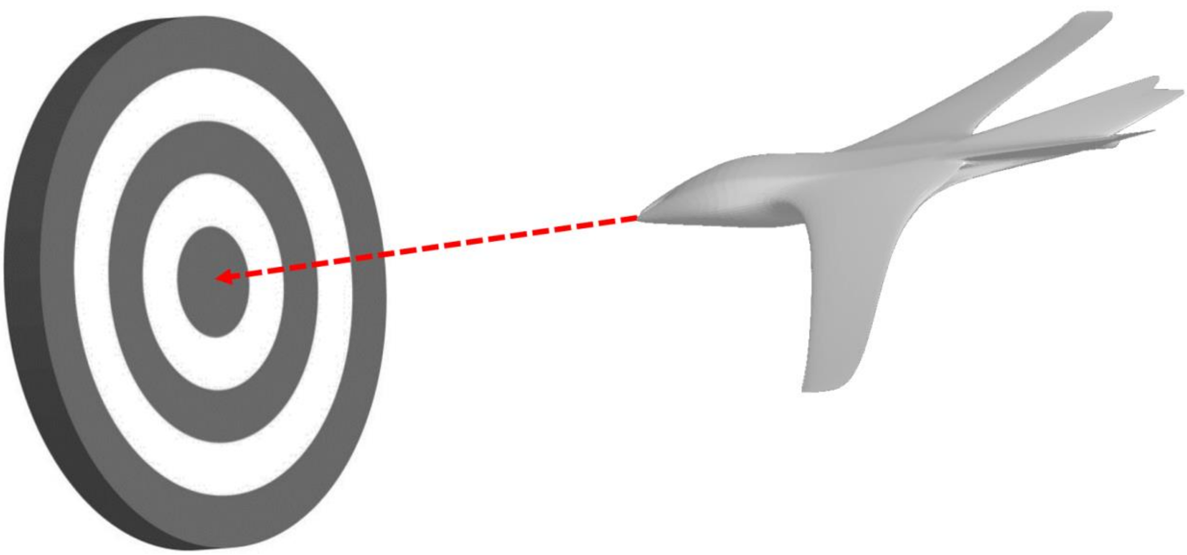
AERODYNAMICS PROJECT (VER. 1.0)

FINAL PROJECT 2024-02: HIGH PRECISION AIRPLANE (GLIDER) DESIGN CHALLENGE



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Summary (justification)

The UPB Aeronautical Engineering Faculty acting under its learning context adopts the CDIO methodology used by the engineering school from Massachusetts Institute of Technology (MIT), which tries to show the students through experimental exercises (real-life projects) the way of developing practical learning methodologies with the use of the following procedure:

- **Conceive** – The student conceives an idea to solve a problem by discussing pre-established requirements, focusing on precise objectives they want and should accomplish. For example, they define customer needs, consider technology, enterprise strategy, and regulations, and develop concepts, techniques, and business plans.
- **Develop** – The student should develop the previously conceived idea using the classical brainstorming method, in which they make a classification of the information and an analytical result analysis. Then, creating the design, the plans, drawings, and algorithms that describe what could be implemented.
- **Implement** – The student implements the developed idea by using tests to identify possible failures in regular operation, opening the option to correct the original design. The design transformation into the product includes manufacturing, coding, testing, and validation.
- **Operate** – The student operates their design once the previous steps have been overcome. They use the implemented product to deliver the intended value, including maintaining, evolving, and retiring the system.

For this activity, it would be expected that the students develop a possible solution to a problem using the resources of the knowledge extracted from the theory, applying as many tools as they can.

Each team is responsible for knowing and following all provided rules, the FAQ, and all contest day briefings.

Questions can be addressed to the contest director as outlined in the communications section at the end of this document.

1. Judging:

Students must design, document, fabricate, and demonstrate that the designed aircraft is a feasible solution for the problem and can achieve the challenge of obtaining the highest score on the specified flight mission. Flight scores are established based on some physical characteristics of the model and on demonstrative mission performance obtained during the challenge contest.

