6th Classwork - Fuselage Design

Mateo Lopez/000465939, Isabel Narvaez/000391116, Alvaro Sanabria/000459467

May 14, 2025

1 Fuselage configuration

Initial parameters to set the fuselage configuration included aircraft type, payload, range, cruise ceiling and design requirements. Mainly due to passenger load and weight, FAR 23 [FAA25] was selected for design parameters. FAR 23 [FAA25] states that for aircraft carrying between 2 and 6 passengers (level 2 certification FAR 23.2005), only 1 crew member is required, with no need for flight attendants.

Following Mohammad's [Sad13] proposal to minimize weight and drag, a single-deck fuselage with 4 seats and a boxy style similar to most GA aircraft for less than 6 occupants was selected as most appropriate for the design parameters. As shown in Figure 1, component allocation follows a logical arrangement with the engine at the front, followed by instrument panel and systems, then a pilot plus passenger section, and finally a baggage area at the rear. The fuel tank is positioned along the bottom of the fuselage as depicted in the image, with the wing box integrated at the top portion, consistent with the high-wing configuration requirements. This arrangement keeps the fuselage compact with usable load (50% of fuel) positioned close to the aircraft's CG and cockpit as forward as possible, aligning with Mohammad's [Sad13] recommendations in Figure 7.3 for effective component distribution.

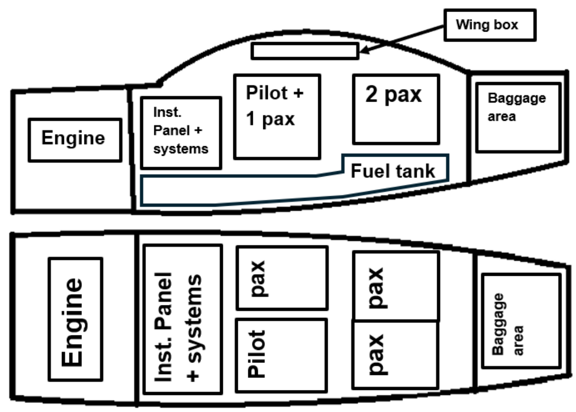

Figure 1: Initial layout

2 Cabin design

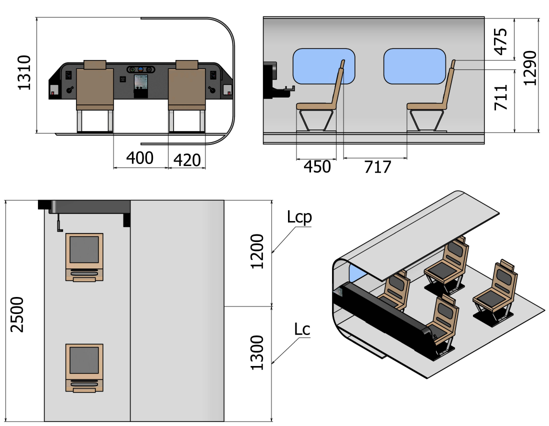

Figure 2: Cabin layout

For passenger sizing, Figure 7.6 and Table 7.4 from Mohammad's Aircraft Design were used to determine measurements and cabin design parameters. Using values of $W_S = 42cm$, $P_S = 65cm$, headroom = 125 cm, $W_A = 40cm$, and a seatback angle of 12°, and applying equations 7.1 and 7.2 for a 2-row by 2-seat configuration with a single aisle, the resulting cabin width $W_C = 2.08m$ and cabin length $L_C = 1.3m$. The cabin length for the cockpit $L_{CP} = 1.2m$, consistent with similar GA aircraft. These dimensions follow the recommendation to accommodate the 90th percentile of passengers and ensure comfort, as discussed by Mohammad (Section 7.4.2), while also keeping the cabin compact and symmetric in line with internal arrangement rules (Section 7.3). The selected parameters comply with FAR 23 [FAA25] guidelines for seat sizing and aisle width. Other relevant dimensions will be discussed in section 4, and overall dimensions are shown in Figure 2. Note that measurements from this figure and afterwards are in mm.

3 Instrument panel proposal

Figure 3: Initial instrument panel layout

To comply with FAR 23.2500 and 23.2510 requirements for safety and operational suitability, the instrument panel will use a dual array of Garmin G1000 systems. One unit serves as the Primary Flight Display (PFD) for flight and navigation data, and the other as the Multi-Function Display (MFD) for engine monitoring, GPS mapping, and additional operational information. Essential analog backups-airspeed indicator, altimeter, and heading indicator-will be included to ensure continued safe operation in case of system failure. Additional panel instruments will include lighting and flaps switching devices, circuit breakers, throttle and mix levers, transponder and communication radios. This arrangement provides redundancy and meets all regulatory requirements for a level 2 certified aircraft and can be seen in Figure 3. One G1000 system may work as backup of the other in case of catastrophic failure (FAR 23.2510(a)), with essential analog main instruments as backup for hazardous failures (FAR 23.2510(b)), ensuring that the possibility of both systems failing simultaneously remains remote (FAR 23.2510(c)).

