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Æ-6 eLena; Conceptual Design of 6-Seater Electric Aircraft

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Globalization has made a huge impact on worldwide interaction and integration in our lives. Traveling between locations, for instance, has become easier with the advancement of transportation modes such as aircraft. However due to the ever-increasing environmental concerns, alternatives of conventional aviation fuels have become necessary in order to provide more eco-friendly flights. Fortunately, alternatives such as aircraft batteries have become feasible with technology improvements, allowing an idea for resolving the issue, namely the development of an electric aircraft. This paper will be focused on designing a six-seater electric aircraft through parametric studies on several aspects such as aircraft configurations, weight and balance, stability, performance, structures, aerodynamics, and cost analysis while also aiming to meeting the given DRO. The designed aircraft, Æ-6 eLena, has a range of 540 km, a takeoff weight of 3003 kg, a cruising speed of 300 km/hr, and a lift-to-drag ratio of 13.5. The conceptual design of this aircraft is intended to be certified under current CASR 23 regulations, with production beginning in 2026.

Keywords: Electric Aircraft; Propeller; 6-Seater; Battery; Æ-6 eLena

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1. Introduction

Current technological developments allow aircraft to develop towards electric aircraft which have several advantages. The use of electricity as an energy source will not produce CO2 emissions and as we know, 2% of the world's carbon dioxide emissions come from the aviation industry. The use of electric aircraft can also reduce operational costs because the cost of electricity is relatively low compared to conventional fuels, thus reducing the cost of flight tickets. For example, a modified DHC-2 deHavilland Beaver seaplane using an electric propulsion system, the eBeaver, costs about $12 per operating hour [1]. This is much lower than using a piston motor which costs $300 to $450 per operating hour. In addition, the take-off weight of an electric airplane is lighter since electric motors weigh less than combustion motors in conventional airplanes and can carry a larger number of passengers or goods.

Based on these reasons, a design will be carried out with the aim of designing a propeller aircraft with an electric motor engine to carry six passengers. This aircraft is targeted for the upper middle class business segment (executive) with regional flight routes between major cities in Indonesia. This selection is based on the statement of the chief executive of MagniX, Roei Ganzarski, that as many as two million airplane tickets are sold each year for flights under 500 miles (804,672 km), indicating the business potential for regional flights [2]. In addition, this aircraft can also be used as medical evacuation (medevac) transportation between major cities.

The aircraft is planned to be CASR Part 23 certified by 2026. The Design, Requirement, and Objectives of the electric propeller aircraft can be seen in the following table.

Table 1. Design Requirements & Objectives

General		
Passengers	5 people	
Crew	1 person	
MTOW	≤ 5000 kg	≤ 11023 lb
Cabin and Instruments		
Flight Deck	1 crew with Multi-Functional Display (MFD)	
Passengers	5 People	
Cabin Volume	≥ 5.5 m^3	
Baggage Volume	≥ 0.9 m^3	
Average Passenger Weight	90 kg (person) 10 kg (baggage)	198.416 lb (person) 22.0462 lb (baggage)
Performance		
Design Range	≥ 400 km	≥ 215.983 nm
Range Standard	NBAA IFR Range Profile minimum reserve: 30 minutes loiter, no alternate	
Design Cruise Altitude	3.048 km	10000 ft
Design Cruise	240 km/h (economical)	129.59 knots (economical)
Maximum Cruise Speed (0.95 MTOW, 10000 ft)	≥ 300 km/h	≥ 161.9 knots
Maximum Service Ceiling (MTOW)	3.6576 km	12000 ft
Take-off Distance (MTOW, Sea Level ISA+15)	≤ 900 m	≤ 2952.76 ft
Landing Distance (0.9 MTOW, Sea Level ISA+15)	≤ 950 m	≤ 3116.8 ft
Maximum Initial Rate of Climb AEO (MTOW, Sea Level ISA+15)	7.62 m/s	≥ 1500 fpm
Maximum Initial Rate of Climb OEI (MTOW, Sea Level ISA+15)	2.54 m/s	≥ 500 fpm
Cost		
BEP	400 units	
Price per Unit in 2026	≤ $1,800,000	

The mission profile developed based on the DRO can be seen in the illustration below. The aircraft will experience engine start/warm up - take off - climb - cruise - descent - loiter 30 minutes - descent - landing - engine off.

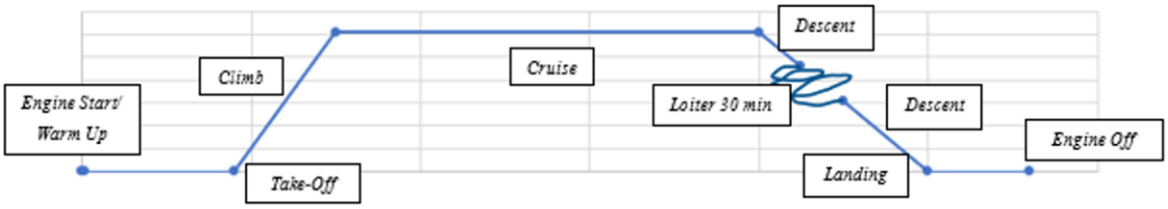


Figure 1. Mission Profile Pesawat Æ-6 eLena

2. Materials and Methods

2.1. Airplane Concept

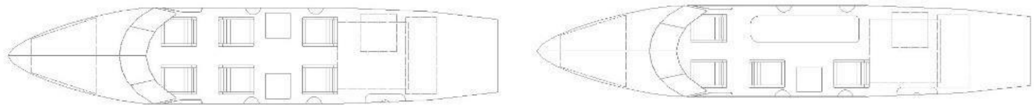
The development of this aircraft used two competing aircraft categories for comparison. The reason behind using different categories is the lack of electric aircraft that have a six-seater configuration. The first category is electric aircraft, namely the Eviation Alice, eFlyer 2, eFlyer 4 which will be used as a comparison in the calculation of weight estimation, matching chart, and aircraft configuration. The second group involves non-electric six-seater aircraft, including Piper PA-34 Seneca, Piper PA-31 Navajo, Daher TBM 910, which are only used as references in aircraft configuration, especially in terms of seat arrangement.

