

6 Degrees of Freedom Rocket Trajectory Simulation with Stochastic Analysis

Jago Strong-Wright & Daniel Gibbons

Preliminary Results, December 2020

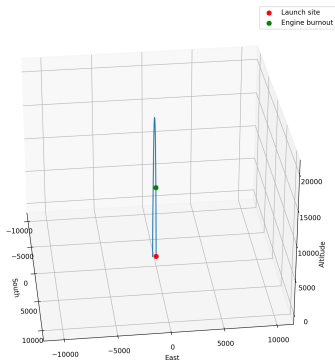
Summary

What we have made so far

- ▶ All 6 axes simulated for full flight
- ▶ Uses the engine data from Joe's simulation
- ▶ Calculates aero forces based on RASAero drag coefficients
- ▶ Includes parachute decent
- ▶ Designed to be as general as possible so it can be used for any flight
- ▶ Structured like a python library including documentation (hopefully finished soon)
- ▶ New module for Monte Carlo simulation to find trajectory error bounds

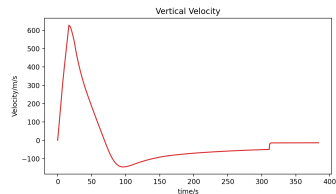
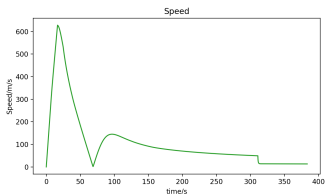
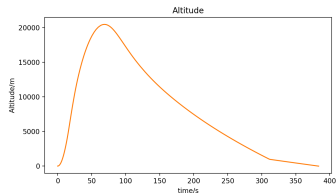
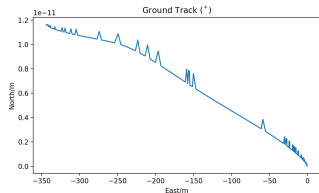
Nominal Flight 1

No wind, rail upright



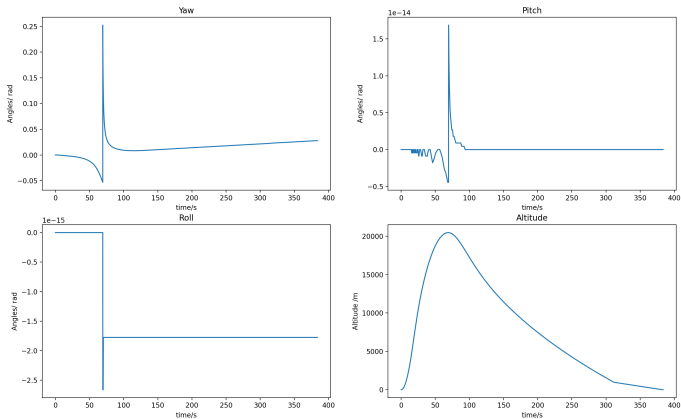
Nominal Flight 1

No wind, rail upright. Jaggedness from automatic step size reduction (note the scale on the downrange is 1×10^{-11})



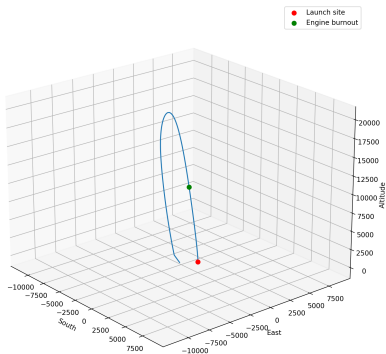
Nominal Flight 1

No wind, rail upright



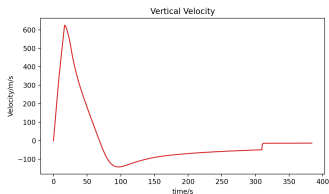
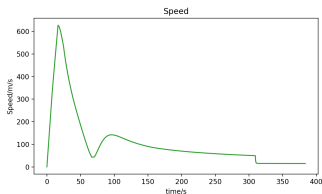
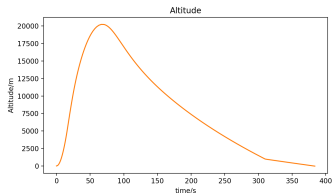
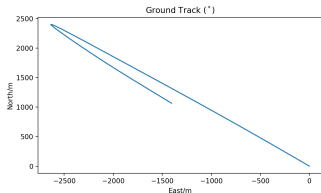
Nominal Flight 2

7m/s south east wind, rail upright. Goes back on its self as it weather cocks.



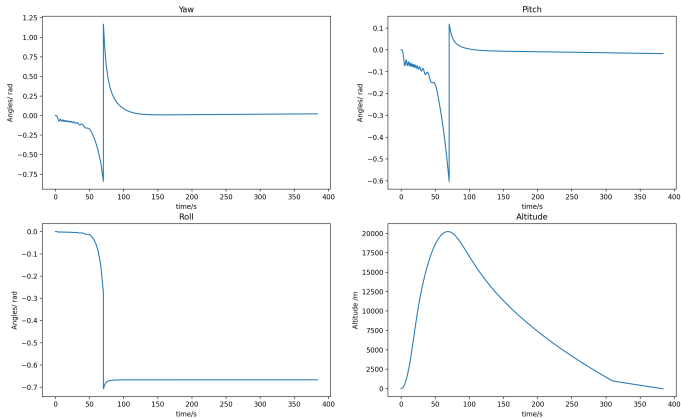
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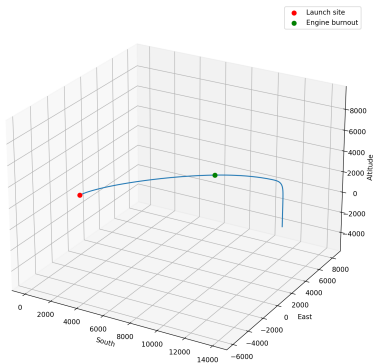
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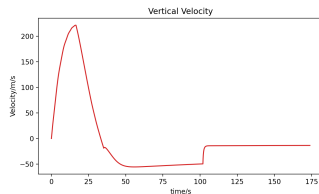
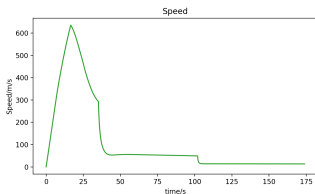
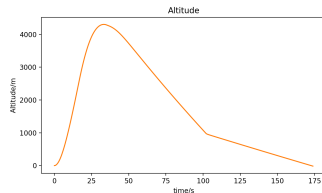
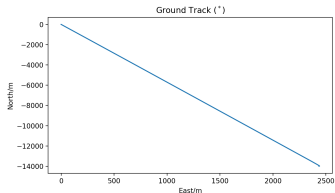
Nominal Flight 3

