Solid Motor and Flight Report

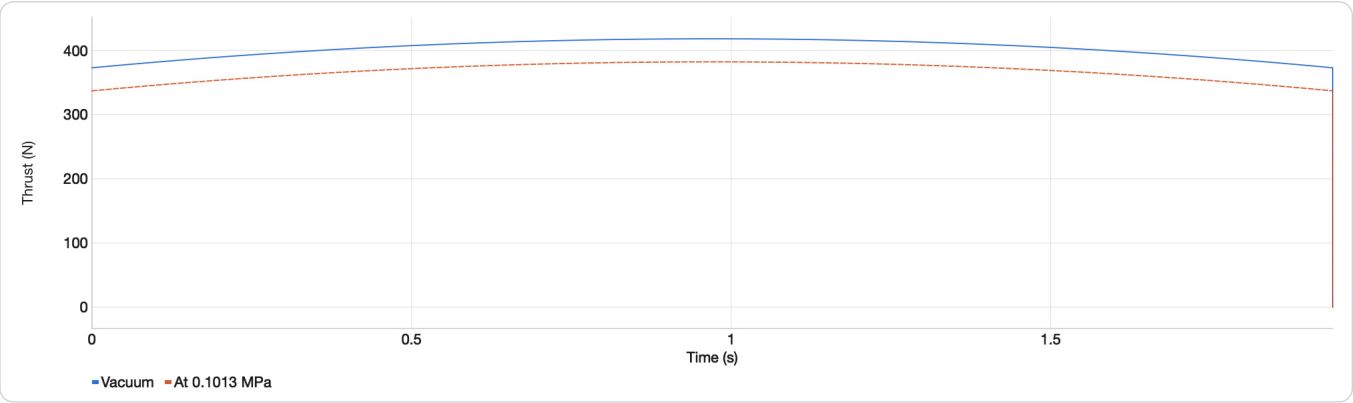
RPL Engine Workbench v2.0.2 · Rocket Propulsion Laboratory LLC

Solid rocket — KNSB motor, dual deployment

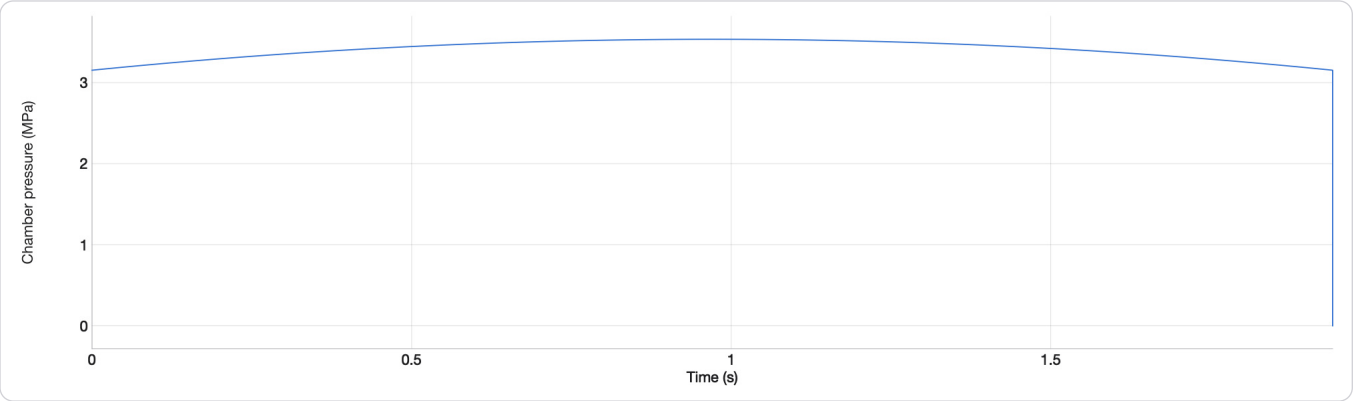
KNSB — potassium nitrate / sorbitol, 65/35 (Nakka) · J367 · peak Pc 3.535 MPa · ε 5.00

712.6 N·s Total impulse at 0.1013 MPa	**1.941 s** Burn time	**367.1 N** Average thrust	**3.535 MPa** Peak chamber pressure
140.8 s Delivered Isp	**0.5162 kg** Propellant mass	**J367** Motor class	**274** Highest Kn