The wing, fuselage, empennage and landing gear configurations to be used on this aircraft and the reasons for their selection can be seen in the following table.

Table 2. Æ-6 eLena Aircraft Configuration

Aircraft Parts	Configuration Options	Reason
Wings	Low wing, monoplane, dihedral, straight, trapezoidal	• The low wing is favorable in ground effect, and has a more efficient structure and stable erodynamics. • Monoplane for more manageable aerodynamic efficiency. • Dihedral to be more laterally and roll stable. • Straight is more efficient at low flying speeds and has a more efficient structure. • Dihedral for more lateral and roll stability.
Fuselage	Semi-monocoque, rectangular	• Semi-monocoques are stronger than monocoques and are easy to mass-produce. • Rectangular is easier to manufacture and has a spacious cabin volume.
Empennage	Conventional tail	• Relatively lighter.
Engine	Tractor, wing-mounted	• Propeller tractor configuration for higher engine efficiency. • Wing-mounted to prevent propeller failure from hitting the cabin.
Landing Gear	Tricycle, fixed (dengan fairing)	• Tricycle to be more stable and easy to control when on the ground. • Non-retractable for easy configuration and added fairing to reduce drag during cruise.

The seating arrangement of this aircraft can be seen in the following illustration. On the flight deck, there is one seat for the pilot and one seat for the passenger while in the passenger cabin there are two rows of seats facing each other, and there is space for movement in the center of each row. For aircraft intended for medical purposes (medevac), the two facing seats can be replaced with a stretcher for the patient.



(a) (b)

Figure 2. Seating Arrangement (a) Passenger Configuration, (b) Medevac Configuration

2.2. *Initial Dimensions and Design Points*

Determination of aircraft weight estimation is done by using weight data from the comparable electric aircraft used. Furthermore, the calculation is iterated according to the needs until the following values are obtained.

Table 3. Weight estimation

Weight Components	Value
$W_{TO}\ (kg)$	3000
$W_{OE}\ (kg)$	1513
$W_P\ (kg)$	600
$W_B\ (kg)$	887
$W_{OI}\ (kg)$	1789
$W_E\ (kg)$	1334

The design point of the aircraft will be determined using the matching chart method [3]. This method is a parameter study based on DRO and existing regulations. There are two important variables that can be obtained from this matching chart, namely wing loading (W/S) and power loading (W/P). These two variables will be used to determine the wing area requirements that are sufficient for all phases of flight and the engine power required.

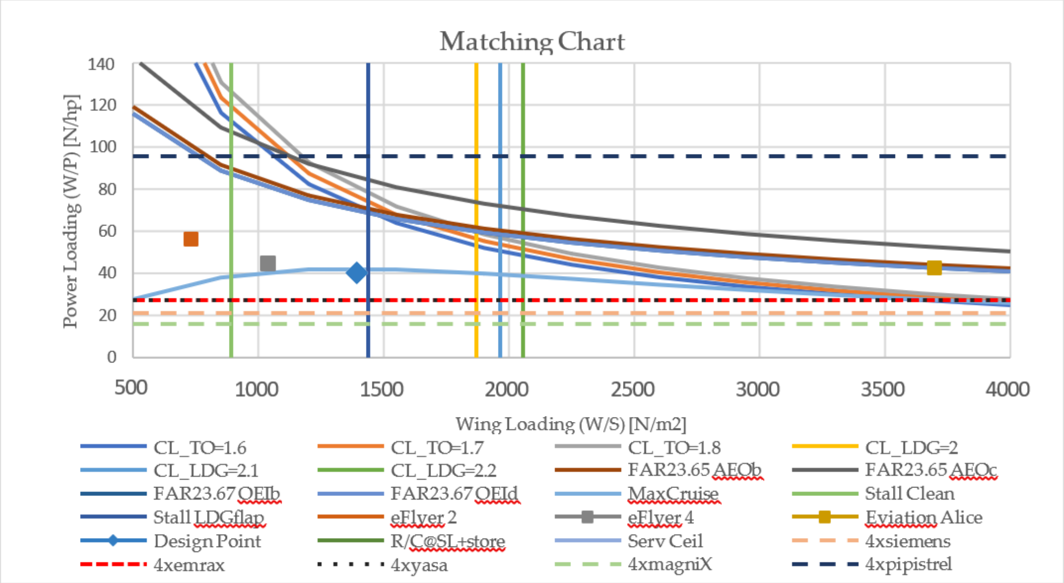


Figure 3. Matching Chart

Based on the matching chart above, the following design point parameter data will be used as a reference in the design of this aircraft

Table 4. Aircraft Design Point Æ-6 eLena

Parameter	Value
$C_{L,max}$	1.3
Wing loading (W/S)	1393 N/m^2
Power loading (W/P)	40 N/hp
Landing Distance	950 m
Take-off Distance	900 m
Rate of Climb (AEO)	1500 fpm

