Bottle Rocket Modeling

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Introduction

Problem

The objective was to use ordinary differential equations to model a bottle rocket with 3 distinct flight phases.

The model is then used to find what parameters are required to reach a target distance of 80m.

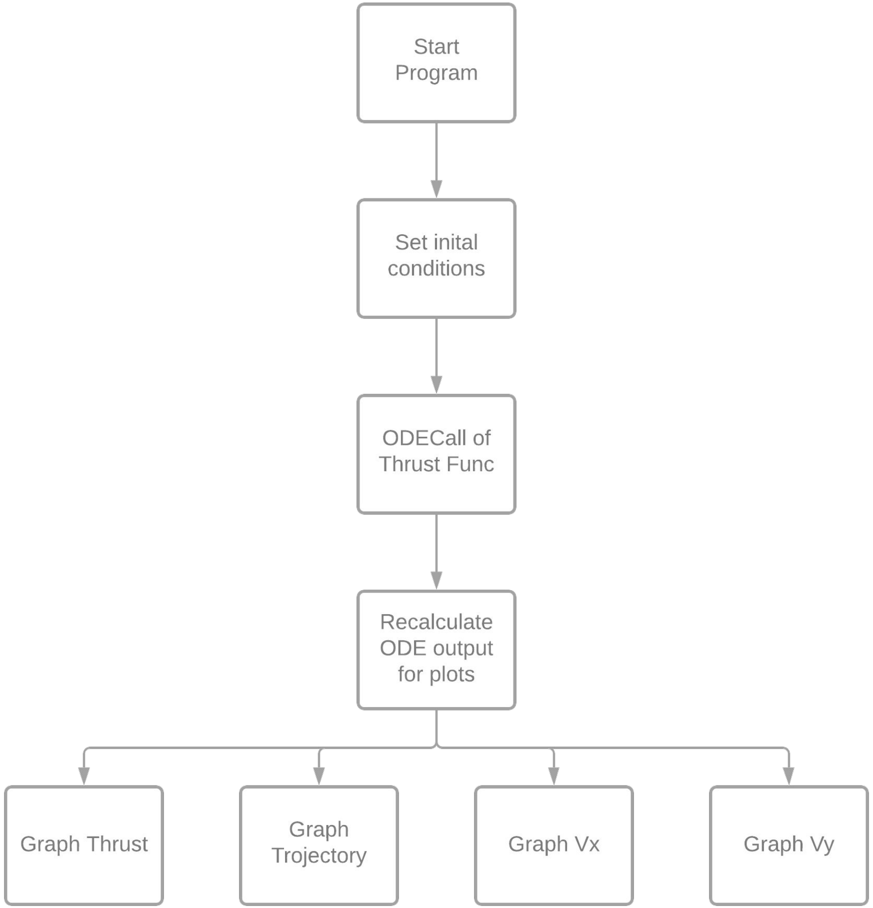
Assumptions

- The rocket is confined to a 2d plane
- No wind
- No friction
- No heat transfer
- The rocket always aerodynamically stable
- No boundary layer
- Pressure is independent of velocity

Code Structure

Main function

Sets initial conditions and calls ODE45 for rocket simulation.