Each team must submit a written final "Design Report". A maximum grade of 5.0 can be an award for the team's "Design Report" and "Flight test", depending on their own prototype's content quality and flight qualities. Scores for the written reports are known during the technical inspection.

The overall team grade combines the final Design Report and Flight performance.

All submitted final Design Reports would pass a process of plagiarism check throughout **Turnitin ®** (moodle). In addition, the final design reports must comply with the AIAA paper template.

2. Objective

Conceive, design, construct, and operate an aerodynamic glider airplane model capable of carrying an external payload, applying the knowledge acquired during the aerodynamics course lectures and laboratory sessions to glide two high-range missions through the air with and without the required payload.

3. Requirements and constraints

All the requirements are compulsory; failure to accomplish any of them implies the probability of passing the technical inspection (first test), and therefore, a successful flight is reduced or nullified.

3.1 Requirements

a. The aircraft must be a glider vehicle (fixed wing) with no propulsion system of any kind allowed. The external payload weight and the flight model vehicle will be launched together from the highest possible location of the UPB sports center (indoors).
b. For both missions, the airplane can be initially thrust-assisted using a catapult to commence the flight (**IMPORTANT NOTE: the students' team that chose this type of initial thrust must provide the catapult**).
c. During the technical inspection and the flight test, no structure/components or external payload can fall from the airplane. Therefore, all decisions made by the safety inspector(s) during the technical inspection and the fly day are **final**.
d. The payload consists of three types of water bottles (different in shape and weight) full of liquid. Each bottle is labeled with a number (1, 2, and 3). The

label number indicates the score that will be added as a grade bonus for the second mission in the following way:

- Bottle No. 1 → 1.0
- Bottle No. 2 → 0.6
- Bottle No. 3 → 0.3

You can find more information about the grade bonus in section 8 of this document. The glider must be able to carry only one of the bottles externally exposed at the bottom part of the fuselage (airplane´s belly). These bottles will be available at building 11, 3rd level floor (office 317 – secretary´s premises). As a clarification, **the airplane must carry only one of the three bottles during flight; each group decides to select which payloads they will use for the flight**. You cannot modify the bottle´s shape; nevertheless, it is allowed to add elements to decrease the payload´s drag. Each group of students is responsible for characterizing and parametrizing each payload (materials, weight, and measures).

e. The payload and the glider model vehicle will be launched from the highest part of the south UPB sports center (indoors).
f. For the first and second missions, the model (including the payload weight) should glide through the air, allowing it to land safely inside the established areas.
g. The solution model must be a glider fixed-wing aircraft (teams are free to choose any configuration).

3.2 Constraints

a. The aerial vehicle must use aerodynamic forces to maintain a steady glide flight.
b. A propulsion system of any kind is not allowed.
c. c. The vehicle must be strong enough to withstand many flights without significantly damaging the integrity of the airplane.
d. If the model suffers any damage during the activity, the group can make (if possible) the respective repairs during the activity.
e. When the airplane is in flight, the device (model) should maintain itself as a unit; if any part falls from the vehicle, the flight is considered invalid.
f. You can have more than one model with the restriction that the other vehicle(s) must have the same design and have to pass the technical inspection. If a group uses two or more different glider models (different designs), the group will be disqualified from the activity, obtaining a grade of zero in the total final project.
g. In case of any modification of the airplane model from the moment it passes the technical inspection until the flight activity, the group will be disqualified with a grade of 0,0 in the functionality (flight) percentage.

h. If the airplane model does not comply with the minimum distance (Z1) and structural integrity requirements during the flights, the group will be graded 0,0 in the functionality (flight) percentage.

i. **The use of control systems** (e.g. transmitters, receivers, Arduino, Ardupilot, Arducopter, Raspberry-pi, etc.) **is forbidden**.

4. General rules

4.1 Group rules

The groups can have a maximum of three students. Each group must represent a specific theme, which identifies them (team and vehicle name). This team theme must be presented in the report and during the flight's due date.

