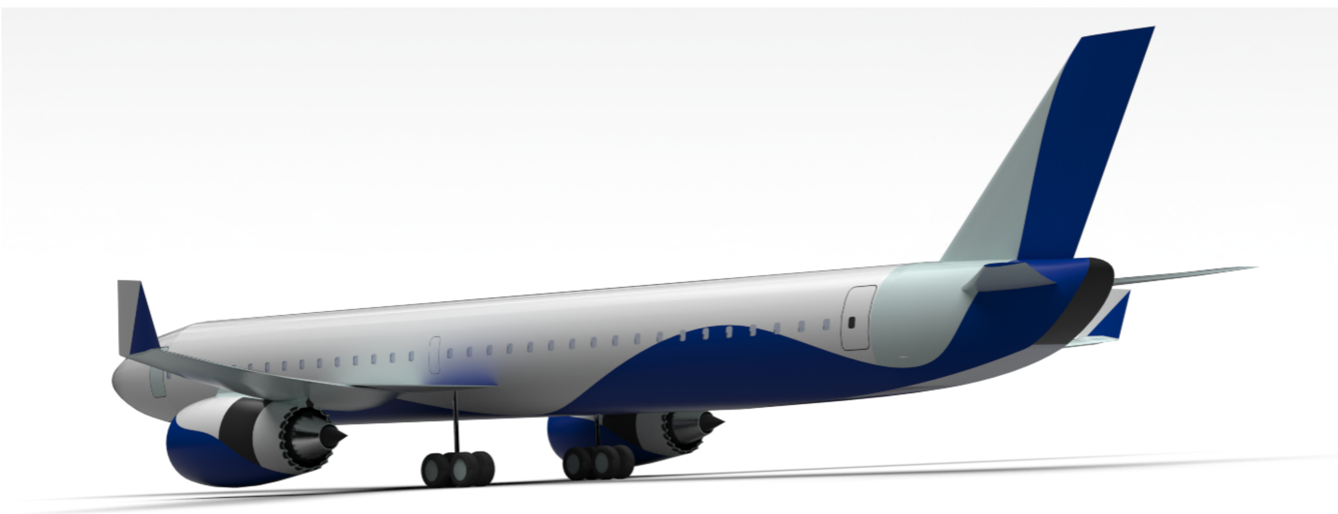


Raytracing render performed in Siemens NX,designed in Solidworks.

Analysis and Design of a Subsonic Commercial Transport

Derrick Ng

Introduction

The purpose of this study is to design a subsonic commercial aircraft and evaluate its costs, risks, and performance. Comparisons with composite and aluminum designs will also be explored. The design specifications are as follows:

Number of passengers	200 (2-class, domestic rules)
Weight of cargo	4000 pounds
Design range	4000 nautical miles
Takeoff field length (TOFL)	6000 feet (sea-level 84F)
Landing approach speed	135 knots (landing empty)
Cruise Mach number	0.82
Initial cruise altitude	35,000 feet

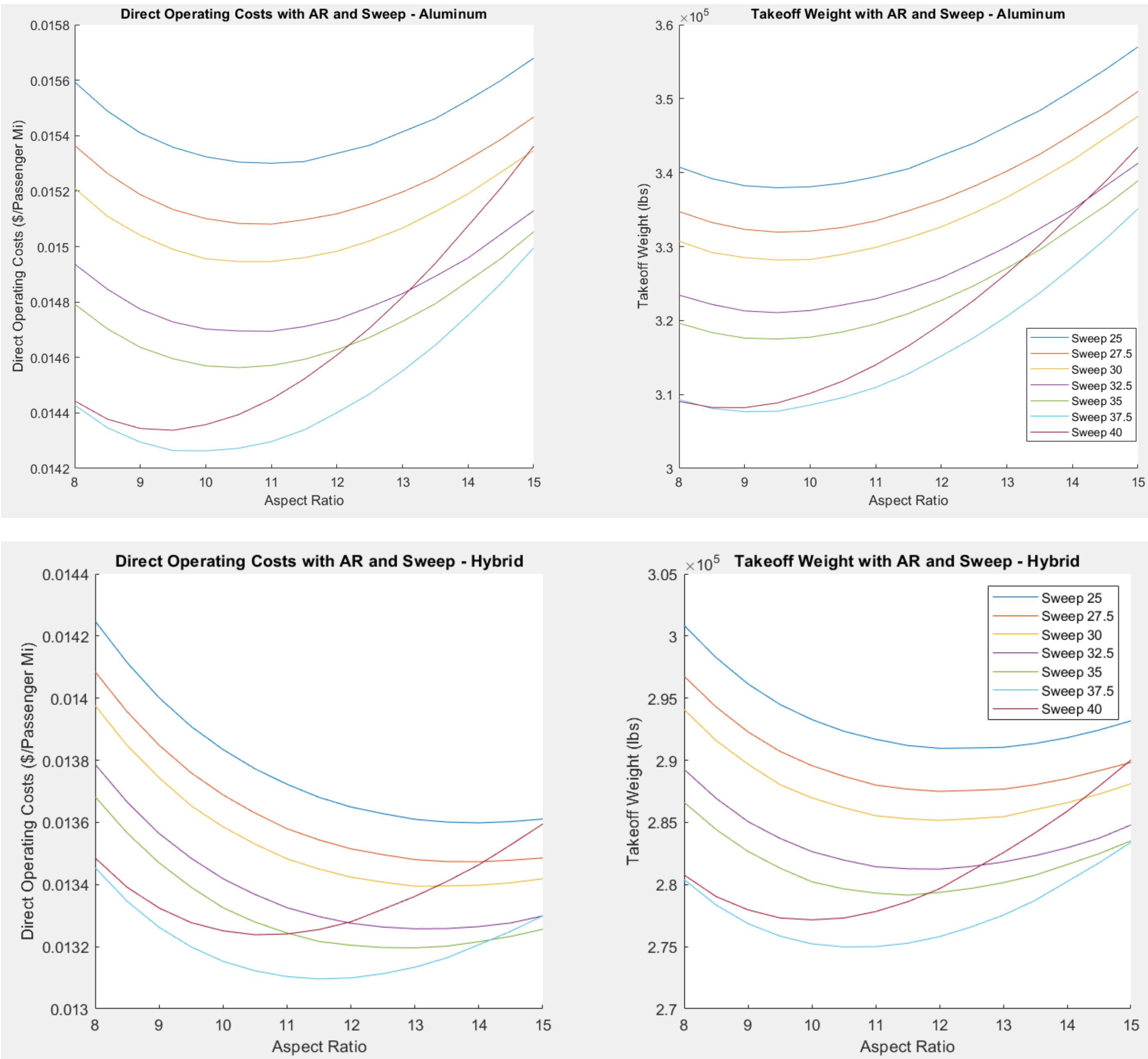
With the specifications, three aircraft designs will be presented and analyzed using the design code. Design variables will be changed to observe their impact on performance and risk, ultimately leading to which variables are most indicative of success. For this comparison the baseline will be an all-aluminum airframe and composite-aluminum hybrids and all composite designs will be analyzed. The primary comparison will be factors that affect DOC (direct operating costs) and weight.

Design Analysis

The design variables for each aircraft variation will be discussed first. In our two main designs, one airframe will feature an all composite design and another will be all aluminum. The secondary design, a hybrid of composite and aluminum structures, will use composite wings/tails, nacelles, and pylons. The fuselage and other fixed equipment will remain aluminum. Justification for the design variables will be discussed and analyzed.

Aspect Ratio and Sweep Angle

Aspect ratio and sweep angle can have an impact on an aircraft's lift and drag characteristics and thickness to chord ratio in addition to slight changes in weight. This change in the aircraft's flight performance is enough to offset its DOC and takeoff weight. Figure 1 shows 3 sets of plots indicating the effects of sweep angle and aspect ratio on DOC and takeoff weight for aluminum, hybrid, and composite designs. Across the board, a **sweep angle of 37.5 degrees** is the most successful with the lowest DOC and takeoff weight. For aluminum the optimal AR is around 10. For hybrid and composite, optimal AR is around 11 or 12. Since the difference is marginal, the optimal **AR is 11**.



