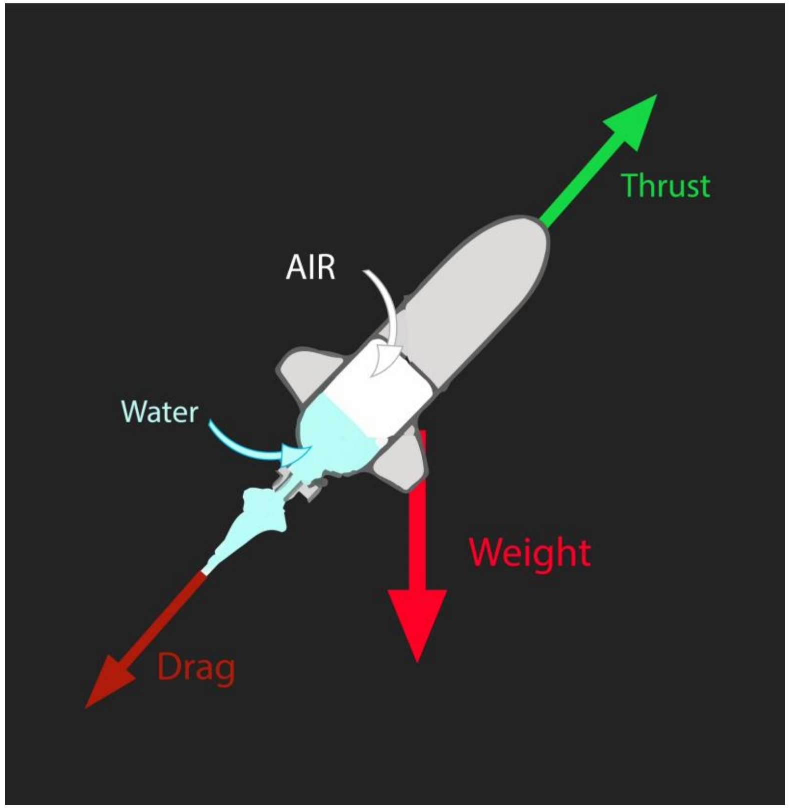
ASEN 2012 PROJECT 2: BOTTLE ROCKET MODELING

By Linus Schmitz

ASSUMPTIONS & SET UP

FBD for the rocket during flight



<u>Assume the following are not changing</u>

- Shape and size of bottle (no deformation)
- External temperature (having no effect on the bottle's contents)
- No additional external forces outside of those listed (drag, gravity and force due to expulsion of water and air)

PHASES OF FLIGHT

Water expelled from bottle

Internal pressure causes water to be expelled out of the bottom of the rocket causing it to begin to rise

