for Research and Development

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SCAN ME




Austin Paothatat Lindsey Dineyazhe Avery Charley Koi Quiver

NORTHERN ARIZONA UNIVERSITY Mechanical Engineering

Department of Mechanical Engineering, Northern Arizona University, Flagstaff, AZ 86011

Abstract

Growth and advancement of research in the aerospace industry has been rapidly increasing due to the commercial presence of launch providers. The rapid development of launch vehicles and satellites requires the need for lower testing costs. Our goal is to design, develop, and manufacture a low-cost supersonic launch vehicle for testing smaller components and electronics in flight conditions for Northrop Grumman. The primary design requirements the team was provided with are to achieve a velocity of Mach 2 with an acceleration of at least 12 Gees and a maximum altitude of 48,000 ft above sea level, the vehicle must have 6-in inner body diameter, 2 stages of the vehicle, and have a payload capacity of up to 10 pounds. The major design choices for our vehicle are carbon fiber outer body and fins, two N-class solid rocket motors, proprietary separation device, and every component of the vehicle is fully reusable. The launch vehicle fulfilled all dimensional and functionality requirements stated by the client.

Requirements

Below is a refined list of requirements specified by our client, Northrop Grumman. Key client requirements are a payload weight limit of 10 pounds, along with a flight velocity of Mach 2 and acceleration of a minimum of 12 G's.

Customer Requirements:

- Two-Stage, Separation System
- 6" Inner Diameter
- Payload Weight – Up to 10 lbs
- Payload Volume – 282.7 in^3 with a 6 in diameter bay
- Budget - $7,000
- Reusable - > 1 use
- Composite Main Structure
- Commercial Rocket Motors

Engineering Requirements

- Maximize Velocity – Mach 2 or higher
- Minimum Acceleration – 12 g
- Minimum Altitude – 30,000ft AGL
- Payload Weight – Up to 10 lbs
- Payload Volume – 282.7 in^3 w/6 in diameter bay
- Budget - $7,000

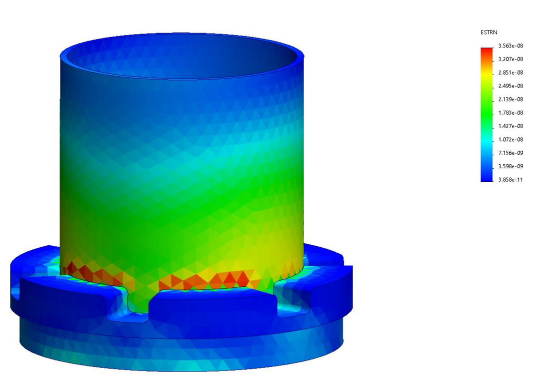
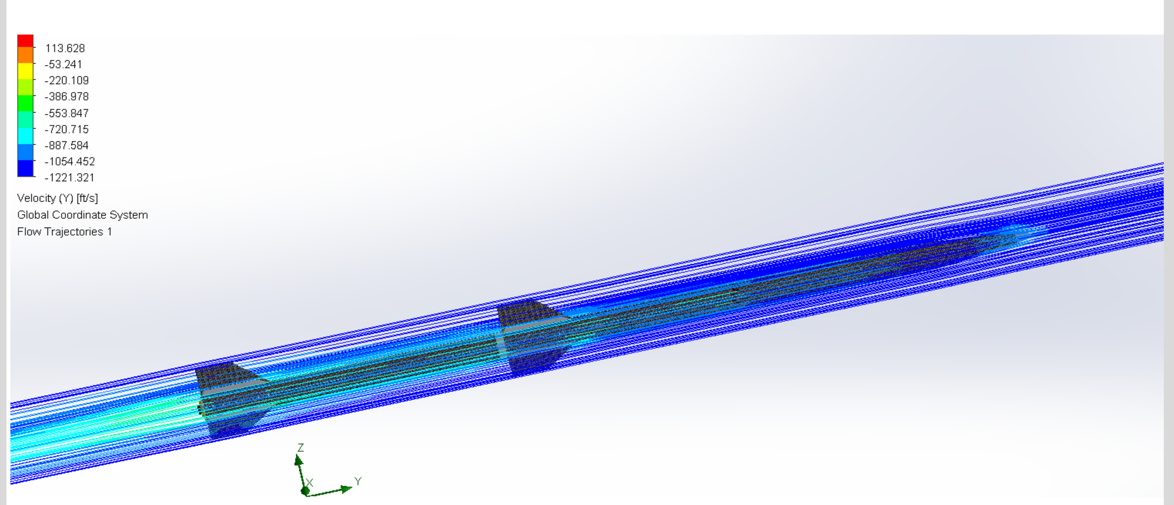


