Final Report

Course: MAE 159 - Aircraft Performance

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Winter 2025 specifications:

Number of passengers (2-class, domestic rules)	210
Weight of cargo (10 pounds/ft^3) Maximum Payload Weight 55,000 lbs	8000 pounds
Range (still air)	3500 nautical miles
Takeoff field length (sea-level, hot day 84° f)	6900 feet
Landing approach speed	135 knots
Cruise Mach number	0.80
Initial cruise altitude	35,000 feet
Maximum wingspan	125 feet
Maximum landing weight with 45% fuel	

Engine Configuration: 2 JT9D-class engines, wing-mounted

Seating Layout: 6 abreast

Wing Design: Taper ratio = 0.35

Date: March 1st, 2025

1. Approach

In this study, commercial transport conventional aircraft design and advanced technology aircraft design are compared for economic performance. Both designs have to satisfy all the specifications requirements and safety requirements while keeping Direct Operating Cost (DOC) as low as possible.

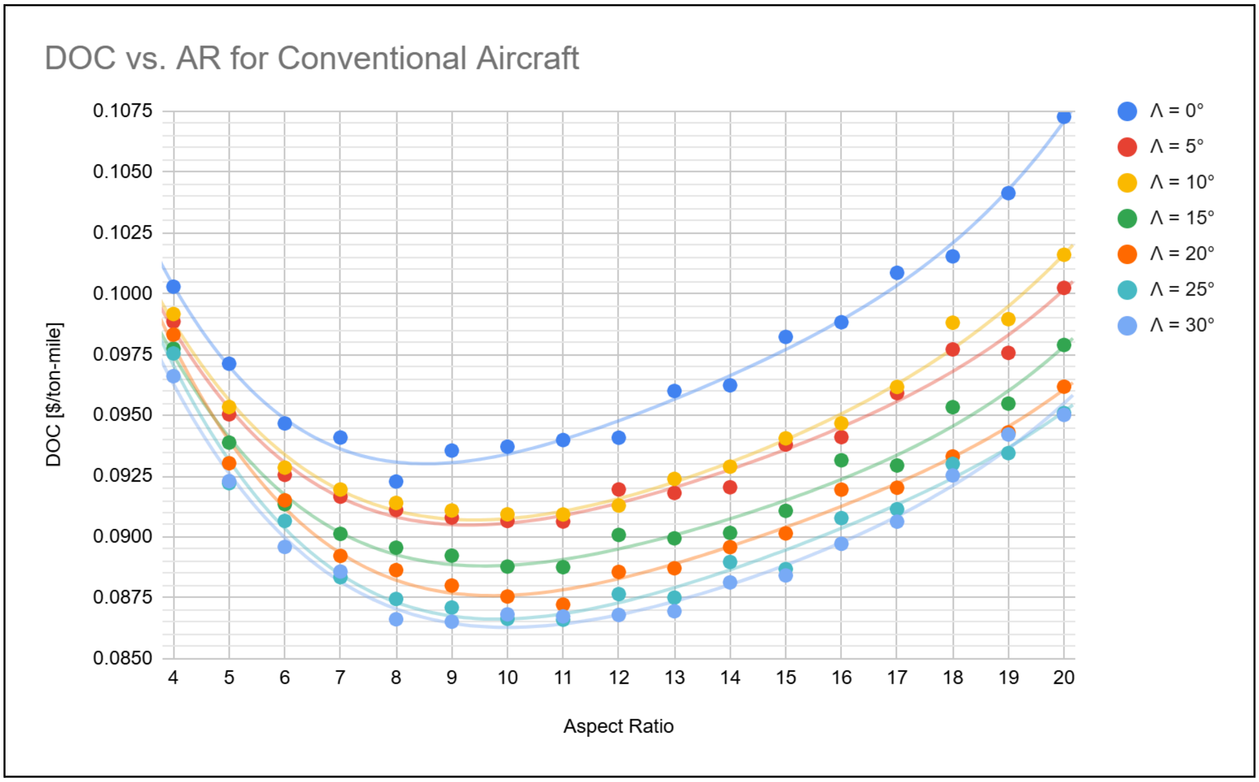
1.1 Design Specifications

Specification	Value
Number of Passengers	210 (2-class, domestic rules)
Cargo Weight	8,000 lbs (10 lbs/ft³)
Maximum Payload Weight	55,000 lbs
Range (still air)	3,500 nautical miles
Takeoff Field Length	6,900 feet (sea-level, hot day 84°F)
Landing Approach Speed	135 knots
Cruise Mach Number	0.8
Initial Cruise Altitude	35,000 feet
Maximum Wingspan	125 feet
Maximum Percent Fuel Weight at Landing	45%

Table 1: Aircraft Design Specifications

Table 1 shows the specifications that the two aircrafts are required to meet. These design parameters define the aircraft's operational capabilities, including passenger and cargo capacity, cruise range, takeoff field length, landing performance, and other aerodynamic constraints. Besides these explicit specifications, the two aircrafts also have to meet all safety requirements such as minimum 1.3 stall velocity operation and passing safety gradients in all flight segments. Optimization is performed by parallelly clearing all requirements and iterating aspect ratio (AR) and swept angle (Λ) for minimum DOC. Other properties of the aircraft are then extracted and calculated from the MATLAB code for further sizing procedure and final design in Solidworks. This process is done twice for the conventional aircraft design and the advanced technology design.

1.2 Wing Sizing Results



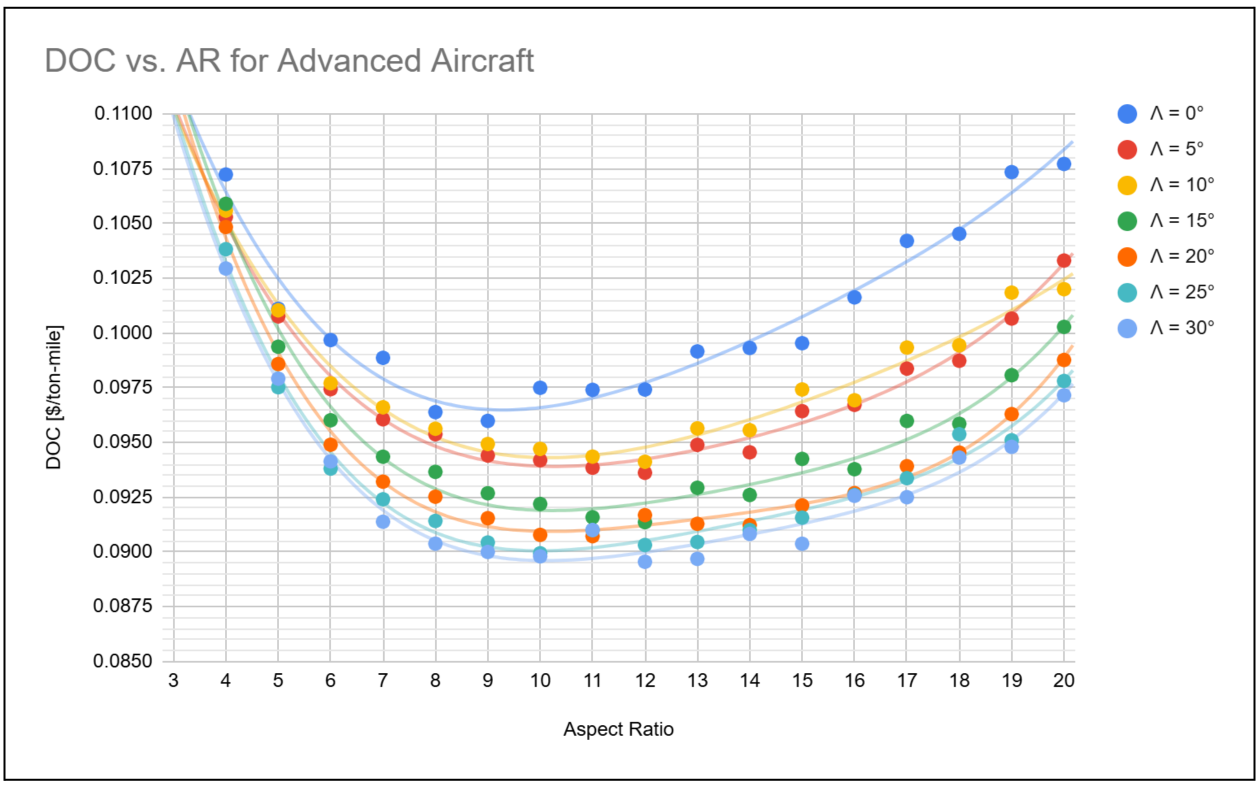


Figure 1: DOC vs. AR for All Aluminum (top) and for All Composite (bottom)

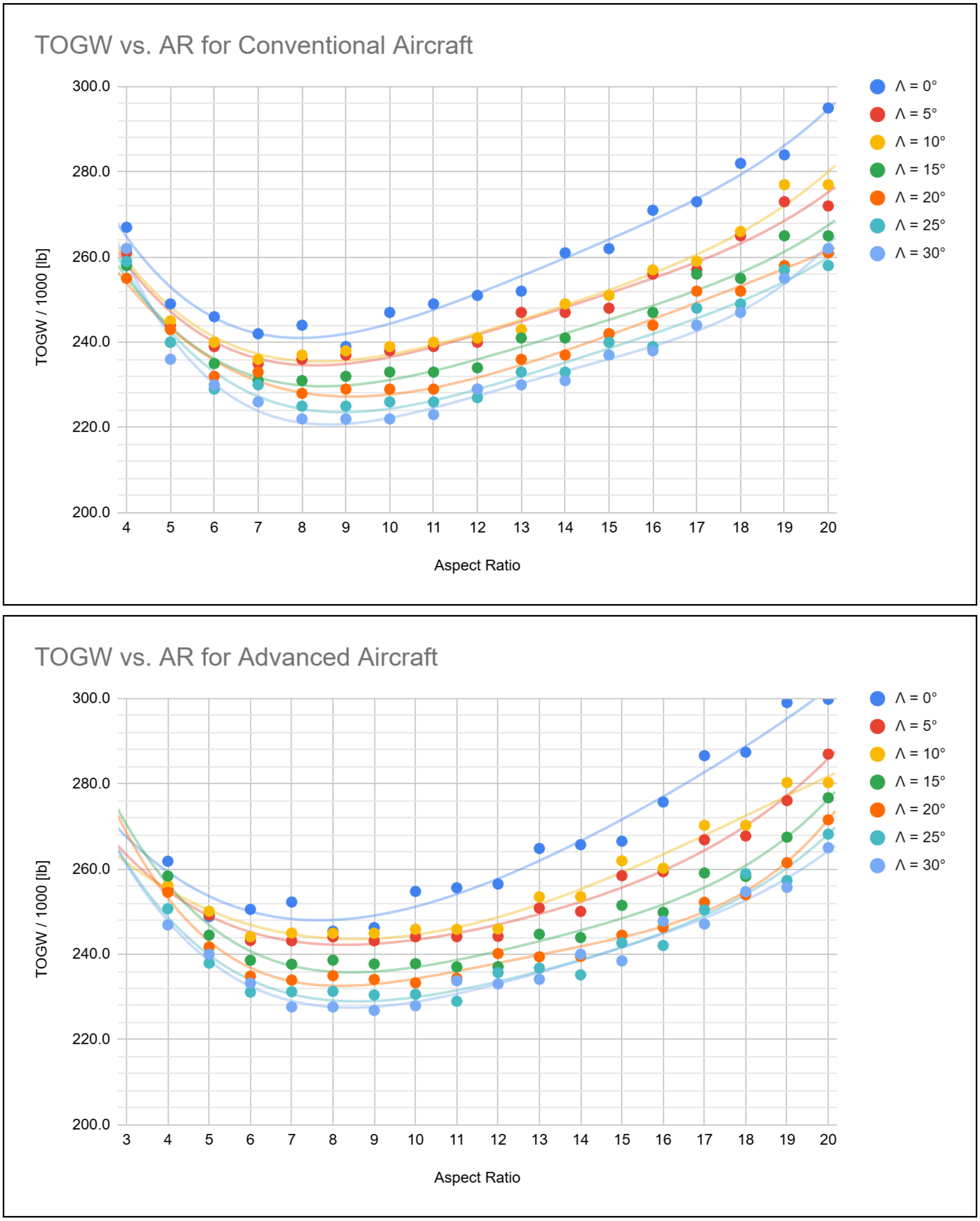


Figure 2: TOGW vs. AR for All Aluminum (top) and for All Composite (bottom)

It's worth noting that both DOC vs. AR graphs and TOGW vs. AR graphs converge at the same AR and Λ. Therefore, minimizing DOC is the same as minimizing Takeoff Gross Weight (TOGW). This makes sense because TOGW and DOC have a linear relationship. As TOGW increases, DOC increases and as TOGW decreases, DOC also decreases.

