DBF Team Application Test:
Propulsion & Avionics Team

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Part I
General Test: Scoring Sensitivity Analysis

I. Introduction

The annual AIAA Design, Build, Fly (DBF) competition presents a complex engineering challenge where the final score is a function of both flight performance and the quality of a technical design report. A thorough interpretation of the competition rules and scoring formula is paramount, as it directly translates mission objectives into quantifiable design requirements [2]. This analysis seeks to deconstruct the 2024-2025 scoring rubric to identify the most influential parameters and guide the design process toward a configuration that maximizes the potential competition score. By understanding how variables such as payload weight, lap time, and assembly time affect the final score, a team can make informed trade-offs, allocate resources effectively, and optimize its design for competitive success.

II. Identification of Scoring Parameters

The final Competition Score is determined by the product of the Total Report Score and the Total Mission Score, with a minor bonus for participation. The primary performance driver is the Total Mission Score, defined as the summation of four distinct mission scores:

$$\text{Total Mission Score} = M1 + M2 + M3 + GM \tag{1}$$

The key design and performance variables are embedded within the scoring formula for each mission.

A. Mission 1: Delivery Flight (M1)

The M1 score is a binary value of 1.0 awarded for the successful completion of three laps within a five-minute window. The only variable is mission success.

B. Mission 2: Captive Carry Flight (M2)

The M2 score is normalized based on a team's performance relative to the top-performing team. The core variable is the Mission 2 Rated Score (R_{M2}):

$$R_{M2} = \frac{W_{\text{Fuel}}}{t_{M2}} \tag{2}$$

where W_{Fuel} is the weight of the fuel carried and t_{M2} is the time to complete three laps. The primary trade-off is between maximizing payload (W_{Fuel}) and minimizing flight time (t_{M2}).

C. Mission 3: Launch Flight (M3)

Similar to M2, the M3 score is normalized. The Mission 3 Rated Score (R_{M3}) is defined as:

$$R_{M3} = N_{\text{Laps}} + \frac{S_{\text{Bonus}}}{W_{X1}} \tag{3}$$

where N_{Laps} is the number of laps flown prior to launch, S_{Bonus} is the bonus score for landing accuracy of the X-1 test vehicle, and W_{X1} is the weight of the X-1 vehicle. This formula creates a strong incentive to minimize W_{X1}.

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III. Quantitative Analysis and Graphical Results

To investigate the relationships between design choices and scores, analytical models were developed and visualized.

A. Mission 2: Fuel Weight vs. Lap Time Trade-Off

A performance model was created to analyze the M2 trade-off. It assumes a baseline 3-lap time of 120 seconds, with a non-linear time penalty for each pound of fuel carried to account for the increase in both mass and induced drag [1]. The results, plotted in Figure 1, illustrate that the M2 score is not maximized at the highest possible fuel load. An optimal fuel weight exists where the benefit of the additional weight is balanced by the penalty of increased flight time. For the given model, this optimum occurs at approximately 3.9 lbs of fuel.

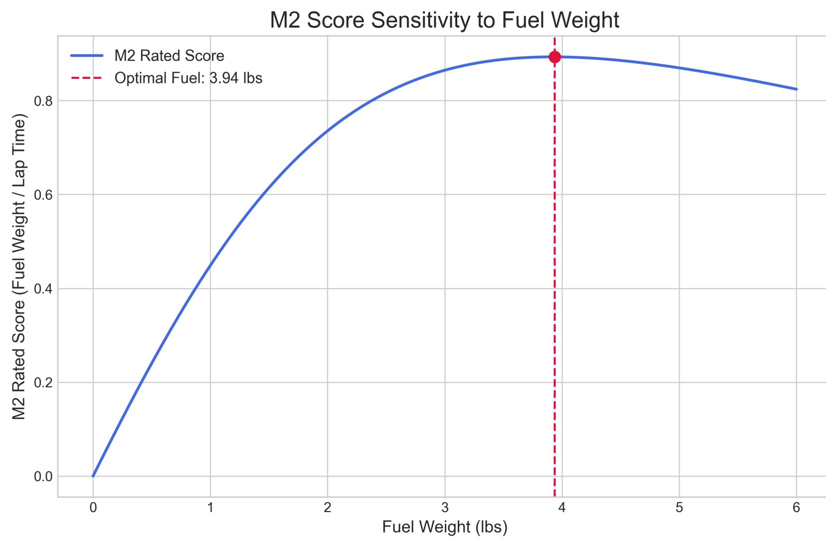

Fig. 1 M2 Rated Score as a function of fuel weight, demonstrating the existence of an optimal payload.