4.2 Written report (design report)

A written report must be delivered in a scientific way (paper) using the AIAA template for LaTeX called "*LaTeX Template for the Preparation of Papers for AIAA Technical Conferences*" found in Overleaf using the following link:

https://www.overleaf.com/latex/templates/latex-template-for-the-preparation-of-papers-for-aiaa-technical-conferences/rsssbwthkptn#.W05bHOhubIV

Inside this paper (report), you must explain and justify each design chosen parameters, calculations, analysis of the results, and tests. Therefore, it is expected (but not limited to) that at least you have developed the following in your report:

- Abstract. (5%)
- Planning (5%) – explain a brief text of how your group developed the design project.
  - Team theme representation
  - Mission analysis (score analysis)
  - Environment Analysis
  - Payload analysis
- Procedure. (25%) – In a logically consecutive manner, explain all the theoretical calculations you developed to obtain the final design of your prototype solution (airplane).
  - Airfoil selection.
  - Aerodynamic forces analysis.
  - Wing platform design and analysis.
  - Fuselage aerodynamic design.
  - Stabilization surface design.
  - Payload arrangement analysis.
  - Glide (soaring) flight path range (performance) for the first and second missions – theoretical.

- Tests. (15%) – Explain the test's objectives and the protocols established to get the required data to be analyzed.
    - Wind tunnel tests (explaining the variables taken into consideration, such as velocities and angles of attack, among others), along with their result analysis and conclusions – considerations for the wind tunnel model must be explained, such as scaling and simplifications.
    - Aircraft's impulse throw method analysis that will be used.
    - Flight tests and result analysis (flying qualities description) – at least two (2) pictures demonstrating the airplane's flight. All groups must show the flight video as evidence of the functionality during the technical inspection. Furthermore, the team must report the structural and flight quality and the possible corrections developed during the design process to improve the aircraft's performance.
- Results analysis. (20%) – Analyze the most important theoretical and practical (tests) results obtained during the design procedure
- Technical conclusions. (20%) – explain all the technical conclusions from the design accomplished at the end. Complement this information with the following:
    - Aircraft specification table.
    - Aircraft flight characteristics table.
    - Present a 3-view drawing with the dimensions (A4 format) – the blueprints must be done by preference using CATIA® software, but you can use another CAD software.
- References. (5%) – APA format.
- Paper format. – under the AIAA paper template, orthography, and redaction (5%).

The report must be delivered as a hard copy (**no electronic reports will be received**). The full report must not exceed 15 pages, including references (NOTE: Appendices are not included in this number of pages, but a maximum of two pages are allowed for this section).

5. Milestones

Each group will have a 40-minute window for the milestone presentations to show the project work done so far in the semester. You will have to present the following basic requirements:

- General design and aircraft description, including CAD drawings with three views and dimensions.
- Description of the technical approaches to meet the proposed requirements.
- Calculation of the aerodynamic forces.
- Balance and weight.

- Wing design and Airfoil selection process.
- Payload characterization.
- The structural design process, including the payload arrangement.
- Launching system (in case of having one).
- Selected materials and manufacturing initial budget estimations.
- Originality and unique features.

All the last items should be covered during the presentations that must have at least the following:

<u>Score equation analysis</u>: Define the main factors your group aims for in the airplane's design, establishing through sensitivity studies the "design drivers" accomplishing the requirements and constraints.
<u>Payload characterization</u>: Define the general measures of the payload, including the weight study and the location of the c.g.
<u>Flight characteristics</u>: Determine the operational velocity, heights, and the aircraft´s initial weight estimation. Study the operating environment, identifying the main measures from the sports center facility, defining heights, lengths, possible obstacles, and operational times.
<u>Airfoil selection (methodology)</u>: This section explains the airfoil selection process and defines the main aerodynamic characteristics of a group of airfoils.
<u>Wing selection (methodology)</u>: From a total operational weight estimation, determine the wing design at least for the most critical flight mission. Establish the flight conditions at every flight mission.
<u>Empennage design</u>: Define the empennage design based on statistical methods.
<u>Fuselage design</u>: The fuselage should withstand the loads imparted by the aerodynamic sources and payload. You must show the approximation of this component through CAD blueprints in which the principal dimensions are identified.
<u>Aerodynamic forces calculation</u>: Define the main aerodynamic forces to which the airplane will be loaded employing mathematical models.
<u>Weight and balance</u>: Establish an approximation of the maximum weight reached by the preliminary design, which is determined by the materials you think to use to build the prototype. Determine the first approach to the c.g. location from these data and justify the results. Then, given the general airplane design and the materials used, you should calculate an approximate structural proposal to counteract the loads the aircraft will be subject to during operation.
<u>Launching system</u>: Indicate the process used to launch the airplane for the flight missions. If the airplane uses an initial impulse system other than hand-launched (e.g., a catapult system), indicate its operational characteristics.

