Yellow Jacket Stingers

F3L RC Glider Optimization

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Aerospace Engineering — Advancing the Dream of Flight

Torrey Pines Gulls

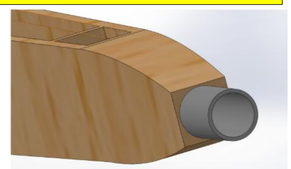
Introduction

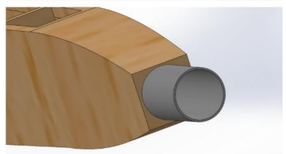
- **What is F3L?:** A provisional international soaring class for RC gliders limited to 2-meter wingspans
- **The Constraint**: High-performance "RES" (Rudder, Elevator, Spoiler) aircraft built primarily from balsa wood and carbon fiber, prohibiting the use of complex ailerons or flaps
- **The Objective**: Competition success is defined by a target flight duration of six minutes and a precision landing near a designated ground marker.
- **The Baseline:** Our project utilizes the Yellow Jacket Kit as a baseline platform for analysis, modification, and performance optimization
- **Research Goal**: The team seeks to optimize the aircraft's sink rate and aero performance through modern simulation tools



Design Modifications

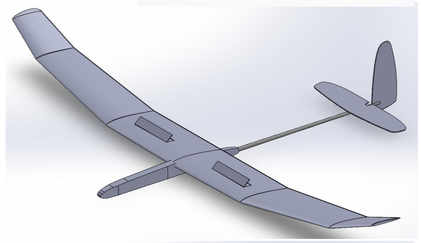
1. Structural Mass Reduction





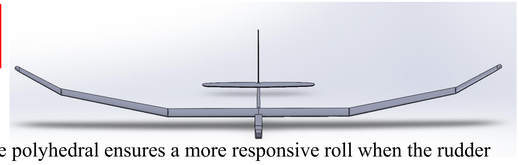
- Objective is to reduce dead weight in the carbon spars to enhance thermal duration performance and launch height
- Retain the outer diameter of the carbon spars while decreasing the inner diameter to ensure compatibility with the pre-cut balsa ribs
- Used FEA to verify that the thinner shelled carob spars could maintain a Factor of Safety (FOS) of at least 1.5 during the most extreme load that the Yellow Jacket experiences, which is during launch with headwind.

2. Split Spoiler Configuration



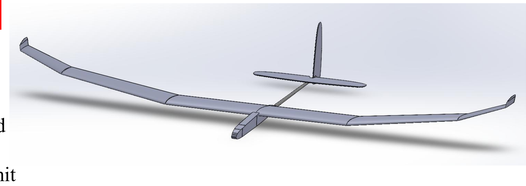
- Objective is to eliminate the turbulent wake that hits the tail that is created from the single spoiler configuration
- Dual spoilers would hypothetically ensure clean laminar flow to the tail
- Would help the pilot maintain pitch and yaw authority better during landing approaches

3. Enhanced Wing Polyhedral Angle



- Goal is to improve turn initiation for precise thermal circling
- Since F3L is limited to RES, more polyhedral ensures a more responsive roll when the rudder is applied
- Limited projected wingspan is 2m, more polyhedral leaves opportunity for more wingspan / wing area
- More wing area → lower wing loading → lower sink rate → better thermalling

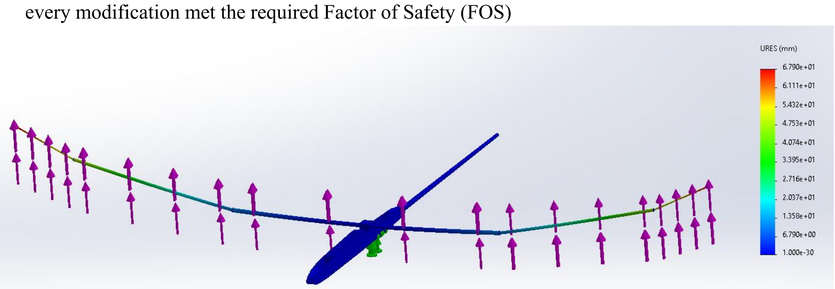
4. Integrated Winglets



- Objective is to prevent air from under the wing rolling over and creating drag
- With increased polyhedral, added winglets can take up the excess space to hit the 2M wingspan limit to optimize L/D performance

Structural Analysis

- **Methodology & Objective**: Finite Element Analysis (FEA) was utilized on our CAD models of the airplane to simulate the physical behavior or the airframe in a digital environment. By defining fixtures and applying specific forces, we predicted stresses and deflections to ensure every modification met the required Factor of Safety (FOS)



- **Optimization Goals**: The primary goal was to optimize the glider toward a 1.5 FOS under the most extreme load case, which is the launch of the glider, to eliminate "dead" weight and maximize competition duration. The 1.5 FOS was used to validate the structural integrity of the other design ideas with modifications to the wing as well.

Step	Action	Metric to Record
Baseline	FEA of Stock YJ under Extreme Limit Load	Initial: Mass, Deflection, FOS
Iteration	Apply modification	New: Mass, Deflection, FOS
Delta	Calculate % change for all three metrics vs. baseline performance	Δ%
Validation	Ensure new FOS > 1.5 under Ultimate Load	Pass/Fail
Efficiency	Calculate stiffness-to-weight change	ΔEfficiency (Target > 0)

- **Analysis Results**: All design modifications passed the final validation check. By refining the internal structure and carbon spars, we achieved a 10% total aircraft weight reduction. The modified airframe maintained a robust FOS of >2.5, significantly exceeding the minimum 1.5 requirement while reducing mass.