THRUST



CHAMBER PRESSURE



BURN SUMMARY

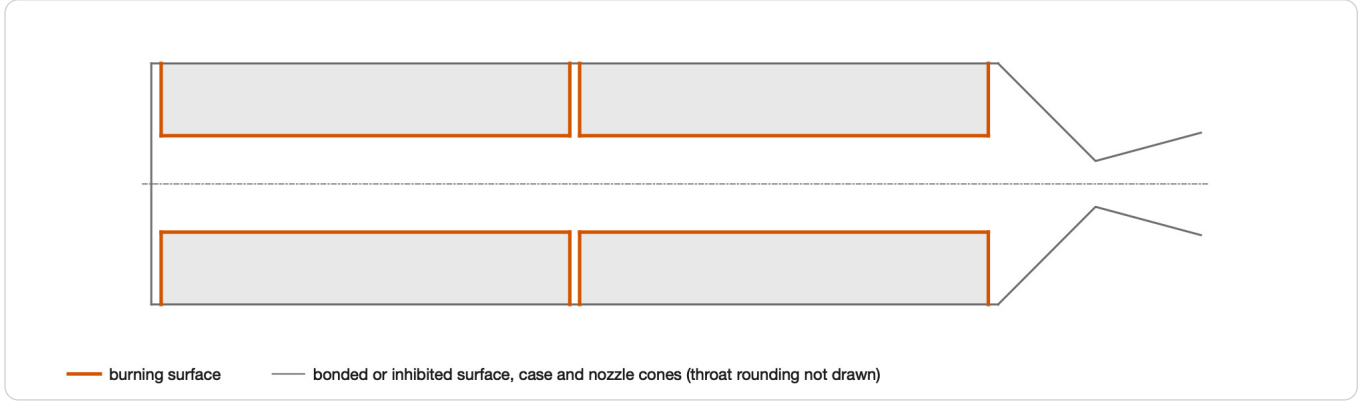
Burn time	1.941 s
Total impulse, vacuum	782.3 N·s
Total impulse at 0.1013 MPa	712.6 N·s
Average thrust, vacuum	403.1 N
Average thrust at 0.1013 MPa	367.1 N
Delivered Isp, vacuum	154.55 s
Delivered Isp at 0.1013 MPa	140.78 s
Propellant mass	0.5162 kg
Web burnt	15.00 mm
Kn at start / highest / at end	243.8 / 273.7 / 243.8
Erosive burning, r/r0 highest (Mukunda-Paul Eq. 12, screened only)	not screened (no gas viscosity in the propellant entry)
Port mass flux over throat mass flux, highest	0.204
Aft port area over throat area at start	4.43

AT PEAK CHAMBER PRESSURE

Time	0.971 s
Chamber pressure	3.535 MPa
Burn rate	7.724 mm/s

Kn	273.7
Thrust, vacuum	418.1 N
Thrust at 0.1013 MPa	382.2 N
Mass flow	0.2759 kg/s
c*, delivered	908.3 m/s
Thrust coefficient, vacuum / ambient	1.6686 / 1.5253
Exit Mach number	2.674
Exit pressure	0.1292 MPa

MOTOR SECTION



GRAIN AND NOZZLE

Segment 1 (2 off): outer / core / length	50.00 mm / 20.00 mm / 85.00 mm
Segment 1: burning surfaces	core, forward end, aft end
Throat / exit diameter	9.500 mm / 21.24 mm
Expansion ratio	5.000
Divergent / convergent half-angle	15.0° / 45.0°
c* efficiency / nozzle efficiency	1.000 / 1.000
Ambient pressure	0.1013 MPa
Hardware mass (case, nozzle, closures)	0.4500 kg

PROPELLANT

Entry	KNSB — potassium nitrate / sorbitol, 65/35 (Nakka) [built-in KNSB-NAKKA]
Density	1841.0 kg/m³

Source: R. Nakka, "KNSB Propellant", Quality Control: ideal density 1.841 g/cm³; nakka-rocketry.net/sorb.html; read 2026-10-11