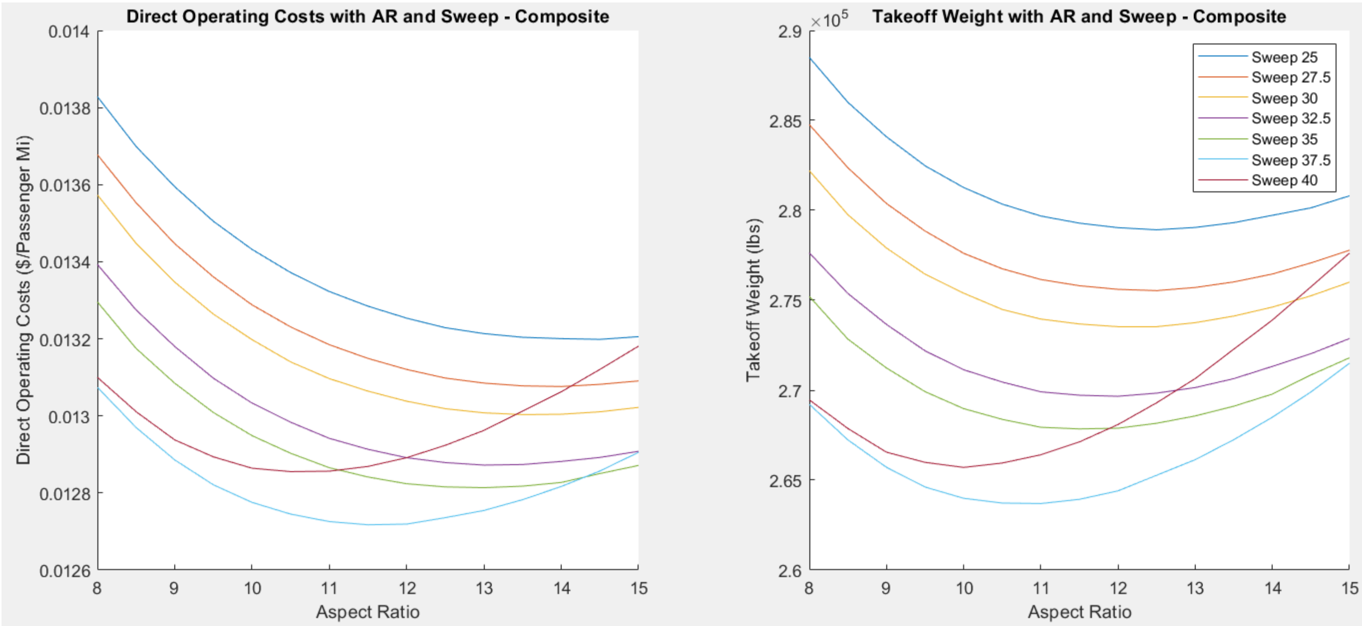


Figure 1: AR and Sweep on aluminum, hybrid, and composite DOC and Takeoff Weight.

Airfoil Type

The airfoil type is an important design parameter to consider. A supercritical or conventional/classical airfoil type can be chosen, shown in Figure 2. A supercritical airfoil has much less camber and has a flatter upper surface when compared to the classical airfoil. For this reason, the supercritical airfoil performs better than the conventional airfoil in transonic flight by delaying the onset of wave drag due to compressible effects. The delayed onset moves the shock closer to the trailing edge and also produces a weaker shock. The result is lower separation with higher divergent mach number.

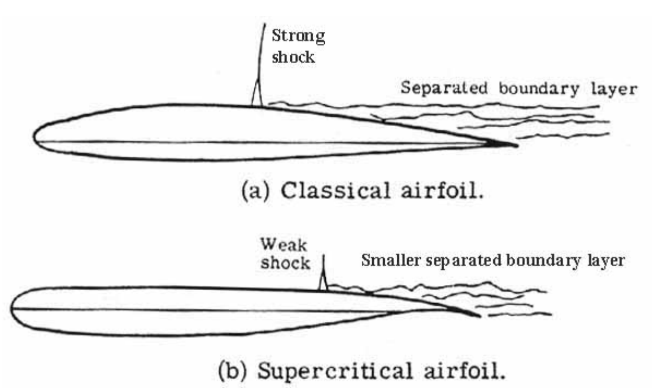
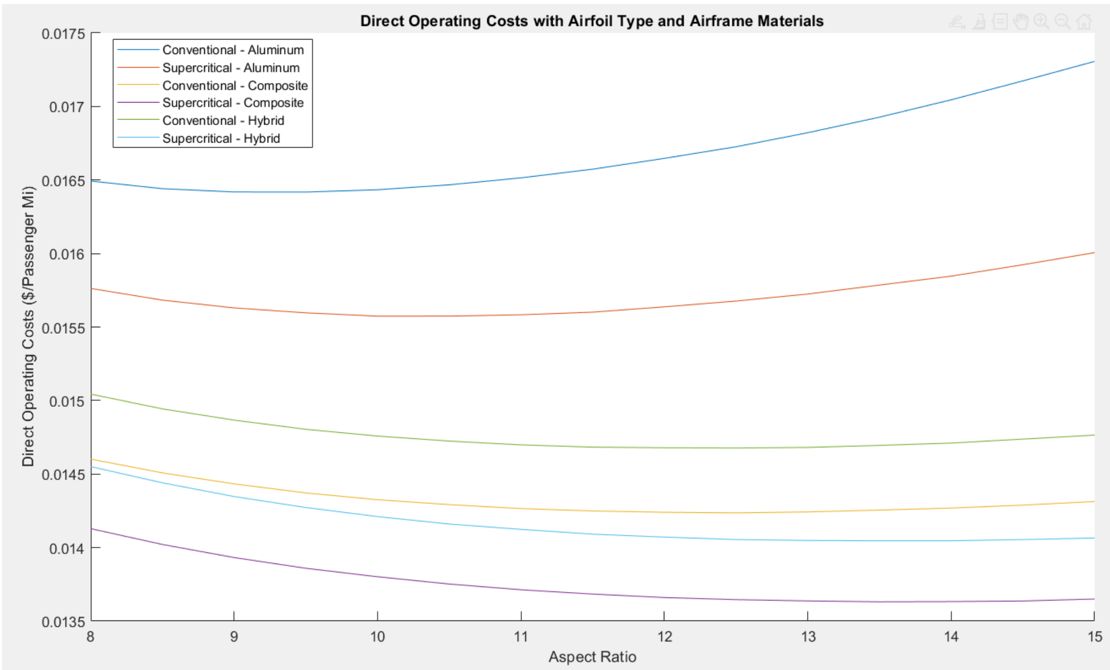


Figure 2: Supercritical and classical airfoil comparison. Adapted from NASA as cited by US Centennial of Flight Commission.

A supercritical airfoil does have some adverse effects with its stalling behavior when compared to a conventional airfoil, with dramatic lift loss and detached flow past the stalling angle. This effect is not simulated in our design analysis code however, and even if it was, modern control systems and other flight surfaces can prevent critical failures. Therefore, the choice of a supercritical airfoil is obvious; this is supported by the decrease in DOC shown in Figure 3.

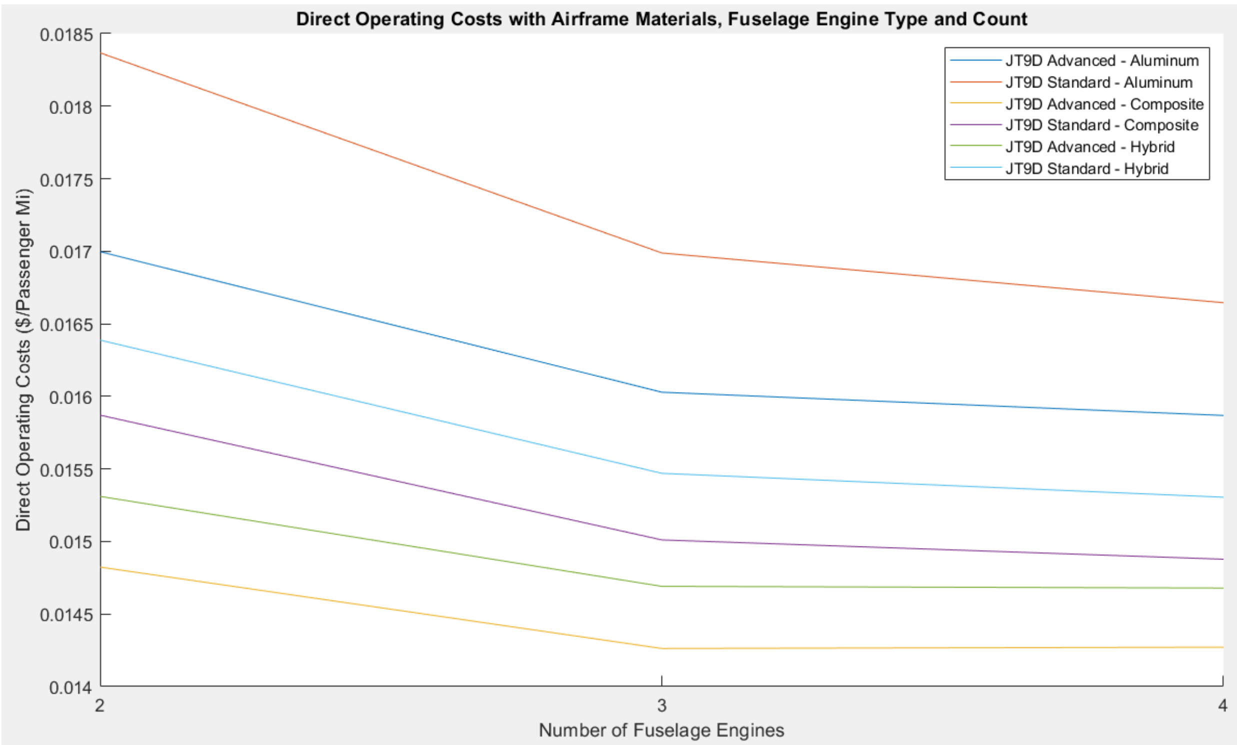


]Figure 3: Supercritical and Conventional airfoil types affecting aluminum, composite, and hybrid designs on DOC.