B. Mission 3: X-1 Vehicle Weight Sensitivity

The M3 bonus component (S_{Bonus}/W_{X1}) is highly sensitive to the X-1 vehicle's weight. As shown in Figure 2, the relationship is hyperbolic, indicating that for any given landing accuracy, the score is maximized by minimizing W_{X1}. This analysis reveals that landing a very light (e.g., 0.1 lb) vehicle in the lowest-value bonus box can yield a higher score than landing a maximum-weight (0.55 lb) vehicle in the highest-value box.

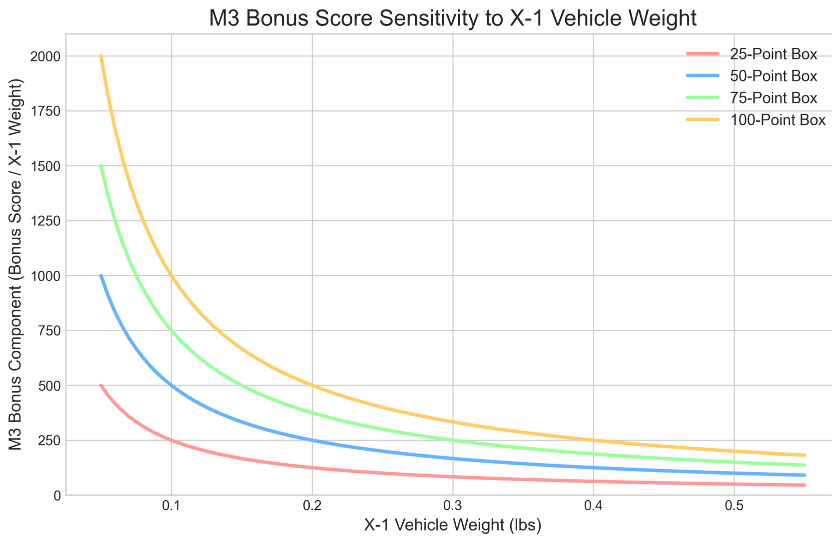

Fig. 2 M3 Bonus Component as a function of X-1 vehicle weight for different bonus box scores.

IV. Strategic Prioritization of the Design Report

The Design Report constitutes a significant portion of the final competition score, with the rubric allocating points unevenly across sections. A strategic allocation of team resources is therefore critical.

A. Tier 1: Highest Priority Sections

The **Preliminary Design** (20 points) and **Detail Design** (30 points) sections collectively account for 50% of the report score. These sections require the most rigorous engineering effort.

- **Preliminary Design:** This section must narrate the design evolution, justifying key decisions through trade studies and analysis. It should present the core performance predictions that validate the chosen concept.
- **Detail Design:** This section must provide a comprehensive description of the final aircraft. The Drawings Package (15 points) is a critical component, requiring high-quality, dimensioned CAD drawings. A detailed Weight and Balance table for all mission configurations is also essential to demonstrate design maturity.

B. Tier 2: Foundational Sections

The **Conceptual Design** (15 points) and **Performance Results** (10 points) sections are foundational to the report's credibility.

- **Conceptual Design:** This section must include the scoring sensitivity analysis and a logical down-selection process for the aircraft configuration.
- **Performance Results:** This section validates the entire design process by comparing flight test data to the analytical predictions presented earlier. Documenting and explaining discrepancies is crucial for demonstrating a thorough engineering process [3].

C. Tier 3: Compliance and Completeness

The remaining sections (Management, Manufacturing, Testing, etc.) and adherence to formatting rules are essential for securing a top score. Penalties for exceeding page limits or file sizes can easily negate points earned in technical sections, making strict compliance a high priority.

