

Laue Labs - Rocket Motor Sim Report (SAMPLE)

EXAMPLE DATA. This sample uses a clearly fictional rocket ("Paper Comet X-1"). Service: \$12, for high-school / ages 10+ student teams who send rocket dimensions and mass and get back this report.

Simulation engine: OpenRocket-based. Primary results come from **OpenRocket 23.09** (official release jar, run headless on Java 21.0.12.1). The rocket was built as an .ork file from the inputs below. A separate transparent Python point-mass sim (sim.py) is used only as a cross-check; apogee differences over 15% are flagged.

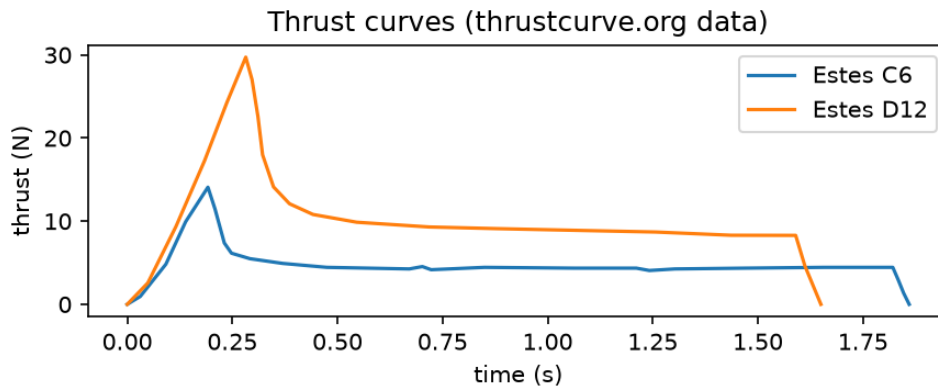
1. Inputs

Item	Value
Nose cone	ogive, length 120 mm
Body tube	OD 41.6 mm, length 450 mm (total length 570 mm)
Fins	3 trapezoidal; root 70 mm, tip 35 mm, span 50 mm, LE sweep 35 mm; root LE 500 mm from nose tip
Empty mass (no motor, incl. parachute)	95 g; empty CG 300 mm from nose tip (as supplied; entered in OpenRocket as a mass/CG override)
Motor mount	24 mm; 18-to-24 mm adapter 6 g used for C6 only
CP (OpenRocket, Mach 0.3, 0 deg AOA)	446 mm from nose tip (sim.py Barrowman cross-check: 445 mm)
Drag	OpenRocket computes its own drag from the geometry (default surface finish and fin thickness; not measured). sim.py cross-check uses constant Cd 0.5 (assumed).
Launch rod	0.914 m (3 ft), vertical
Launch site	elevation 0 m, ISA standard atmosphere
Parachute	457 mm (18 in) diameter, Cd 0.75 (assumed), deployed at apogee
Wind	0 (baseline) and steady 5, 10, 15 mph, no gusts/turbulence

2. Motors (real data from thrustcurve.org)

Motor	Data file used	Source
Estes C6-5	motors/Estes_C6.eng	https://www.thrustcurve.org/simfiles/69eb2379c7d63000021d8c29/ (cert); motor page https://www.thrustcurve.org/motors/Estes/C6/
Estes D12-5	motors/Estes_D12.eng	https://www.thrustcurve.org/simfiles/5f4294d20002e900000004ea/ (user (made from NAR published data)); motor page https://www.thrustcurve.org/motors/Estes/D12/

This example covers the Estes C6 and D12 only. *Composite E motors are adult-flown options only and were not simulated here; their higher speed raises the risk of fin flutter on light fins. Check motor labels and NAR code for age limits.*



3. Results per motor (OpenRocket)

Result	Estes C6	Estes D12
Liftoff mass (g)	124	138
CG at liftoff / burnout (mm from tip)	355 / 338	373 / 343
Stability margin at liftoff (cal)	2.18	1.76
Stability margin at burnout (cal)	2.60	2.47
Velocity off 0.91 m rod (m/s)	11.5 (38 ft/s)	14.9 (49 ft/s)
Max velocity, 0 wind (m/s)	47.7 (157 ft/s)	88.3 (290 ft/s)
Predicted apogee, 0 wind (m)	129 (422 ft)	253 (829 ft)
Predicted apogee, 5 mph wind (m)	125 (411 ft)	251 (824 ft)
Predicted apogee, 10 mph wind (m)	117 (385 ft)	248 (813 ft)
Predicted apogee, 15 mph wind (m)	111 (364 ft)	244 (800 ft)
Time to apogee, 0 wind (s)	5.57	6.70
Motor ejection (burn + delay) (s)	6.86 (5 s delay)	6.65 (5 s delay)
Ejection offset from apogee, 0 wind (s)	+1.29	-0.05
Landing speed under chute (m/s)	3.9 (13 ft/s)	3.9 (13 ft/s)
Descent time from apogee, 0 wind (s)	34	65
Drift at 5 mph, straight-line (m)	73 (241 ft)	144 (473 ft)
Drift at 10 mph, straight-line (m)	138 (453 ft)	285 (934 ft)
Drift at 15 mph, straight-line (m)	196 (644 ft)	420 (1378 ft)
OpenRocket landing distance from pad at 5 mph (m)	45	128
OpenRocket landing distance from pad at 10 mph (m)	90	255
OpenRocket landing distance from pad at 15 mph (m)	143	382

Rod exit vs 4x wind speed (pass/fail)

Wind	4x wind (m/s)	Estes C6 rod exit	Estes D12 rod exit
5 mph	8.9	11.5 m/s - PASS	14.9 m/s - PASS
10 mph	17.9	11.5 m/s - FAIL	14.9 m/s - FAIL
15 mph	26.8	11.5 m/s - FAIL	14.9 m/s - FAIL

Rod exit is the OpenRocket still-air value (vertical rod; wind changes it by under 0.1 m/s).