4 Cockpit design

The cockpit shares the same width (2.08m) and height (1.25m) as the cabin, with a length of 1.2m, consistent with the open layout found in most general aviation aircraft. FAR 23 [FAA25] does not make a distinction between cockpit and cabin areas; furthermore, most GA aircraft contain both areas in one single space. The chosen cockpit length is based on typical values observed in comparable GA aircraft and aligns with recommendations in Mohammad's Aircraft Design (Table 7.4, Figures 7.38–7.39). The instrument panel measures 184 cm in width, is set 375 mm from the seat front, and is 413 mm high, as shown in Figure 4. The seatback angle is 12°, and the sidestick is 215 mm from the seat midpoint, supporting ergonomic operation. The pilot's seat is positioned as far forward as possible to maximize visibility. All primary controls and displays are

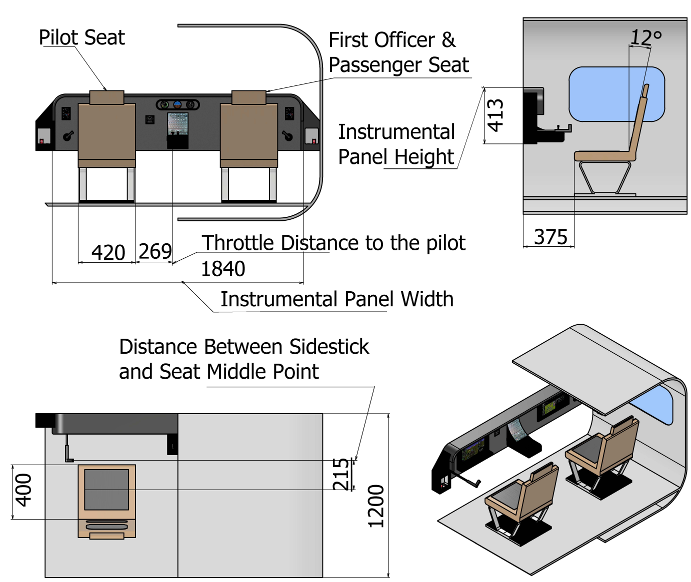

Figure 4: Cockpit layout

within easy reach, ensuring compliance with FAR 23.771, 23.773, and 23.777 for pilot compartment design, view, and control arrangement. The proposed cockpit configurations is shown in Figure 2 and Figure 4.

5 Luggage storage compartment design

The luggage storage compartment was designed following the methodology presented in Chapter 7.7 of Mohammad's Aircraft Design, which recommends first determining the total required cargo volume based on the number and size of passenger bags. For this aircraft, four baggage items each measuring 55×30×35 cm and weighing 10 kg were considered, resulting in a total cargo volume of $0.256m^3$. This volume was then used to define the compartment dimensions and placement within the fuselage. As shown in Figure 5, the luggage area is positioned at the rear of the cabin, directly behind the passenger seats, in line with the internal arrangement principles illustrated previously. This location ensures the compartment is easily accessible for loading and unloading, maintains proper weight distribution near the aircraft's center of gravity, and keeps the fuselage as compact as possible, as recommended by Mohammad (see Figure 7.3 and Section 7.7). The compartment provides sufficient space for all baggage while meeting FAR 23 [FAA25] requirements for cargo restraint and accessibility.