Part II
Propulsion & Avionics Specific Test

Nomenclature

W	Weight (lbf)
S	Wing area (ft^2)
AR	Aspect ratio (–)
e	Oswald efficiency factor (–)
$C_{L,\max}$	Maximum lift coefficient (–)
$C_{L,\mathrm{TO}}$	Lift coefficient used during ground roll (–)
C_{D0}	Parasite (zero-lift) drag coefficient (–)
k	Induced-drag factor = $1/(\pi e\,\mathrm{AR})$ (–)
μ	Rolling-friction coefficient (–)
ρ	Air density (slug/ft^3)
V	True airspeed (ft/s)
q	Dynamic pressure = $\frac{1}{2}\rho V^2$ (lbf/ft^2)
T	Thrust (lbf)
D	Drag (lbf)
n	Load factor (–)
RPM	Propeller rotational speed (rev/min)
Pitch	Propeller geometric pitch (in)
V_{pitch}	Ideal pitch speed = Pitch $\cdot$ RPM$/720$ (ft/s)
η_{prop}	Propulsive efficiency (–)

V. Introduction

DBF missions impose tight takeoff, turning, and endurance constraints at modest speeds. Early in the design cycle, teams must screen sponsored motor/propeller options using bench data, plausible aerodynamic parameters, and site altitudes. This Python tool implements a conservative calculation chain suitable for preliminary selection.

VI. Methods

A. Standard Atmosphere and Density

For each test altitude h (ft), density $\rho(h)$ is computed from a tropospheric International Standard Atmosphere (ISA) model (pressure/temperature lapse with the ideal-gas relation).[7, 8]

B. Aerodynamics and Stall

We assume the parabolic drag polar

$$C_D = C_{D0} + k\,C_L^2, \qquad k = \frac{1}{\pi e\,\mathrm{AR}}, \tag{4}$$

and the load-factor-dependent stall speed

$$V_{\mathrm{stall}}(n) = \sqrt{\frac{2nW}{\rho S C_{L,\max}}}. \tag{5}$$

These relations are standard in aircraft performance texts.[1, 4]

C. Takeoff Ground Roll

Liftoff speed is set by certification-style margin:

$$V_{\text{LOF}} = 1.2\,V_{\text{stall}}(n{=}1), \tag{6}$$

and the ground run is integrated using average forces: runway drag from an average coefficient $C_{D,\text{ground}} = C_{D0} + kC_{L,\text{ground}}^2$, rolling friction $\mu(W - L_{\text{avg}})$, and density-corrected static thrust

$$T_{\text{corr}} = T_0\left(\frac{\rho}{\rho_{\text{SL}}}\right), \tag{7}$$

where the ρ-proportionality follows the propeller thrust coefficient $T = C_T \rho n^2 D^4$ at fixed n, D.[9] The kinematics are $a = F_{\text{net}}/m,\ s = \frac{V_{\text{LOF}}^2}{2a},\ t = \frac{V_{\text{LOF}}}{a}$. The design is viable if $s \le 30$ ft.[1, 2]

D. Propeller Thrust–Speed Model

Given bench static thrust T_0, RPM, and geometric pitch, we define the ideal pitch speed

$$V_{\text{pitch}} = \frac{\text{Pitch} \cdot \text{RPM}}{720} \quad (\text{ft/s}), \tag{8}$$

and use a conservative linear decay of available thrust

$$T(V) = \begin{cases} T_0\left(1 - \frac{V}{V_{\text{pitch}}}\right), & V < V_{\text{pitch}}, \\ 0, & V \ge V_{\text{pitch}}. \end{cases} \tag{9}$$

Static thrust is density-corrected as above. Although simplified, this is consistent with the non-dimensional propeller formulation $T = \rho n^2 D^4 C_T(J)$ and $J = V/(nD)$ used in propeller performance.[9, 10]

E. Maximum Sustainable Speed and Cruise

For straight flight (n=1) we find the largest speed where thrust exceeds drag:

$$\text{find } V_{\max} = \max\{V :\ T(V) \ge D(V)\}, \quad D(V) = qS\left(C_{D0} + kC_L^2\right),\ C_L = \frac{W}{qS}. \tag{10}$$

Cruise is set to a margin below the cap, $V_{\text{cruise}} = 0.9\,V_{\max}$. We also cap the search at $0.95\,V_{\text{pitch}}$ to avoid unrealistic over-pitch operation.

