Aerospace Design Project

Electric Training Sailplane RFP

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1. Context

The students groups shall design an aircraft following the requirements of the AIAA 2024 Graduate Team Aircraft Design Competition: https://www.aiaa.org/get-involved/students-educators/Design-Competitions. In particular they shall comply with the Graduate Team Aircraft Design Request For Proposal – Electric Training Sailplane RFP (https://www.aiaa.org/docs/default-source/uploadedfiles/membership-and-communities/university-students/design-competitions/2023_aiaa_sl_trainer_rfp_r1.pdf?sfvrsn=97921466_0).

The objective is to design a

- “modern electric self-launching sailplane suitable for training and recreational flying”;
- which satisfies the figures of merit listed in the call;
- which complies with the general requirements listed in the call.

2. Organization

Each group, of up to **maximum 8 students**, elects a coordinator who will be responsible for:

- Ensuring the transfer of information between the group members;
- Compiling the group reports from the individual contribution of each group member;
- Submitting the letters of Intent and the Report to AIAA.

During the first project session, the work will be organized into tasks for the two Work Packages (WP1 Conceptual design, WP2 Preliminary Design). For each task one student will be responsible for its completion. After the first session, the distribution of tasks between students will be sent to the project supervisors.

Before the beginning of each session, each group will deliver a short report (1 page) with the details of each student weekly achievements.

3. WP1: Conceptual design

The following items will be studied:

1/ Definition of the design missions and requirements:

- Following the Request for Proposals of the AIAA 2024 Graduate Team Aircraft Design RFP (https://www.aiaa.org/home/get-involved/students-educators/Design-Competitions).
- Following the “Figures of Merit” and “General requirements” of the Request for Proposals.
- Ensuring compatibility with the relevant FAA regulation, see e.g.
    - https://www.faa.gov/aircraft/air_cert/airworthiness_certification/std_awcert/std_awcert_regs/regs
    - https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_21_17-2A.pdf
    - https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/glider_handbook,

- https://www.faa.gov/aircraft/air_cert/airworthiness_certification/sp_awcert/light_sport
- https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-103

2/ Wing

- Design the planform (aspect ratio, surface area, taper ratio, twist, sweep angle, chord, …)
- Choose an airfoil
- Design the control surfaces
- Define the position (setting angle, position on fuselage, …)
- Compute the aerodynamic loads

3/ Empennage / canard (foreplane) / fin

- Design the geometry (aspect ratio, surface area, taper ratio, twist, sweep angle, chord, …) and choose the airfoil
- Design the control surfaces
- Define the position (setting angle, position on fuselage, …)
- Compute the equilibrium

4/ Fuselage & Landing gear design

- Fuselage geometry
- Landing gear position
- Landing gear design including brakes

5/ Propulsion

- Engine, batteries, controller, wiring, heat sink, cowl, strut, propeller, spinner etc. selection as applicable
- Pre-design (using analytical methods) of the propellers (if any)
- Breakdown of the battery system to include metrics (at least specific energy and power
- densities) at the cell level and pack/system level, and also include a technical overview of pack integration strategies.
- Payload Range diagram (for the propeller part)

6/ Structure

- Placard diagram & maneuver/gust envelopes
- Weight and center of gravity position of each component
- Material selection, including recycling possibilities
- Initial layout of internal structures
- This task is also part of the Aeronautical Structures class

7/ Static stability

- Evolution of CG (from nose), neutral point, stability in all the important flight configurations: A diagram depicting the safe center of gravity envelope with weight of each crew member, including a diagram for any removable ballast and the constraint which limits the safe CG range
- Evaluation of aerodynamic center (from nose)

- Calculation of the drag polar
- Calculation of the derivatives of CL, CD, Cm, and Cn

8/ Concepts & Trade off-study

- Concept selection trades: The design report will include trade documentation on the two major aspects of the design development,
    a) the concept selection trades, and
    b) the concept development trade studies.