Aspect ratio trend is in U shape. At extreme low AR, 4, and extreme high AR, 20, the DOC is significantly higher than mid range AR, 7-11. The AR that gives the lowest DOC is around 9, which is expected for most current commercial aircrafts [1]. However, due to the Maximum Wingspan requirement in Table 1, AR is chosen to be 8. At AR value at 9 and above, the wingspan is greater than 125 [ft], thus disqualifying them from design consideration.

Swept angle trend is opposite to DOC. As Λ increases, DOC decreases. Therefore, Λ should be as high as possible to minimize DOC. However, when Λ is too high, the designs cannot pass all specifications and safety requirements. This leads to Λ stops at 30° for both designs because higher Λ values aren't able to pass safety gradients.

1.3 Primary Analysis: Detailed Composite vs Aluminum

WEIGHT [lb]	**Conventional**	**Advanced**
Wing	22,077.63	22,559.16
Fuselage	2,542.66	2,557.72
Nacelle + Pylon	4,661.90	4,842.47
Tail	4,342.67	4,437.39
Power Plant	23,463.19	25,809.51
Fixed Equipment	37,630.00	37,827.83
Fuel	64,994.09	72,136.82

Table 2: Components Weight Comparison Between Conventional and Advanced Designs

Specific fuel consumption (SFC) for conventional aircraft design is 0.68 while SFC for advanced aircraft design is 0.61 because advanced engines provide a 10% decrease in SFC.

In conventional aircraft design, all components are in aluminum while in advanced aircraft design, all components are in composite material. In particular, wing and tail components weight decrease 30%, fuselage weight decreases 15%, fixed equipment weight decreases by 10%, nacelles and pylons decrease by 20%.

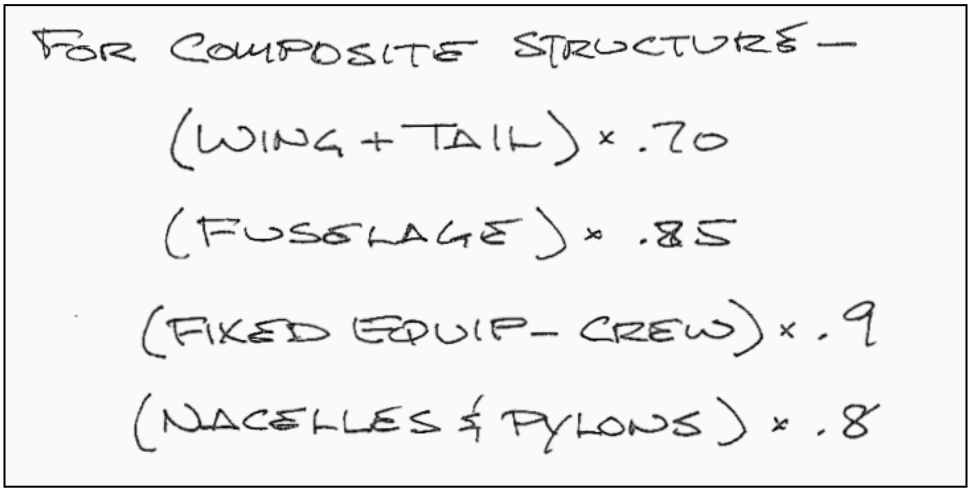


Figure 3: Course Manual Advanced Technology Weight Change

The only exception is the power plant because for advanced technology, the power plant weight is 10% higher to trade off for the 10% decrease of the SFC. Composite material is lighter than aluminum, so theoretically advanced aircraft design should have lower weight compared to conventional aircraft design. However, because of the increase in power plant weight and decreases in SFC, the design optimization loop changed the configuration into a different optimal TOGW thus changing the weight of all components.

1.4 Aircraft Comparison Specs

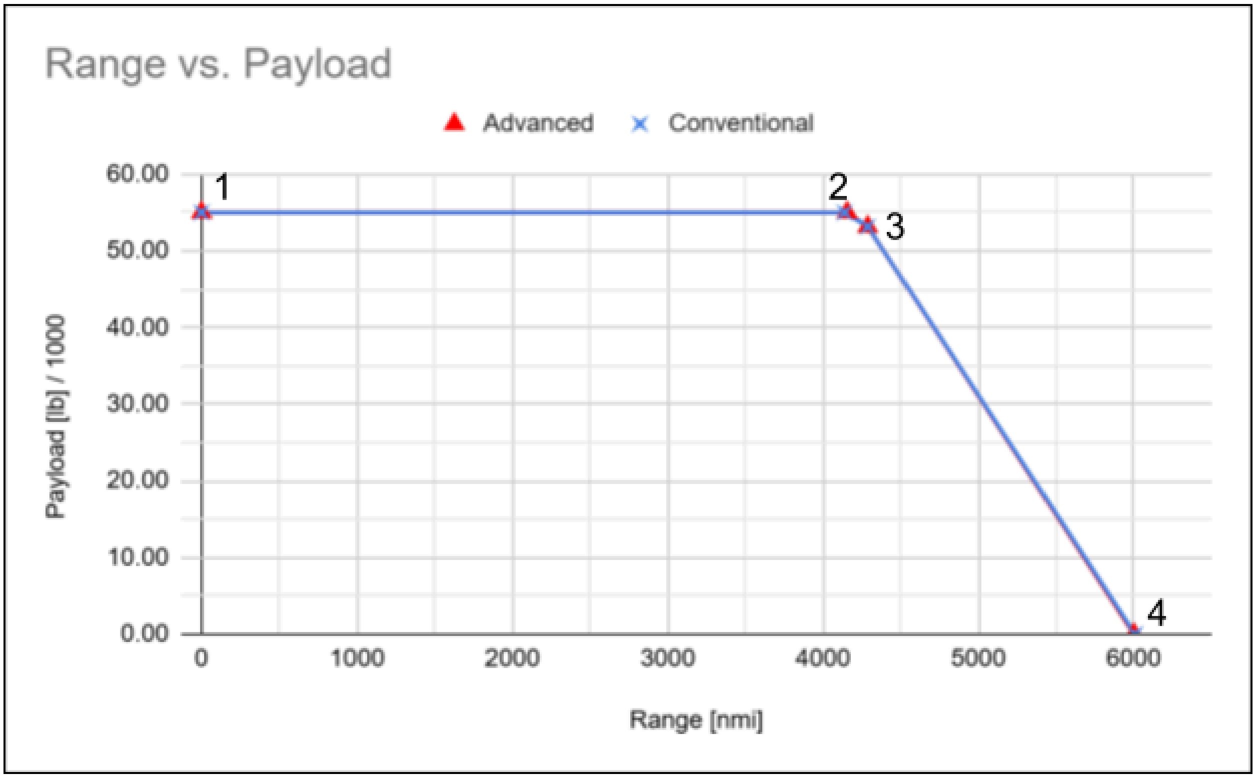
	Conventional	Advanced
WING		
Wingspan [ft]	123.02	122.40
MAC [ft]	16.57	16.48
Planform Area [ft^2]	1,891.67	1,872.76

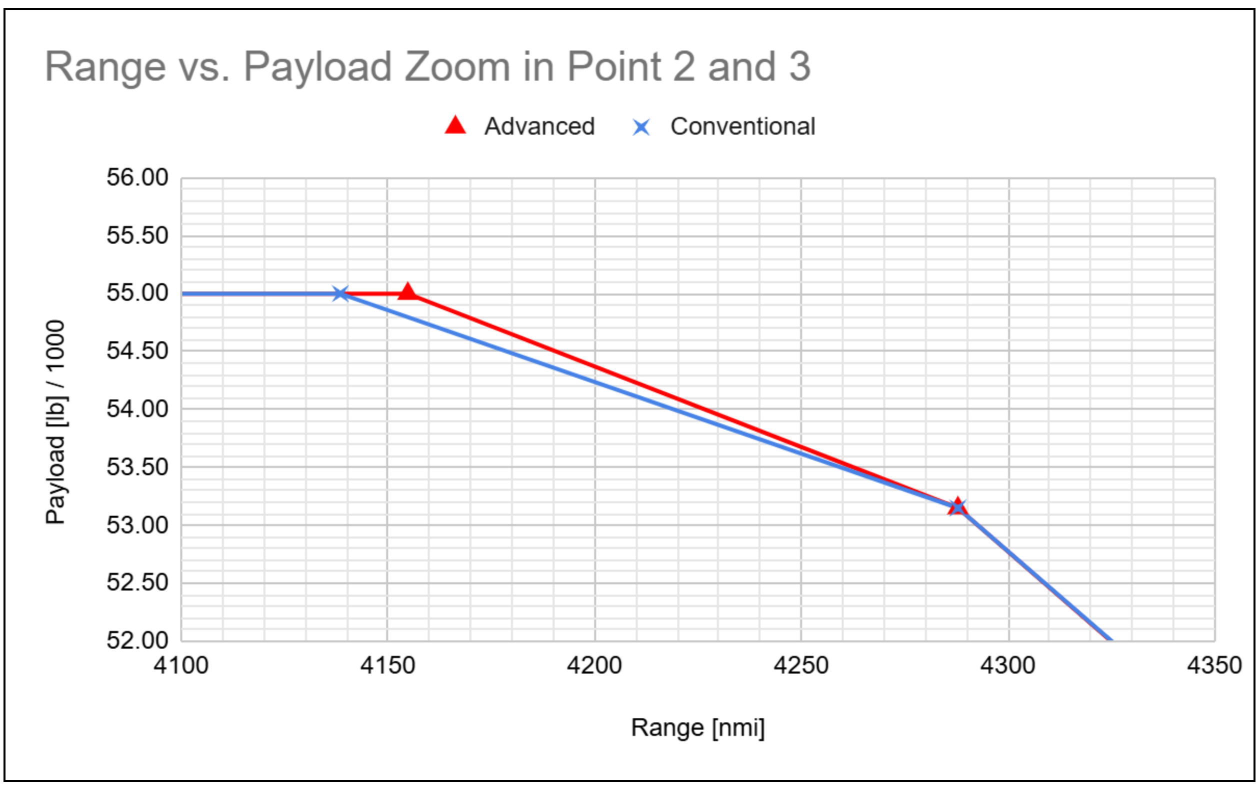
Airfoil Type	Supercritical	Supercritical
Aspect Ratio (AR)	8	8
Swept Angle (°)	30	30
FUSELAGE		
Length [ft]	165.78	165.78
Diameter [ft]	14	14
Seats Abreast	6	6
MATERIAL		
Wing	Aluminum	Composite
Fuselage	Aluminum	Composite
Nacelle + Pylon	Aluminum	Composite
Tail	Aluminum	Composite
Fixed Equipment	Aluminum	Composite
WEIGHT [lb]	**Conventional**	**Advanced**
Wing	22,077.63	22,559.16
Fuselage	2,542.66	2,557.72
Nacelle + Pylon	4,661.90	4,842.47
Tail	4,342.67	4,437.39
Power Plant	23,463.19	25,809.51
Fixed Equipment	37,630.00	37,827.83
Fuel	64,994.09	72,136.82
ENGINES		
Flat Plate Drag Area [ft^2]	30.77	30.60
Engine Type	JT9D	JT9D
Number of Engines	2	2
Max Thrust per Engine [lb]	43,857.47	44,154.67
Takeoff Gross Weight [lb]	222,000.00	227,652.24
All-out Range NM	4,045.84	4,045.84

DOC [$/ton-mile]	0.0865	0.0900
SFC	0.68	0.61
Powerplant Weight [lb]	24,501.38	26,951.52

Table 3: Specification Comparison Between Conventional and Advanced Designs

The comparison between the conventional (full aluminum) and advanced (full composite) aircraft designs reveals a nuanced balance of performance, efficiency, and economic considerations. Both configurations use a supercritical airfoil with similar wing dimensions, maintaining an aspect ratio (AR) of 8 and a swept angle of 30 degrees. This consistency ensures aerodynamic efficiency is primarily determined by structural materials rather than geometric differences. The full composite wing, though slightly heavier (22,559.16 lb) than the aluminum wing (22,077.63 lb), may offer better durability and reduced life-cycle maintenance. The small increase in weight might reflect enhanced structural integrity offered by composites. Both configurations employ JT9D engines, but the advanced design achieves slightly higher thrust per engine (44,154.67 lb vs. 43,857.47 lb). This reflects the ability of composite materials to endure greater stress, possibly enhancing propulsion efficiency. The composite design, with its sophisticated material technology, results in higher fuel capacity (72,136.82 lb vs. 64,994.09 lb) to potentially expand operational range under heavier payloads. However, this benefit comes with an increased Direct Operating Cost (DOC) of $0.0900/ton-mile compared to the aluminum design's $0.0865/ton-mile. This suggests that while composites offer performance improvements, they might slightly elevate operational expenses without significant cost-offsetting measures.