In Figure 3, a plot of various airframe materials with conventional and supercritical airfoil types are shown, plotted as a function of aspect ratio for reference. For each material, it is clear that the DOC decreases by roughly 5% when switching from conventional to supercritical airfoil types. For the effects of supercritical airfoils on takeoff weight, with each respective design having a lower takeoff weight due to lower fuel fraction to achieve the necessary range. Therefore, all following design and analysis will feature a **supercritical airfoil**.

Engine Type, Count, and Mounting

For this study, the JT9D Advanced engines will be used instead of the standard JT9D. JT8D engines will not be considered for their lower thrust and higher fuel fraction requirements. In general, the advanced engines feature 10% lower specific fuel consumption, 10% higher weight, and 10% higher engine costs. Below in Figure 5, the JT9D advanced engines are compared to the standard variant in various engine configurations with different wing and fuselage engine counts. In every configuration, the JT9D advanced engines surpass the standard engine, which makes it the obvious choice. Another important note is that wing mounted engines have comparably lower DOC than fuselage engines for all material cases.



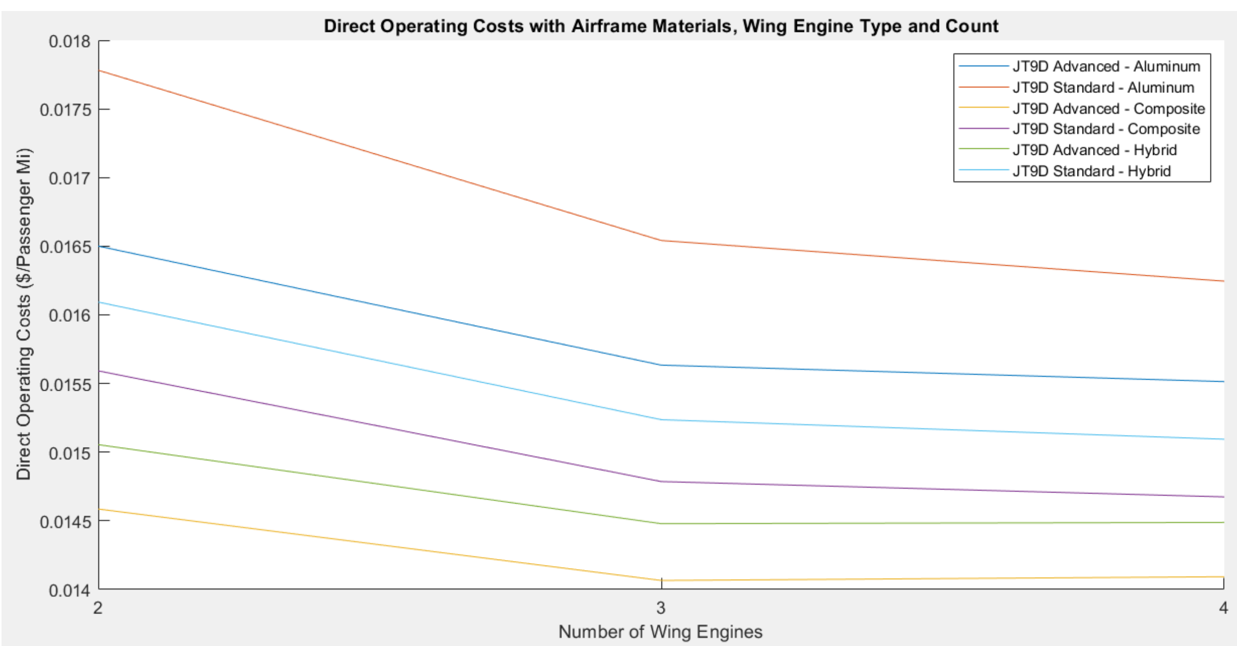


Figure 5: Advanced and Standard JT9D engines at various engine configurations affecting aluminum, composite, and hybrid designs on DOC.

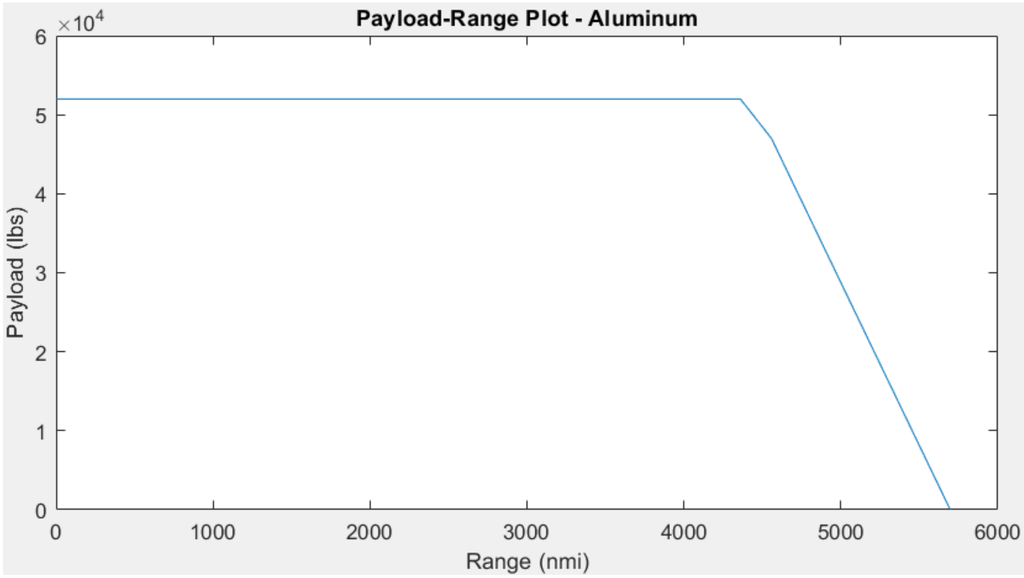
As engine count increases, DOC decreases slightly. In some configurations, DOC can increase very slightly past 3 engines. It is important to note that 3 wing engine designs are not feasible. It may be more important to choose the engine setup with the best reliability and resupply chain for maintenance.

JT9D Advanced engines likely are variants of the standard engine with a larger bypass ratio for better efficiency. These engines have a larger mass flow rate through the bypass duct than the engine core, with this ratio increasing with newer, more advanced engines. The specific fuel consumption of these engines are improved at the expense of specific thrust. This result means that the engine may be operating closer to the maximum thrust available, which can increase risk of damage to the engine and decrease lifetime. Still, newer technologies have made engines more reliable in general. Increasing engine count can reduce the load on each engine at the expense of increased maintenance; however, this also means that there is increased risk of failure.

Overall, the increase of engine count from 2 to 4 only produces marginally better DOC while doubling risk. Although on paper, 4 engines produce a design with a lower DOC, it could be reasoned that some of the factors used in calculating maintenance costs per engine are unaccounted for. In addition, newer engines are designed to be more reliable to run at their rated thrust with increasing lifetimes. It would seem that the best configuration for all material cases is to utilize **JT9D Advanced engines in a 2-engine wing mounted configuration**.

Payload-Range

The payload-range plot can be seen below in Figure 7. It shows the maximum effective payload for each design at a given range. The maximum payload is set to 52,000 lbs, about 5,000 lbs greater than the payload at the design specifications (200 PAX and 4,000 lbs of cargo). Each design can trade its payload for fuel or vice versa. Seen in Figure 7, the aluminum design can support a maximum payload of 52,000 lbs at ranges between 0 and 4,385 nmi, with the payload at specification (47,000 lbs) at a range of 4,559 nmi. With no payload, the aircraft is capable of up to 5,623 nmi. The composite design can only maintain the maximum payload until 4,308 nmi. The no payload range for composite increases to 5933 nmi.



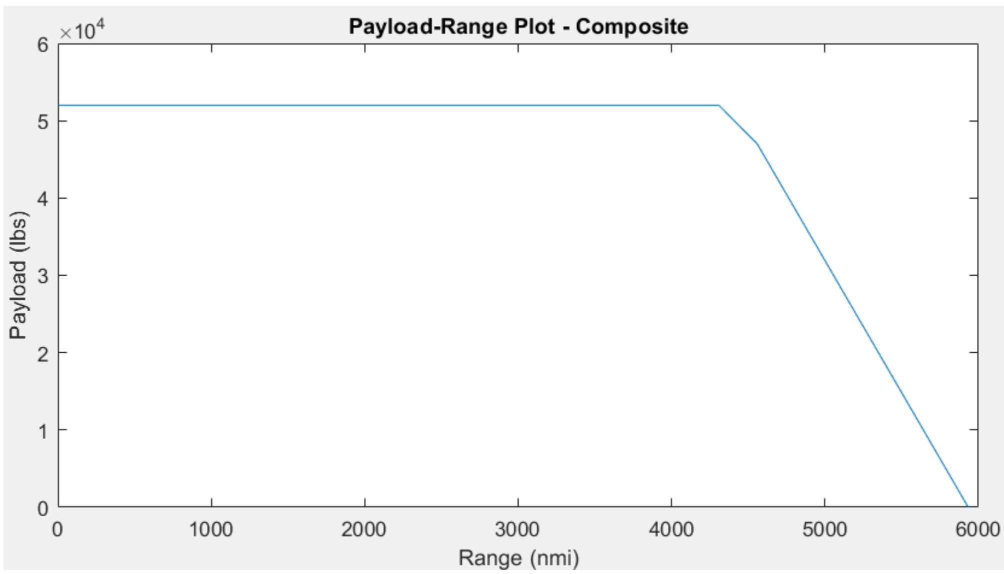


Figure 7: Effective Payload of the designed aircraft at a given range.