2.3. General Configuration

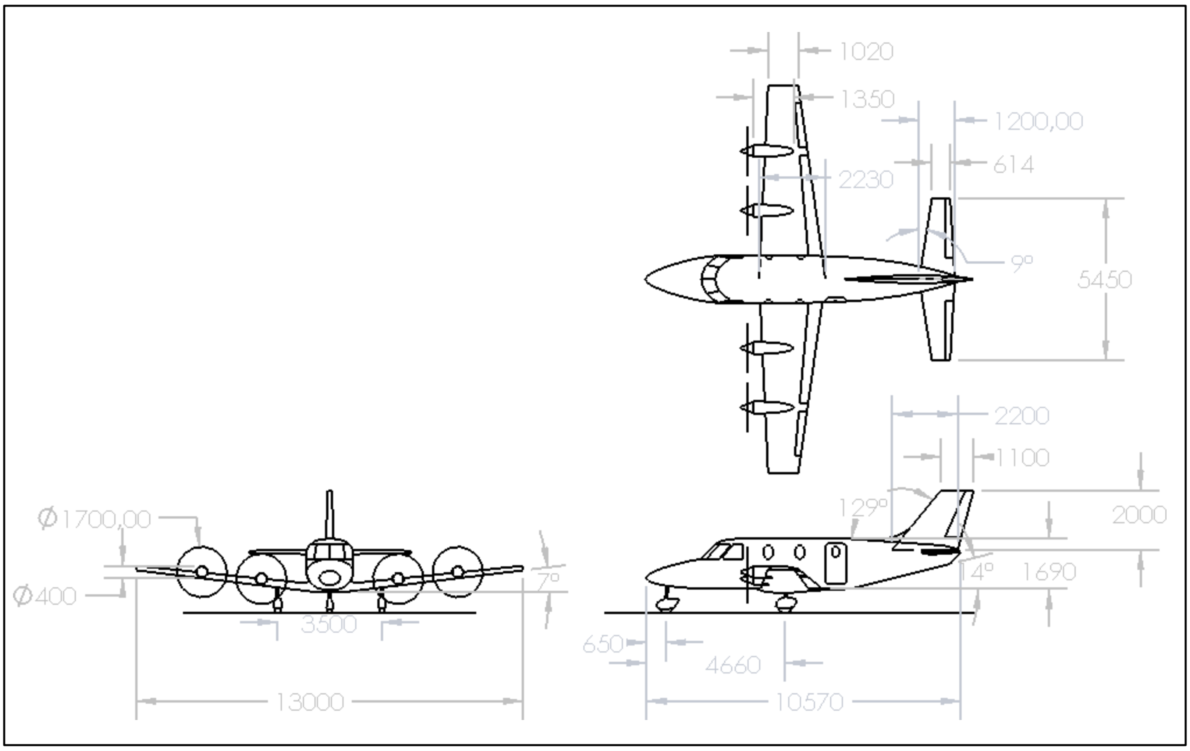


Figure 4. Three-view drawing of Æ-6 eLena

Based on the design points selected from the matching chart, the wing loading values are obtained which will be used in the calculation of the following general aircraft configuration.

2.3.1. Basic Geometry Parameters

Fuselage geometry parameters such as length and diameter will be determined by calculations based on statistical data found in several reference books [4-5]. Wing parameters can be obtained based on the wing loading value and aspect ratio assumptions used in the matching chart calculation. Other wing parameters such as chord root and chord tip lengths and taper ratio can also be obtained by reviewing the comparator aircraft and adjusting the values to the required wing area. Finally, the HTP and VTP parameters can be determined using the tail volume coefficient method [5]. Based on the calculation method described, the basic geometer parameters of the aircraft are obtained as follows.

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Table 5. Basic Aircraft Geometry Parameters

Fuselage Parameters		Parameter	Wing	HTP	VTP
L_f (mm)	10570	Wing Area (m²)	21.125	4.943	3.30
L_f/d_f	6.26	Wing Span (mm)	13000	5450	2000
d_f (mm)	1690	Aspect Ratio	8	6	1.212
L_{fc}/d_f	2.23	Taper Ratio	0.46	0.511	0.5
L_{fc} (mm)	3770	Chord Root (mm)	2230	1200	2200
θ_{fc} (deg)	14	Chord Tip (mm)	1020	614	1100
		MAC (mm)	1702	939	1711
		Dihedral Angle (deg)	7	6	36.2
		Sweep Angle (deg)	0	0	0

2.3.2. Wing and Empennage Design

Selected high lift device in the form of single slotted flap and aileron control plane on the wing. Also designed elevator on HTP and rudder on VTP with calculation method in Raymer (2018) and Sadraey (2012) books [5,6]. NACA 65(2)-415 airfoil is selected as the wing airfoil while the HTP and VTP use NACA 0012 airfoil.

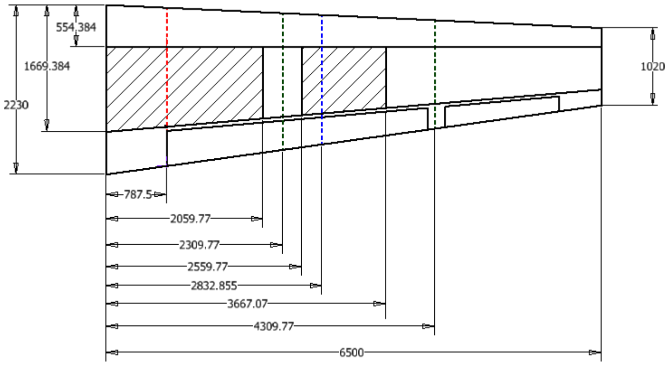
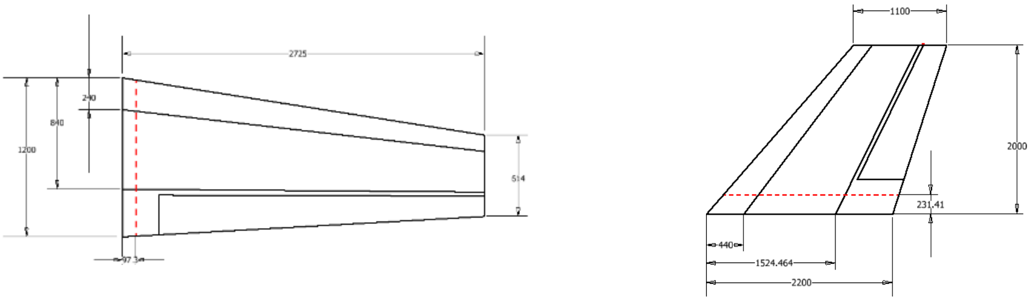