  The student(s) is (are) to develop and present the alternative concepts considered leading to the down-select of their preferred concept. The methods and rationale used for the down-select shall be presented. At a minimum a qualitative assessment of strengths and weaknesses of the alternatives shall be given, discussing merits, leading to a justification as to why the preferred concept was the best design. Quantitative justification of why the selected concept is the best at meeting the measures of merit(s) will strengthen the report.
- Trade-off study (e.g. with 10 % variation of the main parameters): In addition, the submittal shall include the major trade studies conducted justifying the optimization, sizing, architectural arrangement and integration of the specifically selected concept. Quantitative data shall be presented showing why their concept 'works' and is the preferred design compromise that best achieves the design requirements.

4. WP2: Preliminary design

For this study, the following points will be addressed:

1/ Drag study

- Using the CAD geometry from part 2/, extraction of wetted areas, volume, surfaces etc.
- Detailed drag evaluation (Torrenbeek/Raymer books)

2/ CAD

- Create a solid CAD model (with mass, inertia and system integration)
- Evaluate mass, inertia and position of center of gravity from nose
- Create a realistic CAD view

3/ Aerodynamics

- Consider VLM code, and make a convergence analysis
- Compute the aerodynamic loads in various flight conditions (cruise, maneuver, …)
- Use the loads to size the structure
- Update the aerodynamic loads and stability derivatives
- Compare the drag obtained using different methods (including drag study of part 1/)

4/ Structure design

- Estimation of aerodynamics forces during maneuvers/gusts (acceleration, etc. following FAA-Part requirements)
- Estimation of the structural forces
- First design of the structure using analytical formula

- This task is also part of the Aeronautical Structures class

5/ Structure study

- CAD model with FE simulation
- Discussion of the application of aerodynamic loads
- This task is also part of the Aeronautical Structures class

6/ Propulsion

- Model the propeller with BEMT software

7/ Performance

- Reassess performance
- Reassess pitch, roll and yaw derivatives
- Reassess Payload range diagram
- Compare with OAD-ADS software
- Dynamic stability & control analysis (Datcom method)

8/ Costs evaluation

- Identify the cost groups and drivers, assumptions, and design choices aimed at the minimization of production costs.
  - Estimate the non-recurring development costs of the airplane including engineering, FAA/EASA certification, production tooling, facilities and labor.
  - Estimate the fly away cost.
  - Estimate the price that would have to be sold for to generate at least a 15% profit: Show how the airplane could be produced profitably at production rates ranging from 3-6 airplanes per month or a rate that is supported by a brief market analysis.
  - Estimate of direct operating cost per airplane flight hour: i) Tires, brakes, battery, and other consumable quantities; and ii) Estimate of maintenance cost per flight hour

5. Reports and presentation

- Follow deadlines and requirements of AIAA (https://www.aiaa.org/get-involved/students-educators/Design-Competitions)
- Reports
  - In English
  - Content in the AIAA Request for Proposal (https://www.aiaa.org/docs/default-source/uploadedfiles/education-and-careers/university-students/design-competitions/2022-graduate-team-aircraft-design-rfp-dr-saav.pdf?sfvrsn=48c010ec_0)
  - Submission of Final Design Report (see https://www.aiaa.org/docs/default-source/uploadedfiles/membership-and-communities/university-students/design-competitions/2023_aiaa_sl_trainer_rfp_r1.pdf?sfvrsn=97921466_0)
    - Each team or individual must provide an electronic copy of their design report as outlined below to the online Submission site, www.aiaa-awards.org

    - An electronic copy of the report in Adobe PDF format must be submitted to AIAA using the online submission site. Total size of the file cannot exceed 25 MB.
    - Electronic report files must be named(ex): "2024_[university]_DESIGN_REPORT.pdf"
    - A "Signature" page must be included in the report and indicate all participants, including faculty and project advisers, along with students' AIAA member numbers and signatures. If the submitting team is comprised of at-large student members, each student member needs to include the name of the university he or she attends.
    - Electronic reports should be no more than 100 pages, double-spaced (including graphs, drawings, photographs, and appendices) if it were to be printed on 8.5"x11.0" paper, and the font should be no smaller than 10 pt. Times New Roman.
  - Intermediate reports shall be of up to 50 pages.