Ratio of specific heats	1.1370

Source: R. Nakka, "Technical Notepad - KNSB Ideal Performance Calculations" (65/35, 1000 psi), "Specific heat ratio, 2-ph flow" 1.137; nakka-rocketry.net/techsht-knsb.htm; read 2026-10-11

c*, theoretical	908.3 m/s

Source: R. Nakka, "Technical Notepad - KNSB Ideal Performance Calculations" (65/35, 1000 psi), "Characteristic velocity" 908.3 m/s; nakka-rocketry.net/techsht-knsb.htm; read 2026-10-11

Flame temperature	1600 K

Source: R. Nakka, "Technical Notepad - KNSB Ideal Performance Calculations" (65/35, 1000 psi), chamber temperature T0 1600 K in the specific-heat table; nakka-rocketry.net/techsht-knsb.htm; read 2026-10-11

Molecular mass	39.87 kg/kmol

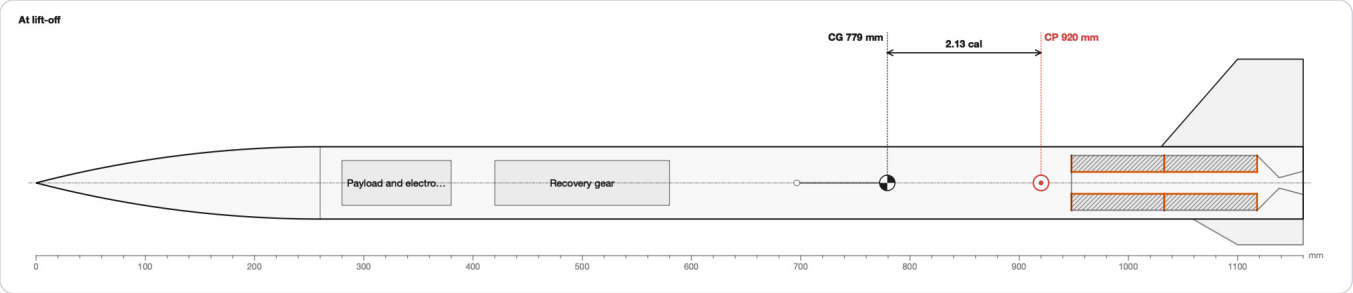
Source: R. Nakka, "Technical Notepad - KNSB Ideal Performance Calculations" (65/35, 1000 psi), "Molecular mass, 2-ph mixture" 39.87 kg/kmol; nakka-rocketry.net/techsht-knsb.htm; read 2026-10-11

Burn rate, 0.1030 MPa to 0.8070 MPa	a = 10.71, n = 0.625
Burn rate, 0.8070 MPa to 1.500 MPa	a = 8.763, n = −0.314
Burn rate, 1.500 MPa to 3.790 MPa	a = 7.852, n = −0.013
Burn rate, 3.790 MPa to 7.030 MPa	a = 3.907, n = 0.535
Burn rate, 7.030 MPa to 10.67 MPa	a = 9.653, n = 0.064

r = a·p^n with r in mm/s, p in MPa. Source: R. Nakka, "KN-Dextrose & KN-Sorbitol Propellants, Burn rate Experimentation", Table 2, metric columns, strand burner; nakka-rocketry.net/bntest.html; read 2026-10-11