Figure 5. Wing design

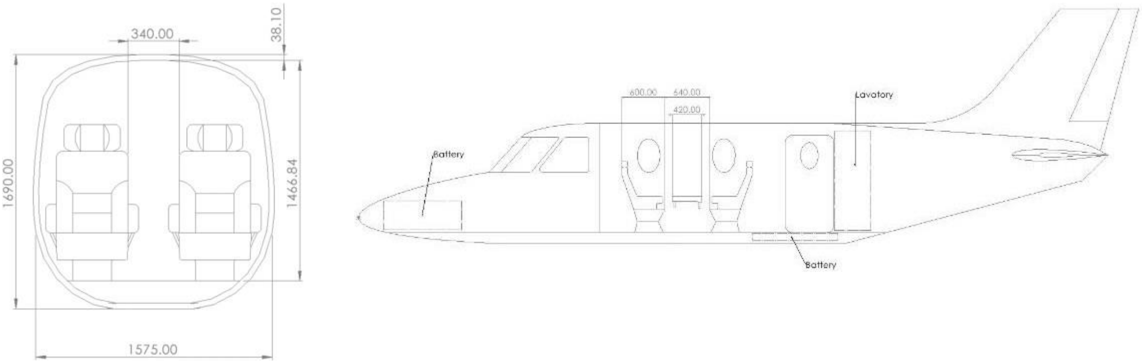


(a) **(b)**

Figure 6. Design of (a) HTP (b) VTP

2.3.3. Fuselage Design

The fuselage cross-section is designed with the required cabin and luggage volumes in mind. The windshield has also been designed to meet the visibility needs of the pilot [4].



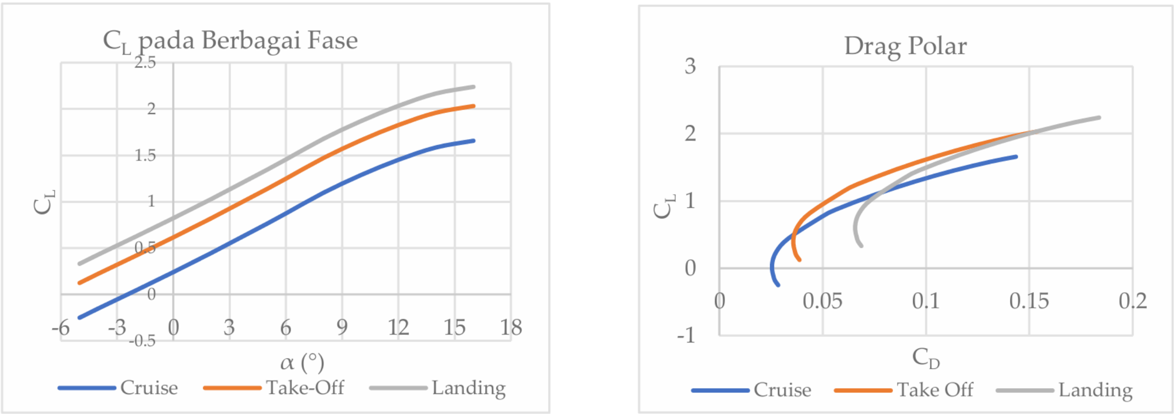
(**a**) (**b**)

Figure 7. (a) Fuselage Cross Section, (b) Side View Fuselage Design (unrevised)

3. Results

3.1. Aerodynamic Analysis

Aerodynamic analysis is performed using Digital Datcom to obtain aerodynamic coefficients in the cruise, take-off (20° flap deflection), and landing (40° flap deflection) phases. Additional drag from the engine nacelle, landing gear, and other components not accounted for in the Digital Datcom analysis will be calculated using the component build up method.



(**a**) (**b**)

Figure 8. (a) Graph of CL against Angle of Attack, (b) Graph of Polar Drag

Based on the analysis that has been carried out, the lift and drag coefficient data is obtained as follows. It can be seen that the values obtained have met the values assumed in the matching chart.

Table 6. Comparison of Analyzed Coefficients with Matching Chart Assumptions

Flying Phase	C_{Lmax}		C_{D0}	
		Matching Chart		Matching Chart
Cruise	1.657	1.3	0.027	0..029
Take-off	2.032	1.7	0.038	0.065
Landing	2.239	2.1	0.068	0.095

The maximum L/D value of 15.5 is obtained at CL = 0.873. However, since the aircraft is flying at $CLL,Cruise$ = 0.4435 the L/D value obtained is 13.5 only.

3.2. Weight and Equilibrium

The aircraft weight breakdown was performed by referring to Raymer's (2018) book [5]. The location of aircraft components is estimated using typical values from comparable aircraft [7]. To reduce the weight of the aircraft, composite materials will be used in the fuselage, wing, and empennage structures, the details of which will be discussed in the aircraft structure layout. Obtained aircraft weight based on the results of weight breakdown of 3003 kg. obtained CG location data in most forward, MTOW, and most aft conditions as follows.