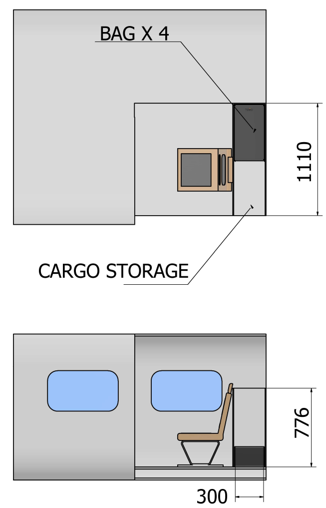

Figure 5: Luggage storage

6 Doors

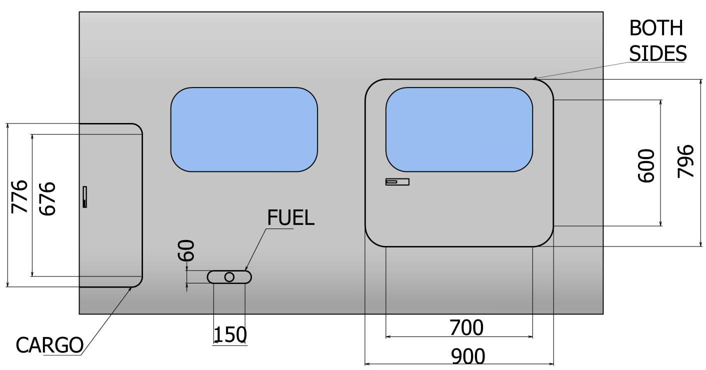

Figure 6: Doors on fuselage right side

The design and placement of doors are based on the ergonomic, cabin, and cargo requirements outlined in Sections 7.4, 7.6, and 7.7 of Mohammad's Aircraft Design, as well as FAR 23.783 for access and egress. As shown in Figure 6, the aircraft features a main passenger door on each side of the fuselage (900 mm × 796 mm) and a cargo door at the rear left (676 mm × 776 mm), ensuring unobstructed access for both occupants and baggage. The fuel tank door is positioned below the cabin windows for convenient ground access during refueling, in line with the internal arrangement principles described in Section 7.9.1. Door locations and dimensions were selected to provide easy entry, efficient evacuation, and convenient luggage handling, while maintaining structural integrity and compliance with all regulatory requirements.

7 Fuel tank allocation

The fuel tank design is based on the methodology described in Section 7.9.1 of Mohammad's Aircraft Design, using Equations 7.21 and 7.24 to determine the required fuel mass and volume. Key parameters -including specific fuel consumption ($C = 0.5lb/hp/h$) from Chapter 4.2.5.5, propeller efficiency ($\eta_p = 0.8$) from Chapter 8.7, and fuel density from Table 7.9 ($\rho_f = 730kg/m^3$)- were selected according to the aircraft's mission and performance requirements. AVGAS 100LL was chosen as the fuel type.

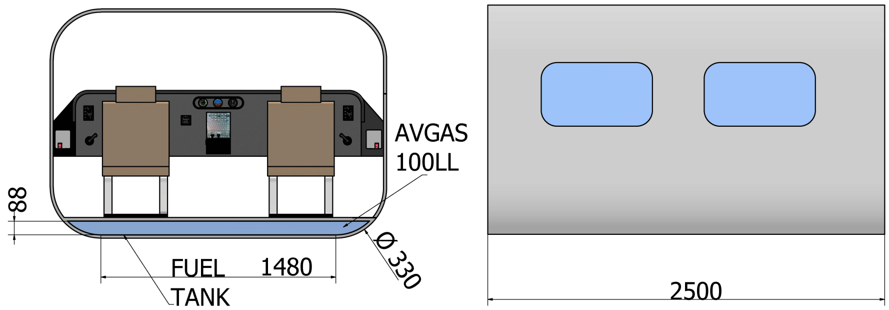

Figure 7: Fuel tank location on cross section view

Using these references and the values provided, the total required fuel mass $m_f = 638.5kg$, yielding a total fuel volume $V_f = 0.88m^3$. In line with the requirements for the GA aircraft, only 50% of this volume ($0.44m^3$) is carried in the internal fuselage tank, with the other 50% in the wings. As shown in Figure 7, the internal tank is positioned along the lower fuselage, with a diameter of 330 mm corresponding to the fuselage's curvature at that section and a minimal height to avoid further displacement of cabin/cockpit dimensions. This location keeps the fuel mass close to the aircraft's center of gravity, minimizes CG shift during flight, and ensures compliance with FAR 23 [FAA25] requirements for fuel system safety, accessibility, and inspection.

8 Systems and equipment location

To determine definitive equipment locations, total fuselage length must be calculated considering remaining spaces such as nose section, rear section and fuselage diameter. For $L_N = 130cm$ assumed from the use of similar engine types such as Lycoming IO360 which are approximately 1m in length, providing adequate clearance of 30cm for fuel lines, oil pumps and other required engine equipment. Rear section length was determined by displacing remaining space under cabin after installation of fuel tanks, considering total available volume using equation 7.4a. $V_{extra} = 1.77m^3$, then using Equation 1, considering an additional 80% of volume to make up for useful space inside the tailcone, yielded $L_R = 3m$. Using equations 7.9 and 7.10, $L_f = 6.8m$ and $D_f = 2.12m$. Further, Mohammad recommends $\alpha_{cone} < 20°$, which is validated by the use of Equation 2, yielding 18.1°. Considering now the total dimensions and space available, systems were distributed as per Figure 8.