VEHICLE AND FLIGHT

VEHICLE



Length / calibre (largest body diameter)	1160 mm / 66.00 mm
Nose	0.1100 kg at station 161.9 mm
Body tube	0.4200 kg at station 710.0 mm
Fins	0.1000 kg at station 1110 mm
Payload and electronics	0.3000 kg at station 330.0 mm
Recovery gear	0.2000 kg at station 500.0 mm
Motor hardware	0.4500 kg at station 1054 mm
Propellant	0.5162 kg at station 1033 mm
Mass: lift-off / end of burn	2.0962 kg / 1.5800 kg
Centre of gravity: lift-off / end of burn	779.2 mm / 696.4 mm
Normal force at low speed, Nose (tangent ogive)	2.000 per rad at station 120.7 mm
Normal force at low speed, Fins	9.660 per rad at station 1086 mm
Centre of pressure at low speed	920.0 mm
Stability margin at low speed: lift-off / burnout mass	2.13 cal / 3.39 cal
Margin leaving the rail	2.21 cal
Lowest margin on the ascent	2.21 cal at t = 0.16 s, Mach 0.08
Highest margin on the ascent	3.69 cal
Leaving the rail in a 4.019 m/s wind	angle of attack 9.0°, margin 1.15 cal
Apogee above the launch site	1977.5 m
Time to apogee	17.83 s
Apogee from the pad	376.9 m toward 175°
Highest airspeed / Mach number	326.2 m/s / 0.966
Highest acceleration	18.87 g
Highest dynamic pressure	0.0614 MPa
Lift-off mass	2.0962 kg
Thrust at the site over lift-off weight: average / peak	17.9 / 18.7
Speed leaving the 2.0 m rail	25.15 m/s
At burnout: time / altitude / speed	1.941 s / 322.1 m / 325.4 m/s
Launch site altitude	300.0 m
Wind at the surface / from	4.000 m/s / 200°
Rail: angle from vertical / leaning toward	3.0° / 160°
Wind aloft (above the site; linear between, the highest held above)	9.000 m/s from 240° at 300.0 m, 14.00 m/s from 290° at 1200.0 m
Drogue: diameter / drag coefficient, opens at apogee	0.3 m / 1.50
Main: diameter / drag coefficient	1.2 m / 1.50
Main opens: height / time / descent rate before it	150.0 m / 130.7 s / 15.67 m/s
Descent rate at the ground / flight time	3.799 m/s / 169.7 s
Landing from the pad	1482.3 m toward 108°

LOADS IN FLIGHT, AT THE INSTANT OF THE LARGEST BENDING MOMENT OFF THE RAIL TO APOGEE

When	t = 0.94 s, Mach 0.48, 0.8° angle of attack, q = 0.0156 MPa
Normal force	8.668 N (build-up)
Largest bending moment	0.4221 N·m at 555.8 mm from the nose
Largest shear force	4.613 N
Fin root	4.695 N shear, 0.1647 N·m bending

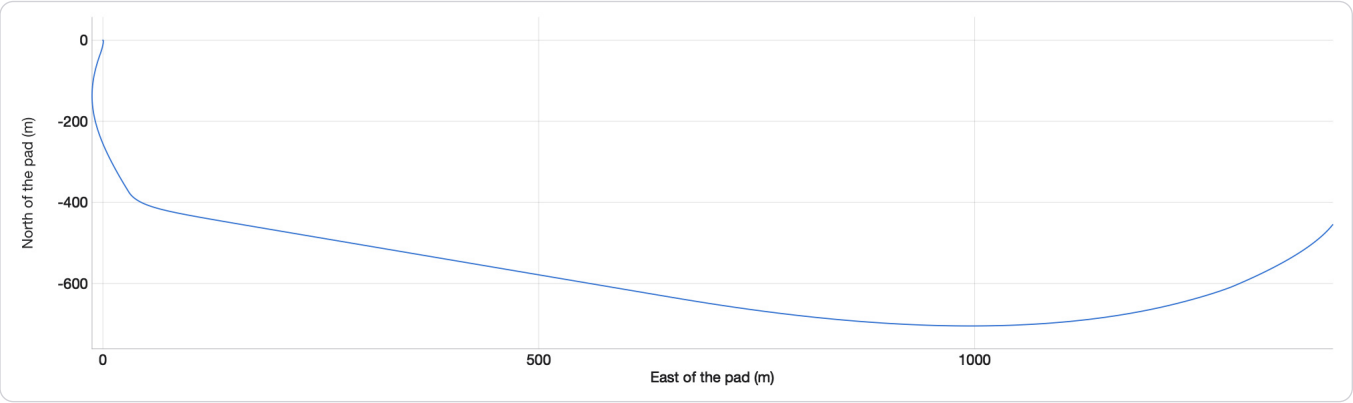
The air's normal force on each part against the inertia of the whole vehicle as a free rigid body: shear force and bending moment along the body, and the root loads of the fin square to the cross-flow. A rigid vehicle; pitch damping, gusts and the body's flexing are not in them.

Not in this report: the vehicle's 3-D CFD solutions on the CFD tab (single solves, runs through the flight, start-ups, the motor's jet). A CFD table the flight flies is in the flight above.