Figure 1 and 2: FEA on Separation System and Rocket Flow Sim



Methods

NAU Machine Shop

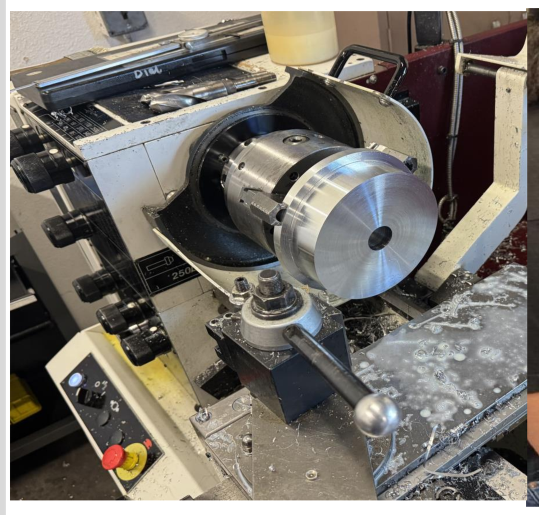


Figure 3: Separation System Part on Harrison Lathe.

Figure 4: Koi Quiver on the Bandsaw

Composite Lab (Novakinetics)

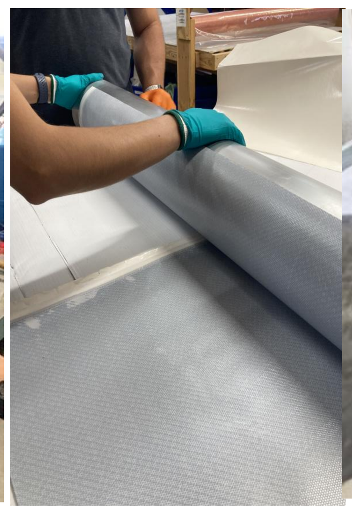


Figure 5: Carbon Fiber lay up (PrePreg)

Figure 6: Sanding and Finishing Body Tubes

RASAero Simulation Software

RASAero was our primary method of simulation for the flight trajectory and parameters. The program allows you to fully model the launch vehicle with dimensions, mass, and allows simulations of different classes of motors. Recovery system components were selected based of the information given in the program to ensure they meet all Tripoli safety regulations for decent rate and recoverability of the vehicle. All parameters for flight and recovery were hand calculated to ensure accuracy of the model. Actual vehicle performance is compared to simulations to verify the accuracy and are adjusted accordingly for future flights. We also utilized Rocksim.

