ME408 Aircraft Performance & Design
Preliminary Design Review 3 (PDR3)

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VELAIR


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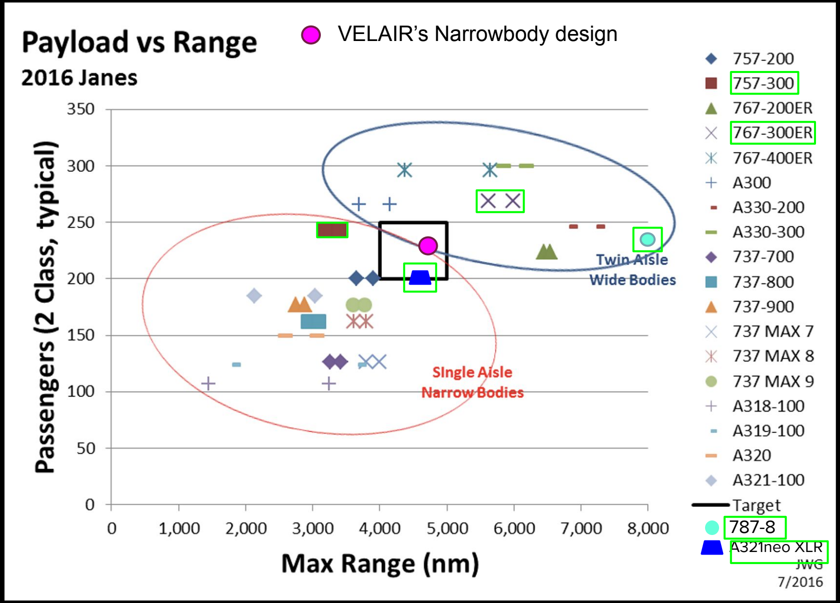
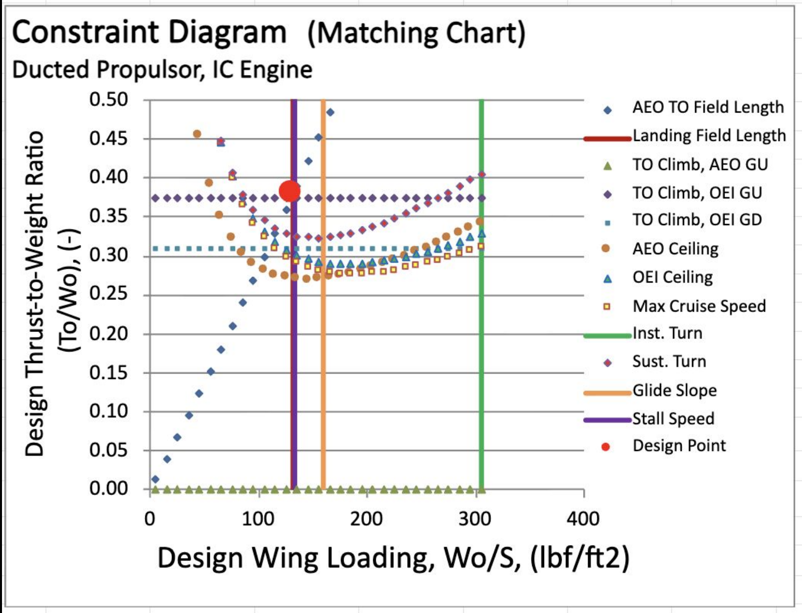
DESIGN PROPOSAL/PROJECT STATEMENT

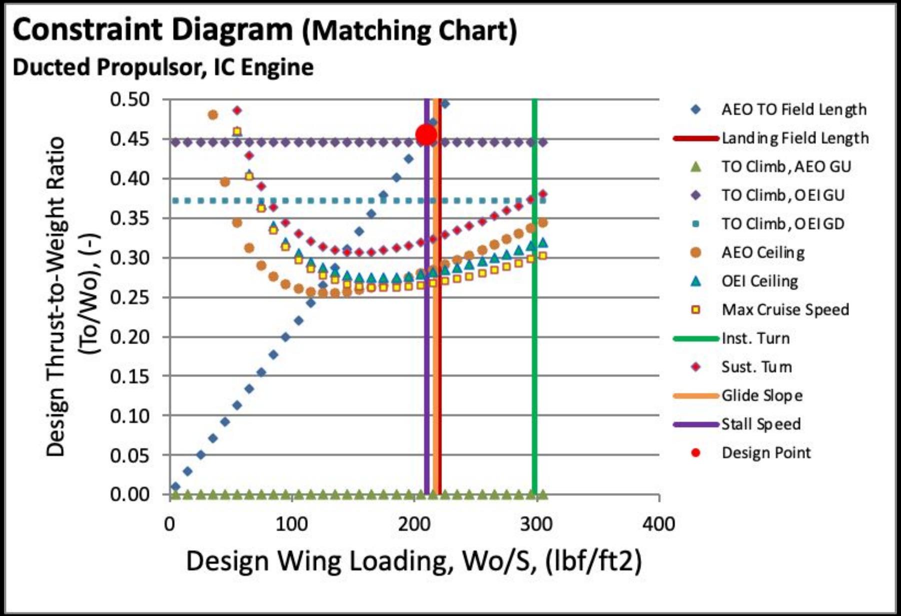
Design an all-new commercial aircraft that occupies the **200-250 passenge r** middle of the market capacity along with delivering a **4000 - 5000 nm range** with a **profit 5% - 10%** filling a gap in the current market between large widebodies and smaller narrow-bodies, a segment that established manufacturers barely plan to serve. We will work to design this aircraft with the comfort of widebodies and the efficiency of narrow-bodies, capturing the best aspects of each.



Things we have changed since the last PDR

- Airfoil selection - NACA 4415 → NACA 65-618
- Flaps: Plain → Slot, Added Leading Edge Flaps: Fixed
- Design Point Selection (Increased Wing Loading and T/W Ratio)





DESIGN PROPOSAL - COMPETITIVE ASSESSMENT & TECHNOLOGY FACTOR/DESIGN STRATEGY

Competitors	Boeing 757-300 (N)	Boeing 767-300 (W)	Boeing 787-8 Dreamliner (W)	Airbus A321neo XLR (N)	Velair (N)
Gross Weight (lbs)	270,000 lb	412,000 lb	502,500 lb	206,130 lb	307913.6 lb
Max Cruise Mach #	0.86	0.86	0.85	0.85	0.85
Range (nm)	3,395 nm	5,230 nm	8,000 nm	4,700 nm	4,700 nm
Payload (lbs/pax)	234	270	242	206-220	226
Crew	2	2	2	2	2
In Service	45	656	422	13	-

