Experimental Ducted Rocket

James Le
ERFSEDS, Embry-Riddle Aeronautical University

Abstract

The Embry-Riddle Future Space Explorers and Developers Society (ERFSEDS) is conducting research in developing the design for an experimental solid fueled ducted rocket. The primary objective of this research is to study the effects of thrust augmentation from installing a duct or a shroud around the back of a solid propellant rocket. Thrust augmentation is the process in which the combination of a primary exhaust jet and an entrained secondary flow in a chamber provide a higher thrust and specific impulse than the rocket firing in isolation. This presentation discusses the work of members of ERFSEDS to design and build a vehicle to test the ducted rocket concept, and the specific impulse and thrust results from multiple flights to study the effects of thrust augmentation. The end goal of this research is to publish findings in hopes of encouraging the design of more efficient rockets that are powered by solid propellant.

Vehicle Design

The current vehicle being used for this study is the ERFSEDS Gryphus 1 rocket. The rocket has a 38mm diameter airframe and is 42 inches tall without the duct installed. The duct is a removable 3 inch diameter phenolic tube that is 22 inches long. The dimensions of the duct were based on the findings of Schaefer for a constant area duct. Gryphus 1 is powered by commercial 38mm solid rocket motors for its flights. To collect data and activate parachute deployment, Gryphus 1 has an electronics bay that houses a Raven 3 flight altimeter. Gryphus 1 has flown 4 times: 3 with the duct and 1 without the duct. The rocket was flown at monthly launch events hosted by the Northeast Florida Association of Rocketry in Bunnell, FL.

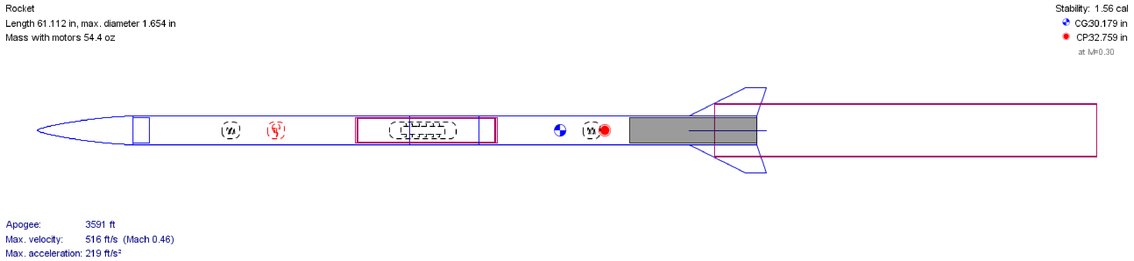

Figure 1. Model of Gryphus 1 in OpenRocket

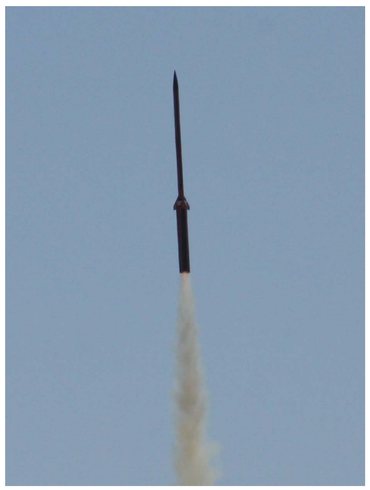

Figure 2. Gryphus 1 during ascent

Conclusion

The current results obtained from flight tests show limited change in ISP and thrust between ducted and non-ducted configuration. Although there is indeed a slight increase in ISP with velocity increase in the vehicle's ducted configuration, the increase is not significant enough for a clear and definite conclusion. For this reason ERFSEDS plans to fly Gryphus 1 to higher maximum velocities later in the Spring 2018 semester. This will allow ERFSEDS to study data from a larger range of velocities including velocities achieved by the club's larger rockets. A larger range of velocity will also allow ERFSEDS to further study the effects of thrust augmentation on a rocket and factors that influence a ducted rocket's performance.

Results

The results shown are from launches that occurred on February 10 and March 24 of 2018. Every flight used a Cesaroni Technology Incorporated H100 solid rocket motor. The plots below show the vehicle's specific impulse against velocity. Since the amount of air entering the duct to mix with the rocket motor exhaust is dependent on the rocket's velocity, it was determined that studying the rocket's specific impulse as a function of velocity would indicate the changes in the rocket's performance during ascent. A plot comparing the thrust of each flight over time is also included.

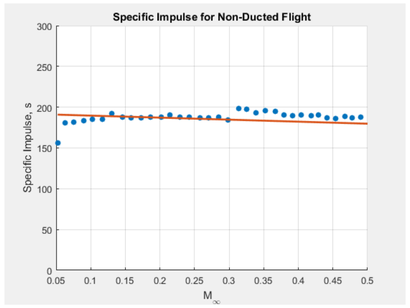

Figure 3. Plot showing the vehicle's near constant specific impulse without the duct attached.

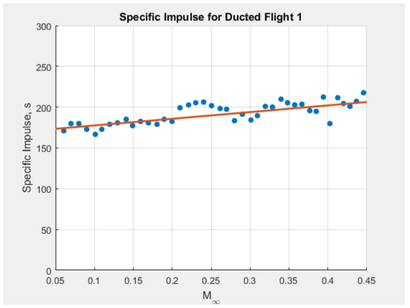

Figure 4. Plot showing increase in ISP during ascent.

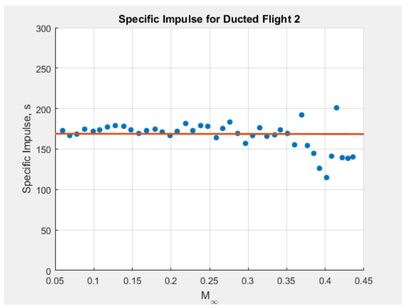

Figure 5. Data from a flight with off-nominal stability during ascent.

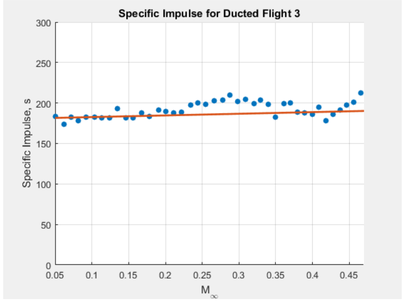

Figure 6. Data from most recent ducted flight showing very slight increase in ISP.

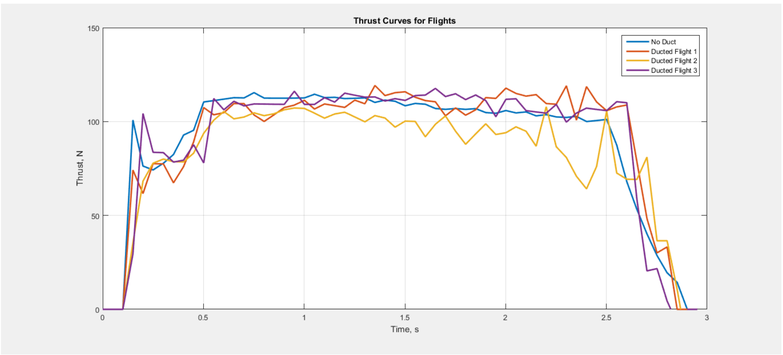

Figure 5. Plot comparing the thrust curves from all flights thus far.

References

Schaefer, R.(1997). Thrust augmentation investigation of a shrouded solid rocket motor, presented at 36th AIAA Aerospace Sciences and Meeting and Exhibition 1998. Reno, NV. American Institute of Aeronautics and Astronautics.