Table 7. Aircraft CG Data in Various Conditions

	Most Forward	MTOW	Most Aft
x_{cg} (mm)	4085	4301	4326
z_{cg} (mm)	345	83	50
x_{cg} $(\%MAC)$	9.91	22.54	24.06

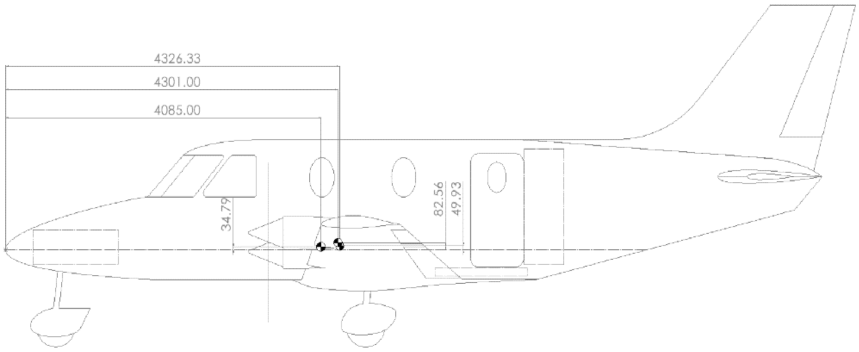


Figure 9. Aircraft CG Location in Various Conditions

3.3. Structure Layout

The structural configuration chosen is semi-monocoque, the connection configuration between the wing and the fuselage chosen is spar carry-through.

3.3.1. Fuselage Structure

A hat-section type stringer skin with Al 2024-T3 material was selected. The selected frame and bulkhead component material is aluminum with Al 7075-T6 type. The distance between components was designed by reviewing the hardpoints on the fuselage as well as the ideal distance from comparable aircraft [8].

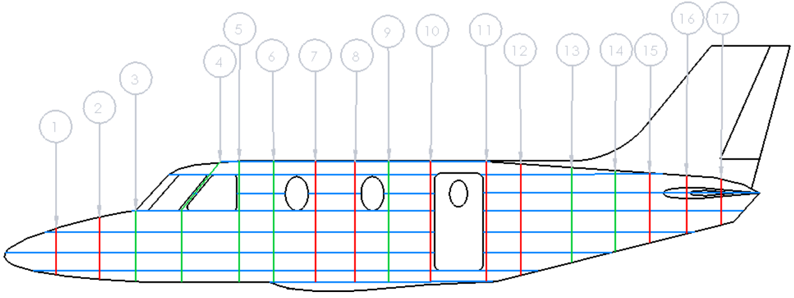


Figure 10. Fuselage Structure

3.3.2. Wings and Empennage structure

The wing and empennage structure is designed with respect to several hardpoints such as the control plane, battery location in the wing, engine location, and landing gear location. By considering the ideal distance between components, the structural layout is obtained as shown in Figures 11 and 12 with details of component types and materials as shown in Table 8.

Table 8. Type and Material Data of Wing and Empennage Components

Parameter		Wings	HTP	VTP
Stringer type		Hat-stringer	Hat-stringer	Hat-stringer
Skin and stringer		CFRP	CFRP	CFRP
Material	Spar	CFRP	CFRP	CFRP
	Ribs	Al 7075-T6	Al 2024-T3	Al 2024-T3
HLD and control plane		CFRP	CFRP	CFRP

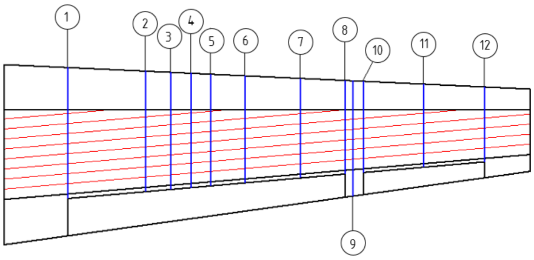
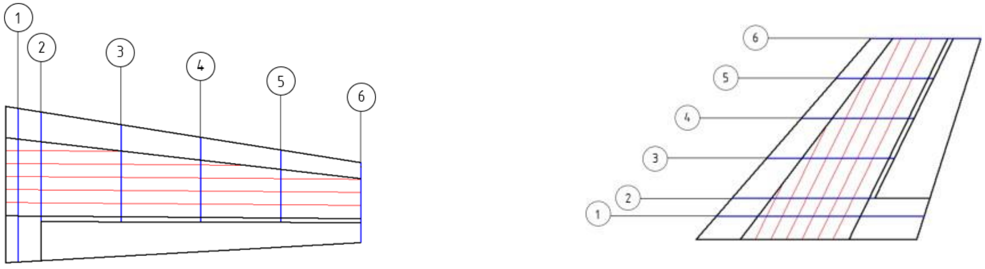


Figure 11. Wings structure



(a) **(b)**

Figure 12. (a) HTP Structure, (b) VTP Structure

3.4. Landing Gear Design

On the Æ-6 eLena aircraft, a tricycle-configured, non-retractable landing gear with fairings is used to compensate for the resulting aerodynamic drag. Referring to reference [5], there are several requirements that must be met.

Table 9. Stability and Load Conditions on Landing Gear

Ground Stability & Clearance Angle

Parameter	**Terms (°)**	**Angles (°)**
Overturn	< 60	40.07
Tip Back	> 15	15.23
Clearance	> 15	16.65

Load Calculation

Landing Gear	**Terms (%)**	**MTOW (%)**	**Most Forward (%)**	**Most Aft (%)**
Nose Landing Gear	8 – 15	8.963	14.328	8.321
Main Landing Gear	85 – 92	91.037	85.672	91.679

As shown in the table, the provisions for ground stability and the calculation of the load on the landing gear have met the requirements.