Costs estimate: Calculate the total project cost by considering the materials selected for the airplane design.

See section 8.1 of this document for more information about the milestones.

6. Tech Inspection (TI)

- The aircraft will enter the TI fully assembled and ready to fly (RTF).
- The aircraft will undergo the wing tip lift test with installed maximum flight payload weight.
- The aircraft will be held and shaken upside down to ensure its structural strength.
- The TI will check that the prototype is the same as the one reported (measures and weights must coincide).
- The aircraft must have an indication (mark) of its c.g. in the empty and fully loaded configuration.

7. Flight activity

As mentioned, this activity will be performed inside the UPB sports center facility (see Figure 1). Each team must check this premise before the challenge flying contest to familiarize themselves with the flight environment (including possible obstacles) and dimension the field length and zones where the vehicle should fly and land safely.

7.1 About the activity (mission 1 and mission 2 explanation)

This activity will undergo as many flight trials (for each mission) as possible. Teams that accomplish the first mission will obtain the pass to perform the second mission. The group or team with the highest score will win the highest grade for this activity. In the following sections, you will find a detailed explanation of the grades obtained in the flight tests.

7.1.1 Activity general rules

The Flight Missions must be flown in order, meaning the second mission cannot be flown until the team successfully scores for the first mission. The result is considered independently, meaning that the closest to the predicted distance (for both missions) by the report are the ones taken for the final grade.

The flight tests are not done all in one, which means that during the activity, you would have time to perform any repair or minor change (if needed) to your model for the next flight test opportunity. In addition, the flight window given to accomplish missions 1 and 2 will be between 1 pm and 5 pm, meaning that you could do as many flights as possible for each mission, but with the restriction that you can only perform mission 2 when mission 1 has a valid score (the airplane lands in Z1).