- Presentations
  - In English
  - Describe and justify your design choices
  - Describe your methodology
  - Insist on the interactions between the parts
  - Around 35 minutes (20 minutes of presentation and 15 minutes of discussion)

- Important dates
  - Register to AIAA (**with receipt and credit card record in order to apply for refund**): before **13 November 2023. Apply for refund before end of November**
  - Letter of intent: to be submitted to AIAA (**www.aiaa-awards.org**) by **9 February 2024** 11:59pm (MIDNIGHT) Eastern Time!!! Require AIAA account!!!!
  - First report (Conceptual Design) for feedback/grading: **16 February 2024**
  - First presentation for feedback: **26 February 2024** at 1:45pm (to be confirmed)
  - Second report (Corrected Conceptual Design and Preliminary Design) for feedback/grading: **26 April 2024**
  - Final report to be submitted to AIAA Headquarters (**www.aiaa-awards.org**): **12 May 2024** 11:59pm (MIDNIGHT) Eastern Time!!! Requires AIAA account!!!
  - Final Presentations for grading: **13 May 2024** at 1:45pm (to be confirmed)

Appendix 1: Structure part guidelines

1. Tasks

1/ Conceptual Design

- Placard diagram & maneuver/gust envelops
- Weight and center of gravity position of each component
- Initial layout of internal structures

2/ Preliminary Design

- Estimation of aerodynamics forces during maneuvers/gusts
  - Acceleration etc. following FAA Part requirements
  - Wing loading
  - Empennage/canard loading
- Evaluation of the structural loads
  - On fuselage directly aft/front of the wing for tail/canard configuration
  - At wing root
  - In different flight configurations
- First design of the structure using analytical formula
  - Using the most critical structural loads
- Finite element verification
  - Using shell models based on a CAD representation
  - Discussion of the applied aerodynamics loads and boundary conditions
  - Verification of the structure integrity

2. Resources

- [Lectures] Aircraft Design (Structure & conceptual design)
- [Lectures] Aeronautical structures (available Q2)

3. Deliverables

1/ Conceptual Design

- Written chapter *Structure/weight* (or equivalent) included in conceptual design report
- Weekly short oral report on project progress

2/ Preliminary Design

- Written chapter *Structure* (or equivalent) included in final design report
- Weekly short oral report on project progress

3/ Aeronautical structures

- Extended version of the written chapter *Structure* (or equivalent), with all the details to be handed by the 24th of May 2024.

Appendix 2: List of parameters (to complete with the values of the two aircraft if they differ)

Parameters	USI	US/Imp
Fuselage		
Height: **HEIGHTfus**		
Width: **WIDTHfus**		
Length: **LENGTHfus**		
Wing		
span: **b**		
Aspect Ratio: **AR**		
Gross Surface: **S**		
Exposed: **S_exp**		
Taper Ratio: **Lambda**		
Cord at root: **Croot**		
Cord at tip: **Ctip**		
Sweep angle at chord quarter: **Lambda_quart**		
Geometric twist: **Eps_gtip**		
Mean Aerodynamic Chord: **MAC**		
X coordinate of Aerodynamic center: **Xac**		
Y coordinate of Aerodynamic center: **Yac**		
Compressibility parameter: **BETA**		
Cruise Mach: **M**		
Average airfoil thickness: **t_bar**		
Fuel volume: **V_fuel**		
Wetted wing surface: **S_wetted_w**		
Wing lift coefficient in cruise: **C_L_w**		

Wing lift coefficient derivative: **a**		
Angle of attack at root (cruise): **Alpha_root**		
Zero-lift angle of attack at root: **Alpha_L0**		
Zero-lift angle of attack of the profile: **Alpha_l0**		
Aerodynamics twist coefficient: **Alpha_01**		
Aerodynamics twist: **Eps_a_tip**		
Maximum lift coefficient of the wing (flaps in): **CLmax**		
Stall velocity (flaps in): **Vs**		
Stall velocity (flaps out): **Vs0**		
Reynolds number: **Re**		
Airfoil lift coefficient derivative: **c_l_a**		
Airfoil design lift coefficient: **c_l_i**		
Maximum camber: **cmax**		
Lift coefficient (cruise): **LW**		
Stability (for each flight configuration)		
Plane lift coefficient (cruise): **CL**		
Empennage/canard plane lift coefficient (cruise): **CLT**		
Surface of the empennage/canard: **ST**		
Fuselage angle of attack: **Alpha_f**		
Zero-lift fuselage angle of attack: **Alpha_f0**		
Pitching moment coefficient: **Cm**		
Wing pitching moment coefficient: **Cm0**		