Design Strategy - Satisfy the middle of the market gap in terms of range and the amount of passengers, with range similar to our narrowbody competitors and passenger allowance similar to wide body competitors

Technology Strategy - Employ a Quality yet Inexpensive and Profitable Design, with a Materials Factor of 0.9, an Aerodynamic Efficiency of 1, and a Specific Fuel Consumption of 0.95

DESIGN STATUS - PRODUCT REQUIREMENTS

Mission Performance	Units	Threshold	Current	Objective	Pass or Fail
Max Cruise Speed	nm/hr	450	490.8	550	**Pass**
Max Cruise Mach Number	-	0.78	0.85	0.85	**Pass**
Range w/Max Payload	nm	4,000	4700	5,000	**Pass**
Radius w/Max Payload	nm	2,000	2350	2,500	**Pass**
Endurance	min	0	0	1	**Pass**
# of Max Sustained g Turns	-	0	0	1	**Pass**
Service Ceiling	ft	35,000	39,000	40,000	**Pass**
Glide Slope	deg	8	3.2	3	**Pass**

Takeoff and Landing Performance					
Takeoff Stall Speed	nm/hr	125	149.9	150	**Pass**
Landing Stall Speed	nm/hr	125	125.3	150	**Pass**
Takeoff Field Length	ft/min	7,000	7,078.9	10,000	**Pass**
Landing Field Length	ft/min	5,000	5,789.7	8,000	**Pass**
Gear up, AEO rate-of-climb at obstacle	ft/min	300	5,541.5	n/a	**Pass**
Gear up, OEI climb gradient at obstacle	%	3.00%	12%	n/a	**n/a**
Gear down, OEI climb gradient at obstacle	%	0.50%	6.9%	n/a	**n/a**

DESIGN STATUS - PRODUCT REQUIREMENTS

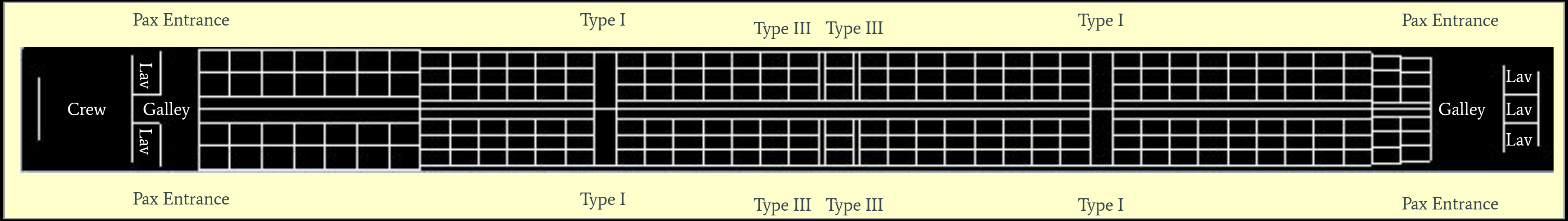
		1970 CER	1986 CER		Pass or Fail	
Costs	**Threshold**	**Design Value**	**Design Value**	**Objective**	**1970 CER**	**1986 CER**
Initial Unit Price / Pave	0.75	0.852	1.241	1.25	**Pass**	**Pass**
Initial Price Markup	10%	24%	23%	25%	**Pass**	**Pass**
Profit (%)	5%	10%	10%	10%	**Pass**	**Pass**

Maneuver Performance	Units	Threshold	Current	Objective	Pass or Fail
Max Sustained Turn Rate	deg/sec	1	1.5	2	**Pass**
Max Instantaneous Turn Rate	deg/sec	1.5	2	2.5	**Pass**
Stall Control					**Pass**
Spin Control					**Pass**

DESIGN STATUS - PRODUCT REQUIREMENTS

Accommodation	Units	Threshold	Design Value	Objective	Pass or Fail
Non-Expendable Payload	**-**	**-**	**-**	**-**	**-**
Crew Allowance	lb/pax	160	200	220	**Pass**
# of Crew	-	1	2	2	**Pass**
Pax Allowance	lb/pax	160	200	220	**Pass**
# of 1st Class seats	-	20	28	40	**Pass**
# of 2nd Class seats	-	180	198	230	**Pass**
Baggage Allowance	lb/pax	25	50	50	**Pass**

DESIGN STATUS - PRODUCT REQUIREMENTS - EMERGENCY EXITS + SEAT ARRANGEMENT



Type 1: Floor Level x4

Type 3: Overwing x4

Pax Entrance: x4, size from competitors A321

Type	Location	Min. Dimensions Width × Height (in.)
Type I	Floor Level	24 × 48
Type II	Floor Level	20 × 44
	Overwing	20 × 44
Type III	Overwing	20 × 36
Type IV	Overwing	19 × 26
Tailcone	Aft of Pressure Hull	20 × 60
Ventral	Bottom of Fuselage	Equiv. Type I
Type A	Floor Level	42 × 72

REFINED WEIGHT ESTIMATE

Summary - Component Weights (lb)		
Commercial Airliner, 226 pax (payload), 4,700 nm, Mmax=0.85		
Component	Symbol	Transport
Wing	Wwing	23,810
Horizontal Tail	Wh-stab	1,010
Vertical Tail	Wv-stab	2,417
Fuselage	Wfuse	26,225
Main Gear	Wmain lg	10,809
Nose / Tail Gear	Wnose lg	711
Propulsion System	Wpp	30,503
Remaining Components	Wrem	47,111
Empty Weight	**We**	**142,596**
Design Gross Weight	Wo	307,914
Empty Weight Fraction	**We/Wo**	**0.463**

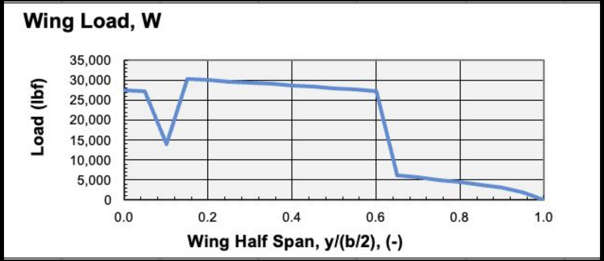
- Empty Weight Factor of 0.4631 indicitaces slight advancements in our technology factor

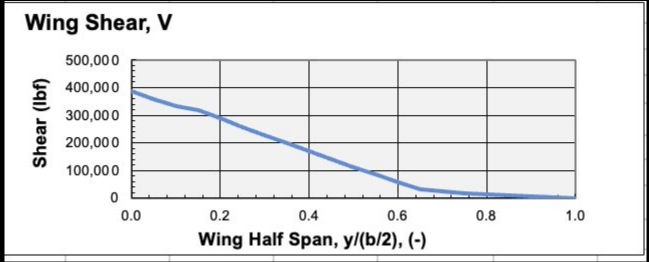
STRUCTURAL DESIGNS & MATERIALS - LOAD FACTORS SUMMARY