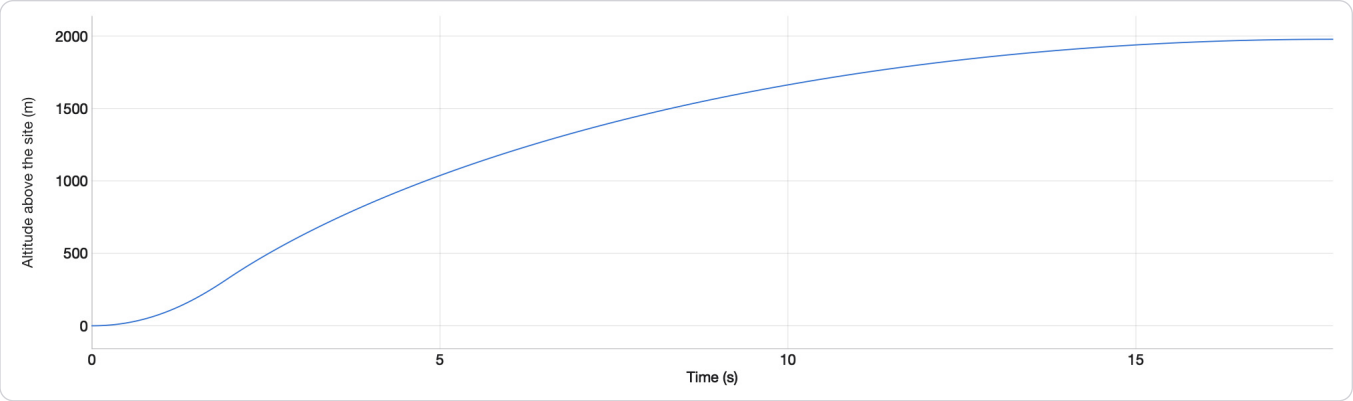
SENSITIVITY: THE VEHICLE FLOWN AGAIN WITH ONE CHANGE AT A TIME

Lift-off mass +5 %	apogee −6.4 m, highest speed −13.06 m/s, landing distance −49.7 m
Drag coefficient +10 %	apogee −100.3 m, highest speed −3.666 m/s, landing distance −86.2 m
Thrust +5 % (impulse +5 %, same burn time)	apogee +60.0 m, highest speed +12.98 m/s, landing distance +55.0 m
Wind +1 m/s at every height	apogee −7.5 m, highest speed +0.0805 m/s, landing distance +100.5 m
Rail leaned 1° more	apogee −6.9 m, highest speed +0.0324 m/s, landing distance +33.7 m

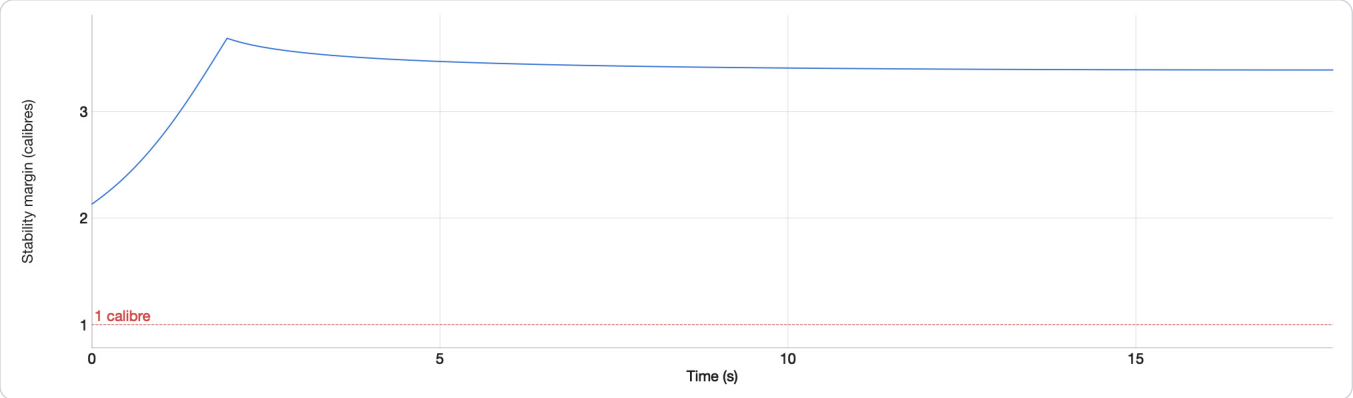
GROUND TRACK (FROM ABOVE)