3.5. Stability and Control Analysis

The static stability coefficient of the Æ-6 eLena aircraft was obtained using Digital DATCOM and can be seen in the following table.

Table 10. Aircraft static stability coefficient Æ-6 eLena

	Parameter	**MTOW**	**Most Forward CG**	**Most Aft CG**	**Stability Requirements**
Longitudinal	C_{m_α} **(per rad)**	-0.466	-1.198	-0.378	<0
	C_{m_q} **(per rad)**	-27.817	-34.194	-27.284	<0
	C_{L_α} **(per rad)**	5.770	5.770	5.770	>0

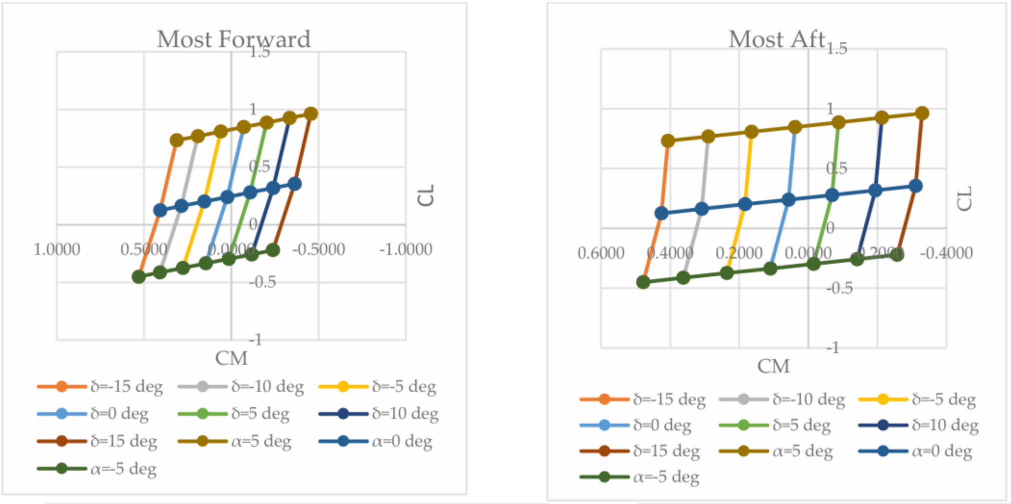
In the table above, it can be seen that the Æ-6 eLena aircraft meets the static stability requirements in the MTOW, most forward CG, and most aft CG configurations. Next, the neutral point that represents the neutral stability of this aircraft will be determined using the static margin approximation. The results of the static margin calculation, center of gravity location and neutral point position can be seen in the following table.

Table 11. Calculation Results of Neutral Point, CG, and Static Margin of Æ-6 eLena Aircraft

	***Most Forward* CG**	***Most Aft* CG**
Static Margin	20.76%	6.55%
X_{cg} (mm)	4085	4326
X_{np} (mm)	4439	4438

From the table above, it can be seen that the Æ-6 eLena aircraft has a static margin of 6.55% in the most aft CG configuration and this value is still within the range of 5-10%. mentioned in reference [5] so it can be said that this aircraft is quite stable as a transport aircraft.

Trim points where the aircraft can fly in steady level flight (γ=0o) will be determined using the trim curve.



(a) **(b)**

Figure 13. Trim Curve of Æ-6 eLena Aircraft

From the graph above, the trim point for the lift coefficient at cruise of CL = 0.4435 shows that the elevator deflection and angle of attack required for trim are α = 2.1° and δe = -0.15° in the most forward CG configuration and α = 2.6° and δe = 2.8° in the most aft CG.

In order to meet the needs of the aircraft in longitudinal motion and lateral-directional motion, an optimum HTP design is required. Therefore, a control analysis was conducted to evaluate the control capacity of the HTP design used. The calculation results based on the method in reference [7] for this aircraft can be seen in the following graph.

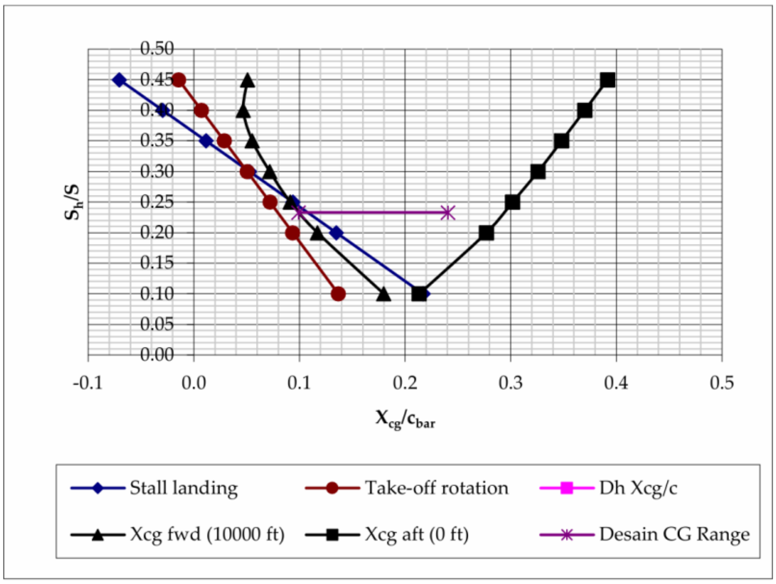


Figure 14. HTP Design Limits

Based on the graph above, it is found that the optimum Sh/S ratio is 0.23.