45 degree rail angle



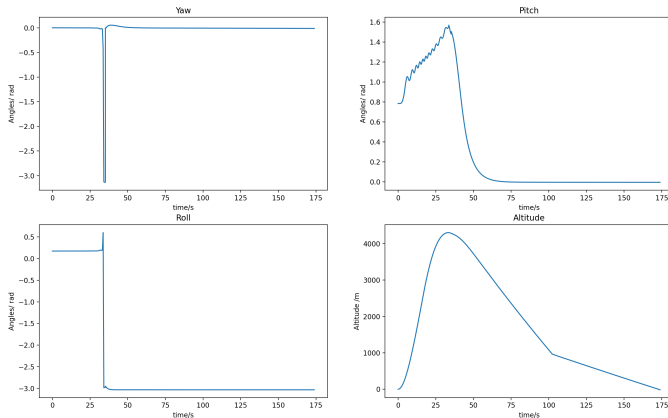
Nominal Flight 3

45 degree rail angle



Nominal Flight 3

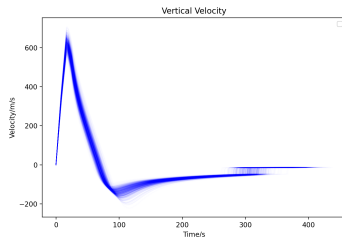
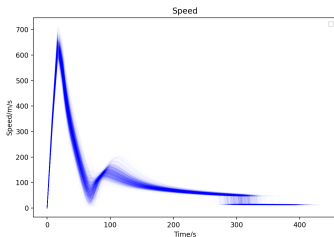
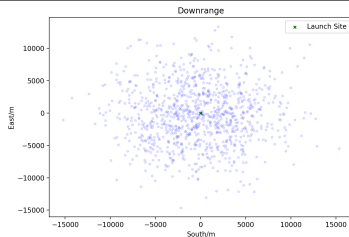
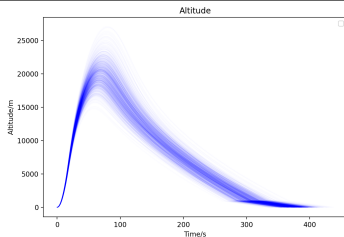
45 degree rail angle



- ▶ Monte Carlo allows you to analyse the effects of variations on a highly non linear system
- ▶ Essentially randomly generating variations/error in the input parameters (e.g. thrust, drag coefficients, rail angle)
- ▶ Possible to calculate errors/confidence intervals for predicted trajectories (maths of this is yet to come)

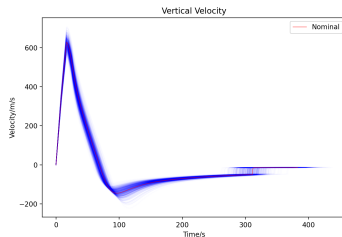
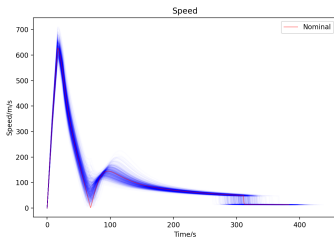
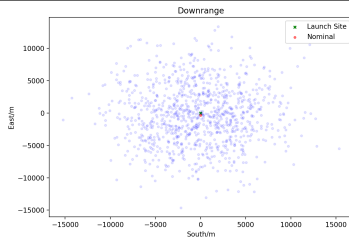
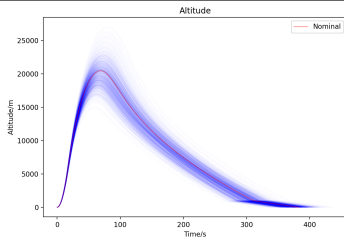
Monte Carlo Analysis

No rail angle or wind, 1000 iterations



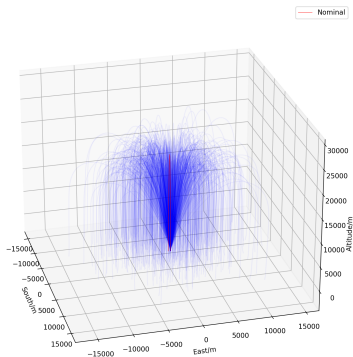
Monte Carlo Analysis

No rail angle or wind, 1000 iterations



Monte Carlo Analysis

No rail angle or wind, 1000 iterations



- ▶ Proper analysis of the Monte Carlo Results
- ▶ New more accurate mass model (we currently just have a cylinder)
- ▶ Better aero model (i.e. including damping etc.)
- ▶ Aerodynamic heating analysis
- ▶ Slosh modeling
- ▶ Couple with CFD for more accurate results
- ▶ Finish documentation
- ▶ Think of a name