F. Adaptive Turn Load Factor

Rather than fixing n=3 outright (which can be infeasible at DBF scales), the algorithm searches $n_{\text{turn}} \in [1, 3]$ (descending) for the highest load factor that admits both a solution $T \ge D$ and a turn speed above a safety margin:

$$V_{\text{turn}} \ge 1.2\,V_{\text{stall}}(n_{\text{turn}}). \tag{11}$$

Turn geometry then uses coordinated-turn relations:

$$R = \frac{V_{\text{turn}}^2}{g\,\tan\phi}, \qquad n = \frac{1}{\cos\phi} \ \Rightarrow\ \tan\phi = \sqrt{n^2 - 1}, \qquad R = \frac{V_{\text{turn}}^2}{g\sqrt{n^2 - 1}}. \tag{12}$$

These formulas follow standard FAA and performance texts.[5, 6]

G. Course Timing & 5-Minute Mission

One lap comprises straights of 500 ft + 1000 ft + 500 ft at V_{cruise} and arcs 180° + 360° + 180° at V_{turn}. The first lap adds takeoff time and a fixed 75 ft climb. The time-limited lap count is $N_{\text{time}} = \left\lfloor \frac{300 - (t_{\text{TO}} + t_{\text{climb}} + t_{\text{lap}})}{t_{\text{lap}}} \right\rfloor + 1$ if the first lap fits.

H. Energy Model and MTOW-Aware Battery Sizing

Electrical power is modeled from aerodynamic power with a lumped propulsive efficiency:

$$P_{\text{elec}} = \frac{D\,V}{\eta_{\text{prop}}}, \tag{13}$$

with segment-specific drag D and speed V.[1, 4] Per-lap energy sums cruise and turn segments; takeoff energy uses the bench input power for t_{TO}. Battery mass is then sized from required energy and pack-level parameters (DoD, Wh/kg). If the resulting total mass exceeds MTOW, the algorithm reduces the planned lap count and re-sizes until MTOW is met, iterating weight-dependent speeds/drag each time. The final battery mass, total weight, speeds, and lap count are then recorded.

VII. Application in the Python Script (Method -> Code Mapping)

This section summarizes how the preceding methods are instantiated in the accompanying Python analysis.

Data and Code Availability The Python scripts and input CSVs used to produce all results are available at DBF-Medellin-Recruiment-Process-2025-2026. This paper corresponds to release `v1.0` (accessed Aug 15th).

A. Configuration and Inputs

Mission, geometry, and modeling constants are defined at the top of the script: `FLIGHT_TIME_LIMIT_S`, `COURSE_ALTITUDE_FT`, `LOAD_FACTOR_N_MAX`, `WING_AREA_FT2`, `ASPECT_RATIO`, `CD0`, `CL_MAX`, `MU_ROLL`, `ETA_PROPULSIVE`, `BATTERY_DOD`, `BATTERY_ENERGY_DENSITY_Wh_per_kg`, `MTOW_LB`, etc. The sponsored components are read from `tmotor_data.csv` via `pandas`.

B. Standard Atmosphere and Density

ISA density, $\rho(h)$, is computed by `isa_density_slug_ft3_from_alt_ft(alt_ft)` using the tropospheric lapse model and ideal gas law; the main loop sweeps user-defined altitudes `ALTITUDES_FT` and passes the resulting ρ into all performance functions.

C. Aerodynamics: Stall and Drag

The class `Aircraft` holds $(S, C_{L,\max}, C_{D0}, e, \text{AR}, \mu, C_{L,\text{ground}})$. The induced factor $k = 1/(\pi e\,\text{AR})$ is provided by `induced_factor(...)`. Stall speed is computed by `stall_speed_fps(W, rho, S, CL_MAX, n)` implementing $V_{\text{stall}}(n) = \sqrt{2nW/(\rho S C_{L,\max})}$. Total drag uses the parabolic polar in `D_lbf(V, rho, W, S, CD0, k, n)`.