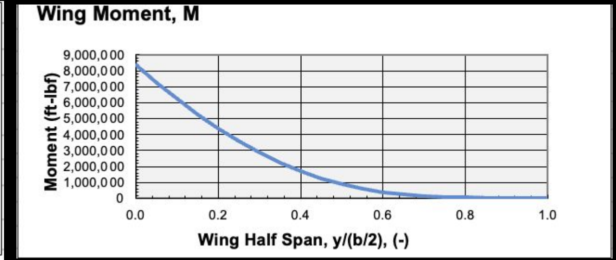
Summary - Load Factors			
Commercial Airliner, 226 pax (payload), 4,700 nm, Mmax=0.85	Pressure		Max Load
Performance Segment	Altitude	Mach	Factors
Acceleration (Climb - 1.2*Vstall to climb speed)	1,500	0.457	0.948
Acceleration (Loiter - MBE to Cruise speed)	35,000	0.825	0.936
Acceleration (Combat - Cruise speed to Max Mach)	35,000	0.85	0.994
Instantaneous Turn Rate	35,000	0.8	1.313
Sustained Turn Rate	35,000	0.8	1.186
Climb - Takeoff	-	-	0.965
Highest angle-of-attack (a)	35,000	0.85	1.021
Max q (dive)	35,000	0.85	2.29
Gust Loads (cruise)	35,000	0.638	0.559
Maximum Calculated Limit Load Factor			2.29
Regulatory Limit Load Factor			3.5
Design Load Factor			**5.25**

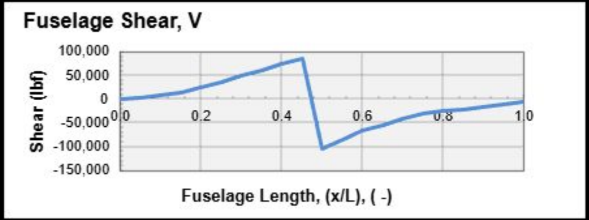
- Instantaneous Turn Rate sets the Design Load Factor
- Instantaneous turns demand lots of lift, causing the high G-force and therefore result in high load factor.

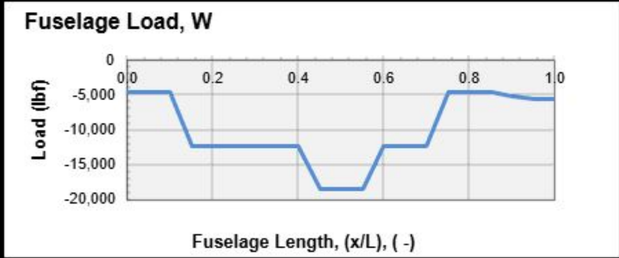
STRUCTURAL DESIGN & MATERIAL SELECTION - DIAGRAMS

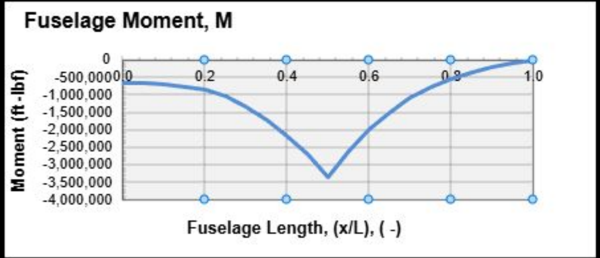






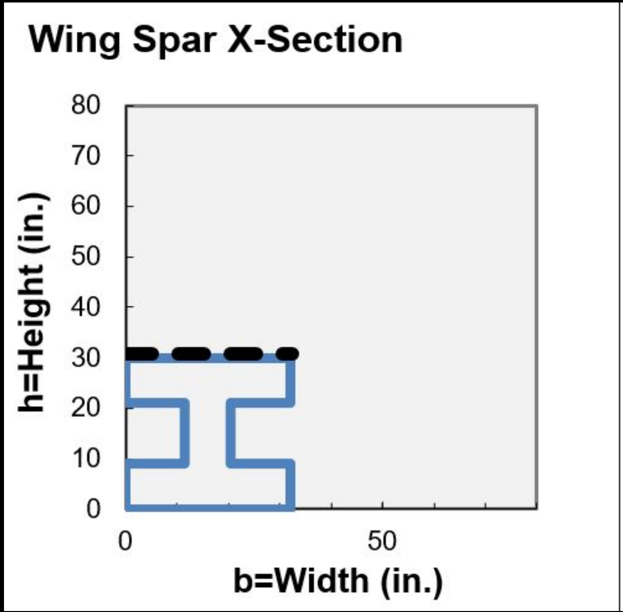


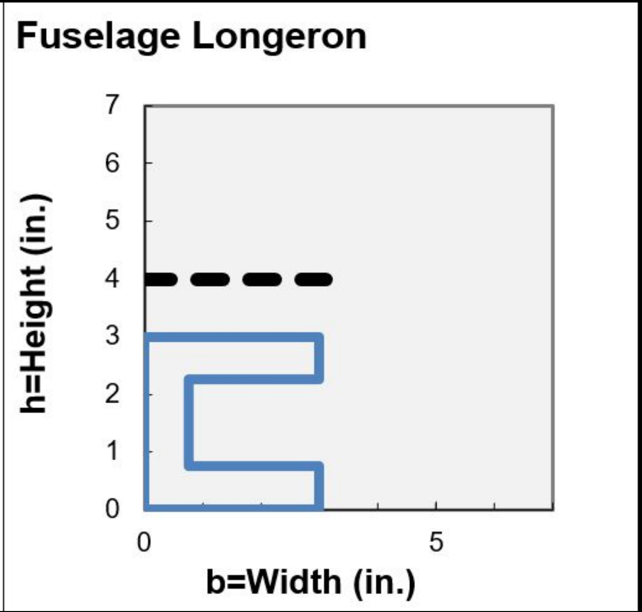




- Locations for max moment in wing makes sense as the wing moment decrease as the length of wing increase.
- Location for max moment in fuselage makes sense because the moments should be low as the wing is located along the center and along with payload.

STRUCTURAL DESIGN & MATERIAL SELECTION - Spar/Longeron





- From both wing and fuselage plots, we have enough space.