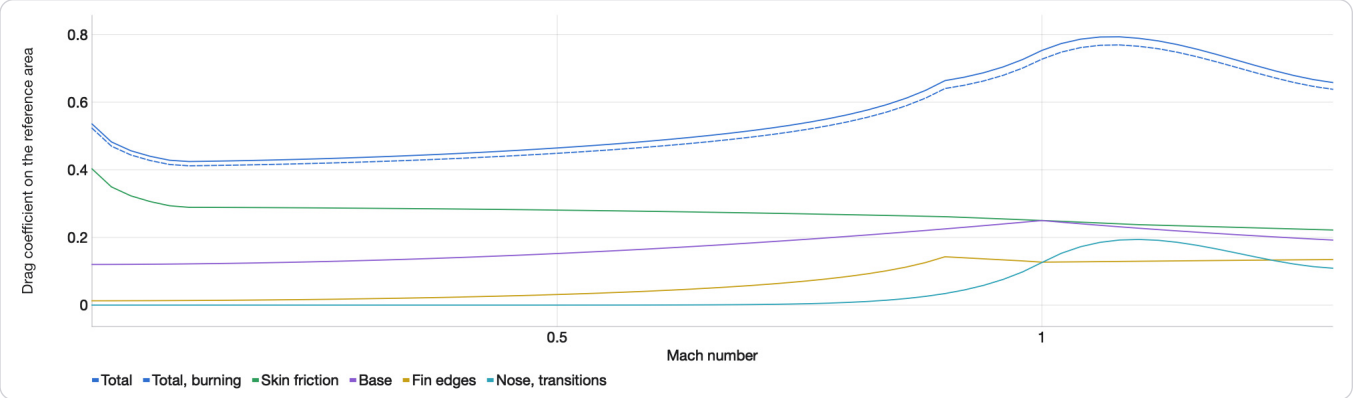
ALTITUDE TO APOGEE



STABILITY MARGIN TO APOGEE



DRAG COEFFICIENT AGAINST MACH NUMBER



ABOVE MACH 0.8 — highest Mach number 0.97. Between the subsonic and the supersonic relations the drag and the centre of pressure are interpolations; treat that part of the flight as approximate.

Flight of a rigid body in three dimensions (x east, y north, z up) from a rail 3° from the vertical leaning toward 160° in a wind of 4 m/s from 200° at the surface and 9 m/s from 240° at 300 m, 14 m/s from 290° at 1200 m above the site, its east and north components linear between them and the highest held above it. On the rail the vehicle moves along it; off the rail its axis turns about its centre of gravity in pitch and yaw (not in roll): thrust along its axis, drag along its velocity relative to the air, and across its axis the normal force of the Barrowman relations at the Mach number flown, at the centre of pressure, with the lift of the body at angle of attack (S. Niskanen, 2013, eq. 3.26), in the plane of the axis and the air met. The moment about the centre of gravity, less the pitch damping (eqs. 3.58 to 3.60 of the same document, or within its range the 3-D CFD table's where it has one), acts on the vehicle's transverse moment of inertia at that instant (each part's own, from its shape, plus its mass times its distance squared; the propellant as the burn has left it). Under the parachute it is a point mass, integrated by fourth-order Runge-Kutta with step halving, with lift-off, rail exit, apogee and landing located inside a step. Thrust is the motor's vacuum thrust curve less nozzle efficiency × ambient pressure × exit area at the altitude flown (attached nozzle flow). Mass falls by the propellant the motor has consumed. Drag is ½·ρ·v²·C_D·A on the vehicle's reference area with C_D from the drag build-up at the Mach and Reynolds numbers flown, the base drag reduced while the motor burns; from apogee the drogue (0.3 m, C_D 1.5) adds its own, and from 150 m above the site the main (1.2 m, C_D 1.5) as well, the drogue staying on. Atmosphere and gravity: U.S. Standard Atmosphere, 1976 (NASA TR R-459), launch site at 300 m above mean sea level. Lift-off mass 2.09619 kg: vehicle 1.13 kg, motor hardware 0.45 kg, propellant on board 0.516193 kg. Not modelled: roll, jet damping, the drag of the body at angle of attack, gusts, vertical wind, rail friction, parachute opening time, ignition and shutdown transients of the motor. Vehicle 1.16 m long, reference diameter 0.066 m (the largest body diameter: one calibre), reference area π/4·d². Mass: every part is a mass at a station; structure at the centroid of its surface, fins at the centroid of their planform, motor hardware at station 1.05392 m; the propellant where the burn has left it (grain ports and end faces burnt back by the web; a nitrous oxide tank with its liquid settled aft). Centre of pressure: Barrowman's method (J. S. Barrowman, M.S. thesis, Catholic University of America, 1967; NASA NTRS 20010047838). Body pieces by slender-body theory, C_Nα = 2·ΔA/A_ref, at every Mach number. Fins below Mach 1 by Diederich's relation with the compressibility factor, at the quarter-chord point of the mean aerodynamic chord; above Mach 1 by first-order strip theory with the fin-tip Mach cone, and between Mach 1 and Mach 1.70622 the Mach-1 value is held (this program's bridging of the transonic gap). Fin-body interference 1 + r/(s + r) on the fins; the lift the fins carry over onto the body is left out, which places the centre of pressure further forward. The stability margin is (centre of pressure − centre of gravity)/calibre at zero angle of attack (with a 3-D CFD table flown, the table's centre of pressure at its first angle within its Mach range, where its normal force grows from zero). Drag at zero angle of attack: turbulent skin friction with roughness 20 µm and compressibility corrections (Barrowman eqs. 4-4 to 4-16), nose, shoulder and boattail pressure drag, fin edge drag and base drag (S. Niskanen, 2013, section 3.4 and appendix B; Barrowman eqs. 4-17 to 4-22). While the motor burns the nozzle exit area is taken out of the base area. The Mach sweep is at the launch site's air (300 m, 1976 standard atmosphere). No launch lugs or rail buttons given. Not modelled: fin-body interference drag, drag due to angle of attack, roll.