Range vs. Payload
Advanced
Conventional
Payload [lb] / 1000
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
1000
2000
3000
4000
5000
6000
Range [nmi]
1
2
3
4


Range vs. Payload Zoom in Point 2 and 3
Advanced
Conventional
Payload [lb] / 1000
56.00
55.50
55.00
54.50
54.00
53.50
53.00
52.50
52.00
4100
4150
4200
4250
4300
4350
Range [nmi]

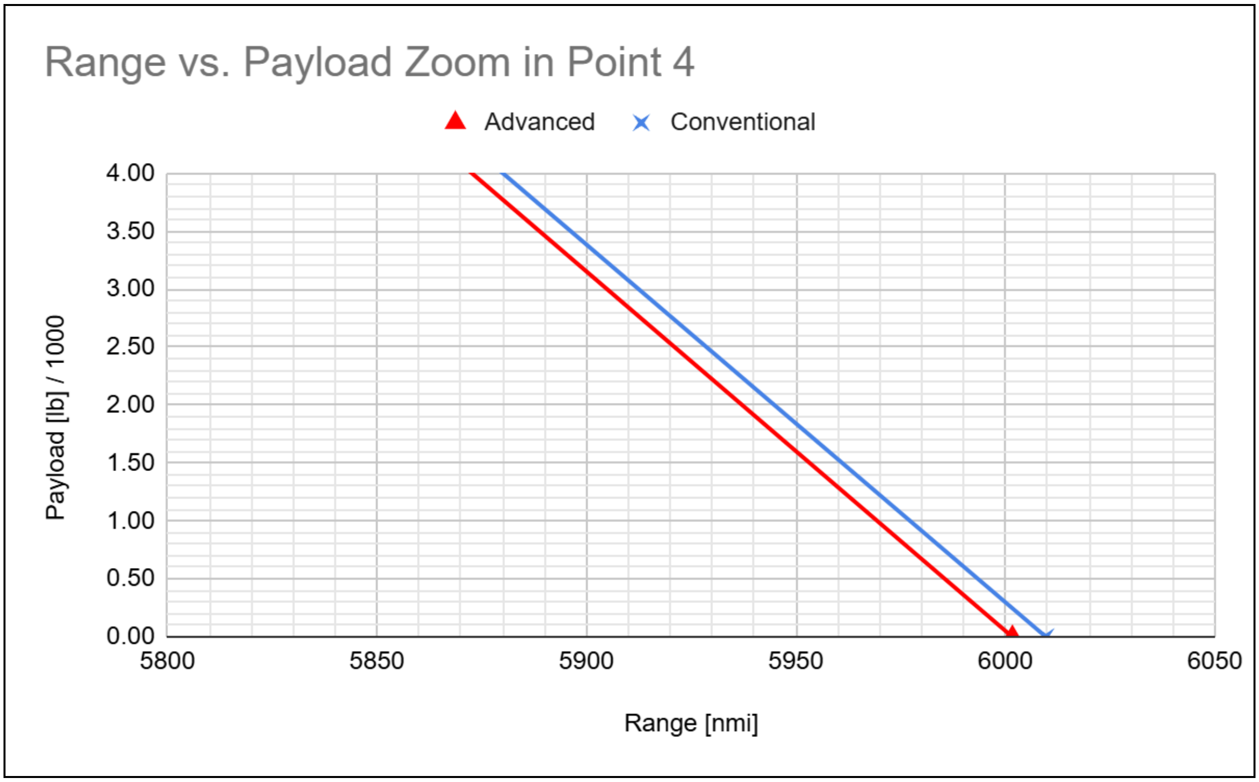


Figure 4: Payload Range Chart

2. Results and Conclusions

After a thorough analysis and comparison of the conventional aluminum and advanced composite configurations, the decision is made in favor of the full aluminum configuration. This choice is based on a combination of efficiency, cost-effectiveness, and familiarity that aligns well with operational and strategic goals.

Aluminum has a long history in the aerospace industry, providing proven reliability and durability. The material's known performance characteristics reduce the risk associated with adopting new technologies and support consistent operational outcomes. The production and material costs for aluminum are markedly lower than those for advanced composites. This results in substantial savings upfront, allowing airlines to allocate resources to other critical areas such as training, maintenance, and expansion. Aluminum's extensive use means simplified maintenance procedures and a wide availability of repair expertise and parts. This leads to reduced maintenance downtimes and costs throughout the aircraft's lifecycle, enhancing overall operational efficiency.

DOC for conventional aircraft is lower compared to advanced aircraft. Therefore, by continuing with aluminum, airlines capitalize on a well-understood material while remaining competitive in markets dominated by cost-sensitive decisions. This choice also supports a conservative risk profile, appealing to stakeholders prioritizing stability and predictability.

3. Description of the Configuration

3.1 Wing and Tails

Wing AR, Λ, and reference area (S_{ref}) is taken from MATLAB code and analysis above. In AR vs. DOC Figure 1 and Figure 2, the lowest points are chosen for the two aircrafts. Then using equations in Schaufele textbook, the rest of the information of the wing can be calculated.

Name	Value / Equation
⊟ Global Variables	
"Root Chord W"	= 2 * "S_ref" / ("Span W" * (1 + "Taper Ratio W"))
"Tip Chord W"	= "Root Chord W" * "Taper Ratio W"
"Swept Angle W"	= 30
"Span W"	= sqr ("S_ref" * "AR W")
"AR W"	= 8
"S_ref"	= 1872.75746643
"Taper Ratio W"	= 0.35
"MAC W"	= (2 / 3) * "Root Chord W" * (1 + "Taper Ratio W" - ("Taper Ratio W" / (1 + "Taper Ratio W")))
"Y W"	= ("Span W" / 6) * ((1 + 2 * "Taper Ratio W") / (1 + "Taper Ratio W"))

Table 4: Equations for Wing in Solidworks

Here the calculation was computed inside Solidworks Equations so that they can be directly implemented in the 3D design as variables. In later design and sizing processes, when these parameters need to be changed, they can be changed easily and updated systematically in Solidworks to smooth out the design process.

For tail sizing, Schaufele is heavily utilized. Tail Volume was determined from the graphs in Fig. 6-9 and 6-15 of Schaufele. This value is then double checked in Tables of Fig. 6-10 and 6-16. Schaufele Fig. 6-17 and 6-18 are used to determine the AR and Taper Ratio (λ) for the tails. These values are a good first estimation of tails. For actually accurate values, however, course MAE 175 offers a more detailed analysis for flight dynamics stability and sizing procedure for tails to keep the aircraft stable during flight.

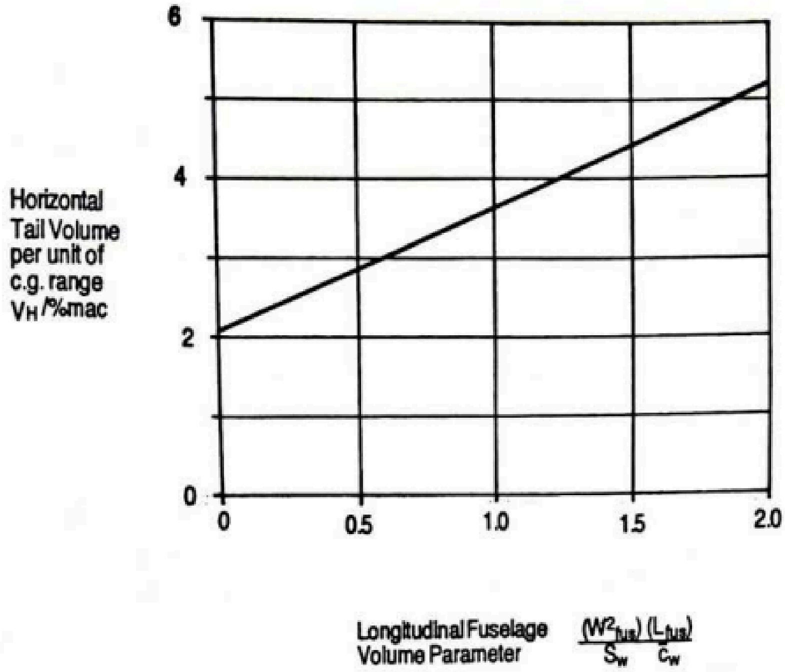


Fig. 6-9 Preliminary Design Chart ~ Horizontal Tail Volume Determination

Aircraft Type	V_H Range
Personal/Utility	.48- .92
Commuters	.46-1.07
Regional Turboprops	.83-1.47
Business Jets	.51 - .99
Jet Transports	.54-1.48
Military Fighter/Attack	.20 - .75

Fig. 6-10 Representative Horizontal Tail Volume Ranges

Figure 5: Fig. 6-9 and 6-10 from Schaufele for Horizontal Tail Volume

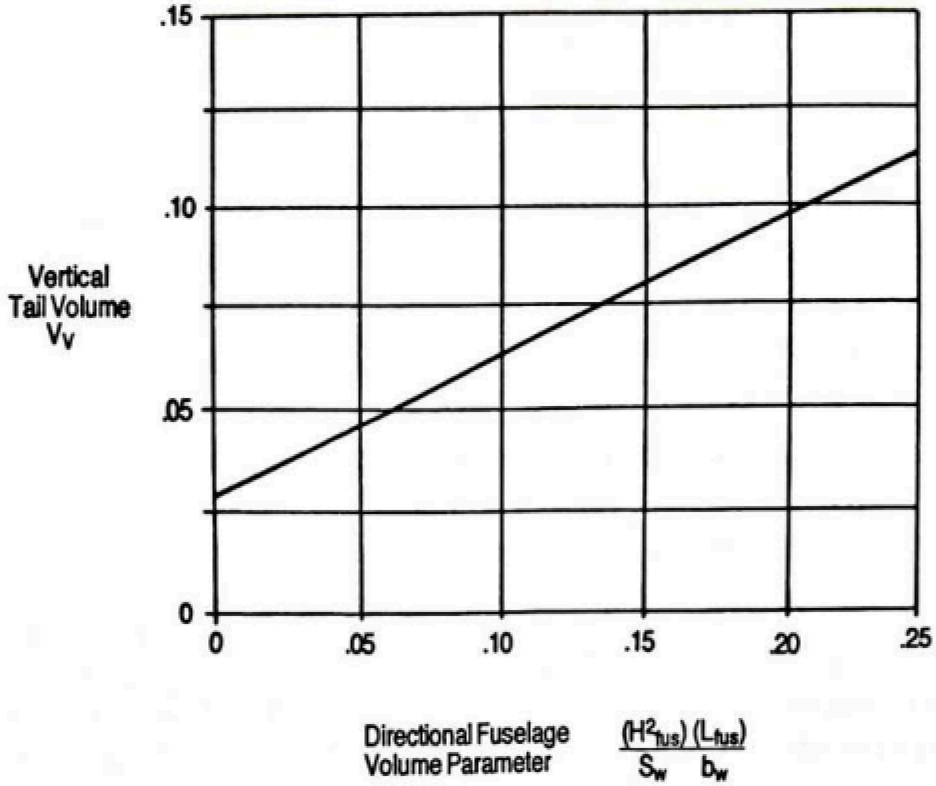


Fig. 6-15 Preliminary Design Chart ~ Vertical Tail Volume Determination

Aircraft Type	V_V Range
Personal/Utility	.024 - .086
Commuters	.041 - .097
Regional Turboprops	.065 - .121
Business Jets	.061 - .093
Jet Transports	.038 - .120
Military Fighter/attack	.041 - .130