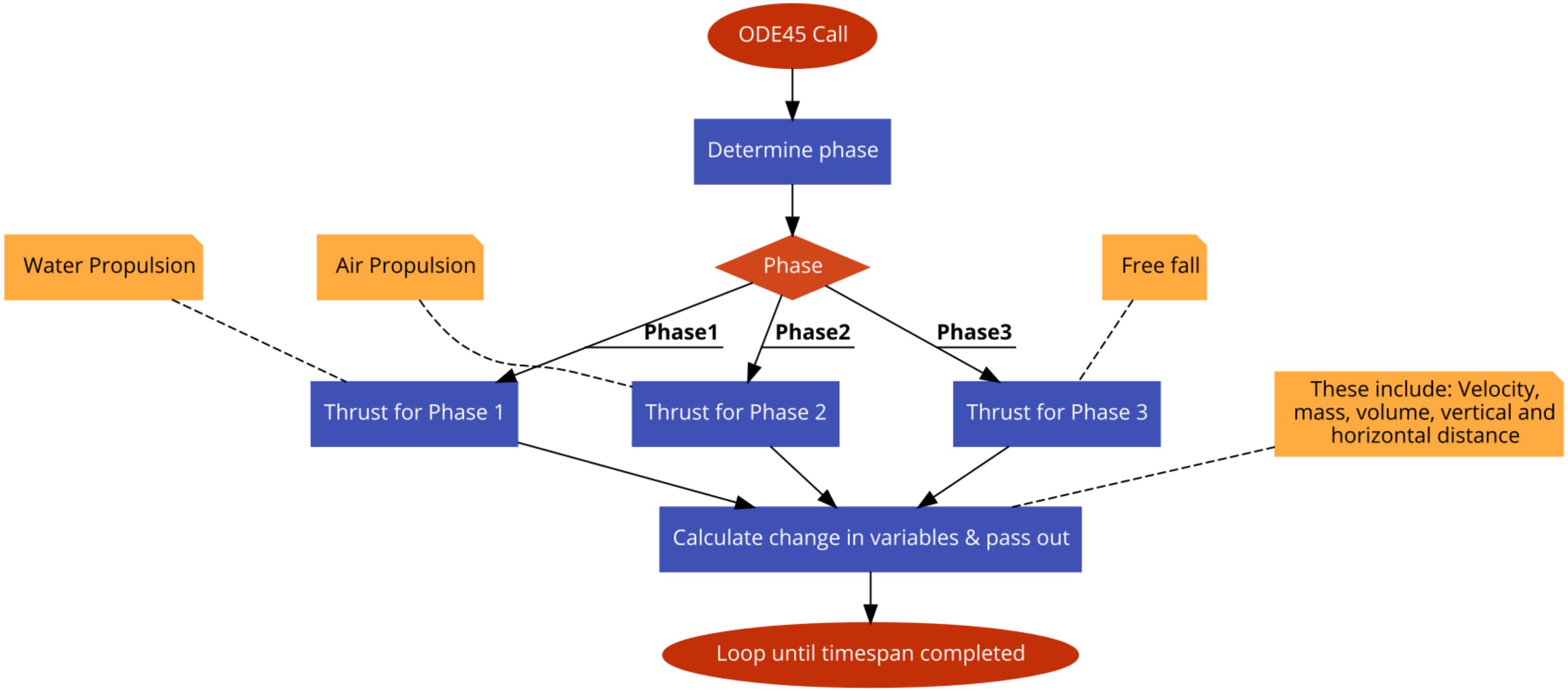
Air pressure equalizing

The water is completely expelled and the residual air pressure in the bottle equalizes with the external air pressure

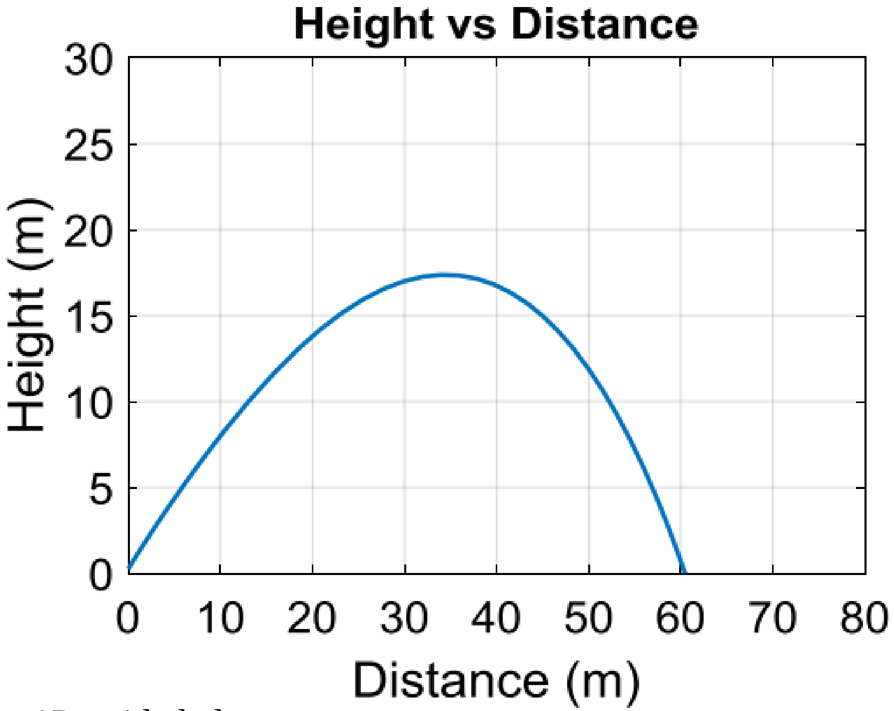
Rocket Freefall

The rocket now coasts and the only force acting on it is gravity. It continues to rise until its upwards velocity hits zero at which point it goes into downwards freefall