STRUCTURAL DESIGN & MATERIAL SELECTION SUMMARY

Summary - Structural Design	**Wing**	**Wing**	**Fuselage**	**Fuselage**
Commercial Airliner, 226 pax (payload), 4,700 nm, Mmax=0.85	**Skin**	**Spar**	**Skin**	**Longerons**
X-Section	n/a	I Beam	n/a	U-Channel (C orientation)
Material Group	Aluminum Alloy	Aluminum Alloy	Aluminum Alloy	Aluminum Alloy
Material	2024-T3 (clad)	2024-T3 (clad)	2024-T3 (clad)	2024-T3 (clad)
Tension $(W_1/W_2)_t$	1.000	1.000	1.000	1.000
Compression $(W_1/W_2)_c$	1.000	1.000	1.000	1.000
Bending $(W_1/W_2)_b$	1.000	1.000	1.000	1.000
Component Weight (lb)	13573	192,622	14,963	16,052
Spar Deflection (in.)	X	2.87	X	X
Spar Deflection (% of half wing span)	X	0.4%	X	X
Spar Height < Wing Thickness ?	X	YES	X	X
# of Bulkheads	X	X	X	42
Bulkhead Spacing (in.)	X	X	X	42.0
# of Longerons	X	X	X	16
Longeron Height < Fuse. Wall	X	X	X	YES

Compressive Stress Ratio	$s_{max} / (s_E / n_{design})$	**0.947**	**0.916**	**Pass**
Tensile Stress Ratio	$s_t / (s_{ut} / n_{design})$	**0.990**	**0.846**	**Pass**

- We selected 2024-T3 clad aluminum structure because it offers an excellent balance of high strength-to-weight ratio, providing adequate strength and stiffness in tension, compression, and bending while remaining making it perfectly suited for a modern commercial airliner.

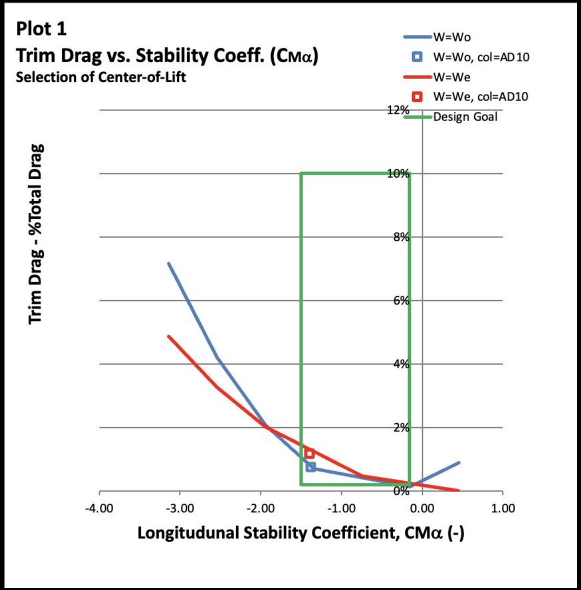
STATIC STABILITY & CONTROL

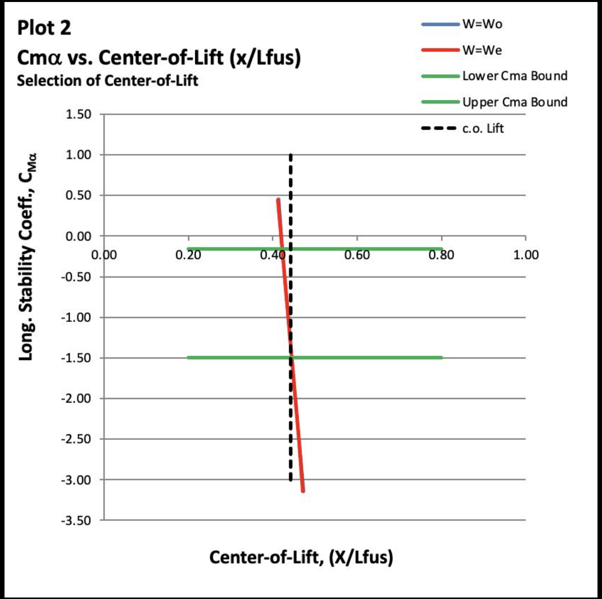
Summary - Static Stability & Control

Commercial Airliner, 226 pax (payload), 4,700 nm, Mmax=0.85

	Values		Compliance		
SM and Trim Drag	at Wo	at We	at Wo	at We	Stability Requirement
-Center of Lift	**0.4430**	0.4430			
-Static Margin	0.5%	0.7%	**Pass**	**Pass**	SM>0%
-Dtrim / Dtotal	0.7%	1.2%	**Pass**	**Pass**	Dtrim/Dtot<0.1
Stability Coefficients					
-Longitudinal, $C_{m\alpha}$	-1.3729	-1.3893	**Pass**	**Pass**	$-1.5<C_{m\alpha}<-0.16$
-Directional, $C_{n\beta}$	0.2308	0.2130	**Pass**	**Pass**	$+0.08<C_{n\beta}<+0.28$
-Lateral, $C_{L\beta}$	-0.2308	-0.2126	**Pass**	**Pass**	$-0.28<C_{L\beta}<-0.08$
Rudder					
Rudder TE Sweepback Angle (deg)	12.5		**Pass**		-12.5 deg<VT sweep<+12.5 deg
H-Stab Interference with Rudder			**Pass**		at most 30% overlap. Manual check. See V-Stab side view below.
All four (4) SM and Trim Drag Tests:			**Pass**		
All six (6) Stability Coefficient Tests:			**Pass**		
All eleven (11) Static Stability & Control Tests:			**Pass**		

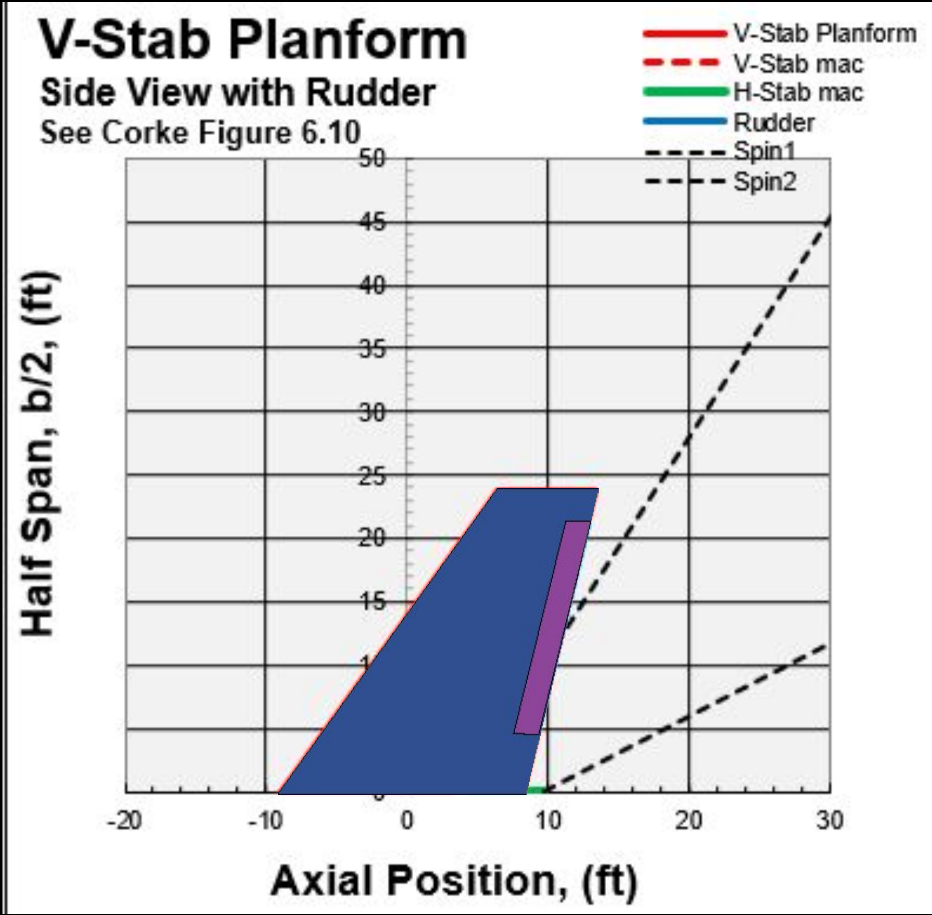
STATIC STABILITY & CONTROL - SELECTION OF CENTER OF LIFT