Fig. 6-16 Representative Vertical Tail Volume Ranges

Figure 6: Fig. 6-15 and 6-16 from Schaufele for Vertical Tail Volume

Aircraft Type	AR	λ	c_e/c	t/c
Personal/Utility	3.5-5.0	.50-1.0	.35-.45	.06-.09
Commuters	3.5-5.0	.50-.80	.35-.45	.06-.09
Regional Turboprops	3.5-5.0	.50-.80	.30-.45	.06-.09
Business Jets	3.5-5.0	.35-.50	.30-.40	.06-.09
Jet Transports	3.5-5.0	.25-.45	.30-.35	.06-.09
Military Fighter/Attack	3.0-4.0	.25-.40	.30-1.0	.03-.04

Fig. 6-17 Summary of Horizontal Tail Geometric Characteristics

Aircraft Type	AR	λ	c_r/c	t/c
Personal/Utility	1.2-1.8	.30-.50	.25-.45	.06-.09
Commuters	1.2-1.8	.30-.80	.35-.45	.06-.09
Regional Turboprops	1.4-1.8	.30 -.70	.25-.45	.06-.09
Business Jets	0.8-1.6	.30-.60	.25-.35	.06-.09
Jet Transports	1.4-1.8	.30-.80	.25-.40	.08-.10
Military Fighter/Attack	1.2-1.6	.25-.40	.20-.35	.03-.09

Fig. 6-18 Summary of Vertical Tail Geometric Characteristics

Figure 6: Fig. 6-16 and 6-17 from Schaufele for Tail AR and Taper Ratio λ

Instead of approximate fuel tanks as rectangles, the fuel tanks for the aircrafts are sized inside Solidworks, the shape is a smaller scaled version airfoil shape of the wing so that it can fully take advantage of the available space and affect CG location as small as possible. In fact, in aircraft stability, fuel tank is a component that changes weight the most, therefore, to ensure stability, fuel tank CG needs to be as close to quarter chord MAC as possible.

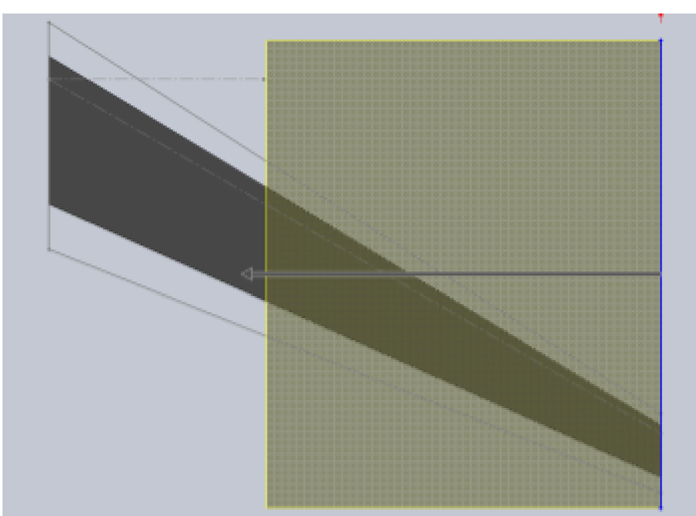


Figure 7: Sizing Fuel Tank

Front and rear wing spar locations are sized as recommended in Schaufele to be 15% to 75% of the chord. This is extruded all the way from root chord to tip chord. After that, the fuse tank is iteratively cut back from tip airfoil side until the desired fuel tank volume is reached

3.2 Fuselage and Exterior Configuration

Fuselage nose and tail was traced from the B737 aircraft drawing and scaled up to the required dimension of the diameter and length for the aircrafts. For the fuselage, the first cut is taken from the MATLAB code for a maximum fuselage length. After doing the interior layout in Section 3.4, a second cut is made for the minimum fuselage length. The fuselage length is then iterated in Center of Gravity (CG) sizing, increasing from minimum fuselage length to maximum fuselage length to make sure stability is satisfied while keeping the length as short as possible to avoid unnecessary weight and material cost.

Nacelles were sized to accommodate the scaled version of the JT9D engine. Sizing procedure follows Schaufele Figure 8-15. The size and shape of the nacelles are dictated by engine dimensions and performance requirements such as Bypass Ratio (BPR) and Sea Level Static Rated Thrust (SLSRT).

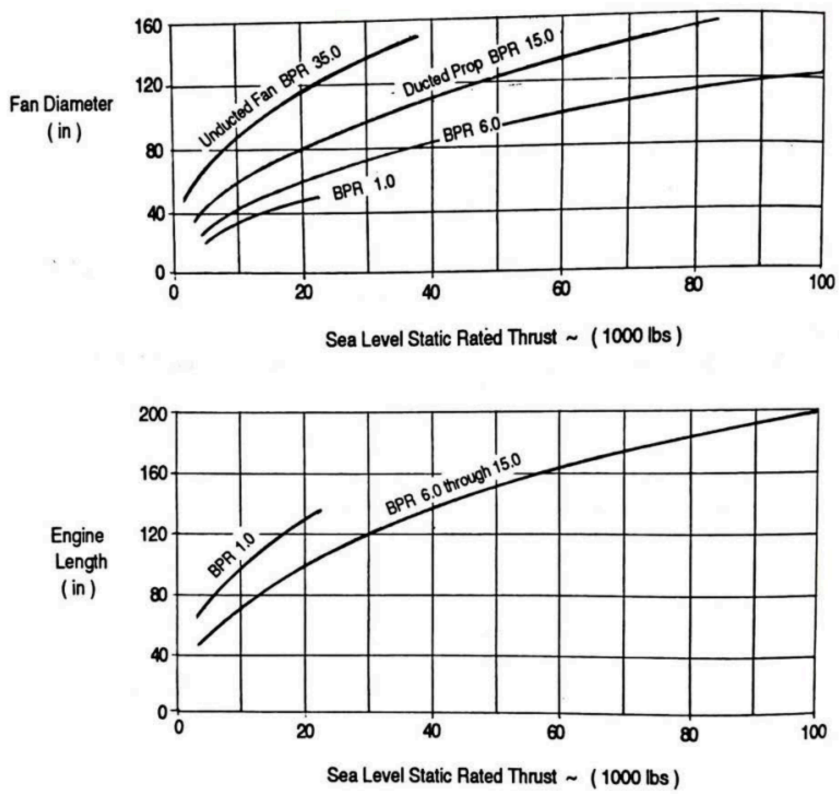


Figure 8: Fig. 8-15 from Schaufele for Nacelle Sizing

Landing Gear Sizing has two parts: one is tire selection and one is angle check. For tire selection, the main gear has to be able to take 100% of the TOGW while the nose gear is 15%

TOGW. With this requirement, in Course Manual Page 87, Figure 4.11, main gear is selected to have 8 tires, 4 tires each side, with rated load of 35,500 lb and dimension 44x16 inch while nose gear is selected to be 2 tires, 25,000 lb, and dimension 40x14 inch.

Type VII - Extra High Pressure Tires Main Wheels

Tire Size	Ply Rating	Max Width inches	Max Diam. inches	Loaded Radius inches	Tire and tube wt. lbs.	Commercial		Military	
						Press lbs/sq.in.	Rated Load lbs	Press lbs/sq.in.	Rated Load lbs.
24 x 7.25	10	7.3	24.0	10.3	29.7	120	6,600		
29 x 7.7	12-16	7.6	28.0	12.2	36-44	160	9,800	220	13,800
34 x 11	18	11.0	33.0	13.9	84.1	125	15,500		
36 x 11	24	11.1	35.0	15.0	86.2			220	25,600
40 x 14	22	13.5	39.2	11.8	112	145	25,000		
44 x 13	26	13.4	43.2	18.4	141.5			200	35,000
44 x 16	26	15.6	43.1	18.0	151.6	165	35,500		
56 x 16	24	16.0	55.8	24.1	258.7			178	45,000
56 x 16	32	16.1	55.8	24.1	296.3			240	60,000
56 x 16	36	16.1	55.8	24.1	297.0			280	71,000

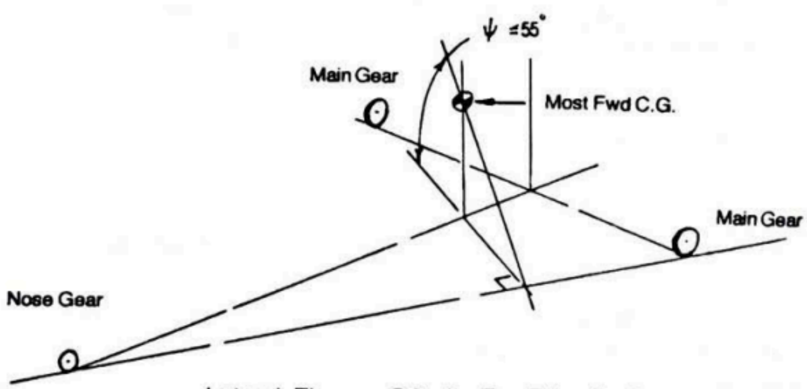
AERODYNAMIC DESIGN

Fig. 4:11. Tire Ratings. Ref. U.S. Rubber Co.

4:2

Figure 9: Fig. 5.22 from Course Manual for Landing Gear Tire Selection

Landing gear has to satisfy aft CG angle at least 20°, tip back angle lengthwise minimum 14°, tip back angle spanwise minimum 5°, and tipover criteria needs Ψ minimum 55°.



Lateral Tipover Criteria For Tricycle Gears

Fig. 7-2 Tipover Criteria for Landing Gears

Figure 10: Figure 7-2 from Schaufele for Landing Gear Sizing

Cargo Containers are decided based on the Interior Layout in Section 3.4. The cargo cannot be too big because there's no space for passengers. On the other hand, cargo cannot be too small because its length would need to exceed fuselage length to satisfy payload and also it requires extra materials to hold the aircraft structure integrity.

3.3 C.G Design

This follows Center of Gravity (CG) sizing procedure to make sure the aircraft CG location is always around MAC quarter chord for a tolerance of 10%. There are four extreme conditions the aircrafts can be in: design, empty, ferry, and landing. In design, all cargo, fuel and passengers are taken into calculation. In empty, none of them are considered. In ferry, only fuel is considered. And finally in landing, only cargo and passengers are considered. If all these extreme four conditions are satisfied, then all the combinations in between are also satisfied.