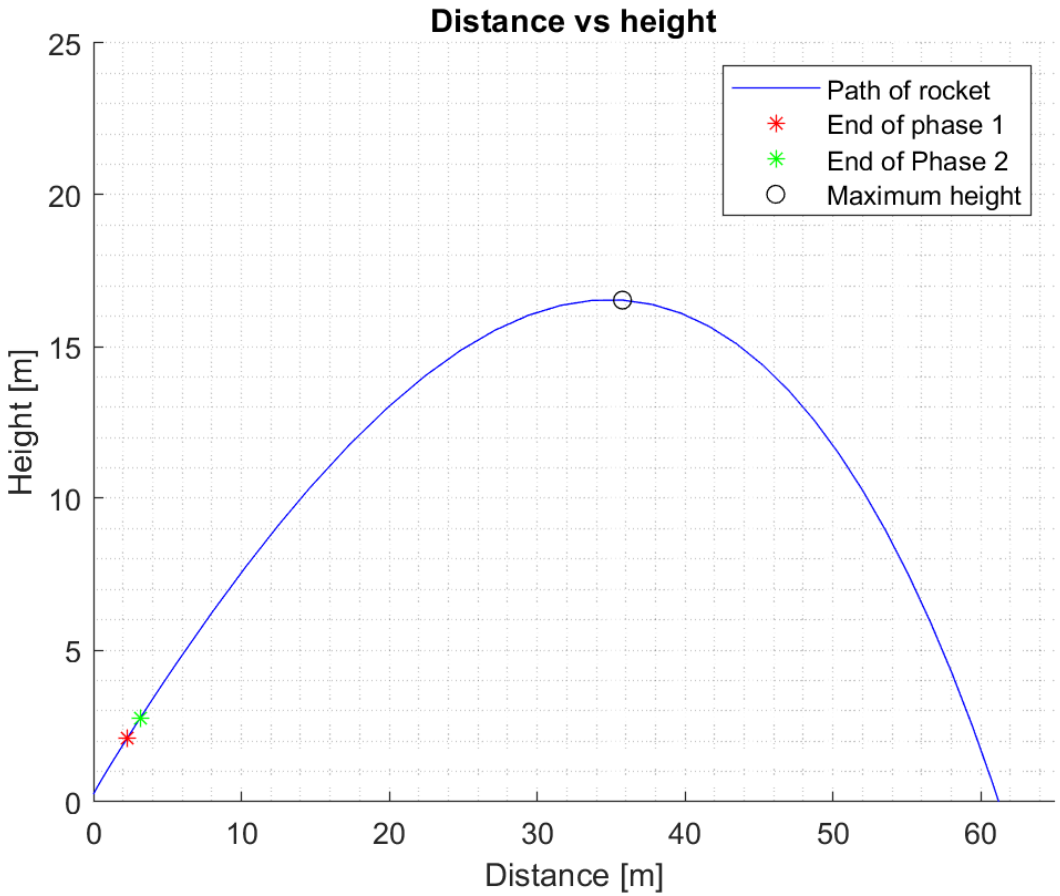
CODE FLOW CHART



VERIFICATION CASE (TRAJECTORY)