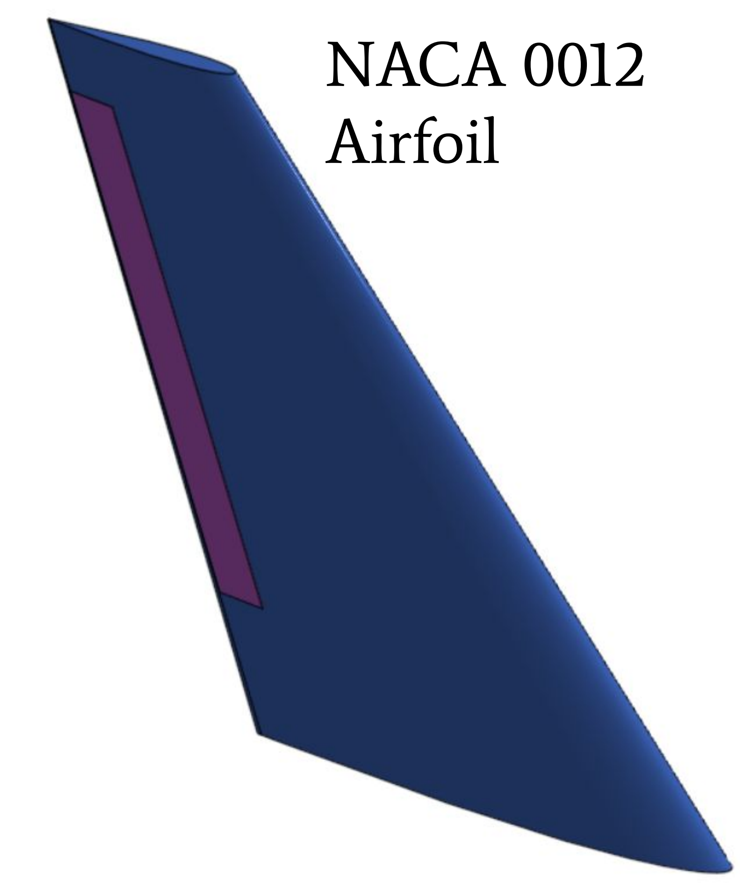




- Adjusted the horizontal stabilizer to better fit our design goal
- We and Wo have very similar COG

STATIC STABILITY & CONTROL - RUDDER DESIGN





COST ESTIMATE - COMPETITIVE ASSESSMENT

Competitor	Quote Year	Quote Price	CPI Ratio	2025 Price	Source
A321neo - XLR	2018	$129,500,000	1.31	$169,645,000	axonaviation
Boeing 757-300	2002	$80,000,000	1.83	$146,400,000	aerocomer
Boeing 787-8 Dreamliner	2004	$248,300,000	1.73	$429,559,000	axon aviation
Average Competitor Price (2025)	$248,534,667				

Parameters	Boeing 757-300 (N)	Boeing 787-8 Dreamliner (W)	Airbus A321neo XLR (N)	Velair (N)
N_D	2	6	1	3
N_P	55	427	476	302
R_D	0.014	0.1	0.05	0.02778

COST ESTIMATE - COST CALCULATIONS

Total Aircraft Costs ($/ac)	**1970 CER**	**1986 CER**
TOTAL Cost Adders	$43,661,226	$63,616,254
Initial Unit Price	**$211,723,545**	**$308,490,168**
Final Unit Price	$170,413,559	$251,278,385
Initial Unit Price / Pave	0.852	1.241
Initial Price Markup	24%	23%
Profit (%)	10%	10%

- Pave = $$248,534,667 ⟶ ≈ $250 million
- Since we are entering into a new market space, we chose a combination of both wide body and narrowbody from competitors to get a combined average of $250M.

COST ESTIMATE - COST CALCULATIONS COMPETITORS

	Threshold	Objective	A321neo XLR (N)	Boeing 757-300 (W)	Boeing 787-8 (W)	Velair (N) - 1970 CER	Velair (N) - 1986 CER
P/P_ave	0.75	1.25	0.6826	0.5891	1.728	0.852	1.241
Pmu	10%	25%	N/A	N/A	N/A	24%	23%

We will be utilizing an average of the 1970 and 1986 CER, as per the comments on the "12" Worksheet

We will be proposing a market share of 11 % based on our design entering a new market between widebody and narrowbody designs

COST ESTIMATE - TECHNOLOGY PLAN

Summary - Cost Estimate

Commercial Airliner, 226 pax (payload), 4,700 nm, Mmax=0.85

Assumptions		**1970 CER**	**1986 CER**
Year		2025	2025
Number of Development Aircraft		3	3
Number of Production Aircraft		302	302
RTD&E Production Rate (per year)		0	0
Acquisition Production Rate (per year)		240	240
Amortization Period (# of ac)		160	160
Technology Factors	**Factor**	**ΔCost ($/ac)**	**ΔCost ($/ac)**
Materials Factor (We/Wo)	0.900	$18,673,591	$27,208,213
Aerodynamic Efficiency Factor (L/D)	1.000	$0	$0
Propulsion Efficiency Factor (SFC)	0.950	$8,845,385	$12,888,101
Configuration Options	**Features**	**ΔCost ($/ac)**	**ΔCost ($/ac)**
Propulsion System Type	conventional	$0	$0
Engine Scale Factor	1.0534	$0	$0
Propeller Type	n/a	$0	$0
T.E. Flap Type	slot	$4,309,290	$6,278,818
L.E. Flap Type	fixed	$3,429,843	$4,997,427
Landing Gear Type	Config 4, wheel fairing C, 25" wheel	$8,403,116	$12,243,696
Total Aircraft Costs ($/ac)		**1970 CER**	**1986 CER**
TOTAL Cost Adders		$43,661,226	$63,616,254
Initial Unit Price		**$211,723,545**	**$308,490,168**
Final Unit Price		$170,413,559	$251,278,385
Initial Unit Price / Pave		0.852	1.241
Initial Price Markup		24%	23%
Profit (%)		10%	10%

