UAV Battery Efficiency Estimator

Aerospace Math Appendix (Unicode Safe)

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0) Symbols & Notation

ρ	Air density ($kg \cdot m^{-3}$)
ρ_0	Sea-level density (1.225 $kg \cdot m^{-3}$)
V	True airspeed ($m \cdot s^{-1}$)
q	Dynamic pressure = $\frac{1}{2}\rho V^2$ (Pa)
S	Wing planform area (m^2)
b	Wingspan (m)
AR	Aspect ratio = b^2/S (—)
W	Weight (N) = m g
C^L	Lift coefficient (—)
C^D	Drag coefficient (—)
$C^D{}_0$	Parasite drag coefficient (—)
e	Oswald efficiency factor (—)
η_p	Propulsive efficiency (—)
P	Shaft/electrical power (W)
BSFC	Brake-specific fuel consumption ($g \cdot kWh^{-1}$)
ΔT	Skin/air temperature rise (°C)

1) Standard Atmosphere (ISA Troposphere ≤ 11 km)

Sea-level reference: ρ_0=1.225 $kg \cdot m^{-3}$, P_0=101325 Pa, T_0=288.15 K, lapse L=0.0065 $K \cdot m^{-1}$, R=287.05 $J \cdot kg^{-1} \cdot K^{-1}$, g=9.80665 $m \cdot s^{-2}$.

$T(h) = \max(1, T_0 - Lh)$

$P(h) = P_0 \cdot (1 - Lh/T_0)$^$(g/(R \cdot L))$

$\rho(h) = P(h)/(R \cdot T(h))$

$\sigma = \rho/\rho_0$

2) Rotorcraft Induced-Power Scaling

Ideal induced power ∝ $1/\sqrt{\rho}$. Model factor: f_ρ = $1/\max(0.3, \sqrt{\sigma})$.

P_hover_scaled = P_hover_nominal × f_ρ

3) Fixed-Wing Aerodynamics & Power Required

Lift: $C^L = W/(qS)$. Aspect ratio $AR = b^2/S$. Parabolic drag polar: $C^D = C^D{}_0 + kC^{L2}$ with $k = 1/(\pi\ e\ AR)$.

$D = q\ S\ C^D$

$P\_req = (D \cdot V)/\max(0.3, \eta_p)$

Safeguards: $C_{D0} \geq 0.05$; $e \leq 0.70$; $0.55 \leq \eta_p \leq 0.65$.

4) Battery Fixed-Wing Power Model (App Implementation)

$P\_tot = hotel + (1+f\_install) \cdot P\_req$, hotel≈15 W, f_install≈0.15; mission penalties and gust penalties applied multiplicatively.

5) Multirotor Power Model (App Implementation)

Baseline draw P_0 from profile, scaled by mass and density plus parasitic $\propto V^2$.

$P \approx P_0 \cdot (m/m\_base) \cdot f\_\rho + 0.018 \cdot (V\_km/h)^2$

Then gust/mission penalties applied.

6) Thermal Model (Convective + Radiative)

Waste heat Q_w ≈ total electrical (battery) or shaft+hotel (ICE).

$h \approx (10.45 - V + 10\sqrt{V}) \cdot (\rho/\rho_0)$

$k\_rad = 4\varepsilon\sigma T_a^3$

$K = (h + k\_rad) \cdot A$

$\Delta T = Q\_w / \max(1,K)$

$\Delta T \leftarrow \Delta T \cdot (1 - 0.35 \cdot CC)$

7) Gust Penalty

Fractional penalty $\varphi\_g \leq 0.35$.

$\varphi\_g = \mathrm{clamp}[0,0.35]\{1.5 \cdot (g\_ms/V)^2 \cdot (WL\_ref/WL)^{0.7} + 0.03 \cdot (W\_ms/8)\}$

$g\_ms \approx 0.6 \cdot g$, $WL\_ref=70\ N \cdot m^{-2}$

8) Climb/Descent Energy

Battery: E_climb = (m g h)/3600 Wh; Descent recovery ~20%. ICE: convert mgh to kWh, multiply by BSFC, divide by fuel density.

9) Endurance & Reserve Policy

Battery: E_use = 0.85·E_pack. t_raw = 60·E_use/P_tot; t_dispatch = 0.70·t_raw. ICE: usable fuel=0.90·tank−climb+assist savings.

10) Wind-Vector Range

Given V_air, W: distance_best = (V_air+W)·t_h; distance_upwind = max(0,(V_air−W)·t_h). If W ≥ V_air, upwind=0.

11) Hybrid Assist

Fraction f of total power from battery for τ minutes. Fuel saved ≈ LPH(P_tot·f)·(τ/60). Thermal: ΔT ← ΔT·(1 − 0.3f).

12) Detectability Scores

AI visual: altitude, speed, gusts, clouds, stealth. IR: ΔT norm, altitude attenuation, cloud attenuation, ICE bias, stealth.

13) Uncertainty & Safeguards

Endurance ±10%. Clamps: σ floor; η_p range; e bound; C_{D_0} floor; ΔT ≥ 0.2°C.

14) Constants

App default constants:

RHO0	$1.225\ kg \cdot m^{-3}$
P0	101325 Pa
T0K	288.15 K
LAPSE	$0.0065\ K \cdot m^{-1}$
R_AIR	$287.05\ J \cdot kg^{-1} \cdot K^{-1}$
G0	$9.80665\ m \cdot s^{-2}$
SIGMA	$5.670374419 \times 10^{-8}\ W \cdot m^{-2} \cdot K^{-4}$
USABLE_BATT_FRAC	0.85
USABLE_FUEL_FRAC	0.90
DISPATCH_RESERVE	0.30
HOTEL_W_DEFAULT	15 W
INSTALL_FRAC_DEF	0.15

15) Code Cross-Reference

air_density(), density_ratio(), rotorcraft_density_scale(), drag_polar_cd(), aero_power_required_W(), realistic_fixedwing_power(), gust_penalty_fraction(), convective_radiative_deltaT(), climb_energy_wh(), climb_fuel_liters(), heading_range_km(), bsfc_fuel_burn_lph(), compute_ai_ir_scores(), render_detectability_alert().

16) Assumptions & Limitations

• Valid for small/medium UAV regime. • No compressibility corrections (V ≪ transonic). • Detectability heuristic only. • Hybrid assist neglects internal resistance and thermal lags. • Terrain/stealth penalties applied multiplicatively.