3.6. *Flying Achievement Analysis*

In the Æ-6 eLena aircraft, the Emrax 268 electric motor engine is used with a peak power of 200kW or 268 hp and 80% propeller efficiency is used and a cruise speed of 300 km/h, so with reference [9] the thrust force is obtained at sea level conditions.

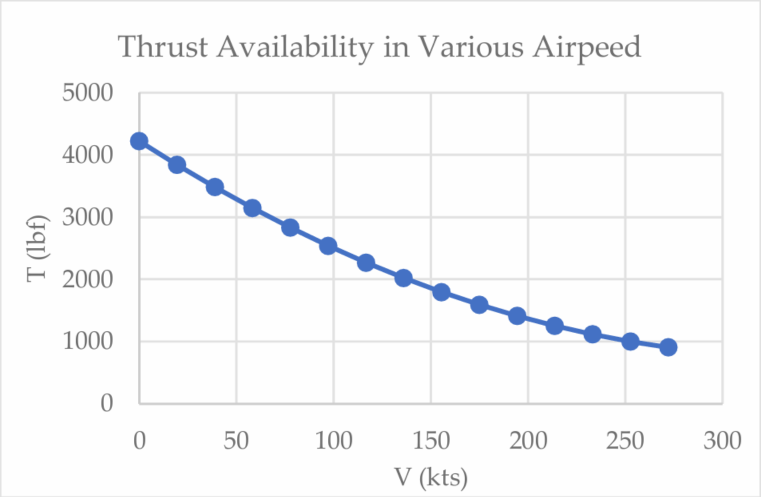


Figure 15. Thrust Availability

Then, using the references [3,10,12], the performance of the Æ-6 eLena aircraft can be calculated starting from the take-off distance, balanced field length, landing distance, ROC, service and absolute ceiling, and range to meet the DRO.

Table 12. Æ-6 eLena Flight Performance Analysis Results

Parameter		Result Calculations	Unit
Take-off distance		560.67	m
Balanced field length		586.8	m
Landing distance		787.31	m
Rate of Climb	AEO	3139.55	fpm
	OEI	2053.58	
Service ceiling		13981.49	ft
Absolute ceiling		14434	ft
Range	Max Payload	540.37	km
	4 Passanger	611.33	

In the table above, it can be observed that the calculation results of the Æ-6 eLena aircraft have met the DRO of each parameter. For the range, since it is different from non-electric aircraft, the weight that can be varied within the range is the weight of passenagers and baggage.

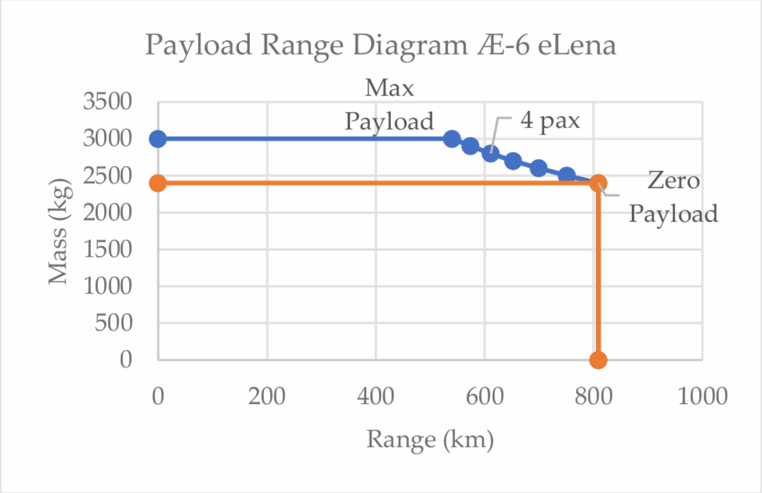


Figure 16. Payload Range Diagram

Then, the flight envelope of the Æ-6 eLena aircraft is obtained to ensure that the structure of the aircraft is safe while operating under the specified load factor conditions. The flight envelope calculation utilizes equations from reference [12] such as load factor value calculation, V-n diagram generation, and gust load calculation.

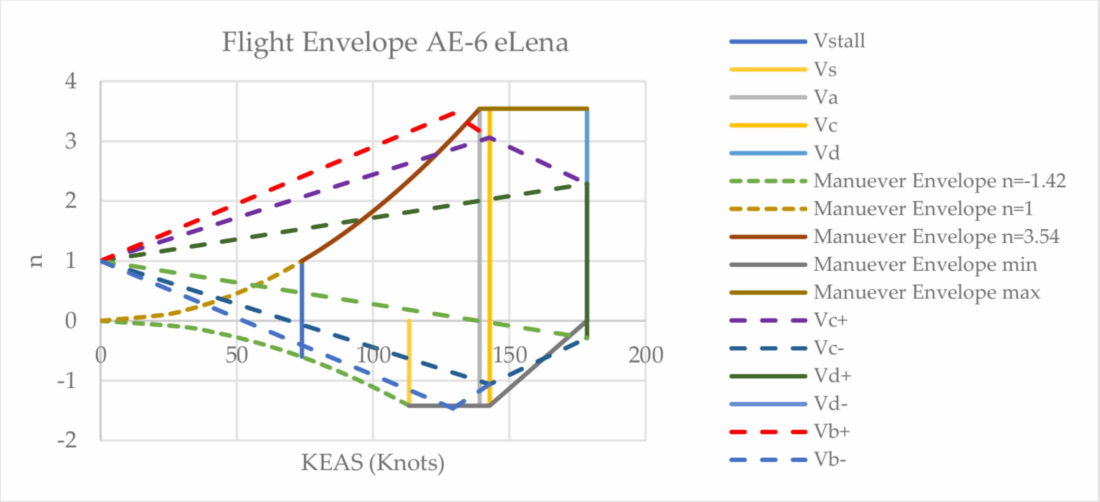


Figure 17. Flight Envelope

As shown in the figure above, the maximum load factor for Æ-6 eLena aircraft is 3.54 and the minimum load factor for Æ-6 eLena aircraft is -1.42.