Component	Design			Empty		
	Weight	Length	Moment	Weight	Length	Moment
Wing	2.21E+04	1.80E+02	3.97E+06	2.21E+04	1.80E+02	3.97E+06
Fuselage	2.54E+03	2.66E+02	6.76E+05	2.54E+03	2.66E+02	6.76E+05
Landing Gear	7.44E+03	1.80E+02	1.34E+06	7.44E+03	1.80E+02	1.34E+06
Nose Tires	2.24E+02	1.40E+02	3.13E+04	2.24E+02	1.40E+02	3.13E+04
Main Tires	1.21E+03	1.85E+02	2.24E+05	1.21E+03	1.85E+02	2.24E+05
Nacelle + Pylon	4.66E+03	1.68E+02	7.83E+05	4.66E+03	1.68E+02	7.83E+05
Tail	4.34E+03	2.56E+02	1.11E+06	4.34E+03	2.56E+02	1.11E+06
PP	2.35E+04	1.68E+02	3.94E+06	2.35E+04	1.68E+02	3.94E+06
Fixed Equipment	3.76E+04	1.80E+02	6.77E+06	3.76E+04	1.80E+02	6.77E+06
Fuel	6.50E+04	1.75E+02	1.14E+07	0.00E+00	1.75E+02	0.00E+00
PAX	4.52E+04	1.80E+02	8.12E+06	0.00E+00	1.80E+02	0.00E+00
Cargo	8.00E+03	1.80E+02	1.44E+06	0.00E+00	1.80E+02	0.00E+00
Sum	2.22E+05		3.98E+07	1.04E+05		1.88E+07

Ferry			Landing		
Weight	Length	Moment	Weight	Length	Moment
2.21E+04	1.80E+02	3.97E+06	2.21E+04	1.80E+02	3.97E+06
2.54E+03	2.66E+02	6.76E+05	2.54E+03	2.66E+02	6.76E+05
7.44E+03	1.80E+02	1.34E+06	7.44E+03	1.80E+02	1.34E+06
2.24E+02	1.40E+02	3.13E+04	2.24E+02	1.40E+02	3.13E+04
1.21E+03	1.85E+02	2.24E+05	1.21E+03	1.85E+02	2.24E+05
4.66E+03	1.68E+02	7.83E+05	4.66E+03	1.68E+02	7.83E+05
4.34E+03	2.56E+02	1.11E+06	4.34E+03	2.56E+02	1.11E+06
2.35E+04	1.68E+02	3.94E+06	2.35E+04	1.68E+02	3.94E+06
3.76E+04	1.80E+02	6.77E+06	3.76E+04	1.80E+02	6.77E+06
6.50E+04	1.75E+02	1.14E+07	0.00E+00	1.75E+02	0.00E+00
0.00E+00	1.80E+02	0.00E+00	4.52E+04	1.80E+02	8.12E+06
0.00E+00	1.80E+02	0.00E+00	8.00E+03	1.80E+02	1.44E+06
1.69E+05		3.02E+07	1.57E+05		2.84E+07

	CG	Delta CG	Delta CG
Design	1.79E+02	0.4372198236	2.64%
Empty	1.82E+02	2.069263294	12.49%
Ferry	1.79E+02	0.5750568254	3.47%
Landing	1.81E+02	1.367619159	8.26%

Table 4: CG Sizing for Conventional Aircraft

Component	Design			Empty		
	Weight	Length	Moment	Weight	Length	Moment
Wing	2.26E+04	1.84E+02	4.15E+06	2.26E+04	1.84E+02	4.15E+06
Fuselage	2.56E+03	2.66E+02	6.80E+05	2.56E+03	2.66E+02	6.80E+05

Landing Gear	7.67E+03	1.84E+02	1.41E+06	7.67E+03	1.84E+02	1.41E+06
Nose Tires	2.24E+02	1.44E+02	3.22E+04	2.24E+02	1.44E+02	3.22E+04
Main Tires	1.21E+03	1.89E+02	2.29E+05	1.21E+03	1.89E+02	2.29E+05
Nacelle + Pylon	4.84E+03	1.72E+02	8.33E+05	4.84E+03	1.72E+02	8.33E+05
Tail	4.44E+03	2.56E+02	1.13E+06	4.44E+03	2.56E+02	1.13E+06
PP	2.44E+04	1.72E+02	4.19E+06	2.44E+04	1.72E+02	4.19E+06
Fixed Equipment	3.78E+04	1.84E+02	6.95E+06	3.78E+04	1.84E+02	6.95E+06
Fuel	7.21E+04	1.81E+02	1.30E+07	0.00E+00	1.81E+02	0.00E+00
PAX	4.52E+04	1.84E+02	8.30E+06	0.00E+00	1.84E+02	0.00E+00
Cargo	8.00E+03	1.84E+02	1.47E+06	0.00E+00	1.84E+02	0.00E+00
Sum	2.31E+05		4.24E+07	1.06E+05		1.96E+07

Ferry			Landing		
Weight	Length	Moment	Weight	Length	Moment
2.26E+04	1.84E+02	4.15E+06	2.26E+04	1.84E+02	4.15E+06
2.56E+03	2.66E+02	6.80E+05	2.56E+03	2.66E+02	6.80E+05
7.67E+03	1.84E+02	1.41E+06	7.67E+03	1.84E+02	1.41E+06
2.24E+02	1.44E+02	3.22E+04	2.24E+02	1.44E+02	3.22E+04
1.21E+03	1.89E+02	2.29E+05	1.21E+03	1.89E+02	2.29E+05
4.84E+03	1.72E+02	8.33E+05	4.84E+03	1.72E+02	8.33E+05
4.44E+03	2.56E+02	1.13E+06	4.44E+03	2.56E+02	1.13E+06
2.44E+04	1.72E+02	4.19E+06	2.44E+04	1.72E+02	4.19E+06
3.78E+04	1.84E+02	6.95E+06	3.78E+04	1.84E+02	6.95E+06
7.21E+04	1.81E+02	1.30E+07	0.00E+00	1.81E+02	0.00E+00
0.00E+00	1.84E+02	0.00E+00	4.52E+04	1.84E+02	8.30E+06
0.00E+00	1.84E+02	0.00E+00	8.00E+03	1.84E+02	1.47E+06
1.78E+05		3.27E+07	1.59E+05		2.94E+07

	CG	Delta CG	Delta CG
Design	1.84E+02	0.1364546776	0.76%
Empty	1.86E+02	1.722203485	9.63%
Ferry	1.84E+02	0.1772362095	0.99%
Landing	1.85E+02	1.145976928	6.41%

Table 5: CG Sizing for Advanced Aircraft

3.4 Interior Configuration

First part of the interior configuration of the aircrafts is the circular cross section in the middle of the fuselage.

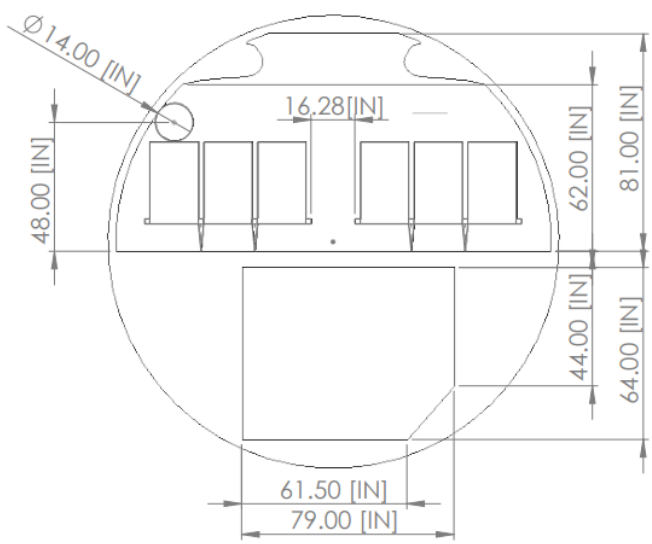


Figure 11: Cross Section Interior Configuration

The cargo is in the bottom while passengers are on top. Distance from floor to top ceiling is minimum 81 inches. The distance between floor and sitting ceiling is 62 inches minimum. Isle width is minimum 15 inches. Lastly, clearance for passengers at window seats has to satisfy 48 inches from floor and 14 inch diameter circle. With these constraints, the cargo is LD-3 cargo with a volume of 174 ft^3. To satisfy payload specifications, the aircraft needs 5 LD-3 cargo.

After the cross section is done, now the second part of the interior configuration is the seating layout where the aircraft is cut horizontally in side view at the floor in the first part. From the Course Manual page 92, Table 2, all the necessary variables can be obtained to design the seating layout of the aircrafts.

Category	**Long Range 3 Class**	**Medium Range 2 Class**	**Short/Medium 2 Class**
PASS MIX %			
1st Class	4-6	7-9	8-11
Business	19 (18-20)	X	X
LAVS			
1st Class	15/LAV (2 MIN)	20/LAV (2 MIN)	ONE REQ'D
Business	35/LAV (2 MIN)	X	X
Economy	50/LAV	50/LAV	50/LAV
Standard Lav Size	38" × 40"		
Galley—Carts / Pass			
1st Class	0.40 CART/PASS	0.30 CART/PASS	0.30 CART/PASS
Business	0.20 CART/PASS	X	X
Economy	0.095 CART/PASS	0.08 CART/PASS	0.075 CART/PASS
Cart Size	12 IN × 34 IN	12 IN × 34 IN	12 IN × 34 IN
Galley Size			
Height	Up to ceiling or as required		
Width	As required, 15" per cart including wall thickness and clearances		
Depth	38	38	36
Seat Pitch			
1st Class	60 IN MIN	40 IN MIN	38 IN MIN
Business	38 IN MIN	X	X
Economy	32 IN MIN	32 IN MIN	32 IN MIN

Depth/Recline			
1st Class	28 IN / 43 IN	28 IN / 36 IN	28 IN / 36 IN
Business	25 IN / 36 IN	X	X
Economy	25 IN / 32 IN	25 IN / 32 IN	25 IN / 32 IN
Bulkhead to Seat Nose			
1st Class	24	24	22
Business	20	X	X
Economy	18	18	20
Aisle Width			
1st Class	25 IN MIN	20 IN ASSUMED	20 IN ASSUMED
Business	20 IN MIN	X	X
Economy	18 IN MIN	18 IN ASSUMED	18 IN ASSUMED
Coat Room			
1st Class	2 IN/PASS	1.5 IN/PASS	1.5 IN/PASS
Business	1 IN/PASS	X	X
Economy	0 IN/PASS	0 IN/PASS	0 IN/PASS

Table 6: Course Manual page 92, Table 2 for Seating Layout Sizing

Because the range specification is at 3,500 nautical miles, the aircrafts are considered as Medium Range. Therefore, only the middle column “Medium Range 2 Class” needs to be considered.

First Class passengers are considered to take 7% of total PAX 210, so about 12 passengers. There must be at least 2 LAVs which are well over qualified for 20 passengers per LAV. There's a minimum 0.3 galley per passenger, so about 4 galley. Coat room is 1.5 inch / passenger, so about 18 inches. Seat pitches, aisle width, seat width, and seat length are 40, 20, 20, and 28 inches. Armrest is the same as economy but there’s no shared armrest for first class.

Economy needs a minimum 50 passengers/LAV so with 198 passengers, it needs to have 4 LAVs. Galley requires 0.08 cart per passenger, so there’ll be 16 of them. Seat pitches, aisle width, seat width, and seat length are 32, 18, 18, and 25 inches. Armrest is 2 inches.

	1st Class	Economy
PAX	12	198
#s of rows	2	33
#s of LAV (restroom)	1	4
#s of Galley	4	16
Coat room	18	0
Seat Pitch	40	32
Aisle Width	20	18
Seat width	20	18
Seat length	28	25
Armrest	2	no shared for 1st class
LAV length	38	
LAV width	40	
Galley length	15	
Galley width	38	
#s of EM Exit Type A	4	2 on each side
EM Exit Type A Length	42	
EM Exist Distance	720	

Table 7: Seating Layout Sizing

For Emergency Exit (EM) doors, Table 2A in Course Manual Page 93 is used to size it. There are a total 210 passengers. Double this amount is 420. All EM doors have to be able to evacuate 420 people. With these requirements, four EM door type A are chosen which yield 440 evacuation capacity.