Table 1: Plane Specifications - Weight Distribution

Component Weights	Aluminum	Hybrid	Composite
Wing (lbs)	35,320.55	21,285.79	20,238.09
Fuselage (lbs)	29,905.51	29,040.39	24,442.04
Landing Gear (lbs)	12,463.65	11,000.08	10,547.90
Nacelle Pylon (lbs)	8,685.00	6,177.96	5,939.81
Tails (lbs)	6,004.49	2,533.01	2,408.33

Power Plant (lbs)	48,082.42	42,753.49	41,105.44
Fixed Equipment (lbs)	39,105.70	37,825.07	37,369.42
Fuel (lbs)	85,117.65	76,563.59	73,904.03
Passengers (lbs)	43,000.00	43,000.00	43,000.00
Cargo (lbs)	4,000.00	4,000.00	4,000.00
MTOW (lbs)	311,684.96	274,179.39	262,955.07

Table 1: Plane Specifications - Design Variables

Material Type	**All Aluminum**	**Hybrid**	**All Composite (Best)**
Airfoil Type	Supercritical	Supercritical	Supercritical
Engine Type	JT9D Advanced	JT9D Advanced	JT9D Advanced
Engine Config	2-wing mounted	2-wing mounted	2-wing mounted
Seats Abreast, Aisles	6, 1	6, 1	6, 1
Sweep Angle (degrees)	37.5	37.5	37.5
Aspect Ratio	9.7	11.0	11.5

Table 2: Plane Specifications - Geometry and Physical Parameters

Material Type	**All Aluminum**	**Hybrid**	**All Composite (Best)**
Wing Area [ft^2]	1,929	1,698	1,626
Span [ft]	145.7	136.7	133.7
Thickness to Chord (t/c)	0.15987	0.15859	0.15818
Fuselage Length [ft]	158.53	158.53	158.53
Fuselage Diameter [ft]	13.08	13.08	13.08

Table 3: Plane Specifications - Performance and Results

Material Type	**All Aluminum**	**Hybrid**	**All Composite (Best)**

Thrust Loading (W/T)	1.9912	1.9764	1.9711
Thrust Per Engine [lbs]	78,082	69,572	66,890
Oswald Efficiency (e)	0.7816	0.7751	0.7727
Climb Rate [ft/min]	8,900	8,870	8,859
Drag Coefficient	0.03244	0.03341	0.03376
Fuel Fraction	0.27317	0.27841	0.28026

Table 4: Plane Specifications - Operating and Initial Costs (1970s)

Material Type	**All Aluminum**	**Hybrid**	**All Composite (Best)**
Init Airplane Cost [USD]	$22,021,555	$19,767,297	$19,060,676
Maint. Costs [per ton mi]	$0.03299	$0.03047	$0.02966
DOC [per ton mi]	$0.12167	$0.11152	$0.10830
DOC [per passenger mi]	$0.01430	$0.01310	$0.01273

Table 5: Plane Specifications - Operating and Initial Costs Adjusted for Inflation (2022)

Material Type	**All Aluminum**	**Hybrid**	**All Composite (Best)**
Init Airplane Cost	$117,595,103	$105,557,364	$101,784,010
Maint. Costs [per ton mi]	$0.17616	$0.16269	$0.15837
DOC [per ton mi]	$0.64973	$0.59552	$0.57835
DOC [per passenger mi]	$0.07634	$0.06997	$0.06796

Looking at Tables 1 through 5 shows a clear picture of the aluminum, hybrid, and composite designs. Again, the hybrid design features composite wings/tails, nacelles, and pylons with aluminum fixed equipment and fuselage. The takeoff weight and fuel weight decrease from aluminum to hybrid to composite: 310,950 lbs, 275,002 lbs, and 263,698 lbs respectively. The lower weight from composite components allows for lower fuel weight with the same fuel fractions. The cost of each airplane and the direct operating costs also decrease substantially from aluminum, hybrid, to composite. With initial capital costs, the hybrid is 11.4% cheaper than the aluminum, and the composite is 15.5% cheaper than aluminum. The adjusted inflation figures (increase of 434%) show a DOC for aluminum, hybrid, and composite as $0.07634, $0.06997, and $0.06796 respectively per passenger mile. It is clear that from this specific analysis, the composite is the clear choice.

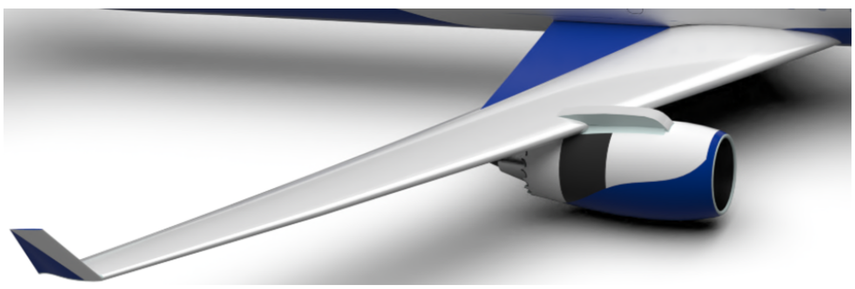
When looking at risk, the outlook of composite designs changes slightly. Composites function inherently differently than aluminum and due to its more impact resistant and brittle nature, the minor damage is difficult to visually identify. Damage assessment is necessary to prevent critical failure of components after an incident. This process may increase DOC and add time and resource demands. It may be better to use a hybrid design to mitigate some risk while having some benefits of decreased DOC and maintenance costs due to resistance to corrosion and fatigue. Overall, without some quantitative data on the risk of using composite components, it is difficult to choose between the hybrid and composite designs. The hybrid design is marginally better than the full-composite design, but it is unknown how much more risk it will add changing the fuselage and fixed equipment to composite. Both hybrid and composite are considerably better than the all aluminum design. It would be recommended to start with a hybrid design and analyze risk up to that point. In addition, it may be difficult to develop all the tools and skills necessary to design, build, and maintain a composite aircraft. An intermediate hybrid design would alleviate the adoption process.

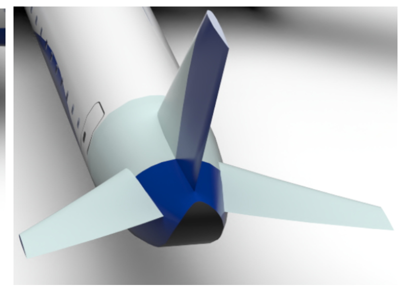
Overall, the most important design variables that dictate the aircraft's performance and economic success are material type, airfoil type, and engine configuration. With composites, DOC, takeoff weight, and thrust per engine were decreased 15% - 18% from aluminum. Utilizing a supercritical airfoil also saw improvements of 5% - 7% in takeoff weight and DOC. The switch from JT9D standard to JT9D Advanced saw improvements between 6% - 8% as well. As previously mentioned, these changes are due to real world physical improvements. Composites make the airframe considerably lighter and also reduce the amount of weight needed. They also require less maintenance than aluminum because they are more impact resistant and less prone to fatigue and corrosion. Supercritical airfoils improve aircraft performance in the transonic regime, delaying the onset of wave drag and moving the shock closer to the trailing edge. This weakens the shock and therefore limits the flow separation and increases the divergence mach number. Newer, more advanced engines will decrease specific fuel consumption and efficiency by increasing the bypass ratio and compression ratio of the engine. Optimization of the high bypass blades can improve this further. Larger fan blades make blades more heavy and can induce shocks at the tip of the blade. By improving the materials used, like utilizing carbon fiber blades, the weight can be reduced. Speed reduction can greatly reduce the rotational speed of the fan blade, allowing even higher bypass ratios in the future.

Final Design

Moving forward with the composite design, the final geometric model and schematic of the airplane will now be drafted.

Wings and Tails





The aircraft wing airfoil is a SC(2)-0714 supercritical airfoil. This was chosen for its similar max t/c ratio. The horizontal tail and vertical tail utilize the NACA 0008 symmetrical airfoil. The parameters for the flight surfaces are given in the below table. Calculation and initial values were taken from Schaufele. This includes the volume coefficient of 1 and 0.08 for the horizontal and vertical tail respectively, which were suggested for transports in preliminary design. The values for aspect ratio and taper ratio for horizontal and vertical tails were also chosen from Schaufele. The sweep angle for the aft tails were increased slightly from the wing's sweep angle to maintain control authority past the divergent Mach number. It is worth noting that the quarter-chord MAC location is roughly 44.2% of the fuselage length, a value very close to that of Schaufele's 46%.

Parameter	Wing	Horizontal Tail	Vertical Tail
AR	11	4	1.6
Taper Ratio	0.35	0.35	0.5
Volume Coeff	None	1	0.08
Tail Arm	None	72.5262	72.5262
Sweep	37.5	40	40
S	1625.69	293.5561574	239.7997093
b	133.726	34.26696119	19.5877394
Chord Root	18.01018224	12.69146711	16.32311617
Chord Tip	6.303563782	4.442013488	8.161558084
MAC	13.09629301	9.22873349	12.69575702
Y Bar	28.06595062	7.191831362	4.352830978

The fuel tank was sized based on the fuel needed in volume, 1472.3 ft^3, which was converted to from the weight in fuel. The table below shows the parameters for the fuel tank sizing and the final parameters of each wing's fuel tank. The tank spars are 25% of the chord length and 85% of the chord length. 90% of the wing's thickness is the fuel tank. Each fuel tank spans out 50 feet and can hold 821.06 ft^3 of fuel. The center of gravity of the fuel tank is 5 ft forward of the quarter-chord MAC location and 11.97 ft closer to the fuselage spanwise.