D. Propeller Model and Pitch Speed

Prop pitch (in) is parsed from strings like `G30*10.5` by `get_prop_pitch_in(...)`. Pitch speed is `Vpitch_fps = (pitch_in * RPM) / 720.0`. Available thrust follows the linear model `T_available_lbf(V, T0, Vpitch)` with density-corrected static thrust

$$T_0(\rho) = T_{0,\text{bench}}\left(\frac{\rho}{0.002377}\right).$$

E. Maximum Sustainable Speed and Cruise

`solve_max_speed_fps(...)` searches $V \in [V_{\text{stall}}(n),\ \alpha\,V_{\text{pitch}}]$ with $\alpha = 0.95$ and returns the largest V such that $T(V) \geq D(V)$. For straight flight the code calls this with $n = 1$; cruise is set as `V_cruise = 0.9 * Vmax`.

F. Adaptive Turn Load Factor

`find_feasible_turn(W, rho, S, CD0, k, T0, Vpitch, n_max)` descends from $n_{\max} = 3$ in small steps, calling `solve_max_speed_fps` at each n and accepting the highest n_{turn} that admits a feasible speed above the safety floor $V_{\text{turn}} \geq 1.2\,V_{\text{stall}}(n_{\text{turn}})$. The chosen $(n_{\text{turn}}, V_{\text{turn}})$ are returned for turn geometry and power.

G. Takeoff Ground Roll

`calculate_takeoff_performance(aircraft, W, T_static, rho)` uses $V_{\mathrm{LOF}} = 1.2\,V_{\mathrm{stall}}(n{=}1)$, an average ground drag $C_{D,\mathrm{ground}} = C_{D0} + k\,C_{L,\mathrm{ground}}^2$, rolling friction $\mu(W - L_{\mathrm{avg}})$, and density-scaled thrust to form F_{net}. It then applies $a = F_{\mathrm{net}}/m$ and returns $s_{\mathrm{TO}} = V_{\mathrm{LOF}}^2/(2a)$ and $t_{\mathrm{TO}} = V_{\mathrm{LOF}}/a$.

H. Course Timing and Geometry

Given `V_cruise` and `V_turn`, the lap time is assembled in `size_battery_and_laps(...)` from

- straights: `(500 + 1000 + 500) / V_cruise`;
- arcs: $t_{180} = \pi R/V_{\mathrm{turn}}$, $t_{360} = 2t_{180}$ with $R = V_{\mathrm{turn}}^2/\big(g\sqrt{n_{\mathrm{turn}}^2 - 1}\big)$.

The first lap adds `t_TO` and a small fixed climb time.

I. Electrical Power and Energy

Aerodynamic power is converted to electrical by `electrical_power_required_W(D, V, ETA_PROPULSIVE)` implementing $P_{\mathrm{elec}} = D\,V/\eta_{\mathrm{prop}}$ for straights and turns separately. Takeoff energy uses the bench input power `Input Power (W)` for the duration `t_TO`.

J. MTOW-Aware Battery Sizing Loop

The core routine `size_battery_and_laps(...)` iterates:

1) assume a battery mass $\Rightarrow$ compute total weight W;
2) compute $V_{\max}(n{=}1)$, V_{cruise}, $(n_{\mathrm{turn}}, V_{\mathrm{turn}})$, t_{lap}, and t_{TO};
3) compute per-lap energy (straights + turns) and takeoff energy;
4) find the largest integer lap count $N \le N_{\mathrm{time}}$ whose required energy, when converted to battery mass via DoD and Wh/kg, keeps $W \le$ MTOW;
5) update the battery mass and repeat until the mass change is < 0.05 lb or a max iteration count is reached.

If no $N \in [0, N_{\mathrm{time}}]$ fits within MTOW, the case is flagged infeasible.

K. Altitude Sweep and CSV Output

The *main* loop iterates altitudes `ALTITUDES_FT`, computes ρ, and calls `size_battery_and_laps` for each motor/prop row. It writes one record per (altitude, combo) to CSV (`OUTPUT_CSV`) including feasibility flags, speeds, turn parameters, takeoff distance/time, battery mass, total mass, and the 5-minute lap count.

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4) find the largest integer lap count $N \leq N_{\text{time}}$ whose required energy, when converted to battery mass via DoD and Wh/kg, keeps $W \leq$ MTOW;
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The *main* loop iterates altitudes `ALTITUDES_FT`, computes ρ, and calls `size_battery_and_laps` for each motor/prop row. It writes one record per (altitude, combo) to CSV (`OUTPUT_CSV`) including feasibility flags, speeds, turn parameters, takeoff distance/time, battery mass, total mass, and the 5-minute lap count.