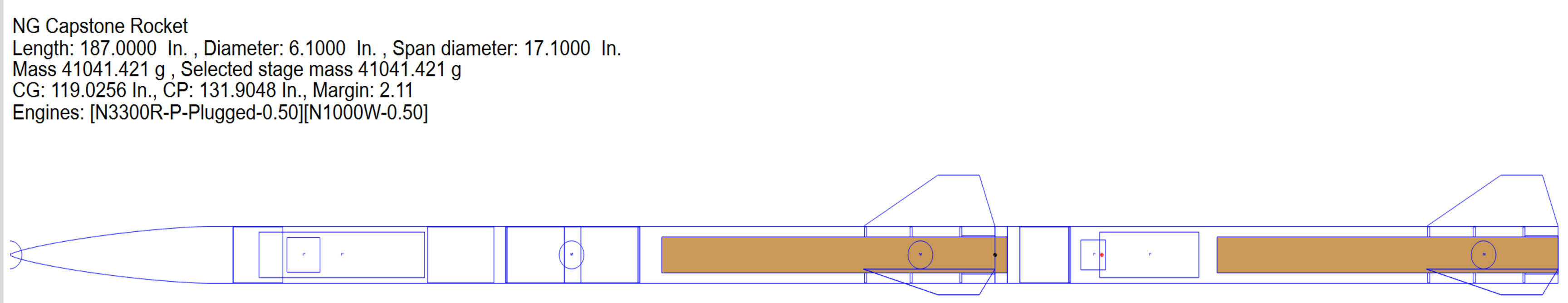


Figure 7: Rocksim Simulation UI

Results

Figure 8: Fully Assembled Launch Vehicle

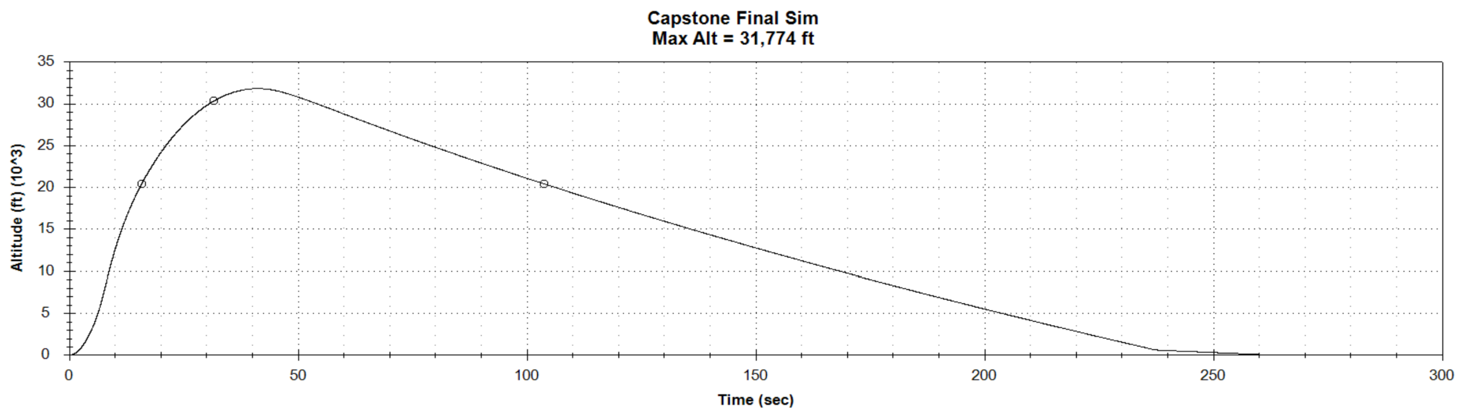


Figure 9: RASAero Flight Profile

Figure 10: Final Launch Vehicle CAD

Table 1: Final Launch Vehicle Results

Requirements	Met/Unmet	Results
Velocity: Mach 2 or higher	Untested	Simulated: Mach 2.015
Min. Acceleration: 12g	Untested	Simulated: 13.37 Gs
Min. Altitude: 30,000 ft AGL	Untested	Simulated: 31,774 ft AGL
Successful Separation	Met	Ground Tested
Payload Weight: 10 lbs	Met	Simulated Payload Weight Verified
Payload Volume: 282.7 in^3	Met	Payload Volume Capacity Met
$7,000 Budget	Met	Under $7,000 Spent
Reusable	Met	Recovery System Ground Test Successful
Composite Main Structure	Met	Carbon Fiber Main Body Structures