The primary wing also features winglets at the wing tips, this reduces the vortices created at the wingtips and provides a lift distribution closer to an elliptical one. The winglets are approximately 6 ft high and are at an angle greater than 75 degrees with the horizon. Both the horizontal tail and the primary wing have a slight dihedral effect of about 6 deg.

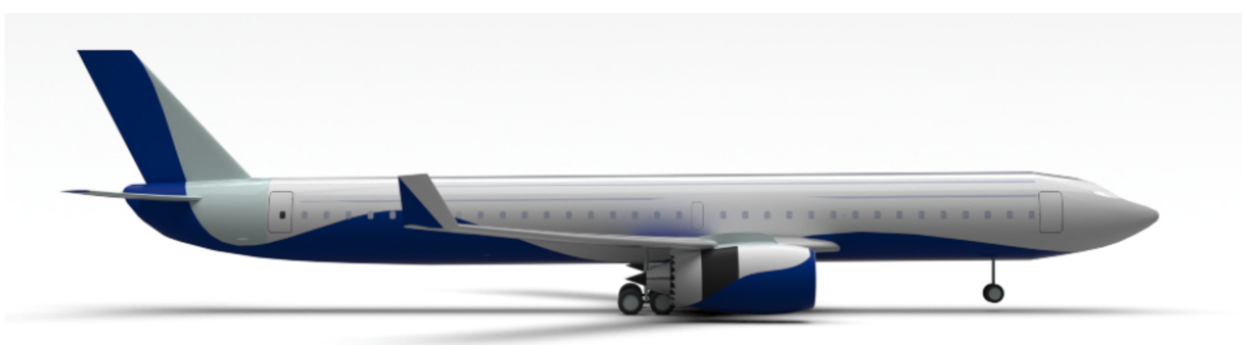
Wing-Fuse Parameters	
t/c	0.15818
Root Chord	18.0101822
Fuel (ft^3)	1472.26426
Tank Height/(t/c)	0.9
Front Spar Location/c	0.25
Rear Spar Location/c	0.85
Fuel (Gallons)	11014.0089
Fuel (FT^3)	1472.26426

Frustum	
Base Height	2.563965563
Base Width	10.80610934
A1	27.70649223
Fuel Tip Chord	9.255999464
Tip Height	1.317702596
Tip Width	5.553599678
A2	7.317992712
Length of Tank	50
Volume of Tank	821.0620544
Centroid Location	19.82669545

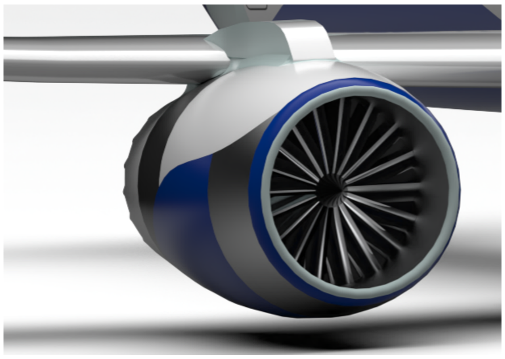
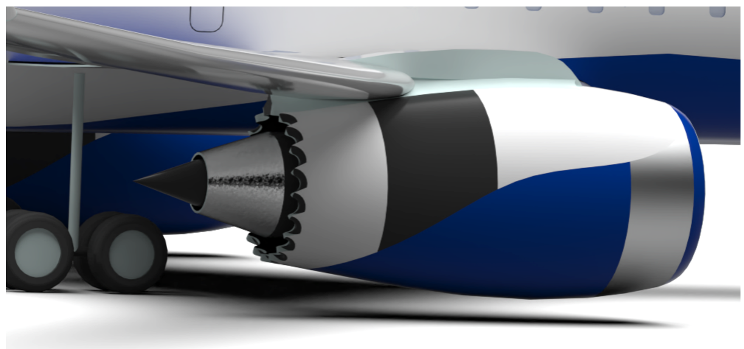
Wing Yehudi	
Area (per)	204.21
Area Wing Ratio	0.251228709
Weight (per)	5,084.39

At the trailing edge of the primary wing near the root, there is a plane extension from the fuselage to the wing. Known as the Yehudi, this wing area allows easier landing gear integration for our wing which has a very high sweep of 37.5 degrees. This surface area also prevents loss of lift due to aggressive sweep angles near the wing root and fuselage interactions, again, bringing the lift distribution closer to elliptical.

Fuselage and Exterior Configuration



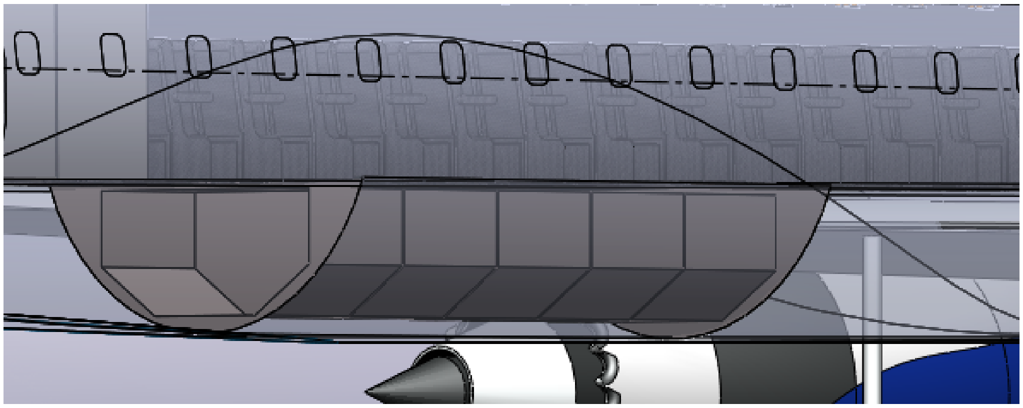
The fuselage length, 158.53 ft, and diameter, 13.08 ft, were generated by the design code. The overall fuselage distribution was calculated using typical values from Schaufele. In the afterbody, the upsweep angle is limited to 6.5 deg from the centerline. An afterbody L/D ratio of 2 was chosen, resulting in an afterbody of 26.16 ft. The nose L/D is 1.5, and the length of the nose is 19.62 ft.

As for engine sizing, the fan diameter and nacelle dimensions are calculated off of known JT9D parameters and coefficients from Schaufele. The engines are placed approximately 40% out spanwise, slightly larger than the advised 33% to push back the center of gravity. The resulting nacelle diameter is 115.5 inches and length 273.35 inches. The center of gravity of the engine/nacelle is 7.47ft in front of the quarter-chord MAC location.


The landing gear is set up with a main gear and a nose gear. The nose gear is designed to bear around 10% of the gross takeoff weight with a two tire, single strut setup. Configuration of the main gear comprises two strut structures each with 4 load bearing wheels. The main gear is mounted on the Yehudi and must bear 100% of the takeoff gross weight. The tires on the nose are 34x11 in and the tires on the main gear are 44x16 in.

The cargo hold consists of five LD-W cargo containers. This is placed 29.67 ft aft of the quarter-chord MAC location. 400 cubic feet of storage are needed for the 4000 lbs cargo spec (10 pounds per cubic foot). Each container has a volume of 83.82 cubic feet.



The tables below summarize some of the data discussed in the fuselage and exterior section.

Engine Sizing	
T_SLS	66889.8
Bypass Ratio	5
Fan Diameter (in)	105
Engine Length (in)	175
Nacell Diameter	115.5
Nacell Inlet Length	73.5
Nacell Length	273.35
Cg Engine	136.675

Dimensioning	
L/D Nose	1.5
Length Nose	19.62
L/D Afterbody	2
Length Afterbody	26.16
Q Chord MAC	72.9238
Tail Arm	72.5262

Cargo LD-W	
Density (lbs/ft^3	10
Volume (ft^3)	400
Area Cargo Cont	23.78
Length	3.525
Vol Cont	83.82
Num Cont	4.77
Dist to MAC	**29.67**

Center of Gravity

There are four configurations to consider different center of gravity locations. Design configuration is a fully loaded airplane with full cargo, fuel, and passengers. Empty configuration has no cargo, fuel, or passengers. Ferry configuration has no fuel nor passengers, but full fuel. Landing configuration has no fuel but full passengers and cargo. The table on the right reflects this. To calculate the center of gravity, the configuration's weight distribution and their reference lengths are needed to calculate each component's resultant moment. For the reference lengths here, a fixed constant of 100 ft is added to each length to ensure the moments calculated will not be negative at any point.