Figure 1. UPB Sport's center – Top view

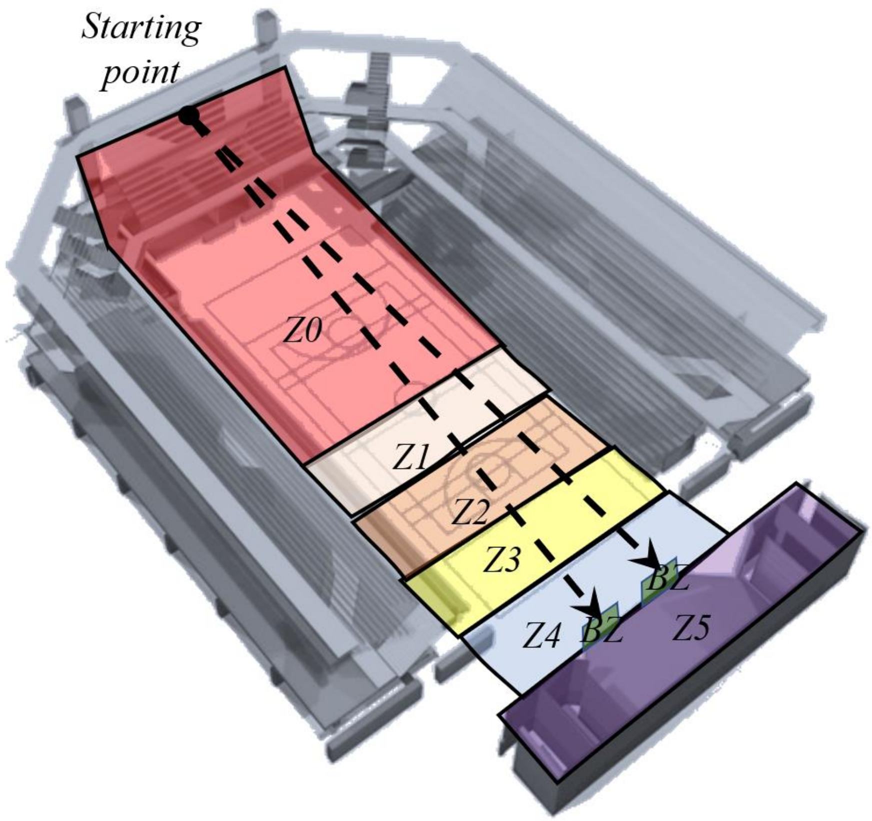

Figure 2. Demarked landing zones inside the facility

Missions 1 and 2 will account for flight distance and precision accuracy this semester. The airplane must be launched from the highest part of the upper south side of the UPB's sports center (see Figure 2 for reference). In addition, there are seven specific zones in which the aircraft can land. Airplane flight is scored depending on the zone in which it lands:

- **Zone 0 (Z0)** is red color in Figure 2.
- **Zone 1 (Z1)** is white color in Figure 2.
- **Zone 2 (Z2)** is orange color in Figure 2.
- **Zone 3 (Z3)** is yellow color in Figure 2.
- **Zone 4 (Z4)** is blue color in Figure 2.
- **Zone 5 (Z5)** is purple color in Figure 2.
- **Bonus Zones (BZ)** are established as the two goalkeepers' arc (goal area) separated in such a way that leaves a space between the two arcs; and is green color in Figure 2

The score will be multiplied by the number depending on which zone the airplane lands in; this means that if your airplane lands in Zone 0 (Z0), your flight factor ZX is zero; if it lands in Zone 1 (Z1), your flight factor ZX will be 1, etc. The BZ will have a factor of 6. The zones can be seen in Figure 2.

7.1.2 Mission 1: Aircraft mission staging

- There is no payload (bottles) for this flight.
- Teams must complete this mission within the flight window to be able to perform mission 2.
- The mission starts when the aircraft leaves the launcher's hand or the launching catapult.
- Mission finishes when any part of the aircraft **touches anything** during the glide flight path.
- To earn a score, the airplane must complete a successful landing, meaning it must be safe and sound at the end of the flight.
- The score for this mission is evaluated as shown in equation 1.

$$M1 = ZX - \left|\frac{x_{report} - x_{flight}}{x_{report}}\right| \qquad \text{Eq. 1}$$

Where:

- ✓ x_{flight} – airplane's distance traveled during the first flight mission (beginning when the aircraft starts its flight until it touches any surface that stops the flight) – $f\,(W_{empty})$.
- ✓ x_{report} – theoretical distance established in the written design report – $f\,(W_{empty})$.
- ✓ ZX – constant factor depending on the landing zone.

7.1.3 Mission 2: Short flight Max payload

- You can only perform mission 2 when you get a valid flight (score) from mission 1 ($M1 > 1.0$).
- For this flight, the payload (bottle) must be attached externally and exposed at the bottom of the airplane's fuselage.
- There will be a maximum 10-minute flight window (depending on the number of teams) for each launch for this mission.
- The mission starts when the aircraft leaves the launcher's hand or the launching catapult.
- Mission finishes when any part of the aircraft touches anything during the glide flight path.
- To earn a score, the airplane must complete a successful landing, meaning it must be safe and sound at the end of the flight.
- The score for this mission will be evaluated as shown in equation 2.

$$M2 = (ZX + WPX) - \left|\frac{x_{report} - x_{flight}}{x_{report}}\right| \qquad \text{Eq. 2}$$

Where:

- ✓ x_{flight} – airplane's distance traveled during the first flight mission (from the moment the aircraft begins flight until it touches any surface that stops the flight) – $f\,(W_{payload})$.
- ✓ x_{report} – theoretical distance established in the written design report – $f\,(W_{payload})$.
- ✓ ZX – constant factor depending on the landing zone.
- ✓ WPX – is the score given depending on the payload size. The score is established in the following manner:

WPX	Score
$X = 1$	1.0
$X = 2$	0.6
$X = 3$	0.3

Note: if the group gets a higher score than 5.0, the extra grade bonus will be added to the lowest grade you have so far in the laboratory.