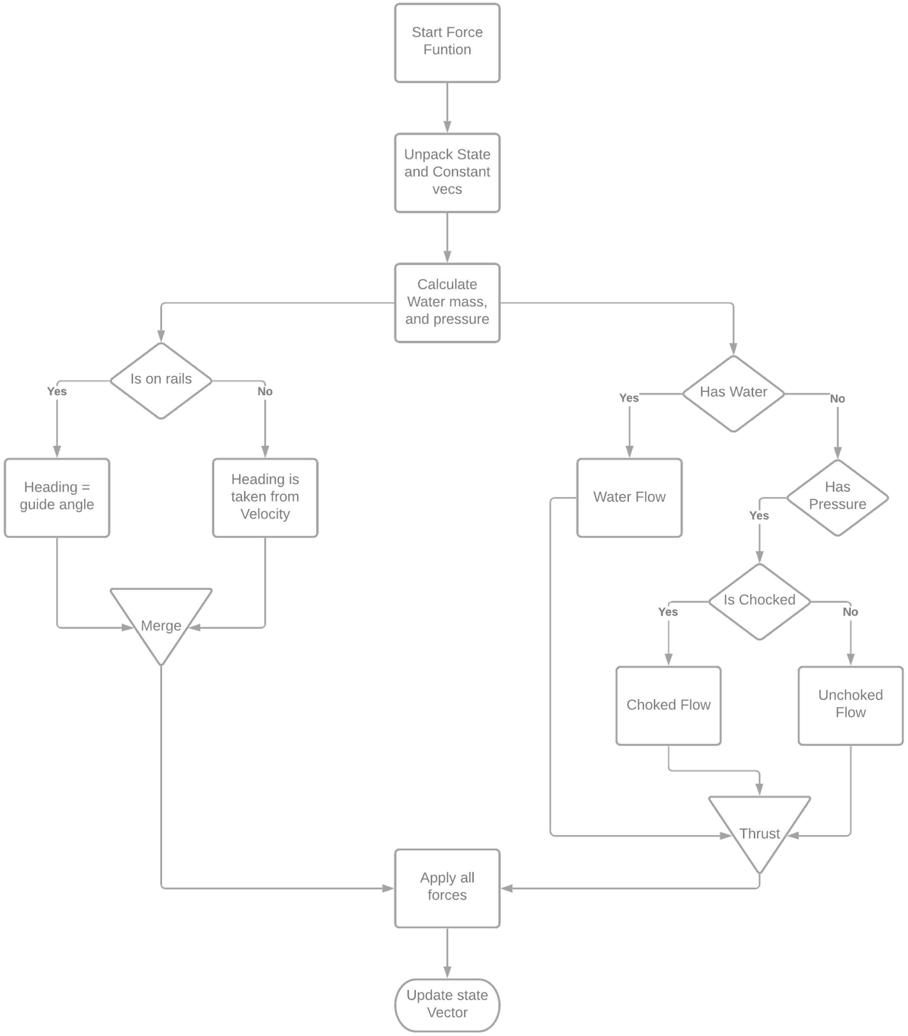


Force function

What the ODE45 Calls to simulate the rocket.

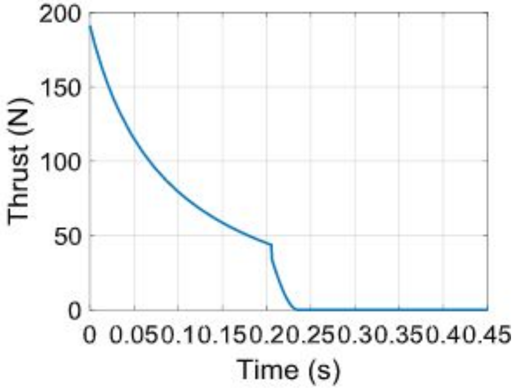
Uses the input state vector to find its phase and calculate the thrust for that phase.

Ends with updating rate of change of state vector.