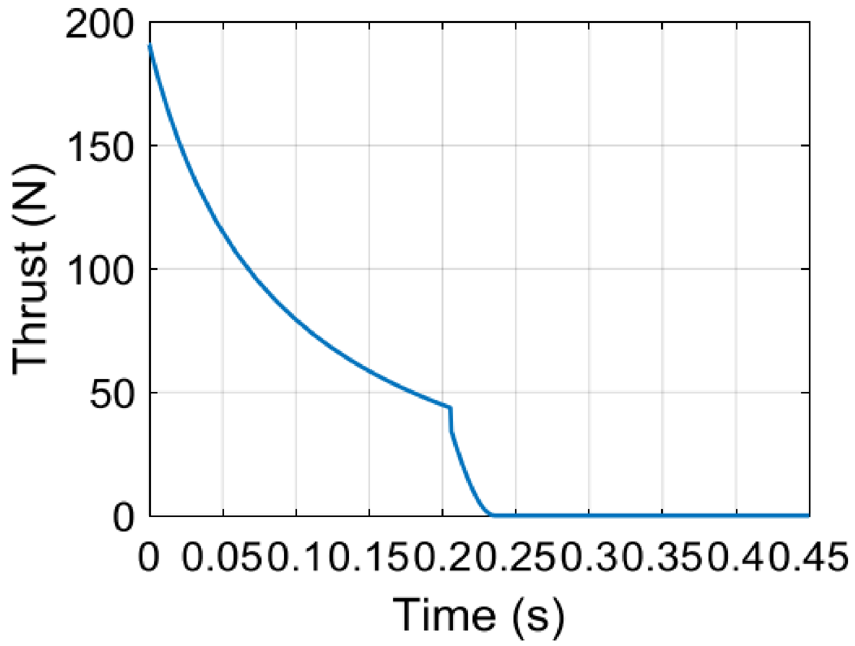


*Provided plot

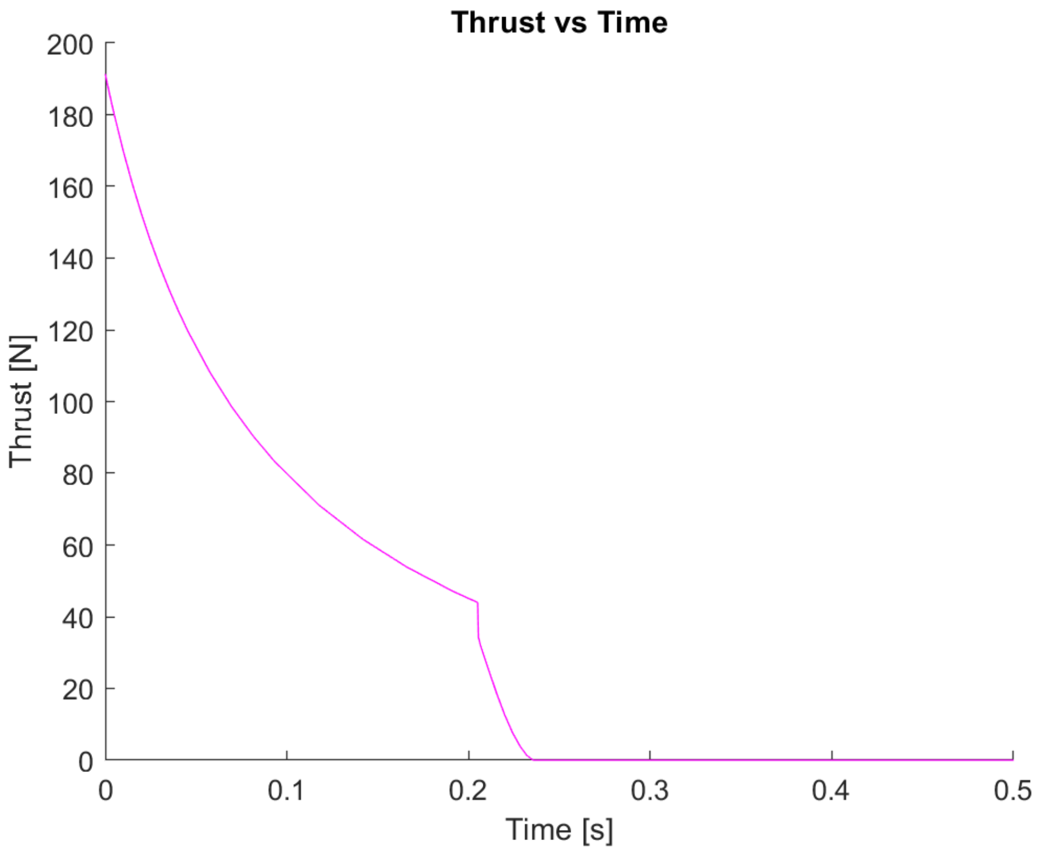


*Calculated plot

VERIFICATION CASE (FORCE)