-Materials factor (0.9), lower than 1 reduces empty weight

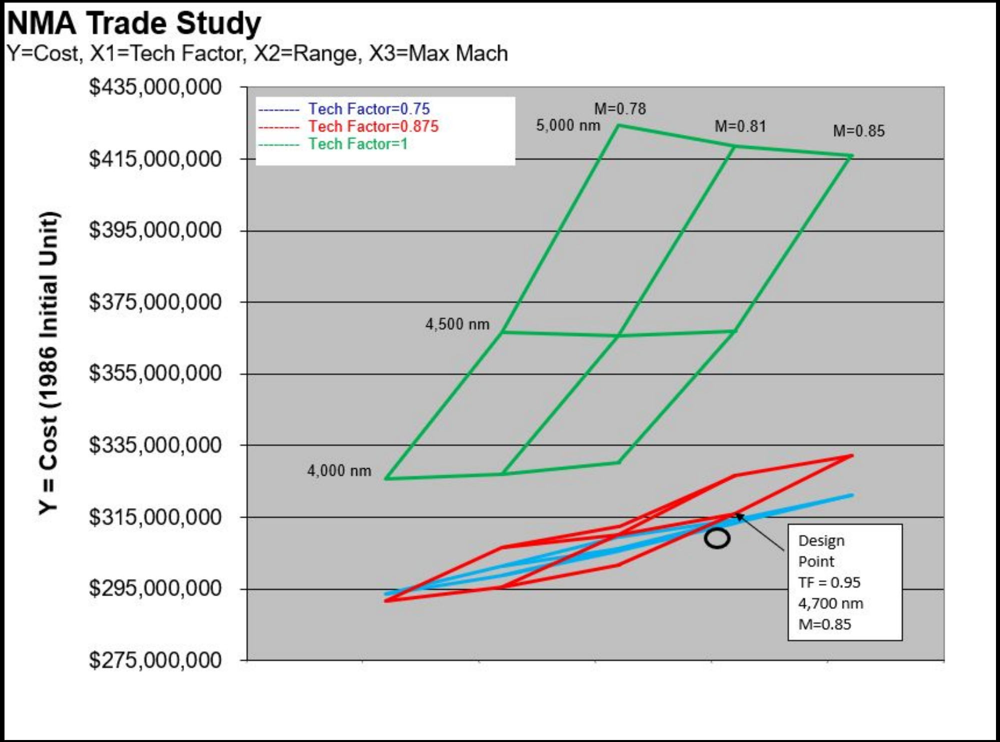
-Aerodynamic Efficiency Factor equal to 1 does not affect the technology

-SFC (0.95) lower than 1 increases fuel efficiency

FINAL DESIGN SUMMARY - Compliance

Iteration Solvers, Safety and Regulatory Compliance	
Mission Analysis (Worksheet 2)	**Pass**
Stall Speed (Worksheet 3)	**Pass**
Drag Bucket (Worksheet 4)	**Pass**
Fuselage Volume (Worksheet 5)	**Pass**
Fuselage Max Diameter (Worksheet 5)	**Pass**
Landing Gear (Worksheet 5)	**Pass**
Engine Selection (Worksheet 7a or 7b)	**Pass**
Propeller Efficiency (Worksheet 7b)	**n/a**
Min Spec Takeoff (Worksheet 8)	**Pass**
Overnose Angle (Worksheet 8)	**Pass**
Material Structural Integrity (Worksheet 10)	**Pass**
Stability & Control (Worksheet 11)	**Pass**
Rudder Design (Worksheet 11)	**Pass**

Design Drivers Trade Studies



We conducted 2 trade studies for our design drivers:

- Y = Non-Expendable payload,

  X = #Total Pax, Pax Allowance, Baggage Allowance

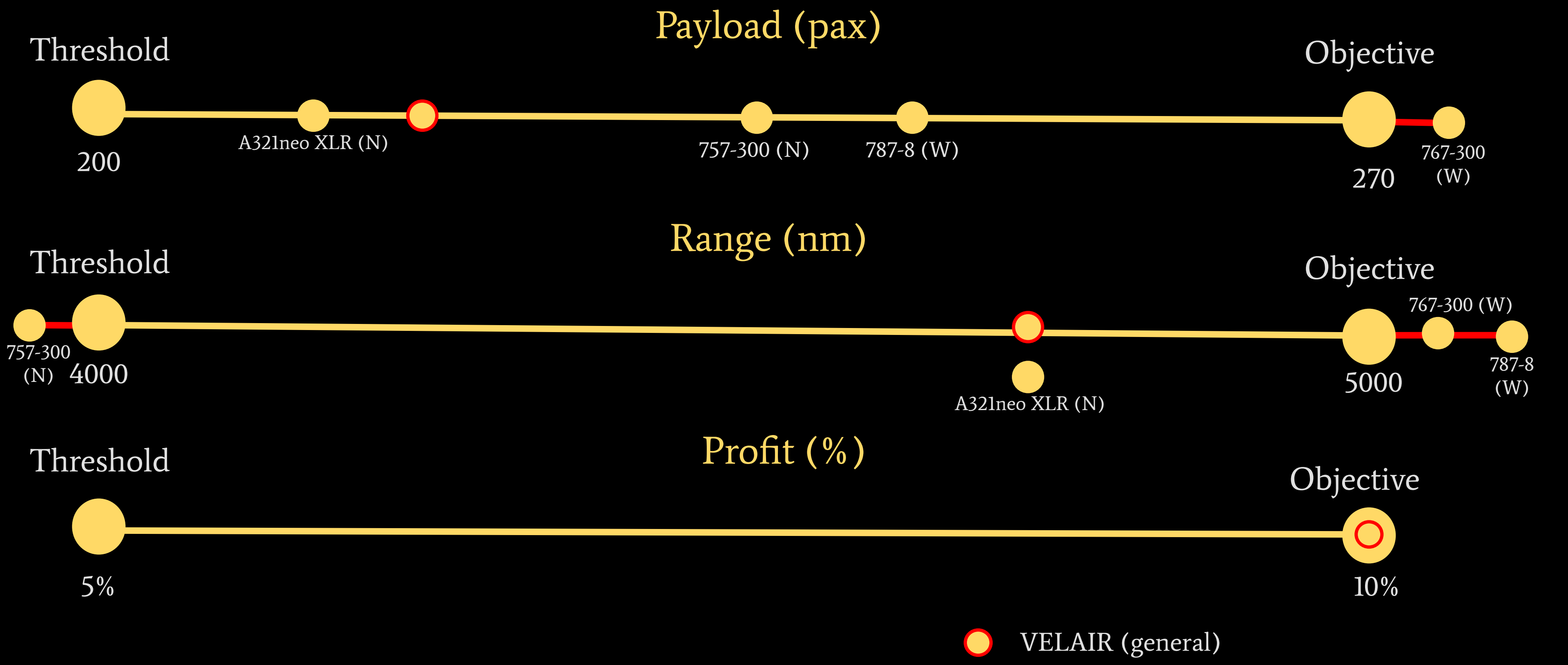
- Y = Cost (Simulates Profit)