TABLE 2 A

EMERGENCY EXIT DOOR DATA

	door type	minimum size	maximum evacuation capacity	crew assist	corner radii
entry door	x	60w x 76h	?	2	≤1/6w
entry door	A	42w x 72h	110	2	≤1/6w
entry door	B	32w x 72h	75	2	≤6inches
	C	30w x 48h	55	1	≤1/3w
	I	24w x 48h	45	1	≤1/3w
	II	20w x 44h	40	1	≤1/3w
	III	36w x 20h	35	1	≤1/3w
	IV	26w x 19h	9	1	≤1/3w
overhead hatch	comm.	36 x 20	-	-	≤1/3w
overhead hatch	military	24 x24	-	-	6 inches

Figure 12: Course Manual Page 93, Table 2A: Emergency Exit Door Sizing

3.5 Full Aircraft Configuration

Final Detailed Layout of Aircraft		
Aircraft Configuration	Full Aluminum	Full Composite
Wing Specifications		
Planform Area [ft^2]	1,891.67	1,872.76
Span [ft]	123.02	122.4
Aspect Ratio [1]	8	8
Sweep Angle [◦]	30	30
Taper Ratio [1]	0.35	0.35
Root Chord [ft]	22.78	22.67
MAC [ft]	16.57	16.48
Tail Specifications		
Horizontal Specifications		
Planform Area [ft^2]	711.34	711.34
Span [ft]	53.34	53.34

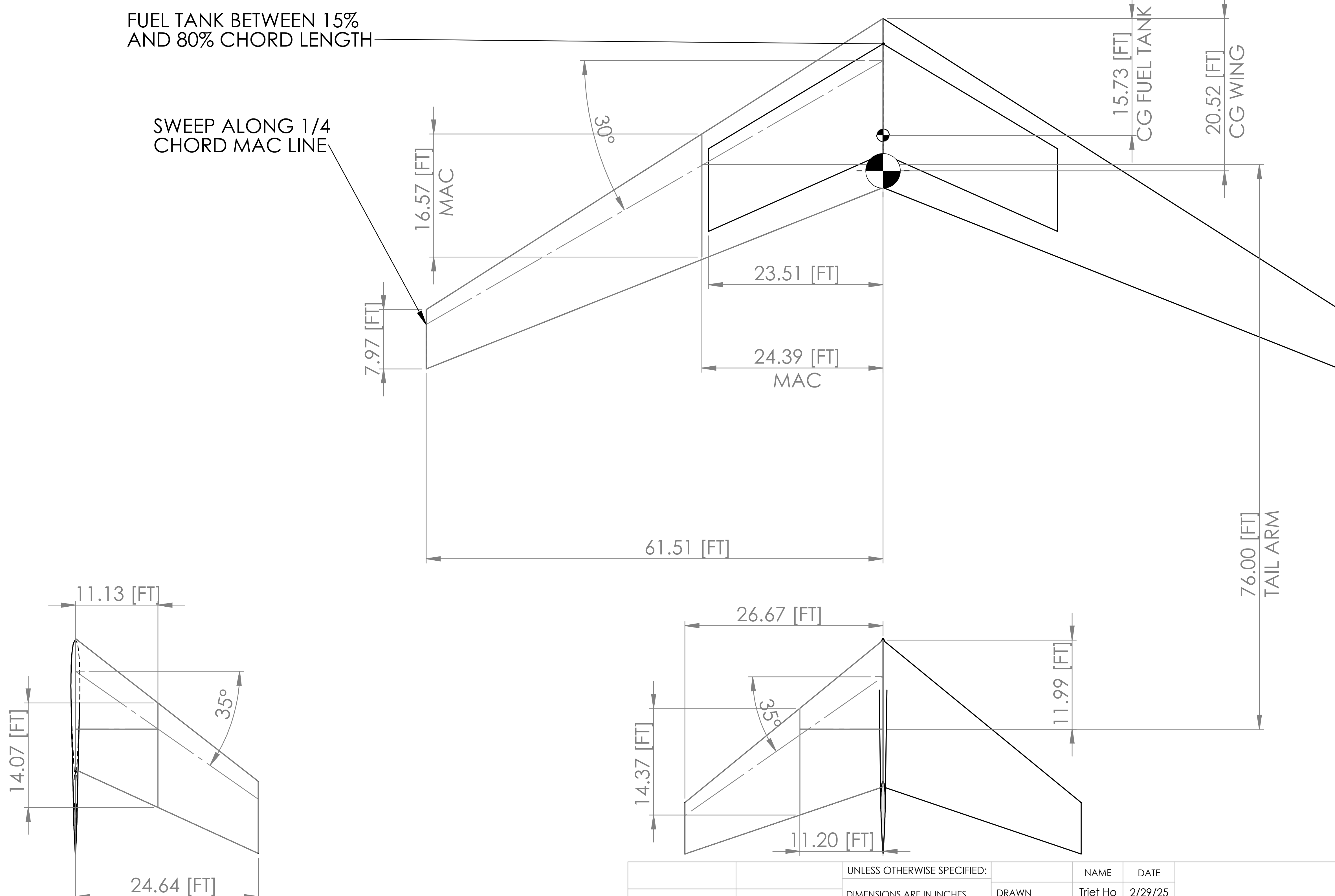
Aspect Ratio [1]	4	4
Sweep Angle [◦]	35	35
Taper Ratio [1]	0.35	0.35
Root Chord [ft]	19.75	19.75
MAC [ft]	14.36	14.36
Tail Arm Horizontal	76	76
Vertical Specifications		
Planform Area [ft^2]	674.3	674.3
Span [ft]	49.27	49.27
Aspect Ratio [1]	3.6	3.6
Sweep Angle [◦]	35	35
Taper Ratio [1]	0.35	0.35
Root Chord [ft]	17.66	17.66
MAC [ft]	14.07	14.07
Tail Arm Vertical	11.13	11.13
Engine Specifications		
Thrust [lb]	42071	41458
Inlet Diameter [ft]	8	9
Length [ft]	20	21.5
Weight [lb]	24,501.38	26951.51626
Fuel Tank Specifications		
Tank Volume [ft^3]	1428.11	1460
Span Wise Location [in]	22.12	23.51
Landing Gear		
Nose Gear Wheels	2	2
Nose Gear Tire Size	40 x 14	40 x 14
Main Gear Wheels	8	8
Main Gear Tire Size	44 x 16	44 x 16
Aft CG Angle	25	25
Tip Back Angle (Lengthwise)	14.16	14.16

Tip Back Angle (Spanwise)	16.4	17
Landing Gear Weight [lb]	8880	9100
Cargo Specifications		
Cargo Container	LD-3	LD-3
Cargo Volume [ft^3]	173.7548611	173.7548611
# Cargo	5	5
Interior Layout		
Exit Type	Type A	Type A
Dimensions [in]	42w x 72h	42w x 72h
Number of Exit	4	4
First Class		
PAX	12	12
Seat Depth/ Recline [in]	28 / 36	28 / 36
Seat Pitch [in]	40	40
Seat Abreast	4	4
Aisle	1	1
# Galleys	3	3
# Lavatory	1	1
Economy		
PAX	198	198
Seat Depth/ Recline [in]	25 / 32	25 / 32
Seat Pitch [in]	32	32
Seat Abreast	6	6
Aisle	1	1
# Galleys	15	15
# Lavatory	4	4

Table 8: Conventional versus Advanced Aircraft Configurations

4. Configuration Drawings

CONVENTIONAL AIRCRAFT



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MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

Wing Tail Diag.

SIZE	DWG. NO.	REV
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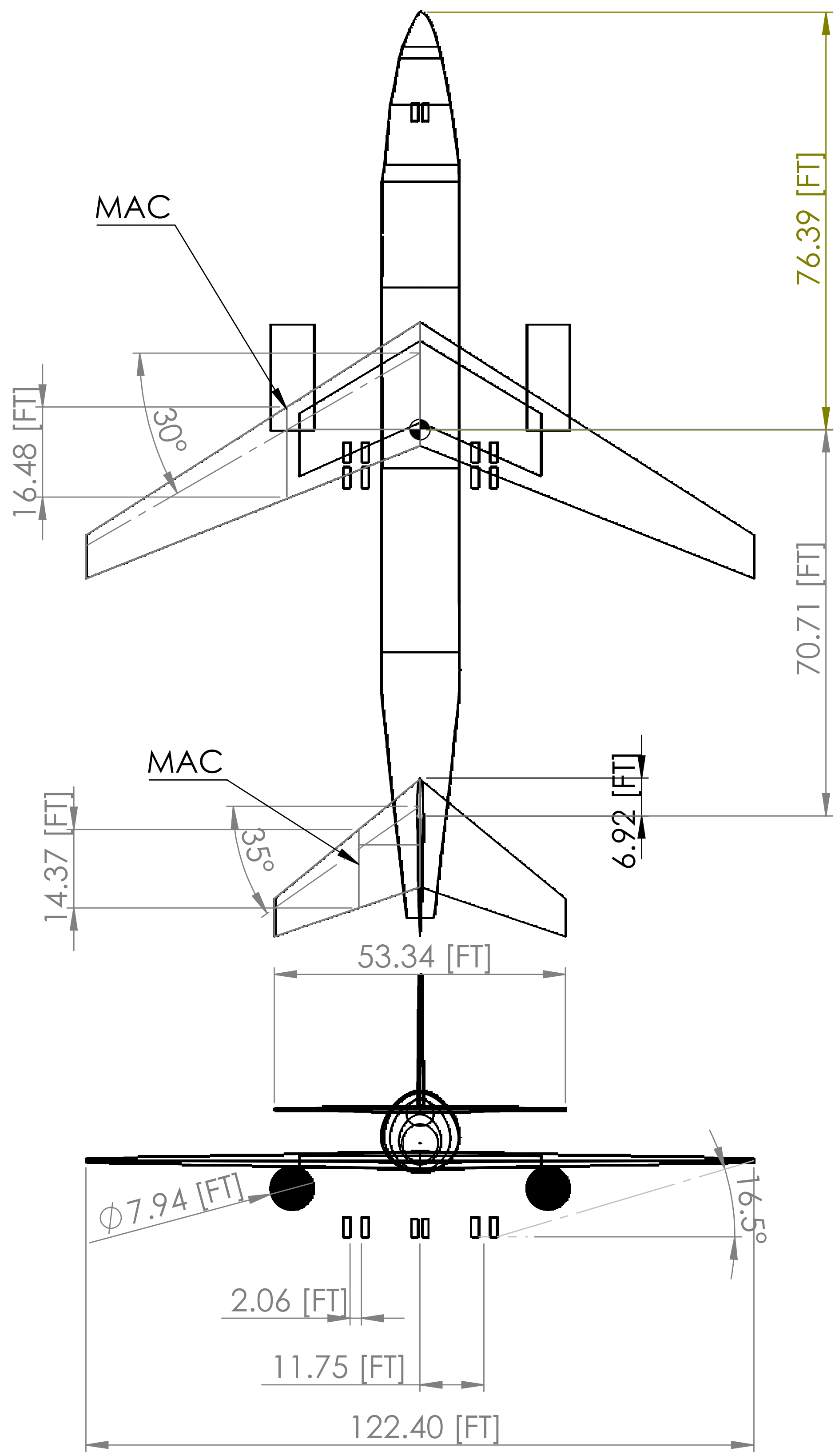