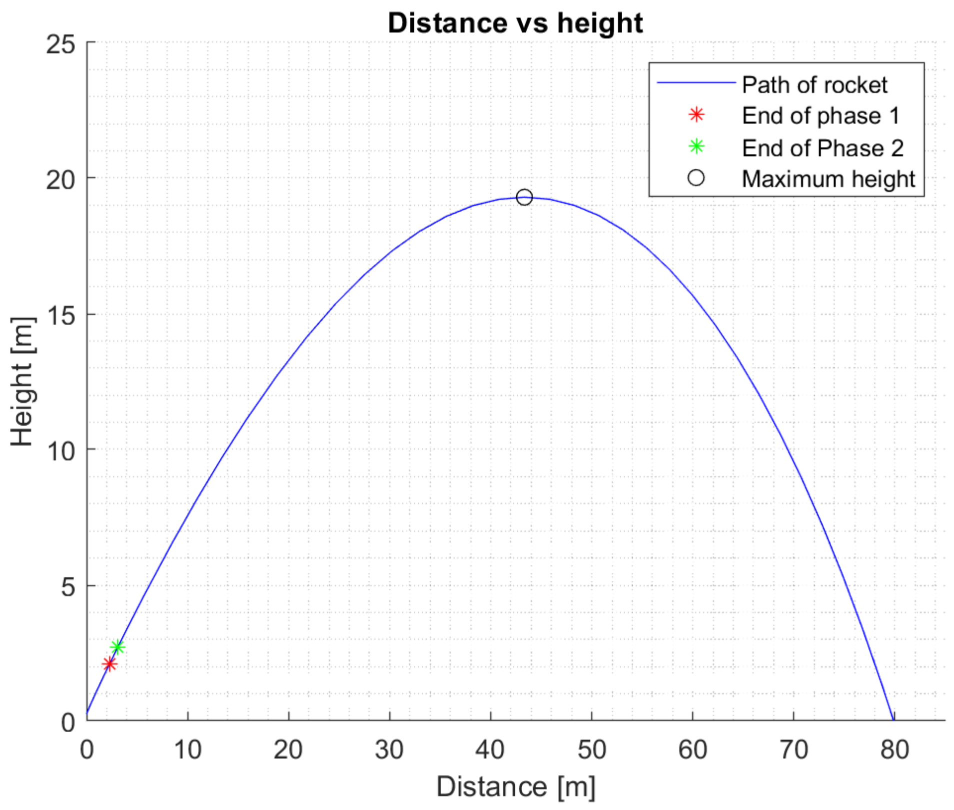
*Provided plot

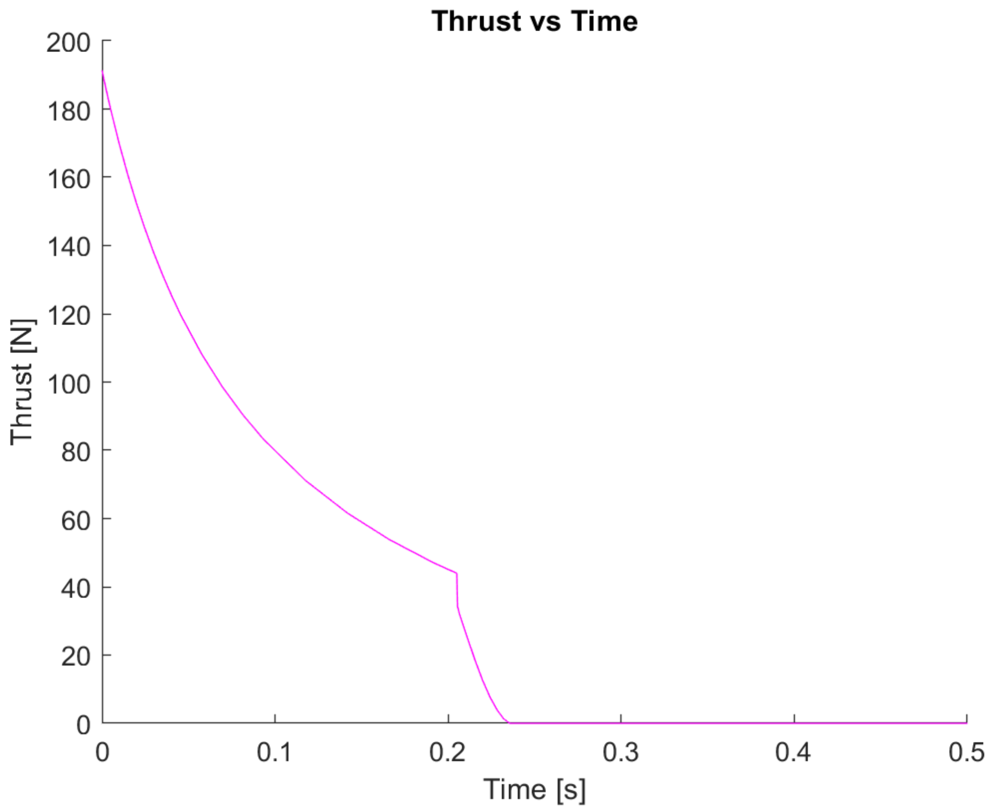


*Calculated plot

TEST CASE 1: COEFFICIENT OF DRAG

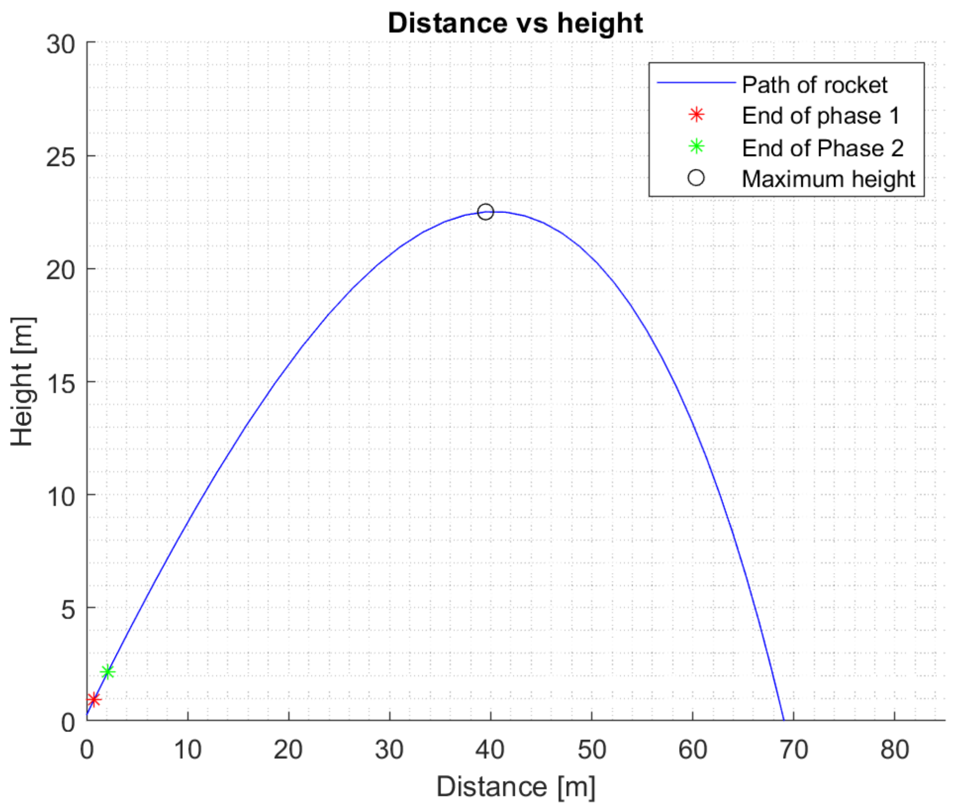
*Drag Coefficient: 0.238

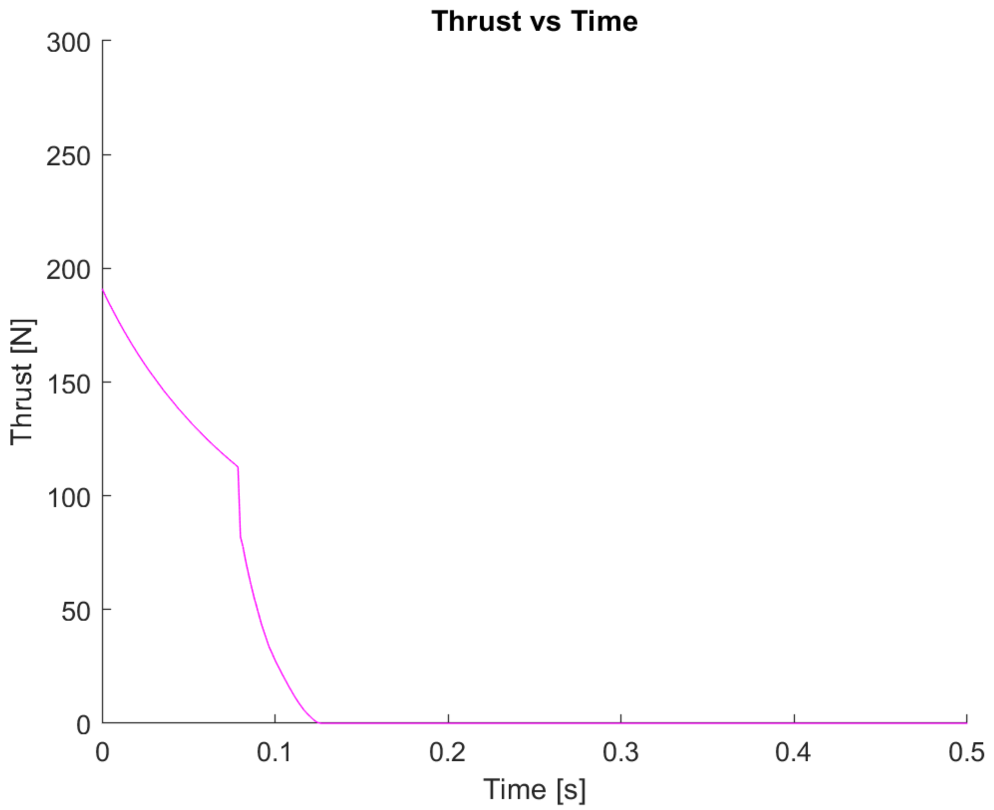




TEST CASE 2: VOLUME OF WATER

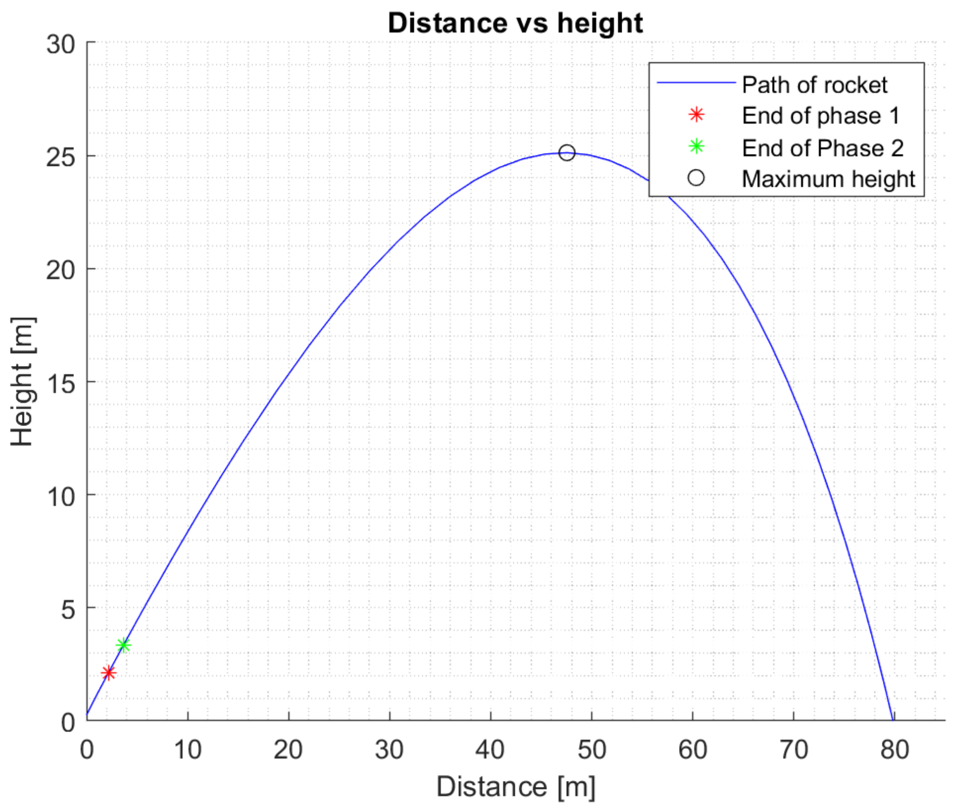
*Volume of water: 0.0005 m^3

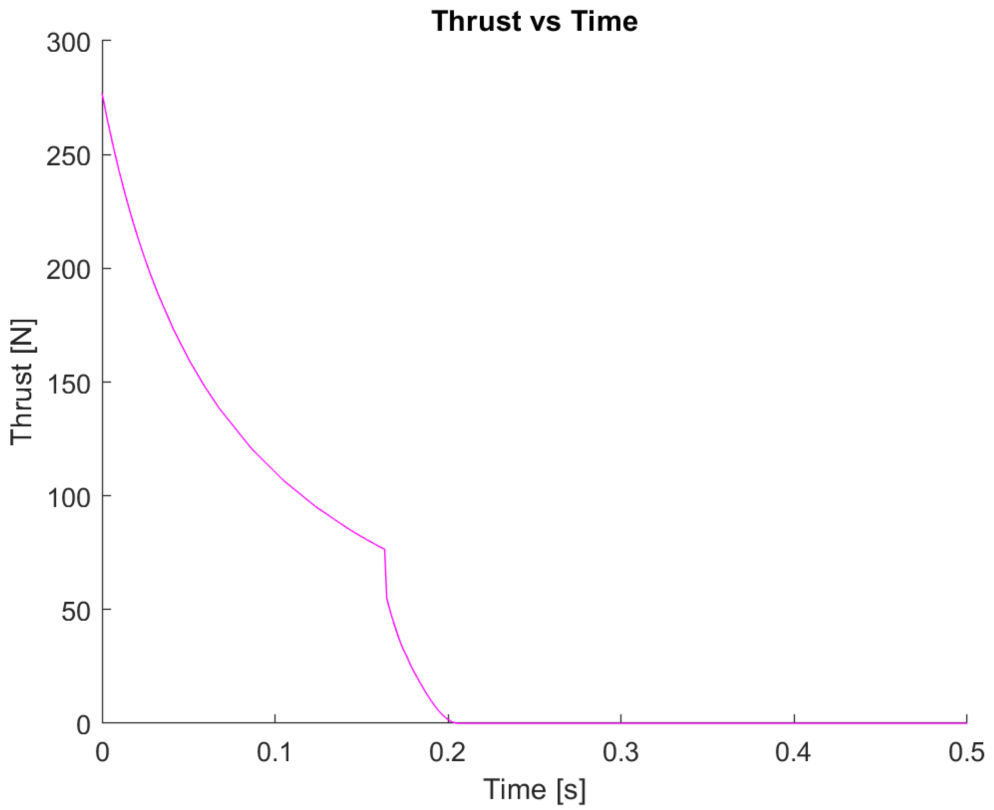




TEST CASE 3:
INTERNAL AIR PRESSURE

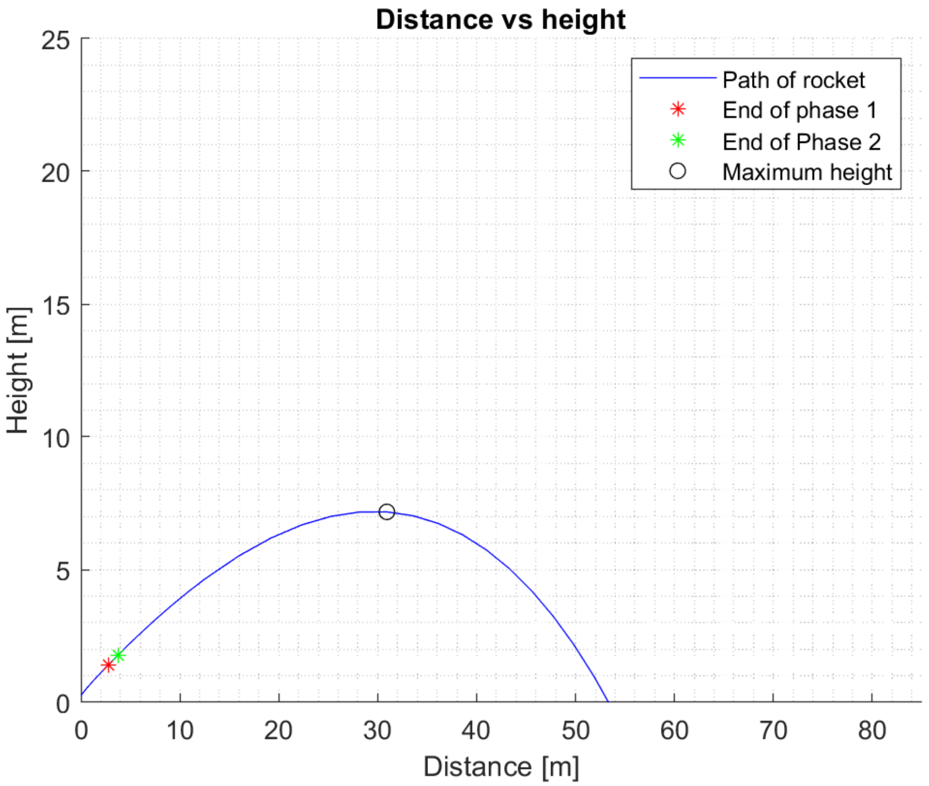
*Air pressure within bottle: 500kPa



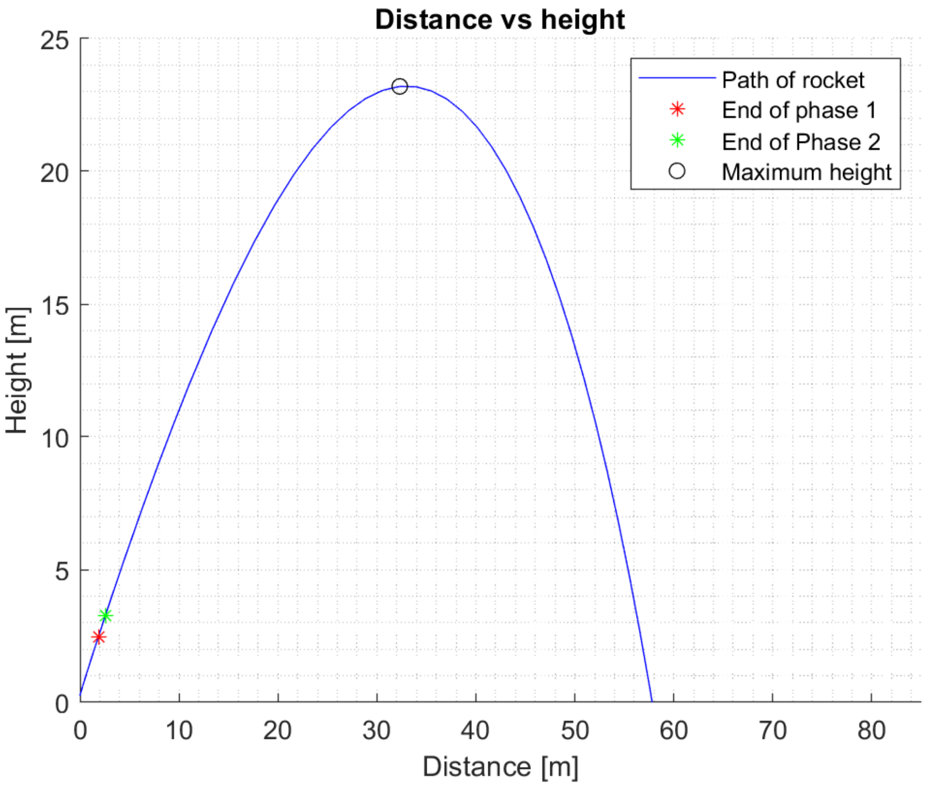


TEST CASE 4: LAUNCH ANGLE

*Thrust will be the same as the verification thrust profile



*Launch stand set at 35°



*Launch stand set at 50°

WHAT TO DO:
GET YOUR ROCKET TO 80 METERS

- Model your rocket's path by determining the change in stages and then using the subsequent aerodynamic equations to determine thrust of the rocket during that time
- Use ODE45 to integrate the change of each variable and plot the trajectory of the rocket
- Examine which variable(s) will cause a change in distance and how much each variable will have to be changed to reach that