IX. Results (Data Products)

For each altitude and motor/prop row, the script writes a CSV record including:

- Feasibility flags and takeoff distance, ≤ 30 ft check.
- V_{pitch}, V_{stall}, V_{max}, V_{cruise}.
- Selected n_{turn}, V_{turn}, turn radius, lap time.
- Sized battery mass, total mass (MTOW enforced), and 5-minute lap count.

This enables sorting by viability, laps, or margins at each field altitude.

A. Selection at Tucson (2600 ft) and Close Contenders

All comparisons below use the site density $\rho \approx 0.002\,201$ slug/ft^3 (Tucson, ~ 2600 ft MSL) and the mission/geometry assumptions in §Methods.

Selected configuration. **V10 KV160 + G30*10.5** was selected. It ties for the most laps within 5 minutes (5 laps) while also delivering the *lowest first-lap time* and *lowest per-lap time* among all 5-lap combinations. It additionally shows the tightest sustained turn radius and strong takeoff margin.

Table 1 Shortlist at ~2600 ft (sorted by first-lap time; all achieve 5 laps).

Motor	Prop	Laps	First lap [s]	Lap [s]	Cruise [mph]	n_turn	Turn [mph]	Turn R [ft]	TO dist [ft]	Weight [lb]
V10 KV160	**G30*10.5**	5	55.26	49.39	44.2	1.7	44.5	96.17	21.67	31.09
VL8022 KV170	VZ29*11	5	62.88	56.69	41.1	1.4	40.2	110.43	29.74	30.89
V807 KV170	G28*9.2	5	63.90	57.72	39.9	1.4	40.3	110.59	29.21	30.93
V10 KV160	G29*9.5	5	60.53	54.57	41.1	1.5	41.8	104.31	24.13	31.08

Why this choice (data-backed). Relative to the nearest contenders that also complete 5 laps:

- **First lap:** $t_{1\text{st}} = 55.26$ s vs. 62.88 s, 63.90 s , and 60.53 s .
- **Per lap:** $t_{\text{lap}} = 49.39$ s vs. 56.69 s, 57.72 s, and 54.57 s; absolute savings of 7.29 s, 8.33 s, and 5.17 s, respectively.
- **Straights:** Higher $V_{\text{cruise}} = 44.2$ mph and $V_{\text{max}} = 49.1$ mph shorten the three straight segments per lap, with healthy margin to pitch speed ($V_{\text{pitch}} = 52.9$ mph).
- **Turns:** Highest feasible load factor among the finalists ($n_{\text{turn}} = 1.7$) yields higher $V_{\text{turn}} = 44.5$ mph and the *tightest* radius $R = 96.2$ ft; competitors' radii are larger by about 12.9 % (VL8022/VZ29*11), 13.0 % (V807/G28*9.2), and 7.8 % (V10/G29*9.5).
- **Takeoff:** Shortest $s_{\text{TO}} = 21.67$ ft (others 24.13 ft to 29.74 ft), comfortably within the 30 ft requirement.
- **Mass/energy:** All four converge near $W \approx 31$ lb with MTOW-aware sizing (battery ~ 0.95 lb). The selected combo achieves faster times without requiring extra battery mass.

Interpretation. For this course, lap time is driven by straight-line speed and feasible turn performance. The V10 KV160 with G30*10.5 improves both: higher V_{cruise} reduces straight-segment time, and a higher feasible n_{turn} (thus higher V_{turn} and smaller R) shortens the $180° + 360° + 180°$ arcs each lap. Because multiple contenders reach 5 laps within the same 300 s window, these savings directly minimize total time and add margin against winds or execution variability.

X. Assumptions, Limits, and Extensions

Propulsor model. The linear $T(V)$ decay to V_{pitch} is conservative and simple; replacing it with $C_T(J)$ curves (e.g., UIUC) would improve fidelity.[10] **Aerodynamics.** The parabolic polar is appropriate in the DBF regime; high-C_L nonlinearities and ground effect are captured only heuristically via $C_{L,\text{ground}}$. **Energy.** Using $P = DV/\eta$ captures speed/drag dependence; more detail (RPM-dependent motor/prop efficiency, ESC and wiring losses) can be folded in later. **Turns.** The adaptive n_{turn} guarantees feasibility while honoring the $n \leq 3$ requirement.