  X = Avg. Technology Factor, Range, Max Mach

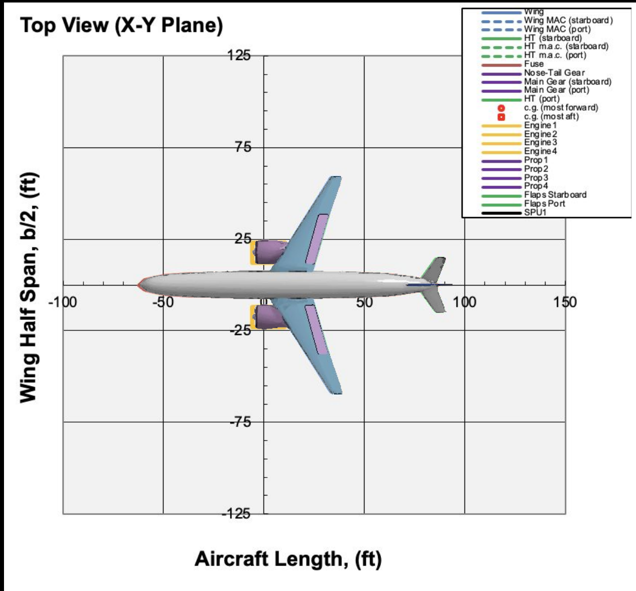
FINAL DESIGN SUMMARY- COMPETITIVE ASSESSMENT - DESIGN DRIVERS

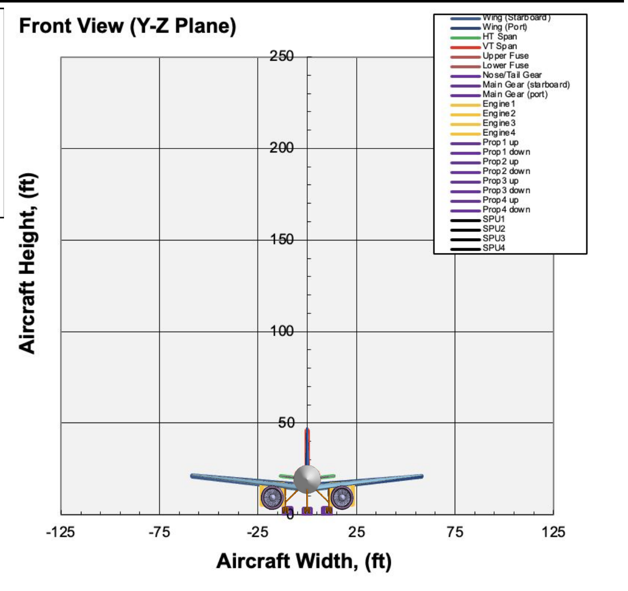
Design Drivers	Boeing 757-300 (N)	Boeing 767-300 (W)	Boeing 787-8 Dreamliner (W)	Airbus A321neo XLR (N)	Velair (N)
Gross Weight (lbs)	270,000 lb	412,000 lb	502,500 lb	206,130 lb	307,913.6 lb
Payload (lbs/pax)	234	270	242	206-220	226
Range (nm)	3,395	5,230	8,000	4,700	4,700
Profit (%)	N/A	N/A	N/A	N/A	10%