Conclusion

- The main goal of developing a research sounding rocket that reaches supersonic flight and can be used multiple times is successful.
- This entire cost of the vehicle is $3703.30, this is under the budget not including the materials donated to the team.
    - Successful in making a rocket that cost $7000.
    - Vehicle is lower cost than most supersonic vehicles that can be used multiple times and carry a payload.
    - Most other high powered supersonic vehicles are minimum diameter, our vehicle is not
    - Commercial sounding launch vehicles typically are built and launched for an average of $1,000,000 per vehicle [1].
- The launch vehicle can fulfill all requirements for a fraction of the price of other sounding launch vehicles proves we are successful in our project.
- In all, the launch vehicle is a successful blueprint build that could be used in for future projects on the same vehicle.

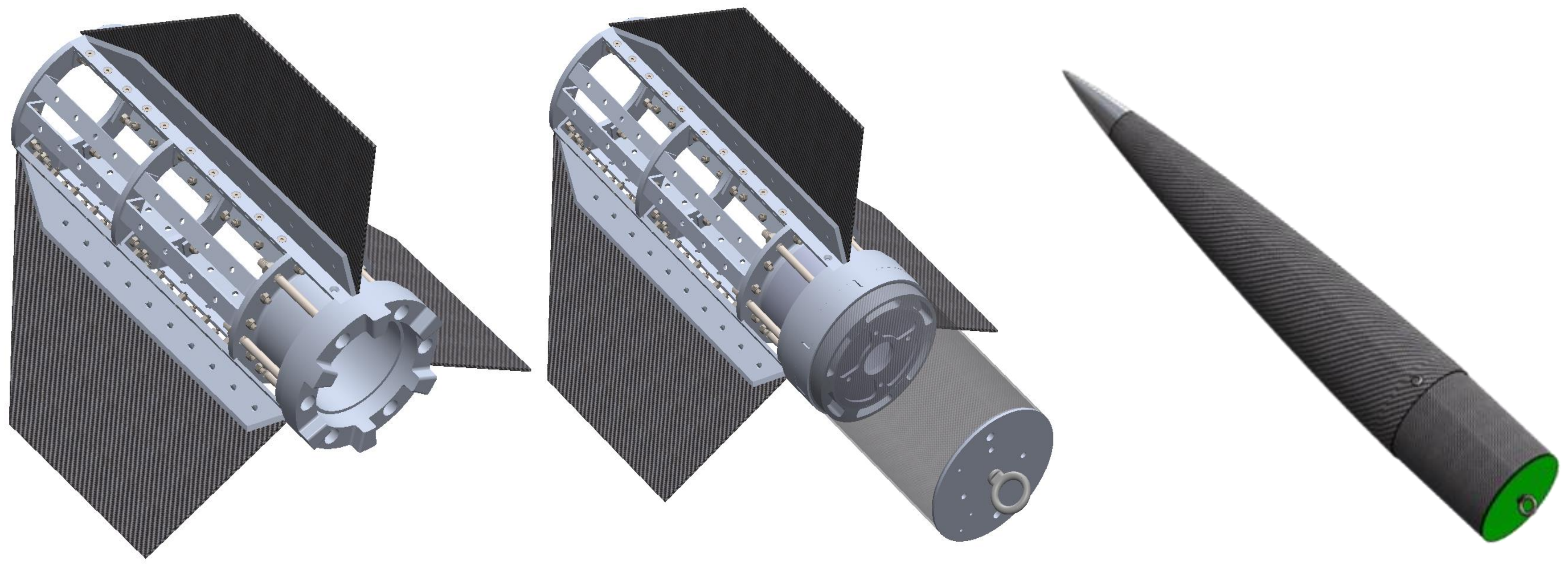


Figure 11-13: Fin Canisters, Separation System, and Nose Cone

Future Work

- Northrop Grumman plan to continue this project with future capstone groups to test payloads and optimize flight profiles.
- The rocket will be used for research purposes in testing smaller components and electronics in flight conditions.
- Alternative motors can also be used to study different flight characteristics.

References

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Acknowledgements

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