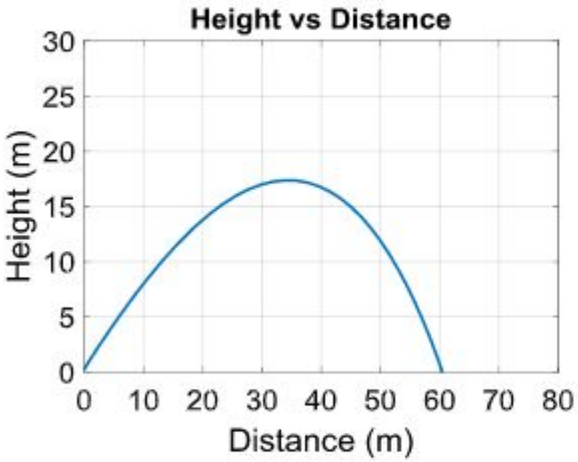


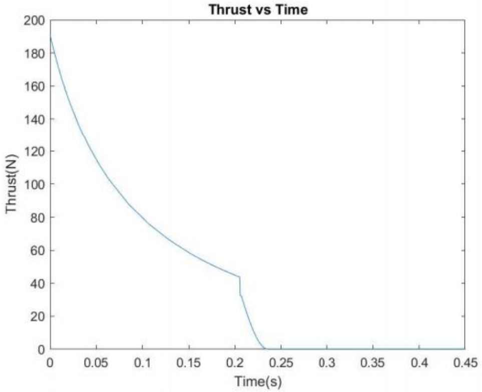
Results

Verification Vs My Plots

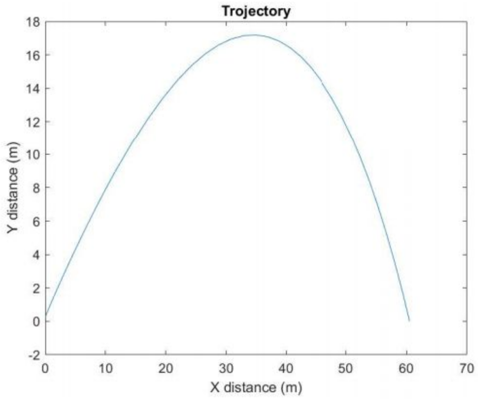


Verification Plots





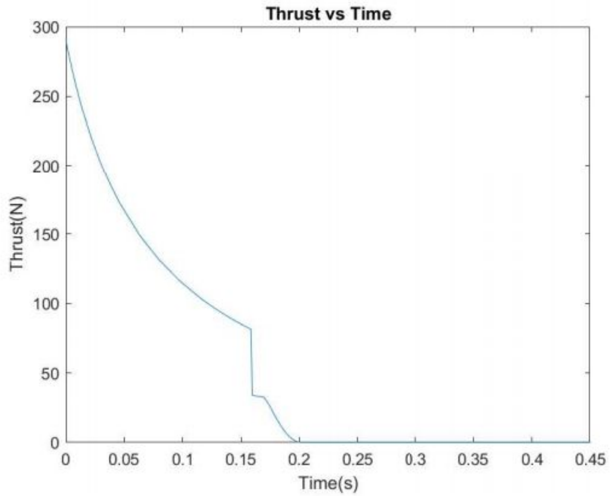
My output

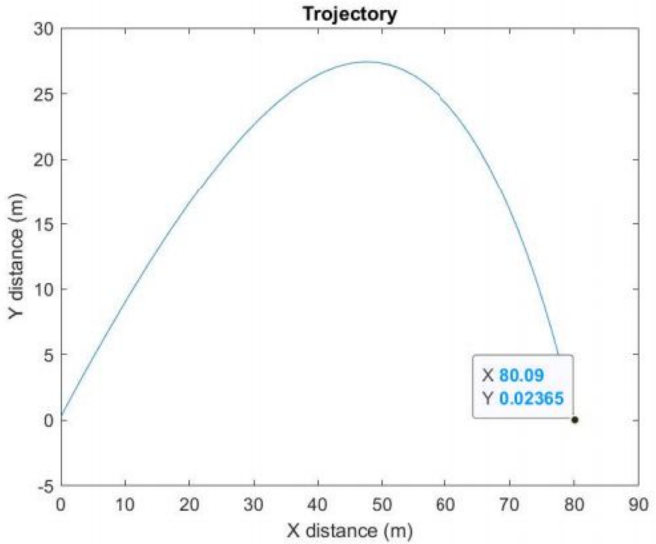


Changing Pressure

Changing the pressure had the largest impact with 76 PSI gage in the bottle allowing the rocket to hit the target keeping all other conditions constant with respect to the verification case.

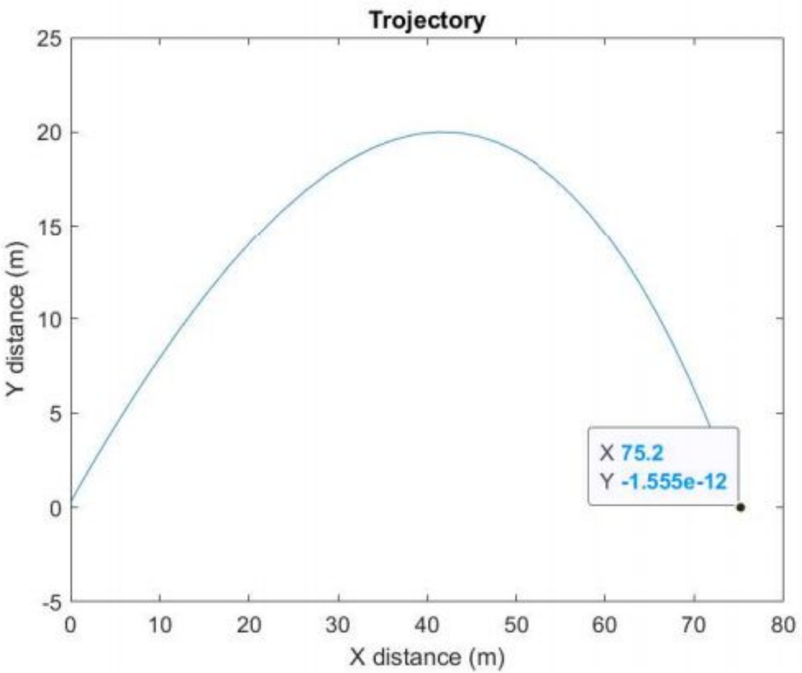
Increasing pressure always increased range, with a reasonable limit at 80 PSI.