X-coordinate of the gravity center: **Xcg**		
Empennage/canard pitching moment coefficient: **CmT**		
Empennage/canard lift: **LT**		
Non-dimensional center of gravity position: **h**		
Non-dimensional AC position: **h0**		
Non-dimensional stability limit of the center of gravity position: **hn**		
Incidence angle of the wing on the fuselage: **iw**		
Plane lift coefficient derivative: **CL_alpha_plane**		
Empennage/canard angle of attack: **Alpha_T**		
Downwash: **Eps**		
Downwash gradient: **d_eps_d_alpha**		
Vertical distance between wing and empennage/canard: **m**		
Stability margin: **Kn**		
Incidence angle of the empennage/canard on the fuselage: **iT**		
Horizontal empennage/canard		
Span: **bT**		
Aspect Ratio: **AR_T**		
Taper ratio: **Lamba_T**		
Sweep angle at chord quarter: **Lambda_quart_T**		
Chord at root: **CTroot**		
Chord at tip: **CTtip**		
Distance between the plane gravity center and the		

empennage AC: **lT**		
Vertical empennage		
Height: **bF**		
Aspect Ratio: **ARF**		
Surface: **SF**		
Taper Ratio: **Lambda_F**		
Sweep angle at chord quarter: **Lambda_quart_F**		
Chord at root: **CFroot**		
Chord at tip: **CFtip**		
Distance between the plane gravity center and the empennage AC: **lF**		
Lift coefficient (critical case): **CLF**		
Lift coefficient (critical case): **LF**		
Yaw moment coefficient (critical case): **CN**		
Yaw moment coefficient derivative: **CNbeta**		
Rudder height: **hr**		
Rudder surface: **Sr**		
Drag		
Drag (cruise): **D**		
Drag coefficient: **CD**		
Zero-lift drag coefficient**:** **CD0**		
e-factor: **E**		
Compressibility drag coefficient: **CompCD**		
Security velocity: **V2**		
Drag coefficient at security velocity: **CDV2s**		
Engine		
Take-off thrust: $\mathbf{T_{to}}$		
Cruise thrust: **T**		
Weights		

Wing: **Ww**		
Empennage/canard weight: **WT**		
Vertical empennage weight (without rudder): **WF1**		
Vertical empennage weight (with rudder): **WF2**		
n_ultime		
Cabin pressure: **DeltaPmax**		
n_limite		
Fuselage weight: **Wfus**		
Gear weight: **Wgear**		
Control weight: **Wsc**		
Propulsion weight: **Wprop**		
Instrument weight: **Winst**		
Electrical devices weight: **Welec**		
Electronical devices weight: **Wetronic**		
Payload: **Wpayload**		
Fuel weight for take-off: **Wto**		
Fuel weight for landing: **Wland**		
Reserve fuel weight: **Wres**		
Fuel weight for climb: **Wclimb**		
Fuel weight for cruise: **Wf**		
Manufacturer empty weight: **MEW**		
Zero-fuel-weight: **ZFW**		
Take-off weight: **Wto**		
Wing loading **W/S**		
Thrust to weight **T/W**		
Fuel ratio **Wf /Wto**		
Range at maximum payload: **d_etoile**		
Landing gear		
Maximum pitch angle: **Theta**		

Maximum roll angle: **Phi**		
Dihedral angle: **Gamma**		
Wing height: **Hg**		
Distance between landing gears: **t**		
Angle of attack at lift-off: **AlphaLOF**		
Lift-off speed: **V_LOF**		
Touch down angle: **ThetaTD**		
Distance between plane gravity center and aft landing gear: **lm**		
Plane gravity center height: **Zcg**		
Positions of centres of gravity:		
Xwing		
XempH		
XempV		
Xfus		
Xsyst_elec		
Xelec_instr		
Xpayload		
Xfuel		