7.2 Activity scoring

The score is divided into two main components: the flight and written report scores. The sub-sequence sections fully explain each component.

7.2.1 Written Report Score (WRS)

The written report has a value of 40% of the total score:

- Abstract (2%)
- Planning (2%)

- Procedure (10%)
- Tests (6%)
- Results analysis (8%)
- Technical conclusions (8%)
- References (2%)
- Format (2%)

7.2.2 Flight score (FS)

The flight score will have a value of 60% of the total score; the general score of the flight is determined using the following equation:

$$Flight\ \ Score = FS_{60\%} = (Functionality \times Flyingquality)_{50\%} + Aesthetics_{10\%}$$

Functionality & Flying quality (50%) – **Functionality** will be dependent on the accuracy between the aerodynamics method(s) (mathematical model) and the flights during the presentation day. The accuracy of the theory and practice and the empty weight will be scored for the Functionality as shown in equation 3. The **Flying quality** factor (0 or 1.0) will depend on the professional judgment perspective determined by the judges concerning the aircraft's overall gliding performance and flight capabilities.

$$Functionality = \frac{1}{2}\left(M1_{W_{empty}} + M2_{W_{payload}}\right) + \left[\left(\frac{W_{empty\_ref}}{W_{empty}}\right) - 1\right] \quad \text{Eq. 3}$$

Where:

- $M\,1_{W_{empty}}$ – mission 1 flight score.
- $M\,2_{W_{payload}}$ – mission 2 flight score.
- W_{empty} – airplane empty weight (Aircraft total weight without the payload bottles).
- W_{empty_ref} – minimum airplane empty weight registered by any team groups (reference empty weight).
- $W_{payload}$ – airplane payload weight (bottles).

Aesthetics (10%) – The groups must have a representative theme that identifies them. For this item, the design and manufacturing will also be considered.

7.2.3 Total score

Equation 4 expresses the 100% activity scoring (grade), including the written report score (WRS), as follows:

$$Grade = (WRS)_{40\%} + (FS)_{60\%} \quad \text{Eq. 4}$$

8. Schedule (Due days/Delivery times)

8.1 Written design report

The report must be submitted by Friday, November 8th, 2024, at 2:00 p.m.

8.2 Technical inspection

The model will be mechanically tested on Tuesday, November 12th. This inspection will be held at the Aerospace Vehicles Laboratory (Building 8/Lab 201) from 2:00 p.m. until 5:00 p.m. It verifies that the model was manufactured according to the requirements and restrictions established in this document.

All aircraft will be lifted with one lift point at each wing tip to verify adequate wing strength and to check for vehicle c.g. location. Team groups **must mark the expected empty and loaded c.g. locations on the aircraft's exterior** (each side of the fuselage). In addition, you must provide a hard point at any part of the airplane to weigh your model.

8.3 Flight

The flight day will be Thursday, November 14th, 2024. Consider this to have time for this activity (all team members must be present on the flight test day). This activity will start at 1 p.m. and finish at 5 p.m.

Note: All scheduled deadlines are strictly enforced. Late entries will NOT be accepted, and late report submissions will NOT be graded. Team groups that do not submit the required written reports will NOT be allowed to fly. The team is responsible for ensuring that all deadlines are known, understood, and met.

9. Communications

Questions regarding the project, schedules, or rules interpretation may be sent to the professor by the request of an appointment or by email at:

juan.alvarado@upb.edu.co

A forum is available to answer any question regarding this project in the **Office team's** platform.