  - Examine the trade offs of each one. Which ones can reach the 80-meter mark?
- Choose a variable to change and by how much
  - In this case internal air pressure, increasing that to 500kPa
- Model using the code built and then test in the real world (COVID-19 permitting)

REFERENCES

- Anand, T., and Nerem , S., “Project 2: Bottle Rocket Modeling ,” Oct. 2020.
- Gaston, T., “Coding Challenge ,” *ASEN 2012 Lecture* , Nov. 2020.
- Gaston, T., “Verifications cases (plots),” Nov. 2020.
- Gaston, T., “Coding assistance with regards to phase conditions and thrust plots,” Nov. 2020.

  (Personal communication during office hours)

DISCUSSION OF VERIFICATION CASE:

- The plots are not perfectly identical
- Calculated maximum height is roughly 1 meter low
- Calculated maximum horizontal distance is roughly 0.6 meters long
- This will give all calculated horizontal distances an error of about 1%
    - Based on a difference of 0.6 meters over a 60-meter distance to the verification case
- The force is very close which means that the error is in some assumption made in the code
    - This might include change in angle or how the length of the stand was considered

DISCUSSION OF TEST CASES:

Coefficient of Drag

- In order to reach 80 meters, need a new coefficient of drag of 0.238 which is not in the acceptable range
- Accuracy of 1% result in reaching the 80-meter mark with ±0.8 meters
- Thrust will not change, drag force will decrease

Volume of Water

- Not possible to reach 80 meters with change in water volume
- Max horizontal distance ~ 69 m
- Use a volume of water of 0.0005 m^3
- Further change of volume lead to decrease in Thrust

Internal Air Pressure

- In order to reach 80 meters, need internal gauge pressure to be 500kPa
- Same accuracy as drag modification
- Increase in thrust result in further distance
- Modifying this will give greatest change in distance

Launch Angle

- Not possible to reach 80 meters with only angle change
- Most efficient launch angle is 45° with available thrust
- Max height attainable is 37.5m if launched vertically
- Must change thrust to reach 80 m mark

OVERVIEW DISCUSSION
HOW TO REACH 80 METERS MOST EFFICIENTLY

- Increase in internal pressure is the only options which will singlehandedly allow the rocket to reach 80 meters. Change in drag could but given that the value needed is not within the acceptable range it is not in fact an option
  - It will be easiest to change the internal pressure because changing the coefficient of drag would mean modifying the shape of the rocket which will most likely change the volume or mass of the bottle. At 500kPa internal gauge pressure this gives the bottle a factor of safety of 2, given that most bottle will fail at around 1000kPa
- If it is required to have launch angle or water volume change then will also have to change coefficient of drag and or internal pressure of the bottle
  - This makes changing either of these variables very tedious because any change in either angle or water volume will also require a change in the air pressure or drag to allow the bottle to reach 80m. This means that in the case of reaching 80m these values are not truly independent