Parametric Rocket: Phase 2

OpenRocket flight simulation

What I did

I rebuilt the rocket in OpenRocket from the same dimensions as my SolidWorks model: an ogive nose cone, a 4.13 cm body tube, three trapezoidal fins, a parachute, and a 29 mm motor mount. I overrode OpenRocket's calculated mass and center of gravity with the values from my SolidWorks Mass Properties report, so the simulation used my design instead of the simulator's own estimate. Then I checked stability and ran three motors: the AeroTech F42-8, G80-7, and G125-9.

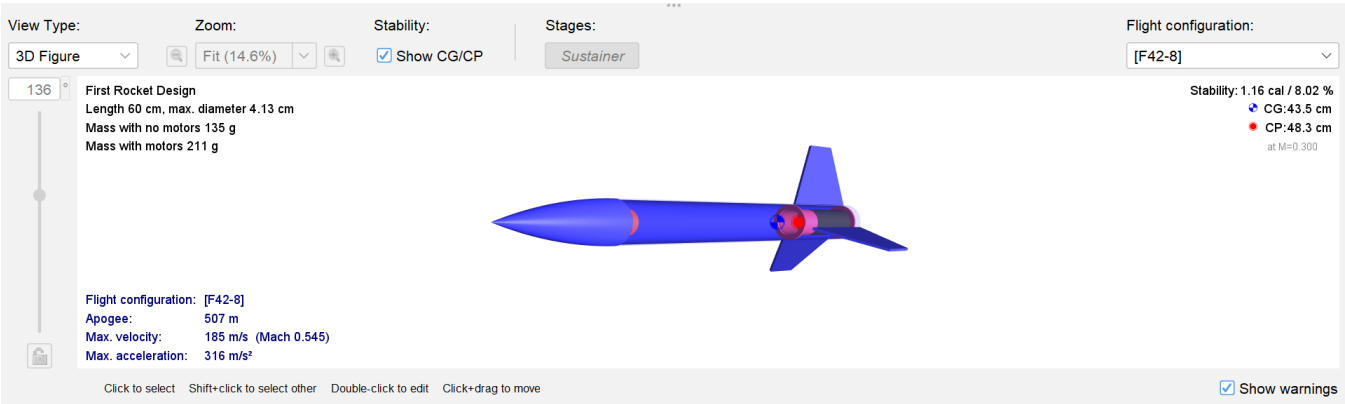


Figure 1. The rocket in OpenRocket's 3D view with the F42-8 loaded, showing the CG and CP markers and the flight summary.

Stability

With the F42-8 loaded, OpenRocket puts the center of gravity (CG) at 43.5 cm and the center of pressure (CP) at 48.3 cm from the nose tip, evaluated at Mach 0.3. The CP is 4.8 cm behind the CG, so the rocket is stable. That is a margin of 1.16 calibers (8.02% of the rocket's length), which is a little below the 1.5-2.0 calibers I was aiming for.

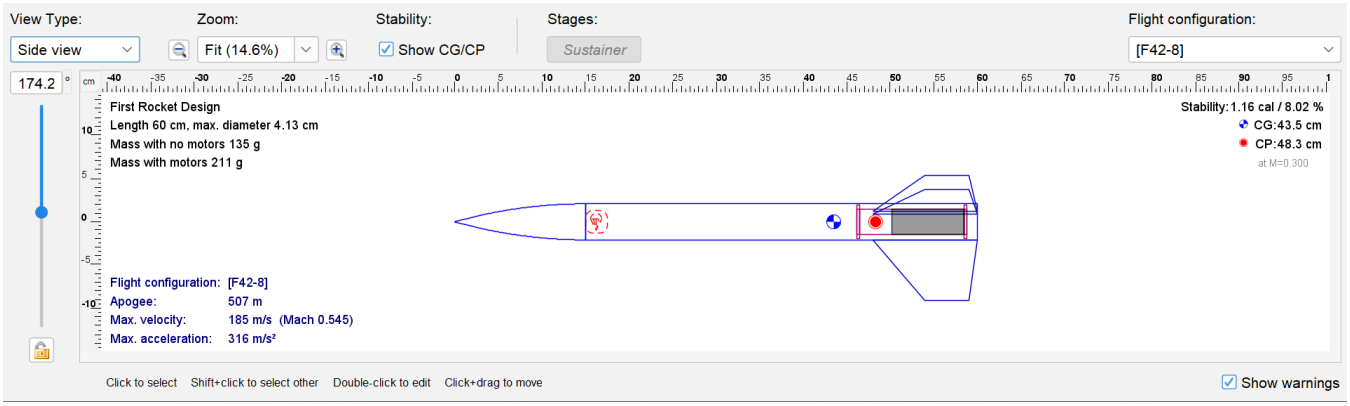


Figure 2. Side view with the CG (blue and white circle) ahead of the CP (red dot). The parachute sits just behind the nose cone.

Simulation results

I ran all three motors and compared them against my 300-500 m apogee target. The F42-8 is the only one close to the target, at 507 m, which is 7 m over the upper limit. The G80-7 and G125-9 reach 809 m and 867 m, well above it, so I picked the F42-8.

Motor	Apogee	Max velocity	Max accel.	Time to apogee	Ground hit vel.
F42-8	507 m	185 m/s	316 m/s^2	8.07 s	5.11 m/s
G80-7	809 m	302 m/s	380 m/s^2	9.12 s	5.53 m/s
G125-9	867 m	342 m/s	510 m/s^2	9.66 s	5.90 m/s

Highlighted row: the motor I picked. Ground hit velocity is the speed at landing under the parachute.

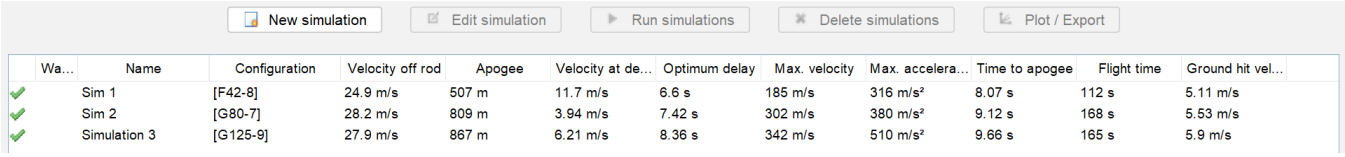


Figure 3. OpenRocket's simulation table for the three motors. I exported the flight data for each as a CSV for the Phase 3 analysis.

What I learned

- **Stability depends on where the fins and the mass are.** The fins are the biggest factor in where the CP sits. Moving them toward the tail pushes the CP aft and increases the margin, and moving them forward does the opposite. The CG follows the mass. The parachute is packed forward in the body, so it pulls the CG toward the nose and adds stability. Without it, the CG sits further aft and the margin gets smaller. The caliber number comes from both moving together.
- **Picking a motor takes more than apogee.** The bigger motors push the max acceleration from 316 up to 510 m/s^2 and the max velocity from 185 up to 342 m/s, which is close to the speed of sound. The F42-8 gave the best apogee for my target and the gentlest flight.
- **Ejection delay matters.** OpenRocket lists an optimum delay for each motor. The F42-8's 8 s delay is longer than its 6.6 s optimum, so the parachute deploys at 11.7 m/s. The G80-7's 7 s delay is close to its 7.42 s optimum, and it deploys at only 3.94 m/s.
- **My stability margin came out below target.** The rocket is stable at 1.16 calibers, but I was aiming for 1.5-2.0. For the next iteration, I would add a small amount of nose weight to move the CG forward.

Next: the flight data goes into Python in Phase 3.