$$L_R = \frac{3V_{cone}}{\pi(W_C/2)^2} \tag{1}$$

$$\alpha_{cone} = \tan^{-1}(\frac{D_f/2}{h_f}) \tag{2}$$

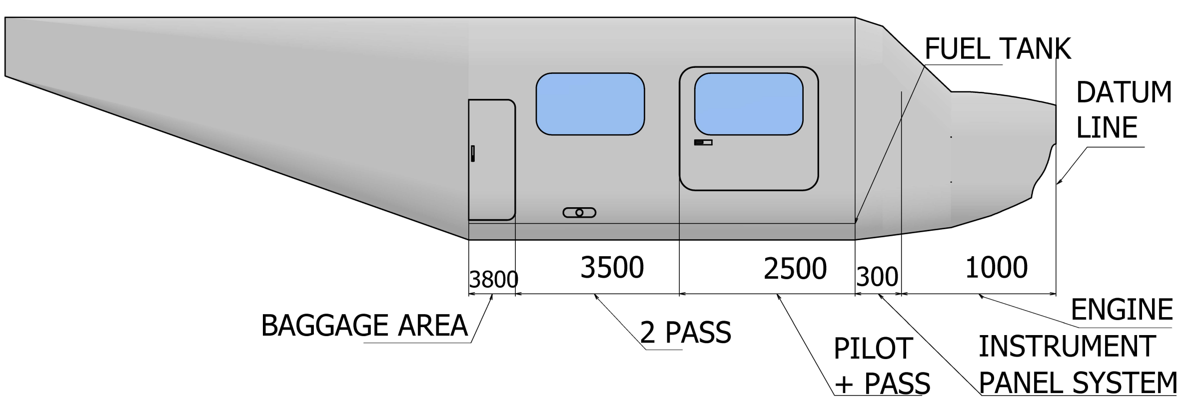

Figure 8: Fuselage side view for component distribution

9 Upsweep angle

The upsweep angle (α_{us}) was determined using the approach described in Chapter 7.10.4 of Mohammad's Aircraft Design. According to this method, the angle is calculated to ensure aerodynamic efficiency and avoid excessive flow separation at the aft fuselage, as recommended in Table 7.9 and Figure 7.35. It is calculated making use of Equation 3, yielding $\alpha_{us} = 19.5°$.

$$\alpha_{us} = \tan^{-1}(\frac{D_f/2}{L_R}) \tag{3}$$

This value aligns with the recommendation in Equation 7.28, which suggests the upsweep angle should not exceed 20° to maintain aerodynamic efficiency and prevent adverse flow effects. This value is within the typical range recommended by Mohammad to prevent flow separation and maintain efficient aft fuselage aerodynamics. The resulting geometry, as shown in Figure 9, ensures compliance with FAR 23 [FAA25] requirements for general aviation aircraft. [Sad13]

10 Final design with dimensions

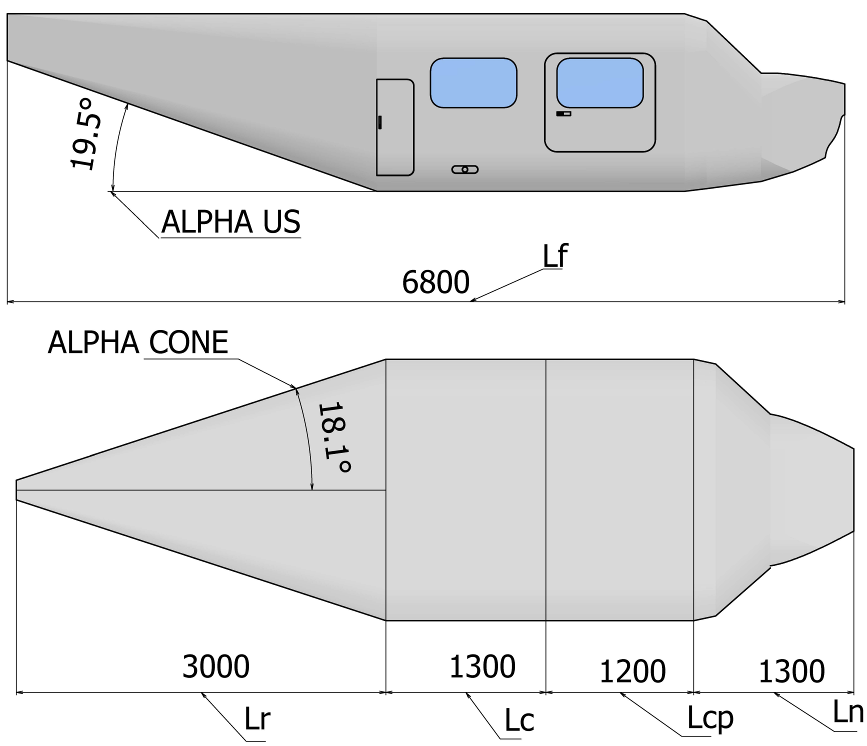

Figure 9: Final design and dimensions

References

[FAA25] FAA, DOT. Airworthiness standards: Normal category airplanes, May 2025.

[Sad13] Mohammad H. Sadraey. *Aircraft design: a systems engineering approach.* Aerospace series. Wiley, Chichestet, West Sussex, online-ausg edition, 2013.