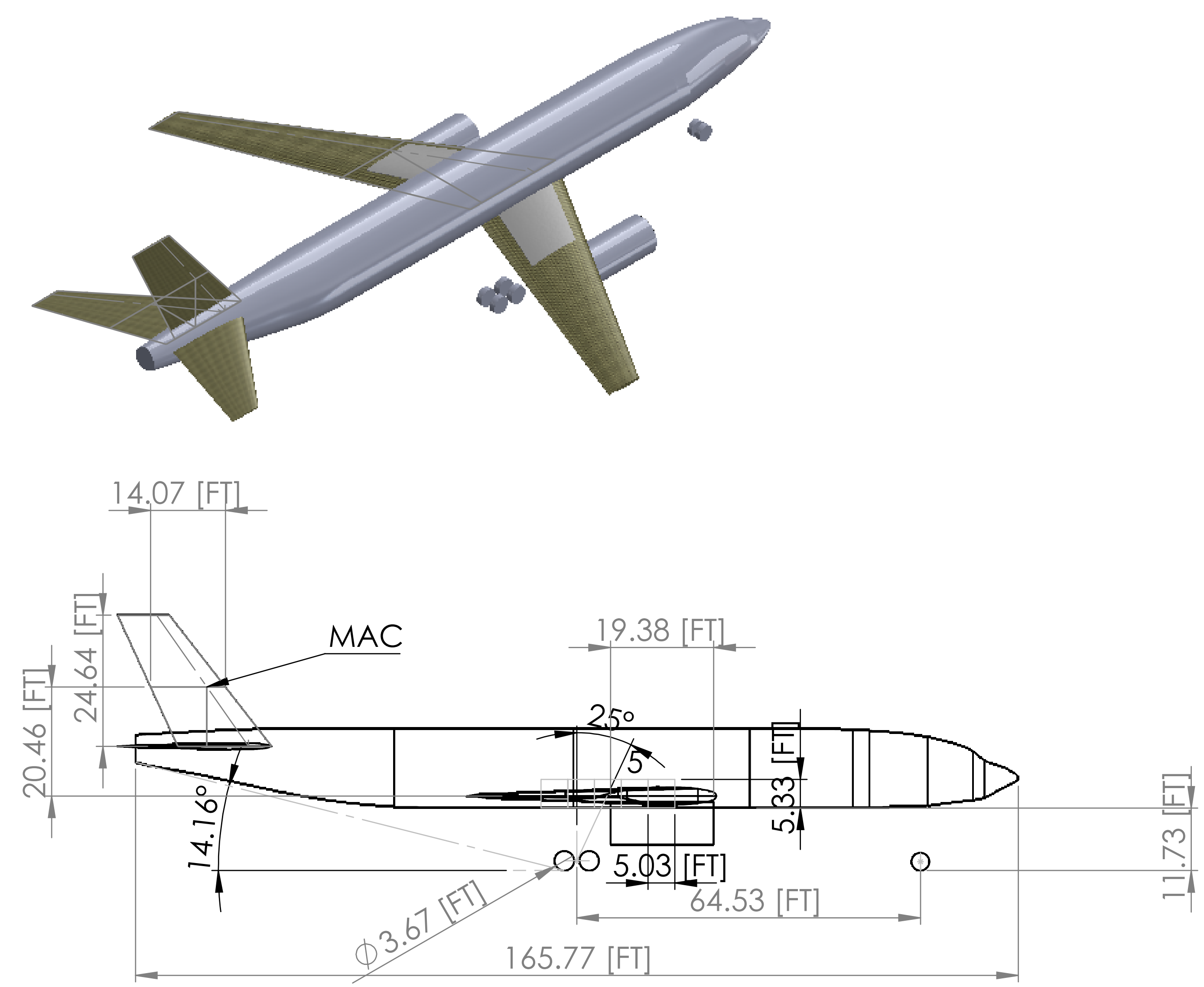

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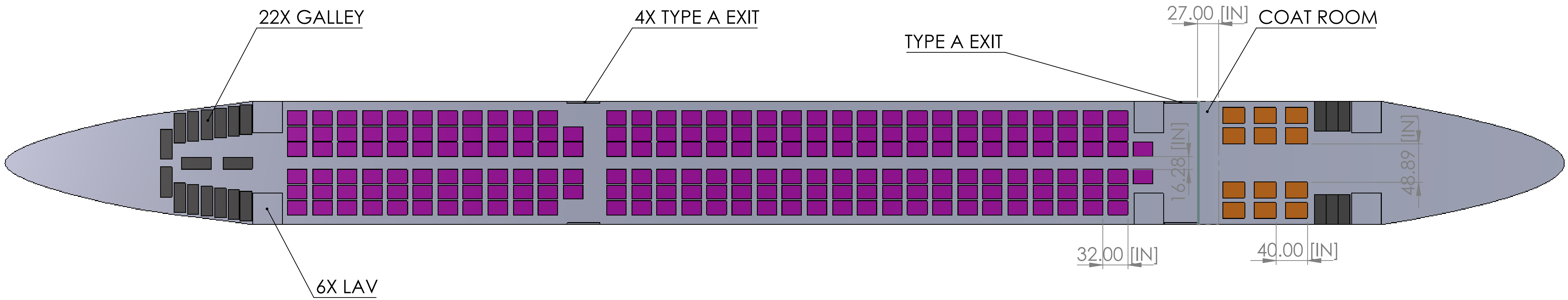

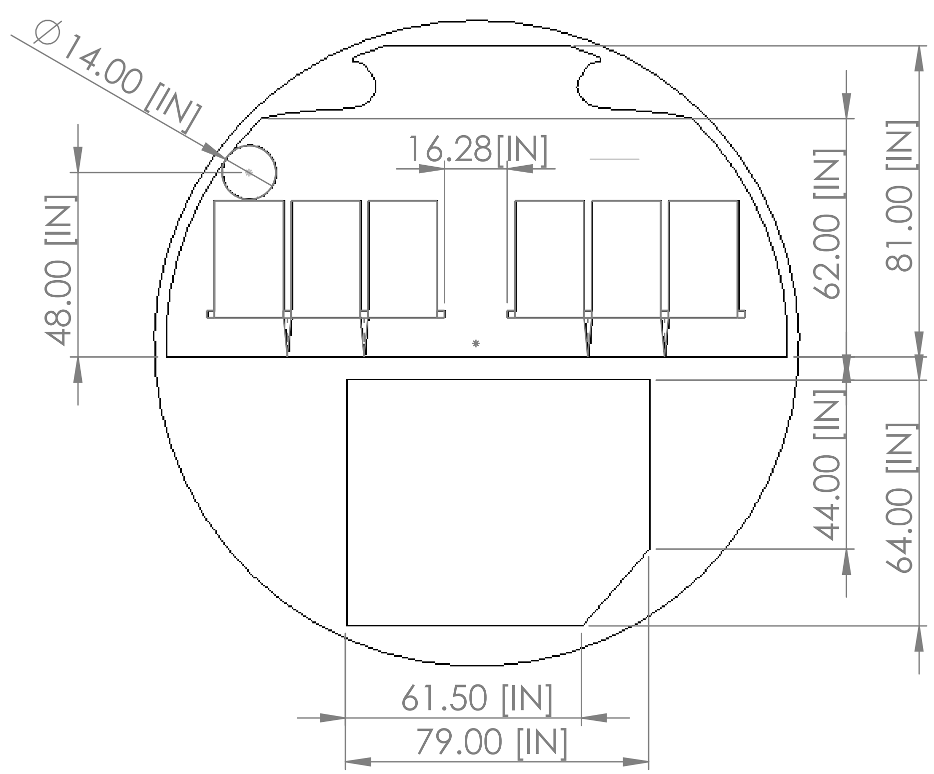

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SIZE	DWG. NO.	REV
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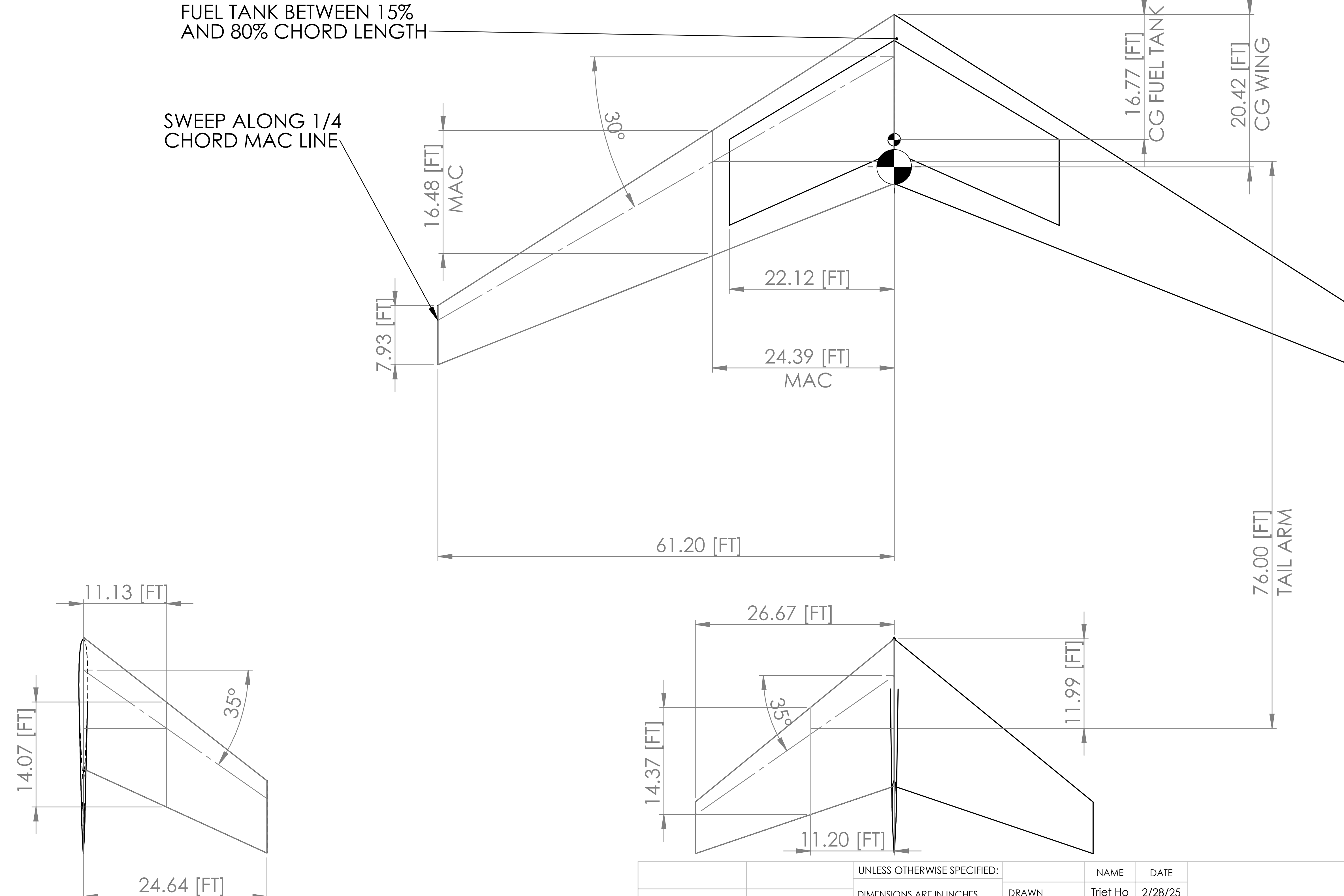
ADVANCED AIRCRAFT