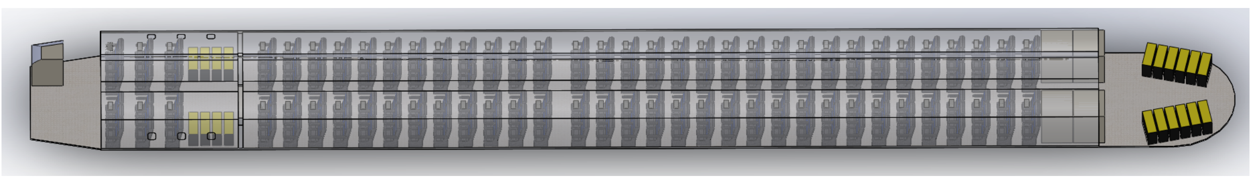
Config	Cargo	Fuel	PAX
Design	4000	73,904	43,000
Empty	0	0	0
Ferry	0	73,904	0
Landing	4,000	0	43,000

Shown on the table on the bottom is the result of such calculations. The final center of gravity location is given for each configuration, calculated by summing the total moments of the components for each setup and dividing by the total weight. The final center of gravity locations (with constant 100 ft removed) are 69.3 ft for design, 70.9 ft for empty, 68.9 ft for ferry, and 70.9 ft for landing. The most forward and aft center of gravity locations are dictated as ±10% of the

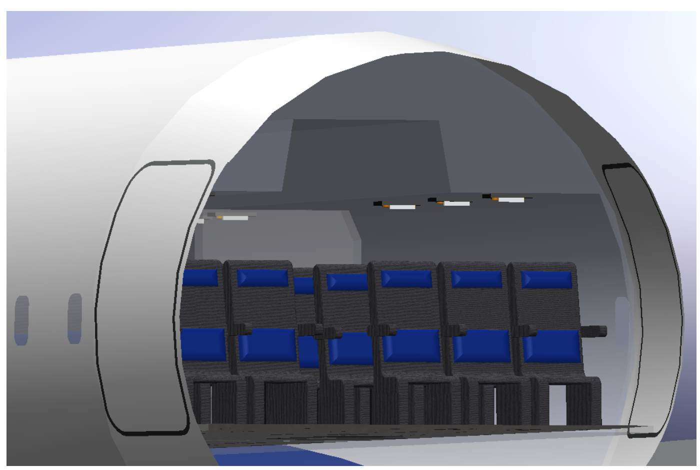
MAC at the quarter-chord MAC location. The MAC is 13.096 feet, and therefore the most forward and most aft locations are 68.69 ft and 71.31 ft respectively. All configurations fall within these margins.

Component		Design			Empty			Ferry			Landing	
	Weight	**Length**	**Moment**	**Weight**	**Length**	**Moment**	**Weight**	**Length**	**Moment**	**Weight**	**Length**	**Moment**
Wing	20,238	170.0	3,440,476	20,238	170.0	3,440,476	20,238	170.0	3,440,476	20,238	170.0	3,440,476
Fuselage	24,442	163.4	3,994,123	24,442	163.4	3,994,123	24,442	163.4	3,994,123	24,442	163.4	3,994,123
Landing Gear	10,548	173.0	1,824,787	10,548	173.0	1,824,787	10,548	173.0	1,824,787	10,548	173.0	1,824,787
Nacelle Pylon	5,940	162.5	965,398	5,940	162.5	965,398	5,940	162.5	965,398	5,940	162.5	965,398
Tails	2,408	248.0	597,146	2,408	248.0	597,146	2,408	248.0	597,146	2,408	248.0	597,146
Power Plant	41,105	162.5	6,680,868	41,105	162.5	6,680,868	41,105	162.5	6,680,868	41,105	162.5	6,680,868
Fixed Equip	37,369	180.0	6,726,495	37,369	180.0	6,726,495	37,369	180.0	6,726,495	37,369	180.0	6,726,495
Fuel	73,904	165.0	12,194,164	0	165.0	0	73,904	165.0	12,194,164	0	165.0	0
Passengers	43,000	168.4	7,241,716	0	168.4	0	0	168.4	0	43,000	168.4	7,241,716
Cargo	4,000	199.7	798,680	0	199.7	0	0	199.7	0	4,000	199.7	798,680
Wing Yehudi	10,169	175.0	1,779,536	10,169	175.0	1,779,536	10,169	175.0	1,779,536	10,169	175.0	1,779,536
Sum	273,124		46,243,389	152,220		26,008,828	226,124		38,202,993	199,220		34,049,224
Delta MAC		**0.687**			**-0.864**			**1.053**			**-0.913**	
Cg		**169.3**			**170.9**			**168.9**			**170.9**	
Forward	168.6903707											
Aft	171.3096293											

Interior Configuration



Most of the interior was designed based on previously determined Interior Arrangement Rules and other figures from *Aircraft Design* based on commercial jet transports. The cabin is configured with a 9% first class mix,maxing 18 first class seats. With a 1 aisle and 6 abreast seating arrangement, the first class consists of 3 rows. One lav is present for first class at a standard size of 38x40 in. The seat pitch for first class is 38 inches. From the cabin floor to the overhead storage bins is 62 inches and there is a ceiling height of 81 inches. The aisle width is a constant 23 inches



throughout the first class and economy class. The windows are located 31 inches from the cabin floor. Most of the seat dimensions are also taken from typical seat arrays for commercial aircraft.

The remainder of the seats are then economy, totalling 182 seats needed. This would be 30.33 rows of seats. Rounding up to 31 rows, we have 186 total seats in economy. With one lav per 50 passengers, a total of 4 are needed for economy class. As for carts, first class has a density of 0.3 carts per passenger and economy has a density of 0.075 carts per passenger. The result is a need for 20 total carts arranged in two galleys. Carts are all standard 12 x 34 inches. The seating arrangement in economy is very similar to first class except for a seat pitch of 32 inches. The first class and economy sections are split by a thin fuselage wall.

The aircraft features 6 doors with 4 primary exits. Two type A doors are used as the forward and aft entrance/exits. Two type II evacuation doors are located mid-fuselage over the wings to ensure that 60 feet between door jams is met as specified by the FAA/DOT. Distance from the front door and the wing exits is 50.9 feet, and the distance from the wing exit to the aft doors is 60 feet. The total evacuation capacity of the aircraft is then 520 passengers. The bottom of the main doors are located on the cabin floor as required by regulation, while the wing exits are half a foot above the cabin floor.

Selected Final Arrangement

Airframe Type	All Composite

Wing

Planform Area (ft^2)	1625.69
Span (ft)	133.736
Aspect Ratio	11
Sweep (deg)	37.5
Taper Ratio	0.35

Root Chord (ft)	18.010
Tip Chord (ft)	6.304
MAC (ft)	13.096
Dihedral Wings	6 degrees from horizontal
Wing Yehudi Area (ft^2)	408.42
Wing Yehudi Length (ft)	15.82
Wing Yehudi Weight (lbs)	10,169

Horizontal Tail

Planform Area (ft^2)	293.556
Span (ft)	34.267
Aspect Ratio	4
Sweep (deg)	42.5
Taper Ratio	0.35
Root Chord (ft)	12.691
Tip Chord (ft)	4.442
MAC (ft)	9.229
Tail Arm Horizontal (ft)	75.03
Dihedral Horizontal	6 degrees from horizontal

Vertical Tail

Planform Area (ft^2)	239.80
Span (ft)	19.588
Aspect Ratio	1.6
Sweep (deg)	40
Taper Ratio	0.5
Root Chord (ft)	16.323

Tip Chord (ft)	8.162
MAC (ft)	12.696
Tail Arm Vertical (ft)	9.93

Engine

Type	JT9D Advanced
Bypass Ratio	5
Inlet Length (ft)	6.125
Nacelle Diameter (ft)	9.625
Nacelle Length (ft)	22.779
Weight (lbs)	41,105.44
Thrust (lbs)	134,004

Fuel Tank

Tank Count	One per wing
Tank Volume (ft^3)	821.06
Tank Height/(t/c)	0.9
Front Spar/c	0.25
Rear Spar/c	0.85
Spanwise Length (ft)	50
Center of Gravity WRT Fuselage Line (ft)	11.97 spanwise
Center of Gravity WRT .25c MAC (ft)	5 forward

Landing Gear

Nose Gear Config	2 Wheels, Single Strut
Nose Gear Tire Size (in)	34 x 11
Main Gear Config	8 Wheels, Dual Strut
Main Gear Tire Size (in)	44 x 16

Aft CG Angle (deg)	20
Tip Back Angle (Lengthwise) [deg]	12
Tip Back Angle (Spanwise) [deg]	39.19
Landing Gear Weight (lbs)	10,548

Cargo

Cargo Weight (lbs)	4000
Cargo Density (lbs/ft^3)	10
Cargo Volume (ft^3)	400
Cargo Container	LD-W
Container Count	5
Center of Gravity WRT .25c MAC (ft)	29.67 lengthwise