If a row shows FAIL, the fix is a **longer rod or calm air only**.

Cross-check: OpenRocket vs sim.py (0 wind)

Quantity	Estes C6	Estes D12
Apogee (m)	OR 129 / sim.py 142 (+10.4%)	OR 253 / sim.py 297 (+17.5%)
Max velocity (m/s)	OR 47.7 / sim.py 49.7 (+4.2%)	OR 88.3 / sim.py 94.3 (+6.8%)
Rod exit (m/s)	OR 11.5 / sim.py 11.5 (-0.2%)	OR 14.9 / sim.py 14.7 (-1.2%)
Liftoff stability (cal)	OR 2.18 / sim.py 2.16 (-0.9%)	OR 1.76 / sim.py 1.74 (-1.1%)
Burnout stability (cal)	OR 2.60 / sim.py 2.58 (-0.7%)	OR 2.47 / sim.py 2.45 (-0.8%)
Apogee difference over 15%?	no	YES - flagged

4. Plain-language notes

Estes C6: stability 2.18 cal at liftoff, 2.60 cal at burnout. Rod exit 11.5 m/s - see the pass/fail table; where it fails, use a longer rod or calm air only. Apogee: OpenRocket predicts 129 m in still air; the sim.py cross-check is +10.4% different. Ejection fires +1.3 to +1.6 s from apogee across 0-15 mph (+ = after apogee). Late ejection means a harder chute opening. Check the shock cord and chute attachment.

Estes D12: stability 1.76 cal at liftoff, 2.47 cal at burnout. Rod exit 14.9 m/s - see the pass/fail table; where it fails, use a longer rod or calm air only. Apogee: OpenRocket predicts 253 m in still air; the sim.py cross-check is +17.5% different (over 15%, flagged). Ejection fires -0.1 to +0.0 s from apogee across 0-15 mph (+ = after apogee).

Stability: margin = $(CP - CG) / \text{body diameter}$, shown at liftoff (full motor) and at burnout (empty motor case). A common guideline is 1-2 calibers; under 1 is marginal, well over 2 tends to weathercock (turn into the wind). **The sim.py cross-check uses Barrowman, which neglects body lift; OpenRocket includes some body lift at angle of attack. True margin may be somewhat lower than the cross-check shows.** Sources: Tripoli RocketLab Delta "Rules of Thumb" <https://info-central.rocketlabdelta.com/design/rules-of-thumb/> ; NASA Student Launch "Rocketry by the Numbers" (1.5-2.0 desirable, at least 1) <https://www.nasa.gov/wp-content/uploads/2023/09/nasa-sl-2024-arw-rocketry-by-the-numbers-508.pdf>

Rod-exit speed: NAR "Launching Safely in the 21st Century" recommends guiding the rocket until it is going at least 4x the wind (or gust) speed: <https://www.nar.org/pdf/launchsafe.pdf> . 4x wind is 8.9 / 17.9 / 26.8 m/s at 5 / 10 / 15 mph; the pass/fail table above compares each motor against those lines. If it fails: longer rod or calm air only.

Apogee: OpenRocket is the primary number. The independent sim.py cross-check (vertical, constant Cd, no weathercocking) differs by the percentages in the cross-check table; treat the spread between the two as a rough idea of the uncertainty, not a measured error bar. Wind lowers apogee in OpenRocket because the rocket turns into the wind.

Wind drift shown is the straight-line case: steady wind speed (stated) x parachute descent time from OpenRocket, assuming the chute deploys at apogee. Real ejection happens at burn + delay, which is offset from

apogee as listed per motor; an ejection after apogee means the rocket falls faster before the chute opens. OpenRocket's landing distance from the pad is also listed for reference; it includes weathercocking upwind during ascent. Gusts are not modelled. Launch only within field limits.

Landing speed is the descent rate under the parachute near the ground, from the stated chute size and Cd.

5. Safety

Follow the NAR Model Rocket Safety Code (<https://www.nar.org/safety-information/model-rocket-safety-code/>). Fly only with adult supervision. Use only certified, commercially made motors, used as the manufacturer directs. Check the launch site size and wind limits in the Safety Code before flying.

An adult must handle and install motors and igniters.

Never fly if the report shows rod exit below the 4x wind line for today's wind.

Recover only from open ground; never retrieve from trees, power lines, or roads.

This simulation is an estimate, not a guarantee: real flights differ with build quality, actual mass/CG, drag, motor variation, weather and recovery deployment. Always verify CG by balancing the finished rocket with the motor installed.

6. Method and limitations

Primary: OpenRocket 23.09 6-DOF simulation of the rocket built from the inputs (files openrocket/*.ork; script openrocket/run_openrocket.py). Empty mass and CG are entered as overrides; motor thrust curves are the thrustcurve.org .eng files. Wind is steady (turbulence 0), rod vertical, launch into the wind. Stability from OpenRocket's Barrowman-based CP at Mach 0.3, 0 deg angle of attack, with CG from its mass calculator at launch and burnout. Cross-check: sim.py vertical point-mass integration (1 ms steps), drag $0.5 \rho v^2 C_d A$ with constant Cd, Barrowman CP (body-tube lift neglected). Not modelled in either: gusts, fin flutter, ejection-timing effects on descent, build imperfections. Full detail in method-for-review.md.