MODEL AND LIMITS

Solid motor: quasi-steady burn of 1 grain segment entry (cylindrical, closed-form burnback), 402 curve points, integrated in web distance by 3-point Gauss-Legendre. Performance values are at the instant of peak chamber pressure (t = 0.97051 s); totals are in the burn block. Propellant "KNSB — potassium nitrate / sorbitol, 65/35 (Nakka)" (built-in entry KNSB-NAKKA). Burn rate: burnRateRanges[2] of 5, 1.5 MPa to 3.79 MPa, a = 7.852 (r in mm/s, p in MPa), n = -0.013; source: R. Nakka, "KN-Dextrose & KN-Sorbitol Propellants, Burn rate Experimentation", Table 2, metric columns, strand burner; nakka-rocketry.net/bntest.html; read 2026-10-11. Density 1841 kg/m³; source: R. Nakka, "KNSB Propellant", Quality Control: ideal density 1.841 g/cm³; nakka-rocketry.net/sorb.html; read 2026-10-11. c*: stored 908.3 m/s; source: R. Nakka, "Technical Notepad - KNSB Ideal Performance Calculations" (65/35, 1000 psi), "Characteristic velocity" 908.3 m/s; nakka-rocketry.net/techsht-knsb.htm; read 2026-10-11; c* efficiency 1. Gamma 1.137; source: R. Nakka, "Technical Notepad - KNSB Ideal Performance Calculations" (65/35, 1000 psi), "Specific heat ratio, 2-ph flow" 1.137; nakka-rocketry.net/techsht-knsb.htm; read 2026-10-11. Nozzle: ideal constant-gamma Cf [RPE9 Eq. 3-30] × nozzle efficiency 1. Assumptions: all burning surfaces ignite at t = 0; no ignition transient, chamber filling or tail-off (thrust drops to zero at burnout); uniform chamber pressure along the grain; gas stored in the volume freed by burnt propellant neglected; burn rate depends on pressure only (no erosive burning, no grain-temperature effect); outer grain surface bonded to the case; one gamma (two-phase losses only through the efficiencies); attached nozzle flow. Delivered Isp is total impulse over burnt propellant weight and includes no ignition, tail-off or sliver loss. Erosive burning not screened: the propellant entry gives no gas viscosity.

Preliminary design values. They are not qualification data: verify independently and by test before any hardware decision.