Doors

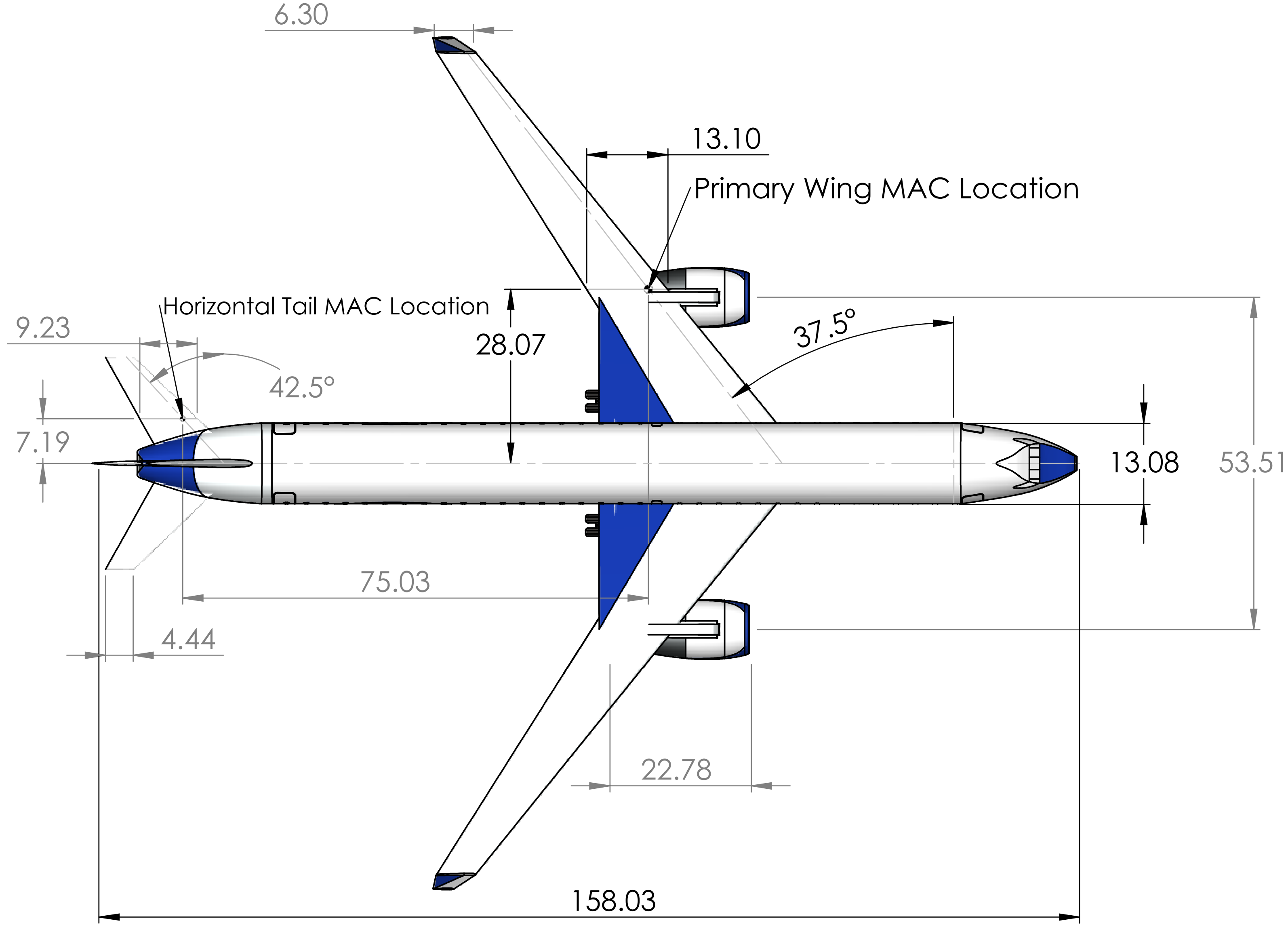
Main Doors	2x Type A Forward, 2x Type A Aft
Main Door Dimension (in)	42 x 72
Evac Doors	2x Type II Evac Located on Wing
Evac Door Dimension (in)	20 x 48
Full Evac Capacity	520

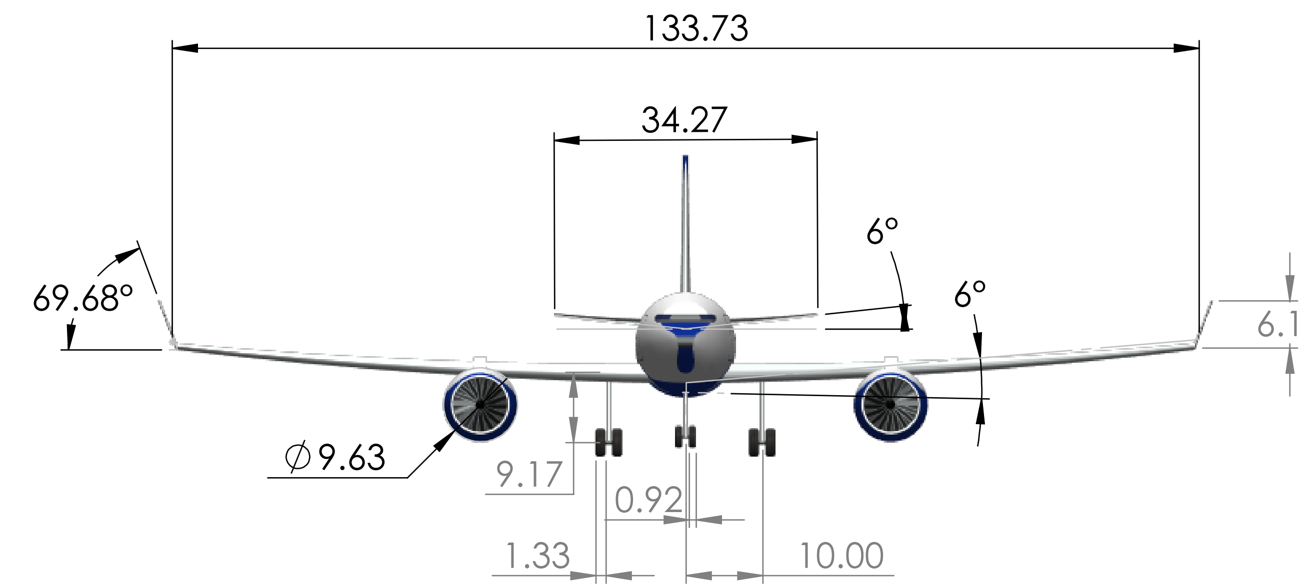
Interior Arrangement

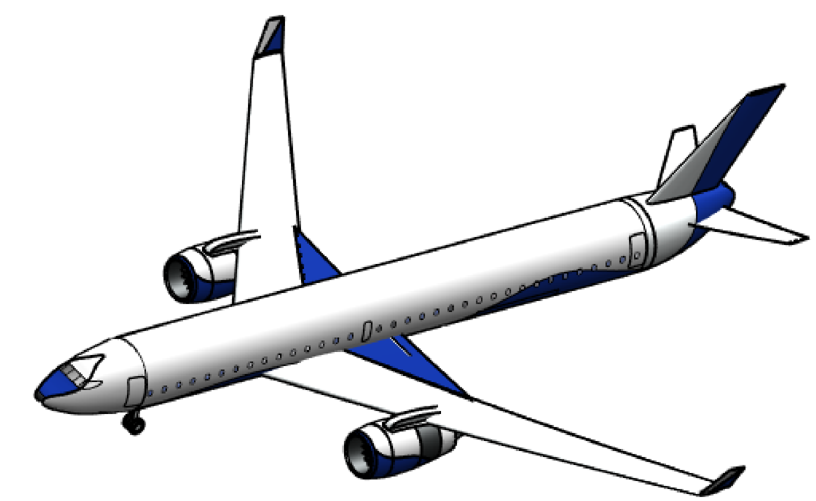
Aisle, Abreast	1, 6
Number of First Class	18
First Class Seat Depth (in)	26
First Class Seat Pitch (in)	38
First Class Aisle Width (in)	23
First Class Lavs	1
Number of Economy	186

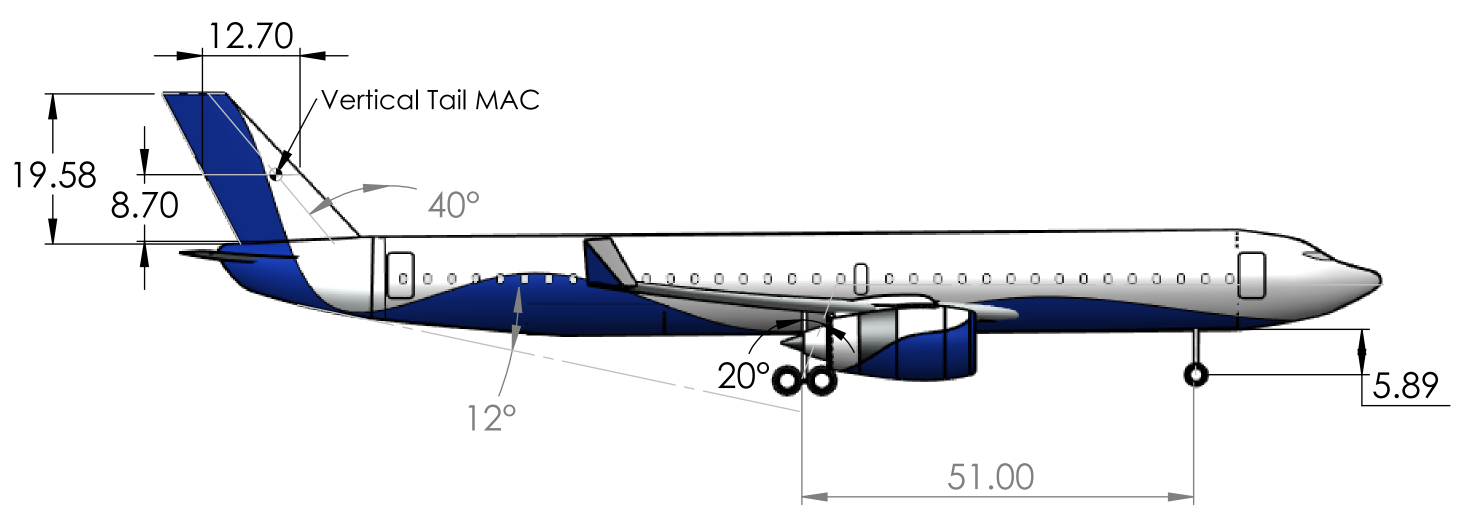
Economy Seat Depth (in)	26
Economy Seat Pitch (in)	32
Economy Aisle Width (in)	23
Economy Lavs	4
Galley Count	2
Cart Count	20