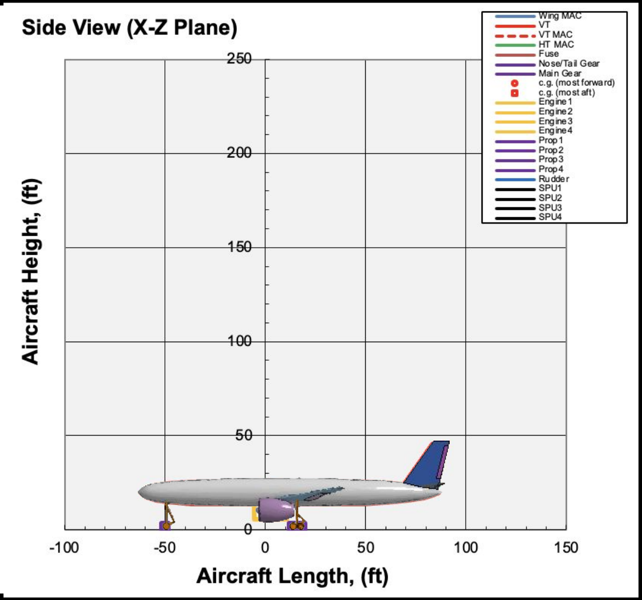
FINAL DESIGN SUMMARY- COMPETITIVE ASSESSMENT - DESIGN DRIVERS



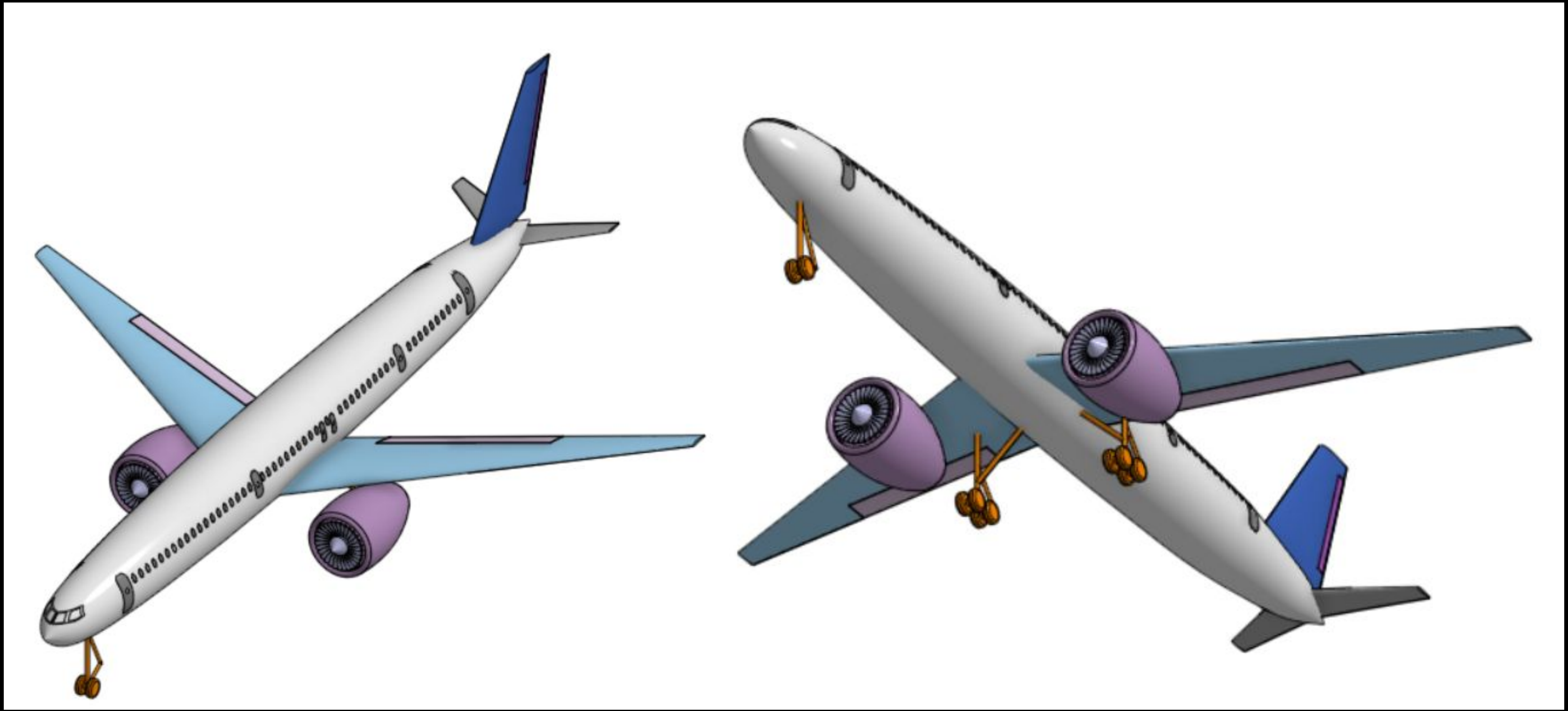
FINAL DESIGN SUMMARY - 3 VIEW



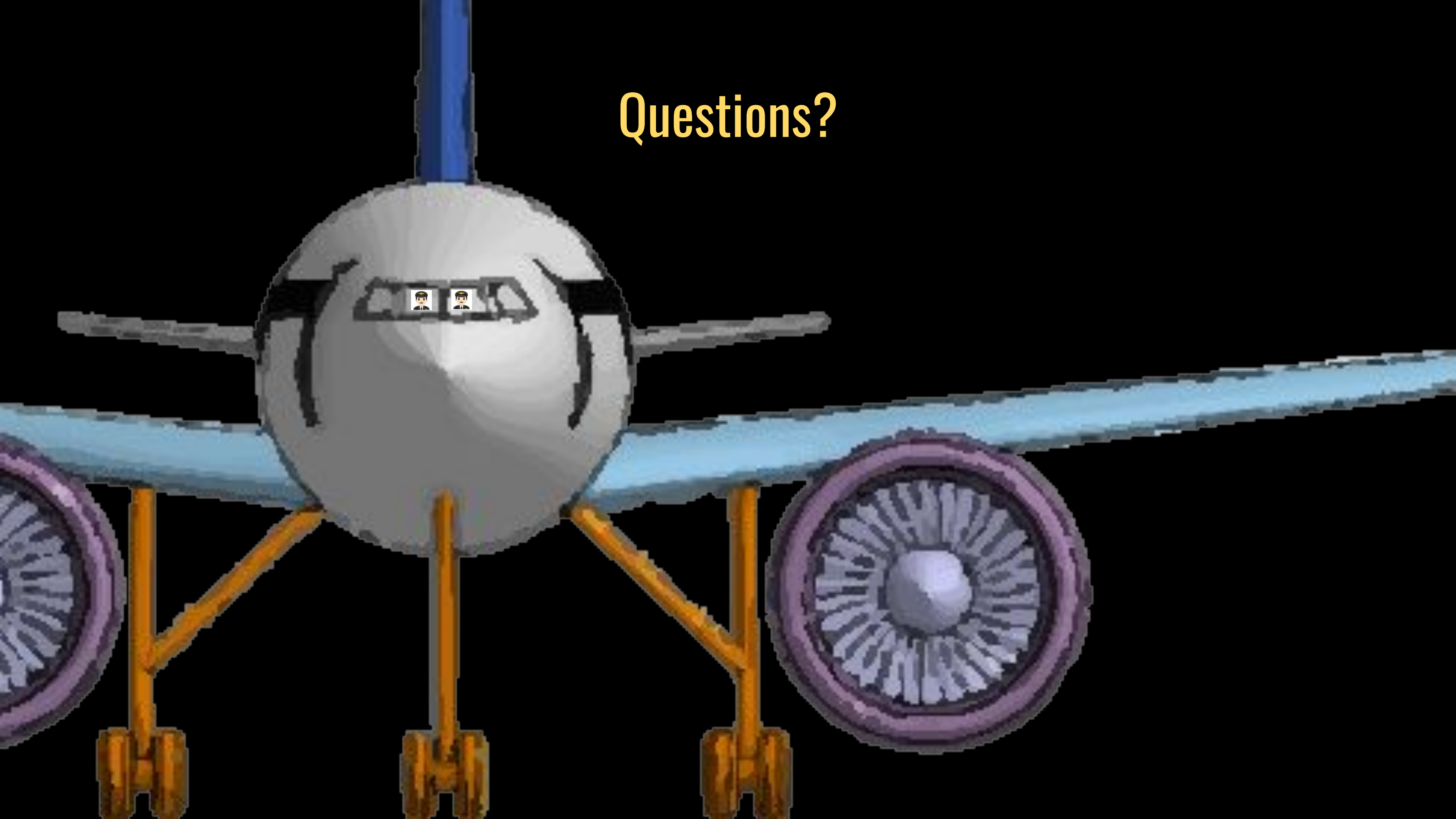




FINAL DESIGN SUMMARY - FINAL CAD Model View



Questions?



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