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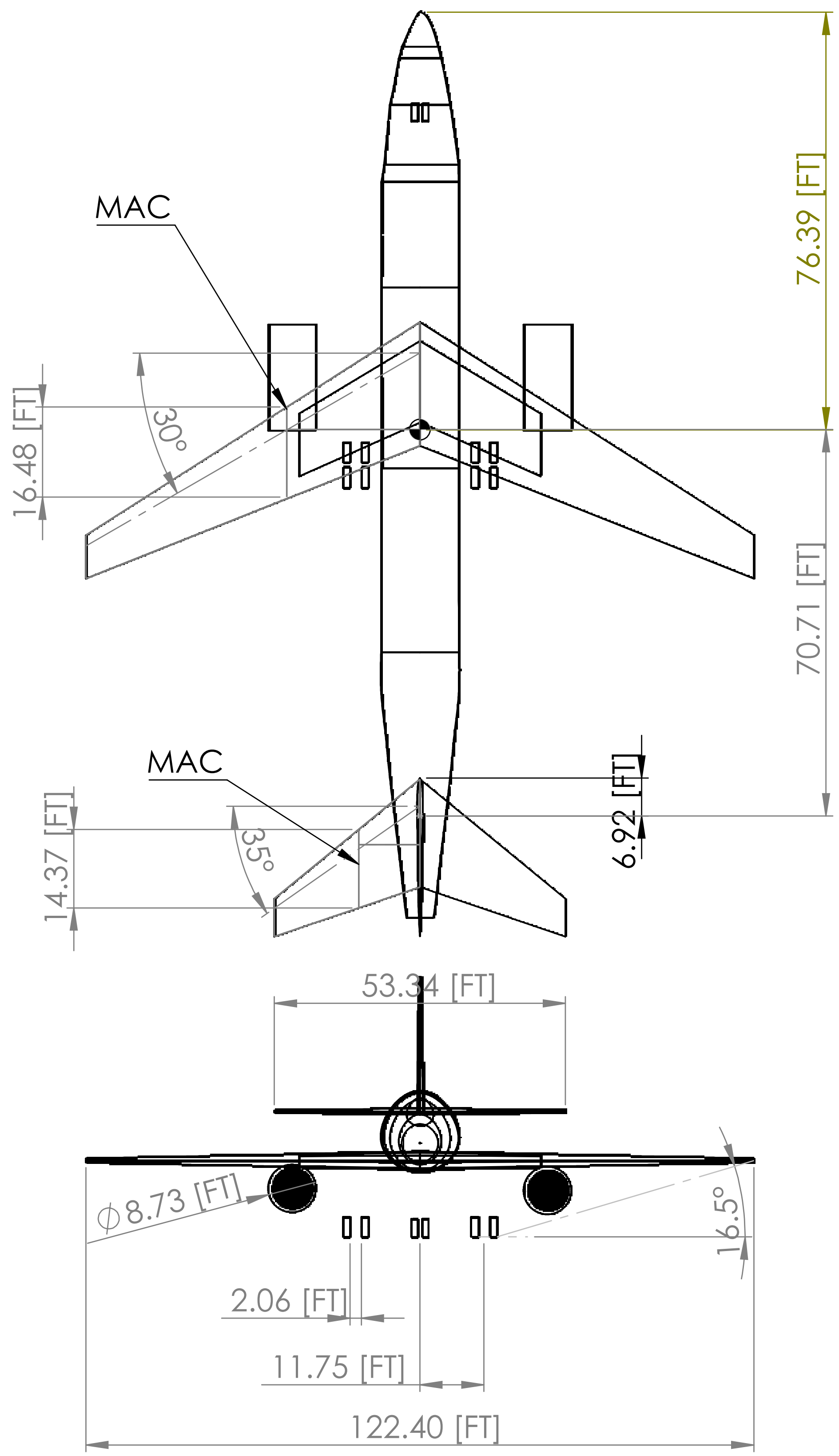

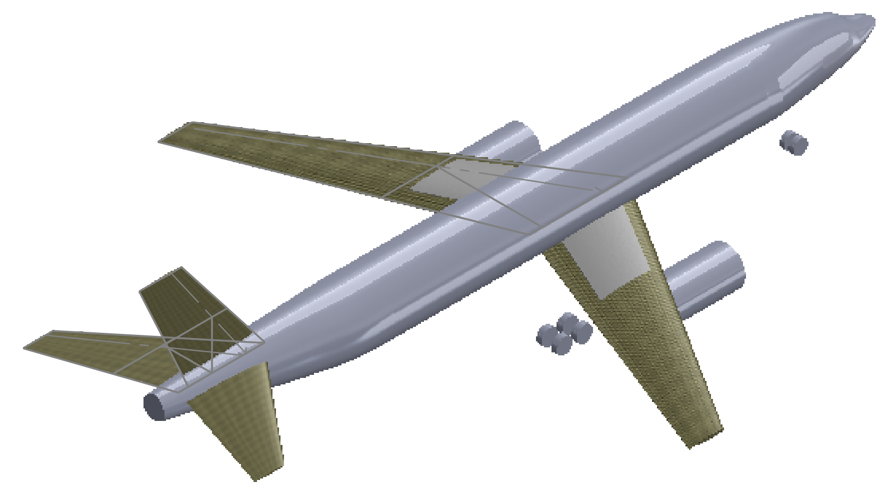

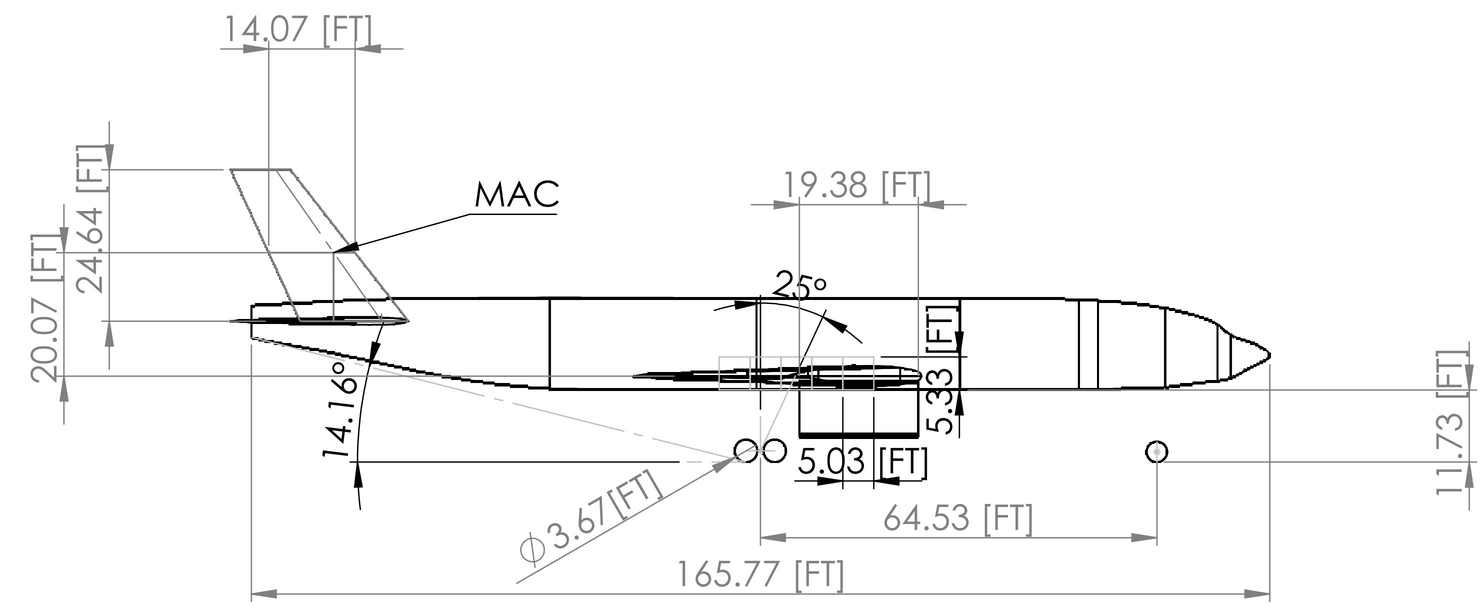

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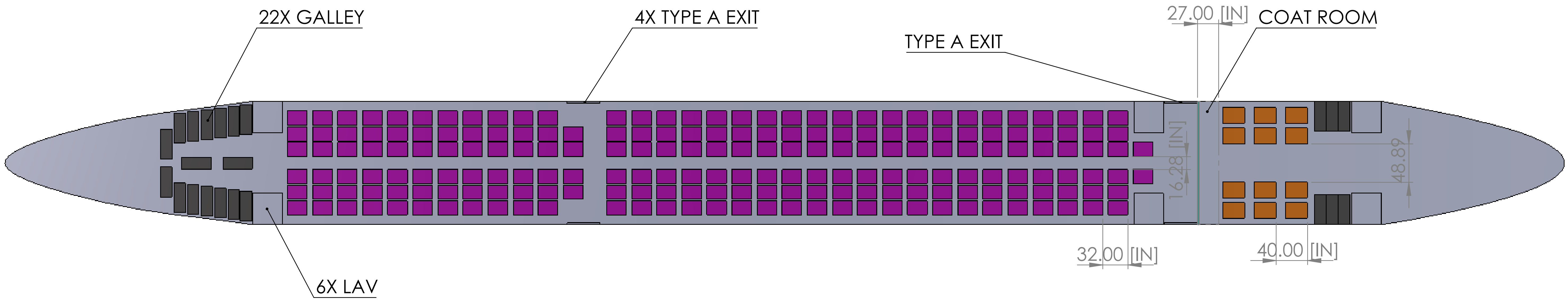

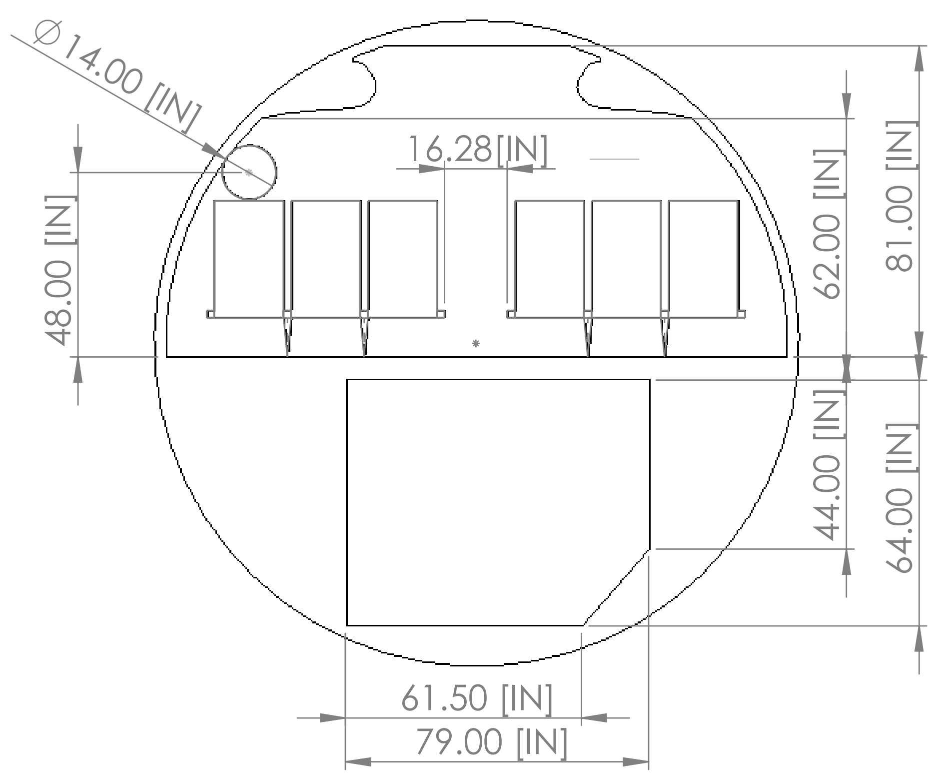

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5. Conclusion

This study's exploration of conventional and advanced aircraft designs offered valuable insights into the trade-offs between different material choices in aerospace. The comparison between full aluminum and full composite configurations reflects key considerations in modern aircraft design. While composites offer weight savings and potential performance improvements, aluminum stands out for its balance of cost, reliability, and ease of maintenance.

Our analysis supports aluminum as a practical choice for meeting operational goals, especially when cost efficiency and maintenance simplicity are priorities. Its established role in the industry ensures a reliable and conservative approach to fleet management, helping airlines stay competitive in markets where operational costs are closely scrutinized. That said, the benefits of composite materials shouldn't be dismissed. Despite higher initial costs, composites offer notable advantages like reduced fuel consumption and extended range, which could prove valuable in specific scenarios. Throughout the study, iterative design processes and computational modeling underscored the importance of key parameters like aspect ratio and swept angle. These elements significantly impact economic performance, highlighting the need for a holistic approach that balances performance, cost, and operational reliability.

Looking ahead, staying adaptable to technological advancements and regulatory changes will be crucial. As the industry moves towards more sustainable and efficient solutions, design strategies will need to evolve. While this analysis leans towards aluminum for immediate benefits, it also emphasizes the importance of innovation and flexibility in future aircraft development.

6. Work Cited

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