Executive Summary

Overall objective is to maximize performance (final velocity) and minimize cost of the first stage of a rocket.

- Final Velocity will be determined from a 2D simulation of a rocket traveling through the atmosphere.
- Cost will be based off of historical data relating thrust at sea level to cost of engines and data relating the dry mass of rockets to cost of manufacturing.

- Design variables will include:

    - area ratio (ratio between the cross sectional area of the throat and the cross sectional area of the nozzle).
    - propellent mass flow (amount of propellent flowing through the engine)
    - *dry mass (mass of rocket minus the fuel and payload)*

Background

Rocket companies are constantly trying to squeeze performance out of their designs due to high costs associated with launching payloads into orbit.

- Stakeholders:
    - private launch companies
    - governments
- needs:
    - lower costs to increase profits
    - higher performing designs to expand launch capabilities

Formulation

The basic multi-objective optimization problem is:

- minimize cost, maximize final velocity
- wrt: area ratio, propellent mass flow, dry mass
- constraints: none (this might change depending on the initial results of the simulation)

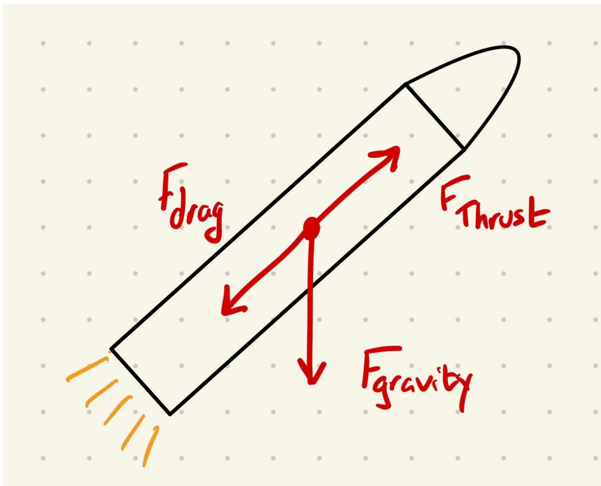
Simulation

There are hundreds of variables that go into determing the final velocity of a first stage booster. I am making the following variables constant to simplify the simulation:

- phsyical shape of the rocket (diameter, length, nosecone)

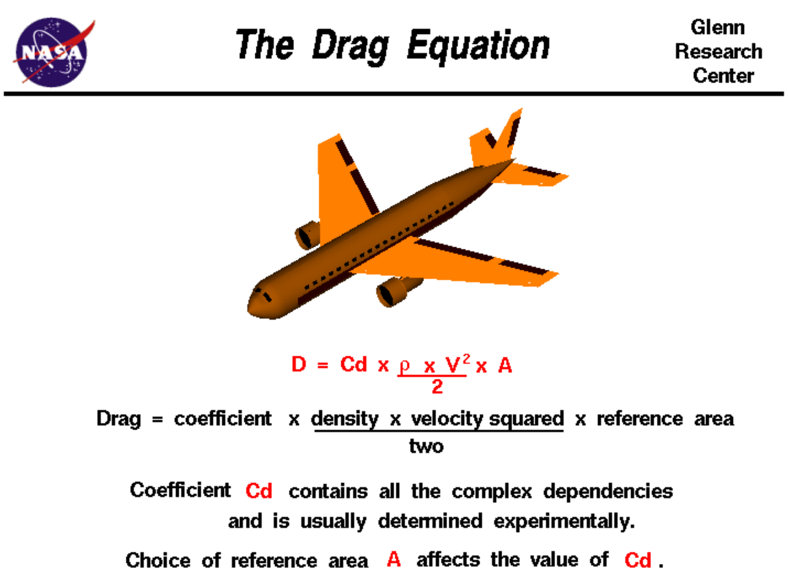
- mass of payload and second stage
- fuel mass and type (assuming homogenous fuel with constant flow rate)
- thrust profile
- gravity

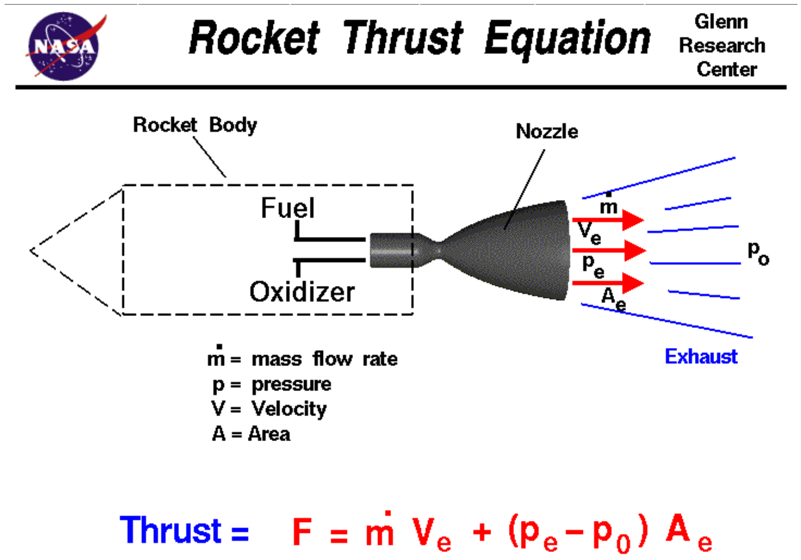
The follwing free body shows the forces I am considering:



I am assuming the rocket will be a point mass so that a changing thrust vector will not produce torque. I am also assuming that the drag force will always be anti-parallel to the direction of the thrust.

There will be several equations to determine the drag force and thrust. I have not finalized these equations, but I have included some of the examples I am currently working with:





Cost will be determined by a mix of historical data and external models. I have found a few examples in my research but have not finalized what equations/data I will use.

In general, there will be a tradeoff between reducing the complexity and getting more realistic/interesting results.

Optimization

I am currently aiming towards using monte carlo simulations to generate a series of results. There should be a distinct pareto frontier I can analyze to draw conclusions from the project.

Results / Conclusion

I am hoping to have several designs that fall along the pareto frontier that I can analyze in further detail and relate to historical launch vehicles

- There will likely be unrealistic trends in my data due to some of the simplifications I made in