3.7. *Cost Analysis*

The cost analysis will cover the life cycle costs of the Æ-6 eLena aircraft. Some of the costs to be analyzed are research, development,test, andengineering or RDTE. Other costs such asmanufacturing and acquisition,operating cost, anddisposal will also be calculated in this analysis. The equation to perform the cost analysis calculation is based on references [5,13,14].

Table 13. Estimated Price of Æ-6 eLena Aircraft

Year	Base Year (2020)	Design Year (2026)
Price Cost	$1,425,963	$1,632,850
BEP	400 units	
Duration	8 years and 4 months	

As shown in the table above, the estimated price of the Æ-6 eLena aircraft in 2026 or design year will be around US$ 1,632,850 with a break even point (BEP) of 400 units. The price of the Æ-6 eLena will then be compared with comparable aircraft with similar configurations. The same inflation assumption is used for the estimation of the Æ-6 eLena aircraft, which is 3%.

Table 14. Price Comparison of Comparator Aircraft

Comparator Aircraft	Price	Year	Estimated Price in 2026
Eviation Alice	$4,000,000	2019	$5,016,750.25
Piper PA-31 Navajo	$220,000	1982	$730,998.35
eFlyer 800	$6,000,000	2021	$6,955,644.45
Beechraft Baron G58	$1,495,000	2019	$1,875,010.41
Cessna Caravan	$2,200,000	2013	$3,028,084.18
Æ-6 eLena Price Estimation			$1,632,850

It can be seen from the table above that the price of the Æ-6 eLena aircraft is competitive with other comparable aircraft with similar configurations. It also meets the DRO objective of less than US$1,800,000 by 2026.

3.8. DRO Fulfillment

Then, the design and analysis results of the Æ-6 eLena aircraft will be rechecked with the given DRO.

Table 15. Comparison of DRO and Design Results of Æ-6 eLena Aircraft

Parameter	DRO	Æ-6 eLena	Description
General			
Passanger	5 people	5 people	Fulfilled
Crew	1 person	1 person	Fulfilled
MTOW	≤ 5000 kg	3003 kg	Fulfilled
Cabin and Instruments			
Cabin Volume	≥ 5.5 m^3	≥ 5.5 m^3	Fulfilled
Baggage Volume	≥ 0.9 m^3	≥ 0.9 m^3	Fulfilled
Performance			
Design Range (Max Payload)	≥ 350 km	540.37 km	Fulfilled
Design Range (4 Passanger)	≥ 400 km	611.33 km	Fulfilled
Design Cruise Altitude	10000 ft	10000 ft	Fulfilled
Design Cruise	240 km/h	300 km/h	Fulfilled
Maximum Cruise Speed (0.95 MTOW, 10000 ft)	≥ 300 km/h	300 km/h	Fulfilled
Maximum Service Ceiling (MTOW)	12000 ft	13982.49 ft	Fulfilled
Take-off Distance (MTOW, Sea Level ISA+15)	≤ 900 m	560.67 m	Fulfilled
Landing Distance (0.9 MTOW, Sea Level ISA+15)	≤ 950 m	787.31 m	Fulfilled
Maximum Initial Rate of Climb AEO (MTOW, Sea Level ISA+15)	≥ 1500 fpm	3139.55	Fulfilled
Maximum Initial Rate of Climb OEI (MTOW, Sea Level ISA+15)	≥ 500 fpm	2053.58	Fulfilled
Cost			
BEP	400 units	400 units	Fulfilled
Price per Unit in 2026	≤ $1,800,000	$1,632,850	Fulfilled

It can be seen in the table above that the results of the design and analysis process for the Æ-6 eLena aircraft have fulfilled all the DROs given.

4. Discussion

The results of the flight performance calculation show that the value obtained has met the needs of the DRO. Especially the distance traveled, the value obtained exceeds the needs by approximately 190km. This excess value can backfire for the weight of the battery that needs to be carried. In future research, iterations need to be carried out to obtain a mileage value that is close to the DRO requirements. By reducing the battery weight, we can allocate the remaining weight to increase the payload or strengthen the structure.

One of the advantages of electric transportation that needs to be considered is the ease of battery removal. By replacing a depleted battery with a fully charged battery quickly can certainly add to the selling value of this aircraft. In further research, iteration can be done by allocating excess battery weight to strengthen the battery opening structure later.

Further research is also needed to estimate the battery cooling system requirements. The installation weight approach of 10% of the battery weight needs to be reviewed when adding this system. In addition to the cooling system, the power flow system in and out of some batteries also needs to be considered.

5. Conclusions

Electric aircraft have been growing rapidly in the international aviation industry. Key advantages such as reducedCO2 emissions, cheaper ticket prices, etc. make electric aircraft more promising for use in the future. In this research paper , the design process of a six-passenger electric aircraft has been carried out and all DROs given have been fulfilled by the design team as listed in Table 15.

In this research process, there are not many references that can be used as guidelines for work. This is due to the lack of studies on electric aircraft. Therefore, the various approaches taken need to be reviewed. In addition, optimization is also needed regarding important aspects such as aircraft stability, flight performance, and more optimal aerodynamic values.

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