Manufacturing

The Yellow Jacket is an advanced, highly technical, and precise build that took over 70 hours to complete.

- **Precision balsa and composite construction** demands careful sanding and shaping of each rib, spar, and sheeting panel to maintain exact aerodynamic profiles critical for F3RES competition performance
- **Tight dimensional tolerances** throughout the airframe require constant dry-fitting and measurement before any adhesive is applied, errors compound quickly and are difficult to correct later
- **Wing joiner alignment** must be perfect; even a fraction of a degree of twist or dihedral asymmetry will cause tracking issues during soaring flight
- **Multiple adhesive types:** Cyanoacrylate and epoxy are used at different stages, requiring the builder to know which bond is appropriate for each joint and structure
- **Covering and finishing** the lightweight structure without warping the framework demands patience, heat discipline, and an experienced hand with the iron
- **All-up weight is critical:** Every gram of excess glue, filler, or paint directly impacts climb rate and glide ratio, making careful material discipline essential throughout the build

Implementation of Design Modifications

- **Lighter spars were precisely cut and dry-fitted** to the existing spar channels before any adhesive is applied, any gaps or misalignment at that stage are nearly impossible to correct once glued
- **Increasing the polyhedral angle required physically re-angling the spar joints** and re-cutting the wing saddle, then re-covering the affected panels without introducing warps or stress wrinkles into the film
- **A split spoiler demands cutting clean, straight apertures into an already-sheeted wing surface**, one of the most unforgiving operations in the entire build, where a slipped cut means replacing the sheeting entirely
- **Spoiler linkage had to be routed internally through the wing structure**, requiring careful planning of horn placement and pushrod paths before the wing is ever closed up



Aerodynamic Optimization

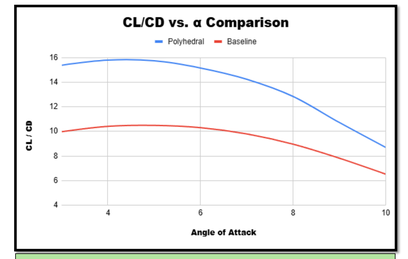
Methodology: The "Digital Wind Tunnel"

- **Software**: ANSYS Fluent 2026 was utilized to simulate 3D airflow around the aircraft geometry
- **Discretization:** The continuous fluid domain was modeled using a high-fiedilty (high accuracy), 1-million cell poly-hexcore mesh, which allows for precise calculation of boundary layer friction and pressure gradients

Ansys

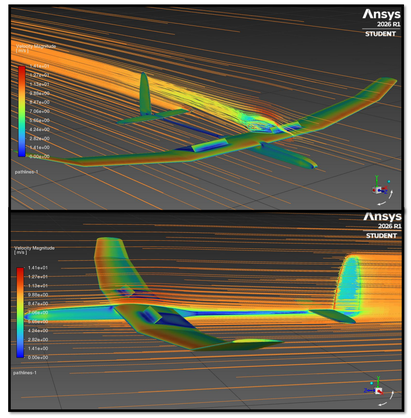
Performance Objectives

- **Thermal Efficiency:**
  - **Theory:** High-pressure air under the wing naturally rolls over the wingtips into the low-pressure zone above, creating induced drag (vortices). Winglets physically block this roll-over.
  - **Validation:** By tracking the Coefficient of Lift and Drag across a sweep of Angles of Attack, CFD mathematically guarantees that the reduction in induced drag outweighs the added skin friction.
  - **Result:** Winglets successfully shifted the maximum Lift/Drag ratio higher during low-speed, high-angle thermal circling.



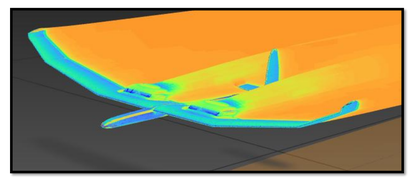
This Chart shows a higher maximum CL/CD for each angle of attack compared to the baseline model

- **Handling & Stability:**
  - **The Problem:** Deploying the stock center spoiler creates a massive wake of turbulent, separated air that directly swallows the horizontal stabilizer, eliminating the pilot's elevator authority during landing.
  - **The Solution:** The single center spoiler was redesigned into a dual-split configuration.
  - **Validation:** Velocity streamline visualizations and tail downforce calculations verify that the turbulent wake now passes harmlessly on either side of the horizontal stabilizer.



System Level Integration

- **The Problem:** Individual modifications can cause unexpected interference drag when combined on the final aircraft.
- **Validation:** A final digital wind tunnel test was run on a "Master CAD" featuring the polyhedral wing angle increase, winglets, and the dual-split spoilers.
- **Result:** Verified that the localized improvements function together without causing system-level aerodynamic penalties.



Key Improvements in Performance

1. Over a 50% increase in Lift/Drag in both flat gliding flight and high thermal climbing angle of attacks
2. 40% less vertical tail side force.
3. Less turbulent wake over the horizontal stabilizer and therefore the elevators.
4. 10% reduction in airplane weight
5. Maintained a Factor of Safety of over 2.5

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