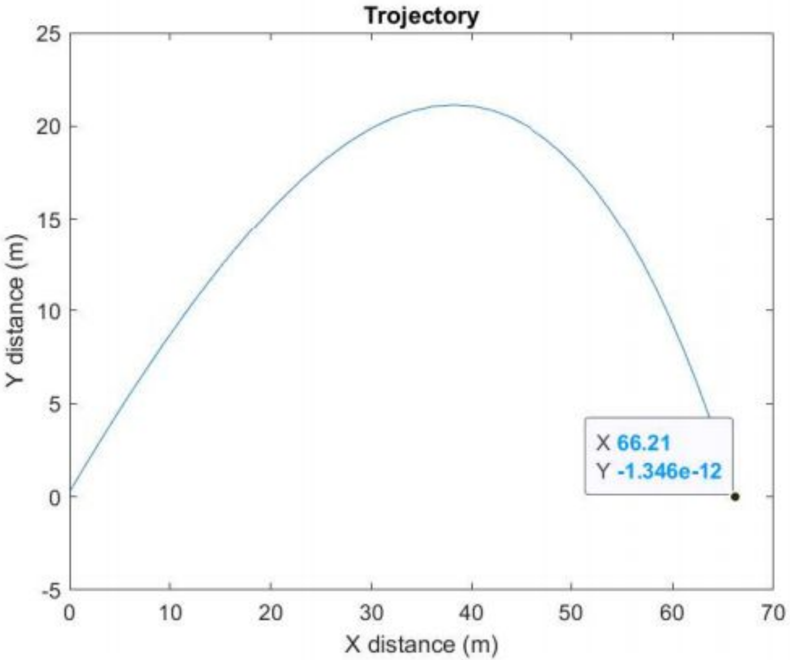
Changing Drag

Changing the drag coefficient in the range of 0.5-0.3 could not get the rocket on target on its own. At a minimum drag of 0.3 the max distance was 75.2m.



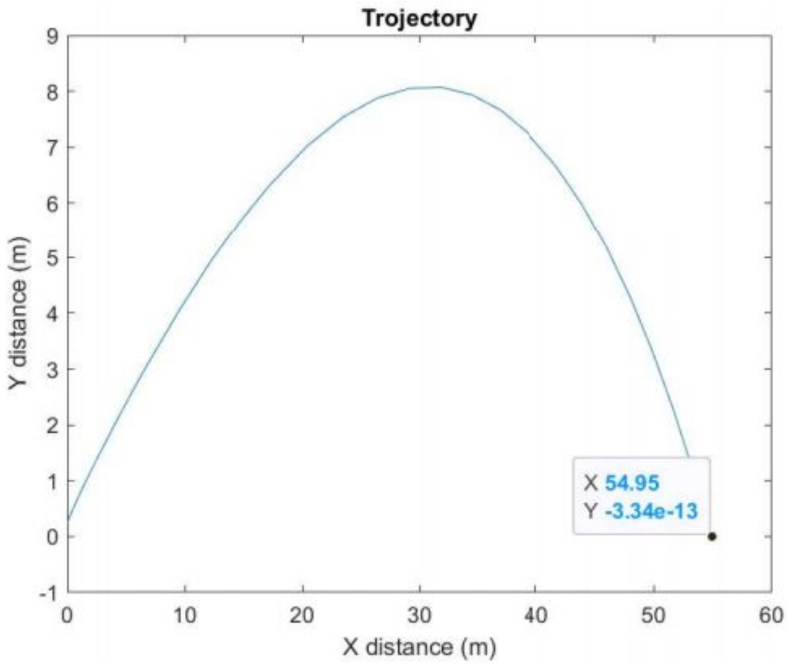
Changing Volume of Water

Changing the volume of water could not get the rocket on target on its own. With a max distance of 66.2m the best volume of water was about 0.75 liters or ⅜ of the volume.



Changing Launch Angle

The test case started close to the optimal angle with any significant changes in angle resulting in decreased range.



Discussion

Trade offs

The most direct way to reach the goal of 80 meters was increasing pressure, the trade off with increased pressure is the chance of blowing up on the pad also increases. Although at 76 PSI the rocket was able to reach the target 80m the max safe pressure for a 2 liter soda bottle is pt at 90 PSI([1] Benson) by the NASA k-12 guide on water rockets.

The other notable trade off is the amount of water, as the more water get a longer thrust period, but less acceleration due to higher mass, and less air at a given pressure. All of the trade offs converge to a middle ground of the best water volume for a given pressure.

Conclusion

Main Takeaways

The computer model made for this project is a good starting point for approximating model water rockets, with outputs in the reasonable range of real world examples. This project also demonstrated how ODE45 can be used to efficiently create models for complex problems where an analytical solution is not existent or not worth calculating.

Citations

[1] Benson, T., “Water Rocket Safety,” NASA Glenn Research Center., Retrieved 6 December 2020. https://www.grc.nasa.gov/www/k-12/rocket/BottleRocket/safety.htm