Engineering Drawings









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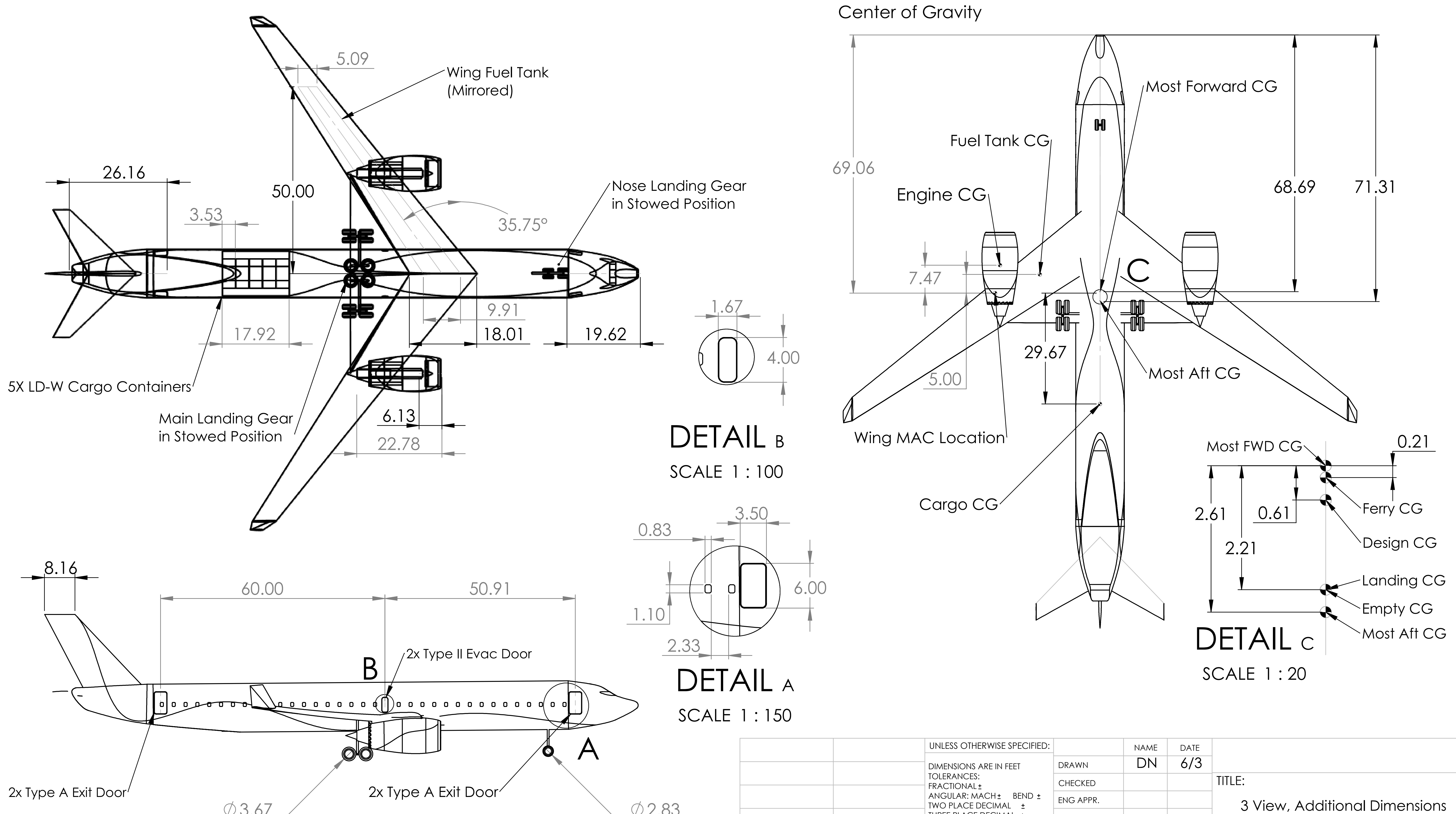

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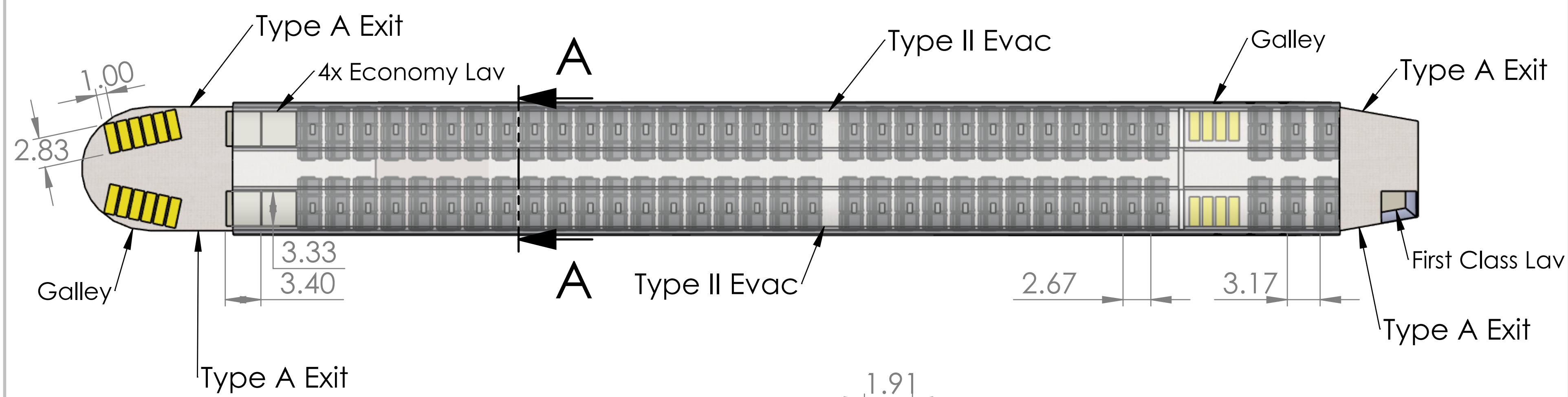

SECTION A-A

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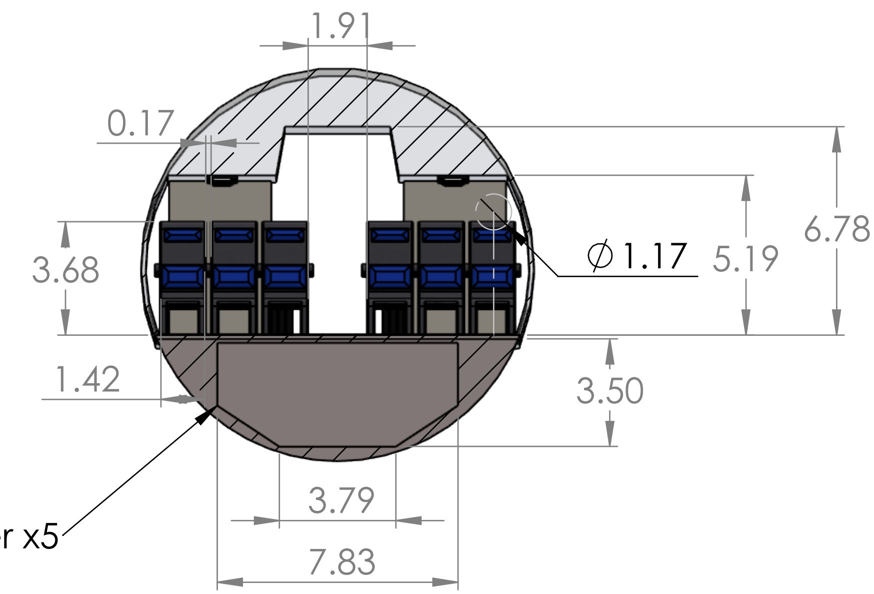

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Conclusion

The final design of the aircraft is capable of delivering 4000 lbs of cargo and 200 passengers over 4300 nmi. This can be extended to just below 6000 nmi with the removal of cargo and passenger load. This range exceeds that of the Boeing 737. Composite airframe structures and advancements in turbofan engines make significant improvements to aircraft design. With these additions, the airframe can achieve greater efficiency, lower DOC, and lower fuel and takeoff weights. When coupling this with other options such as high aspect ratio swept wings, supercritical airfoils, winglets, and anti-shock bodies, the improvements add up significantly. The fully dimensioned plane resembles that of a medium class transport like the 737, and its performance, cost, and other parameters are also extremely similar.

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