Part III
Manufacturing Test (Design)

XI. Geometry and Control Surface

- Planform: constant chord, semi-span 300 mm, chord 100 mm, airfoil NACA 2424 (ribs from 4 mm balsa).
- Aileron: spans 150 mm (50% of the panel) from 90 mm to 240 mm along the span; chord 20 mm (aft of the 80% chord line).
- Hinge line: at 80% chord (80 mm from the leading edge).

XII. Round Balsa Spars (spanwise members at fixed chordwise stations)

Table 2 Spanwise round balsa spars and where they run.

Member	Chordwise position (from LE)	Diameter	Span coverage
Main spar	20% chord = 20 mm	Ø6 mm balsa dowel	Full span (0–300 mm)
Rear spar	65% chord = 65 mm	Ø6 mm balsa dowel	Full span (0–300 mm)
Hinge backer (fixed wing)	84% chord = 84 mm	Ø5 mm balsa dowel	Full span (0–300 mm)
Aileron leading-edge spar	92% chord = 92 mm	Ø2 mm balsa dowel	Inside aileron (90–240 mm)

A. Ribs (airfoils)

- Ribs: NACA 2424, 4 mm balsa; at (mm): 0 (root), 30, 60, 90, 120, 150, 180, 210, 240, 270, 300 (tip).
- Drill/laser holes in ribs at the chordwise stations listed above to pass the round spars.

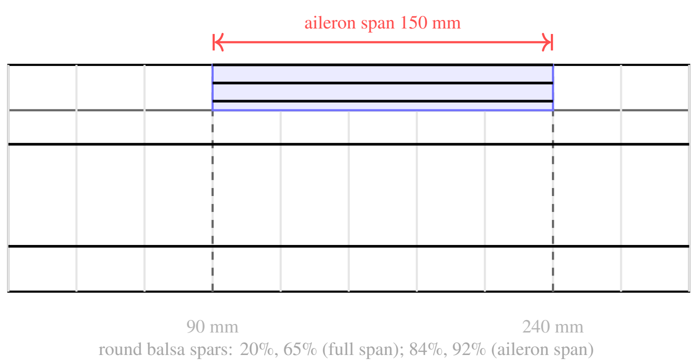

Fig. 3 Right wing planform (top view). Single aileron from 30% to 80% of the semi-span (90–240 mm), chord 20 mm. Spar lines at 20%, 65% (full span), and 80%, 84%, 92%, 100% within the aileron region.

B. Assembly

1) **Laser cut ribs with spar holes (including aileron ribs).**
    - Export the rib outlines at the chosen chord and airfoil. Add circular holes at the planned chordwise stations for all spars (main, rear, and aileron members) per the build drawing.
    - Include the same hole pattern in the ribs that sit under the aileron span so the spars (and the trailing edge member) can pass through. Mark each rib with its span station for quick indexing on the jig.
    - After cutting, lightly deburr each hole with a round file so dowels slide freely without slop.
2) **Prepare the aileron section; pass the trailing edge (TE) spar through the pertinent ribs.**

- Identify the ribs that lie within the aileron span. Dry-fit the TE spar through those ribs only so the ribs act as bearings.
- Verify the TE spar runs straight and level along the entire aileron span with even clearance in each rib hole.

3) **Install the other three spars across the full wing (including the aileron).**
   - Pin the two primary spars on a flat board at their chordwise stations (e.g., main and rear). Slide all ribs (root to tip) onto these spars and square them to the board. Dry-fit first to confirm alignment and incidence (washout ~0 for this test build).
   - Tack-glue ribs to the *fixed* spars, working from root to tip while re-checking squareness, keeping glue away from any spar that must rotate or slide relative to the ribs.
4) **Mount the servo inside the aileron; link it to the TE spar.**
   - Install the micro servo centered in the aileron pocket.
   - Attach a short pushrod from the servo arm to a control horn fixed on the TE spar. The connection point on the spar should provide a near-perpendicular pushrod at neutral to minimize bias.

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